CICS Transaction Server for z/OS
5.6

# *Java Applications in CICS*

IBM

**Note**

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This edition applies to the IBM® CICS® Transaction Server for z/OS®, Version 5 Release 6 (product number 5655-Y305655-BTA ) and to all subsequent releases and modifications until otherwise indicated in new editions.

# Contents

# About this PDF

This PDF tells you how to develop and use Java™ applications and enterprise beans in CICS. It is for experienced Java application programmers with little experience of CICS, and no need to know more about CICS than is necessary to develop and run Java programs. It is also for experienced CICS users and system programmers, who need to know about CICS requirements for Java support.

For details of the terms and notation used, see Conventions and terminology used in CICS documentation in IBM Documentation.

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# Chapter 1. CICS and Java

CICS provides the tools and runtime environment to develop and run Java applications in a Java Virtual Machine (JVM) that is under the control of a CICS region.

CICS provides a JVM server runtime environment for Java application development. You can develop, build, and deploy applications using the IBM CICS SDK for Java, Gradle modules, or Maven modules.

If you are a Java developer, check out Get started with Java in CICS.

## IBM Semeru Runtime Certified Edition for z/OS Java 11Java 17Java 21

Java on z/OS provides comprehensive support for running Java applications. CICS uses the IBM Semeru Runtime Certified Edition for z/OS Version 11.0.17.0, Version 17.0.7.0 or Version 21.0.4.0 as the minimum release level.

Some Liberty features require specific Java versions, and these are called out in Liberty features. In addition, if any of your applications perform an RMI call, you must ensure you have the same Java level at client and run time.

The Certified Edition contains a Java Runtime Environment that supports the full set of Java APIs and a set of development tools. In Java 11, Java 17 and Java 21, the base JRE is different from the Java 8 JRE. While your Java 8 bytecode might run in later Java versions, it is worth reviewing your applications.

To allow remote debug of a Java 11, Java 17 or Java 21 runtime (JVM) there is a change to the syntax. The `agentlib` property now requires an explicit `hostname:port`. Specifying the port alone is no longer enough to successfully connect to and debug a Java 11, Java 17 runtime or Java 21 runtime.

You need to download the Java 11, Java 17 or Java 21 version of the JZOS jar if your applications use it. To download the file, and for more information, see JZOS JAR for IBM Semeru Runtime Certified Edition for z/OS. To download and install the latest Explorer SDK, and for more information, see CICS Explorer product documentation.

Java 21 In Java 21, the default character set for standard Java APIs is UTF-8, except for the console input and output encoding. Earlier versions of Java use an EBCDIC default character set. Processing of EBCDIC-based data is common in CICS Java applications so this change is significant. For more information, see File encoding and UTF-8 as default charset.

## IBM 64-bit SDK for z/OS, Java Technology Edition Java 8

Java on z/OS provides comprehensive support for running Java applications. CICS uses the IBM 64-bit SDK for z/OS, Java Technology Edition, Version 8. Some Liberty features require specific Java versions, and these are called out in Liberty features.

The SDK contains a Java Runtime Environment that supports the full set of Java APIs and a set of development tools. To help increase general purpose processor productivity and contribute to lowering the overall cost of computing for z/OS Java technology-based applications, special processors are available in certain z Systems® hardware. The IBM zEnterprise® Application Assist Processor (zAAP) can provide additional processor capacity to run eligible Java workloads, including Java workloads in CICS.

Find information about Java on the z/OS platform and download the 64-bit version of the SDK at Java Standard Edition Products on z/OS.

## JVM server

The JVM server is the runtime environment for Java applications in CICS. A JVM server can handle many concurrent requests from different Java applications in a single JVM. Use of a JVM server reduces the number of JVMs that are required to run Java applications in a CICS region. To use a JVM server, Java applications must be threadsafe and must comply with the OSGi or Java EE specifications. JVM server provides the following benefits:

- Eligible Java workloads can run on specialty engine processors, reducing the cost of transactions.
- Different types of work such as threadsafe Java programs and web services, can run in a JVM server.
- Application life cycle can be managed in the OSGi framework, without restarting the JVM server.
- Java applications that are packaged using OSGi can be ported more easily between CICS and other platforms.
- Java EE applications can be deployed into the Liberty JVM server.

  **Note:** OSGi applications in CICS can be installed in a Liberty JVM server but cannot use any of the Liberty services or features as they are not supported.

## IBM CICS SDK for Java

CICS Explorer® is a freely available download for Eclipse-based Integrated Development Environments (IDEs). The IBM CICS SDK for Java that is included with CICS Explorer provides support for developing and deploying applications that comply with the OSGi Service Platform specification.

The OSGi Service Platform provides a mechanism for developing applications using a component model and deploying those applications into a framework as OSGi bundles. An *OSGi bundle* is the unit of deployment for an application component and contains version control information, dependencies, and application code. The main benefit of OSGi is that you can create applications from reusable components that are accessed only though well-defined interfaces called *OSGi services*. You can also manage the life cycle and dependencies of Java applications in a granular way.

The IBM CICS SDK for Java allows development of Java applications for any supported release of CICS. The SDK includes the Java CICS library (JCICS) to access CICS services along with examples to get started with developing applications for CICS. You can also use the tool to convert existing Java applications to OSGi.

The IBM CICS SDK for Enterprise Java (Liberty) is included as an option with CICS Explorer and supports packaging of Liberty applications into CICS bundles that can be deployed to CICS.

## Gradle and Maven modules

As an alternative to the IBM CICS SDK for Java, you can define your projects as Maven or Gradle modules, express dependencies by referencing the Maven Central artifacts, and then package and deploy your application in a CICS bundle using the CICS-provided Gradle or Maven plug-in.

**Why use Gradle or Maven for CICS development?**

- **Simplified dependency management with Maven Central artifacts:** Java developers can easily add dependencies on the Java CICS APIs and other CICS libraries with a few lines of configuration.
- **More flexibility with the development environment:** Gradle and Maven support is available in most Java IDEs, such as Eclipse, IntelliJ IDEA, and Visual Studio Code. Java developers can write application code in a familiar IDE.
- **Bundle deployment with ease and confidence at development time with the Gradle and Maven plug-ins** (Requires the CICS bundle deployment API):
  - Java developers can redeploy a bundle into a CICS region within seconds, without the need for a zFS connection or to disable, discard, and reinstall the bundle manually.
  - Java developers can integrate CICS bundle build and deployment into their toolchain, saving lots of manual work.
  - The API ensures controlled access both to the CICS system definition data set (CSD) for BUNDLE definition installation and to the bundle directory on zFS, so that system programmers can allow Java developers to deploy bundles without granting additional access.

**What you can do with Gradle or Maven in CICS**

- **Resolving compilation dependencies from Maven Central**

A list of CICS Java APIs and other libraries are provided on Maven Central under the `com.ibm.cics` group ID. Depending on your organization's policy, you can either reference these artifacts directly from Maven Central, or have them mirrored to your enterprise repository by using repository managers such as Artifactory or Nexus.

- **Building and deploying CICS bundles using Gradle or Maven plug-ins**

  The Gradle and Maven plug-ins are open source and provided on GitHub (cics-bundle-maven and cics-bundle-gradle). You can use them to build CICS bundles and, when the CICS bundle deployment API is configured, to deploy CICS bundles. A subset of CICS bundle parts, including WAR files (.war), EAR files (.ear), and OSGi bundles (.jar), is supported.

  For instructions on how to configure CICS for the CICS bundle deployment API, see Configuring the CMCI JVM server for the CICS bundle deployment API.

# The OSGi Service Platform

The OSGi Service Platform provides a mechanism for developing applications by using a component model and deploying those applications into an OSGi framework. The OSGi architecture is separated into a number of layers that provide benefits to creating and managing Java applications.

The OSGi framework is at the core of the OSGi Service Platform specification. CICS uses the Equinox implementation of the OSGi framework. The OSGi framework is initialized when a JVM server starts. Using OSGi for Java applications provides the following major benefits:

- New Java applications, and new versions of Java applications, can be deployed into a live production system without having to restart the JVM, and without impacting the other Java applications deployed in that JVM.
- Java applications are more portable, easier to re-engineer, and more adaptable to changing requirements.
- You can follow the Plain Old Java Object (POJO) programming model, giving you the option of deploying an application as a set of OSGi bundles with dynamic life cycles.
- You can more easily manage and administer application bundle dependencies and versions.

The OSGi architecture has the following layers:

- Modules layer
- Life cycle layer
- Services layer

## Modules layer

The unit of deployment is an OSGi bundle. The modules layer is where the OSGi framework processes the modular aspects of a bundle. The metadata that enables the OSGi framework to do this processing is provided in a bundle manifest file.

One key advantage of OSGi is its class loader model, which uses the metadata in the manifest file. There is no global class path in OSGi. When bundles are installed into the OSGi framework, their metadata is processed by the module layer and their declared external dependencies are reconciled against the exports and version information declared by other installed modules. The OSGi framework works out all the dependencies and calculates the independent required class path for each bundle. This approach resolves the shortcomings of plain Java class loading by ensuring that the following requirements are met:

- Each bundle provides visibility only to Java packages that it explicitly exports.
- Each bundle declares its package dependencies explicitly.
- Packages can be exported at specific versions, and imported at specific versions or from a specific range of versions.
- Multiple versions of a package can be available concurrently to different clients.

### Life cycle layer

The bundle life cycle management layer in OSGi enables bundles to be dynamically installed, started, stopped, and uninstalled, independently from the life cycle of the JVM. The life cycle layer ensures that bundles are started only if all their dependencies are resolved, reducing the occurrence of `ClassNotFoundException` exceptions at run time. If there are unresolved dependencies, the OSGi framework reports the problem and does not start the bundle.

Each bundle can provide a bundle activator class, which is identified in the bundle manifest, that the framework calls as part of bundle start and stop events.

### Services layer

The services layer in OSGi intrinsically supports a service-oriented architecture through its non-durable service registry component. Bundles publish services to the service registry, and other bundles can discover these services from the service registry. These services are the primary means of collaboration between bundles. An OSGi service is a Plain Old Java Object (POJO), published to the service registry under one or more Java interface names, with optional metadata stored as custom properties (name/value pairs). A discovering bundle can look up a service in the service registry by an interface name, and can potentially filter the services that are being looked up based on the custom properties.

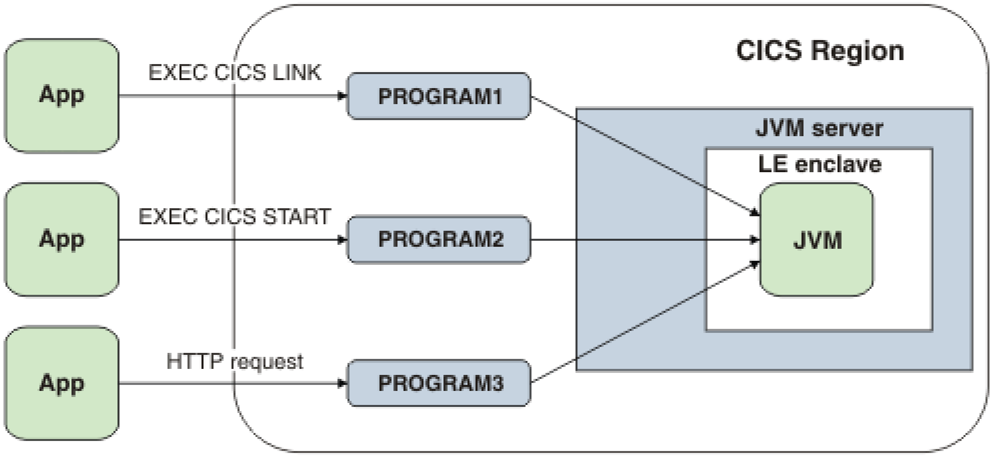
Services are fully dynamic and typically have the same life cycle as the bundle that provides them.

## JVM server runtime environment

A *JVM server* is a runtime environment that can handle many concurrent requests for different Java applications in a single JVM. You can use a JVM server to run threadsafe Java applications in an OSGi framework, run web applications in Liberty, and process web service requests in the Axis2 web services engine.

A JVM server is represented by the JVMSERVER resource. When you enable a JVMSERVER resource, CICS requests storage from MVS, sets up a Language Environment® enclave, and launches the 64-bit JVM in the enclave. CICS uses a JVM profile that is specified on the JVMSERVER resource to create the JVM with the correct options. In this profile, you can specify JVM options and system properties, and add native libraries; for example, you can add native libraries to access DB2® or IBM MQ from Java applications.

One of the advantages of using JVM servers is that you can run many requests for different applications in the same JVM. In the following diagram, three applications are calling three Java programs in a CICS region concurrently using different access methods. Each Java program runs in the same JVM server.



### Java applications

To run a Java application in a OSGi JVM server, it must be threadsafe and packaged as one or more OSGi bundles in a CICS bundle. The JVM server implements an OSGi framework in which you can run OSGi bundles and services. The OSGi framework registers the services and manages the dependencies and versions between the bundles. OSGi handles all the class path management in the framework, so you can add, update, and remove Java applications without stopping and restarting the JVM server.

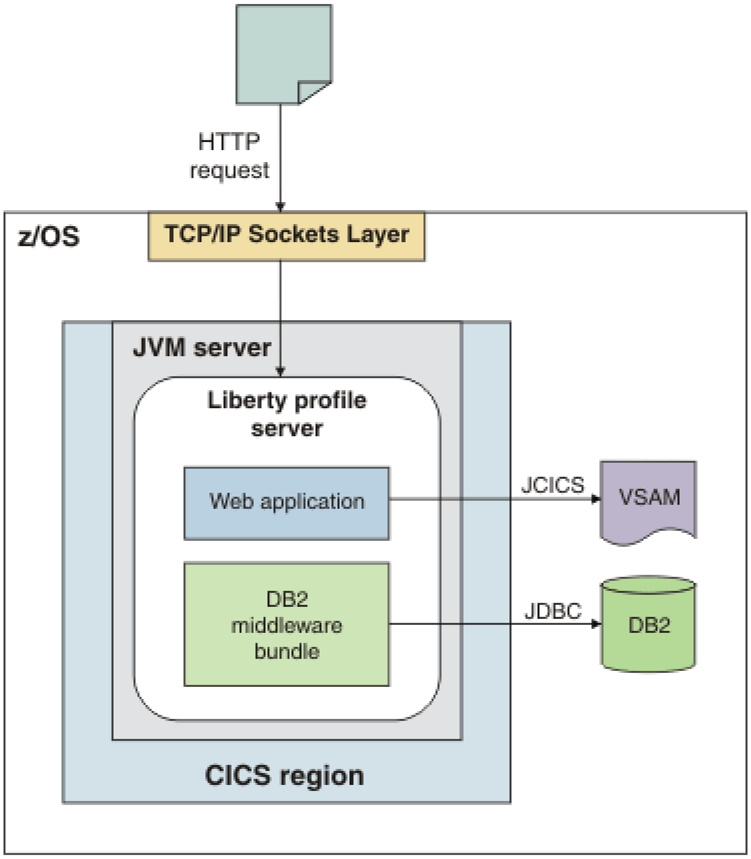
The unit of deployment for a Java application that is packaged using OSGi is a CICS bundle. The BUNDLE resource represents the application to CICS and you can use it to manage the lifecycle of the application. The IBM CICS SDK for Java provides support for deploying OSGi bundles in a CICS bundle project to zFS.

To access the Java application from outside the OSGi framework, use a PROGRAM resource to identify the JVM server in which the application is running and the name of the OSGi service. The OSGi service points to the CICS main class.

For more information about using the OSGi framework in a JVM server, see Java applications that comply with OSGi.

## Java web applications

In addition to running Java applications in an OSGi framework, the JVM server also supports running WebSphere® Application Server Liberty. Liberty is a lightweight application server for running web applications. Web applications can use JCICS to access resources and services in CICS, and to access data in DB2. Applications running in Liberty are accessed through the TCP/IP sockets layer in z/OS rather than through web support in CICS.



Java web applications can follow the Liberty model for deployment, where developers can deploy web archive (WAR) files or enterprise application archive (EAR) files directly into the drop-in directory of Liberty, or use the CICS application model of creating CICS bundles. CICS bundles provide lifecycle management and can package an application that contains many components, including OSGi bundles and WAR files, together.

To access OSGi bundles from a web application, you must deploy your application as an Enterprise Bundle Archive (EBA) file. To develop EBAs, you can use Rational® Application Developer, or you can use a combination of the Eclipse IDE, the IBM CICS SDK for Java, and WebSphere Application Server Developer Tools for Eclipse. The latter set of tools is free to use but, apart from the IBM CICS SDK for Java, IBM support is not available for them.

For more information about using Liberty, see Java applications in a Liberty JVM server.

### Web services

You can use a JVM server to run the SOAP processing for web service requester and provider applications. If a pipeline uses Axis2, a SOAP engine that is based on Java, the SOAP processing occurs in a JVM server. The advantage of using a JVM server for web services is that you can offload the work to a zAAP processor.

For more information about using a JVM server for web services, see Java web services.

## JVM profiles

JVM profiles are text files that contain Java launcher options and system properties, which determine the characteristics of JVMs. You can edit JVM profiles using any standard text editor.

When CICS receives a request to run a Java program, the name of the JVM profile is passed to the Java launcher. The Java program runs in a JVM, which was created using the options in the JVM profile.

CICS uses JVM profiles that are in the z/OS UNIX System Services directory specified by the JVMPROFILEDIR system initialization parameter. This directory must have the correct permissions for CICS to read the JVM profiles.

### Sample JVM profiles

CICS includes several sample JVM profiles to help you configure your Java environment. They are customized during the CICS installation process. These files are used by CICS as defaults or for system programs.

A JVM profile lists the options that are used by the CICS launcher for Java. Some of the options are specific to CICS and others are standard for the JVM runtime environment. For example, the JVM profile controls the initial size of the storage heap and how far it can expand. The profile can also define the destinations for messages and dump output produced by the JVM. The JVM profile is named in the JVMPROFILE attribute in a JVMSERVER resource definition.

You can copy the samples and customize them for your own applications. The sample JVM profiles supplied with CICS are in the directory `/usr/lpp/cicsts/cicsts56/JVMProfiles` on z/OS UNIX.

**Note:** If you are unable to find the sample JVM profiles in `/usr/lpp/cicsts/cicsts56/JVMProfiles`, or the directory does not exist, then it is likely you have not run the DFHIJVMS job to populate the directories and create the JVM profiles. You can find this job in SDFHINST and it is documented in the Program Directory for CICS Transaction Server for z/OS. See Program Directories for more information.

Copy the samples from the installation directory to the directory that you specified in the **`JVMPROFILEDIR`** system initialization parameter. The sample JVM profiles in the installation location are overwritten if you apply an APAR that includes changes to these files. To avoid losing your modifications, always copy the samples to a different location before adding your own application classes or changing any options.

The following table summarizes the key characteristics of each sample JVM profile.

*Table 1. Sample JVM profiles supplied with CICS*

| JVM profile | Characteristics |
|---|---|
| DFHJVMAX.jvmprofile | The supplied sample profile for an Axis2 JVM server. The JVM profile is specified on the JVMSERVER resource. CICS uses DFHJVMAX.jvmprofile to initialize the JVM server. |
| DFHJVMST.jvmprofile | The supplied sample profile for a JVM server for a Security Token Service. The JVM profile is specified on the JVMSERVER resource. CICS uses DFHJVMST.jvmprofile to initialize the JVM server. |
| DFHOSGI.jvmprofile | The supplied sample profile for an OSGi JVM server. The JVM profile is specified on the JVMSERVER resource. CICS uses DFHOSGI.jvmprofile to initialize the JVM server. |
| DFHWLP.jvmprofile | The supplied sample profile for a Liberty JVM server. The JVM profile is specified on the JVMSERVER resource. CICS uses DFHWLP.jvmprofile to initialize the Liberty JVM server. |

# Structure of a JVM

JVMs that run under CICS use a set of classes and class paths that are defined in JVM profiles and use 64-bit storage. Each JVM runs in a Language Environment enclave that you can tune to make the most efficient use of MVS storage.

## Classes and class paths in JVMs

A JVM running under CICS can use different types of class or library files: primordial classes (system and standard extension classes), native C DLL library files, and application classes.

The JVM recognizes the purpose of each of these components, determines how to load them, and determines where to store them. The class paths for a JVM are defined by options in the JVM profile, and (optionally) are referenced in JVM properties files.

- *Primordial classes* are the z/OS JVM code that provide the base services in the JVM. Primordial classes can be categorized as system classes and standard extension classes.
- *Native C dynamic link library (DLL) files* have the extension `.so` in z/OS UNIX. Some libraries are required for the JVM to run, and additional native libraries can be loaded by application code or services. For example, the additional native libraries might include the DLL files to use the Db2® JDBC drivers.
- *Application classes* are the classes for applications that run in the JVM, and include classes that belong to user-written applications. Java application classes also include those supplied by IBM or by other vendors, to provide services that access resources, such as the JCICS interfaces classes, JDBC and JNDI, which are not included in the standard JVM setup for CICS. When Java application classes are loaded into the class cache the are kept and can be reused by other applications running in the same JVM.

The class paths on which classes or native libraries can be specified are the library path, and the standard class path.

- The *Library path* specifies the native C dynamic link library (DLL) files that are used by the JVM, including the files required to run the JVM and additional native libraries loaded by application code or services. Only one copy of each DLL file is loaded, and all the JVMs share it, but each JVM has its own copy of the static data area for the DLL.

  The base library path for the JVM is built automatically using the directories specified by the **USSHOME** system initialization parameter and the **JAVA_HOME** option in the JVM profile. The base library path is not visible in the JVM profile. It includes all the DLL files required to run the JVM and the native libraries used by CICS. You can extend the library path using the **LIBPATH_SUFFIX** option or the **LIBPATH_PREFIX** option. **LIBPATH_SUFFIX** adds items to the end of the library path, after the IBM-supplied libraries. **LIBPATH_PREFIX** adds items to the beginning, which are loaded in place of the IBM-supplied libraries if they have the same name. You might have to do this for problem determination purposes.

Compile and link with the LP64 option any DLL files that you include on the library path . The DLL files supplied on the base library path and the DLL files used by services such as the Db2 JDBC drivers are built with the LP64 option.

- The *Standard class path* must not be used for OSGi enabled JVM servers because the OSGi framework automatically determines the class path for an application from information in the OSGi bundle that contains the application. The standard class path is retained for use by JVM servers that are not configured for OSGi (for example the Axis2 environment in CICS). For exceptional scenarios, such as Axis2, in which the standard class path is used, you can use a wildcard suffix on the class path entries to specify all JAR files in a particular directory.

  CICS also builds a base class path automatically for the JVM using the `/lib` subdirectories of the directories specified by the **USSHOME** system initialization parameter. This class path contains the JAR files supplied by CICS and by the JVM. It is not visible in the JVM profile.

You do not have to include the system classes and standard extension classes (the primordial classes) on a class path, because they are already included on the boot class path in the JVM.

## Storage heap in JVMs

The runtime JVM storage is managed by a single 64-bit storage heap.

The heap for each JVM is allocated from 64-bit storage in the Language Environment enclave for the JVM. The size of each heap is determined by options in the JVM profile.

The single storage heap is known as the *heap*, or sometimes as the *garbage-collected heap*. Its initial storage allocation is set by the **-Xms** option in a JVM profile, and its maximum size is set by the **-Xmx** option.

You can tune the size of a heap to achieve optimum performance for your JVMs. See Tuning JVM server heap and garbage collection.

## Where JVMs are constructed

When a JVM is required, the CICS launcher program for JVMs requests storage from MVS, sets up a Language Environment enclave, and launches the JVM in the Language Environment enclave. Each JVM is constructed in its own Language Environment enclave, to ensure isolation between JVMs running in parallel.

The Language Environment enclave is created using the Language Environment preinitialization module, CELQPIPI, and the JVM runs as a z/OS UNIX process. The JVM therefore uses MVS Language Environment services rather than CICS Language Environment services. The storage used for a JVM is MVS 64-bit storage, obtained by calls to MVS Language Environment services. This storage resides in the CICS address space, but is not included in the CICS dynamic storage areas (DSAs).

The Language Environment enclave for a JVM can expand, depending on the storage requirements of the JVM. The Language Environment runtime options used by CICS for a Language Environment enclave control the initial size of, and incremental additions to, the Language Environment enclave heap storage.

You can tune the runtime options that CICS uses for a Language Environment enclave, so that the amount of storage CICS requests for the enclave is as close as possible to the amount of storage specified by your JVM profiles. You can therefore make the most efficient use of MVS storage. For more information about tuning storage, see Language Environment enclave storage for JVMs.

## CICS task and thread management

CICS uses the open transaction environment (OTE) to run JVM server work. Each task runs as a thread in the JVM server and is attached by using a T8 TCB. A major benefit of using OSGi is that applications in an OSGi framework can use an ExecutorService to create threads that run extra tasks in CICS asynchronously. CICS takes special measures to deal with runaway tasks.

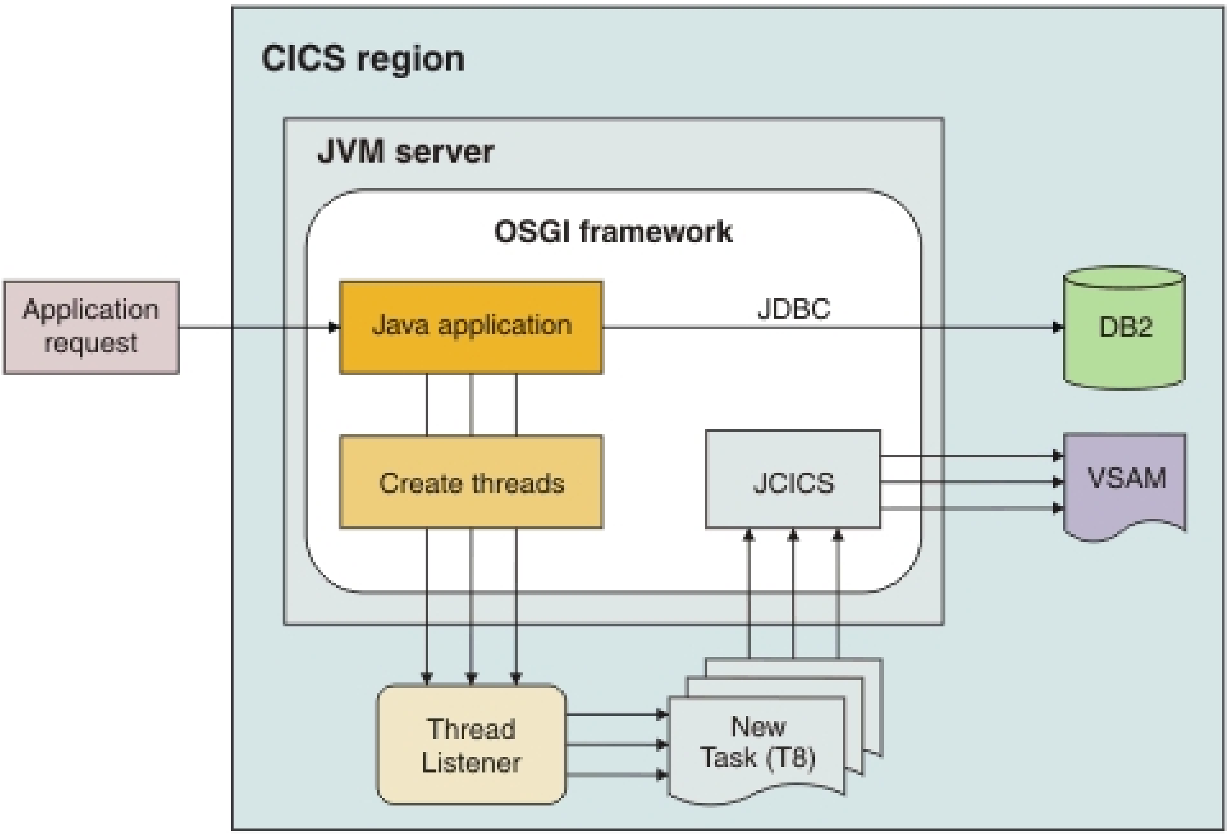
When CICS enables a JVM server, the JVM server runs on a Language Environment process thread. This thread is a child of the TP TCB. Every CICS task is attached to a thread in the JVM by using a T8 TCB. You can control how many T8 TCBs are available to the JVM server by setting the THREADLIMIT attribute on the JVMSERVER resource.

The T8 TCBs that are created for the JVM server exist in a virtual pool and cannot be reused by another JVM server that is running in the same CICS region. The maximum number of T8 TCBs that can exist in a CICS region across all JVM servers is 2000 and the maximum for a specific JVM server is 256.

### Multithreaded applications

Java applications that are running in an OSGi framework can also start CICS tasks asynchronously by using an ExecutorService OSGi service. The JVM server registers the ExecutorService as an OSGi service on startup. The ExecutorService automatically uses an implementation that is supplied by CICS that creates threads that can use the JCICS API to access CICS services. This approach means the application does not have to use specific JCICS API methods to create threads. However, an application can also use the CICSExecutorService to run work on a separate CICS capable thread.

When the JVM server is enabled, it starts the CJSL transaction to create a long-running task that is called the JVM server listener. This listener waits for new thread requests from the application and runs the CJSA transaction to create CICS tasks that are dispatched on a T8 TCB. This process is shown in the following diagram:



In advanced scenarios, an application can use the OSGi service to run many threads asynchronously. These threads all have access to CICS services through JCICS and run under T8 TCBs.

## Execution keys for JVM servers

A Java program must use a JVM that is running in the correct execution key. JVM servers run in CICS key. To use a JVM server, the PROGRAM resource for the Java program must have the EXECKEY attribute set to CICS. CICS uses a T8 TCB to run the JVM and obtains MVS storage in CICS key.

## Runaway tasks

The CICS JVM server infrastructure supports use of the task runaway detection mechanism. Unlike traditional CICS tasks, a task running Java on a T8 TCB cannot be terminated without consequences to other workload in the same JVM. Language Environment and the JVM server run in a POSIX-compliant environment, which mandates that if a TCB/Thread is terminated, the parent process is also terminated. In turn, all child processes are terminated abruptly - and cause all tasks in the JVM to fail immediately.

A task running in a JVM server that exceeds the modified RUNAWAY interval experiences a more controlled termination process. This differs from the traditional CICS behavior and you should evaluate whether you want runaway intervals to apply to your Java tasks, or what value to set.

### JVMSERVER controlled runaway processing

When a task running Java experiences a runaway interval condition, the JVMSERVER intercepts the condition and triggers a `DISABLE PHASEOUT`. New work is prevented from entering the JVM and existing work is left to drain. Subsequently, should the task complete its processing, the JVMSERVER re-enables and becomes available for new requests. In many cases if a task running Java exceeds the runaway interval value, it is likely to be a bad application, such as a tightly looping application and prevents successful PHASEOUT/RECYCLE of the JVMSERVER. When an application is detected, the runaway timer triggers again after another interval and the `JVMSERVER DISABLE PHASEOUT` is escalated to a `JVMSERVER DISABLE PURGE`. Remaining tasks are subject to PURGE processing and in most cases are terminated. If further runaway intervals are exceeded, the `JVMSERVER DISABLE` escalates to FORCEPURGE and ultimately KILL - until all running tasks are forcefully terminated. The JVMSERVER recycles back to the ENABLED state ready for new requests. If the JVMSERVER had to escalate as far as a `DISABLE KILL` request, it is prudent to recycle CICS at the earliest opportunity.

### Modified runaway interval value

A runaway condition for a task that is running in a JVM server can cause temporary availability problems for the whole JVM server. For this reason, CICS modifies the runaway interval value that was configured, by multiplying it by a factor of 10 (up to a maximum value of 45 minutes). This new value is the effective runaway interval. This higher runaway interval reduces the possibility of a runaway condition being detected for an inefficient (but otherwise working) application. For example, if the transaction definition specifies RUNAWAY=SYSTEM, and the ICVR system initialization parameter indicates a default limit of 5000 milliseconds, then the effective runaway interval for that task when it runs in a JVM server is 50000 milliseconds.

### Setting the runaway interval value

By default the CJSA transaction definition that is used for Liberty JVM servers and for work in an OSGi JVM server started from the `CICSExecutorService` has runaway detection active and set to the system interval. If you do not want runaway intervals to apply to these tasks, you can run work under your own transaction definitions with the runaway interval set to 0, or another value of your choice. Liberty workload is typically controlled by URIMAPs, while the `CICSExecutorService` provides the `CICSTransactionRunnable` and `CICSTransactionCallable` interfaces to allow customized transaction definitions to be used.

## Shared class cache

Using a Java shared class cache provides a means of improving JVM startup time, reducing overall storage usage, and optimizing the compilation process. A class cache can be used with all JVM servers (OSGi, Liberty, and classpath-based).

The IBM® SDK, Java Technology Edition on z/OS® supports a shared class cache. To enable a JVM server to use the class cache, and set the size, you must use JVM command line parameters. Other operational requirements, such as monitoring usage of the class cache and destroying class caches, are also performed using options on the Java command.

For more information about Java class data sharing, see Class data sharing.

A shared class cache can contain the following elements:

- Java classes, including application classes, JVM server infrastructure, and Java bootstrap classes.
- Ahead-of-time (AOT) compiled code.

### Enabling the class cache

To enable class cache, use a JVM command line parameter, for example:

```
-Xshareclasses:name=cics.<group>
```

Where `<group>` might be the JVM profile symbol `&applid;` if you want to share classes within the same region only. Alternatively, you can select an arbitrary identifier that all JVM servers of a particular type would connect to, with common classes. The granularity of sharing is user-specific depending on your needs, the size of the class cache, and the number of shared applications. You can ensure a number of JVM servers of common functions share a class cache name, and that the size of the class cache is large enough to accommodate all uses.

### Checking the class cache

You can check how full the class cache is by running the z/OS UNIX command `JAVA_HOME/bin/java -Xshareclasses:name=<named_cache>,printStats`. This query returns a `Cache is nn% full` message.

**Important:** If your cache was created using a different `compressedRefs` setting than that currently in effect within the JVM, you will receive a message indicating you should use the correct JVM level. In such situations, you should check that the `compressedRefs` settings in effect when you created your cache, are the same as those in effect when your JVM was created.

For more information, see Dealing with cache problems.

### Setting or changing the class cache size

1. Modify the JVM profile to define the named cache size `-Xscmx256M`
2. Shutdown all JVM servers using the cache.
3. Remove the cache using `JAVA_HOME/bin/java -Xshareclasses:name=<named_cache>,destroy`
4. Start the JVM servers.

As an alternative to steps 2 and 3 of this procedure, you can restart z/OS.

## Which JVM server to use: Liberty JVM or OSGi JVM?

CICS provides a JVM server as the runtime environment to host Java applications in the CICS region. A fundamental choice is which JVM server to use.

In CICS, the OSGi JVM server is a Java runtime that incorporates an OSGi framework. That same technology is used for the Liberty JVM server. The key difference between the two is that the Liberty

JVM server embeds an instance of a Liberty server. See Design choices for Java in CICS for a high-level view and the corresponding options for type of application, packaging, and deployment.

## Choosing Liberty JVM

A Liberty JVM server is appropriate where web technology, Enterprise Java APIs, or both are required. For example:

- You want to modernize the presentation interfaces of your CICS application, replacing 3270 screens with web browser and RESTful clients.
- You want to use Java standards-based development tools to package, co-locate, and manage a web client with other existing CICS applications.
- You already use Liberty applications in WebSphere Application Server and want to port them to run in CICS.
- You already use Jetty or similar servlet engines in CICS and want to migrate to an application server that is based on Liberty.
- You want to use data source definitions to access Db2 databases from Java. See Defining the CICS Db2 connection.
- You want to coordinate updates that are made to CICS recoverable resources with updates that are made to a remote resource manager through a type 4 JDBC database driver, by using the Java Transaction API (JTA).
- You want to develop services that follow REpresentational State Transfer (REST) principles by using JAX-RS.
- You want to develop applications through support of a standard, annotation-based model by using JAX-WS.
- You want to develop Java EE applications that send and receive secure messages through JMS.

To work with a Liberty JVM server, see Developing Java applications to run in a Liberty JVM server.

## Choosing OSGi

An OSGi JVM server is appropriate when Java SE APIs are required. An OSGi JVM server is a lighter option that does not require the configuration of an angel process or the associated security, which makes it a good choice in the following situations:

- You want to create Java workloads that can run on a zAAP to reduce the cost of transactions.
- You have experience of writing Java applications that use OSGi on other platforms and want to create Java applications in CICS.
- You want to provide Java applications as a set of modular components that can be reused and updated independently, without affecting the availability of applications and the JVM in which they are running.
- You can follow the Plain Old Java Object (POJO) programming model, giving you the option of deploying an application as a set of OSGi bundles with dynamic lifecycles.
- New Java applications, and new versions of Java applications, can be deployed into a live production system without having to restart the JVM, and without impacting the other Java applications that are deployed in that JVM.

There are some clashes of concepts between OSGi and CICS, such as bundles, that can catch you out and some capabilities, such as class loading, that have hidden depths. The OSGi Demystified articles in IBM Developer offer tips to deal with these complexities.

To work with an OSGi server, see Guidance for using OSGi.

# Java applications that comply with OSGi

CICS includes the Equinox implementation of the OSGi framework to run Java applications that comply with the OSGi specification in a JVM server.

The OSGi Service Platform specification, as described in "The OSGi Service Platform" on page 3, provides a framework for running and managing modular and dynamic Java applications. The default configuration of a JVM server includes the Equinox implementation of an OSGi framework. Java applications that are deployed on the OSGi framework of a JVM server benefit from the advantages of using OSGi and the qualities of service that are inherent in running applications in CICS.

You might want to use Java applications for any of the following reasons:

- You want to create Java workloads that can run on a zAAP to reduce the cost of transactions.
- You have experience of writing Java applications that use OSGi on other platforms and want to create Java applications in CICS.
- You want to provide Java applications as a set of modular components that can be reused and updated independently, without affecting the availability of applications and the JVM in which they are running.

To effectively develop, deploy, and manage Java applications that comply with OSGi, you must use the IBM CICS SDK for Java and CICS Explorer:

- The IBM CICS SDK for Java enhances an existing Eclipse Integrated Development Environment (IDE) to provide the tools and support to help Java developers create and deploy Java applications in CICS. Use this tool to convert existing Java applications to OSGi bundles.
- CICS Explorer is an Eclipse-based systems management tool that provides system administrators with views for OSGi bundles, OSGi services, and the JVM servers in which they run. Use this tool to enable and disable Java applications, check the status of OSGi bundles and services in the framework, and get some preliminary statistics on the performance of the JVM server.

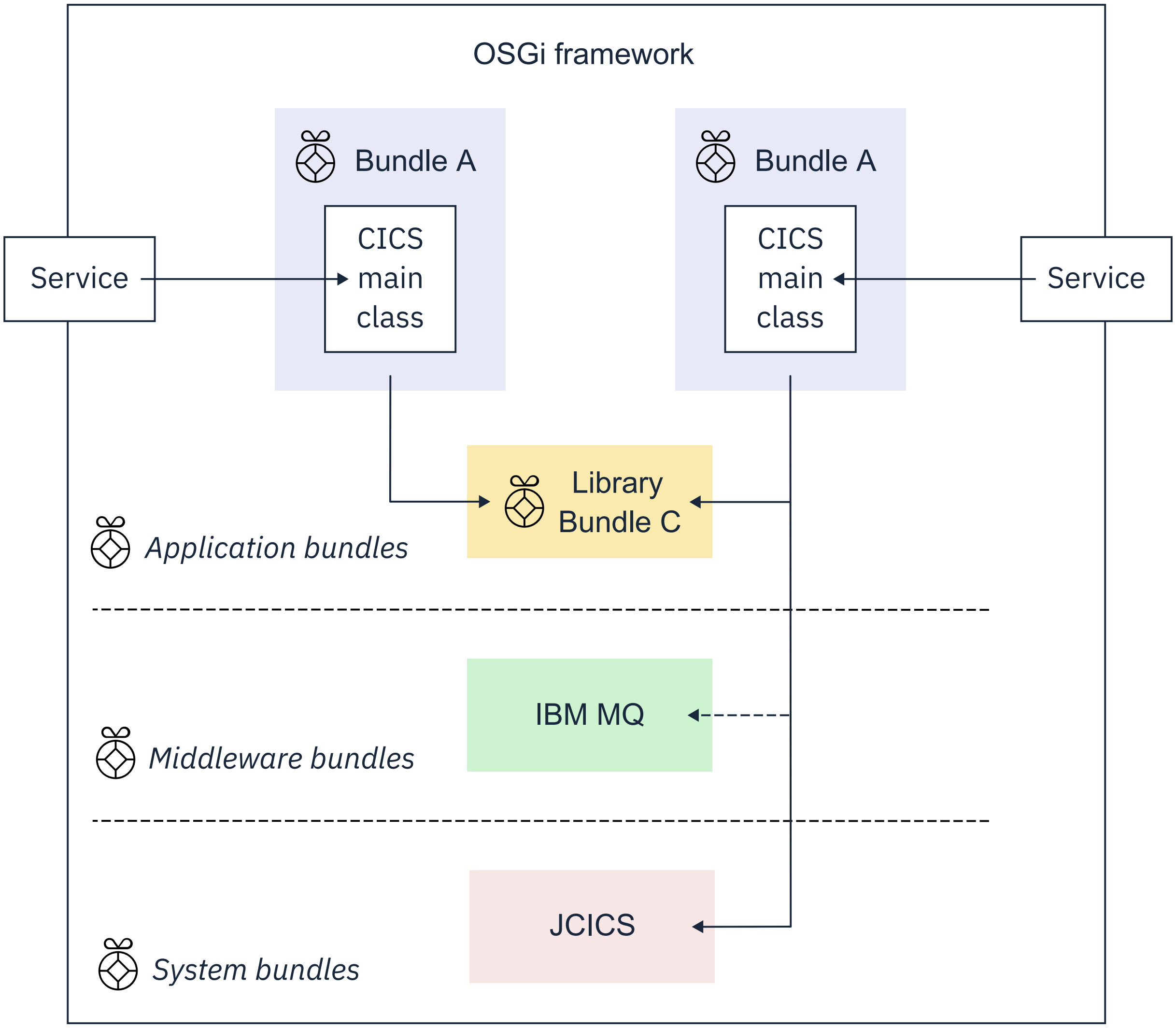
Any Java developer or systems administrator who wants to work with OSGi requires access to these freely available tools.

The following examples describe how you can run Java applications that use OSGi in CICS.

## Run multiple Java applications in the same JVM server

The JVM server can handle multiple requests in the same JVM concurrently. Therefore, you can call the same application multiple times concurrently or run more than one application in the same JVM server.

When you decide how to split your applications between JVM servers, you can plan how to use the OSGi model to componentize your applications into a set of OSGi bundles. You must also decide what supporting OSGi bundles are required in the framework to provide services to your applications. The OSGi framework can contain different types of OSGi bundle, as shown in the following diagram:


OSGi framework
Bundle A
CICS main class
Bundle A
CICS main class
Service
Service
Library Bundle C
Application bundles
IBM MQ
Middleware bundles
JCICS
System bundles

**Application bundles**

An application bundle is an OSGi bundle that contains application code. OSGi bundles can be self-contained or have dependencies on other bundles in the framework. These dependencies are managed by the framework, so that an OSGi bundle that has an unresolved dependency cannot run in the framework. In order for the application to be accessible outside the framework in CICS, an OSGi bundle must declare a CICS main class as its OSGi service. If a PROGRAM resource points to the CICS main class, other applications outside the OSGi framework can access the Java application. If you have an OSGi bundle that contains common libraries for one or more applications, a Java developer might decide not to declare a CICS main class. This OSGi bundle is available only to other OSGi bundles in the framework.

The deployment unit for a Java application is a CICS bundle. A CICS bundle can contain any number of OSGi bundles and can be deployed on one or more JVM servers. You can add, update, and remove application bundles independently from managing the JVM server.

**Middleware bundles**

A middleware bundle is an OSGi bundle that contains classes to implement system services, such as connecting to WebSphere MQ. Another example might be an OSGi bundle that contains native code and must be loaded only once in the OSGi framework. A middleware bundle is managed with the lifecycle of the JVM server, rather than the applications that use its classes. Middleware bundles are specified in the JVM profile of the JVM server and are loaded by CICS when the JVM server starts up.

**System bundles**

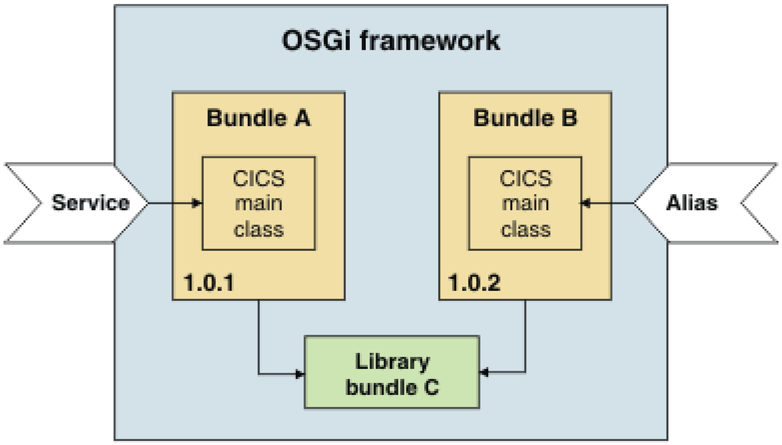
A system bundle is an OSGi bundle that manages the interaction between CICS and the OSGi framework to provide key services to the applications. The primary example is the JCICS OSGi bundles, which provide access to CICS services and resources.

To simplify the management of your Java applications, follow these best practices:

- Deploy tightly coupled OSGi bundles that comprise an application in the same CICS bundle. Tightly coupled bundles export classes directly from each other without using OSGi services. Deploy these OSGi bundles together in a CICS bundle to update and manage them together.
- Avoid creating dependencies between applications. Instead, create a common library in a separate OSGi bundle and manage it in its own CICS bundle. You can update the library separately from the applications.
- Follow OSGi best practices by using versions when you are creating dependencies between bundles. Using a range of versions mean that an application can tolerate compatible updates to bundles that it depends on.
- You should always explicitly declare the packages that your OSGi bundle uses, even if the tooling does not indicate an error. You can do this by adding or updating the `Import-Package` bundle header in your OSGi bundle manifest. Tools such as Eclipse make assumptions about the availability of **`javax.*`** packages that might not be correct for a runtime environment where an explicit Import is necessary.
- Set up a naming convention for the JVM servers and agree the convention between the system programmers and Java developers.
- Avoid the use of singleton OSGi bundles. Discarding a singleton bundle that other bundles depend on can cause the dependent bundles to fail.

## Run multiple versions of the same Java application in a JVM server

The OSGi framework supports running multiple versions of an OSGi bundle in a framework, so you can phase in updates to the application without interrupting its availability. While you can install multiple implementations of the same OSGi service into the framework, the service with the highest version property is used when that service is called. In CICS the version property is inferred from the underlying OSGi bundle. So if you want to run multiple versions of the same Java application in a JVM server at the same time and the different versions of the OSGi bundle have the same CICS main class, you must use an alias on one definition of the CICS main class. The alias is specified with the declaration of the CICS main class and registered in the OSGi framework as the OSGi service for a specific version of the application. Specify the alias on another PROGRAM resource to make that version of the application available.



## Java applications in a Liberty JVM server

CICS provides a Java EE application server that can run lightweight Java servlets and JavaServer Pages. Developers can use the rich features of the Liberty in CICS specifications to write Java EE applications for CICS. The application server runs in a JVM server and is built on WebSphere Application Server Liberty.

Liberty is a lightweight application server for application development that starts quickly and can run on different platforms. It is optimized for Java developers to quickly develop and test applications, requiring a minimal amount of effort to configure and start the web server. Java developers package the application and web server together for simple deployment by using Eclipse tools that are freely available. Web services support available includes Java API for RESTful Web Services (JAX-RS) and Java API for XML Web Services (JAX-WS). For more information about Liberty, see Liberty overview.

Liberty is installed with CICS to run as a application server in a JVM server. The Liberty JVM server supports a subset of the features that are available in Liberty; you can run OSGi applications, Java servlets, and JSP pages. For more information about what features are supported, see Liberty features.

You might want to use the Liberty JVM server and associated tools for any of the following reasons:

- You want to modernize the presentation interfaces of your CICS application, replacing 3270 screens with web browser and RESTful clients.
- You want to use Java standards-based development tools to package, co-locate, and manage a web client with other existing CICS applications.
- You already use Liberty applications in WebSphere Application Server and want to port them to run in CICS.
- You already use Jetty or similar servlet engines in CICS and want to migrate to an application server that is based on Liberty.
- You want to use data source definitions to access Db2 databases from Java. See Defining the CICS Db2 connection.
- You want to coordinate updates made to CICS recoverable resources with updates made to a remote resource manager via a type 4 JDBC database driver, using the Java Transaction API (JTA).
- You want to develop services that follow REpresentational State Transfer (REST) principles using JAX-RS.
- You want to develop applications through support of a standard, annotation-based model using JAX-WS.
- You want to develop Java EE applications that send and receive secure messages via JMS.

### CICS exception handling in Liberty applications

Liberty applications can use several different transactional APIs, including the JCICS API. Most Liberty components (except for EJBs) require the explicit use of the Java Transactions API (JTA) to coordinate transactions across those APIs. For example, if you need JCICS and remote JDBC activity to rollback following an Exception issued in application code, you must start a JTA transaction before interacting with the JDBC connection.

CICS implements an automatic rollback-CICS-transactions-on-Exception policy for simple servlets hosted in Liberty. This policy ensures that CICS transactions roll back if an Exception is thrown from an ordinary servlet. This is sufficient to provide basic transactional integration for simple servlets that use the JCICS API, but the policy does not address some of the more complicated scenarios you might encounter.

For example, the rollback-CICS-transactions-on-Exception policy doesn't integrate with other non-CICS resource adapters such as remote JDBC and JCA connections. If you need to coordinate transactions between CICS and other resource managers, you must use JTA to explicitly coordinate the transactions. This causes Liberty, CICS, and the remote transaction managers, to jointly negotiate whether to commit or rollback the transactions.

The rollback-CICS-transactions-on-Exception policy is available for simple servlets, but isn't available to the entire range of extensibility points available in a Liberty environment. Advanced users who exploit other plugin, callback, and extension points might not experience automated rollback of the CICS transaction when throwing an Exception. If you need predictable transactionality for Exceptions thrown from such components, use JTA to coordinate the transactions; an alternative option is to issue an explicit JCICS Abend to force CICS to rollback the CICS transaction for application detected errors.

For more information, see CICS exception handling in JCICS programs.

### CICS tasks for Liberty applications

In order for a Liberty application to use the JCICS API and other CICS resources, such as a JDBC DataSource with type 2 connectivity, requests must run under a CICS task. CICS creates a task for an application request at different times, dependent on the type of request. For HTTP requests, a task is created before the Liberty application is invoked. For other types of requests, for example message-driven beans (MDBs), inbound JCA, and remote EJBs, a task is created as required.

If the application does not interact with CICS, no CICS task is created for non-HTTP requests.

CICS performs the following actions when a CICS task is created:

- The CICS transaction security check occurs.
- CICS monitoring begins for the task.
- CICS trace for the task starts.
- The name of the Java thread is changed to include the CICS task number and transaction ID.

For non-HTTP applications, these actions occur the first time a JCICS API or a JDBC DataSource with type 2 connectivity is used. If the application does not interact with CICS, no CICS monitoring or transaction security occurs.

CICS abend handling for uncaught Java exceptions does not apply unless there is a CICS task. If an application throws an exception before the JCICS API or a JDBC DataSource with type 2 connectivity is used, no AJ05 abend occurs.

## Java web services

CICS includes the Axis2 technology to run Java web services. Axis2 is an open source web services engine from the Apache foundation and is provided with CICS to process SOAP messages in a Java environment.

Axis2 is a Java implementation of a web services SOAP engine that supports a number of the web services specifications. It also provides a programming model that describes how to create Java applications that can run in Axis2. Axis2 is provided with CICS to process web services in a Java environment, and therefore supports offloading eligible Java processing to zAAP processors.

The JVM server supports running Axis2 to process inbound and outbound SOAP messages in a Java SOAP pipeline, without changing any of your existing web services. However, you can also create a web service from a Java application and run it in the same JVM server. By deploying the application to the Axis2 repository of the JVM server, both the Java application and SOAP processing are eligible for running on a zEnterprise Application Assist Processor (zAAP).

You might want to use Java web services for one of the following reasons:

- You have experience of Axis2 web services on other platforms and want to create web services in CICS.
- You want to use standard Java APIs to create Java data bindings that integrate with Axis2.
- You have complicated WSDL documents that are difficult to handle with the CICS web services assistants.

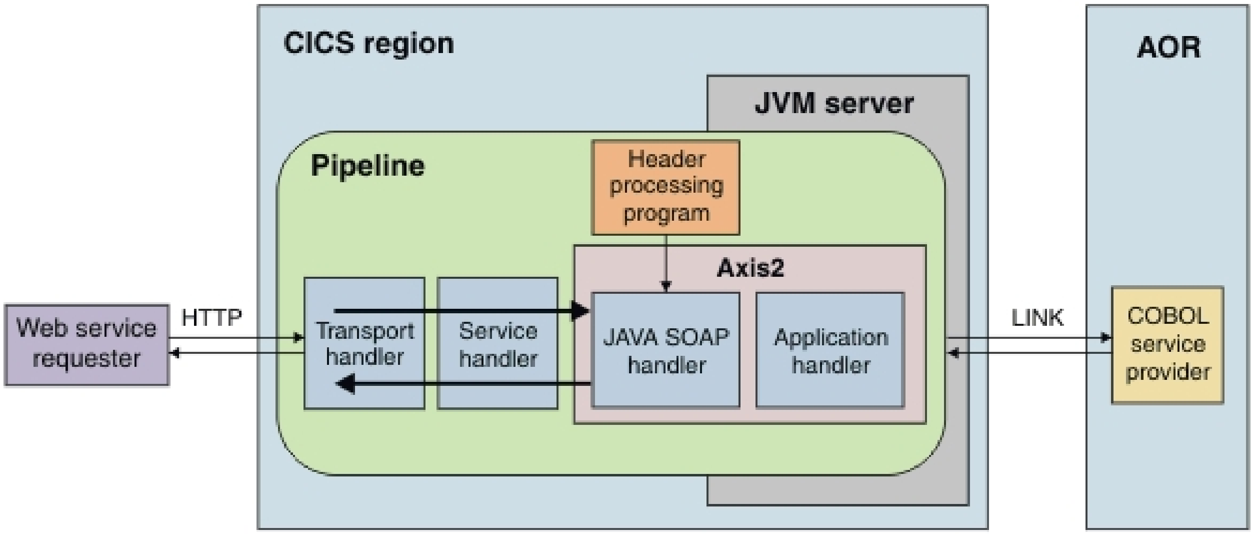
The following examples describe how you can use Java with web services.

## Process SOAP messages in a JVM server

Most SOAP processing that occurs in the web services pipeline is performed by the SOAP handler and application handler. You can optionally run this SOAP processing in a JVM server and use zAAPs to run the work. You can continue to use web service applications that are written in COBOL, C, C++, or PL/I.

If you have existing web services, you can update the configuration of your pipelines to use a JVM server. You do not have to change the web services. If the pipeline uses a SOAP header processing program, it is best to rewrite the program in Java by using the Axis2 programming model. The header processing program can share the Java objects with Axis2 without doing any further data conversion. If you have a header processing program in COBOL for example, the data must be converted from Java into COBOL and back again, which can slow down the performance of the SOAP processing.

The scenario shown in the following diagram is an example of a COBOL application that is a web service provider. The request is processed in a pipeline that is configured to support Java. The SOAP handler and application handler are Java programs that are processed by Axis2 and run in a JVM server. The application handler converts the data from XML to COBOL and links to the application.



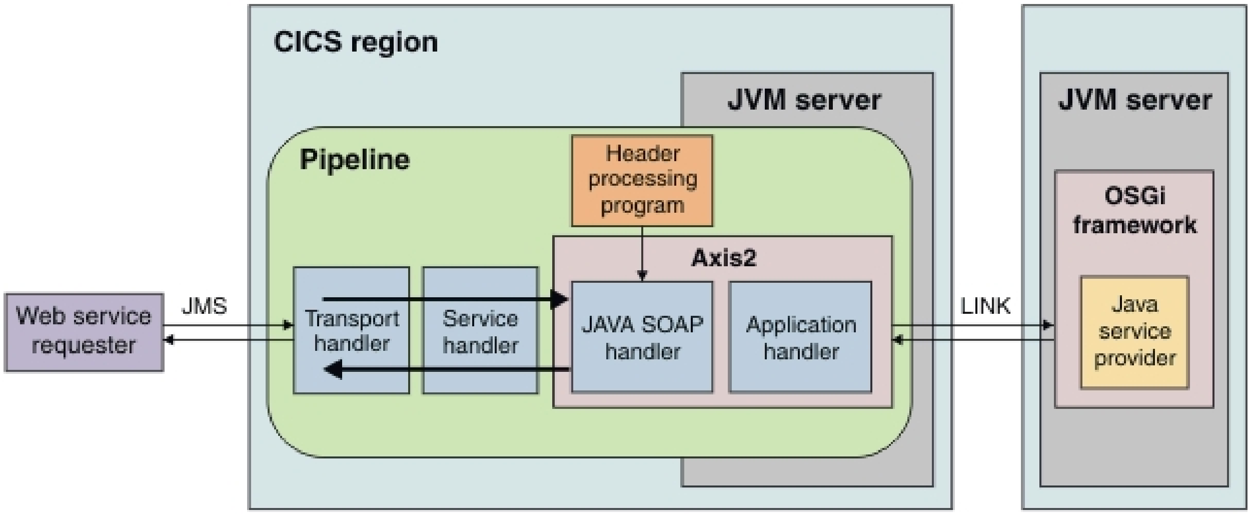
When you are planning your environment, ensure that you use a set of dedicated regions for your JVM servers. In this example, the COBOL application runs in an application-owning region (AOR) that is separate from the CICS region where the JVM server runs. You can use workload management to balance the workloads, for example on the **EXEC CICS LINK** from the application handler or on the inbound request from the web service requester.

## Write a Java application that uses output from the CICS web services assistant

You can write a Java application that interprets the language structures and uses the data bindings generated by the CICS web services assistant. The web services assistant can produce language structures from WSDL or WSDL from language structures. The assistant also produces a web service binding that describes how to convert the data between XML and the target language during SOAP processing.

If you use the assistant to generate a language structure, you can use IBM Record Generator for Java or the Rational J2C Tools to work with the language structures to generate Java classes. These tools provide a way for Java developers to interact with other CICS applications. In this example, you can use these tools to write a Java application that can handle an inbound SOAP message after CICS has converted the data from XML. For more information, see Interacting with structured data from Java.

The scenario shown in the following diagram is an example of a Java application that is a web service provider. The SOAP processing is handled by Axis2 in a JVM server. The application handler links to the Java application, which is packaged and deployed as one or more OSGi bundles and runs in a JVM server.



The advantage of this approach is that because the data bindings were generated by the web services assistant, the web service is represented in CICS by the WEBSERVICE resource. You can use statistics, resource management, and other facilities in CICS to manage the web service. The disadvantage is that the Java developer must work with language structures for a programming language that might be unfamiliar.

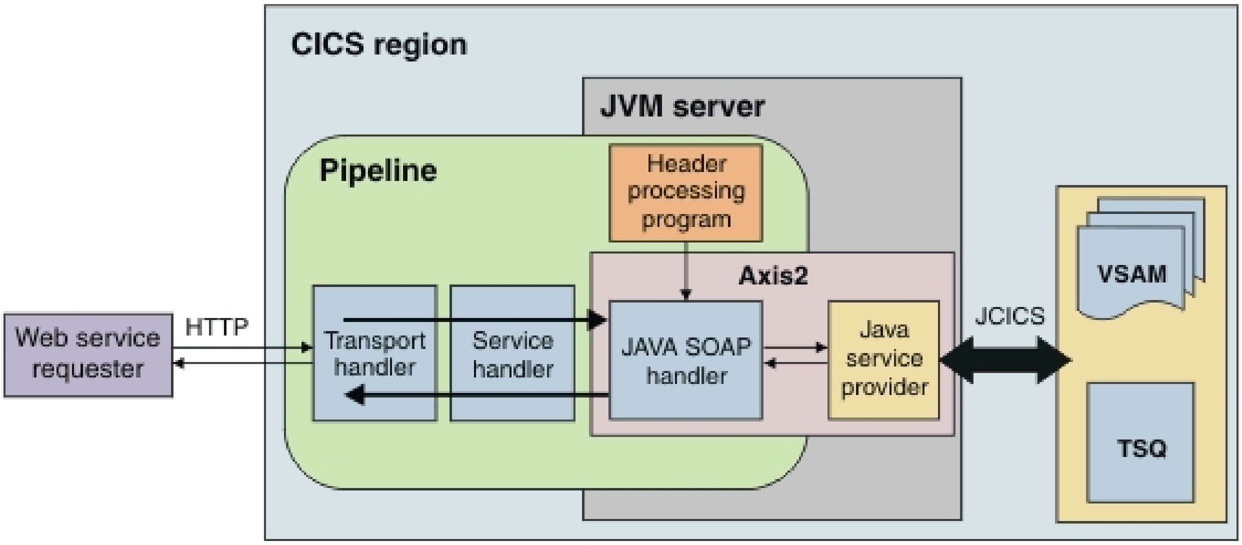
When you are planning your environment for this type of application, use a separate JVM server to run the application:

- You can more effectively manage and tune the JVM servers for the different workloads.
- You can use workload management on the inbound requests and **EXEC CICS LINK** to balance workloads and scale the environment.
- You can take advantage of the OSGi support in CICS to manage the Java application.

## Write a Java application that uses Java data bindings

You can write a Java application that generates and parses the XML for SOAP messages. The Java API provides standard Java libraries to work with XML; for example, you can use the Java Architecture for XML Binding (JAXB) to create the Java data bindings, and the Java API for XML Web Services (JAX-WS) libraries to generate and parse the XML. If you use these libraries, the application can run in Axis2 in the same JVM server as the SOAP pipeline processing.

The scenario shown in the following diagram is an example of a Java application that is a web service provider and is processed by the Axis2 SOAP engine in a JVM server.



The Java application uses Java data bindings and interacts with the Java SOAP handler, so there is no application handler. In this example, the web service requester uses HTTP to connect to the CICS region, but you can also use JMS. The Java application uses JCICS to access CICS services, in this example VSAM files and a temporary storage queue.

The advantage of this approach is that the Java developer uses familiar technologies to create the application. Also, the Java developer can work with complex WSDL documents that the web services assistant cannot process to produce a binding. However, this approach has some limitations:

- You cannot use WS-Security for this type of application, so if you want to use security, use SSL to secure the connection.
- No context switch for the user ID occurs in the pipeline processing. To change the user ID on the request, use a URIMAP resource.
- Because you are not using the web service binding from the web services assistant, there is no WEBSERVICE resource.
- If the application is a web service requester, the pipeline processing is bypassed. So you do not get the qualities of service that are available in the pipeline.

If you implement workload management in your CICS regions, you must plan how to route this type of workload. Because the Java application runs in the same JVM server as the SOAP processing, CICS does not provide a routing opportunity. However, you can implement a distributed program link in the JAX-WS application to another program if routing is required.

## Spring Boot support in CICS

The CICS Liberty JVM server supports Spring Boot applications by using the Spring application programming model. Spring Boot provides a simpler and faster way of configuring, building, and running Spring applications. Spring was originally designed to simplify Java Enterprise Edition (EE), by using plain old Java objects (POJOs) and dependency injection. It now extends and encompasses many aspects of Java EE development. Spring Boot builds on Spring by adding components to avoid complex configuration, reduce development time, and offer a simpler startup experience. Most Spring Boot applications require little Spring configuration. For more information about Spring and Spring Boot, see Spring Boot overview.

Spring Boot applications can run on CICS Liberty without modification by configuring the springBoot-1.5 or springBoot-2.0 features and deploying them as applications of `'type="spring"'`, as JAR files with .spring extension in `dropins`, or as JAR files with .jar extension in `dropins/spring`. It also is possible to configure Spring Boot applications for integration with CICS transactions and security, and to call the CICS API by using JCICS. For more information on integrations, see Spring Boot applications.

When built as a web application archive (WAR), a Spring Boot application can be deployed and managed by using CICS bundles in the same way as can other CICS Liberty applications. A Spring Boot application can use the annotation `@CICSProgram` to define a method as the target of a CICS program. This can be linked from COBOL or other non-Java CICS programs by using the channel and container interface.

# Chapter 2. CICS management client interface (CMCI)

The CICS management client interface (CMCI) is a system management application programming interface (API) for use by HTTP client applications such as IBM CICS Explorer. The CMCI provides the CMCI REST API and the CMCI GraphQL API for clients to manage installed and definitional system resources, and the CICS bundle deployment API to deploy bundles into single CICS development regions with Maven and Gradle plug-ins. It also supports advanced client authentication, including multifactor authentication (MFA).

Depending on your environment, you can set up the CMCI in either a CICSPlex® SM environment or in a single CICS region that is not managed by any CICSPlex SM.

**CMCI in a CICSPlex SM environment**
Allows you to manage definitional resources, such as CSD and BAS resources, and operational resources in all of the CICS regions managed by CICSPlex SM, with an HTTP client.

**CMCI in a single CICS region**
Allows you to manage only the CSD and operational resources associated with that region through an HTTP client, and the context is specified as the application ID of that CICS region.

When a single CICS region is configured with the CMCI, it becomes a CICS System Management Single Server (SMSS).

## What is the CMCI JVM server?

The CMCI JVM server is a Liberty server. It is an optional, but highly recommended component of the CMCI that enhances support for CMCI requests. In addition to the basic CMCI REST API, the CMCI JVM server performs client authentication, including the support for multifactor authentication (MFA). It also provides powerful capabilities of system management and application development, through the CMCI GraphQL API and the CICS bundle deployment API.

Table 2 on page 23 compares functions that are available to the CMCI configured with the CMCI JVM server with those available to the basic CMCI (that is, without the CMCI JVM server).

*Table 2. Function availability in CMCI*

| Function | CMCI with the CMCI JVM server (default in CICSPlex SM) | Basic CMCI |
|---|---|---|
| **Authentication support** | | |
| User ID / password | √ | √ |
| Certificate | √ | √ |
| PassTicket | √ | |
| MFA | √ | |
| **API support** | | |
| REST API | √ | √ |
| GraphQL API | √ | |
| CICS bundle deployment API | √ (Additional configuration required) | |

The CMCI JVM server is used by default by the CMCI in a CICSPlex SM environment. For CICSPlex SM, the enablement of the CMCI JVM server is controlled by feature toggle `com.ibm.cics.cmci.jvmserver`. For an SMSS, it's controlled by the **CPSMCONN** system initialization parameter.

## CMCI REST API versus CMCI GraphQL API: What is it? And what's the difference?

The CMCI REST API and the CMCI GraphQL API are both HTTP-based application programming interfaces that can be used to develop HTTP client applications that manage installed and definitional CICS and CICSPlex SM resources on CICS regions being managed by CICSPlex SM.

The CMCI REST API is designed based on Representational State Transfer (RESTful) principles, so you need to retrieve data from multiple endpoints with fixed data structures. That means each client of that API needs to be built with understanding of how to derive the relationships between resources. In comparison, these relationships are a fundamental part of the GraphQL API, so this API can expose only a single endpoint with more flexibility. This means that in a single query request, a client can query many types of CICS resources across CICSplexes, and specify exactly what data it needs with explicitly expressed relationships between the resources.

For example, the GraphQL query in Figure 1 on page 24 retrieves data about the local transactions and associated programs, including use counts, in all regions in all connected CICSplexes. To achieve the same effect with the CMCI REST API, you might first access an endpoint that returns the list of local transactions available, and then an endpoint that returns all the programs. Then your client code must be written to post-process these results to match up the local transactions and programs. With GraphQL, relationships within the queried resources are also more explicitly shown through the CMCI GraphQL API than through the CMCI REST API.

```
{
  cicsplexes {
    cicsResources {
      loctran {
        records {
          name
          to_program {
            name
            useCount
          }
        }
      }
    }
  }
}
```

*Figure 1. CMCI GraphQL API Query requesting programs associated with local transactions*

## CICS bundle deployment API: What is it?

Through the CICS bundle deployment API, the CMCI supports deploying CICS bundles into a single CICS region.

This REST API receives a CICS bundle as a zip file over HTTP. The bundle will be unzipped, installed into, and enabled in the appropriate CICS region automatically. If a CICS bundle with the same name already exists, it will be disabled and discarded before the new bundle is installed.

The CICS bundle deployment API can increase Java developers' productivity by enabling them to see their application changes reflected in a running CICS region within seconds. Developers can also use the CICS-provided Gradle or Maven plug-in (`cics-bundle-maven-plugin` or `com.ibm.cics.bundle`) that leverages the API, to integrate CICS bundle build and deployment into a toolchain.

The API also enables Java developers to deploy bundles whilst the system programmer retains control. A functional ID or another user ID with sufficient access deals with the bundle lifecycle and interacts with zFS on behalf of developers.

For more information about the API, see “How it works: CICS bundle deployment API” on page 32.

To configure CICS for the API, see Configuring the CMCI JVM server for the CICS bundle deployment API.

**Related information**

Setting up CMCI

# How it works: CMCI REST API

The CICS management client interface (CMCI) provides a REST application programming interface (API) for system management clients such as IBM CICS Explorer. The CMCI REST API can also be used in an automated process, by leveraging the Ansible IBM z/OS CICS collection.

The CMCI REST API is supported through HTTP. The client initiates an HTTP request to the CMCI. If the interface determines that the request is valid, it constructs a CICSPlex SM API command or, in the case of a stand-alone CICS region, a CICS system command. After running the command, the CMCI creates an HTTP response. If the request is successful, this takes the form of an HTTP 200 (OK) response and an XML feed containing a result set, which it passes back to the client. If the request is not successful, the response consists of a non-OK HTTP response code with details of the failure.

The format for CMCI HTTP requests and responses is based on the HTTP/1.1 protocol. See The HTTP protocol for more information about this protocol.

## How to make CMCI HTTP requests

A CMCI request takes the form of an HTTP header followed by a URI (Universal Resource Identifier) and, where appropriate, an XML body containing details of any changes to be made to CICS or CICSPlex SM resources.

The header incorporates one of the following HTTP methods:

**DELETE**
Removes resources from the CICSPlex SM data repository, removes resources from the CICS system definition data set (CSD), or discards installed resources.

**GET**
Retrieves information about resources in the CICSPlex SM data repository, retrieves information about resources on the CSD, or retrieves information about installed resources.

**POST**
Creates resources on the CICSPlex SM data repository or resources in the CSD.

**PUT**
Updates existing resources in the CICSPlex SM data repository, updates existing resources in the CSD , or sets attributes and performs actions on installed resources. Also performs actions on CICSPlex SM and CSD resources.

The URI includes the name of a CICS or CICSPlex SM resource, and specifies a series of parameters that refine the scope and nature of the query to identify one or more instances of the specified resource. In a GET request, the URI also specifies whether the API retains or discards a set of results. If the API retains the results, a new request can act on the retained results without having to repeat the retrieval operation. You can also use subsequent requests to page through the retained results selecting one or more records at a time.

POST and PUT requests include an XML body. In a PUT request the body contains either details of the changes to be made to resource attributes, or the action to be performed on the targeted resources. In a POST request, the body incorporates the attribute values you want to give to the new resource instance.

GET and DELETE requests do not require an XML body. If additional parameters are required for a DELETE request, those parameters must be included in the URI and can optionally be added to the XML body.

## Find out more

CMCI REST API reference gives your details on the DELETE, GET, POST, and PUT methods, CMCI resource names, CMCI XML body elements, diagnostic aids, and so on.

# How it works: CMCI GraphQL API

The CICS management client interface (CMCI) provides a GraphQL application programming interface (API) for system management clients such as IBM CICS Explorer. The CMCI GraphQL API is supported through HTTP. With the GraphQL API, a client can query many types of CICS resources across CICSplexes or regions in a single request. In the single query request, the client can specify exactly what data it needs about multiple CICS resources, with inherent relationships between the CICS resources explicitly expressed. For more information about GraphQL, see Introduction to GraphQL.

**Notes:**

- The aggregation function in CICS Explorer is also supported by the CMCI GraphQL API in CICS TS. For more information, see Configuring for CICS Explorer.
- The CMCI GraphQL API is supported in a CICSPlex SM environment as of CICS TS 5.5, and in a single CICS region (SMSS) environment as of CICS TS 5.6 with APAR PH35122.
- To set up the CMCI GraphQL API in CICS, you need to configure a CMCI JVM server within the WUI region of a CICSplex or a single CICS region. For instructions, see Setting up CMCI.

## What is a GraphQL query?

A simple GraphQL query request looks like this:

```
{
  cicsplexes {
    name
  }
}
```

*Figure 2. Simple query requesting CICSplex names*

At the root of the query is the `cicsplexes` field, which finds all the CICSplexes that the WUI server is connected to. The `name` field nested in the `cicsplexes` field requests the name of each CICSplex.

Query responses are returned as JSON objects, with the requested data enclosed in the value of the `data` field. The structure of the response follows that in the query.

```
{
  "data": {
    "cicsplexes": [
      {
        "name": "CICSPLX01"
      },
      {
        "name": "CICSPLX02"
      }
    ]
  }
}
```

*Figure 3. Response to simple query about CICSplex names*

In an SMSS region, the structure of a GraphQL query is different and looks like this:

```
{
  smssRegion {
    name
  }
}
```

*Figure 4. Simple query requesting SMSS region name*

The structure of the response is similar to the CICSplex, and looks like this:

```
{
  "data": {
    "smssRegion": {
      "name": "IYCWENSS"
    }
  }
}
```

*Figure 5. Response to simple query about SMSS region name*

In CICS TS, the GraphQL API has support for:

- Basic system topology (CICSplexes, Regions, System Groups)
- Querying regions for the resources installed in them
- Querying BAS repositories and CSD repositories for definitions
- Aggregating and grouping resources
- Navigating links between resources

To retrieve more information, add more fields to the query, including nested ones. See "Sample queries" on page 29.

## How to make GraphQL API requests

The GraphQL API endpoint is at:

```
https://host:port/graphql
```

where *host* and *port* are the host name and the port number of your CMCI JVM server.

The GraphQL API accepts GET and POST requests.

**For GET requests:**

A `Content-Type: application/json` header must be sent. The query is supplied by the `query` query parameter. The operation is supplied by the optional `operationName` query parameter.

For example, the simple query in Figure 2 on page 26 can be sent by using the following URL:

```
https://host:port/graphql?query={cicsplexes{name}}
```

Likewise, for the simple query in Figure 4 on page 26, a GET request is similar, and can be sent by using the following URL:

```
https://host:port/graphql?query={smssRegion{name}}
```

**For POST requests:**

A `Content-Type: application/json` header must be sent. The body of the request must be a JSON-encoded object.

```
{
    "query": "query_body",
    "operationName": "operation_name"
}
```

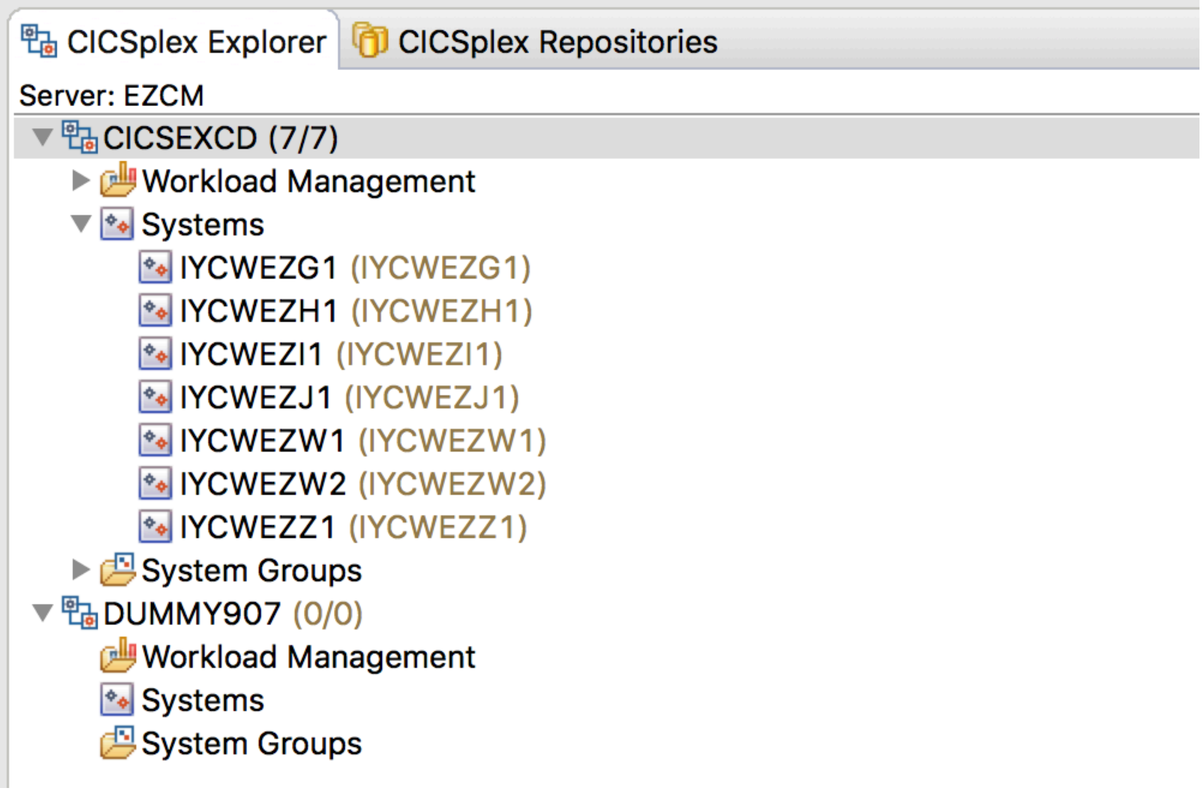
where only the `query` field is mandatory.

Alternatively, a `Content-Type: application/graphql` header can be sent on POST requests. In this case, the body of the request must be the GraphQL query itself, and no operation name can be specified.

See "Sample queries" on page 29 for sample code of GraphQL queries.

## Example: the CICSplex Explorer view of CICS Explorer

The GraphQL API can provide a more responsive experience in user interfaces such as CICS Explorer. Take the **CICSplex Explorer** view of CICS Explorer as an example, consider what information is needed in CICS Explorer to build the **CICSplex Explorer** view:



```
CICSplex Explorer    CICSplex Repositories
Server: EZCM
▼ CICSEXCD (7/7)
    ▶ Workload Management
    ▼ Systems
        IYCWEZG1 (IYCWEZG1)
        IYCWEZH1 (IYCWEZH1)
        IYCWEZI1 (IYCWEZI1)
        IYCWEZJ1 (IYCWEZJ1)
        IYCWEZW1 (IYCWEZW1)
        IYCWEZW2 (IYCWEZW2)
        IYCWEZZ1 (IYCWEZZ1)
    ▶ System Groups
▼ DUMMY907 (0/0)
    Workload Management
    Systems
    System Groups
```

At its most basic, you need to know what CICSplexes are in the environment, and which CICS regions are in those CICSplexes. With a REST API, you have to make multiple requests:

1. Ask for a list of CICSplexes in the environment.
2. For each CICSplex, ask for a list of the regions in that CICSplex.

Even this simple example demonstrates that the number of requests you have to make grows with the complexity of the information you ask for. When you consider adding region groups into the mix, and members of those region groups, even more information needs to be requested.

Here's how to ask for the information you need to populate the **CICSplex Explorer** view in the GraphQL API:

```
{
  cicsplexes {
    name
    regions {
      name
    }
  }
}
```

And here's the response:

```
{
  "data": {
    "cicsplexes": [
      {
        "name": "DUMMY907",
        "regions": []
      },
      {
        "name": "CICSEXCD",
        "regions": [
          {
            "name": "IYCWEZW2"
          },
          {
            "name": "IYCWEZG1"
          },
          {
            "name": "IYCWEZW1"
          },
          {
            "name": "IYCWEZH1"
          },
          {
            "name": "IYCWEZI1"
          },
          {
            "name": "IYCWEZJ1"
          },
          {
            "name": "IYCWEZZ1"
          }
        ]
      }
    ]
  }
}
```

The GraphQL supplies all the data you require in a single request with explicitly shown relationships between CICS resources. When enabled for the CMCI connection, it can drastically reduce the time you need to retrieve information through CICS Explorer. It also powers the aggregation function in CICS Explorer for Aqua 3.2 to provide aggregation and grouping of CICS resources.

## Sample queries

You can use GraphiQL, an online GraphQL visualization editor, to test your GraphQL queries or the samples. The URL to GraphiQL is:

```
https://host:port/graphiql
```

where *host* and *port* are the host name and the port number of your CMCI JVM server.

**GraphiQL tips:**

- GraphiQL provides auto-completion and a built-in documentation explorer for GraphQL schema reference. You can display available field names by pressing Ctrl+Space.
- To easily differentiate queries in GraphiQL history, you can specify a unique query name by prefixing the query with `query` *`QueryName`*.

The following example queries the count of local files of all regions in all the connected CICSplexes, and the name of each CICSplex and region. It also has a query name `LocalFilesInRegionsInCICSplexes`.

```
query LocalFilesInRegionsInCICSplexes {
  cicsplexes {
    name
    regions {
      name
      cicsResources {
        locfile {
          count
        }
      }
    }
  }
}
```

You can add more attributes to be queried. This example queries all CICSplexes and all the regions in each CICSplex. Within each region, it retrieves the `name`, `useCount`, and `status` fields of all the local transactions.

```
{
  cicsplexes {
    name
    regions {
      name
      cicsResources {
        loctran {
          records {
            name
            useCount
            status
          }
        }
      }
    }
  }
}
```

You can specify which CICSplex or CICS region to be queried. This example queries Region AORRGN in CICSplex PLEX1, retrieving the `name`, `useCount`, and `status` fields of all the local transactions in the region.

```
{
  cicsplex(name: "PLEX1") {
    name
    region(name: "AORRGN") {
      name
      cicsResources {
        loctran {
          records {
            name
            useCount
            status
          }
        }
      }
    }
  }
}
```

Removing the CICSplex and region specifications, this example queries all connected CICSplexes and the `name`, `useCount`, and `status` fields of all the local transactions in those CICSplexes.

```
{
  cicsplexes {
    name
    cicsResources {
      loctran {
        records {
          name
          useCount
          status
        }
      }
    }
  }
}
```

This example is similar to the previous one, except that it uses a filter to retrieve only transactions starting with `CED`.

```
{
  cicsplexes {
    name
    cicsResources {
      loctran(filter: {name: {value: "CED*"}}) {
        records {
          name
          useCount
          status
        }
      }
    }
  }
}
```

You can also query CICS definitions. This request queries the name and update attributes for all file definitions in the CICSplex data repository.

```
{
  cicsplex(name: "PLEX1") {
    drep {
      cicsDefinitions {
        filedef {
          records {
            name
            update
          }
        }
      }
    }
  }
}
```

Similarly, this request queries the name for all pipeline definitions in the CSD for Region AORRGN in CICSplex PLEX1.

```
{
  cicsplex(name: "PLEX1") {
    region(name: "AORRGN") {
      csd {
        cicsDefinitions {
          pipedef {
            records {
              name
            }
          }
        }
      }
    }
  }
}
```

This query performs aggregation of all local files in each CICSplex, grouping them by common values of the name attribute and retrieving the count of aggregated records within each aggregation group, the name of each group, and the average, minimum, and maximum `readCount` within each group.

```
{
  cicsplexes {
    name
    cicsResources {
      locfile {
        groupBy(attribute: "name") {
          count
          aggregateRecord {
            name {
              value
            }
            readCount {
              average
              min
              max
            }
          }
        }
      }
    }
  }
}
```

The following example queries the current local transactions connected to the SMSS region. It retrieves records and displaying name, priority, status, tracing, purgeability, and deadlock timeout under each SMSS region name.

```
{
  smssRegion {
    name
    cicsResources{
      loctran{
       records{
          name
          priority
          profile
          status
          tracing
          purgeability
          deadlockTimeout
        }
      }
```

```
        }
    }
}
```

# How it works: CICS bundle deployment API

The CICS management client interface (CMCI) supports deploying CICS bundles into a single region through the CICS bundle deployment API. The API is supported by the CMCI JVM server that is configured either in the WUI region of the target region's CICSplex, or in the target region itself if it's a CICS System Management Single Server (SMSS).

**Table of contents**

## Overview

The API is used at development time for Java developers to check their application changes in a running CICS region within seconds. The API also supports the CICS-provided Maven and Gradle plug-ins that can be used to integrate CICS bundle build and deployment into a developer's toolchain. For more information about CICS support for Maven and Gradle, see Java support in CICS.

**Note:** CICS supports bundle installation from the CICS system definition data set (CSD) to a single region.

The CICS bundle deployment API enables Java developers to deploy bundles whilst the system programmer retains control. This is achieved by removing the need for developers to write bundles to zFS through FTP, or to install bundles from CSD. These actions are taken by the API, by using a functional ID or another user ID with sufficient access.

The diagram shows a typical scenario where multiple application developers push bundles to the API, which is configured in the WUI region of a CICSplex. For an SMSS environment, the API is configured in the CMCI JVM server of the target region.

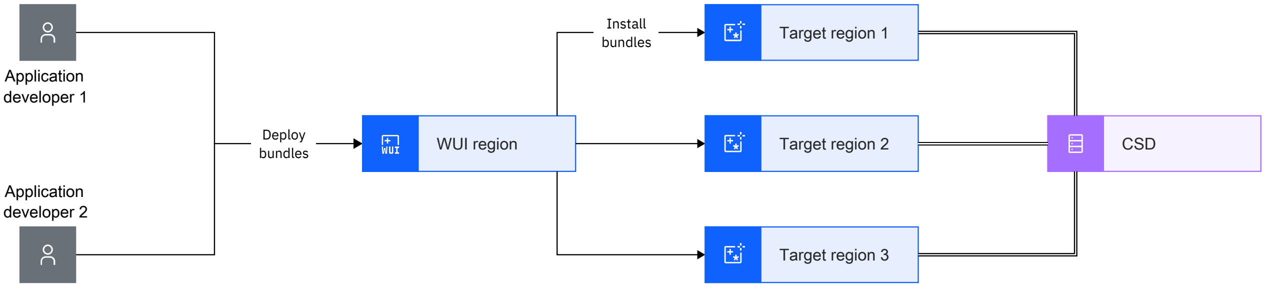


*Figure 6. Multiple developers pushing bundles to API*

This REST API receives a CICS bundle that contains the developer's application as a zip file over HTTP. The bundle will be unzipped, installed into, and enabled in the appropriate CICS region automatically. If a CICS bundle with the same name already exists, it will be disabled and discarded before the new bundle is installed.

Typically, the system programmer provides the Java developer with necessary parameters, for example, the CICSplex, CICS Region, CSD Group, and name of the BUNDLE definition. The system programmer then creates the BUNDLE definition, configured with the correct bundle directory attribute for the application that is being developed.

## How the API works

As described before, the API manages the bundle lifecycle and interacts with zFS on behalf of the developer after receiving the bundle. Usually the API is driven by a client such as the CICS-provided `cics-bundle-maven-plugin` or `com.ibm.cics.bundle`.

The API is configured with a **bundles directory**. This is a location on zFS that should be dedicated for the use of the API in managing bundles. Bundles pushed to the API are unzipped into the bundles directory and accessed by the CICS target region. This is transparent to developers and managed by the system programmer. Developers using this API do not need to interact with bundles on zFS.

For each application a developer is working on, the system programmer creates a **BUNDLE definition in the CSD**. The BUNDLE definition's BUNDLEDIR attribute must be configured with a path to the right version of the application uploaded to the bundles directory, for example, `/u/path/to/bundles/dir/ApplicationName_1.0.0`. The system programmer provides the BUNDLE definition name and CSD group for the developer to drive the API. Developers using this API do not need to install, disable, or discard the CICS BUNDLE resource.

The diagram shows **a bundle's lifecycle** from the time when it's published by an application developer until it gets installed into a CICS region. It's handled by the API automatically without users' intervention.

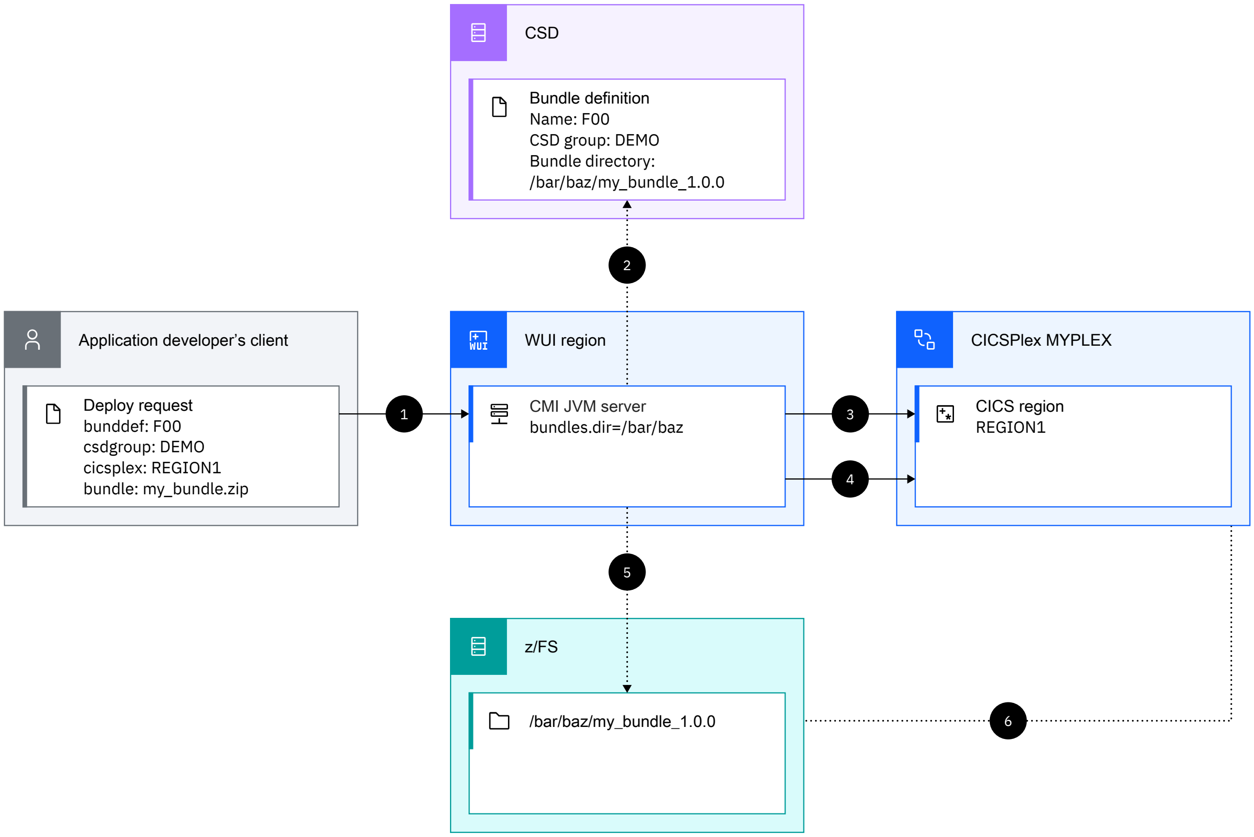


*Figure 7. Bundle's lifecycle in the API*

1 The application developer publishes the application bundle through the CICS bundle deployment API.

**Validate**

2 The CMCI JVM server finds the BUNDLE definition in the target region's CSD and checks that the BUNDLE definition's bundle directory (BUNDLEDIR) attribute value is within the API's configured bundles directory.

**Uninstall**

3 The CMCI JVM server checks whether any previously installed bundle with the same name as the BUNDLE definition specified exists in the target region. Such a bundle is disabled and discarded as required.

**4** The CMCI JVM server deletes any previous bundle with the same name and version from the bundles directory on zFS. Then, it unpacks the published bundle to the bundles directory.

**Install**

**5** The CMCI JVM server initiates a CSD install of the BUNDLE definition.

**6** The target region reads the bundle from zFS and installs it.

## Security model of the API

A functional ID is introduced to ensure controlled access. As a result, application developers are able to deploy bundles through specific access to the CICS bundle deployment API, and without general access to manipulate bundles. Different users IDs are involved in the API's workflow as follows:

- The application developer is authenticated as normal, to make sure their user ID has access to the API.
- The task switches from the application developer's user ID to a configured deployment functional ID.
- The deployment functional ID writes the bundle to zFS and initiates a CSD install of the bundle to the target region.
- The region user ID of the target region reads the bundle from zFS during installation.

The security mechanism of the API requires additional configurations for the API to work:

- The system programmer must configure SAF correctly to enable bundle deployment using the API.
- The API works only in regions configured as SEC=YES.

For instructions, see Configuring the CMCI JVM server for the CICS bundle deployment API.

## How to make CICS bundle deployment API requests

CICS provides a Maven and a Gradle plug-in that uses this API to publish bundles to CICS. Java developers can use it for bundle deployment at development time. For instructions, see cics-bundle-maven. Alternatively, if you want to write your own tooling, the API can be invoked by using any standard REST client.

The format of API requests is based on HTTP/1.1. The API uses the POST request only, and accepts multipart form data. A `Content-Type: multipart/form-data` header must be sent. String parameters and the zipped bundle file are accepted as form data parts in the payload.

The API returns an HTTP response code and a JSON description of the outcome of the request. A response code of `4xx` indicates that a user has incorrectly addressed the API. A response code of `5xx` indicates that the system is set up incorrectly.

The API endpoint is served alongside your standard CMCI interface. For example, if your CMCI interface is available at `mycicshost.com` on port 4444, your API endpoint URL would be `https://mycicshost.com:4444/managedcicsbundles`.

Call the API with these parameters:

**cicsplex**
Required only for a CICSPlex SM environment. The name of the CICSplex that the target region belongs to.

**region**
Required only for a CICSPlex SM environment. The name of the region that the bundle should be installed into.

**csdgroup**
The name of the CSD group where the source BUNDLE definition exists.

**bunddef**
The name of the BUNDLE definition.

**bundle**
The zip file that contains the bundle contents, as `content-type application/zip`. The `META-INF` directory should be in the root of the zip file.

For example, to call the API from your local workstation using the command-line tool cURL, your command line might look like this:

```
curl -i -X POST -u MYUSER -F cicsplex=MYPLEX -F region=MYREGION -F csdgroup=CSDGRP
-F bunddef=MYBUND -F bundle=@c:/path/to/bundle_0.0.1.zip https://mycicshost.com:4444/
managedcicsbundles
```

The CICS bundle deployment API unzips the content of the uploaded zip file without performing any codepage conversion. Each file in the bundle must be encoded in the correct codepage prior to being zipped.

### What's next

Configure your CMCI JVM server to enable the API. See Configuring the CMCI JVM server for the CICS bundle deployment API

**Related information**

Managing Java dependencies using Maven or Gradle

## CMCI security features: How CMCI authenticates clients

When an HTTP system management client such as CICS Explorer attempts to sign on, the CMCI verifies the user credentials. The user credentials can be a user ID and password, a PassTicket, an MFA token or a certificate. If the CMCI JVM server is enabled, it handles the authentication process. Authentication through a PassTicket or an MFA token is only available with the CMCI JVM server.

### How the CMCI JVM server authenticates clients

Figure 8 on page 35 illustrates the client authentication workflow based on CICS Explorer.

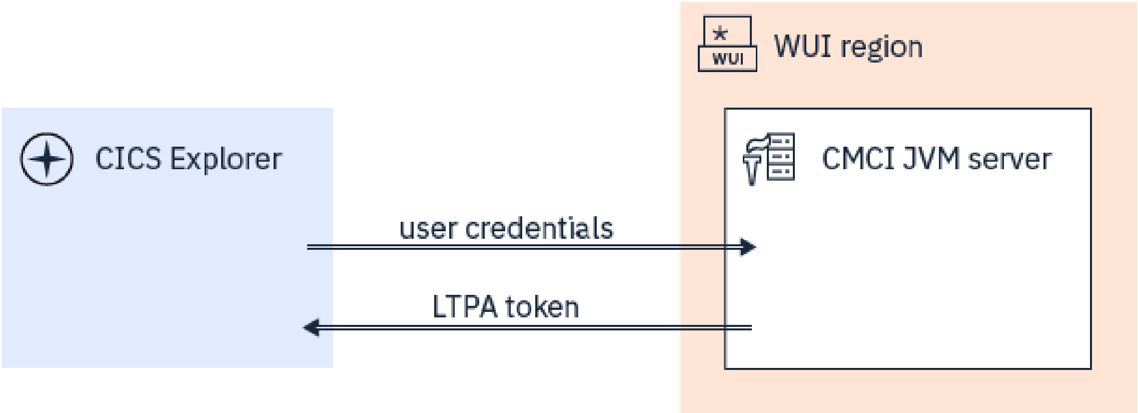


*Figure 8. CMCI HTTP client authentication workflow*

1. When a user logs on from CICS Explorer, CICS Explorer passes the user credentials to the CMCI JVM server. The user credentials can be a user ID and password, a PassTicket, an MFA token or a certificate.
2. The CMCI JVM server validates the user credentials by using SAF interfaces to the external security manager (ESM) and generates an LTPA token.
3. The CMCI JVM server replies to CICS Explorer with the response and the LTPA token.

In subsequent requests, CICS Explorer will use the LTPA token to authenticate the user.

**Note:**

- The LTPA token is a cookie; therefore, the HTTP client must accept cookies.

- Although a JVM server is used for the transport and authentication of the CMCI, most of the processing still occurs in the CICS core; therefore, do not expect increased specialty engine offload from the CMCI JVM server.

### LTPA timeout

An LTPA token has a fixed lifetime. It cannot be extended or renewed, even if a user is active in a session. Upon timeout, the user is logged out and must provide login credentials again to get a new token. The expiration time of the LTPA token is configurable. For instructions, see Configuring LTPA in Liberty.

### Sharing LTPA tokens

With the single sign-on (SSO) configuration support in Liberty, you can set up Liberty to allow the sharing of LTPA tokens among multiple regions. HTTP client users can authenticate once and have access to other regions that share the same LTPA keys. For more information, see Customizing SSO configuration using LTPA cookies in Liberty.

### How CMCI without the CMCI JVM server authenticates clients

If the CMCI JVM server is not used with the CMCI, the user is authenticated using a certificate or a basic authenticator in the HTTP header.

One-time-use tokens (such as MFA tokens and PassTickets) are not supported.

### Find out more

Authentication overview gives you an overview of the authentication process in Liberty and describes LTPA and SSO in details.

Setting up CMCI gives you configuration instructions.

# Chapter 3. Developing Java applications

You can write Java applications that use CICS services and run under CICS control. CICS provides the run time environment through a JVM server. You can connect to your Java programs through technologies such as web services or z/OS Connect Enterprise Edition.

Using the IBM CICS SDK for Java or other Java IDEs, you can develop applications that use the CICS Java APIs (JCICS and JCICSX) to access CICS resources and interact with programs that are written in other languages. You can declare Java dependencies in a Maven or Gradle module and develop the Java applications in the same way as you do for other platforms.

Check out Get started with Java in CICS for a summary of developing Java applications.

## Java runtime environment in CICS

CICS provides the JVM server environment for running threadsafe Java applications. Applications that are not threadsafe cannot use a JVM server.

The JVM server is a runtime environment that can run tasks in a single JVM. This environment reduces the amount of virtual storage required for each Java task, and allows CICS to run many tasks concurrently.

CICS tasks run in parallel as threads in the same JVM server process. The JVM is shared by all CICS tasks, which might be running multiple applications concurrently. All static data and static classes are also shared. So to use a JVM server in CICS, a Java application must be threadsafe. Each thread runs under a T8 TCB and can access CICS services by using the JCICS API.

Do not use the `System.exit()` method in your applications. This method causes both the JVM server and CICS to shut down, affecting the state and availability of your applications.

### Multithreaded applications

You can write application code to start a new thread or call a library that starts a thread. If you want to create threads in your application, the preferred method is to use a generic `ExecutorService` from the OSGi registry. The `ExecutorService` automatically uses `CICSExecutorService` to create CICS threads when the application is running in a JVM server. This approach means the application is easier to port to other environments and you do not have to use specific JCICS API methods.

However, if you are writing an application that is specific to CICS, you can choose to use the `CICSExecutorService` class in the JCICS API to request new threads.

Whichever approach you choose, the newly created threads run as CICS tasks and can access CICS services. When the JVM server is disabled, CICS waits for all CICS tasks running in the JVM to finish. By using the `ExecutorService` or `CICSExecutorService` class, CICS is aware of the tasks that are running and you can ensure that your application work completes before the JVM server shuts down.

You should only use JCICS objects in the task that created them. Any attempt to share the objects between tasks can produce unpredictable results.

For further details on using the CICS ExecutorService refer to "Threads" on page 57.

### JVM server startup and shutdown

Because static data is shared by all threads that are running in the JVM server, you can create OSGi bundle activator classes to initialize static data and leave it in the correct state when the JVM shuts down. A JVM server runs until disabled by an administrator, for example to change the configuration of the JVM or to fix a problem. By providing bundle activator classes, you can ensure that the state is correctly set for your applications. CICS has a timeout that specifies how long to wait for these classes to complete before continuing to start or stop the JVM server. You cannot directly use JCICS in startup and termination classes. However, a developer can start a new JCICS-enabled thread from an activator, by using the `CICSExecutorService.runAsCICS()` API. Any JCICS commands will run under the authority of the user id that issued the install command. Therefore it is prudent for an administrator to understand the resources used in bundle activators before they install them.

# Setting up your development environment

You can use the JCICS or JCICSX API to develop Java applications that can access CICS resources. Both APIs are available in the IBM CICS SDK for Java, Maven Central, or in the USSHOME directory of your CICS installation.

## About this task

Both JCICS and JCICSX APIs provide you with the Java interface to access CICS services. The JCICS API is the Java equivalent of the **EXEC CICS** API that is provided for other CICS supported languages, such as COBOL. The JCICSX API supports a subset of JCICS functionality with new Java API classes that provide developers with the capabilities of mocking and remote development. The JCICSX API classes can be used together with the JCICS API, but only the commands using JCICSX can benefit from these enhanced features. See "Java development using JCICSX" on page 87 for more information.

The table shows where the APIs are provided and what tools you can use to consume them.

*Table 3. JCICS and JCICSX API locations*

| Java code authoring tool | JCICS API | JCICSX API classes |
|---|---|---|
| CICS Explorer | Yes, provided in the preinstalled IBM CICS SDK for Java, which resolves dependencies automatically. | Yes, provided in the preinstalled IBM CICS SDK for Java in IBM CICS Explorer for Aqua 3.2[1] (Fix Pack 5.5.0.9) or later, which resolves dependencies automatically. |
| Apache Maven and Gradle (to access artifacts from Maven Central) | Yes. You can declare the dependency using any Java IDE that supports Gradle or Maven. | Yes. You can declare the dependency using any Java IDE that supports Gradle or Maven. |
| Any other tool, to import the API jars provided in USSHOME | Yes. You need to manually import the dependency. | Yes. You need to manually import the dependency. |

**Note:** If you want to develop Java EE applications for CICS, you must install the IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer.

CICS Explorer provides the following tools for you to develop, package, and deploy Java applications that are hosted in the CICS JVM server:

- The IBM CICS SDK for Java provides support for the JCICS API and JCICSX API classes.
- Eclipse and the Eclipse Web Tools Platform provide the tools to develop Java EE applications.
- The IBM CICS SDK for Enterprise Java (Liberty) provides the Java EE, Jakarta EE, MicroProfile and Liberty APIs in the form of a Java build path library or OSGi target platform.
- CICS Explorer provides the tools to package, deploy, and manage Java applications within CICS bundles.
- Explorer for z/OS provides the tools to work with files, data sets, and jobs on z/OS, including viewing JVM server log files.

The SDKs can resolve dependencies automatically as long as you add the correct library to your build path or select the correct OSGi target platform.

[1] Aqua refers to IBM Explorer for z/OS Aqua.

Consuming dependencies from Maven Central offers more flexibility in the choice of IDE and integrates easily into popular build toolchains such as Gradle or Maven. The Maven Central artifacts contain the JCICS, JCICSX, CICS annotation, CICS annotation processor libraries and a bill of material (BOM) for you to declare dependencies and develop applications for CICS in your IDE of choice. The artifacts can be obtained directly from Maven Central, or from locally hosted and allow-listed repositories using tools such as JFrog Artifactory or Sonatype Nexus. You can then use the CICS-provided Maven and Gradle plug-ins to package and deploy CICS bundles that contain your applications into a CICS region.

## Procedure

- To use the SDKs in CICS Explorer:
  a) The IBM CICS SDK for Java is preinstalled in CICS Explorer. If you want to develop Java EE applications, install the IBM CICS SDK for Enterprise Java (Liberty) into your CICS Explorer as a plug-in. For instructions, see Downloading and starting CICS Explorer in the CICS Explorer product documentation and Installing the CICS SDK for Java EE, Jakarta EE and Liberty in the CICS Explorer product documentation.
  b) Restart your development environment.
  c) Add libraries to your build path or select your target platform, for the SDK to revolve dependencies correctly for your projects. See Step 1 in "Creating a Dynamic Web Project" on page 116, "Creating an OSGi Application Project " on page 117, and "Creating an Enterprise Application Project" on page 119.
- To use Gradle or Maven:
  a) Ensure your environment fulfills either of the following prerequisites:
    - If you want to use Gradle or Maven with the command line, you must install them on your machine. See Downloading and Installing Maven and Installing Gradle.
    - Your IDE must support Gradle or Maven. Such IDEs include Eclipse, IntelliJ IDEA, and Visual Studio Code.
  b) Create your project using Gradle or Maven and import dependencies based on the API you want to use, as described in "Managing Java dependencies using Gradle or Maven" on page 46. You might need to add extra Gradle or Maven configuration, depending on your project type. See Step 1 in "Creating a Dynamic Web Project" on page 116, "Creating an OSGi Application Project " on page 117, and "Creating an Enterprise Application Project" on page 119.
- To use the JAR files in the USSHOME directory, see "Manually importing Java libraries" on page 54.

## Results

Your development environment is ready to develop Java applications for CICS.

## What to do next

For JCICS users, you can refer to the JCICS Javadoc information. If you're using the IBM CICS SDK for Java, you can use the examples that are provided with the IBM CICS SDK for Java to get started. For more information, see Java samples: Servlet examples.

For JCICSX users, see JCICSX Javadoc for more information.

# Developing applications using the IBM CICS SDKs

CICS Explorer includes the IBM CICS SDK for Java and optionally the IBM CICS SDK for Enterprise Java (Liberty). These SDKs provide an environment for developing and deploying Java applications to CICS, including support for OSGi and web projects.

If you want to develop Java applications without using an SDK, see "Managing Java dependencies using Gradle or Maven" on page 46.

You can use the IBM CICS SDK for Java to create new applications, or repackage existing Java applications to comply with the OSGi specification. OSGi provides a mechanism for developing applications by using a component model and deploying those applications to a framework as OSGi bundles. An *OSGi bundle* is the unit of deployment for an application and contains version information, dependencies, and application code. The main benefit of OSGi is that you can create applications from reusable components that are accessed only through well-defined interfaces called *Java packages* . You can then use OSGi services to access the Java packages. You can also manage the lifecycle and dependencies of Java applications in a granular way. For information about developing applications with OSGi, see OSGi Alliance.

You can use the IBM CICS SDK for Java to develop a Java application to run in any supported release of CICS. Different releases of CICS support different versions of Java, and the JCICS API is also extended in later releases to support more features of CICS. For example, the JCICSX API classes are supported as of CICS TS 5.6. To avoid use of the wrong classes, the IBM CICS SDK for Java provides a feature to set up a target platform or project libraries. You can define which release of CICS you are developing for, and the IBM CICS SDK for Java automatically hides the Java classes that you cannot use.

If you are using the Liberty JVM server, the IBM CICS SDK for Enterprise Java (Liberty) can help you work with Dynamic Web Projects and OSGi Application Projects. You can create an application that has a modern web layer and business logic that uses JCICS to access CICS services. If your web application needs to access code from another OSGi bundle, it must be deployed as an OSGi Application Project (EBA file). You must either include the other OSGi bundle in the application manifest, or install the other bundle in the Liberty `bundle_repository` as a common library. The EBA file must include a web-enabled OSGi bundle (WAB file) to provide the entry point to the application and to expose it as a URL to a web browser.

**Prerequisite:** Before you start developing applications using the IBM CICS SDKs, make sure you have set up the development environment.

## Setting up the Target Platform

You must set up and update the target platform of your Eclipse development environment as necessary before developing or deploying OSGi-based Java applications.

### About this task

You can use a template target platform as-is or update it with additional support. The CICS Explorer Software Development Kit (SDK) only supplies Java classes necessary for the usage of the CICS or web APIs. To add support for additional interfaces, you must add the OSGi plug-in that contains the third party Java classes to the Eclipse Target Platform. This procedure makes the exported packages available to all applications that use this target platform. If you need to add third party Java classes to your target platform, ensure the JAR file that contains those classes is available as an OSGi plug-in and is copied to the local workstation.

### Procedure

1. In Eclipse, click **Window** > **Preferences**.
2. In the **Preferences** page, expand **Plug-in Development** and click **Target Platform**.
3. Create or update a target definition as needed:
   - If you need a new target definition, click **Add** to create a target definition in the wizard.
     a) Select **Template** and select the target platform that matches your CICS version, for example, **CICS TS 5.6**.
     b) Click **Next** in the wizard and then click **Finish**.
   - If your target definition is already in the list, proceed to the following steps.

To update the target definition with additional Java classes:

4. Optional: Select the target definition in the **Target Platform** dialog and click **Edit**, which opens the **Edit Target Definition** dialog.

5. Optional: Under the **Locations** tab, click **Add**. Browse the directory and add the OSGi plug-in that contains the third party bundle JARs.
6. Optional: After the OSGi plug-in content is added, in the **Edit Target Definition** dialog, click **Finish**.
7. After creating or updating the target definition, return to the **Preferences** page and click **Apply and Close**.

### Results

You have successfully set up and updated the OSGi environment to include both the third party OSGi bundles and the CICS OSGi bundles that are required for Java application development.

### What to do next

Deploy the Java application into a CICS JVM server, and add the third party JARs as an OSGi middleware bundle or to the Liberty shared bundle repository. For further details, see Updating OSGi middleware bundles and Manually tailoring server.xml.

## Creating a plug-in project

You create your CICS Java application as an Eclipse plug-in project that complies with the OSGi specification. The OSGi Service Platform provides a mechanism for developing applications by using a component model and deploying those applications into a framework as OSGi bundles. The plug-in project is an OSGi bundle, and contains all the files and artifacts needed for the CICS Java application. The plug-in project is then included in a CICS bundle project before being exported to the host system.

### Before you begin

You need to set the Target Platform. For more information, see “Setting up the Target Platform” on page 40.

### About this task

This task creates a new plug-in project. You can leave the settings on their default values unless otherwise stated. When the project is created you must edit the manifest and add the JCICS API dependencies.

### Procedure

1. On the Eclipse menu bar click **File** > **New** > **Project** to open the New Project wizard.
2. Select **Plug-in Project** from the list provided, then click **Next** to open the New Plug-in Project wizard.
3. In the **Project name** field, enter a name for the project, for example `com.ibm.cics.example.accounting`. In the Target Platform section, select **an OSGi framework** and select **standard** from the menu. Click **Next**.

   The Content pane is displayed.
4. In the **Version** field remove the ".qualifier" from the end of the version number.
5. In the **Execution Environment** field select the Java level that matches the execution environment in your CICS runtime target platform, for example **JavaSE-1.7**.
6. Uncheck the **Generate an activator** check box and click **Finish**.

   The new plug-in project is created in the Package Explorer view.
7. You must now edit the plug-in manifest file and add the `JCICS` and `com.ibm.record` API dependencies. If you do not perform these steps, you will be able to export and install the bundle, but it will not run.

   a) In the Package Explorer view, right-click the project name and click **Plug-in Tools** > **Open Manifest**.

      The manifest file opens in the manifest editor.

   b) Select the **Dependencies** tab and in the Imported Packages section, click **Add**.

      The Package Selection dialog opens.

c) Select the package `com.ibm.cics.server` and click **OK**.

   The package is displayed in the Imported Packages list.

d) Repeat the previous step to install the following package, if it is required for your application:

   **`com.ibm.record`**
   The Java API for legacy programs that use IByteBuffer from the Java Record Framework that came with VisualAge®. Previously in the `dfjcics.jar` file.

e) Select **File** > **Save** to save the manifest file.

### Results

The new plug-in project is created containing the JCICS API dependencies.

### What to do next

You can now create your CICS Java application. If you are new to developing Java applications for CICS, you can use the JCICS samples provided with the IBM CICS SDK for Java to help you get started.

**Note:** After you have developed your application, you must add a CICS-MainClass declaration to the manifest file and declare the classes used in the application. See the related link for more information.

For more information on plug-in development, see the section *Plug-in development environment (PDE) user guide* in the Eclipse Help documentation.

When your Java application is finished, you must deploy it in a CICS bundle to zFS. CICS bundles can contain one or more plug-ins and are the unit of deployment for your application in CICS.

## Updating the plug-in project manifest file

When you develop a JCICS application, or package an existing application in a plug-in project, you must update the project manifest file and include a `CICS-MainClass` header.

### About this task

The `CICS-MainClass` header is used to declare the classes that can be called by a `LINK`, START or RUN command, or a transaction initial program. Do not use lazy activation policies for OSGi bundles that declare a CICS main class. CICS activates the OSGi bundles as soon as they are started in the OSGi framework. You must add the declaration manually to the manifest file.

### Procedure

1. If the manifest file is not already open in the editor, right-click the project name in the Package Explorer view and click **Plug-in Tools > Open Manifest**.

   The manifest file opens in the manifest editor.
2. Select the **MANIFEST.MF** tab. The content of the file is displayed.
3. Add the following declaration to the manifest file:

   `CICS-MainClass:` *`packagename.classname`* where:

   ***packagename***
   Is the fully qualified Java package name.

   ***classname***
   Is the name of the class used in the application. If more than one class is used, repeat the *`packagename.classname`* element, separated by a comma.

   You can use aliases in the `CICS-MainClass` header; for example, the declaration `CICS-MainClass: examples.hello.HelloCICSWorld; alias=greeting` assigns the alias `greeting` to the `CICS-MainClass` `examples.hello.HelloCICSWorld`. When you define the program to CICS, you use the alias name, `greeting`, instead of the class name. An alias is useful if you have multiple versions of the same program, each with the same class name. By using aliases you can identify the different versions.

The following example shows a manifest file with a `CICS-MainClass` header for the classes `HelloCICSWorld` and `HelloWorld`.

```
Manifest-Version: 1.0
Bundle-ManifestVersion: 2
Bundle-Name: Hello Plug-in
Bundle-SymbolicName: com.ibm.cics.server.examples.hello
Bundle-Version 1.0.0
Bundle-RequiredExecutionEnvironment: JavaSE-1.7
Import-Package: com.ibm.cics.core.bundle,
  com.ibm.cics.core.model.builders,
  com.ibm.cics.server;version="[1.300.0,2.0.0)"
CICS-MainClass: examples.hello.HelloCICSWorld,
  examples.hello.HelloWorld
```

4. When you have added all the class declarations, select **File > Save** to save the manifest file.

### Results

You can now add the plug-in project to a CICS bundle and deploy it to zFS. CICS bundles can contain one or more plug-ins and are the unit of deployment for your application in CICS.

### What to do next

Create a CICS bundle project. See Creating a CICS bundle project in the CICS Explorer product documentation.

## Creating a Java EE application

The CICS Explorer help provides full details on how you can perform each of the following steps to develop and deploy applications.

### Procedure

1. Set up a target platform for your Java development.

   .

   The target platform ensures that you use only the Java classes that are appropriate for the target release of CICS in your application development.
2. Create an OSGi Bundle Project or a plug-in project for your Java application development.
   a) The default version of the project is `1.0.0.qualifier`. In the **Version** field either remove the `.qualifier` from the end of the version number, if you do not wish to use one, or set it to something meaningful, for example the date/time stamp.

   Develop your Java application using best practices; for example, to organize the dependencies between OSGi bundles, use Import-Package / Export-Package in preference to Require-Bundle.
3. If you are new to developing Java applications for CICS, you can use the examples that are provided with the IBM CICS SDKs to get started.

   To use JCICS in a OSGi Java application, you must import the `com.ibm.cics.server` package.
4. Optional: In Liberty, create a dynamic web application (WAR) or a web-enabled OSGi Bundle Project (WAB) to develop your application presentation layer.

   You can create servlets and JSP pages in a Dynamic Web Project. For a WAR file, you must also add the Liberty libraries to your build path to give you access to the Liberty API bundles. For further details, refer to “Setting up your development environment” on page 38.
5. Package your application for deployment:
   a) If you are deploying a web-enabled OSGi Bundle Project (WAB), create an OSGi Application Project (EBA).

b) Create one or more CICS bundle projects to reference your EBA, your EAR file, or your web application (WAR file).

CICS bundles are the unit of deployment for your application in CICS. Put the web applications that you want to update and manage together in a CICS bundle project. You must know the name of the JVMSERVER resource in which you want to deploy the application.

You can also add CICS resources to the CICS bundle project, such as PROGRAM, URIMAP, and TRANSACTION resources. These resources are dynamically installed and managed with the Java application.

c) Optional: If you want to deploy the application to a CICS platform, create an application project that references your CICS bundles.

An application provides a single management point for deploying and managing the application across a CICSplex in CICS. For more information, see How it works: applications.

d) You should always explicitly declare the packages that your OSGi bundle uses, even if the tooling does not indicate an error. You can do this by adding or updating the **`Import-Package`** bundle header in your OSGi bundle manifest. Tools such as Eclipse make assumptions about the availability of **`javax.*`** packages that might not be correct for a runtime environment where an explicit Import is necessary.

6. Deploy your Java application to zFS by exporting the application project or CICS bundle projects. Alternatively, you can save the projects in a source repository for deployment.

### Results

You have successfully developed and exported your application by using the IBM CICS SDKs.

### What to do next

Install the application in a JVM server. If you do not have authority to create resources in CICS, the system programmer or administrator can create the application for you. You must tell the system programmer or administrator where the exported bundle is located and the name of the target JVM server.

## Adding a project to a CICS bundle project

When you create a CICS bundle project a manifest file is created in the `META-INF` directory. You can edit the manifest file to include one or more of the following types of projects; Dynamic Web Project, Enterprise Application Project, OSGi Application Project, or OSGi Bundle Project. The included projects can be source or pre-built. When you export the CICS bundle project, all included projects are contained in the CICS bundle on zFS.

### Before you begin

This task describes how to add details of a project to a CICS bundle. If you have not created a CICS bundle project, see Creating a CICS bundle project in the CICS Explorer product documentation.

### About this task

You can add details of a project to a CICS bundle by using one of the following wizards; **Dynamic Web Project Include**, **Enterprise Application Project Include**, **OSGi Application Project Include**, or **OSGi Bundle Project Include**. The wizards update the bundle manifest file to include details of the project that is being added, and creates a resource file with a file extension of `.warbundle`, `.earbundle`, `.ebabundle`, or `.osgibundle` that points to the project.

**Note:** To add OSGi bundles that are not included in an OSGi application project to a CICS bundle project, you must have a `build.properties` file that includes the location of the output folder. For example, the `build.properties` file might have the following content:

```
source.. = src/
output.. = bin/
bin.includes = META-INF/
```

## Procedure

1. In CICS Explorer, open one of the wizards you need (**Dynamic Web Project Include**, **Enterprise Application Project Include**, **OSGi Application Project Include**, or **OSGi Bundle Project Include**) in either of the following ways:
   - Using the right-click menu: In the **Package Explorer** view, right-click the bundle project that you want to update, and click the wizard you want to open.
   - Using the **CICS bundle manifest** editor:
     a. In the **Package Explorer** view, expand the bundle project you want to update and double-click the `cics.xml` file in the `META-INF` folder.
     b. In the **CICS bundle manifest** editor that opens, click **New** in the **Defined resources** section of the **Overview** page.
2. Optional: For an OSGi project, specify the version or version range to include:
   - Select **Use this version** to include the specific version of the selected OSGi project, as shown in the **Version** field.
   - Select **Use version range** to include the highest version in a defined version range of the selected OSGi project when you export that OSGi project. By default, the version range is from the version of the selected OSGi project to the next highest major version. You can use the fields and the buttons to specify a different range.
3. In the **JVM server** field, enter the name of the JVM server where the application component is going to run.
4. Optional: The name of the resource file that is created is generated from the project name and is displayed in the wizard. You can use the **Back** button to change the file name.
5. Click **Finish**.

## Results

A project resource file is added to the bundle project and the manifest file is updated. You can repeat these steps to add more projects to the CICS bundle project.

## What to do next

You can add resources to the CICS bundle project for your application. For example, you can create a program to make your Java application available to other applications in CICS.

You can deploy your CICS bundle to a z/OS UNIX file system, as described in Deploying a CICS bundle in the CICS Explorer product documentation. When the CICS bundle project is exported to zFS, all the files and artifacts needed for the application are compiled and exported.

Alternatively, you can package your CICS bundle project in a cloud-style application project for deployment into a CICS platform. By using an application project, you can group together all the CICS bundle projects that comprise your application and deploy and install them in a single step. For more information, see Creating a CICS Application Binding project in the CICS Explorer product documentation.

## Updating the project build path

How to update the project build path.

### About this task

Using a Dynamic Web Project creates a WAR file archive for deployment. This does not use the OSGi framework in Eclipse so you need to add third party JAR files to the project build path. This example uses IBM MQ JAR files.

### Procedure

1. In Eclipse select the web project and right-click **Build Path** > **Configure Build Path**. This will display the Java Build Path window.
2. Add the CICS and Liberty libraries, click **Add Library** > **Liberty JVM server** > **Next** > **Finish**.
3. Click **Add External JARs** and navigate to the directory where the previously downloaded IBM MQ JAR files are located. Select the following JAR files depending on which imports are used in the applications:

   - com.ibm.mq.jar
   - com.ibm.mq.jmql.jar
   - com.ibm.mq.headers.jar

   **Note:** Step 3 is optional if you are using IBM MQ only.

### Results

The build path of the project now has the correct interfaces for development of a web application using both CICS and IBM MQ APIs.

# Managing Java dependencies using Gradle or Maven

When writing your own build scripts for Java development, you can use build toolchains such as Gradle or Maven to resolve Java dependencies. As an alternative to the IBM CICS SDK for Java , they can retrieve libraries from a remote repository or allow-listed local repositories. After finishing coding, you can use the CICS-provided Gradle and Maven plug-ins to build and deploy a CICS bundle that includes your Java application.

Gradle and Maven are supported by most Java integrated development environments (IDEs) and automation tools such as Jenkins and Travis CI. Therefore, you can integrate the compilation, building, and deployment of applications into a pipeline more easily during development.

### What artifacts are available

These artifacts are provided by CICS on Maven Central:

*Table 4. CICS-provided artifacts on Maven Central*

| Group ID | Artifact ID | Description |
|---|---|---|
| `com.ibm.cics` | `com.ibm.cics.ts.bom` | The bill of materials (BOM) that defines the versions of all the artifacts to ensure they are at the same CICS TS level.<br>**Tip:**<br>You're recommended to use the BOM to control the version numbers of the other CICS-provided dependencies and omit version numbers from their declarations.<br>In Maven, the BOM also provides the correct dependency scope to avoid clashes with runtime-provided libraries. You're recommended to use the BOM to control the scope of dependencies and omit scopes from their declarations.<br>See how to use with Gradle or use with Maven. |
| | `com.ibm.cics.server` | The CICS Java class library (JCICS), a Java library that provides the **`EXEC CICS`** API support for Java applications in CICS TS.<br>See how to use with Gradle or use with Maven. |
| | `com.ibm.cics.jcicsx` | The JCICSX API classes that support a subset of CICS functions, available in CICS TS 5.6 or later.<br>The classes can be run remotely and are easier to mock and stub than the Java classes of JCICS. The JCICSX API classes can be used together with the JCICS API, but only the commands that use JCICSX can benefit from those enhanced features.<br>See how to use with Gradle or use with Maven. |
| | `com.ibm.cics.server.invocation.annotations` | CICS annotations, a Java library that provides the `@CICSProgram` annotation to enable CICS programs to invoke Java applications in a Liberty JVM server.<br>See how to use with Gradle or use with Maven. |
| | `com.ibm.cics.server.invocation` | The CICS annotation processor, a Java library that is used during compilation to create metadata that enables CICS programs to invoke Java applications in a Liberty JVM server.<br>See how to use with Gradle or use with Maven. |

## What's next

It is important that the correct Gradle configuration or Maven scope is used for each dependency you reference. This can avoid runtime conflicts as well as keeping the size of the application smaller. To find out more, see “Declaring Java dependencies using Gradle” on page 48 or “Declaring Java dependencies using Maven” on page 51.

## Declaring Java dependencies using Gradle

When creating a Gradle build script, you need to refer to dependencies supplied by CICS. Use this guide to understand how to reference each dependency.

For a complete list of all dependencies available, see “Managing Java dependencies using Gradle or Maven” on page 46.

**Prerequisites:** Before developing Java applications for CICS with Gradle, you must make sure that:

- You already have Gradle support installed in your workstation or IDE.
- You have created a Gradle module to include your application, or that you have converted an existing Java project to a Gradle module. Most Java IDEs support this function.

For instructions, see the Gradle related information in “Setting up your development environment” on page 38.

### How to declare dependencies

You declare dependencies in the Gradle module's `build.gradle` file. The following instructions include snippets showing how to declare a dependency on each artifact. More recent versions might be available, so check Maven Central for all available versions.

**Note:** The snippets shown on Maven Central are auto-generated and might not show the correct Gradle configurations such as `compileOnly`. Follow the syntax in this topic instead to ensure the dependencies are correctly declared.

You can declare dependencies on these CICS-supplied artifacts:

- The CICS bill of materials (BOM): `com.ibm.cics.ts.bom`
- The CICS Java class library (JCICS): `com.ibm.cics.server`
- The JCICSX API classes: `com.ibm.cics.jcicsx`
- The CICS annotations: `com.ibm.cics.server.invocation.annotations`
- The CICS annotation processor: `com.ibm.cics.server.invocation`

**The CICS bill of materials (BOM): `com.ibm.cics.ts.bom`**

All versions are available at com.ibm.cics.ts.bom on Maven Central.

**Note:** You declare a dependency on a BOM file to manage versions of other libraries. The BOM itself does not import any library. Therefore, you must also reference other libraries along with the BOM.

Refer to this library as follows:

```
repositories {
    mavenCentral()
}

dependencies {
    compileOnly enforcedPlatform('com.ibm.cics:com.ibm.cics.ts.bom:5.6-20200609123739')
}
```

*Figure 9. `build.gradle`*

In Gradle, the BOM controls the version of any other CICS-provided dependency in the same module or its child modules by using the `enforcedPlatform` keyword, which ensures that the versions specified in the BOM overrides any other versions found in the dependency graph.

**Note:** `enforcedPlatform` is supported from Gradle 5.0.

Make sure that you specify a BOM version that provides support for the other dependencies of your application, and that your target CICS system is at the same or later CICS TS release and APAR maintenance level. In the previous snippet, the `enforcedPlatform` tag specifies the BOM version, consisting of:

- The CICS version (`5.6`)
- the time stamp when the BOM is built (`20200609123739`)
- if relevant, the version of the CICS TS APAR that includes server-side updates to the libraries. For example, `PH25409` in a version number `5.5-20200519131930-PH25409`.

The BOM only affects libraries that use the same Gradle scope configuration, such as `compileOnly`, which ensures that the dependency is provided by the CICS TS runtime and not packaged with the module. Therefore, you must specify the BOM for all the configurations that will use CICS dependencies, with the same scope configuration. For example, if you are referencing the JCICS library (`com.ibm.cics.server`) using the `compileOnly` configuration, you need to control its version with the BOM as follows:

```
dependencies {
    compileOnly enforcedPlatform('com.ibm.cics:com.ibm.cics.ts.bom:5.6-20200609123739')
    compileOnly("com.ibm.cics:com.ibm.cics.server")  //dependency on JCICS
}
```

*Figure 10. `build.gradle`*

Likewise, if you declare a dependency on the annotation processor (`com.ibm.cics.server.invocation`), you need to define a BOM with the `annotationProcessor` configuration. This is because the annotation processor dependency must use the `annotationProcessor` configuration.

```
dependencies {
    annotationProcessor
enforcedPlatform('com.ibm.cics:com.ibm.cics.ts.bom:5.6-20200609123739')
    annotationProcessor ("com.ibm.cics:com.ibm.cics.server.invocation")  //dependency on
annotation processor
}
```

*Figure 11. `build.gradle`*

### The CICS Java class library (JCICS): `com.ibm.cics.server`

All versions are available at com.ibm.cics.server on Maven Central.

Refer to this library as follows:

```
repositories {
    mavenCentral()
}

dependencies {
    compileOnly 'com.ibm.cics:com.ibm.cics.server'
}
```

*Figure 12. `build.gradle`*

The version number is omitted because they are inherited from the BOM. If you don't use a BOM, reference this library as follows, where the version number includes the OSGi `Bundle-Version`, the CICS release, and (if relevant) the APAR number.

```
repositories {
    mavenCentral()
}

dependencies {
    compileOnly 'com.ibm.cics:com.ibm.cics.server:1.800.0-5.6'
}
```

*Figure 13. `build.gradle`*

**The JCICSX API classes: `com.ibm.cics.jcicsx`**

All versions are available at com.ibm.cics.jcicsx on Maven Central.

Refer to this library as follows:

```
repositories {
    mavenCentral()
}

dependencies {
    compileOnly 'com.ibm.cics:com.ibm.cics.jcicsx'
}
```

*Figure 14. `build.gradle`*

The version number is omitted because it's inherited from the BOM. If you don't use a BOM, also specify a version number for this dependency.

Its version number includes the OSGi `Bundle-Version`, the CICS release, and (if relevant) the APAR number.

**The CICS annotations: `com.ibm.cics.server.invocation.annotations`**

All versions are available at com.ibm.cics.server.invocation.annotations on Maven Central.

Refer to this library as follows:

```
repositories {
    mavenCentral()
}

dependencies {
    compileOnly 'com.ibm.cics:com.ibm.cics.server.invocation.annotations'
}
```

*Figure 15. `build.gradle`*

The version number is omitted because it's inherited from the BOM. If you don't use a BOM, also specify a version number for this dependency.

Its version number includes the CICS release and (if relevant) the CICS TS APAR number.

**The CICS annotation processor: `com.ibm.cics.server.invocation`**

All versions are available at com.ibm.cics.server.invocation on Maven Central.

You're recommended to use the separate processor path for annotation processors, rather than adding them directly to the class path. For this reason, the configuration for `com.ibm.cics.server.invocation` differs from the other artifacts.

Refer to this library as follows:

```
repositories {
    mavenCentral()
}

dependencies {
    annotationProcessor 'com.ibm.cics:com.ibm.cics.server.invocation'
}
```

*Figure 16. `build.gradle`*

The version number is omitted because it's inherited from the BOM. Make sure that the BOM is defined with the same `annotationProcessor` configuration. If you don't use a BOM, specify a version number for this dependency.

Its version number includes the CICS release and (if relevant) the CICS TS APAR number.

## What's next

**Write an application using the CICS Java API**

CICS provides two versions of Java API: JCICS and JCICSX. For their differences, see Explore the Java APIs.

You can also find their API documentation at JCICS Javadoc information or JCICSX Javadoc.

**Try some samples**

CICS provides a series of samples for you to get started. See Try Java in your environment.

**Build and deploy your application**

After finishing the application code, you can build the application and integrate it into your build toolchain in the same way as you build and deploy other Gradle modules. CICS provides a Gradle plug-in for you to deploy your applications into CICS at development time.

This tutorial provides step-by-step instructions on how to build a CICS bundle from an existing Gradle-built Java application. Use the sample provided therein to have a try.

# Declaring Java dependencies using Maven

When creating a Maven build script, you will need to refer to dependencies supplied by CICS. Use this guide to understand how to reference each dependency.

For a complete list of all dependencies available, see “Managing Java dependencies using Gradle or Maven” on page 46.

**Prerequisites:** Before developing Java applications for CICS using Maven, you must make sure that:

- You already have Maven installed in your workstation or IDE.
- You have created a Maven module to include your application, or that you have converted an existing Java project to a Maven module. Most Java IDEs support this function.

For instructions, see the Maven related information in “Setting up your development environment” on page 38.

## How to declare dependencies

You declare dependencies in the Maven module's `pom.xml` file. The following instructions include snippets showing how to declare a dependency on each artifact. More recent versions might be available, so check Maven Central for all available versions.

**Note:** The snippets shown on Maven Central are auto-generated and might not show the correct Maven directives such as `<scope>import</scope>`. Follow the syntax in this topic instead to ensure the dependencies are correctly declared.

You can declare dependencies on these CICS-supplied artifacts:

- The CICS bill of materials (BOM): `com.ibm.cics.ts.bom`
- The CICS Java class library (JCICS): `com.ibm.cics.server`
- The JCICSX API classes: `com.ibm.cics.jcicsx`
- The CICS annotations: `com.ibm.cics.server.invocation.annotations`
- The CICS annotation processor: `com.ibm.cics.server.invocation`

**The CICS bill of materials (BOM): `com.ibm.cics.ts.bom`**

All versions are available at com.ibm.cics.ts.bom on Maven Central.

**Note:** You declare a dependency on a BOM file to manage versions of other libraries. The BOM itself does not import any library. Therefore, you must also reference other libraries along with the BOM.

Refer to this library as follows:

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>com.ibm.cics</groupId>
            <artifactId>com.ibm.cics.ts.bom</artifactId>
            <version>5.6-20200609123739</version>
            <type>pom</type>
            <scope>import</scope>
        </dependency>
    </dependencies>
</dependencyManagement>
```

*Figure 17. `pom.xml`*

In Maven, the BOM controls the configurations of the other dependencies as follows:

- The BOM controls the version of any other CICS dependency in the same module or its child modules if the version of that dependency is not otherwise specified.

  Make sure that you specify a BOM version that provides support for the other dependencies of your application, and that your target CICS system is at the same or later CICS TS release and APAR maintenance level. In the previous snippet, the `version` tag specifies the BOM version, consisting of:

  – The CICS version (`5.6`)

  – the time stamp when the BOM is built (`20200609123739`)

  – if relevant, the version of the CICS TS APAR that includes server-side updates to the libraries. For example, PH25409 in a version number `5.5-20200519131930-PH25409`.

- The BOM specifies that the other dependencies have a `provided` scope where relevant, so you don't need to specify `<scope>provided</scope>` in those Maven dependencies. When this scope is specified, the dependency will be provided by the eventual runtime and must not be packaged as part of the module. It not only reduces the application size, but also avoids hard-to-diagnose problems caused by inconsistent versions being used or classes being loaded from more than one class loader.

  If you do not use a BOM, you must specify `<scope>provided</scope>` when declaring those dependencies in Maven.

### The CICS Java class library (JCICS): `com.ibm.cics.server`

All versions are available at com.ibm.cics.server on Maven Central.

Refer to this library as follows:

```
<dependencies>
    <dependency>
        <groupId>com.ibm.cics</groupId>
        <artifactId>com.ibm.cics.server</artifactId>
    </dependency>
</dependencies>
```

*Figure 18. `pom.xml`*

The version number and the scope configuration are omitted because they are inherited from the BOM. If you don't use a BOM, reference this library as follows, where the version number includes the OSGi `Bundle-Version`, the CICS release, and (if relevant) the APAR number.

```
<dependencies>
    <dependency>
        <groupId>com.ibm.cics</groupId>
        <artifactId>com.ibm.cics.server</artifactId>
        <version>1.800.0-5.6</version>
        <scope>provided</scope>
    </dependency>
</dependencies>
```

*Figure 19. `pom.xml`*

### The JCICSX API classes: `com.ibm.cics.jcicsx`

All versions are available at com.ibm.cics.jcicsx on Maven Central.

Refer to this library as follows:

```
<dependency>
    <groupId>com.ibm.cics</groupId>
    <artifactId>com.ibm.cics.jcicsx</artifactId>
</dependency>
```

*Figure 20. `pom.xml`*

The version number and scope configuration are omitted because they are inherited from the BOM. If you don't use a BOM, also specify the version number and `<scope>provided</scope>` for this dependency.

Its version number includes the OSGi `Bundle-Version`, the CICS release, and (if relevant) the APAR number.

### The CICS annotations: `com.ibm.cics.server.invocation.annotations`

All versions are available at com.ibm.cics.server.invocation.annotations on Maven Central.

Refer to this library as follows:

```
<dependencies>
    <dependency>
        <groupId>com.ibm.cics</groupId>
        <artifactId>com.ibm.cics.server.invocation.annotations</artifactId>
    </dependency>
</dependencies>
```

*Figure 21. `pom.xml`*

The version number and scope configuration are omitted because they are inherited from the BOM. If you don't use a BOM, also specify the version number and `<scope>provided</scope>` for this dependency.

Its version number includes the CICS release and (if relevant) the CICS TS APAR number.

### The CICS annotation processor: `com.ibm.cics.server.invocation`

All versions are available at com.ibm.cics.server.invocation on Maven Central.

You're recommended to use the separate processor path for annotation processors, rather than adding them directly to the class path. For this reason, the configuration for `com.ibm.cics.server.invocation` differs from the other artifacts.

Refer to this library as follows:

```
<build>
    <plugins>
        <plugin>
            <artifactId>maven-compiler-plugin</artifactId>
            <version>3.8.1</version>
            <configuration>
                <annotationProcessorPaths>
                    <annotationProcessorPath>
                        <groupId>com.ibm.cics</groupId>
                        <artifactId>com.ibm.cics.server.invocation</artifactId>
                        <version>5.6</version>
                    </annotationProcessorPath>
                </annotationProcessorPaths>
            </configuration>
        </plugin>
    </plugins>
</build>
```

*Figure 22. `pom.xml`*

**Note:**

You need to specify the version number of this artifact even if you use a BOM.

Its version number includes the CICS release and (if relevant) the CICS TS APAR number.

### What's next

**Write an application using the CICS Java API**

CICS provides two versions of Java API: JCICS and JCICSX. For their differences, see Explore the Java APIs.

You can also find their API documentation at JCICS Javadoc information or JCICSX Javadoc.

**Try some samples**

CICS provides a series of samples for you to get started. See Try Java in your environment.

**Build and deploy your application**

After finishing the application code, you can build the application and integrate it into your build toolchain in the same way as you build and deploy other Maven modules. CICS provides a Maven plug-in for you to deploy your applications into CICS at development time.

This tutorial provides step-by-step instructions on how to build a CICS bundle from an existing Maven-built Java application. Use the sample provided therein to have a try.

## Manually importing Java libraries

When creating your own build scripts, if you want to manually import Java libraries to resolve dependencies instead of using the IBM CICS SDK for Java or Maven Central artifacts, you can copy the `.jar` files out of the CICS installation directories.

**Note:** Copying `.jar` files manually makes them prone to get out of sync with updates. You can use the artifacts on Maven Central to ensure that you always have the correct version of libraries. Otherwise, you must have a mechanism to refresh the copied `.jar` files. A full refresh is required when a new release of CICS is installed.

The `.jar` files are located within the `/lib` directory of the CICS USSHOME directory on zFS.

The application development `.jar` files are:

- `com.ibm.cics.jcicsx.jar`, which provides support for the JCICSX API.
- `com.ibm.cics.server.invocation.jar`, which provides support for the CICS annotation processor, a Java library that is used to create metadata that enables CICS programs to invoke Java applications in a Liberty JVM server.
- `com.ibm.cics.server.invocation.annotations.jar`, which provides support for CICS annotations, a Java library that provides the `@CICSProgram` annotation to enable CICS programs to invoke Java applications in a Liberty JVM server.
- `com.ibm.cics.server.jar`, which provides support for the JCICS API.
- `com.ibm.record.jar`, which contains the Java API for legacy programs that use IByteBuffer from the Java Record Framework that came with VisualAge.

**Related information**

"Deploying applications to a JVM server" on page 199

To deploy a Java application to a JVM server, the application must be packaged appropriately to install and run successfully. You can use the IBM CICS SDKs, or the CICS-provided Gradle or Maven plug-in to package and deploy the application.

# Considerations for a shared JVM

When you are developing Java applications to run in CICS, be aware that changes to shared resources within the JVM might be seen by all running applications and threads. Ensure that your applications do not leave the JVM in an unexpected state that other applications might rely on.

The following points are important considerations to think about:

- If your application resets the default time zone, other applications that use the same JVM server will use the new default time zone, which might be unexpected.
- Do not use **`System.exit()`** in your applications. Using **`System.exit()`** causes both the JVM server and CICS to shut down.
- Ensure that your applications are Threadsafe. Static variables that are shared between applications need careful review to ensure that there is no cross contamination between applications. A typical pattern to ensure uniqueness, is to use ThreadLocal variables.
- If objects are referenced by static variables, they are not candidates for garbage collection. In a JVM server, static state persists for all applications until the JVM server is disabled by the system programmer.
- It is possible to have multiple connections to Db2 from different applications. Therefore, when a task finishes with Db2, it is best practice to close the connection even if that connection is later deleted when the task completes.
- Sockets created using classes from the `java.net` package are not CICS domain sockets and cannot be managed or monitored by CICS.

# Java development using JCICS

You can write Java applications to access CICS services by using the Java APIs provided by CICS. The JCICS API supports most of the CICS functions provided by the **`EXEC CICS`** API.

**Contents**

## Why use JCICS?

- Java is one of the most popular programming languages for modern application development. Compared to the **`EXEC CICS`** API, which is provided for other CICS supported languages such as COBOL, the JCICS API allows you to write applications in Java and call into CICS services directly. This makes it easier for Java developer to write CICS applications.
- Unlike other CICS high level languages, no translation step is necessary during compilation as the underlying **`EXEC CICS`** calls are dynamically generated via the Java Native Interface (JNI).
- The JCICS API supports most of the functions of the **`EXEC CICS`** API and is tightly coupled with it. Therefore, if you understand the **`EXEC CICS`** API and have some knowledge of Java, you can familiarize yourself with JCICS quickly.

## Restrictions of JCICS

The following restrictions apply to Java applications written in JCICS:

- The classes in JCICS cannot be run remotely in development environments. If you need to link to a remote CICS program from your workstation, consider using the JCICSX API classes.
- It's not as easy to mock using the JCICS API as using JCICSX.
- The syntax of JCICS resembles the **`EXEC CICS`** commands in design so might not be as natural as that of other Java APIs. As an alternative, you can use the JCICSX API classes, which take advantage of more recent Java constructors that might be more familiar to some Java programmers.
- Do not use the `System.exit()` method. Using this method when the application is running in a JVM server will terminate the JVM server, quiesce CICS, and might lead to data inconsistency. You can use a Java security policy, code scans, or other measures to prevent the `System.exit()` method from being called.
- Do not share JCICS objects between threads. You can only call instance methods on JCICS objects from the thread that created them.
- Do not use finalizers in CICS Java programs.

If you are using JCICS in an OSGi environment, also see "Guidance for using OSGi" on page 93.

## JCICS usage and samples

### Resolving the JCICS dependency

You can get the JCICS API from any of the following places:

- The build path library supplied with the IBM CICS SDK for Java in CICS Explorer.

  When using CICS Explorer to add a library to your project, JCICS will automatically be available as an API in your client. See Step 1 in "Creating a Dynamic Web Project" on page 116 to configure your Dynamic Web project to target CICS TS. If you haven't installed CICS Explorer, install it as described in "Setting up your development environment" on page 38.
- The `com.ibm.cics.server` artifact on Maven Central. If you haven't installed Gradle or Maven, install either of them as described in "Setting up your development environment" on page 38.

  If your enterprise uses locally hosted or allow-listed repositories, you can use tools such as JFrog Artifactory or Sonatype Nexus to configure the artifact to be obtained from such repositories.
- The `com.ibm.cics.server.jar` file supplied with CICS in the `USSHOME` directory. For instructions, see "Manually importing Java libraries" on page 54.

**Note:** If you are importing the JCICS package into an OSGi bundle, you need to specify the package version. For more information, see "Guidance for using OSGi" on page 93.

### Developing applications in JCICS

Use the classes from the JCICS library in the same way as Java classes. For explanation of each JCICS class, see JCICS Javadoc information. For examples and full sample code, see "JCICS API services and examples" on page 58 and Sample CICS Java applications in GitHub.

When developing for CICS, mind that CICS attempts to pass control to the method with a signature of `main(CommAreaHolder)` in the class specified by the `JVMCLASS` attribute of the PROGRAM resource. If this method is not found, CICS tries to invoke method `main(String[])`.

## Troubleshooting

You can use your Java IDE's debugger, console message, and error handling information to debug your applications. In addition, you can use the CEDX transaction to test your application program in CICS.

If an error that relates to CICS occurs, for example the remote JVM server or the CICS transaction, a response (RESP) code is returned. The system programmer can use the JVM server's traces and logs for debugging. For more information, see Troubleshooting Java applications.

## Threads

In a JVM server environment, an application that is running in an OSGi framework can use an `ExecutorService` to create threads that run on CICS tasks asynchronously.

CICS provides an implementation of the Java `ExecutorService` interface. This implementation creates threads that can use the JCICS API to access CICS services. The JVM server registers the CICS `ExecutorService` as an OSGi service on startup. Use this service instead of the Java `Thread` class to create tasks that can use JCICS.

The `ExecutorService` that is provided by CICS is registered as high priority in the OSGi framework, so that it can be used by applications to create threads. Typically, an application uses the highest priority `ExecutorService`, unless it filters services to use a specific implementation.

If you want to create threads in your application, the preferred method is to use a generic `ExecutorService` from the OSGi registry. The OSGi registry automatically uses the CICS `ExecutorService` to create CICS threads when the application is running in a JVM server. This approach means that the application is decoupled from the implementation, so you do not have to use the JCICS API method to create threads.

However, if you are writing an application that is specific to CICS, you can choose to use a `CICSExecutorService` class in the JCICS API to request new threads.

### CICSExecutorService

This class implements the `java.util.concurrent.ExecutorService` interface. The `CICSExecutorService` class provides a static method that is called `runAsCICS()` that you can use to send a `Runnable` or `Callable` Java object for execution on a new JCICS enabled thread. The `runAsCICS()` method is a utility method which performs the OSGi registry look-up to obtain an instance of a `CICSExecutorService` for the application.

For work that is spawned from a parent CICS thread, a new CICS task is created, and runs under the task `user ID` and `transaction ID` inherited from the parent. If the work is spawned from a non- CICS thread, the default CJSA `transaction ID` and default CICS `user ID` are used. If you want to guarantee the new task runs under a `transaction ID` of your choice, then your `Runnable` or `Callable` object should implement the `CICSTransactionRunnable` or `CICSTransactionRunnable` interface.

```
CICSExecutorService.runAsCICS(Runnable runnable)
```

```
CICSExecutorService.runAsCICS(Callable callable)
```

### Restrictions

For applications that are not running in an OSGi framework, for example an Axis2 Java program, you can access JCICS only on the initial application thread as the `ExecutorService` is not available. Additionally, you must ensure that all threads other than the initial thread finish before you take any of the following actions:

- `link` methods in class `com.ibm.cics.server.Program`
- `setNextTransaction(String)` method in class `com.ibm.cics.server.TerminalPrincipalFacility`
- `setNextCOMMAREA(byte[])` method in class `com.ibm.cics.server.TerminalPrincipalFacility`
- `commit()` method in class `com.ibm.cics.server.Task`
- `rollback()` method in class `com.ibm.cics.server.Task`
- Returning an `AbendException` exception from class `com.ibm.cics.server`

## Data encoding

The JVM can use a different code page from CICS for character encoding; CICS must always use an EBCDIC code page, but the JVM can use another encoding such as ASCII. When you are developing an application that uses the JCICS API, you must ensure that you use the correct encoding.

The JCICS API uses the code page that is specified in the CICS region and not the underlying JVM. So if the JVM uses a different file encoding, your application must handle different code pages. To help you determine which code page CICS is using, CICS provides several Java properties:

- The **`com.ibm.cics.jvmserver.supplied.ccsid`** property returns the code page that is specified for the CICS region. By default, the JCICS API uses this code page for its character encoding. However, this value can be overridden in the JVM server configuration.
- The **`com.ibm.cics.jvmserver.override.ccsid`** property returns the value of an override in the JVM profile. The value is a code page that the JCICS API uses for its character encoding, instead of the code page that is used by the CICS region.
- The **`com.ibm.cics.jvmserver.local.ccsid`** property returns the code page that the JCICS API is using for character encoding in the JVM server.

You cannot set any of these properties in your Java application to change the encoding for JCICS. To change the code page, you must ask a system administrator to update the JVM profile to add the JVM system property **`-Dcom.ibm.cics.jvmserver.override.ccsid`**.

### Encoding example

Any JCICS methods that accept `java.lang.String` parameters as input are automatically encoded with the correct code page before the data passes to CICS . Similarly, any `java.lang.String` values that are returned from the JCICS API are encoded in the correct code page. The JCICS API provides helper methods in most classes; these helper methods work with strings and data to determine and set the code page on behalf of the application.

If your application uses the `String.getBytes()` or new `String(byte[] bytes)` methods, the application must ensure it uses the correct encoding. If you want to use these methods in your application, you can use the Java property to encode the data correctly:

```
String.getBytes(System.getProperty("com.ibm.cics.jvmserver.local.ccsid"))
String(bytes, System.getProperty("com.ibm.cics.jvmserver.local.ccsid"))
```

The following example shows how to use the JCICS encoding when the application reads a field from a COMMAREA:

```
public static void main(CommAreaHolder ca)
{
    //Convert first 8 bytes of ca into a String using JCICS encoding
    String str=new String(ca.getValue(), 0, 8, System.getProperty("com.ibm.cics.jvmserver.local.ccsid"));
}
```

## JCICS API services and examples

CICS supports a range of APIs and services for Java applications. Many of the services available to non-Java programs through the **EXEC CICS** API are available to Java programs through the JCICS API along with the standard Java SE APIs provided by the Java SDK.

These topics provide details on the JCICS services and the integration with Java exception handling. Other JEE APIs are available in the Liberty JVM server; for further details, see "Developing Java applications to run in a Liberty JVM server" on page 95.

A set of samples are also provided in GitHub to demonstrate how to use the JCICS API in an OSGi JVM server environment.

## APPC mapped conversations

APPC unmapped conversation support is not available from the JCICS API.

APPC mapped conversations:

| **Methods** | **JCICS class** | **EXEC CICS Commands** |
|---|---|---|
| `initiate()` | AttachInitiator | ALLOCATE, CONNECT PROCESS |
| `converse()` | Conversation | CONVERSE |
| `get*()` methods | Conversation | EXTRACT ATTRIBUTES |
| `get*()` methods | Conversation | EXTRACT PROCESS |
| `free()` | Conversation | FREE |
| `issueAbend()` | Conversation | ISSUE ABEND |
| `issueConfirmation()` | Conversation | ISSUE CONFIRMATION |
| `issueError()` | Conversation | ISSUE ERROR |
| `issuePrepare()` | Conversation | ISSUE PREPARE |
| `issueSignal()` | Conversation | ISSUE SIGNAL |
| `receive()` | Conversation | RECEIVE |
| `send()` | Conversation | SEND |
| `flush()` | Conversation | WAIT CONVID |

## Basic Mapping Support (BMS)

Basic mapping support (BMS) is an application programming interface between CICS programs and terminal devices. JCICS provides support for some of the BMS application programming interface.

| **Methods** | **JCICS class** | **EXEC CICS Commands** |
|---|---|---|
| `sendControl()` | TerminalPrincipalFacility | SEND CONTROL |
| `sendText()` | TerminalPrincipalFacility | SEND TEXT |
|  | Not supported | SEND MAP, RECEIVE MAP |

## Channel and container examples

*Containers* are named blocks of data designed for passing information between programs. Containers are grouped in sets called *channels*, which act as the interface between programs. Channels and containers offer the advantage that more than 32KB of data can be passed, and both character and binary data can be specified. Character data (or strings in Java terms) is automatically converted at the API level, whereas binary data (or a byte array in Java terms) is flowed unconverted. By contrast, COMMAREAs are confined to a 32KB limit and are unstructured byte arrays. Multiple containers can be passed between programs within a channel, providing a high degree of flexibility about how to structure data.

For introductory information about channels and containers, and guidance about using channels in non-Java applications, see Transferring data between programs using channels. For information about tools that allow Java programs to access existing CICS application data, see "Interacting with structured data from Java" on page 175.

Table 5 on page 60 lists the classes and methods that implement JCICS support for channels and containers.

*Table 5. JCICS support for channels and containers*

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `containerIterator()` | Channel | STARTBROWSE CONTAINER |
| `createContainer()` | Channel | |
| `delete()` | Channel | DELETE CHANNEL |
| `deleteContainer()` | Channel | DELETE CONTAINER CHANNEL |
| `getContainer()` | Channel | |
| `getContainerCount()` | Channel | QUERY CHANNEL |
| `getName()` | Channel | |
| `delete()` | Container | DELETE CONTAINER CHANNEL |
| `get()` | Container | GET CONTAINER CHANNEL |
| `getLength()` | Container | GET CONTAINER CHANNEL NODATA |
| `getDatatype()` | Container | |
| `getName()` | Container | |
| `put()` | Container | PUT CONTAINER CHANNEL |
| `getOwner()` | ContainerIterator | |
| `hasNext()` | ContainerIterator | |
| `next()` | ContainerIterator | GETNEXT CONTAINER BROWSETOKEN |
| `remove()` | ContainerIterator | |
| `link()` | Program | LINK |
| `setNextChannel()` | TerminalPrincipalFacility | RETURN CHANNEL |
| `issue()` | StartRequest | START CHANNEL |
| `createChannel()` | Task | |
| `getCurrentChannel()` | Task | ASSIGN CHANNEL |
| `containerIterator()` | Task | STARTBROWSE CONTAINER |

The CICS condition CHANNELERR results in a `ChannelErrorException` being thrown; the CONTAINERERR CICS condition results in a `ContainerErrorException` ; the CCSIDERR CICS condition results in a `CCSIDErrorException`.

### *Creating channels and containers in JCICS*

To create a channel, use the `createChannel()` method of the `Task` class.

For example:

```
Task t=Task.getTask();
Channel custData = t.createChannel("Customer_Data");
```

The string supplied to the `createChannel` method is the name by which the `Channel` object is known to CICS. (The name is padded with spaces to 16 characters, to conform to CICS naming conventions.)

To create a new container in the channel, use the `Channel` `createContainer()` method. For example:

```
Container custRec = custData.createContainer("Customer_Record");
```

The string supplied to the `createContainer()` method is the name by which the `Container` object is known to CICS. The name is padded with spaces to 16 characters, if necessary, to conform to CICS naming conventions. If a container of the same name already exists in this channel, a `ContainerErrorException` is thrown.

### *Putting data into a container*

To put data into a `Container` object, use the `Container.put()` method.

Data can be added to a container as a string. For example:

```
String custNo = "00054321";
byte[] custRecIn = custNo.getBytes();
custRec.put(custRecIn);
```

Or :

```
custRec.putString("00054321");
```

### *Passing a channel to another program or task*

To pass a channel on a program-link use the `link()` method of the `Program` class.

```
programX.link(custData);
```

To set the next channel on a program-return call, use the `setNextChannel()` method of the `TerminalPrincipalFacility` class:

```
terminalPF.setNextChannel(custData);
```

To pass a channel on a START request, use the `issue` method of the `StartRequest` class:

```
startrequest.issue(custData);
```

### *Receiving the current channel*

It is not necessary for a program to receive its current channel explicitly. However, a program can get its current channel from the current task.

If a program gets the current channel from the current task, the task can extract containers by name:

```
Task t = Task.getTask();
Channel custData = t.getCurrentChannel();

if (custData != null) {
    Container custRec = custData.getContainer("Customer_Record");
} else {
    System.out.println("There is no Current Channel");
}
```

### *Getting data from a container*

Use the `Container.get()` method to read the data in a container into a byte array.

```
byte[] custInfo = custRec.get();
```

### *Browsing the current channel*

A JCICS program that is passed a channel can access all of the `Container` objects without receiving the channel explicitly.

To do this, it uses a `ContainerIterator` object. The `ContainerIterator` class implements the `java.util.Iterator` interface. When a `Task` object is instantiated from the current task, its `containerIterator()` method returns an `Iterator` for the current channel, or null if there is no current channel. For example:

```
Task t = Task.getTask();
ContainerIterator ci = t.containerIterator();
```

```
while (ci.hasNext()) {
    Container custData = ci.next();
    // Process the container...
}
```

### *Channel and containers examples*

This example shows an excerpt of a Java class called `Payroll` that calls a COBOL server program named PAYR. The `Payroll` class uses the JCICS `com.ibm.cics.server.Channel` and `com.ibm.cics.server.Container` classes to work with a channel and its containers.

```
public class Payroll
{
    ...
    Task t=Task.getTask();

    // create the payroll_2004 channel
    Channel payroll_2004 = t.createChannel("payroll-2004");

    // create the employee container
    Container employee = payroll_2004.createContainer("employee");

    // put the employee name into the container
    employee.putString("John Doe");

    // create the wage container
    Container wage = payroll_2004.createContainer("wage");

    // put the wage into the container
    wage.putString("2000");

    // Link to the PAYROLL program, passing the payroll_2004 channel
    Program p = new Program();
    p.setName("PAYR");
    p.link(payroll_2004);

    // Get the status container which has been returned
    Container status = payroll_2004.getContainer("status");

    if (status != null)
    {
        // Get the status information
        byte[] payrollStatus = status.get();
    }

    ...
}
```

*Figure 23. Java class that uses the JCICS `com.ibm.cics.server.Channel` and `com.ibm.cics.server.Container` classes to pass a channel to a COBOL server program*

The following abbreviated code snippet shows how to use channels and containers to pass a character string input container on a program link and then to retrieve and read both a character string and a binary container. A full working example is available in the LinkProg3 sample and the corresponding back-end program is available at LinkServEduchan.

```
        //Initialize constants to define program name, and container data and names
        private static final String PROG_NAME = "EDUCHAN";
        private static final String CHANNEL="EDUCHAN";
        private static final String INPUT_CONTAINER="INPUTDATA";
        private static final String DATE_CONTAINER="CICSTIME";
        private static final String CICSRC_CONTAINER="CICSRC";
        private static final String INPUTSTRING="Hello from Java";
....

        Task task = Task.getTask();
        Program prog = new Program();
        prog.setName(PROG_NAME);
....
        //Create a Channel object to be associated with the task
        Channel testChannel = task.createChannel(CHANNEL);

        Container inputContainer = testChannel.createContainer(INPUT_CONTAINER); 1
        inputContainer.putString(INPUTSTRING); 2

        prog.link(testChannel); 3

        Container charContainer = testChannel.getContainer(DATE_CONTAINER); 4
        if (charContainer!=null)
        {
            resultStr = charContainer.getString();
        } 5

        Container bitContainer = testChannel.getContainer(CICSRC_CONTAINER); 6
        if (bitContainer!=null)
        {
            byte[] ba = bitContainer.get();
            ByteBuffer bb = ByteBuffer.wrap(ba);
            cicsrc = bb.getInt(); 7
        }
```

*Figure 24. Passing and retrieving containers*

Detailed explanation is as follows:

**1 2**

Creates the input container named INPUTDATA. And the `createContainer()` method signature takes the String `Hello from Java` as input which will cause CICS to create a character based container as opposed to a binary container. The encoding of this data will be stored internally in UTF-16 when created in Java in order to handle the Unicode String data, and will be automatically converted to the local EBCDIC encoding if read from a COBOL program.

**3**

Passes the channel as a reference on the `Program.link()` method. The invoked program EDUCHAN will receive the INPUTDATA container, reverse the input data, and return the formatted time in a character container along with an integer return code in a binary container.

**4 - 5**

Creates a new container object `charContainer` and gets the character container defined as CICSTIME from the channel. If it does not exist, this will return `null` rather than throw a `CICSConditionException`, which is the usual JCICS error model. Therefore the code tests for `null` before reading the string data using the `Container.getString()` method.

**6 - 7**

Creates a new container object `bitContainer` and gets the binary container defined as CICSRC from the channel. Again this will return null if the container is not present, so the code tests for `null`. Then you can create a byte array and get the data from the `bitContainer`. The data is a 32-bit integer from a CICS response code, so you need to wrap the data into a `ByteBuffer` and then read the integer from it.

## Diagnostic services

The JCICS application programming interface has support for these CICS trace and dump commands.

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| | Not supported | DUMP |
| enterTrace() | EnterRequest | ENTER |

## Document services

This section describes JCICS support for the commands in the DOCUMENT application programming interface.

Class `Document` maps to the **EXEC CICS DOCUMENT** API.

The default no-argument constructor for class `Document` creates a new document in CICS. The constructor `Document(byte[] docToken)` accepts a document token for an existing document that has previously been created. For example, another program can create a document and pass its document token to the Java application in a COMMAREA or container.

Constructors for class `DocumentLocation` map to the AT and TO keywords of the EXEC CICS DOCUMENT API.

Setters and getters for class `SymbolList` map to the SYMBOLLIST, LENGTH, DELIMITER, and UNESCAPE keywords of the **EXEC CICS DOCUMENT** API.

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| create*() | Document | DOCUMENT CREATE |
| append*() | Document | DOCUMENT INSERT |
| insert*() | Document | DOCUMENT INSERT |
| addSymbol() | Document | DOCUMENT SET |
| setSymbolList() | Document | DOCUMENT SET |
| retrieve*() | Document | DOCUMENT RETRIEVE |
| get*() | Document | DOCUMENT |

## Environment services

CICS environment services provide access to CICS data areas, parameters, and resource attributes that are relevant to an application program.

The **EXEC CICS** commands and options that have equivalent JCICS support are:

- ADDRESS
- ASSIGN
- INQUIRE SYSTEM
- INQUIRE TASK
- INQUIRE TERMINAL/NETNAME

### *ADDRESS*

The following support is provided for the **ADDRESS** API command options.

For complete information about the **EXEC CICS ADDRESS** command, see ADDRESS.

**ACEE**
The Access Control Environment Element (ACEE) is created by an external security manager when a CICS user signs on. This option not supported in JCICS.

**COMMAREA**
A COMMAREA contains user data that is passed with a command. The COMMAREA pointer is passed automatically to the linked program by the **CommAreaHolder** argument.

**CWA**
The Common Work Area (CWA) contains global user data, sharable between tasks. A copy of the CWA can be obtained using the getCWA() method of the Region class.

**EIB**
The EIB fields contains information about the CICS command last executed. Access to EIB values is provided by methods on the appropriate objects. For example,

**eibtrnid**
is returned by the getTransactionName() method of the Task class.

**eibaid**
is returned by the getAIDbyte() method of the TerminalPrincipalFacility class.

**eibcposn**
is returned by the getRow() and getColumn() methods of the Cursor class.

**TCTUA**
The Terminal Control Table User Area (TCTUA) contains user data associated with the terminal that is driving the CICS transaction (the principal facility). This area is used to pass information between application programs, but only if the same terminal is associated with the application programs involved. The contents of the TCTUA can be obtained using the getTCTUA() method of the TerminalPrincipalFacility class.

**TWA**
The Transaction Work Area (TWA) contains user data that is associated with the CICS task. This area is used to pass information between application programs, but only if they are in the same task. A copy of the TWA can be obtained using the getTWA() method of the Task class.

## *ASSIGN*

The following support is provided for the **ASSIGN** API command options.

For detailed information about this command, see ASSIGN.

| Methods | JCICS class |
|---|---|
| getABCODE() | AbendException |
| getApplicationContext() | Task |
| getAPPLID() | Region |
| getCurrentChannel() | Task |
| getCWA() | Region |
| getName() | TerminalPrincipalFacility or ConversationPrincipalFacility |
| getFCI() | Task |
| getNetName() | TerminalPrincipalFacility or ConversationPrincipalFacility |
| getPrinSysid() | TerminalPrincipalFacility or ConversationPrincipalFacility |
| getProgramName() | Task |
| getQNAME() | Task |

| Methods | JCICS class |
|---|---|
| `getSTARTCODE()` | Task |
| `getSysid()` | Region |
| `getTCTUA()` | TerminalPrincipalFacility |
| `getTERMCODE()` | TerminalPrincipalFacility |
| `getTWA()` | Task |
| `getUSERID()`, `Task.getUSERID()` | Task, TerminalPrincipalFacility or ConversationPrincipalFacility |

No other ASSIGN options are supported.

### *INQUIRE SYSTEM*

Support is provided for the **`INQUIRE SYSTEM`** SPI options.

| Methods | JCICS class |
|---|---|
| `getAPPLID()` | Region |
| `getSYSID()` | Region |

No other **`INQUIRE SYSTEM`** options are supported.

### *INQUIRE TASK*

The following support is provided for the **`INQUIRE TASK`** API command options.

| Methods | JCICS class |
|---|---|
| `getSTARTCODE()` | Task |
| `getTransactionName()` | Task |
| `getUSERID()` | Task |

**FACILITY**

You can find the name of the task's principal facility by calling the `getName()` method on the task's principal facility, which can in turn be found by calling the `getPrincipalFacility()` method on the current `Task` object.

**FACILITYTYPE**

You can determine the type of facility by using the Java `instanceof` operator to check the class of the returned object reference.

No other INQUIRE TASK options are supported.

### *INQUIRE TERMINAL and INQUIRE NETNAME*

The following support is provided for **`INQUIRE TERMINAL`** and **`INQUIRE NETNAME`** SPI options.

| Methods | JCICS class |
|---|---|
| `getUSERID()` | Terminal, ConversationalPrincipalFacility |
| `Terminal.getUser()` | Terminal, ConversationalPrincipalFacility |

You can also find the USERID value by calling the `getUSERID()` method on the current `Task` object, or on the object representing the task's principal facility.

No other **`INQUIRE TERMINAL`** or **`INQUIRE NETNAME`** options are supported.

## File services and examples

JCICS provides classes and methods that map to the **`EXEC CICS`** API commands for each type of CICS file and index.

For information about tools that allow Java programs to access existing CICS application data, see Interacting with structured data from Java.

CICS supports the following types of files:

- Key Sequenced Data Sets (KSDS)
- Entry Sequenced Data Sets (ESDS)
- Relative Record Data Sets (RRDS)

KSDS and ESDS files can have alternative (or secondary) indexes. CICS does not support access to an RRDS file through a secondary index. Secondary indexes are treated by CICS as though they were separate KSDS files in their own right, which means they have separate FD entries.

There are a few differences between accessing KSDS, ESDS (primary index), and ESDS (secondary index) files, which means that you cannot always use a common interface.

Records can be read, updated, deleted, and browsed in all types of file, with the exception that records cannot be deleted from an ESDS file.

See VSAM data sets: KSDS, ESDS, RRDS for more information about data sets.

Java commands that read data support only the equivalent of the SET option on **`EXEC CICS`** commands. The data returned is automatically copied from CICS storage to a Java object.

### Categories of Java interfaces relating to File Control

The Java interfaces relating to File Control are in five categories:

**File**
The superclass for the other file classes; contains methods common to all file classes.

**KeyedFile**
Contains the interfaces common to a KSDS file accessed using the primary index, a KSDS file accessed using a secondary index, and an ESDS file accessed using a secondary index.

**KSDS**
Contains the interface specific to KSDS files.

**ESDS**
Contains the interface specific to ESDS files accessed through Relative Byte Address (RBA, its primary index) or Extended Relative Byte Address (XRBA). To use XRBA instead of RBA, issue the `setXRBA(true)` method.

**RRDS**
Contains the interface specific to RRDS files accessed through Relative Record Number (RRN, its primary index).

### `File` and `FileBrowse` objects

For each file, there are two objects that can be operated on; the `File` object and the `FileBrowse` object.

**`File` objects**
The File object represents the file itself and can be used with methods to perform the following API operations:

- DELETE
- READ
- REWRITE
- UNLOCK

- WRITE
- STARTBR

A `File` object is created by the user application explicitly starting the required file class. The `FileBrowse` object represents a browse operation on a file. There can be more than one active browse against a specific file at any time, each browse being distinguished by a REQID. Methods can be instantiated for a `FileBrowse` object to perform the following API operations:

- ENDBR
- READNEXT
- READPREV
- RESETBR

**`FileBrowse` objects**

A `FileBrowse` object is not instantiated explicitly by the user application; it is created and returned to the user class by the methods that perform the STARTBR operation.

## Mapping from JCICS classes and methods to CICS API commands

The following tables show how the JCICS classes and methods map to the **`EXEC CICS`** API commands for each type of CICS file and index. In these tables, the JCICS classes and methods are shown in the form `class.method()`. For example, `KeyedFile.read()` references the `read()` method in the `KeyedFile` class.

## Classes and methods for keyed files

This table shows the classes and methods for keyed files.

*Table 6. Classes and methods for keyed files*

| KSDS primary or secondary index class and method | ESDS secondary index class and method | CICS File API command |
|---|---|---|
| `KeyedFile.read()` | `KeyedFile.read()` | **`READ`** |
| `KeyedFile.readForUpdate()` | `KeyedFile.readForUpdate()` | **`READ UPDATE`** |
| `KeyedFile.readGeneric()` | `KeyedFile.readGeneric()` | **`READ GENERIC`** |
| `KeyedFile.rewrite()` | `KeyedFile.rewrite()` | **`REWRITE`** |
| `KSDS.write()` | `KSDS.write()` | **`WRITE`** |
| `KSDS.delete()` | | **`DELETE`** |
| `KSDS.deleteGeneric()` | | **`DELETE GENERIC`** |
| `KeyedFile.unlock()` | `KeyedFile.unlock()` | **`UNLOCK`** |
| `KeyedFile.startBrowse()` | `KeyedFile.startBrowse()` | **`START BROWSE`** |
| `KeyedFile.startGenericBrowse()` | `KeyedFile.startGenericBrowse()` | **`START BROWSE GENERIC`** |
| `KeyedFileBrowse.next()` | `KeyedFileBrowse.next()` | **`READNEXT`** |
| `KeyedFileBrowse.previous()` | `KeyedFileBrowse.previous()` | **`READPREV`** |
| `KeyedFileBrowse.reset()` | `KeyedFileBrowse.reset()` | **`RESET BROWSE`** |
| `FileBrowse.end()` | `FileBrowse.end()` | **`END BROWSE`** |

## Classes and methods for non-keyed files

This table shows the classes and methods for non-keyed files. ESDS and RRDS are accessed by their primary indexes.

*Table 7. Classes and methods for non-keyed files*

| ESDS primary index class and method | RRDS primary index class and method | CICS File API command |
|---|---|---|
| ESDS.read() | RRDS.read() | **READ** |
| ESDS.readForUpdate() | RRDS.readForUpdate() | **READ UPDATE** |
| ESDS.rewrite() | RRDS.rewrite() | **REWRITE** |
| ESDS.write() | RRDS.write() | **WRITE** |
|  | RRDS.delete() | **DELETE** |
| KeyedFile.unlock() | RRDS.unlock() | **UNLOCK** |
| ESDS.startBrowse() | RRDS.startBrowse() | **START BROWSE** |
| ESDS_Browse.next() | RRDS_Browse.next() | **READNEXT** |
| ESDS_Browse.previous() | RRDS_Browse.previous() | **READPREV** |
| ESDS_Browse.reset() | RRDS_Browse.reset() | **RESET BROWSE** |
| FileBrowse.end() | FileBrowse.end() | **END BROWSE** |
| ESDS.setXRBA() |  |  |

## Writing and reading data

Data to be written to a file must be in a Java byte array.

Data is read from a file into a RecordHolder object.

You do not need to specify the **KEYLENGTH** value on any File method; the length used is the actual length of the key passed. When a FileBrowse object is created, it contains the length of the key specified on the startBrowse method, and this length is passed to CICS on subsequent browse requests against that object.

You do not need to provide a **REQID** for a browse operation; each browse object contains a unique REQID which is automatically used for all subsequent browse requests against that browse object.

## Samples

The following snippet shows how to use the KSDS class to read and write structured records to a VSAM file. In this example a StockPart record is used to represent the structured record, and was created from a COBOL copybook structure using IBM Record Generator for Java .

```
private static final String FILE_NAME = "XMPLKSDS";
private final KSDS ksds;
....

public void addRecord(StockPart sp)
{
    this.ksds = new KSDS();
    this.ksds.setName(FILE_NAME);
    //Get the byte structure from the generated record using the getByteBuffer() method on the
StockPark record
    byte[] record = sp.getByteBuffer();

    //Create a byte array containing the key for this record
    byte[] key = StockPartHelper.getKey(sp);
    try
    {
        //Write the record into the VSAM file using the specified key
        this.ksds.write(key, record);
    }
    //Catch specific responses from the WRITE FILE commmand
    catch (DuplicateRecordException dre)
    {  // Collision on the generated key
        String strMsg = "Tried to insert duplicate key 0x%08X";
        Task.getTask().out.println( String.format(strMsg, sp.getPartId()) );
        throw new RuntimeException(dre);
    }
    //Catch specific responses from the WRITE FILE commmand
    catch (InvalidRequestException ire)
    {
        if ( ire.getRESP2() == 20 ) // File not addable
        {
            String strMsg = "Add operations not permitted for file %s";
            Task.getTask().out.println( String.format(strMsg, this.ksds.getName()) );
        }
        // Throw an exception to rollback the current UoW
        throw new RuntimeException(ire);
    }
    //Catch all other responses and throw an exception to abend the task
    catch (CicsConditionException cce)
    {
        throw new RuntimeException(cce);
    }
}
```

For full working samples, go to GitHub, where sample CICS Java programs are provided to demonstrate how to use the JCICS API in an OSGi JVM server environment. In particular, use `com.ibm.cicsdev.vsam` for accessing KSDS, ESDS, and RRDS VSAM files.

## HTTP and TCP/IP services

Getters in classes `HttpHeader`, `NameValueData`, and `FormField` return HTTP headers, name and value pairs, and form field values for the appropriate API commands.

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `get*()` | CertificateInfo | EXTRACT CERTIFICATE / EXTRACT TCPIP |
| `get*()` | HttpRequest | EXTRACT WEB |
| `getHeader()` | HttpRequest | WEB READ HTTPHEADER |
| `getFormField()` | HttpRequest | WEB READ FORMFIELD |
| `getContent()` | HttpRequest | WEB RECEIVE |
| `getQueryParm()` | HttpRequest | WEB READ QUERYPARM |
| `startBrowseHeader()` | HttpRequest | WEB STARTBROWSE HTTPHEADER |
| `getNextHeader()` | HttpRequest | WEB READNEXT HTTPHEADER |
| `endBrowseHeader()` | HttpRequest | WEB ENDBROWSE HTTPHEADER |
| `startBrowseFormField()` | HttpRequest | WEB STARTBROWSE FORMFIELD |
| `getNextFormField()` | HttpRequest | WEB READNEXT FORMFIELD |
| `endBrowseFormField()` | HttpRequest | WEB ENDBROWSE FORMFIELD |
| `startBrowseQueryParm()` | HttpRequest | WEB STARTBROWSE QUERYPARM |
| `getNextQueryParm()` | HttpRequest | WEB READNEXT QUERYPARM |
| `endBrowseQueryParm()` | HttpRequest | WEB ENDBROWSE QUERYPARM |
| `writeHeader()` | HttpResponse | WEB WRITE |

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| getDocument() | HttpResponse | WEB RETRIEVE |
| getCurrentDocument() | HttpResponse | WEB RETRIEVE |
| sendDocument() | HttpResponse | WEB SEND |

**Note:** Use the method get HttpRequestInstance() to obtain the HttpRequest object.

Each incoming HTTP request processed by CICS Web support includes an HTTP header. If the request uses the POST HTTP verb it also includes document data. Each response HTTP request generated by CICS Web support includes an HTTP header and document data.

To process this JCICS provides the following Web and TCP/IP services:

**HTTP Header**
You can examine the HTTP header using the HttpRequest class. With HTTP in GET mode, if a client has filled in an HTTP form and selected the submit button, the query string is submitted.

**SSL**
CICS Web support provides the TcpipRequest class, which is extended by HttpRequest to obtain more information about which client submitted the request as well as basic information on the SSL support. If an SSL certificate is provided, you can use the CertificateInfo class to examine it in detail.

**Documents**
If a document is published to the server (HTTP POST), it is provided as a CICS document. You can access it by calling the getDocument() method on the HttpRequest class. See "Document services" on page 64 for more information about processing existing documents.

To serve the HTTP client web content resulting from a request, the server programmer needs to create a CICS document using the Document Services API and call the sendDocument() method.

For more information on CICS Web support see CICS Web support. For more information on the JCICS web classes see JCICS Javadoc information.

## Program services and examples

JCICS supports the CICS program control commands; LINK, RETURN, and INVOKE APPLICATION.

For information about tools that allow Java programs to access existing CICS application data, see Interacting with structured data from Java.

Table 8 on page 71 lists the methods and JCICS classes that map to CICS program control commands.

*Table 8. Relationship between methods, JCICS classes, and CICS commands*

| EXEC CICS Commands | JCICS class | JCICS methods |
|---|---|---|
| LINK | Program | link() |
| RETURN | TerminalPrincipalFacility | setNextTransaction(),<br>setNextCOMMAREA(),<br>setNextChannel() |
| INVOKE APPLICATION | Application | invoke() |

**LINK**
You can transfer control to another program that is defined to CICS by using the link() method. The target program can be in any language that is supported by CICS.

**RETURN**
Only the pseudoconversational aspects of this command are supported. It is not necessary to make a CICS call to return; the application can terminate as normal. The pseudoconversational functions are supported by methods in the TerminalPrincipalFacility class: setNextTransaction()

is equivalent to using the TRANSID option of RETURN; `setNextCOMMAREA()` is equivalent to using the COMMAREA option; while `setNextChannel()` is equivalent to using the CHANNEL option . These methods can be invoked at any time during the running of the program, and take effect when the program terminates.

**INVOKE**

Allows invocation of an application by naming an operation that corresponds to one of its program entry points, without having to know the name of the application entry point program and regardless of whether the program is public or private.

## Samples

### Example 1

The following code snippet shows how to use Task and Program to link to another CICS program.

```
private static final String PROG_NAME = "EC01"; 1
private static final int CA_LEN = 18 ;  2
....
public static void main(String[] args) 3
{
...
    Task task = Task.getTask(); 4
    task.out.println("Hello world"); 5

    Program prog = new Program(); 6
    prog.setName(PROG_NAME);
    prog.setSyncOnReturn(false);
    byte[] ca = new byte[CA_LEN]; 7
    prog.link(ca);
```

Detailed explanation is as follows:

**1 2**

Initializes constants including the name of the CICS program and the length of the COMMAREA input.

**3**

The `main(String[] args)` constructor signifies this as the entry point for this CICS program, which allows this class to be named in the `CICS-MainClass` header in the OSGi bundle manifest.

**4**

Gets the Task object representing the CICS task that the current Java thread is using. This will drive the underlying **`CICS ASSIGN`** command on first usage.

**5**

Sends output to the print writer. The output will be directed to either the user’s terminal or the standard output (stdout) if there is no terminal.

**6**

Instantiates an instance of a Program, and then set properties such as the name and whether or not the **`LINK`** command uses the **`SYNCONRETURN`** option.

**7**

Creates a byte array and then passes this as input on the `Program.link()` method. This will drive an **`EXEC CICS LINK`** command to the CICS program named in the `prog.setName` method. The COMMAREA will be passed as a byte array, which is an unstructured array of bytes of the specified length. Most CICS programs expect structured data as input. Therefore, if you need to build a Java bean to map to this, you can use IBM Record Generator for Java or Rational J2C Tools to build wrapper classes to map the records.

Note that there is no return type from the `Program.link()` method; instead the data is updated in the original place within the referenced COMMAREA.

### Example 2

The program that is invoked by a **LINK** command can also be written in Java, and in this case it passes the COMMAREA as a simple byte array. The following sample Java version of the EC01 CICS COBOL program shows how to use the CommAreaHolder class to receive the byte array mapping to the COMMAREA.

```
public class LinkServEC01
{
    //Initialize constants
    private static final int CA_LEN = 18 ;
    private static final String CA_LEN_ABCODE = "LEN";
    private static final SimpleDateFormat dfTime = new SimpleDateFormat("dd/MM/yy HH:mm:ss");
    //Get the local encoding of the CICS region, this defaults to EBCDIC
    private static final String CCSID =
System.getProperty("com.ibm.cics.jvmserver.local.ccsid");

    public static void main(CommAreaHolder cah)
    {

        Task task = Task.getTask();

        //Check input array is long enough, and terminate the task using an abend if input is
too short
        if (cah.getValue().length < CA_LEN )
        {
            task.abend(CA_LEN_ABCODE);
        }

        //Build time string for return to caller
        Date timestamp = new Date();
        byte ba[] = dfTime.format(timestamp).getBytes(CCSID);
        //Create byte array from the time string using the CICS encoding and copy into the
CommAreaHolder for return to the calling program as the COMMAREA
        System.arraycopy (ba, 0, cah.getValue(), 0, ba.length);
    }
....
```

**Learn more**

For more samples on how to perform **CICS LINK** operations using both COMMAREAs, channels, and containers, see the com.ibm.cicsdev.link sample at GitHub.

## Scheduling services

JCICS provides support for the CICS scheduling services, which let you retrieve data stored for a task, cancel interval control requests, and start a task at a specified time.

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| cancel() | StartRequest | CANCEL |
| retrieve() | Task | RETRIEVE |
| issue() | StartRequest | START |

To define what is to be retrieved by the Task.retrieve() method, use a java.util.BitSet object. The com.ibm.cics.server.RetrieveBits class defines the bits which can be set in the BitSet object; they are:

- RetrieveBits.DATA
- RetrieveBits.RTRANSID
- RetrieveBits.RTERMID
- RetrieveBits.QUEUE

These correspond to the options on the **EXEC CICS** RETRIEVE command.

The Task.retrieve() method retrieves up to four different pieces of information in a single invocation, depending on the settings of the RetrieveBits. The DATA, RTRANSID, RTERMID and QUEUE data are placed in a `RetrievedData` object, which is held in a `RetrievedDataHolder` object. The following example retrieves the data and transid:

```
BitSet bs = new BitSet();
bs.set(RetrieveBits.DATA, true);
bs.set(RetrieveBits.RTRANSID, true);
RetrievedDataHolder rdh = new RetrievedDataHolder();
t.retrieve(bs, rdh);
byte[] inData = rdh.value.data;
String transid = rdh.value.transId;
```

## Serialization services

JCICS provides support for the CICS serialization services, which let you schedule the use of a resource by a task.

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `dequeue()` | SynchronizationResource | DEQ |
| `enqueue()`, `tryEnqueue()` | SynchronizationResource | ENQ |

## Storage services

No support is provided for explicit storage management using CICS services (such as **EXEC CICS** GETMAIN). You should find that the standard Java storage management facilities are sufficient to meet the needs for task-private storage.

Sharing of data between tasks must be accomplished using CICS resources.

Names are generally represented as Java strings or byte arrays; you must ensure that these are of the necessary length.

## Temporary storage queue services and examples

A temporary storage (TS) queue is a set of data items that can be read and re-read in any sequence, and TSQ resources can be dynamically created at runtime. JCICS supports the CICS temporary storage commands: DELETEQ TS, READQ TS, and WRITEQ TS.

### Interaction between JCICS methods and EXEC CICS commands

For information about tools that allow Java programs to access existing CICS application data, see Interacting with structured data from Java.

Table 9 on page 74 lists the methods and JCICS classes that map to CICS temporary storage commands.

*Table 9. Relationship between methods, JCICS classes and CICS commands*

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `delete()` | TSQ | DELETEQ TS |
| `readItem()`, `readNextItem()` | TSQ | READQ TS |
| `writeItem()`, `rewriteItem()`, `writeItemConditional()`, `rewriteItemConditional()` | TSQ | WRITEQ TS |

**DELETEQ TS**

You can delete a temporary storage queue (TSQ) using the `delete()` method in the TSQ class.

**READQ TS**

The CICS INTO option is not supported in Java programs. You can read a specific item from a TSQ using the `readItem()` and `readNextItem()` methods in the TSQ class. These methods take an `ItemHolder` object as one of their arguments, which will contain the data read in a byte array. The storage for this byte array is created by CICS and is garbage-collected at the end of the program.

**WRITEQ TS**

You must provide data to be written to a temporary storage queue in a Java byte array. The `writeItem()` and `rewriteItem()` methods suspend if a NOSPACE condition is detected, and wait until space is available to write the data to the queue. The `writeItemConditional()` and `rewriteItemConditional()` methods do not suspend in the case of a NOSPACE condition, but return the condition immediately to the application as a `NoSpaceException`.

## Examples

The following snippets show how to use the TSQ class to write string data to a TSQ and then read it back using a JCICS holder. A full working example of this code is available in the TSQExample2 sample.

```
public class TSQExample2 extends TSQCommon
{
    //Initialize constants
    private static final String TSQ_NAME = "MYTSQ";
    private static final int DEPTH_COUNT = 5;
    private static final String CCSID =
System.getProperty("com.ibm.cics.jvmserver.local.ccsid");

    public static void main(String[] args)
    {
        //Create TSQ object and set TSQ name and storage type as MAIN (in memory)
        TSQ tsq = new TSQ();
        tsq.setName(TSQ_NAME);
        tsq.setType(TSQType.MAIN);

        //Loop around writing multiple records to the TSQ
        for (int i = 1; i <= DEPTH_COUNT; i++)
        {

            String msg = MessageFormat.format("TSQ write from JCICS item {0}", i);
            //Create byte array from the input string using the CICS encoding
            byte[] data;
            try
            {
                data = msg.getBytes(CCSID);
            }
            catch (UnsupportedEncodingException uee)
            {
                throw new RuntimeException(uee);
            }
            try {
                //Write each item to the TSQ using the TSQ.writeItem() method
                this.tsq.writeItem(data);
            }
            catch (CicsConditionException cce)
            {
                throw new RuntimeException(cce);
            }
        }
    }
```

The following method `readFromQueue()` shows how to use a JCICS `ItemHolder` to read bytes from a TSQ.

```
public void readFromQueue()
{
    //Create a JCICS ItemHolder to be used to read bytes from the TSQ
    ItemHolder holder = new ItemHolder();

    for (int i = 1; i <= DEPTH_COUNT; i++)
    {
        try
        {
            //Use the TSQ.readItem() method to loop around reading items from the TSQ into the
ItemHolder, starting from an index of 1 as this is the first record in a TS queue
            this.tsq.readItem(i, holder);
        }
        catch (CicsConditionException cce)
        {
            throw new RuntimeException(cce);
        }

        //Extract the byte array from the item holder
        byte[] data = holder.getValue();
        String strData;
        try
        {
            //Create a new string using the CICS encoding
            strData = new String(data, CCSID);
        }
        catch (UnsupportedEncodingException uee)
        {
            throw new RuntimeException(uee);
        }
    ....
    }
}
```

## Terminal services

JCICS provides support for these CICS terminal services commands.

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `converse()` | TerminalPrincipalFacility | CONVERSE |
|  | Not supported | HANDLE AID |
| `receive()` | TerminalPrincipalFacility | RECEIVE |
| `send()` | TerminalPrincipalFacility | SEND |
|  | Not supported | WAIT TERMINAL |

If a task has a terminal allocated as a principal facility, CICS automatically creates two Java `PrintWriter` components that can be used as standard output and standard error streams. These components are mapped to the task terminal. The two streams, which have the names `out` and `err`, are public files in the `Task` object and can be used in the same way as System.out and System.err.

Data to be sent to a terminal must be provided in a Java byte array. Data is read from the terminal into a `DataHolder` object. CICS provides the storage for the returned data which is deallocated when the program ends.

## Threads and tasks example

If your CICS Java application is running within an OSGi or Liberty environment, you can run work under a separate thread on a separate CICS task/transaction by using the `CICSExecutorService`.

Submit a Java Runnable or Callable object to the Executor service and the submitted application code will run on a separate thread under a new CICS task. Unlike normal threads created from Java, Executor controlled threads have access to the JCICS API and CICS services. In a CICS OSGi or Liberty environment you can use standard OSGi APIs to find the `CICSExecutorService`, or you can use the JCICS API convenience method `CICSExecutorService.runAsCICS()`, which finds the service and submits the Runnable or Callable object on your behalf.

**Note:** For non-HTTP requests in Liberty, a CICS task is created only when the first JCICS or JDBC DataSource with type 2 connectivity call is made.

The following example shows an excerpt of a Java class that submits a Runnable piece of application code to the `CICSExecutorService`. The application code simply writes to a CICS TSQ.

```
public class ExecutorTest
{
    public static void main(String[] args)
    {
        // Inline the new Runnable class
        class CICSJob implements CICSTransactionRunnable
        {
            public void run()
            {
                // Create a temporary storage queue
                TSQ test_tsq = new TSQ();
                test_tsq.setType(TSQType.MAIN);

                // Set the TSQ name
                test_tsq.setName("TSQWRITE");

                // Write to the temporary storage queue
                // Use the CICS region local CCSID so it is readable
                String test_string = "Hello from a non CICS Thread - "+ threadId;

                try
                {
test_tsq.writeItem(test_string.getBytes(System.getProperty("com.ibm.cics.jvmserver.local.ccsid")));
                }
                catch (Exception e)
                {
                    e.printStackTrace();
                }
            }

            @Override
            public String getTranid()
            {
                // *** This transaction id should be installed and available ***
                return "IJSA";
            }
        }

        // Create and run the new CICSJob Runnable
        Runnable task = new CICSJob();
        CICSExecutorService.runAsCICS(task);
    }
}
```

## Transforming between data and XML

JCICS supports API commands to transform data to XML and vice versa. These commands provide the equivalent functions to the **`EXEC CICS TRANSFORM DATATOXML`** and **`TRANSFORM XMLTODATA`** commands.

| Methods | JCICS class | EXEC CICS commands |
|---|---|---|
| `SetName` | XmlTransform | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `dataToXML` | Transform | TRANSFORM DATATOXML |
| `xmltoData` | Transform | TRANSFORM XMLTODATA |
| `setChannel` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `setDataContainer` | TransformInput | TRANSFORM DATATOXML<br>TRANSFORM XMLTODATA |
| `setElementName` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |

| Methods | JCICS class | EXEC CICS commands |
|---|---|---|
| `setElementNamespace` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `setNsContainer` | TransformInput | TRANSFORM XMLTODATA |
| `setTypeName` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `setTypeNamespace` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `setXmlContainer` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `setXmltransform` | TransformInput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `getElementName` | TransformOutput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `getElementNamespace` | TransformOutput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `getTypeName` | TransformOutput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |
| `getTypeNamespace` | TransformOutput | TRANSFORM DATATOXML, TRANSFORM XMLTODATA |

## Transient data queue services

JCICS supports the CICS transient data commands, DELETEQ TD, READQ TD, and WRITEQ TD. All options are supported except the INTO option. For a set of examples on TDQ, see the com.ibm.cicsdev.tdq sample project on GitHub.

### Interaction between JCICS methods and EXEC CICS commands

For information about tools that allow Java programs to access existing CICS application data, see Interacting with structured data from Java.

Table 10 on page 78 lists the methods and JCICS classes that map to CICS transient data commands.

*Table 10. Relationship between methods, JCICS classes and CICS commands*

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `delete()` | TDQ | DELETEQ TD |
| `readData()`, `readDataConditional()` | TDQ | READQ TD |
| `writeData()` | TDQ | WRITEQ TD |

**DELETEQ TD**

You can delete a transient data queue (TDQ) using the `delete()` method in the TDQ class.

**READQ TD**

The CICS INTO option is not supported in Java programs. You can read from a TDQ using the `readData()` or the `readDataConditional()` method in the TDQ class. These methods take as a parameter an instance of a `DataHolder` object that will contain the data read in a byte array. The storage for this byte array is created by CICS and is garbage-collected at the end of the program.

The `readDataConditional()` method drives the CICS NOSUSPEND logic. If a QBUSY condition is detected, it is returned to the application immediately as a `QueueBusyException`.

The `readData()` method suspends if it attempts to access a record in use by another task and there are no more committed records.

**WRITEQ TD**
You must provide data to be written to a TDQ in a Java byte array.

## Unit of work (UOW) services

JCICS provides support for the CICS SYNCPOINT service.

*Table 11. Relationship between JCICS and EXEC CICS commands for UOW services*

| Methods | JCICS class | EXEC CICS Commands |
|---|---|---|
| `commit()`, `rollback()` | Task | **SYNCPOINT** |

In a Liberty JVM server, UOW syncpointing can be controlled by using the Java Transaction API (JTA). For more information, see "Java Transaction API (JTA) " on page 130.

## Web services example

JCICS supports all API commands that are available for working with web services in an application.

| Methods | JCICS class | EXEC CICS commands |
|---|---|---|
| `invoke()` | WebService | INVOKE WEBSERVICE |
| `create()` | SoapFault | SOAPFAULT CREATE |
| `addFaultString()` | SoapFault | SOAPFAULT ADD FAULTSTRING |
| `addSubCode()` | SoapFault | SOAPFAULT ADD SUBCODESTR |
| `delete()` | SoapFault | SOAPFAULT DELETE |
| `create()` | WSAEpr | WSAEPR CREATE |
| `delete()` | WSAContext | WSACONTEXT DELETE |
| `set*()` | WSAContext | WSACONTEXT BUILD |
| `get*()` | WSAContext | WSACONTEXT GET |

The following example shows how you might use JCICS to create a web service request:

```
Channel requesterChannel = Task.getTask().createChannel("TestRequester");
Container appData = requesterChannel.createContainer("DFHWS-DATA");
byte[] exampleData = "ExampleData".getBytes();
appData.put(exampleData);

WebService requester = new WebService();
requester.setName("MyWebservice");
requester.invoke(requesterChannel, "myOperationName");

byte[] response = appData.get();
```

To handle the application data that is sent and received in a web service request, if you are working with structured data, you can use a tool such as IBM Record Generator for Java to generate classes. See "Interacting with structured data from Java" on page 175. You can also use Java to generate and consume XML directly.

# CICS exception handling in JCICS programs

CICS conditions and exceptions are integrated into the Java exception-handling architecture to handle problems that occur in CICS. You can use a set of Java exceptions and methods to handle CICS error conditions, and abend or roll back CICS tasks.

**Contents**

## Class hierarchy of JCICS exceptions

The JCICS API classes contain checked exceptions and unchecked exceptions. CICS checked exceptions extend the `CicsException` class. They correspond to the response codes of error conditions returned from the underlying **EXEC CICS** commands and need to be handled by your program. CICS unchecked exceptions extend the `CicsRuntimeException` class and represent failures within CICS or ABENDs.

The following diagram shows the class hierarchy of some example exceptions in JCICS:

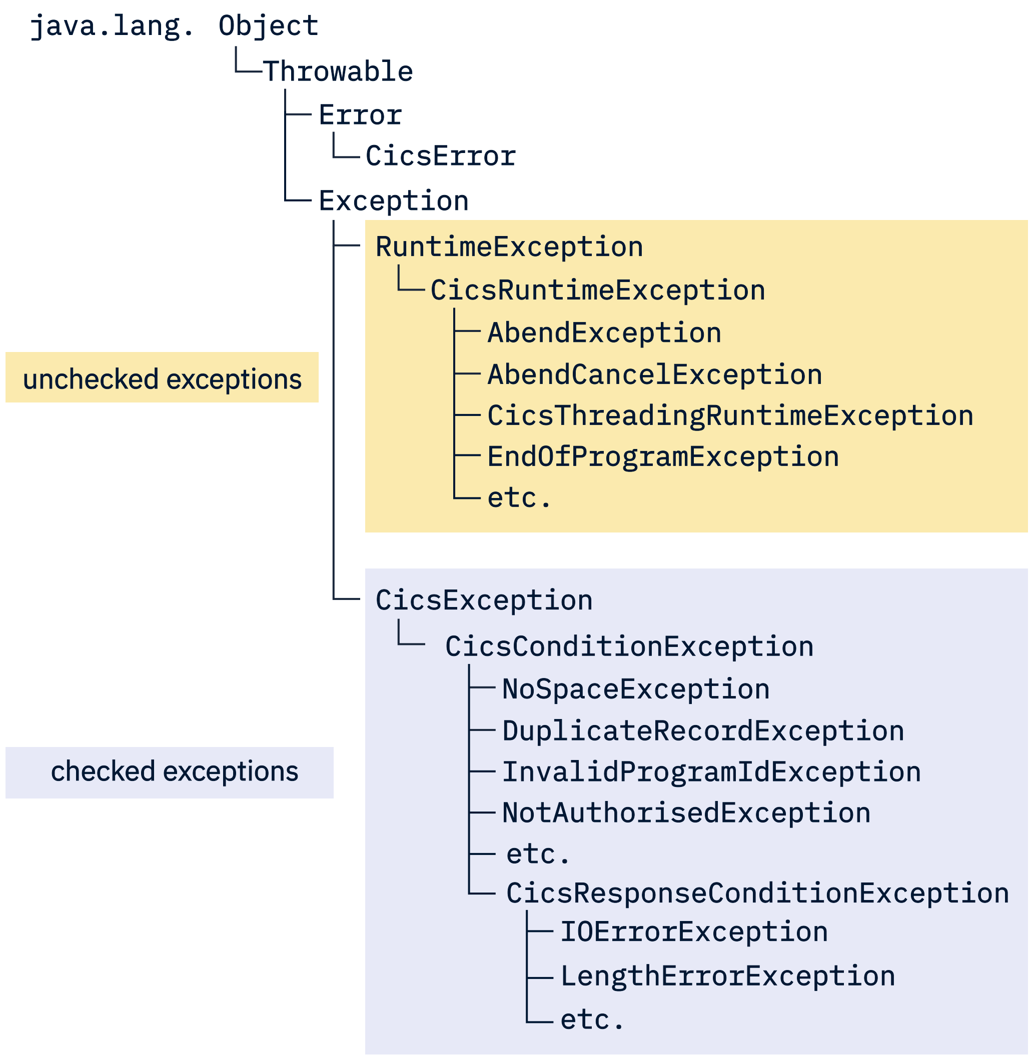


*Figure 25. Class hierarchy of checked and unchecked exceptions in JCICS*

For more information about each class, see JCICS Javadoc information.

## Catching checked exceptions

In Java, **checked exceptions** are used when you want the user of your API to design how to handle the exceptional situation. They must either be caught or declared as part of the method signature using the `throws` keyword. Any Java code that calls a method declared as throwing a checked exception must either provide logic to catch the checked exception, or add the exception to its own method signature, in order to propagate the exception further up the stack. The constraints on checked exceptions are enforced at compile time, and failure to adhere to the specification will result in a compilation error.

By contrast, in traditional high-level languages such as COBOL, when a CICS command returns an error (such as unknown program on a link), it returns a response code (for example, `PGMIDERR`) to the application using the data area supplied in the **RESP** parameter of the CICS command. This enables the application to handle or ignore errors on a call-by-call basis.

```
EXEC CICS LINK PROGRAM('ECIPROG') RESP(RESP)
        END-EXEC
IF RESP = DFHRESP(INVREQ)
  .......
END-IF
```

In JCICS, things are similar because almost all JCICS commands can throw sub-classes of the checked `CICSConditionException`, which represent error response codes from the underlying **`EXEC CICS`** commands. The full list of Java exception classes and the CICS error conditions they map to can be found at “Mapping between CICS conditions and JCICS exceptions” on page 84.

For example, an `INVREQ` response code maps to an `InvalidRequestException` class. The class hierarchy looks like this:

```
java.lang.Exception
  com.ibm.cics.server.CicsException
    com.ibm.cics.server.CicsConditionException
      com.ibm.cics.server.CicsResponseConditionException
        com.ibm.cics.server.InvalidRequestException
```

The following example shows how the `InvalidRequestException` class, which maps into the `INVREQ` response code, can be used in a `Program.link()` call. Each sub-class of `CicsConditionException`, including `InvalidRequestException`, can be individually caught so specific errors can be caught or ignored.

Order is important, a compilation error is displayed if a catch clause for a more generic exception appears before a catch clause for a more specific one (that is, for one of its sub-classes). This example logs a message for the `InvalidRequestException` and carries on processing. This means the transaction will continue normal processing and thus potentially commit any recoverable data, so make sure you don’t do this for fatal errors. The example then catches all other CICS errors (`catch(CicsConditionException cce)`) and throws them up the stack using a new `RuntimeException` class to drive subsequent error handling, which by default will abend the CICS task and rollback the transaction.

```
task task = Task.getTask();
task.out.println("Hello world");

try
{
        Program prog = new Program();
        prog.setName(PROG_NAME);
        prog.setSyncOnReturn(false);
        byte[] ca = new byte[CA_LEN];
        prog.link(ca);

}
catch (InvalidRequestException ire)
{
    task.out.println("Invalid request on link - INVREQ");
}
catch (CicsConditionException cce)
{
    throw new RuntimeException(cce);
}
```

## Catching unchecked exceptions

In Java, unexpected error conditions are represented by Java classes that extend the `RuntimeException` class and are known as ***unchecked exceptions***. Unchecked exceptions are not subject to the compile time checking mandated for checked exceptions, although they can be caught if required. In the JCICS API, all the unchecked exceptions extend the `CICSRuntimeException` class.

All of the unchecked exceptions that extend the `CICSRuntimeException` class represent conditions within CICS that are generally not handled by an application, to avoid interrupting the Java applications. They can include CICS ABENDs or some internal CICS events, such as program termination. Java code running in CICS must not catch these exceptions without re-throwing them, either explicitly in a catch block, or implicitly by catching a superclass of these exceptions such as `Exception` or `Throwable` as follows:

```
try
{
    ...
}
catch ( Exception e )
{
    ...
}
```

Instead, they need to be allowed to propagate out of the Java environment and back to CICS, where the task will abend. Included in this list is the AbendException class, which represents an ABEND of a CICS task. These ABENDs typically occur during sync point processing. The AbendException class must only be caught if you want to develop your own Java abend handling routine and re-throw the exception. If a Java exception such as a null pointer exception is allowed to propagate out of the Java code and back to the JVM server runtime, this is generally surfaced as one of the CICS ABENDs prefixed with AJ. Most commonly, an uncaught exception will result in an AJ04 abend, and the transaction will be rolled back.

**Consideration for web applications:** Any Java exception that is not handled by a web application will be caught by the web container and drive the servlet exception handling process. As part of this processing any uncommitted CICS units of work will be rolled back by CICS.

**Important:** Applications must not call Task.abend() after catching an AbendException. If Task.abend() is called, CICS issues the message DFHSJ1007, and disables and restarts the JVMSERVER.

### Abending and rolling back CICS tasks

It is also possible for a Java application to abend or roll back the CICS task directly. This can be achieved using the Task.abend() or Task.rollback() methods in the Task class, as shown in the LinkServEC01 sample. Abending the CICS task is similar in concept to the throwing of Java exception because it allows a CICS ABEND handler written in COBOL (or another language) to take control of error processing.

The various forms of the Task.abend() method allow an application to optionally specify an abend code or whether a dump is required. The forceAbend() methods provide the same options as the equivalent abend methods, but are equivalent to specifying the CANCEL keyword on the **EXEC CICS ABEND** command. Invoking a forceAbend() method always terminates the task abnormally, and overrides any existing CICS abend handlers that have been established for the task.

Rolling back the transaction is equivalent to issuing an **EXEC CICS SYNCPOINT ROLLBACK** command, and allows the task to continue but rolls back all the updates that have taken place so far in the current unit-of-work. In JCICS this is achieved using the Task.rollback() method of the Task class as follows:

```
try
{
    Task.getTask().rollback();
}
catch (InvalidRequestException ire)
{
    .....
}
```

LinkServEC01 contains a full sample where Task.rollback() is used to roll back the CICS task.

Note that when accessing resources that are controlled by the Liberty transaction manager, such as a remote Db2 database using JDBC type 4 connectivity, it is necessary to use the Java transaction API (JTA) to create a Java transaction to control the global transaction scope, including the subordinate CICS unit-of-work. In this case it is not possible to use the Task.rollback() method and instead the JTA API needs to be used.

## CICS error-handling commands

CICS condition handling is integrated into the Java exception-handling architecture, as described in CICS exception handling in JCICS programs.

The Java equivalent to the **EXEC CICS** error handling commands are as follows:

**HANDLE ABEND**

To handle an ABEND generated by a program in any CICS supported language, use a Java try-catch statement, with AbendException appearing in a catch clause.

**HANDLE CONDITION**

To handle a specific condition, such as PGMIDERR, use a catch clause that names the appropriate exception; in this case `InvalidProgramException`. Alternatively, use a catch clause that names `CicsConditionException` , if all CICS conditions are to be caught.

**IGNORE CONDITION**

This command is not relevant in Java applications.

**POP HANDLE and PUSH HANDLE**

These commands are not relevant in Java applications. The Java exceptions that are used to represent CICS ABENDs and conditions are caught by any catch block in scope.

## Mapping between CICS conditions and JCICS exceptions

In JCICS, the response code of an error condition that is returned by a CICS command is mapped into a Java exception.

*Table 12. Java exception mapping*

| CICS condition | Java exception in JCICS |
|---|---|
| ALLOCERR | AllocationErrorException |
| CBIDERR | InvalidControlBlockIdException |
| CCSIDERR | CCSIDErrorException |
| CHANNELERR | ChannelErrorException |
| CONTAINERERR | ContainerErrorException |
| DISABLED | FileDisabledException<br>ResourceDisabledException |
| DSIDERR | FileNotFoundException |
| DSSTAT | DestinationStatusChangeException |
| DUPKEY | DuplicateKeyException |
| DUPREC | DuplicateRecordException |
| END | EndException |
| ENDDATA | EndOfDataException |
| ENDFILE | EndOfFileException |
| ENDINPT | EndOfInputIndicatorException |
| ENQBUSY | ResourceUnavailableException |
| ENVDEFERR | InvalidRetrieveOptionException |
| EOC | EndOfChainIndicatorException |
| EODS | EndOfDataSetIndicatorException |
| EOF | EndOfFileIndicatorException |
| ERROR | ErrorException |
| EXPIRED | TimeExpiredException |
| FILENOTFOUND | FileNotFoundException |
| FUNCERR | FunctionErrorException |
| IGREQID | InvalidREQIDPrefixException |

*Table 12. Java exception mapping (continued)*

| CICS condition | Java exception in JCICS |
|---|---|
| IGREQCD | InvalidDirectionException |
| ILLOGIC | LogicException |
| INBFMH | InboundFMHException |
| INVERRTERM | InvalidErrorTerminalException |
| INVEXITREQ | InvalidExitRequestException |
| INVLDC | InvalidLDCException |
| INVMPSZ | InvalidMapSizeException |
| INVPARTNSET | InvalidPartitionSetException |
| INVPARTN | InvalidPartitionException |
| INVREQ | InvalidRequestException |
| INVTSREQ | InvalidTSRequestException |
| IOERR | IOErrorException |
| ISCINVREQ | ISCInvalidRequestException |
| ITEMERR | ItemErrorException |
| JIDERR | InvalidJournalIdException |
| LENGERR | LengthErrorException |
| MAPERROR | MapErrorException |
| MAPFAIL | MapFailureException |
| NAMEERROR | NameErrorException |
| NODEIDERR | InvalidNodeIdException |
| NOJBUFSP | NoJournalBufferSpaceException |
| NONVAL | NotValidException |
| NOPASSBKRD | NoPassbookReadException |
| NOPASSBKWR | NoPassbookWriteException |
| NOSPACE | NoSpaceException |
| NOSPOOL | NoSpoolException |
| NOSTART | StartFailedException |
| NOSTG | NoStorageException |
| NOTALLOC | NotAllocatedException |
| NOTAUTH | NotAuthorisedException |
| NOTFINISHED | NotFinishedException |
| NOTFND | RecordNotFoundException<br>NotFoundException |
| NOTOPEN | NotOpenException |

*Table 12. Java exception mapping (continued)*

| CICS condition | Java exception in JCICS |
|---|---|
| OPENERR | DumpOpenErrorException |
| OVERFLOW | MapPageOverflowException |
| PARTNFAIL | PartitionFailureException |
| PGMIDERR | InvalidProgramIdException |
| QBUSY | QueueBusyException |
| QIDERR | InvalidQueueIdException |
| QZERO | QueueZeroException |
| RDATT | ReadAttentionException |
| RETPAGE | ReturnedPageException |
| ROLLEDBACK | RolledBackException |
| RTEFAIL | RouteFailedException |
| RTESOME | RoutePartiallyFailedException |
| SELNERR | DestinationSelectionErrorException |
| SESSBUSY | SessionBusyException |
| SESSIONERR | SessionErrorException |
| SIGNAL | InboundSignalException |
| SPOLBUSY | SpoolBusyException |
| SPOLERR | SpoolErrorException |
| STRELERR | STRELERRException |
| SUPPRESSED | SuppressedException |
| SYMBOLERR | SymbolErrorException |
| SYSBUSY | SystemBusyException |
| SYSIDERR | InvalidSystemIdException |
| TASKIDERR | InvalidTaskIdException |
| TCIDERR | TCIDERRException |
| TEMPLATERR | TemplateErrorException |
| TERMERR | TerminalException |
| TERMIDERR | InvalidTerminalIdException |
| TOKENERR | TokenErrorException |
| TRANSIDERR | InvalidTransactionIdException |
| TSIOERR | TSIOErrorException |
| UNEXPIN | UnexpectedInformationException |
| USERIDERR | InvalidUserIdException |
| WRBRK | WriteBreakException |

*Table 12. Java exception mapping (continued)*

| CICS condition | Java exception in JCICS |
|---|---|
| WRONGSTAT | WrongStatusException |

**Note:** `NonHttpDataException` is thrown by `getContent()` if the CICS command WEB RECEIVE indicates that the data received is a non-HTTP message (by setting TYPE=HTTPNO).

For more information about each Java exception class, see JCICS Javadoc information.

# Java development using JCICSX

The JCICSX API classes allow you to access CICS services through a Java API. They support a subset of CICS functionality, can be run remotely, and are easier to mock and stub than the Java classes of JCICS. The JCICSX API classes can be used together with the JCICS API, but only the commands using JCICSX can benefit from these enhanced features.

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## Why use JCICSX?

The JCICSX API classes extend parts of the JCICS API with the capability of remote development and mocking. They have the following benefits:

- The classes allow easy mocking and stubbing. The JCICSX API classes make it easier to apply inversion of control and inject test doubles, so that you can mock the JCICSX method calls on your workstation during unit testing, using frameworks such as Mockito, EasyMock, and PowerMock.
- The classes can be run remotely in development environments. You can link to programs or pass data through channels and containers in a remote CICS region by executing CICS Java applications on your local workstation, without having to repeatedly deploy the applications to CICS. In addition, no modification is required to the application code regardless of whether it runs in CICS or on your local workstation.
- The syntax is simplified and natural for Java developers who are more familiar with more recent Java constructors.
- You can leverage capabilities of modern Java IDEs, such as content assist, debugging, smart navigation, and hot-swapping. This is achieved through the support of mocking and remote development in a local IDE, including IntelliJ and Eclipse.
- Code written using the JCICSX API classes can execute without change, both in remote development mode and when deployed to run in CICS.
- It's compatible with the JCICS API. JCICSX API classes can be used alongside the JCICS API in the same program, but only pure JCICSX programs can benefit from the enhanced features such as remote development. For example, if you mix JCICS and JCICSX in the same program, you won't be able to run it remotely in your development environment.

## Restrictions of JCICSX

The JCICSX API classes support only a subset of CICS functionality that addresses some of the most common scenarios for using Java in CICS, focused on linking to CICS programs using channels and containers. For more information, see "Appendixes" on page 90. If you need to use functions beyond that scope, consider using the JCICS API.

Client-side tooling is available initially to enable Liberty users to use JCICSX to access CICS from a servlet.

JCICSX API classes will not work correctly within worker threads that are dispatched as part of an asynchronous servlet.

## Security model of JCICSX

For remote development, JCICSX requires a Liberty JVM server to be set up in CICS to receive the remote JCICSX requests. The JCICSX client-side tooling creates a new CICS Task with a call to the server. Subsequent JCICSX requests from that client will run under the same task, and must be issued by the same user. This is transparent when using the client-side tooling. The Liberty JVM server can be configured to use authentication and authorization for JCICSX calls, and the communication between the client and the remote server can be configured to use SSL. For more information, see Configuring security for remote JCICSX API development and Configuring SSL (TLS) for remote JCICSX API development.

In other cases, for example when the applications are deployed to run in CICS, JCICSX adopts an identical security model to that of JCICS.

## Configuring the environment for JCICSX

Configure your environment for JCICSX as follows:

- If you want to use JCICSX for remote development, extra configuration is needed to set up supporting infrastructure in CICS and on your local workstation. Note that the supporting infrastructure in CICS is required only in development regions. The JCICSX API is available in all CICS JVM servers by default.
- **Mandatory:** Set up your compilation environment by importing the JCICSX dependency.

**Required for remote development System programmers must configure a Liberty JVM server in CICS TS with the JCICSX server feature (`cicsts:jcicsxServer-1.0`) enabled**

Note that JCICSX supports remote development for Liberty servlets.

1. Set up a Liberty JVM server in a development CICS region that the application will remotely execute against. You are advised to set up a JVM server solely for the purpose of remote development so that the remoting JVM server and the actual application JVM servers can have different configuration. Otherwise, the configuration might conflict. For more information, see Set up a Liberty JVM server.
2. Add the `cicsts:jcicsxServer-1.0` Liberty feature to the Liberty JVM server's `server.xml` file:

```
<featureManager>
    <feature>cicsts:jcicsxServer-1.0</feature>
</featureManager>
```

3. Let the developer know the hostname and `httpEndpoint` port of this Liberty JVM server.
4. If needed, configure security for the remoting Liberty JVM server. See Configuring security for remote JCICSX API development.

**Required for remote development Developers configure the local development environment to run Java code locally and to make remote calls for JCICSX**

1. If you do not have a Liberty runtime on your local workstation, install one, for example, WebSphere Liberty Web Profile. It must be at Liberty 19.0.0.3 or later. For more information, see WebSphere Liberty for developers.

2. Install the `jcicsxClient-1.0` Liberty feature into the general Liberty runtime on your local workstation. On a command line, navigate to the `bin` directory of your local Liberty server, and enter the following installUtility command:

   ```
   installUtility install jcicsxClient-1.0 jsonp-1.0
   ```

3. Create a local Liberty JVM server that uses the Liberty runtime on your workstation to run the Java code.
4. Enable the `jcicsxClient-1.0` feature in your local Liberty server by adding this to your `server.xml`:

   ```
   <featureManager>
       <feature>usr:jcicsxClient-1.0</feature>
   </featureManager>
   ```

5. Configure the `server.xml` file in your local Liberty server with the hostname and port of the remote Liberty JVM server that your system programmer created, which contains the `cicsts:jcicsxServer-1.0` feature:

   ```
   <usr_jcicsxClient serverUri="http://hostname:port"/>
   ```

   If the remote Liberty JVM server is configured to use authentication, you can encrypt the user password by using the securityUtility command provided in the `bin` directory of the local Liberty server. So your snippet might look like this:

   ```
   <usr_jcicsxClient serverUri="http://hostname:port">
       <basicAuthentication user="myUser"
   password="{aes}ADwac72WXpSCr2YDUv3hHgjfOa0moXZDj626MmM4DbtT"/>
   </usr_jcicsxClient>
   ```

6. If the remote Liberty JVM server uses SSL connection for data encryption, your local Liberty server needs to trust the certificate of the remote server. See instructions for application developers in Configuring SSL (TLS) for remote JCICSX API development.

**Required Developers resolve the JCICSX dependency**

The JCICSX API classes are available in CICS TS alongside the JCICS API in CICS TS 5.6 or later. You can import JCICSX API classes from any of the following places:

1. The build path library supplied with the IBM CICS SDK for Java in IBM CICS Explorer for Aqua 3.2[2] (Fix Pack 5.5.0.9) or later.

   When using CICS Explorer to add a library to your project, JCICSX will automatically be available as an API in your client. See Step 1 in “Creating a Dynamic Web Project” on page 116 to configure your Dynamic Web project to target CICS TS. If you haven't installed CICS Explorer, install it as described in “Setting up your development environment” on page 38.
2. The `com.ibm.cics.jcicsx` artifact on Maven Central. If you haven't installed Gradle or Maven, install either of them as described in “Setting up your development environment” on page 38.

   If your enterprise uses locally hosted or allow-listed repositories, you can use tools such as JFrog Artifactory or Sonatype Nexus to configure the artifact to be obtained from such repositories.
3. The `com.ibm.cics.jcicsx.jar` file supplied with CICS in the USSHOME directory, which you can copy to your compilation environment. For more information, see “Manually importing Java libraries” on page 54.

## JCICSX use cases and samples

After configuration is complete, you can start coding to the JCICSX API classes.

During unit testing, you can mock the JCICSX method calls on your workstation using familiar testing frameworks.

[2] Aqua refers to IBM Explorer for z/OS Aqua.

When the Liberty JVM server is enabled for remote development, you can run the application code in your local Liberty server to check how your code will behave when running in CICS or explore what information is returned on the API commands, by making remote calls into a CICS region. When you run your application within the local Liberty server, any JCICSX calls will automatically be redirected to your CICS region. When your application is deployed to a JVM server running in a real CICS region, the same JCICSX calls will be made directly against CICS.

Typical use cases of JCICSX are shown in "JCICSX examples" on page 91. For details of all JCICSX API classes, see JCICSX Javadoc.

## Best practices

If you're developing using JCICSX, you are advised to run your code in a local Liberty server on your workstation. This can reduce issues around different applications conflicting with each other when running in a shared JVM server in a CICS development region.

If you're planning to deploy applications to a Liberty JVM server running in CICS TS, see "Considerations for a shared JVM" on page 55 for best practices.

## Troubleshooting

You can use your Java IDE's debugger, console message, and error handling information to debug your applications. JCICSX also allows multiple clients to debug at the same time. In addition, you can use the CEDX transaction to test your application program in CICS.

If an error that relates to CICS occurs, for example the remote JVM server or the CICS transaction, a response (RESP) code is returned. The system programmer can use the JVM server's traces and logs for debugging. For more information, see Troubleshooting Java applications.

## Appendixes

### Appendix 1. JCICSX API classes

The JCICSX API classes support a subset of the CICS functionality as follows. For details about each class, see JCICSX Javadoc.

*Table 13. JCICSX API classes*

| Classes | Description |
|---|---|
| CICSContext | The environment that the API is executing in. Entry point to the JCICSX API. |
| Channel | Create or delete a channel, or retrieve information about the containers in it. |
| Container | Create a container, retrieve information about a container, get data from and put data into a container, or delete a container. |
| ProgramLinker | Link to a program. |

### Appendix 2. Mapping between JCICSX and EXEC CICS API commands

This table shows how JCICSX API methods map onto **EXEC CICS**API commands. Only methods that have mapping relationships are listed.

*Table 14. Mapping between JCICSX and* ***EXEC CICS*** *API commands*

| **Classes** | **Methods** | **EXEC CICS API commands** |
|---|---|---|
| BITContainer<br>CHARContainer<br>WritableBITContainer<br>WritableCHARContainer<br>WritableContainer | append | EXEC CICS PUT64 CONTAINER APPEND |
| | put | EXEC CICS PUT64 CONTAINER |
| Channel | exists<br>getContainerCount | EXEC CICS QUERY CHANNEL |
| | delete | EXEC CICS DELETE CHANNEL |
| | iterator | EXEC CICS STARTBROWSE CONTAINER<br>EXEC CICS GETNEXT CONTAINER<br>EXEC CICS ENDBROWSE CONTAINER |
| ChannelProgramLinker | link | EXEC CICS LINK PROGRAM |
| Container | delete | EXEC CICS DELETE CONTAINER CHANNEL |
| | getLength | EXEC CICS GET CONTAINER CHANNEL NODATA |
| ProgramLinker | link | EXEC CICS LINK PROGRAM |
| ReadableBITContainer | get | EXEC CICS GET64 CONTAINER |
| | read | EXEC CICS GET64 CONTAINER |
| ReadableCHARContainer | get | EXEC CICS GET64 CONTAINER |
| ReadableContainer | | |

## JCICSX examples

Examples using JCICSX API classes, as well as their JCICS equivalents, are provided to give a basic understanding of how JCICSX can be used in typical use cases.

For more samples to play with, go to JCICSX samples in GitHub.

### Setting up channels and containers

**Example 1**

The example shows how to set up a channel named XYZ with two containers:

- A CHAR container called CONT1 with the text scenarios in it.
- A BIT container called CONT2 with the content of the bytes byte array.

The JCICSX snippet shows the use of opinionated container types: the Java code is aware of the difference between BIT and CHAR in containers, and different methods are available for each type.

### JCICSX

```
CICSContext task = CICSContext.getCICSContext();
Channel channel = task.getChannel("XYZ");
channel.getCHARContainer("CONT1").put("scenarios");
channel.getBITContainer("CONT2").put(bytes);
```

### JCICS

```
Task task = Task.getTask();
Channel channel = task.getChannel("XYZ");
channel.createContainer("CONT1").putString("scenarios");
channel.createContainer("CONT2").put(bytes);
```

## Linking to a program

### Example 2

This example shows how to link to program ABC without passing any input.

### JCICSX

```
CICSContext task = CICSContext.getCICSContext();
task.createProgramLinker("ABC").link();
```

### JCICS

```
Task task = Task.getTask();
Program abcProgram = new Program();
abcProgram.setName("ABC");
abcProgram.link();
```

### Example 3

This example shows how to link to program ABC with a channel named XYZ, passing a CHAR container named `CONT-IN` with the text `scenarios` in it, then get the content of a CHAR container called `CONT-OUT` and return it as a string.

The JCICSX snippet shows that JCICSX has convenient ways of calling common models: adding containers, linking, and getting response data.

### JCICSX

```
CICSContext task = CICSContext.getCICSContext();
return task
    .createProgramLinkerWithChannel("ABC", task.getChannel("XYZ"))
    .setStringInput("CONT-IN", "scenarios")
    .link()
    .getOutputCHARContainer("CONT-OUT")
    .get();
```

### JCICS

```
Task task = Task.getTask();
Channel channel = task.createChannel("XYZ");
channel.createContainer("CONT-IN").putString("scenarios");

Program abcProgram = new Program();
abcProgram.setName("ABC");
abcProgram.link();

return channel.getContainer("CONT-OUT").getString();
```

### Mocking

**Example 4**

The JCICSX API can be easily mockable. There are many mocking frameworks you can use; this JCICSX example shows how to use Mockito to return some mocked contents of a container. Mocking out the CICS calls enables you to independently unit test the logic of your application.

```
CICSContext task = Mockito.mock(CICSContext.class);
Channel channel = Mockito.mock(Channel.class);
CHARContainer container = Mockito.mock(CHARContainer.class);
Mockito.when(task.getChannel("ABC")).thenReturn(channel);
Mockito.when(channel.getCHARContainer("container")).thenReturn(container);
Mockito.when(container.get()).thenReturn("the contents of my container");
```

# Guidance for using OSGi

A number of considerations for developing OSGi applications.

## Defining dependencies

When an OSGi bundle uses Java packages from another OSGi bundle, the interface between the two bundles must be explicitly expressed. The bundle that uses the package must add the package to the **Import-Package** statement in its manifest.mf. The bundle that provides the package must add the package to the **Export-Package** statement in its manifest.mf. When both OSGi bundles are deployed into the environment, the dependency can be resolved.

All packages that are used by an OSGi bundle, including JRE extensions such as **javax.*** must be explicitly imported. This is the case even if the run time would otherwise find these packages through other means such as bootdelegation. Assume that only the core **java.*** packages are available by default.

**Versioning of JCICS dependencies:** The com.ibm.cics.server package (JCICS) will increment in version number when there are API additions, API removals, or bug-fixes during service or development work. However, version increments are not guaranteed on a release boundary. Versions, and which CICS release they apply to, are described in Package com.ibm.cics.server.

It is prudent to declare Imports as a compatible range, beginning at your applications minimum supported level, up to (but not including), the next breaking API change. For example: Import-Package: com.ibm.cics.server;version="[1.800.0,2.0.0)".

There are alternative ways of expressing dependencies - in particular the bundle header **Require-Bundle**. However, **Require-Bundle** is more coarse-grained and ties the consumer to a specific bundle. Using **Require-Bundle** also prevents architectural flexibility and restricts the ability to version packages independently.

## JCICS restrictions in OSGi bundles

The JCICS API classes have these restrictions when used in OSGi bundles:

- JCICS API calls cannot be used in the activator classes of OSGi bundles.

  **Note:** The Java thread that runs the OSGi bundle activator will not be JCICS-enabled.
  A developer can start a new JCICS-enabled thread from an activator, by using the CICSExecutorService.runAsCICS() method. Any JCICS commands will run under the authority of the user ID that issued the install command. Therefore, it is prudent for an administrator to understand the resources used in OSGi bundle activators before they install them. For more information on how to use the runAsCICS() method, see "Threads and tasks example" on page 76.
- Start and stop methods used in OSGi bundle activators must return in a reasonable amount of time.

## JRE class visibility, bootdelegation, and system.packages.extra

In OSGi, loading of core JRE packages/classes (`java.*`) is always delegated to the bootstrap classloader. It is assumed that there is only one JRE in the system, and so explicit dependency statements are not required. For that reason, it is never necessary to add a `java.*` dependency to a bundle manifest. However, for other parts of the JRE, application bundles that require these packages must code an Import-Package statement; for example vendor-specific extensions `javax.*` `com.sun.*` and `com.ibm.*` require an import. This is because they are not delegated to the bootstrap classloader and instead treated as part of the OSGi system.

The OSGi framework provides a system bundle that exposes known extension packages to the system automatically. The application bundle registers its dependency by including an Import statement, just as for all other packages provided by OSGi bundles. The advantage of this approach is that extensions can be replaced with newer implementations by installing an OSGi bundle that contains the new code.

An exception to this process is where a particular package is added to the bootdelegation list by using a special OSGi property. Although convenient (as no Import statement is required to access these packages), it restricts the flexibility of OSGi and is not considered best practice. Occasionally there are vendor-specific extensions that aren't automatically added to the system bundle by the OSGi implementation. For these cases, and assuming the package is genuinely available from the JRE, the property `-Dorg.osgi.framework.system.packages.extra` can be used to add the packages to the system bundle and allow application Imports to resolve.

## Bundle activators

Bundle activators are classes within an OSGi bundle that implement the **`BundleActivator`** interface. To use an activator, an OSGi bundle must declare it using the **`Bundle-Activator`** header in the bundle manifest. The **`BundleActivator`** interface has `start` and `stop` methods that can be used to perform initialization or termination work. A common pattern is to look up service dependencies for use within the application. However, it is better to employ a component model, such as Declarative Services to activate components and their service dependencies.

## Singleton bundles

A singleton bundle is used to prevent any other version of a bundle being loaded in memory, there can be only one resolved version in the run time at any point. The use of a singleton bundle can be desirable where access to a single system resource is required from a set of applications.

## OSGi bundle fragments

Fragments are OSGi bundles that are dynamically attached to host bundles by the OSGi framework. They share the class loader for their host bundle, and do not participate in the lifecycle of the bundle - for that reason they do not support bundle activators. Common use-cases for fragments are as bundle patches. A fragment provided ahead of `.` on the **`Bundle-ClassPath`** allows classes to be preferentially loaded from the fragment instead of the host.

## OSGi service registry

The OSGi service registry enables a bundle to publish objects to a shared registry. A service is advertised under a Java interface and made available to other bundles installed in the OSGi environment.

## Microservices (µServices)

Microservices are a software architecture style in which complex applications are composed of small, independent components which communicate with each other using language-agnostic APIs. These services are small, highly decoupled, and focus on doing a small task, facilitating a modular approach to system building. The use of µServices between OSGi components provides flexibility and dynamic update capabilities that cannot be achieved by using bundle wiring alone. For this reason, the use of µServices is encouraged over bundle-wiring.

### Bundle and package versioning

A favored approach to package versioning in OSGi is the semantic versioning model. Given a version number MAJOR.MINOR.PATCH, increment the:

1. MAJOR version when you make incompatible API changes
2. MINOR version when you add functionality that is compatible with an earlier version
3. PATCH version when you make bug fixes that are compatible with an earlier version

### Execution environment

Execution environments (EEs) are symbolic representations of JREs, for example:

```
Bundle-RequiredExecutionEnvironment: JavaSE-1.7
```

You need to use the lowest version of EE that gives you all the features you require. When creating a new OSGi bundle, the most recent actively maintained Java execution environment is usually adequate - only if a specialized application requires a lower version would you set it at a lower level. When a particular EE is chosen, it must be left alone unless there is a clear advantage to moving up. Increasing the version of your EE can create more work with no real value, such as exposing your code to new warnings, and deprecations.

# Developing Java applications to run in a Liberty JVM server

Configure the Liberty JVM server to run a web container if you want to deploy Java EE applications that use WebSphere Application Server Liberty.

## Liberty features

CICS supports features from WebSphere Application Server Liberty, which enables Enterprise Java applications to be deployed into a Liberty JVM server.

All features in Tables 2-14 relate to CICS integrated-mode Liberty. The features are also supported in CICS standard-mode Liberty without any of the restrictions, unless noted otherwise. Table 15 provides a set of CICS features to integrate Liberty features with the CICS qualities of service.

Many features from Java EE 6 and Java EE 7, and Java EE 7 and Java EE 8 must not be used concurrently. For information about feature compatibility, see Supported Java EE 6 and 7 feature combinations and Supported Java EE 7 and 8 feature combinations. For information about editing the `server.xml`, see Server configuration.

### List of tables

Table 12: Liberty features supported for Security

Table 13: Liberty features supported for Systems Management

Table 14: Liberty features supported for z/OS

Table 15: CICS Liberty features

*Table 15. Liberty features alphabetically*

| Features A - EjbL | Features EjbP - Jpa-2.0 | Features Jpa-2.1 - Mo | Features Mp - Z |
|---|---|---|---|
| adminCenter-1.0 | ejbPersistentTimer-3.2 | jpa-2.1 | mpConfig-1.1 |
| appClientSupport-1.0 | ejbRemote-3.2 | jpa-2.2 | mpFaultTolerance-1.0 |
| appSecurity-1.0 | el-3.0 | jsf-2.0 | mpHealth-1.0 |
| appSecurity-2.0 | j2eeManagement-1.1 | jsf-2.2 | mpJwt-1.0 |
| appSecurity-3.0 | jacc-1.5 | jsf-2.3 | mpMetrics-1.0 |
| batch-1.0 | jakartaee-8.0 | json-1.0 | oauth-2.0 |
| batchManagement-1.0 for JEE7 | jaspic-1.1 | jsonb-1.0 | openidConnectClient-1.0 |
| beanValidation-1.0 for JEE6 | javaMail-1.5 | jsonp-1.0 | openidConnectServer-1.0 |
| beanValidation-1.0 for JEE7 | javaMail-1.6 | jsonp-1.1 | osgiConsole-1.0 |
| beanValidation-1.1 for JEE6 | javaee-7.0 | jsp-2.2 | osgi.jpa-1.0 |
| beanValidation-1.1 for JEE7 | javaee-8.0 | jsp-2.3 | restConnector-1.0 |
| blueprint-1.0 | jaxb-2.2 for JEE7 | jta-1.1 | servlet-3.0 |
| cdi-1.0 | jaxb-2.2 for JEE6 | jta-1.2 | servlet-3.1 |
| cdi-1.2 | jaxrs-1.1 | jwt-1.0 | servlet-4.0 |
| cicsts:core-1.0 | jaxrs-2.0 | ldapRegistry-3.0 | sessionDatabase-1.0 |
| cdi-2.0 | jaxrs-2.1 | localConnector-1.0 | springBoot-1.5 |
| cicsts:defaultApp-1.0 | jaxrsClient-2.0 | managedBeans-1.0 | springBoot-2.0 |
| cicsts:distributedIdentity-1.0 | jaxrsClient-2.1 | mdb-3.1 | ssl-1.0 |
| cicsts:jcaLocalEci-1.0 | jaxws-2.2 for JEE7 | mdb-3.2 | wab-1.0 |
| cicsts:jdbc-1.0 | jaxws-2.2 for JEE6 | microProfile-1.0 | wasJmsClient-1.1 |
| cicsts:link-1.0 | jca-1.6 | microProfile-1.2 | wasJmsClient-2.0 |
| cicsts:security-1.0 | jca-1.7 | microProfile-1.3 | wasJmsSecurity-1.0 |
| cicsts:standard-1.0 | jcaInboundSecurity-1.0 for JEE6 | microProfile-1.4 | wasJmsServer-1.0 |
| cicsts:zosConnect-1.0 | jcaInboundSecurity-1.0 for JEE7 | microProfile-2.0 | webCache-1.0 |
| cicsts:zosConnect-2.0 | jdbc-4.0 | microProfile-2.1 | webProfile-6.0 |

*Table 15. Liberty features alphabetically (continued)*

| Features A - EjbL | Features EjbP - Jpa-2.0 | Features Jpa-2.1 - Mo | Features Mp - Z |
|---|---|---|---|
| concurrent-1.0 | jdbc-4.1 | microProfile-2.2 | webProfile-7.0 |
| distributedMap-1.0 | jdbc-4.2 | microProfile-3.0 | webProfile-8.0 |
| ejb-3.2 | jms-1.1 | microProfile-3.2 | websocket-1.0 |
| ejbHome-3.2 | jms-2.0 | microProfile-4.0 | websocket-1.1 |
| ejbLite-3.1 | jmsMdb-3.1 | microProfile-4.1 | wmqJmsClient-2.0 |
| ejbLite-3.2 | jndi-1.0 | mongodb-2.0 | zosTransaction-1.0 |
|  | jpa-2.0 | monitor-1.0 | zosSecurity-1.0 |

*Table 16. Liberty features supported for Java EE 8 Full Platform and Jakarta EE 8 Platform.*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| appClientSupport-1.0 | Enables the Liberty server to process client modules and support remote client containers. | **Tip:** The Application Client module runs in both the client and the server. The client executes the client specific logic of the application. The other portion of code runs in a client container on the server and communicates data from the business logic running on the server to the client. For more information, see Preparing and running an application client. |
| batch-1.0 | Enables support for the Java Batch 1.0 API defined in JSR-352. This feature does not support Java batch applications that are packaged in an Enterprise Bundle Archive (EBA). |  |
| concurrent-1.0 | Enables the creation of managed executors that allow applications to submit tasks to run concurrently, with thread context that is managed by the application server. It also enables the creation of managed thread factories to create threads that run with the threadcontext of the component that looks up the managed thread factory. | **Restriction:** The transaction property `ManagedTask.SUSPEND` is not supported by a Liberty JVM server.<br>**Restriction:** The user ID that is attached to the transaction of a new thread is always the user ID that is attached to the parent transaction.<br>**Restriction:** Use of a `ManagedThreadFactory` creates standard Java threads, not CICS-enabled Java threads. |

*Table 16. Liberty features supported for Java EE 8 Full Platform and Jakarta EE 8 Platform. (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| ejb-3.2 | Enables support for Enterprise JavaBeans written to the EJB 3.2 specification. | Enterprise JavaBeans (EJB)<br>**Important:** When using EJB-related features, the transaction attribute **`NotSupported`** is respected by the JTA Liberty transaction system but not the CICS unit of work. |
| jacc-1.5 | Enables support for Java Authorization Contract for Containers (JACC) version 1.5. | Developing a Java Authorization Contract for Containers (JACC) Authorization Provider |
| jakartaee-8.0 | Combines the Liberty features that support the Jakarta EE 8.0 Platform. | Jakarta EE 8 and Java EE 8 in Liberty<br>**Note:**<br>Jakarta EE 8, which includes new versions of features such as servlet-4.0 cannot be used with the wab-1.0 feature. To prevent CICS automatically including wab-1.0, and to take advantage of Jakarta EE 8 APIs, set the property `com.ibm.cics.jvmserver.wlp.wab=false` in the JVM profile. |
| javaee-8.0 | Combines the Liberty features that support the Java EE 8.0 Full Platform. | Jakarta EE 8 and Java EE 8 in Liberty<br>**Note:**<br>In Java EE 8, the `jsonb-1.0` feature is enabled by `jaxrs-2.1` as an alternative to the IBM JSON4J support provided in `json-1.0`.<br>Java EE 8, which includes new versions of features such as servlet-4.0 cannot be used with the wab-1.0 feature. To prevent CICS automatically including wab-1.0, and to take advantage of Java EE 8 APIs, set the property `com.ibm.cics.jvmserver.wlp.wab=false` in the JVM profile. |
| javaMail-1.6 | Allows applications to use the JavaMail 1.6 API. | |
| jaxws-2.2 | Enables support for Java API for XML-Based Web Services 2.2. JAX-WS web services and clients communicate using XML. | |

*Table 16. Liberty features supported for Java EE 8 Full Platform and Jakarta EE 8 Platform. (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| jca-1.7 | Enables the configuration of resource adapters to access Enterprise Information Systems (EIS) from applications. | "Java EE Connector Architecture (JCA)" on page 145<br>**Restriction:** The use of JCICS API and Db2 JDBC type 2 connectivity capabilities is not supported in threads that are created by the JCA API `javax.resource.spi.BootstrapContext.createTimer()`. For the same effect, use the concurrent APIs (`javax.enterprise.concurrent.ManagedScheduledExecutorService`). |
| jcaInboundSecurity-1.0 | Enables security inflow for resource adapters. Allows JCA inbound resource adapters to flow security contexts by extending the `javax.resource.spi.work.SecurityContext` abstract class. | |
| jdbc-4.2 | Enables the configuration of DataSources to access Databases from applications. | Creating a default CICS Db2 DataSource with type 2 connectivity for Liberty<br>**Note:** The `jdbc-4.0`, `jdbc-4.1` and `jdbc-4.2` implementations reside in the same Db2 JCC driver and are mutually exclusive. |
| j2eeManagement-1.1 | Allows applications to utilize the interfaces defined in the JSR77 specification. | |
| servlet-4.0 | Enables support for HTTP Servlets written to the Java Servlet 4.0 specification, including support for the HTTP/2 protocol. | |
| jms-2.0 | Enables the configuration of resource adapters to access messaging systems using the Java Message Service API. | "Java Message Service (JMS)" on page 141 |
| wasJmsClient-2.0 | Provides applications with access to message queues hosted in Liberty through the JMS API. | "Java Message Service (JMS)" on page 141 |
| wasJmsSecurity-1.0 | Enables an embedded messaging server to authenticate and authorize access from JMS clients. | "Java Message Service (JMS)" on page 141 |

*Table 16. Liberty features supported for Java EE 8 Full Platform and Jakarta EE 8 Platform. (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| wasJmsServer-1.0 | Enables an embedded messaging server that is JMS compliant. Applications can send and receive messages using the `wasJmsClient` feature. | "Java Message Service (JMS)" on page 141 |
| webProfile-8.0 | Combines the Liberty features that support the Java EE 8.0 Web Profile. | **Note:** Java EE 8, which includes new versions of features such as servlet-4.0 cannot be used with the wab-1.0 feature. To prevent CICS automatically including wab-1.0, and to take advantage of Java EE 8 APIs, set the property `com.ibm.cics.jvmserver.wlp.wab=false` in the JVM profile. |

*Table 17. Liberty features supported for Java EE 8 Web Profile*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| appSecurity-3.0 | Enables support for securing the server runtime environment and applications using Security-1.0 as defined in JSR-375. | Configuring security for a Liberty JVM server with the Java EE security API 1.0 |
| beanValidation-2.0 | Provides an annotation based model for validating JavaBeans. | |
| cdi-2.0 | Provides a common mechanism to inject component such as EJBs or Managed Beans into other components such as JSPs or other EJBs. | |
| ejbLite-3.2 | Enables support for Enterprise JavaBeans written to the EJB Lite subset of the EJB 3.2 specification. | Using EJB-related features |
| el-3.0 | Enables support for the Expression Language (EL) 3.0 specification. | |
| jaspic-1.1 | Java Authentication SPI for Containers (JASPIC) allows a Java EE Application Server to use custom authentication. JASPIC providers are defined in JSR-196. If a JASPIC provider and a TAI are configured in the same server, then the TAI has no effect. Therefore, JASPIC is a standard Java EE technology and a more portable solution than a TAI for Java EE applications. | |
| jaxrs-2.1 | Enables support for Java API for RESTful Web Services v2.1. | |

*Table 17. Liberty features supported for Java EE 8 Web Profile (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| jaxrsClient-2.1 | Enables support for Java Client API for JAX-RS 2.1. | |
| jdbc-4.0 , jdbc-4.1, jdbc-4.2 | Enables the configuration of DataSources to access Databases from applications. | Creating a default CICS Db2 DataSource with type 2 connectivity for Liberty<br>**Note:** The `jdbc-4.0`, `jdbc-4.1` and `jdbc-4.2` implementations reside in the same Db2 JCC driver and are mutually exclusive. |
| jndi-1.0 | Enables the use of Java Naming and Directory Interface (JNDI) to access server configured resources such as DataSources or JMS Connection Factories. | |
| jpa-2.2 | Enables support for applications that use application-managed and container-managed JPA written to the Java Persistence API 2.2 specification. | |
| jsf-2.3 | Enables support for applications that use application-managed and container-managed JPA. | |
| jsonb-1.0 | Provides a standard for converting between Java objects and JavaScript Object Notation (JSON). | |
| jsonp-1.1 | Provides a standardized method for constructing and manipulating data to be rendered in JavaScript Object Notation (JSON). | |
| jsp-2.3 | Enables support for Java Server Pages (JSPs) that are written to the JSP 2.3 specification. | "Java EE and Liberty applications" on page 116 |
| managedBeans-1.0 | Enables support for the Managed Beans 1.0 specification. | |
| servlet-4.0 | Enables support for HTTP Servlets written to the Java Servlet 4.0 specification, including support for the HTTP/2 protocol. | |
| websocket-1.1 | Enables a web browser or client application and a web server application to communicate by using one full duplex connection. | |
| webProfile-8.0 | Provides a convenient combination of the Liberty features that are required to support the Java EE 8 Web Profile. | |

*Table 18. Liberty features supported for Java EE 7 Full Platform*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| appClientSupport-1.0 | Enables the Liberty server to process client modules and support remote client containers. | **Tip:** The Application Client module runs in both the client and the server. The client executes the client specific logic of the application. The other portion of code runs in a client container on the server and communicates data from the business logic running on the server to the client. For more information, see Preparing and running an application client. |
| batch-1.0 | Enables support for the Java Batch 1.0 API defined in JSR-352. This feature does not support Java batch applications that are packaged in an Enterprise Bundle Archive (EBA). | |
| beanValidation-1.0 | Provides an annotation-based model for validating JavaBeans. | |
| concurrent-1.0 | Enables the creation of managed executors that allow applications to submit tasks to run concurrently, with thread context that is managed by the application server. It also enables the creation of managed thread factories to create threads that run with the threadcontext of the component that looks up the managed thread factory. | **Restriction:** The transaction property `ManagedTask.SUSPEND` is not supported by a Liberty JVM server.<br>**Restriction:** The user ID that is attached to the transaction of a new thread is always the user ID that is attached to the parent transaction.<br>**Restriction:** Use of a `ManagedThreadFactory` creates standard Java threads, not CICS-enabled Java threads. |
| ejb-3.2 | Enables support for Enterprise JavaBeans written to the EJB 3.2 specification. | Enterprise JavaBeans (EJB)<br>**Important:** When using EJB-related features, the transaction attribute **`NotSupported`** is respected by the JTA Liberty transaction system but not the CICS unit of work. |
| ejbHome-3.2 | Enables the use of home interfaces in Enterprise JavaBeans. | Using EJB-related features |
| ejbPersistentTimer-3.2 | Enables the use of persistent timers in Enterprise JavaBeans. | Using EJB-related features<br>**Restriction:** Db2 JDBC type 2 connectivity is not supported for persisting EJB timers. |
| ejbRemote-3.2 | Enables the use of remote interfaces in Enterprise JavaBeans. | Using EJB-related features |
| jacc-1.5 | Enables support for Java Authorization Contract for Containers (JACC) version 1.5. | Developing a Java Authorization Contract for Containers (JACC) Authorization Provider |

*Table 18. Liberty features supported for Java EE 7 Full Platform (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| jaspic-1.1 | Java Authentication SPI for Containers (JASPIC) allows a Java EE Application Server to use custom authentication. JASPIC providers are defined in JSR-196. If a JASPIC provider and a TAI are configured in the same server, then the TAI has no effect. Therefore, JASPIC is a standard Java EE technology and a more portable solution than a TAI for Java EE applications. | |
| j2eeManagement-1.1 | Allows applications to utilize the interfaces defined in the JSR77 specification. | |
| javaMail-1.5 | Allows applications to utilize the JavaMail 1.5 API. | |
| javaee-7.0 | Combines the Liberty features that support the Java EE 7.0 Full Platform. | |
| jaxb-2.2 | Enables support for the Java Architecture for XML Binding 2.2 specification, which provides easy mapping of Java classes to XML documents. | |
| jaxws-2.2 | Enables support for Java API for XML-Based Web Services 2.2. JAX-WS web services and clients communicate using XML. | |
| jca-1.7 | Enables the configuration of resource adapters to access Enterprise Information Systems (EIS) from applications. | "Java EE Connector Architecture (JCA)" on page 145<br>**Restriction:** The use of JCICS API and Db2 JDBC type 2 connectivity capabilities is not supported in threads that are created by the JCA API `javax.resource.spi.BootstrapContext.createTimer()`. For the same effect, use the concurrent APIs (`javax.enterprise.concurrent.ManagedScheduledExecutorService`). |
| jcaInboundSecurity-1.0 | Enables security inflow for resource adapters. Allows JCA inbound resource adapters to flow security contexts by extending the `javax.resource.spi.work.SecurityContext` abstract class. | |

*Table 18. Liberty features supported for Java EE 7 Full Platform (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| jdbc-4.1jdbc-4.2 | Enables the configuration of DataSources to access Databases from applications. | Creating a default CICS Db2 DataSource with type 2 connectivity for Liberty<br>**Note:** The `jdbc-4.0`, `jdbc-4.1` and `jdbc-4.2` implementations reside in the same Db2 JCC driver and are mutually exclusive. |
| mdb-3.2 | Enables the use of Message-Driven Enterprise JavaBeans written to the EJB 3.2 specification. | |
| jms-2.0 | Enables the configuration of resource adapters to access messaging systems using the Java Message Service API. | "Java Message Service (JMS)" on page 141 |
| servlet-3.1 | Enables support for HTTP Servlets written to the Java Servlet specification. | "Java EE and Liberty applications" on page 116 |
| wasJmsClient-2.0 | Provides applications with access to message queues hosted in Liberty through the JMS API. | "Java Message Service (JMS)" on page 141 |
| wasJmsSecurity-1.0 | Enables an embedded messaging server to authenticate and authorize access from JMS clients. | "Java Message Service (JMS)" on page 141 |
| wasJmsServer-1.0 | Enables an embedded messaging server that is JMS compliant. Applications can send and receive messages using the `wasJmsClient` feature. | "Java Message Service (JMS)" on page 141 |
| webProfile-7.0 | | |

*Table 19. Liberty features supported for Java EE 7 Web Profile*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| appSecurity-2.0 | Provides support for securing the server runtime environment and applications. `appSecurity-2.0` supersedes `appSecurity-1.0`. | Configuring security for a Liberty JVM server |
| beanValidation-1.1 | Provides an annotation-based model for validating JavaBeans. | |
| cdi-1.2 | Provides a common mechanism to inject component such as EJBs or Managed Beans into other components such as JSPs or other EJBs. | |
| ejbLite-3.2 | Enables support for Enterprise JavaBeans written to the EJB Lite subset of the EJB 3.2 specification. | Using EJB-related features |

*Table 19. Liberty features supported for Java EE 7 Web Profile (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| el-3.0 | Enables support for the Expression Language (EL) 3.0 specification. | |
| jaxrs-2.0 | Provides support for the Java API for RESTful Web Services (JAX-RS) in Liberty. | |
| jaxrsClient-2.0 | Enables support for the Java Client API for JAX-RS 2.0. | The jaxrsClient-2.0 feature is enabled by jaxrs-2.0. Configuring JAX-RS 2.0 client. |
| jdbc-4.0 , jdbc-4.1, jdbc-4.2 | Enables the configuration of DataSources to access Databases from applications. | Creating a default CICS Db2 DataSource with type 2 connectivity for Liberty<br>**Note:** The `jdbc-4.0`, `jdbc-4.1` and `jdbc-4.2` implementations reside in the same Db2 JCC driver and are mutually exclusive. |
| jndi-1.0 | Enables the use of Java Naming and Directory Interface (JNDI) to access server configured resources such as DataSources or JMS Connection Factories. | |
| jpa-2.1 | Enables support for applications that use application-managed and container-managed JPA. | |
| jsf-2.2 | Provides support for web applications that use the JavaServer Faces (JSF) framework. | |
| jsonp-1.0 | Provides a standardized method for constructing and manipulating data to be rendered in JavaScript Object Notation (JSON). | |
| jsp-2.3 | Enables support for Java Server Pages (JSPs) that are written to the JSP 2.3 specification. | "Java EE and Liberty applications" on page 116 |
| managedBeans-1.0 | Enables support for the Managed Beans 1.0 specification. | |
| servlet-3.1 | Enables support for HTTP Servlets written to the Java Servlet specification. | "Java EE and Liberty applications" on page 116 |
| webProfile-7.0 | Combines the Liberty features that support the Java EE 7.0 Web Profile | |
| websocket-1.0 | Enables a web browser or client application and a web server application to communicate by using one full duplex connection. | |

Table 19. Liberty features supported for Java EE 7 Web Profile (continued)

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| websocket-1.1 | Enables a web browser or client application and a web server application to communicate by using one full duplex connection. | |

Table 20. Liberty features supported for Java EE 6 Technologies

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| jaxb-2.2 | Provides support to map between Java classes and XML representations. | |
| jaxrs-1.1 | Enables support for the Java Architecture for XML Binding 2.2 specification, which provides easy mapping of Java classes to XML documents. | |
| jaxws-2.2 | Provides support for SOAP web services. | |
| jca-1.6 | Enables the configuration of resource adapters to access Enterprise Information Systems (EIS) from applications. | "Java EE Connector Architecture (JCA)" on page 145<br>**Restriction:** The use of JCICS API and Db2 JDBC type 2 connectivity capabilities are not supported within threads that are created by the JCA API `javax.resource.spi.BootstrapContext.createTimer()`. Instead, for the same effect, use the concurrent APIs (`javax.enterprise.concurrent.ManagedScheduledExecutorService`). |
| jcaInboundSecurity-1.0 | Enables security inflow for resource adapters. Allows JCA inbound resource adapters to flow security contexts by extending the `javax.resource.spi.work.SecurityContext` abstract class. | |
| jdbc-4.0 , jdbc-4.1, jdbc-4.2 | Enables the configuration of DataSources to access Databases from applications. | Creating a default CICS Db2 DataSource with type 2 connectivity for Liberty<br>**Note:** The `jdbc-4.0`, `jdbc-4.1` and `jdbc-4.2` implementations reside in the same Db2 JCC driver and are mutually exclusive. |
| jms-1.1 | Enables the configuration of resource adapters to access messaging systems using the Java Message Service API. | "Java Message Service (JMS)" on page 141 |

*Table 20. Liberty features supported for Java EE 6 Technologies (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| jmsMdb-3.1 | Enables the use of JMS Message-Driven Enterprise JavaBeans. MDBs allow asynchronous processing of messages within a Java EE component. | |
| mdb-3.1 | Enables the use of Message-Driven Enterprise JavaBeans. MDBs allow asynchronous processing of messages within a Java EE component. | |
| wasJmsClient-1.1 | Provides applications with access to message queues hosted in Liberty through the JMS API. | Java Message Service (JMS) |
| wasJmsSecurity-1.0 | Enables an embedded messaging server to authenticate and authorize access from clients. | Java Message Service (JMS) |
| wasJmsServer-1.0 | Enables an embedded messaging server in the server. Applications can operate on messages by using the `wasJmsClient` feature. | Java Message Service (JMS) |

*Table 21. Liberty features supported for Java EE 6 Web Profile*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| appSecurity-2.0 | Provides support for securing the server runtime environment and applications. `appSecurity-2.0` supersedes `appSecurity-1.0`. | **Tip:** The Application Client module runs in both the client and the server. The client executes the client specific logic of the application. The other portion of code runs in a client container on the server and communicates data from the business logic running on the server to the client. For more information, see Preparing and running an application client. |
| beanValidation-1.0 | Provides an annotation-based model for validating JavaBeans. | |
| beanValidation-1.1 | Provides an annotation-based model for validating JavaBeans. | |

*Table 21. Liberty features supported for Java EE 6 Web Profile (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| cdi-1.0 | Provides a mechanism to inject components such as EJBs or Managed Beans into other components such as JSPs or EJBs. | |
| ejbLite-3.1 | Enables support for Enterprise JavaBeans written to the EJB Lite subset of the EJB specification. | Using EJB-related features |
| jdbc-4.0 jdbc-4.1jdbc-4.2 | Enables the configuration of DataSources to access Databases from applications. | Creating a default CICS Db2 DataSource with type 2 connectivity for Liberty<br>**Note:** The `jdbc-4.0`, `jdbc-4.1` and `jdbc-4.2` implementations reside in the same Db2 JCC driver and are mutually exclusive. |
| jndi-1.0 | Provides support for a single Java Naming and Directory Interface (JNDI) entry definition in the server configuration of Liberty. | |
| jpa-2.0 | Enables support for applications that use application-managed and container-managed JPA. | |
| jsf-2.0 | Provides support for web applications that use the JavaServer Faces (JSF) framework. | |
| jsp-2.2 | Enables support for servlet and JavaServer Pages (JSP) applications. | "Java EE and Liberty applications" on page 116 |
| servlet-3.0 | Provides support for HTTP Servlets written to the Java Servlet specification. | "Java EE and Liberty applications" on page 116 |
| managedBeans-1.0 | Enables support for the Managed Beans 1.0 specification. | |
| webProfile-6.0 | Provides a convenient combination of the Liberty features that are required to support the Java EE 6 Web Profile. | |

*Table 22. Liberty features supported for Enterprise OSGi*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| blueprint-1.0 | Enables support for deploying OSGi applications that use the OSGi blueprint container specification. | **Important:** The transaction attribute `NotSupported` is respected by the JTA Liberty transaction system but not the CICS unit of work. |

*Table 22. Liberty features supported for Enterprise OSGi (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| osgi.jpa-1.0 | This feature is superseded by the `blueprint-1.0` and `jpa-2.0` features that both include OSGi capability. When those features are both added to the server, this feature is added automatically. | |
| wab-1.0 | Provides support for web application bundles (WAB) that are inside enterprise bundles (EBA). | "Creating an OSGi Application Project " on page 117<br>**Note:** This feature is automatically added by CICS when the JVM system property `com.ibm.cics.jvmserver.wlp.wab=true`. |

*Table 23. Liberty features supported for Extended Programming Models*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| json-1.0 | Provides access to the JavaScript Object Notation (JSON4J) library that provides a set of JSON handling classes for Java environments.<br>**Note:** If upgrading from jaxrs-2.0 to jaxrs-2.1 the json-1.0 feature is no longer enabled by default. | |
| jta-1.1 | Supports the Java Transaction API (JTA).<br>**Note:** Java Transaction API is a protected Liberty feature. | "Java Transaction API (JTA) " on page 130 |
| jta-1.2 | Supports the Java Transaction API (JTA).<br>**Note:** Java Transaction API is a protected Liberty feature. | "Java Transaction API (JTA) " on page 130 |
| mongodb-2.0 | Provides support for the MongoDB Java Driver and allows remote database instances to be configured in the server configuration. Applications interact with these databases through the MongoDB APIs. | |
| springBoot-1.5 | Provides support for Spring Boot applications using Spring Boot version 1.5.x. | Spring Boot applications |
| springBoot-2.0 | Provides support for Spring Boot applications using Spring Boot version 2.0.x. | Spring Boot applications |

*Table 24. Liberty features supported for MicroProfile*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| microProfile-1.0 | Combines the Liberty features that support the MicroProfile for enterprise Java. | These versions of MicroProfile are for use with Java EE 6 and Java EE 7. |
| microProfile-1.2 | Combines the Liberty features that support MicroProfile 1.2 for enterprise Java. | |
| microProfile-1.3 | Combines the Liberty features that support MicroProfile 1.3 for enterprise Java. | |
| microProfile-1.4 | Combines the Liberty features that support MicroProfile 1.4 for enterprise Java. | |
| microProfile-2.0 | Combines the Liberty features that support MicroProfile 2.0 for enterprise Java. | |
| microProfile-2.1 | Combines the Liberty features that support MicroProfile 2.1 for enterprise Java. | |
| microProfile-2.2 | Combines the Liberty features that support MicroProfile 2.2 for enterprise Java. | |
| microProfile-3.0 | Combines the Liberty features that support MicroProfile 3.0 for enterprise Java. | |
| microProfile-3.2 | Combines the Liberty features that support MicroProfile 3.2 for enterprise Java. | |
| microProfile-4.0 | Combines the Liberty features that support MicroProfile 4.0 for enterprise Java. | These versions of MicroProfile are for use with Java EE 8 or Jakarta EE 8. |
| microProfile-4.1 | Combines the Liberty features that support MicroProfile 4.1 for enterprise Java. | |
| mpConfig-1.1 | Provides a unified mechanism to access configuration, providing a single view of multiple sources. | |
| mpFaultTolerance-1.0 | Provides support for the MicroProfile Fault Tolerance API for enterprise Java. | **Restriction:** MicroProfile Fault Tolerance 1.0 is not designed to work with transactions (UOW, JTA, etc.). Updates to CICS resources should not be made in methods annotated @Bulkhead, @CircuitBreaker, @Fallback, @Retry or @Timeout. |

*Table 24. Liberty features supported for MicroProfile (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| mpHealth-1.0 | Provides support for the MicroProfile Health API for enterprise Java. | |
| mpJwt-1.0 | Enables web applications or microservices to use JSON Web Token (JWT) to authenticate users instead of, or in addition to, the configured user registry. | The default value for attribute `ignoreApplicationAuthMethod` is false. This indicates all requests received by Liberty need to have a JWT token in the HTTP header.<br>The default value for attribute `mapToUserRegistry` is false. For integration with CICS security set this value to true. |
| mpMetrics-1.0 | Provides support for the MicroProfile Metrics API for enterprise Java. | |

*Table 25. Liberty features supported for Operations*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| batchManagement-1.0 | Provides managed batch support for the Java batch container. This includes the Batch REST management interface, job logging support, and a command line utility for external scheduler integration. | |
| distributedMap-1.0 | Provides a local cache service, which can be accessed through the `DistributedMap` API. | |
| localConnector-1.0 | Allows the use of a local JMX connector that is built into the JVM to access JMX resources in the server. | " Java Management Extensions API (JMX) " on page 142 |
| monitor-1.0 | Enables performance monitoring of Liberty runtime components by using a JMX client. | " Java Management Extensions API (JMX) " on page 142 |
| osgiConsole-1.0 | Enables an OSGi console to aid with debug of the runtime. | Troubleshooting Java applications |
| restConnector-1.0 | Enables remote access by JMX clients through a REST-based connector and requires SSL and user security configuration. | " Java Management Extensions API (JMX) " on page 142 |
| sessionDatabase-1.0 | Enables persistence of HTTP sessions to a datasource that uses JDBC. | |

*Table 25. Liberty features supported for Operations (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| webCache-1.0 | Enables local caching for web responses. It includes the `distributedMap` feature and performs automatic caching of web application responses to improve response times and throughput. | |
| wmqJmsClient-2.0 | Provides applications with access to message queues hosted on IBM MQ through the `JMS 2.0` API. | **Restriction:** Only supported when the JMS application connects to IBM MQ using the client mode transport. Requires V9.0.1 of the IBM MQ Resource Adapter for Liberty.<br>**Important:** This restriction also applies to CICS standard-mode Liberty. |

*Table 26. Liberty features supported for Security*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| appSecurity-1.0 | Provides support for securing the server runtime environment and applications. `appSecurity-2.0` supercedes `appSecurity-1.0`. | Configuring security for a Liberty JVM server |
| appSecurity-2.0 | Provides support for securing the server runtime environment and applications. `appSecurity-2.0` supersedes `appSecurity-1.0`. | Configuring security for a Liberty JVM server |
| jwt-1.0 | Allows runtime to create JWT tokens. | |
| ldapRegistry-3.0 | Enables support for using an LDAP server as a user registry. Any server that supports LDAP Version 3.0 can be used. Multiple LDAP registries can be configured, and then federated to achieve a single logical registry view. | Configuring security for a Liberty JVM server by using distributed identity mapping |
| oauth-2.0 | Enables web applications to integrate OAuth 2.0 for authenticating and authorizing users. | Authorization using OAuth 2.0<br>Configuring persistent OAuth 2.0 services |
| openidConnectClient-1.0 | Enables web applications to integrate OpenID Connect Client 1.0 for authenticating users instead of, or in addition to, the configured user registry. | |

*Table 26. Liberty features supported for Security (continued)*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| openidConnectServer-1.0 | Enables web applications to integrate OpenID Connect Server 1.0 for authenticating users instead of, or in addition to, the configured user registry. | |
| ssl-1.0 | Provides support for Secure Sockets Layer (SSL) connections and SAF keyrings. | Configuring SSL (TLS) for a Liberty JVM server using RACF<br>Setting up SSL (TLS) client certificate authentication in a Liberty JVM server<br>Configuring SSL (TLS) for a Liberty JVM server using a Java keystore |
| transportSecurity-1.0 | Enables support for Secure Sockets Layer (SSL) connections. | |

*Table 27. Liberty features supported for Systems Management*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| adminCenter-1.0 | Enables the Liberty Admin Center, a web-based graphical interface for deploying, monitoring and managing Liberty servers in standalone environments. | Configuring Admin Center<br>**Restriction:** Collectives are not supported in CICS. |

*Table 28. Liberty features supported for z/OS*

| Liberty feature | Liberty feature description | Using this feature in CICS |
|---|---|---|
| zosSecurity-1.0 | enables the server to use the SAF Registry in the z/OS platform for authenticating users and authorizing access to applications | **Restriction:** zosSecurity-1.0 is enabled by cicsts:security-1.0 |
| zosTransaction-1.0 | Enables Liberty to synchronize and manage transactional activity between the z/OS Resource Recovery Services (RRS), the transaction manager of the application server, and the resource manager. | **Restriction:** `zosTransaction-1.0` is only supported for JMS applications that connect to IBM MQ using BINDINGS mode transport in CICS standard-mode Liberty. |

For more information about the function in these features, see the documentation for Liberty at Liberty overview. For details of Liberty restrictions, see Runtime environment known restrictions.

## CICS Liberty features

The following table provides a set of CICS features to integrate Liberty features with the CICS qualities of service. The Liberty JVM server mode can be set by specifying CICS_WLP_MODE in the JVM profile.

*Table 29. CICS Liberty features*

| CICS Feature | CICS Liberty mode | Description | Using this CICS feature |
|---|---|---|---|
| cicsts:core-1.0 | Integrated-mode | Provides core CICS features, and Java Transaction API (JTA) 1.0. | This feature is required when using Integrated-mode CICS Liberty.<br>**Restriction:** The JVM server should be disabled before adding or removing this feature. |
| cicsts:defaultApp-1.0 | Integrated-mode and standard-mode | Verifies that the Liberty server is running and provides information on the server configuration. Browse the JVM Profile, the JVM server logs, the Liberty server.xml, and the messages log by using the FileViewer servlet. | Configuring the CICS Default Web Application |
| cicsts:distributedIdentity-1.0 | Integrated-mode and standard-mode | Provides support for distributed identity mapping. | Configuring security for a Liberty JVM server by using distributed identity mapping |
| cicsts:jcaLocalEci-1.0 | Integrated-mode | Provides a locally optimized JCA ECI resource adapter for calling CICS programs. | "Using the JCA local ECI resource adapter" on page 147<br>**Restriction:** The JVM server should be disabled before adding or removing this feature. |
| cicsts:jcicsxServer-1.0 | Integrated-mode | When enabled in a Liberty JVM server in CICS, the server can receive remote requests from Java applications using JCICSX API classes. | "Configuring the environment for JCICSX" on page 88 |
| cicsts:jdbc-1.0 | Integrated-mode and standard-mode | Provides support for applications to access a local CICS Db2 database that uses JDBC. This feature has been superseded by jdbc-4.0 and jdbc-4.1, except when used directly with DriverManager. | Acquiring a connection to a database<br>**Restriction:** The JVM server should be disabled before adding or removing this feature. |

*Table 29. CICS Liberty features (continued)*

| CICS Feature | CICS Liberty mode | Description | Using this CICS feature |
|---|---|---|---|
| cicsts:link-1.0 | Integrated-mode | Provides support to start a Java EE application that is running in a Liberty JVM server either as the initial program of a CICS transaction or by using the **LINK**, **START**, or **START CHANNEL** commands from any CICS program. | "Linking to Java applications in a Liberty JVM server by using the @CICSProgram annotation" on page 122 |
| cicsts:security-1.0 | Integrated-mode and standard-mode | Provides integration of Liberty security with CICS security, including propagation of thread identity. | Configuring security for a Liberty JVM server<br>**Restriction:** The JVM server should be disabled before adding or removing this feature. |
| cicsts:standard-1.0 | Standard-mode | Enables users to port and deploy Liberty applications from other platforms to CICS without changing your application. Standard mode is ideal for hosting applications that are written for and rely on the Java EE Full Platform, but do not require full integration with CICS. | CICS standard-mode Liberty: Java EE 7 Full Platform support without full CICS integration |
| cicsts:zosConnect-1.0 | Integrated-mode | Integrates z/OS Connect with CICS Liberty JVM server. | **Note:** This feature is stabilized. You can continue to use the feature. However, consider using the IBM z/OS Connect Enterprise Edition product.<br>**Restriction:** The JVM server should be disabled before adding or removing this feature. |
| cicsts:zosConnect-2.0 | Integrated-mode | Integrates z/OS Connect with CICS Liberty JVM server. | **Note:** This feature is stabilized. You can continue to use the feature. However, consider using the IBM z/OS Connect Enterprise Edition product.<br>**Restriction:** The JVM server should be disabled before adding or removing this feature. |

# Java EE and Liberty applications

To provide modern interfaces to CICS applications, you can develop a presentation layer that uses web application technology. You can use the IBM CICS SDK for Java in CICS Explorer or the CICS-provided artifacts on Maven Central to create, package, and build the applications. The IBM CICS SDK for Enterprise Java (Liberty), which is optionally installed with CICS Explorer, also provides support to deploy the application to run in CICS.

### About this task

Three types of web application projects can be deployed on a Liberty server:

- Dynamic Web Project (WAR)
- OSGi Application Project (EBA)
- Enterprise Application Project (EAR)

A WAR can contain dynamic Java EE resources such as Liberty in CICS, filters, and associated metadata, in addition to static resources such as images and HTML files.

An EBA is a Java archive file that can contain WABs and OSGi bundles. WABs are web-enabled OSGi bundles that contain JSP servlets and files, filters, and associated metadata, in addition to static resources such as images and HTML files.

An EAR is a way of organizing WAR and EJB modules into a single container in the same way as an EBA organizes WABs and OSGi bundles.

## Creating a Dynamic Web Project

To develop a web presentation layer for your Java application, you can create a Dynamic Web Project.

### Before you begin

Ensure that you have set up the development environment.

A restriction added by Liberty, prevents access to OSGi bundles from servlets that are deployed in a WAR file. The restriction includes access to OSGi bundles installed directly in a CICS bundle. To overcome this restriction, you must deploy your application as a WAB, as part of an EBA (OSGi Application Project). An EBA is a container in which web and OSGi components can interact.

### About this task

If you are using the IBM CICS SDK for Java or IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer (as shown in the following instructions) or IBM Developer for z/OS (IDz), you can refer to the CICS Explorer help, which provides full details on how you can complete each of the following steps to develop and package web applications.

If you are using a build toolchain such as Apache Maven or Gradle, you can use CICS-provided artifacts on Maven Central to define Java dependencies.

### Procedure

1. Create a web project for your application.
   - CICS Explorer If you're using CICS Explorer, create a Dynamic Web Project and update your build path to add the Liberty libraries.
     a. Right-click the Dynamic Web Project, and click **Build Path** > **Configure Build Path**. The properties dialog opens for the project.
     b. In the Java Build Path, click the **Libraries** tab.
     c. Click **Add Library** and select **CICS with Enterprise Java and Liberty**.
     d. Click **Next**, select the CICS version, and then click **Finish** to complete adding the library.

e. Click **OK** to save your changes.

- Gradle For Gradle users, create a Gradle project. In the `build.gradle` file, specify the following and declare dependencies on CICS-provided artifacts.

  ```
  plugins {
      id 'war'
  }
  ```

- Maven For Maven users, create a Maven project. In the `pom.xml` file, specify `<packaging>war</packaging>` and declare dependencies on CICS-provided artifacts. If you are unfamiliar with Maven, you can start with the maven-archetype-webapp archetype and modify it.

2. Develop your web application. You can use the JCICS API to access CICS services, JDBC to access DB2 and JMS to access IBM MQ. The IBM CICS SDK for Enterprise Java (Liberty) includes examples of web components that use JCICS and JDBC.
3. Optional: If you want to secure the application with CICS security, create a `web.xml` file in the Dynamic Web Project to contain a CICS security constraint. The IBM CICS SDK for Enterprise Java (Liberty) includes a template for this file that contains the correct information for CICS. See Authenticating users in a Liberty JVM server for further information.
4. Create one or more CICS bundle projects to package your application. Add definitions and imports for CICS resources. Each CICS bundle contains an ID and version so you can manage changes in a granular way.
5. Optional: Add a URIMAP and TRANSACTION resource to a CICS bundle if you want to map inbound web requests from a URI to run under a specific transaction. If you do not define these resources, all work runs under a supplied transaction, which is called CJSA. These resources are installed dynamically and managed as part of the bundle in CICS.

### Results

You set up your development environment, created a web application from a Dynamic Web Project, and packaged it for deployment.

### What to do next

When you are ready to deploy your application, export the CICS bundle projects to zFS. The referenced projects are built and included in the transfer to zFS. Alternatively, you can follow the Liberty deployment model by exporting the application as a WAR and deploying it to the dropins directory of a running Liberty JVM server.

## Creating an OSGi Application Project

An OSGi Application Project (EBA) groups together a set of bundles. The application can consist of different OSGi bundles types.

### Before you begin

Ensure that you have set up the development environment.

**Note:** To develop and build an OSGi Application Project, you must install the IBM CICS SDK for Enterprise Java (Liberty) and the Liberty Developer Tools (LDT) if you are using CICS Explorer on Eclipse Marketplace. If you want to export the bundle without building it, you can add the built project to the root of your CICS bundle directly. Otherwise, you might receive a validation or exporting failure error. See CICS Explorer cannot export a bundle in Troubleshooting Liberty JVM servers and Java web applications.

### About this task

If you are using the IBM CICS SDK for Java or IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer (as shown in the following instructions) or IBM Developer for z/OS (IDz), you can refer to the CICS Explorer help, which provides full details on how you can complete each of the following steps to develop and package OSGi applications.

If you are using a build toolchain such as Apache Maven or Gradle, you can use CICS-provided artifacts on Maven Central to define Java dependencies.

## Procedure

1. CICS Explorer If you're using CICS Explorer, set up a target platform for your Java development, using the CICS TS 5.6 **with Enterprise Java and Liberty** template. You might get a warning that the target is a newer version than the current Eclipse installation, but you can ignore this warning message.
2. Create an OSGi Bundle Project for your application.
   - CICS Explorer If you're using CICS Explorer, the target platform effectively makes the packages available, so you must include the appropriate Import statements in the bundle manifest. A web-enabled OSGi Bundle Project is the bundle equivalent of a Dynamic Web Project. You can use a web-enabled OSGi Bundle Project to deploy an application within an OSGi Application Project (an Enterprise Bundle Archive, or EBA file). You can mix web-enabled OSGi Bundle Projects (WAB files) and non-web-enabled OSGi Bundle Projects in your OSGi Application Project. A web-enabled OSGi Bundle Project would typically implement the front end of the application, and interact with the non-web OSGi bundles, which contain the business logic.

     **Restriction:** EBA files are not supported in Java EE 8 and upwards.
   - Gradle For Gradle users, create a Gradle-enabled OSGi project using the BND Gradle Plugins, and then declare dependencies on CICS-provided artifacts.
   - Maven For Maven users, create a Maven project. In the `pom.xml` file, specify `<packaging>bundle</packaging>` and the following dependency:

     ```
     <dependency>
       <groupId>net.wasdev.maven.tools.targets</groupId>
       <artifactId>liberty-target</artifactId>
       <version><your_liberty_version></version>
       <type>pom</type>
       <scope>provided</scope>
     </dependency>
     ```

     Instead of specifying the dependency above, you can start with an OSGi bundle archetype, for example, the osgi-web31-liberty artifact, and modify it. Then declare dependencies on CICS-provided artifacts.
3. Develop your web application. You can use the JCICS API to access CICS services and JDBC to connect to Db2. The IBM CICS SDK for Java includes examples of web components and OSGi bundles that use JCICS and Db2. Create OSGi bundles that use JCICS to separate the business from the presentation logic. You can also use semantic versioning in OSGi bundles to manage updates to the business logic of the application. For each WAB or OSGi bundle that uses Db2 through the JDBC DriverManager interface, include an Import-Package header for `com.ibm.db2.jcc` in the bundle manifest. Omitting this import will result in the error message `java.sql.SQLException: No suitable driver found for jdbc:default:connection`. The import is not required when using the JDBC DataSource interface.
4. Optional: If you want to authenticate users of the web application, create a `web.xml` file in the web project to contain a security constraint. The IBM CICS SDK for Java includes a template for this file that contains the correct information for CICS. See Authenticating users in a Liberty JVM server for further information.
5. Create an OSGi Application Project that references your OSGi bundles.
6. Create a CICS bundle project that references the OSGi Application Project. You can also add definitions and imports for CICS resources. Each CICS bundle contains an ID and version so you can manage changes in a granular way.
7. Optional: Add a URIMAP and TRANSACTION resource to a CICS bundle if you want to map inbound web requests from a URI to run under a specific transaction. If you do not define these resources, all work runs under a supplied transaction, which is called CJSA. These resources are installed dynamically and managed as part of the bundle in CICS.

### Results

You set up your development environment, created a OSGi web application, and packaged it for deployment.

### What to do next

When you are ready to deploy your application, export the CICS bundle projects to zFS. The referenced projects are built and included in the transfer to zFS. Alternatively, you can follow a development deployment model by exporting the application as an EBA file and deploying it to the dropins directory of a running Liberty JVM server. You should be aware that Security and other qualities of service are not configurable using dropins.

## Creating an Enterprise Application Project

To develop components such as an Enterprise Java Bean module (EJB module) or to group web projects, EJBs, or both together, you can use an Enterprise Application Project.

### Before you begin

Ensure that the web development tools are installed in your Eclipse IDE. For more information, see "Setting up your development environment" on page 38.

### About this task

If you are using the IBM CICS SDK for Java or IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer (as shown in the following instructions) or IBM Developer for z/OS (IDz), you can refer to the CICS Explorer help, which provides full details on how you can complete each of the following steps to develop and package Enterprise Applications.

If you are using a build toolchain such as Apache Maven or Gradle, you can use CICS-provided artifacts on Maven Central to define Java dependencies.

### Procedure

1. Create a project for your application.

   - CICS Explorer If you're using CICS Explorer, create an Enterprise Application Project.
   - Maven For Maven users, create a Maven project. In the `pom.xml` file, specify `<packaging>ear</packaging>` and declare dependencies on CICS-provided artifacts.
   - Gradle For Gradle users, create a Gradle project. In the `build.gradle` file, specify the following and declare dependencies on CICS-provided artifacts.

   ```
   plugins {
       id 'ear'
   }
   ```

2. Develop the components of your application. These components are typically EJB modules and Dynamic Web Projects. Add the components to your Enterprise Application Project.

   For more information, see Creating an Enterprise JavaBeans (EJB) project.

3. Create one or more CICS bundle projects to package your Enterprise Application. Add definitions and imports for CICS resources. Every CICS bundle contains an ID and version so you can manage changes in a granular way.

4. Optional: Add a URIMAP and TRANSACTION resource to a CICS bundle if you want to map inbound web requests from a URI to run under a specific transaction. If you do not define these resources, all work runs under a supplied transaction, which is called CJSA. These resources are installed dynamically and managed as part of the bundle in CICS.

### Results

You set up your development environment, created an Enterprise Application Project, and packaged it for deployment.

### What to do next

When you are ready to deploy your application, export the CICS bundle projects to zFS. The referenced projects are built and included in the transfer to zFS. Alternatively, you can follow the Liberty deployment model by exporting the application as a EAR and deploying it with an `<application>` element, or placing it in the drop-ins directory of a running Liberty JVM server.

## Creating a URI map and transaction

You can install applications resources through traditional methods such as CSD or BAS, or you can add application resources to CICS bundles. CICS bundles provide a convenient and co-located technique to group application code and CICS resources together. This is useful if, for example, you deploy an Enterprise Java application in a CICS bundle. You might want to provide a URI map that maps the inbound web requests to run under a specific application transaction.

### Before you begin

To create the application resources, you must have a CICS bundle project in your Project Explorer. For more information, see Creating a CICS bundle project in the CICS Explorer product documentation. You use this CICS bundle project to package the application for deployment.

### About this task

By default all Enterprise Java application requests use a transaction that is called CJSA that is supplied by CICS. However, you can map the application URI from an inbound request to a different transaction. You might find this feature useful if you want to securely control access to the application because a security administrator can configure CICS to control which transactions are accessed by users.

### Procedure

1. Create a definition for the application transaction:
   a) Switch to the Eclipse Resource perspective. Right-click the CICS bundle project and click **New** > **Transaction Definition**.

      The New Transaction Definition wizard opens.

   b) Enter a 4-character name for the transaction.

      Do not start the transaction name with C because this letter is reserved by CICS.

   c) Enter the program name `DFHSJTHP`.

      You must use this CICS program because it handles the security checking of inbound Enterprise Java requests to the Liberty server.

   d) Click **Finish** to create the definition in the CICS bundle project.

   Do not set attributes to create a remote transaction because the application transaction must always run in the CICS region where the Enterprise Java application is running.

2. Create a definition for the URI map:
   a) Right-click the CICS bundle project and click **New** > **URI Map Definition**.

   b) Enter an 8-character name for the URI map.

      Do not start URI maps names with DFH because this prefix is reserved by CICS.

   c) Enter the host name.

      You can either use a `*` to match any host name, or specify the host name of the machine where your application is going to run.

   d) Enter the path for the application URI.

   CICS matches the URI in the inbound request to the value in the URI map and runs the application transaction.

   e) In the Usage section, select **JVM server** and optionally enter the port number.

   f) Click **Finish** to create the URI map.

3. Edit the URI map definition:

   a) Edit the Scheme field to enter the scheme for the URI map. HTTP is the default, but you can set HTTPS if you want to use SSL security to encrypt the request.

      You can use basic authentication, where a user ID and password are supplied in the HTTP header, on both HTTP and HTTPS requests.

   b) Edit the Transaction field to enter the name of the application transaction.

   c) Optional: Edit the user ID field to enter a user ID to run the application request.

      This value is ignored if basic authentication is enabled. If you do not supply a value and the HTTP request does not include a user ID and password, CICS runs the request under the default user ID of the CICS region.

### Results

You created a URI map and a transaction in the CICS bundle project. When the bundle is deployed and installed, these resources are created dynamically in the CICS region.

### What to do next

You can create extra resources if you want to run different application operations under different transactions, or if you want to support both HTTP and HTTPS schemes. If your application is ready to deploy, see Deploying a CICS bundle in the CICS Explorer product documentation.

## Migrating Java EE applications to run in Liberty JVM server

If you have a Java EE application running in a Liberty instance that accesses CICS over a network, you can run the application in a Liberty JVM server to optimize performance.

### About this task

CICS supports a subset of the features that are available in Liberty. For a list of supported features in CICS integrated-mode Liberty, see “Liberty features” on page 95.

If your application uses security, you can continue to use Liberty security features however without further action it is possible that the CICS task will run under transaction CJSA, URIMAP matching in CICS will not be available and any resource access will be performed under the CICS default user ID. To better integrate your security solution with CICS, allowing your CICS tasks to run under the same user ID as determined by Liberty, see Authenticating users in a Liberty JVM server.

### Procedure

1. Update the application to use the JCICS API to access CICS services directly, ensuring that the correct JCICS encoding is used when the application passes data to and from CICS.

   For more information about encoding, see “Data encoding” on page 58. This step only applies if you are using CICS integrated-mode Liberty or CICS standard-mode Liberty with the `runAsCICS()` API.

2. If you want to use CICS security for basic authentication, update the security constraint in the `web.xml` file of the Dynamic Web Project to use a CICS role for authentication. This step only applies if you are using CICS integrated-mode Liberty or CICS standard-mode Liberty and submitting work to the `CICSExecutorService` using the `runAsCICS()` method.

   ```
   <auth-constraint>
       <description>All authenticated users of my application</description>
       <role-name>cicsAllAuthenticated</role-name>
   </auth-constraint>
   ```

3. Package the application as a WAR (Dynamic Web Project), an EBA (OSGi Application Project) file or an EAR (Enterprise Application Archive) file, in a CICS bundle.

   **Restriction:** EBA files are not supported in Java EE 8 and upwards.

   CICS bundles are a unit of deployment for an application. All CICS resources in the bundle are dynamically installed and managed together. Create CICS bundle projects for application components that you want to manage together.
4. Deploy the CICS bundle projects to zFS and install the CICS bundles in the Liberty JVM server.

### Results

The application is running in a JVM server.

## Linking to Java applications in a Liberty JVM server by using the `@CICSProgram` annotation

By adding the `@CICSProgram` annotation to your Java programs, you allow CICS programs to link to Enterprise Java or Spring Boot applications running in a Liberty JVM server using the CICS **`LINK`** command. The syntax also supports using the Java program as the initial program of a CICS 3270 transaction, or as the target of a **`START`**, or **`START CHANNEL`** or **`RUN TRANSID`** command.

To be linked to by a CICS program, an Enterprise Java application needs to be a plain Java object (POJO) packaged in a Web ARchive (WAR) or Enterprise Application Archive (EAR). A Spring Boot application can be packaged in a WAR or a Java Archive (JAR). You cannot link to an EJB, a CDI bean, or an OSGi application (EBA). Dependency injection in the POJO is not supported, including injecting EJBs using `@EJB`. Instead, you can use a JNDI lookup to obtain a reference to a resource such as an EJB. This information applies to CICS integrated-mode Liberty only. In a Spring Boot application, injection using an annotation such as `@Autowired` is fully supported.

There are three main reasons for linking to a Java application from a CICS program:

- Java code is part of an existing web application and you want to link it to a CICS application. You only need to maintain a single piece of logic and your code can access CICS resources by using JCICS APIs.
- You want to write a new piece of function in Java as part of your CICS application. For example, you might want to use third party libraries or APIs that already exist in Java.
- You want to re-implement existing COBOL applications in Java. For example, you might want to reduce the cost of maintenance and make the most of your Java skills, or you might want your applications to be eligible to run on specialty engines rather than general processors.

When you link to a Java application from a CICS program, CICS sends a message to a JCA resource adapter running inside Liberty. The JCA resource adapter links to the target Java application on the same CICS task as the calling program. The Java application runs under the same unit-of-work (UOW) as the calling program, so any updates made to recoverable CICS resources are committed or backed out when the transaction ends. However, when the Java application is invoked, there is no JTA transaction context. If the application starts a JTA transaction, a syncpoint is performed to commit the CICS UOW, and create a new one. This also occurs if a JTA transaction is started by the container on behalf of the application, for example if the application calls an EJB with the `REQUIRED` transaction attribute.

As best practice, the code that is linked by the CICS program must be part of your application's business logic (rather than presentation logic). For example, it would not make sense to link a servlet from a CICS program because no HTTP request is involved.

### Configuring a Liberty JVM server to link from CICS programs to Enterprise Java or Spring Boot applications

To configure your Liberty JVM server to support linking to Enterprise Java or Spring Boot applications, add the `cicsts:link-1.0` feature to `server.xml`. Ensure that you add the feature before deploying the Java applications.

## Security

When you link to an Enterprise Java or a Spring Boot application from a CICS program, the Java application runs under the same CICS security context as the calling task. This means that the user ID of the calling CICS task is used to authorize access to any resources accessed by using the JCICS API from the application. Web security authentication mechanisms such as `<auth-constraint>` rules in the `web.xml` do not apply in this situation.

In addition to the CICS task user ID, Liberty also creates a Java security Subject for the linked to application. This Subject can be used for Java security role authorization on called components such as EJB session beans by using the `@RolesAllowed` annotation. This Subject is set to the same user ID as the CICS task user ID when the `cicsts:security-1.0` feature is present in your `server.xml`. Liberty does not authenticate the Subject user ID. Liberty checks that the user ID is present in the Liberty security registry, and then asserts the CICS task user ID as the Subject user ID. For more information, see The Java EE Tutorial.

If you exclude the `cicsts:security-1.0` feature from your `server.xml`, the Java application is linked to with the Liberty unauthenticated user ID, which by default is `WSGUEST`.

If you are not using a SAF registry for the Liberty server, but the task user ID is present in the non-SAF Liberty registry, then the task user ID is still passed to the application. If the task user ID is not present in the non-SAF Liberty registry, the Java application is linked to with the Liberty unauthenticated user ID.

If your Liberty server requires that the `cicsts:security-1.0` is configured for Web application security, but the linked to Java application does not perform Java security role authorization, setting the Java system property `com.ibm.cics.jvmserver.wlp.security.subject.create=false` is recommended. This improves performance by ensuring that the assertion of the CICS task user ID as the Java Subject is not attempted.

When you link to Spring Boot applications from a CICS program, the CICS user ID is not passed to Spring security by default. Spring Boot offers configuration and programmatic options to achieve this. For more information, see Spring Boot Java applications for CICS, Part 2: Security, and Configuring security for a Liberty JVM server.

# Preparing Java applications in a Liberty JVM server to be called by a CICS program

You can use the `@CICSProgram` annotation to enable a Java method to be called by a CICS application. CICS creates the PROGRAM resource for you. The application runs in a Liberty JVM server. Spring Boot applications can be deployed in a WAR or JAR. Enterprise Java applications can be deployed in a WAR or EAR.

## Before you begin

Identify which Java class and method you want to call. Then, while adhering to site standards and CICS naming rules, determine a suitable CICS program name.

Ensure that the Liberty JVM server is configured to enable linking to the type of application that you require. For more information, see Linking to Java applications in a Liberty JVM server by using the @CICSProgram annotation.

**Note:** To avoid concurrency issues, JCICS fields should be defined within the link-target method, or a subsequent prototype-scoped Bean, and not on the linked-to component class.

## Procedure

1. Add the `@CICSProgram` annotation class to the classpath of your Web Project.
    - CICS Explorer If you are using the preinstalled **IBM CICS SDK for Java** in CICS Explorer, the SDK includes the Liberty JVM server libraries, which provide the `@CICSProgram` annotation. Add the **CICS with Enterprise Java and Liberty** library to your Java project by right-clicking the project and configuring the Build Path. This will also provide the CICS annotation processor dependency. For

detailed instructions on configuring the Build Path, see Step 1 in “Creating a Dynamic Web Project” on page 116.

- GradleMaven If you're using your own build toolchain, you need to declare dependency on the `com.ibm.cics.server.invocation.annotations` artifact that's available on Maven Central or use the `com.ibm.cics.server.invocation.annotations.jar` file. For more information, see “Managing Java dependencies using Gradle or Maven” on page 46 and “Manually importing Java libraries” on page 54.

2. Create a class to contain the methods that CICS calls.

   Creating a class is good practice because it keeps the CICS specific code separate from the rest of your application.

3. Create a method for each CICS PROGRAM resource to be created.
4. Annotate each method with the `@CICSProgram` annotation, giving it a parameter of the PROGRAM name, such as `@CICSProgram("PROGNAME")`.

   CICS PROGRAM names:

   - Must be 1 - 8 characters;
   - Must match the pattern `A-Z a-z 0-9 $ @ #`.

   Example of a simple class with a single method, annotated with the `@CICSProgram` annotation:

```
public class CustomerLinkTarget
{
    @CICSProgram("CUSTGET")
    public void getCustomer()
    {
        // do work here
    }
}
```

5. Enable annotation processing for the Web Project.

   - CICS Explorer If you are using **CICS Explorer**, either:
     - Hover over a `@CICSProgram` annotation with a warning underline and use the quick-fix to enable annotation processing, or:
     - Right-click the Web Project and select **Properties**. Search for the **Annotation Processing** page. Check both **Enable project-specific settings** and **Enable annotation processing**.
   - GradleMaven If you're using a build toolchain such as Gradle or Maven, configure the Java compiler to use `com.ibm.cics.server.invocation` as an annotation processor, as described in Managing Java dependencies using Maven or Gradle.

6. Validate the annotation is correctly specified.

   - CICS Explorer If you are using CICS Explorer, validation happens automatically to ensure that your annotation is correctly positioned and that the method that it annotates and the containing class fulfills the following requirements.
   - Maven If you're using Maven in Eclipse, you can use the m2e-apt plugin to get the annotation processing configured in Eclipse based on the dependencies specified in your `pom.xml` file.

   The annotation:

   - Must be on a method;
   - Must have a value attribute of a PROGRAM name.

   The method:

   - Must be concrete (not abstract);
   - Must be public;
   - Must have no arguments;
   - Must be declared `void`.

The class:

- Must have a constructor with no arguments (implicit or explicit), unless all annotated methods are static;
- Must be top level (not nested or anonymous);
- Must not have more than one method that is annotated with the same PROGRAM name.

7. Write the content of the annotated method. The content is likely to involve the following stages:

   a) Obtain containers from the channel;

   b) Obtain input data from containers in a channel;

   c) Use data mapping code to convert the input data to Java objects;

   d) Call the application business logic;

   e) Use data mapping code to convert the resulting Java objects to output data;

   f) Place the output data in containers in a channel.

   Example of a class with a single method, annotated with the @CICSProgram annotation, and code to take input data from a container and put output data to a container:

```
public class CustomerLinkTarget
{
    @CICSProgram("CUSTGET")
    public void getCustomer()
    {
        Channel currentChannel = Task.getTask().getCurrentChannel();
        Container dataContainer = currentChannel.getContainer("DATA");

        // do work here

        Container resultContainer = currentChannel.createContainer("RESULT");
        byte[] results = null; // change this to be the result of the work
        resultContainer.put(results);
    }
}
```

8. Build the application.

   - CICS Explorer If you are in CICS Explorer, you can right-click the Web Project and select **Export** > **WAR file**, or right-click a containing CICS Bundle Project and select **Export Bundle to z/OS UNIX file system**.
   - If you are using the CICS build toolkit, the annotation processor is invoked automatically.
   - GradleMaven If you are building the Java code by using other tools, ensure that the dependency on the CICS annotation and the annotation processor configuration are correctly specified by using the artifacts on Maven Central. If you've done that in Steps "1" on page 123 and "5" on page 124, they are resolved automatically during build. Otherwise, you must ensure the com.ibm.cics.server.invocation.annotations.jar JAR file (which defines the @CICSProgram annotation) is on the classpath of the Java compiler. Also, ensure that the com.ibm.cics.server.invocation.jar JAR file (containing the annotation processor) is on the classpath of the Java compiler, or is otherwise specified in the **-processorpath** option. You can find both JAR files in the *usshome* /lib directory on z/OS UNIX , where *usshome* is the value of the **USSHOME** system initialization parameter.
   - If you are using tools other than Gradle or Maven, you must ensure that the com.ibm.cics.server.invocation.annotations.jar JAR file (which defines the @CICSProgram annotation) is on the classpath of the Java compiler. Ensure that the com.ibm.cics.server.invocation.jar JAR file (containing the annotation processor) is on the classpath of the Java compiler or is otherwise specified in the -processorpath option. You can find both JAR files in the usshome/lib directory on z/OS UNIX, where usshome is the value of the USSHOME system initialization parameter.
   - If the class is packaged in a library JAR inside the WEB-INF/lib directory of a WAR file, export the generated metadata when you are building the JAR. CICS Explorer In CICS Explorer , you can do this by adding the library project to the deployment assembly of the Dynamic Web Project. From the properties dialog for the Dynamic Web Project, choose the Deployment Assembly page, click the **Add**

button, and select the library project. CICS does not support `@CICSProgram` annotations on classes that are packaged in a utility JAR within an EAR file.

**Note:** The CICS annotation processor generates additional classes and XML files within the `com.ibm.cics.server` package to represent your annotated resources, alongside your annotated code.

9. Deploy the application.

### Results

If the application is installed by a CICS bundle, PROGRAM resources are created as the CICS bundle becomes ENABLED. If the application is installed directly from `server.xml` or from a file by using an `<application>` element; PROGRAM resources are created as the application is installed.

You can now link to the Java program from another CICS program by using:

```
EXEC CICS LINK PROGRAM("CUSTGET") CHANNEL()
```

## Preparing a Spring Boot application to be called by a CICS program

With CICS TS APAR PH14856, you can use annotations to enable a Java method to be invoked by a CICS application - CICS creates the PROGRAM resource for you. The Spring Boot application runs in a Liberty JVM server, and can be deployed within a JAR or WAR.

### Before you begin

First, identify which Java class and method you want to call. Then, adhering to site standards and CICS naming rules, determine a suitable CICS program name.

Make sure that the Liberty JVM server is configured to enable linking to Spring Boot applications. For more information, see Linking to Java applications in a Liberty JVM server by using the @CICSProgram annotation.

**Note:** To avoid concurrency issues, JCICS fields should be defined within the link-target method, or a subsequent prototype-scoped Bean, and not on the linked-to component class.

### Procedure

1. Add the `@CICSProgram` annotation class to the classpath of your project.
   - CICS Explorer If you are using the preinstalled IBM CICS SDK for Java in CICS Explorer, the SDK includes the Liberty JVM server libraries, which provide the `@CICSProgram` annotation.
   - GradleMaven If you're using your own build toolchain, you need to declare dependence on the `com.ibm.cics.server.invocation.annotations` artifact that's available on Maven Central or use the `com.ibm.cics.server.invocation.annotations.jar` JAR file as described in Managing Java dependencies using Maven or Gradle.
2. Create a class to contain the methods that CICS calls. Creating a class keeps the CICS-specific code separate from the rest of your application.
3. Create a method for each CICS PROGRAM resource to be created.
4. Annotate each method with the `@CICSProgram` annotation, giving it a parameter of the PROGRAM name, such as `@CICSProgram("CUSTGET")`.

   CICS PROGRAM names:

   - Must be 1 - 8 characters;
   - Must match the pattern `A-Z a-z 0-9 $ @ #`.

   Example of a simple class with a single method, annotated with the `@CICSProgram` annotation:

   ```
   @Component
   public class CustomerLinkTarget
   {
   ```

```
    @CICSProgram("CUSTGET")
    public void getCustomer()
    {
        // do work here
    }
}
```

Add `targetType = TargetType.SPRINGBEAN` if your class does not contain @Service, @Repository, @Controller, or @Component annotations.

```
public class CustomerLinkTarget
{
    @CICSProgram(value ="CUSTGET", targetType = TargetType.SPRINGBEAN)
    public void getCustomer()
    {
        // do work here
    }
}
```

5. Enable annotation processing for the project.
   - CICS Explorer If you are using CICS Explorer, either:
     - Hover over a `@CICSProgram` annotation with a warning underline and use the quick-fix to enable annotation processing, or:
     - Right-click the project and select **Properties**. Search for the **Annotation Processing** page. Check both **Enable project-specific settings** and **Enable annotation processing**.
   - GradleMaven If you're using a build toolchain such as Gradle or Maven, configure the Java compiler to use `com.ibm.cics.server.invocation` as an annotation processor, as described in Managing Java dependencies using Maven or Gradle.
6. Validate the annotation is correctly specified.
   - CICS Explorer If you are using CICS Explorer, validation happens automatically to ensure that your annotation is correctly positioned and that the method that it annotates and the containing class fulfills the following requirements.
   - Maven If you're using Maven in Eclipse, you can use the m2e-apt plugin to get the annotation processing configured in Eclipse based on the dependencies specified in your `pom.xml` file.

   The annotation:

   - Must be on a method.
   - Must have a value attribute of a PROGRAM name.

   The method:

   - Must be concrete (not abstract).
   - Must be public.
   - Must have no arguments.

   The class:

   - Must be top level (not nested or anonymous).
   - Must not have more than one method that is annotated with the same PROGRAM name.
7. Write the content of the annotated method. The content is likely to involve the following stages:

   a) Obtain containers from the channel.

   b) Obtain input data from containers in a channel.

   c) Use data-mapping code to convert the input data to Java objects.

   d) Call the application business logic.

   e) Use data mapping code to convert the resulting Java objects to output data.

   f) Place the output data in containers in a channel.

Example of a class with a single method, annotated with the `@CICSProgram` annotation, and code to take input data from a container and put output data to a container:

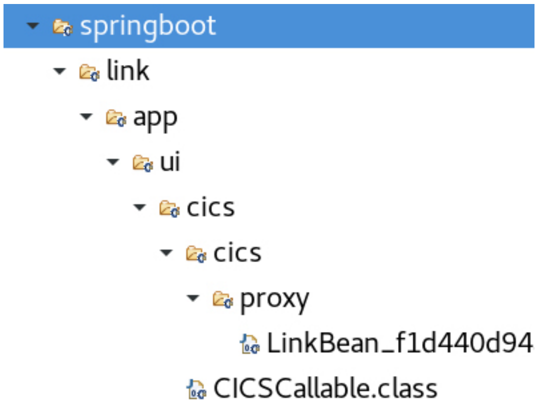
```
@Component
public class CustomerLinkTarget
{
    @CICSProgram("CUSTGET")
    public void getCustomer()
    {
        Channel currentChannel = Task.getTask().getCurrentChannel();
        Container dataContainer = currentChannel.getContainer("DATA");

        // do work here

        Container resultContainer = currentChannel.createContainer("RESULT");
        byte[] results = null; // change this to be the result of the work
        resultContainer.put(results);
    }
}
```

8. Ensure that the generated CICS proxy class is scanned for annotations by Spring.

   The CICS annotation processor generates a proxy class (a Spring bean) which needs to be scanned for annotations by the Spring framework. If you use the @SpringBootApplication annotation within the same package or a parent package, this happens automatically.

   The annotation processor generates the proxy class in a sub-package within the same package as the class in which you annotate with @CICSProgram. CICS Explorer You can check these in the **Navigator** view in CICS Explorer.

   In this example, the class with the @CICSProgram annotation is in the package `springboot.link.app.ui.cics`, and the annotation processor generates the proxy class in `springboot.link.app.ui.cics.cics.proxy`



springboot
link
app
ui
cics
cics
proxy
LinkBean_f1d440d94
CICSCallable.class

   If you are not already using annotations, you must explicitly configure Spring to scan for annotations:

   a) Add component scan to your Spring component class.

   ```
   @ComponentScan(basePackages = "org.example.cics.proxy")
   ```

   If you are using XML configuration, you can enable component scan with:

   ```
   <context:component-scan base-package="org.example.cics.proxy"/>
   ```

9. Build the application.

   - CICS Explorer If you are in CICS Explorer, you can right-click the project and select `Export -> WAR file` , or right-click a containing CICS Bundle Project and select **Export Bundle to z/OS UNIX file system**.
   - If you are using the CICS build toolkit, the annotation processor is invoked automatically.
   - GradleMaven If you are building the Java code by using other tools, ensure that the dependency on the CICS annotation and the annotation processor configuration are correctly specified by using the artifacts on Maven Central. If you've done that in Steps "1" on page 126

and “5” on page 127, they are resolved automatically during build. Otherwise, you must ensure the `com.ibm.cics.server.invocation.annotations.jar` JAR file (which defines the `@CICSProgram` annotation) is on the classpath of the Java compiler. Also, ensure that the `com.ibm.cics.server.invocation.jar` JAR file (containing the annotation processor) is on the classpath of the Java compiler, or is otherwise specified in the **`-processorpath`** option. You can find both JAR files in the *`usshome`* `/lib` directory on z/OS UNIX , where *usshome* is the value of the **`USSHOME`** system initialization parameter.

- If the class is packaged in a library JAR inside the `WEB-INF/lib` directory of a WAR file, export the generated metadata when you are building the JAR. CICS Explorer In CICS Explorer , you can do this by adding the library project to the deployment assembly of the Dynamic Web Project. From the properties dialog for the Dynamic Web Project, choose the Deployment Assembly page, click the **Add** button, and select the library project.

10. Deploy the application.

### Results

If the application is installed by a CICS bundle, PROGRAM resources are created as the CICS bundle becomes ENABLED. If the application is installed directly from `server.xml` or from a file by using an `<application>` element, PROGRAM resources are created as the application is installed.

You can now link to the Spring Boot application from another CICS program by using:

```
EXEC CICS LINK PROGRAM("CUSTGET") CHANNEL()
```

## Program Lifecycle

When a Java EE application is installed into Liberty the `cicsts:link-1.0` feature searches for methods that are annotated with `@CICSProgram`. For each one, it dynamically installs a PROGRAM resource. If a Java EE application is installed into Liberty by using a CICS bundle, the PROGRAM resources are created when the bundle is enabled. Otherwise, PROGRAM resources are created when Liberty installs the application.

When an application is removed, CICS deletes any dynamically installed PROGRAM resources that are associated with that application. If the application was installed by using a CICS bundle, CICS deletes the programs when the bundle is disabled. If an application is removed while tasks that invoke the application are still in progress, errors might occur. Therefore, disable any PROGRAM resources that are associated with a Java EE application and allow work to drain before you remove the application. Otherwise, programs are deleted when Liberty uninstalls the application.

In most cases, you do not need to create your own PROGRAM definition. You might want to create your own PROGRAM definition if you do not want CICS to create one for you automatically, or if you want to specify particular attributes. To create a private program as part of a CICS application that is deployed on a platform, you must define it in a CICS bundle that is installed as part of that application. You can create a program definition in the CSD, BAS or in a CICS bundle, and install it yourself. When CICS finds a method that is annotated with `@CICSProgram` and a matching PROGRAM resource is already installed, CICS does not replace it.

When you are creating your program definition, you must specify the same classname as the class that contains the method that is annotated with `@CICSProgram` . You can optionally specify the method name as well. CICS validates this information when the program is invoked. The JVMCLASS attribute should contain the classname and optionally the method name in the format `wlp:classname#methodname` , for example:

```
wlp:com.example.CustomerLinkTarget#getCustomer
```

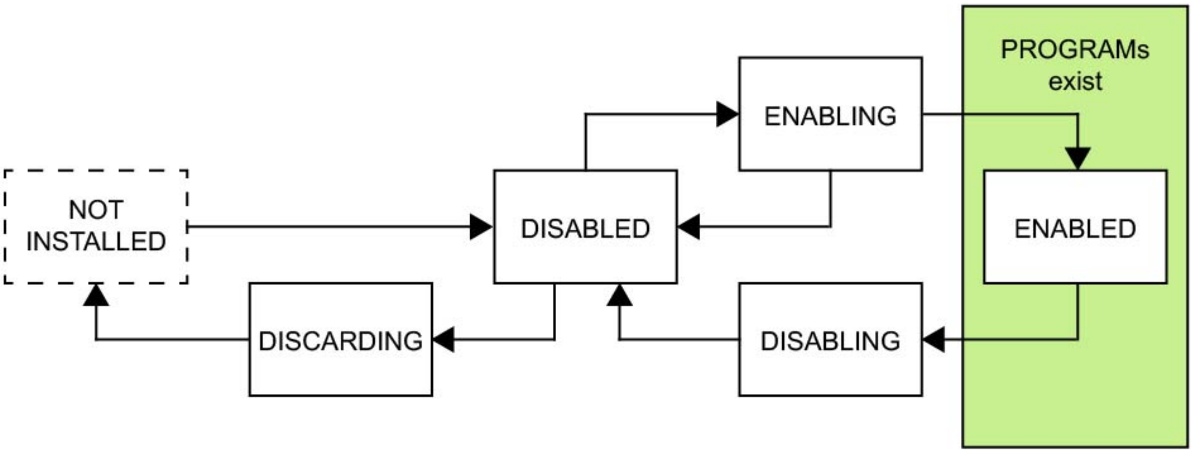


*Figure 26. The lifecycle of a CICS bundle, showing when PROGRAM resources for `@CICSProgram` annotations exist*

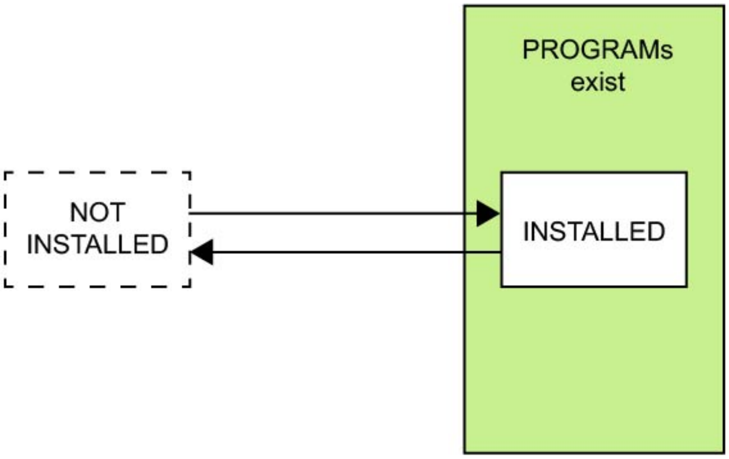


*Figure 27. The lifecycle of a stand-alone web application, showing when PROGRAM resources for @CICSProgram annotations exist*

## Java Transaction API (JTA)

The Java Transaction API (JTA) can be used to coordinate transactional updates to multiple resource managers.

You can use the Java Transaction API (JTA) to coordinate transactional updates to CICS resources and other third party resource managers, such as a type 4 database driver connection within a Liberty JVM server. In this scenario, the Liberty transaction manager is the transaction coordinator and the CICS unit of work is subordinate, as though the transaction had originated outside of the CICS system.

**Note:** If you have the JVM profile option `com.ibm.cics.jvmserver.wlp.jta.integration=false` and use autoconfigure, or are manually configuring `server.xml` and include the `<cicsts_jta Integration="false"/>` element, then the CICS unit of work will not participate in the JTA transaction and is committed or rolled back separately.

A type 2 driver connection to a local Db2 database using a CICS data source is accessed using the CICS Db2 attachment. It is not necessary to use JTA to coordinate with updates to other CICS resources.

In JTA you create a UserTransaction object to encapsulate and coordinate updates to multiple resource managers. The following code fragment shows how to create and use a User Transaction:

```
InitialContext ctx = new InitialContext();
UserTransaction tran = (UserTransaction)ctx.lookup("java:comp/UserTransaction");

DataSource ds = (DataSource)ctx.lookup("jdbc/SomeDB");
Connection con = ds.getConnection();

// Start the User Transaction
tran.begin();

// Perform updates to CICS resources via JCICS API and
// to database resources via JDBC/SQLJ APIs

if (allOk) {
    // Commit updates on both systems
    tran.commit();
} else {
    // Backout updates on both systems
    tran.rollback();
}
```

If you are using an OSGi application, ensure that you include the following entry in the MANIFEST.MF:

```
Import-Package: javax.transaction;version="[1.1,2)"
```

Your development environment might not highlight this dependency by default. It is advisable to explicitly check and to ensure the minimum version of 1.1 is specified. If you allow the runtime environment to resolve the dependency itself, it might resolve to the lower version of the package from the underlying JRE, and conflict with the Liberty runtime.

Unlike a CICS unit of work, a UserTransaction must be explicitly started using the `begin()` method. Invoking `begin()` causes CICS to commit any updates that may have been made prior to starting the UserTransaction. The UserTransaction is terminated by invoking either of the `commit()` or `rollback()` methods, or by the web container when the web application terminates. While the UserTransaction is active, the program can not invoke the JCICS `Task commit()` or `rollback()` methods.

The JCICS methods `Task.commit()` and `Task.rollback()` will not be valid within a JTA transaction context. If either is attempted, an InvalidRequestException will be thrown.

The Liberty default is to wait until the first UserTransaction is created before attempting to recover any indoubt JTA transactions. However, CICS will initiate transaction recovery as soon as the Liberty JVM server initialization is complete. If the JVM server is installed as disabled, recovery will run when it is set to enabled.

If you are using EJBs, see Using JTA transactions in EJBs .

## Java Persistence API (JPA)

The JPA can be used to create object oriented versions of relational database entities for developers to make use of in their applications.

You can use the JPA to provide annotations and XML extensions which you can use to describe tables in their database and their contents, including data types, keys and relationships between tables. Developers can use the API to perform database operations instead of using SQL.

CICS supports `jpa-2.0`, `jpa-2.1`, and `jpa-2.2`. For information on how the versions differ, see Java Persistence API (JPA) feature overview.

- `Entity objects` are simple Java classes, and can be concrete or abstract. Each represents a row in a database table, and properties and fields are used to maintain states. Each field is mapped to a column in the table, and key information about that particular field is added in; for example, you can specify primary keys, or fields that can't be null.

  ```
  @Entity
  @Table(name = "JPA")
  public class Employee implements Serializable
  {
  ```

```
    @Id
    @Column(name = "EMPNO")
    private Long EMPNO;

    @Column(name = "NAME", length = 8)
    private String NAME;

    private static final long serialVersionUID = 1L;

    public Employee()
    {
        super();
    }

    public Long getEMPNO()
    {
        return this.EMPNO;
    }

    public void setEMPNO(Long EMPNO)
    {
        this.EMPNO = EMPNO;
    }

    public String getNAME()
    {
        return this.NAME;
    }

    public void setNAME(String NAME)
    {
        this.NAME = NAME;
    }
}
```

- The `EntityManagerFactory` is used to generate an `EntityManager` for the persistence unit. `EntityManager` maintains the active collection of `entity objects` being used by an application. You can use the `EntityManager` class to initialize the classes and create a transaction for managing data integrity. Next, you interact with the data using the `Entity` class `get` and `set` methods, before using the `Entity` transaction to commit the data.

  The following example contains sample code to insert a record:

```
@WebServlet("/Create")
public class Create extends HttpServlet
{
    private static final long serialVersionUID = 1L;

    @PersistenceUnit(unitName = "com.ibm.cics.test.wlp.jpa.annotation.cics.datasource")
    EntityManagerFactory emf;

    InitialContext ctx;

    /**
    * @throws NamingException
    * @see HttpServlet#HttpServlet()
    */
    public Create() throws NamingException
    {
        super();
        ctx = new InitialContext();
    }

    /**
    * @see HttpServlet#doGet(HttpServletRequest request,
    HttpServletResponse response)
    */
    protected void doGet(HttpServletRequest request, HttpServletResponse
        response) throws ServletException, IOException
    {
        // Get the servlet parms
        String id = request.getParameter("id");
        String name = request.getParameter("name");

        // Create a new employee object
        Employee newEmp = new Employee();
        newEmp.setEMPNO(Long.valueOf(id));
        newEmp.setNAME(name);
        // Get the entity manager factory
        EntityManager em = emf.createEntityManager();

        // Get a user transaction
        UserTransaction utx;

        try
        {
            // Start a user transaction and join the entity manager to it
            utx = (UserTransaction) ctx.lookup("java:comp/UserTransaction");
            utx.begin();
            em.joinTransaction();

            // Persist the new employee
            em.persist(newEmp);

            // End the transaction
            utx.commit();
        }
        catch(Exception e)
        {
            throw new ServletException(e);
        }

        response.getOutputStream().println("CREATE operation completed");
    }
}
```

- `@PersistenceUnit` expresses a dependency on an `EntityManagerFactory` and its associated persistence unit. The name of the persistence unit as defined in the `persistence.xml` file. To connect the entities and tables to a database we then create a `persistence.xml` file in our bundle. The `persistence.xml` file describes the database that these entities connect to. The file includes important information such as the name of the provider, the entities themselves, the database connection URL and drivers.

  The following example contains a sample `persistence.xml`:

```
<?xml version="1.0" encoding="UTF-8"?>
<persistence version="2.0"
    xmlns="http://java.sun.com/xml/ns/persistence"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://java.sun.com/xml/ns/persistence
    http://java.sun.com/xml/ns/persistence/persistence_2_0.xsd">

    <persistence-unit name="com.ibm.cics.test.wlp.jpa.annotation.cics.datasource">
        <jta-data-source>jdbc/jpaDataSource</jta-data-source>

        <class>com.ibm.cics.test.wlp.jpa.annotation.cics.datasource.entities.Employee</class>

        <properties>
            <property name="openjpa.LockTimeout" value="30000" />
            <property name="openjpa.Log" value="none" />
            <property name="openjpa.jdbc.UpdateManager" value="operation-order" />
        </properties>
    </persistence-unit>
</persistence>
```

## Enterprise JavaBeans (EJB)

Enterprise JavaBeans (EJB) is a Java API, and a subset of the Java EE specification. EJBs contain the business logic of an application, and are fully supported by CICS Liberty, including the Lite subset.

The Liberty features that provide the support for EJBs are:

*Table 30. Liberty features that provide support*

| Feature | Support | Java EE version |
|---|---|---|
| ejbLite-3.1 | This feature enables the Lite subset of the EJB technology as defined in the EJB specification. This subset includes support for local session beans that are written to the EJB 3.x APIs. | Java EE 6 |
| mdb-3.1 | This feature enables the message-driven bean subset of the EJB technology, which is similar to the support that the ejbLite feature enables for session beans. | Java EE 6 |
| ejbLite-3.2 | This feature enables the Lite subset of the EJB technology as defined in the EJB specification. This subset includes support for local session beans that are written to the EJB 3.x APIs, non-persistent EJB timers, and asynchronous local interface methods. | Java EE 7 |
| mdb-3.2 | This feature enables the message-driven bean subset of the EJB technology, which is similar to the support that the ejbLite feature enables for session beans. | Java EE 7 |
| ejbHome-3.2 | Enables support of the EJB 2.x APIs, specifically, support for the `javax.ejb.EJBLocalHome` interface. The `javax.ejb.EJBHome` interface is also supported when combined with the ejbRemote feature. | Java EE 7 |
| ejbRemote-3.2 | Enables support for remote EJB interfaces | Java EE 7 |
| ejbPersistentTimers-3.2 | Enables support for persistent EJB timers. | Java EE 7 |
| ejb-3.2 | Enables full EJB 3.2 support. Covers all EJB 3.2 technology, including remote EJB technology. | Java EE 7 |

## Procedure

Enable the feature in the `server.xml` file. For example:

```
<featureManager>
    <feature>ejb-3.2</feature>
</featureManager>
```

For more information, see:

- Developing EJB 3.x applications for information about developing EJB applications by using WebSphere Developer Tools.
- Developing Enterprise bean (EJB) persistent timer applications for information about developing EJB persistent timer applications.
- Using enterprise JavaBeans applications that call local EJB components in another application for information on using enterprise JavaBeans applications that call local EJB components in another application.

## Creating an Enterprise JavaBeans (EJB) project

To develop EJBs for your Java application, you can create an EJB project.

### Before you begin

Ensure that the web development tools are installed in your Eclipse IDE. For more information, see "Setting up your development environment" on page 38.

### About this task

The CICS Explorer help provides full details on how you can complete each of the following steps to develop and package EJB applications.

### Procedure

1. Create an EJB project for your application.
2. Develop your EJB application. You can use the JCICS API to access CICS services, JDBC to access DB2 and JMS to access IBM MQ.
3. Optional: To secure the application, you can use security annotations, or you can specify security constraints in an `ejb-jar.xml` file. For more information, see Enterprise application security.
4. Add your EJB project to an Enterprise Application Project (EAR).

### Results

Your development environment is set up, you created an EJB project, and packaged it for deployment.

## Using JTA transactions in EJBs

How to use JTA transactions in Enterprise JavaBeans (EJBs) on Liberty.

### About this task

EJBs are Java objects that are managed by the Liberty JVM server, allowing a modular architecture of Java applications. The Liberty JVM server supports EJB Lite 3.1, EJB Lite 3.2, or EJB 3.2. EJBs are deployed to a Liberty server using an Enterprise Application Archive (EAR) file created from an Enterprise Application Project. Enterprise Application Projects can contain both EJB and Web projects.

EJB Lite is enabled by adding the relevant feature `ejbLite-3.1` or `ejbLite-3.2` to the `server.xml` configuration file. EJB is enabled by adding `ejb-3.2` to the `server.xml` configuration file. EJBs are deployed into a container. This container works in the background ensuring that aspects like session management, transactions and security are adhered to.

EJBs support two types of transaction management: container that is managed and bean managed. Container managed transactions provide a transactional context for calls to bean methods, and are defined using Java annotations or the deployment descriptor file `ejb-jar.xml`. Bean managed transactions are controlled directly using the Java Transaction API (JTA) . In both cases, the CICS® unit of work (UOW) remains subordinate to the outcome of the Liberty JTA transaction assuming that you have not disabled CICS JTA integration using the `<cicsts_jta Integration="false"/>` `server.xml` element.

There are six different transaction attributes that can be specified for container managed transactions:

- Mandatory
- Required
- RequiresNew
- Supports
- NotSupported
- Never

A JTA transaction is a distributed UOW as defined in the JEE specification. Setting of a method's transaction attribute determines whether or not the CICS task, under which the method executes, runs under its own UOW or is part of a wider, distributed JTA transaction.

**Note:** Although it is respected by the Liberty JTA transaction system, the transaction attribute `NotSupported` does not integrate with and is not supported by the CICS UOW. This applies to EJBs in general.

The following table describes the resulting transactional context of an invoked EJB method, depending on the transaction attribute and whether or not the calling application already has a JTA transactional context.

**Important:** Liberty does not support outbound or inbound transaction propagation. For more information, see Using enterprise JavaBeans with remote interfaces on Liberty.

*Table 31. EJB transaction support*

| Transaction Attribute | No JTA transaction | Pre-existing JTA transaction | Accessing a remote EJB with a pre-existing JTA transaction | Exception behavior |
|---|---|---|---|---|
| Mandatory | Throws exception `EJBTransactionRequiredException`. | Inherits the existing JTA transaction. | Throws exception `com.ibm.websphere.csi.CSITransactionMandatoryException`. | Rollback |
| Required<br>This is the default transaction attribute. | EJB container creates new JTA transaction. | Inherits the existing JTA transaction. | Throws exception `com.ibm.websphere.csi.CSITransactionRequiredException`. | Rollback |
| RequiresNew | EJB container creates new JTA transaction. | Throws exception `javax.ejb.EJBException`. | EJB container creates a new JTA transaction that is managed by the remote server. | Rollback |
| Supports | Continues without a JTA transaction. | Inherits the existing JTA transaction. | Throws exception `com.ibm.websphere.csi.CSITransactionSupportedException`. | Rollback if called from JTA |
| NotSupported | Continues without a JTA transaction. | Suspends the JTA transaction but not the CICS UOW. | The remote server continues without a JTA transaction. | No rollback |
| Never | Continues without a JTA transaction. | Throws exception `javax.ejb.EJBException`. | The remote server continues without a JTA transaction. | No rollback |

**Important:** Calling a method marked as `NotSupported` will suspend the JTA transaction but not suspend the CICS UOW. Any modification of CICS resources during this method call will still be recoverable.

**Note:** If JTA integration is enabled, the transaction attribute `RequiresNew` is supported by a CICS Liberty JVM server, with the restriction that the CICS UOW cannot be nested. Attempting to call a method that is marked as `RequiresNew` when already in a JTA transaction causes an exception to be thrown.

If you call an EJB from a servlet or a POJO and do not explicitly configure the EJB transactional attribute, then by default, container-managed transaction management applies, as does a default transaction attribute of `Required`. This means each call to the EJB starts a new JTA transaction with a subordinate CICS UOW and commits the JTA transaction after each call. If you do not require the use of JTA with EJBs consider using the transaction attribute `Never`.

For information about additional Enterprise JavaBeans (EJB) feature restrictions, see Liberty: Runtime environment known issues and restrictions.

## Enterprise Java Bean (EJB) methods with remote interfaces

EJB methods with remote interfaces can be remotely accessed or hosted by CICS Liberty by using RMI-IIOP technologies. You can enable remote EJB support with the `ejbRemote-3.2` feature.

When you use remote EJB interfaces, there are considerations that you must be aware of. For more information, see Using enterprise JavaBeans with remote interfaces on Liberty.

### Accessing EJB methods with remote interfaces

1. To configure CICS Liberty to run an application that accesses EJB methods with remote interfaces, you must enable the `ejbRemote-3.2` feature by adding the feature into the `server.xml` file, as follows:

   ```
   <featureManager>
       <feature>ejbRemote-3.2</feature>
   </featureManager>
   ```

2. Configure your application binding files, for example `ibm-*-bnd.xml`, for remote EJB references that are defined either in the deployment descriptor `<ejb-ref>`, or with source code annotations, for example `@EJB`. A binding is not required for EJB references that provide a lookup name, either on the annotation or in the deployment descriptor. In the binding file, the EJB reference can be bound by using one of the `java:` names for an EJB or with one of the `corbaname:names`:

   ```
   @EJB(name="TestBean")
       TestRemoteInterface testBean;
   ```

   The binding is defined:

   ```
   <ejb-ref name="TestBean" binding-name=
   "corbaname:rir:#ejb/global/TestApp/TestModule/TestBean!test.TestRemoteInterface"/>
   ```

3. Configure your application client to include stub classes.

### Hosting EJB methods with remote interfaces

1. To host EJBs in CICS Liberty so they can be called by other JVMs, you must enable the `ejbRemote-3.2` feature by adding the feature to the `server.xml` file, as follows:

   ```
   <featureManager>
       <feature>ejbRemote-3.2</feature>
   </featureManager>
   ```

2. Configure the IIOP server to customize ports and security settings. For more information, see Configuring IIOP-RMI Transport for Remote EJBs.
3. Create an EJB application. For more information, see Creating an Enterprise JavaBeans (EJB) project.
4. Generate stub classes. In Eclipse, right-click the EJB project and select **Java EE Tools** > **Create EJB Client JAR**.
5. Deploy the EJB application to CICS Liberty as part of an EAR. For more information, see Creating an Enterprise Application project.
6. Check the Liberty `messages.log` file to ensure that the EJB is enabled and bound to a namespace. You should see this message:

   ```
   CNTR0167I: The server is binding the ejb.remote.ejb.view.MyBeanRemote
   interface of the MyBean enterprise bean in the ejb.remote.ejb.jar module of the
   ejb.remote application. The binding location is:
   java:global/ejb.remote/ejb.remote.ejb/MyBean!remote.ejb.view.MyBeanRemote
   ```

## *Configuring IIOP-RMI transport for remote EJBs*

Internet Inter-ORB Protocol Remote Method Invocation (IIOP-RMI) transport is used by CICS Liberty to communicate with EJB methods that have remote interfaces. This communication can be secured by using Common Secure Interoperability Protocol Version 2 (CSIv2).

IIOP-RMI is used by CICS Liberty as the technology for calling EJB methods with remote interfaces. Using the `ejbRemote-3.2` feature supports both inbound and outbound IIOP-RMI calls.

Inbound calls allow CICS Liberty to listen as an object request broker (ORB) on a TCP/IP port for IIOP-RMI requests and call the target EJB method. See "Configuring Inbound IIOP Communication" on page 138 for details.

Outbound calls are where CICS Liberty makes a request to an ORB to start an EJB method. Outbound calls can be made to the same JVM server the call was made for, or any other Java virtual machine (JVM) capable of acting as an ORB. See "Configuring Outbound IIOP Communication" on page 138 for details.

This communication can be secured by using CSIv2, a technology that satisfies the CORBA (Common Object Request Broker Architecture) for authentication, delegation, and privileges. CSIv2 also supports the use of transport layer security (TLS). See Configuring CSIv2 to secure IIOP Communication for details.

For more information, see Common Secure Interoperability version 2 (CSIv2).

### Configuring Inbound IIOP Communication

Enable the `ejbRemote-3.2` feature by adding it to the `server.xml` file.

```
<featureManager>
    <feature>ejbRemote-3.2</feature>
</featureManager>
```

Optionally, you can configure an IIOP endpoint in the `server.xml` file.

```
<iiopEndpoint id="defaultIiopEndpoint" host="host.example.com" iiopPort="2809" />
```

**Important:** By default the IIOP endpoint listens on `localhost:2809`. The default ORB references the IIOP endpoint `defaultIiopEndpoint`. See Configuring CSIv2 to secure IIOP Communication for more information on configuring ORBs for inbound security.

### Configuring Outbound IIOP Communication

Enable the `ejbRemote-3.2` feature by adding it to the `server.xml` file.

```
<featureManager>
    <feature>ejbRemote-3.2</feature>
</featureManager>
```

Optionally you can configure an ORB with the name service of the remote server.

```
<orb id="defaultOrb" nameService="corbaname::host.example.com:2809" />
```

**Important:** By default the ORB references the local IIOP endpoint `defaultIiopEndpoint`. See Configuring CSIv2 to secure IIOP Communication for more information on configuring ORBs for outbound security.

## *Configuring CSIv2 to secure IIOP communication*

The following information covers some of the general cases for configuring both inbound and outbound CSIv2 security for IIOP communication.

Inbound calls allow CICS Liberty to listen as an object request broker (ORB) on a TCP/IP port for IIOP-RMI requests and call the target EJB method.

Outbound calls are where CICS Liberty makes a request to an ORB to start an EJB method. Outbound calls can be made to the same JVM server the call was made for, or any other Java virtual machine (JVM) capable of acting as an ORB.

In the following example, the *client* is the JVM making the outbound request and the *server* is the JVM receiving the inbound request. Either one, or both of these, can be the CICS Liberty JVM server. For more information, see Configuring Common Secure Interoperability version 2 (CSIv2) in Liberty.

## Configuring CSIv2 to use TLS

### Inbound

- Create a keystore that contains the certificate for the server.

```
<keyStore id="iiopKeyStore" ... />
```

- Create an SSL repertoire (the SSL element) that references the keystore.

```
<ssl id="iiopSSL" keyStoreRef="iiopKeyStore" />
```

- Create an IIOP endpoint with an IIOPS port.

```
<iiopEndpoint id="defaultIiopEndpoint" host="host.example.com" iiopPort="2809">
    <iiopsOptions iiopsPort="9402" sslRef="iiopSSL" />
</iiopEndpoint>
```

**Important:** By default the IIOPs options `sslRef` references the `defaultSSLConfig` SSL repertoire.

### Outbound

- Create a keystore. You can include a key that allows the keystore to trust a root certificate, which trusts all the certificates that are signed by that certificate.

```
<keystore id="iiopTrustStore" ... />
```

- Create an SSL repertoire (the SSL element) that references the keystore.

```
<ssl id="iiopSSL" trustStoreRef="iiopTrustStore" ... />
```

- Create an ORB with the CSIv2 client policy.

```
<orb id="defaultOrb" nameService="corbaname::host.example.com">
    <clientPolicy.csiv2>
        <layers>
            <transportLayer sslRef="iiopSSL" />
        </layers>
    </clientPolicy.csiv2>
</orb>
```

## Configuring CSIv2 to allow propagation of the user ID from the client to the server

### Inbound

- Create an ORB with the CSIv2 server policy.

```
<orb id="defaultOrb">
    <serverPolicy.csiv2>
        <layers>
            <attributeLayer identityAssertionEnabled="true" />
        </layers>
    </serverPolicy.csiv2>
</orb>
```

- Optionally, you can specify one or more identities to be trusted by the server.

```
<attributeLayer identityAssertionEnabled="true" trustedIdentities="MYUSER" />
```

### Outbound

- Create an ORB with the CSIv2 client policy.

```
<orb id="defaultOrb" nameService="corbaname::host.example.com:2809">
    <clientPolicy.csiv2>
        <layers>
            <attributeLayer identityAssertionEnabled="true" />
        </layers>
    </clientPolicy.csiv2>
</orb>
```

- Optionally, you can provide a trusted identity to be authorized by the server.

```
<attributeLayer identityAssertionEnabled="true" trustedIdentity="MYUSER"
     trustedPassword="MYPASSWD" />
```

**Important:** The trusted user must exist in a user registry on the server. The `trustedPassword` can be encoded by using the Liberty `securityUtility` tool.

## Configuring CSIv2 to use TLS Client Authentication

### Inbound

- Create a keystore. You can include a key that allows the keystore to trust a root certificate, which trusts all the certificates that are signed by that certificate.

```
<keyStore id="iiopTrustStore" ... />
```

- Create an SSL repertoire (the SSL element) that references the keystore.

```
<ssl id="iiopSSL" trustStoreRef="iiopTrustStore" ... />
```

- Create an IIOP endpoint with an IIOPS endpoint.

```
<iiopEndpoint id="defaultIiopEndpoint" host="host.example.com" port="2809">
    <iiopsOptions iiopsPort="9402" sslRef="iiopSSL" />
</iiopEndpoint>
```

- Create an ORB with the CSIv2 server policy.

```
<orb id="defaultOrb">
    <serverPolicy.csiv2>
        <layers>
            <attributeLayer identityAssertionEnabled="true" ... />
            <transportLayer sslRef="iiopSSL" />
        </layers>
    </serverPolicy.csiv2>
</orb>
```

### Outbound

- Create a keystore that contains the clients certificate.

```
<keyStore id="iiopKeyStore" ... />
```

- Create an SSL repertoire (the SSL element) that references the keystore.

```
<ssl id="iiopSSL" keyStoreRef="iiopKeyStore" />
```

- Create an ORB with the CSIv2 client policy.

```
<orb id="defaultOrb">
    <clientPolicy.csiv2>
        <layers>
            <attributeLayer identityAssertionEnabled="true" />
            <transportLayer sslRef="iiopSSL" />
        </layers>
    </clientPolicy.csiv2>
</orb>
```

## Java Message Service (JMS)

Java Message Service (JMS) is an API that allows application components based on Java EE to create, send, receive, and read messages. JMS support in Liberty is supplied as a group of related features that support the deployment of JMS resource adapters.

JMS can run in a managed mode in which queues, topics, connections, and other resources are created and managed through server configuration. This includes the configuration of JMS connection factories, queues, topics, and activation specifications. Alternatively it can run in unmanaged mode where all resources are manually configured as part of the application. The Liberty embedded JMS messaging provider is managed, and therefore all resources are set up as part of the server.xml configuration.

### JMS specifications

The JMS specification level supported in a Liberty JVM server is JMS 2.0 support. JMS 2.0 support (`jms-2.0`) enables the configuration of resource adapters to access messaging systems using the Java Message Service API at the 2.0 specification level.

### JMS clients

Different JMS client providers are supported in the Liberty JVM server through the following Liberty features:

- WebSphere MQ JMS 2.0 client ( `wmqJmsClient-2.0` ) - the WebSphere MQ JMS client feature that allows JMS 2.0 or 1.1 client applications to send and receive messages from a remote MQ server.
- WebSphere Application Server JMS 2.0 client (`wasJmsClient-2.0`) - WebSphere Application Server client feature that allow JMS 2.0 or 1.1 client applications to send and receive messages from the messaging engine that is enabled through the `wasJmsServer` feature.
- Any other JMS resource adapter that complies with the JCA 1.6 specification can also be used in Liberty by using generic JCA resource adapters links, see Overview of JCA configuration elements.

### JMS providers

Liberty in CICS TS supports usage of the:

- Liberty embedded JMS messaging provider.
  - WebSphere messaging server (`wasJmsServer-1.0`) - the JMS server feature enables the embedded JMS messaging provider to be hosted within Liberty by using the server feature so that a separate JMS server does not need to be installed or configured, see Enabling JMS messaging for a single Liberty server . The server can also be hosted in a separate Liberty instance either inside CICS or in a Liberty server hosted in z/OS or on a distributed platform, see Enabling JMS messaging between two Liberty servers . The WebSphere JMS messaging client component can also be configured to talk to JMS via SIBUS running in a WebSphere Application Server, see Enabling interoperability between Liberty and WebSphere Application Server traditional.
  - WebSphere messaging security (`wasJmsSecurity-1.0`) - the JMS security feature provides security support for the embedded JMS messaging provider client and server components. The JMS security feature can be used with the `cicsts:security-1.0` feature to specify which users from the security registry are to be used by a connection factory when authenticating requests against the embedded JMS messaging server. For information on authorization, see Authorizing users to connect to the messaging engine.
- JMS access to IBM MQ in a CICS standard-mode Liberty JVM server when the JMS application connects using either bindings or client mode transport.
- JMS access to IBM MQ in a CICS integrated-mode Liberty JVM server when the JMS application connects using the client mode transport.
- Third-party JMS resource adapters that comply with the JCA 1.6 specification.

# Java Management Extensions API (JMX)

The Java Management Extensions API (JMX) is used for resource monitoring and management.

JMX is a Java framework and API that provides a way of exposing application information by using a widely accepted implementation. Various tools, such as JConsole can then be configured to read that information. The information is exposed by using managed beans (MBeans) - non-static Java classes with public constructors. Get and set methods of the bean are exposed as attributes , while all other methods are exposed as operations.

You can connect to JMX in a Liberty JVM server to view the attributes and operations of MBeans, both locally and from a remote machine. A local connection requires adding the `localConnector-1.0` feature to your `server.xml` and allows you to connect from within the same JVM server. Adding the `restConnector-1.0` feature to your `server.xml` allows you to connect by way of a RESTful interface, which provides remote access to JMX.

## Using WebSphere MBeans to monitor your applications

1. To begin, you must acquire a reference to your MBeanServer. This example looks for the **`JvmStats`** MBean and uses the **`findMBeanServer`** method to check which server the MBean is registered to. Then, referring to the correct MBeanServer object, you can obtain reference to your MBean and get data back from the attributes that it exposes. This example looks for the **`UpTime`** attribute of the **`JvmStats`** MBean.

```
// Create an ObjectName object for the MBean that we're looking for.
ObjectName beanObjName = null;
beanObjName = new ObjectName("WebSphere:type=JvmStats");

// Obtain the full list of MBeanServers.
java.util.List servers = MBeanServerFactory.findMBeanServer(null);
MBeanServer mbs = null;

// Iterate through our list of MBeanServers and attempt to find the one we want.
for (int i = 0; i < servers.size(); i++)
{
    // Check if the MBean domain matches what we're looking for.
    mbs = (MBeanServer)servers.get(i);

    if (mbs.isRegistered(beanObjName))
    {
        Object attributeObj = mbs.getAttribute(beanObjName, "UpTime");
        System.out.println("UpTime of JVM is: " + attributeObj + ".");
    }
}
```

## Remote connectivity to JMX in Liberty

Remote connectivity to JMX in a Liberty JVM server requires use of an SSL connection and Java Platform, Enterprise Edition (JEE) role authorization. The client code then obtains a reference to the remote MBean using a `JMXServiceURL`.

1. All the JMX MBeans accessed through the REST connector are protected by a single JEE role named **`administrator`**. To provide access to this role edit the `server.xml` and add the authenticated user to the administrator role.

```
<administrator-role>
<user>myuserid</user>
<group>group1</group>
</administrator-role>
```

   For more information on using JEE roles, see Authorization using SAF role mapping.

2. A remote RESTful JMX client must access the Liberty JVM server by using SSL. To configure SSL support for a Liberty JVM server, refer to topic Configuring SSL (TLS) for a Liberty JVM server using RACF. In addition, the JMX client requires access to the restConnector client-side JAR file and an SSL client keystore containing the server's signing certificate. The `restConnector.jar` comes as part of the CICS WLP installation, which is available at &USSHOME;`/wlp/clients`.

3. In the client-side code, you need to create a JMXServiceURL object. This allows you to obtain a reference to the remote MBeanServerConnection object. See example where <host> and <httpsPort> match those of your server:

```
JMXServiceURL url = new JMXServiceURL("service:jmx:rest://<host>:<httpsPort>/IBMJMXConnectorREST");
JMXConnector jmxConnector = JMXConnectorFactory.connect(url, environment);
MBeanServerConnection mbsc = jmxConnector.getMBeanServerConnection();
```

4. When you successfully obtain the connection, the MBeanServerConnection object provides the same capability and set of methods as a local connection from the MBeanServer object.

For more information about the MBeans that are provided by WebSphere, see WebSphere Liberty: List of provided MBeans.

## Java Authorization Contract for Containers (JACC)

Liberty supports authorization that is based on the Java Authorization Contract for Containers (JACC) specification in addition to the default authorization. When security is enabled in Liberty, the default authorization is used unless a JACC provider is specified.

### About this task

JACC enables third-party security providers to manage authorization in the application server. The default authorization does not require special setup, and the default authorization engine makes all of the authorization decisions. However, if a JACC provider is configured and set up for Liberty to use, all of the enterprise beans and web authorization decisions are delegated to the JACC provider. JACC defines security contracts between the Application Server and authorization policy modules. These contracts specify how the authorization providers are installed, configured, and used in access decisions. To add the jacc-1.5 feature to your Liberty server, add a third-party JACC provider which is not a part of Liberty.

You can develop a JACC provider to have custom authorization decisions for Java EE applications by implementing the com.ibm.wsspi.security.authorization.jacc.ProviderService interface that is provided in the Liberty server. The JACC specification, JSR 115, defines an interface for authorization providers. In the Liberty server, you must package your JACC provider as a user feature. Your feature must implement the com.ibm.wsspi.security.authorization.jacc.ProviderService interface.

### Procedure

1. Create an OSGi Bundle Project to develop the Java class.

   Your project might have compile errors. To fix these errors, you need to import two packages, javax.security.jacc and com.ibm.wsspi.security.authorization.jacc.

   Edit the file MANIFEST.MF to import the missing package:

```
Manifest-Version: 1.0
Service-Component: OSGI-INF/myjaccExampleComponent.xml,
Bundle-ManifestVersion: 2
Bundle-Name: com.example.myjaac.osgiBundle
Bundle-SymbolicName: com.example.myjaac.osgiBundle
Bundle-Version: 1.0.0
Bundle-RequiredExecutionEnvironment: JavaSE-1.7
Import-Package: com.ibm.wsspi.security.authorization.jacc;version="1.0.0",
javax.security.jacc;version="1.5.0"
```

   An example of the service component XML, myjaccExampleComponent.xml:

```
<?xml version="1.0" encoding="UTF-8"?>
<scr:component xmlns:scr="http://www.osgi.org/xmlns/scr/v1.1.0" immediate="true"
 name="TestPolicyServiceProvider">
    <implementation class="com.example.myjaac.osgiBundle.TestPolicyServiceProvider"/>
    <property name="javax.security.jacc.policy.provider" type="String" value=""/>
    <property name="javax.security.jacc.PolicyConfigurationFactory.provider" type="String" value=""/>
    <service>
        <provide interface="com.ibm.wsspi.security.authorization.jacc.ProviderService"/>
    </service>
</scr:component>
```

2. Create a Liberty Feature Project to add the previous OSGi bundle into the user Liberty feature, under `Subsystem-Content` in the feature manifest file.
3. Refine the feature manifest to add the necessary OSGi subsystem content: `com.ibm.ws.javaee.jacc.1.5; version="[1,1.0.200)"; location:="dev/api/spec/"`.

```
Subsystem-ManifestVersion: 1.0
IBM-Feature-Version: 2
IBM-ShortName: jacc15CICSLiberty-1.0
Subsystem-SymbolicName: com.example.myjaac.libertyFeature;visibility:=public
Subsystem-Version: 1.0.0
Subsystem-Type: osgi.subsystem.feature
Subsystem-Content: com.example.myjaac.osgiBundle;version="1.0.0",
 com.ibm.ws.javaee.jacc.1.5;version="[1,1.0.200)";location:="dev/api/spec/"
Manifest-Version: 1.0
```

   If you need to add one more Subsystem-Content, you must add at least one `space` before you type the content. If you do not add a `space`, CICS returns `java.lang.IllegalArgumentException`.
4. Export the Liberty Feature Project as a Liberty Feature (ESA) file.
5. FTP the ESA file to zFS.
6. Use the `installUtility` command to install the ESA file.

   ```
   ./wlpenv installUtility install myFeature.esa
   ```

7. Add the `jacc-1.5` feature and the ESA file containing the JACC provider as a user feature to `server.xml`.

   ```
   <feature>jacc-1.5</feature>
   <feature>usr:jacc15CICSLiberty-1.0</feature>
   ```

## Java Authentication Service Provider Interface for Containers (JASPIC)

The Java Authentication Service Provider Interface for Containers (JASPIC) specification defines a service provider interface (SPI). Authentication providers, that implement message authentication mechanisms, can be integrated in client or server message processing containers or runtimes.

### About this task

Authentication providers that are integrated through the JASPIC interface, operate on network messages that are provided by their calling container. The providers transform outgoing messages so that the source of the message can be authenticated by the receiving container, and the recipient of the message can be authenticated by the message sender. Incoming messages are authenticated and returned to their calling container, which is the identity that is established as a result of the message authentication.

JSR 196 defines a standard SPI, and standardizes how an authentication module is integrated into Java EE containers. A message processing model and details of a number of interaction points on the client and server are provided. A compatible web container uses the SPI at these points to delegate the corresponding message security processing to a server authentication module (SAM).

Liberty supports the use of third-party authentication providers that are compliant with the servlet container that is specified in `jaspic-1.1`. The servlet container defines interfaces that are used by the security runtime environment in collaboration with the web container. These start authentication modules before and after a web request is processed by an application. Authentication that uses JASPIC modules is used only when JASPIC is enabled in the security configuration.

### Procedure

1. Create an OSGi Bundle Project to develop the Java class.

   Your project might have compile errors. To fix these errors, you need to import two packages, `javax.security.auth.message` and `com.ibm.wsspi.security.jaspi`. The Target Platform must be edited to add the missing JARs into the lists `com.ibm.ws.security.jaspic` from `<cics_install>/wlp/lib` directory and `com.ibm.ws.javaee.jaspic.<version_number>` from `<cics_install>/wlp/dev/api/spec` directory. FTP these to your development system and add them to the build path.

Edit the file `MANIFEST.MF` to import the missing package.

```
Manifest-Version: 1.0
Bundle-ManifestVersion: 2
Bundle-Name: com.example.myjaspic.osgiBundle
Bundle-SymbolicName: com.example.myjaspic.osgiBundle
Bundle-Version: 1.0.0
Bundle-RequiredExecutionEnvironment: JavaSE-1.7
Import-Package: com.ibm.wsspi.security.jaspi;version="1.0.13",
javax.security.auth.message;version="1.0.0",
javax.security.auth.message.callback;version="1.0.0",
javax.security.auth.message.config;version="1.0.0",
javax.security.auth.message.module;version="1.0.0",
javax.servlet;version="2.7.0",
javax.servlet.http;version="2.7.0"
Service-Component: myjaspicExampleComponent.xml
```

An example of the service component XML, `myjaspicExampleComponent.xml`:

```
<?xml version="1.0" encoding="UTF-8"?>
<scr:component xmlns:scr="http://www.osgi.org/xmlns/scr/v1.1.0" name="com.example.myjaspic.osgiBundle">
    <implementation class="com.example.myjaspic.osgiBundle.TestJASPICProviderService"/>
    <service>
        <provide interface="com.ibm.wsspi.security.jaspi.ProviderService"/>
    </service>
</scr:component>
```

2. Create a Liberty Feature Project to add the previous OSGi bundle into the user Liberty feature, under `Subsystem-Content` in the feature manifest file.
3. Edit the feature manifest to add the necessary OSGi subsystem content: `com.ibm.websphere.appserver.jaspic-1.1; type="osgi.subsystem.feature"`.

```
Subsystem-ManifestVersion: 1.0
IBM-Feature-Version: 2
IBM-ShortName: jaspic11CICSLiberty-1.0
Subsystem-SymbolicName: com.example.myjaspic.libertyFeature;visibility:=public
Subsystem-Version: 1.0.0.201611081617
Subsystem-Type: osgi.subsystem.feature
Subsystem-Content: com.example.myjaspic.osgiBundle;version="1.0.0",
  com.ibm.websphere.appserver.jaspic-1.1;type="osgi.subsystem.feature",
  com.ibm.websphere.appserver.servlet-3.0;ibm.tolerates:="3.1";type="osgi.subsystem.feature"
Manifest-Version: 1.0
```

   If you need to add one more Subsystem-Content, you must add at least one `space` before you type the content. If you do not add a `space`, CICS returns `java.lang.IllegalArgumentException`.

4. Export the Liberty Feature Project as a Liberty Feature (ESA) file.
5. FTP the ESA file to zFS.
6. Use `installUtility` to install the ESA file.

```
./wlpenv installUtility install myFeature.esa
```

7. Add the `jaspic-1.1` feature and the ESA file containing the JASPIC provider as a user feature to `server.xml`.

```
<feature>jaspic-1.1</feature>
<feature>usr:jaspic11CICSLiberty-1.0</feature>
```

## Java EE Connector Architecture (JCA)

JCA connects enterprise information systems such as CICS, to the JEE platform.

JCA supports the qualities of service for security credential management, connection pooling and transaction management, provided by the JEE application server. Using JCA ensures these qualities of service are managed by the JEE application server and not by the application. This means the programmer is free to concentrate on writing business code and need not be concerned with quality of service. For information about the provided qualities of service and configuration guidance see the documentation for your JEE application server. JCA defines a programming interface called the Common Client Interface (CCI). This interface can be used with minor changes to communicate with any enterprise information system.

## The programming interface model

Applications that use the CCI have a common structure for all enterprise information systems. JCA connects the enterprise information systems (EIS) such as CICS, to the JEE platform. These connection objects allow a JEE application server to manage the security, transaction context and connection pools for the resource adapter. An application must start by accessing a connection factory from which a connection can be acquired. The properties of the connection can be overridden by a ConnectionSpec object. After a connection has been acquired, an interaction can be created from the connection to make a particular request. The interaction, like the connection, can have custom properties that are set by the InteractionSpec class. To perform the interaction, call the execute() method and use record objects to hold the data. For example:

```
ConnectionFactory cf = <Lookup from JNDI namespace>
Connection c = cf.getConnection(ConnectionSpec);
Interaction i = c.createInteraction();
InteractionSpec is = newInteractionSpec();
i.execute(spec, input, output);
i.close();
c.close();
```

The example shows the following sequence:

1. Use the ConnectionFactory object to create a connection object.
2. Use the Connection object to create an interaction object.
3. Use the Interaction object to run commands on the enterprise information system.
4. Close the interaction and the connection.

If you are using a JEE application server, you create the connection factory by configuring it using the administration interface of the server. In the Liberty server this is defined through the `server.xml` configuration. When you have created a connection factory, enterprise applications can access it by looking it up in the JNDI ( Java Naming Directory Interface). This type of environment is called a managed environment, and allows a JEE application server to manage the qualities of service of the connections. For more information about managed environments see your JEE application server documentation.

## Record objects

Record objects are used to represent data passing to and from the EIS. It is advised that application development tools are used to generate these Records. Rational Application Developer provides the J2C tooling that allows you to build implementations of the Record interface from specific native language structures such as COBOL copybooks, with in-built support for data marshalling between Java and non-Java data types.

## Resource adapter example

You can install a basic example resource adapter and configure instances of the resources it provides, see Configuring and deploying a basic JCA Resource Adapter.

## The Common Client Interface

The CCI provides a standard interface that allows developers to communicate with any number of EISs through their respective resource adapters, using a generic programming style. The CCI is closely modeled on the client interface used by Java Database Connectivity (JDBC), and is similar in its idea of Connections and Interactions.

## Using the JCA local ECI resource adapter

The JCA local ECI resource adapter is provided with CICS TS and invokes local CICS programs. This is an optimized path to migrate applications using the CICS Transaction Gateway ECI resource adapter into CICS Liberty. This section applies to integrated mode Liberty only.

The JCA local ECI resource adapter is used to connect to CICS programs, passing data in either COMMAREAs or channels and containers. The resource adapter is provided by the CICS Liberty feature.

**Note:** The JCA local ECI resource adapter and the CICS Transaction Gateway ECI resource adapter cannot be used in the same Liberty JVM server.

Table one shows the JCA objects corresponding to the CICS terms.

*Table 32. CICS terms and corresponding JCA objects*

| CICS term | JCA object: property |
|---|---|
| Abend code | CICSTxnAbendException |
| COMMAREA | Record |
| Channel | ECIChannelRecord |
| Container with a data type of BIT | byte[] |
| Container with a data type of CHAR | String |
| Program name | ECIInteractionSpec:FunctionName |
| Transaction | ECIInteractionSpec:TPNName |

For further details see "JCA local ECI support" on page 188.

### *Configuring the JCA local ECI resource adapter*

You can configure the JCA local ECI resource adapter using connection factories as defined in the JCA specification.

To start using the JCA local ECI, add the feature `cicsts:jcaLocalEci-1.0` to the featureManager element of the `server.xml`.

```
<featureManager>
<feature>cicsts:jcaLocalEci-1.0</feature>
</featureManager>
```

The JCA local ECI provides a default connection factory **`defaultCICSConnectionFactory`** bound to the JNDI name **`eis/defaultCICSConnectionFactory`** . Optionally if a different JNDI name is required configure additional connection factories using the properties subelement as follows:

```
<connectionFactory id="localEci" jndiName="eis/ECI">
<properties.com.ibm.cics.wlp.jca.local.eci/>
</connectionFactory>
```

**Tip:** You do not need any attributes on the properties element.

### *Porting JCA ECI applications into a Liberty JVM server*

JCA applications can be easily ported into a Liberty JVM server using the JCA local ECI resource adapter support.

## Porting

Porting existing JCA applications that use the CICS Transaction Gateway ECI resource adapter from a stand-alone JEE application server into a CICS Liberty JVM server can be achieved through these steps:

1. Add the `cicsts:jcaLocalEci-1.0` , and `webProfile-6.0` features to the `server.xml` file.

For example:

```
<featureManager>
...
<feature>cicsts:jcaLocalEci-1.0</feature>
<feature>webProfile-6.0</feature>
...
</featureManager>
```

2. You can either update the source so that the JNDI name of the Connection Factory is **`eis/defaultCICSConnectionFactory`** , or add a **`connectionFactory`** and **`properties.com.ibm.cics.wlp.jca.local.eci`** to `server.xml`.
3. Deploy the application into CICS , see Deploying a Java EE application in a CICS bundle to a Liberty JVM server.

If the application uses any restricted features of the ECI resource adapter, the code for the application will have to be changed to remove these unsupported features. For more information, see Restrictions of the JCA local ECI resource adapter.

### *Using the local ECI resource adapter to link to a program in CICS*

Running a program in CICS using the JCA local ECI resource adapter is done by using the execute() method of the ECIInteraction class.

#### About this task

This task shows an application developer how to use the JCA local ECI resource adapter to run a CICS program passing in a COMMAREA using a JCA record. For further details on how to extend the Record interface to represent a CICS COMMAREA, see Using the JCA local ECI resource adapter with COMMAREA and for details on how to link to a CICS program that uses channels and containers, see Using the JCA local ECI resource adapter with channels and containers.

#### Procedure

1. Use JNDI to look up the ConnectionFactory object named `eis/defaultCICSConnectionFactory`.
2. Get a Connection object from the ConnectionFactory.
3. Get an Interaction object from the Connection.
4. Create a new ECIInteractionSpec object.
5. Use the set methods on ECIInteractionSpec to set the properties of the execution, such as the program name and COMMAREA length.
6. Create a record object to contain the input data (see COMMAREA/Channel topics) and populate the data.
7. Create a record object to contain the output data.
8. Call the execute method on the Interaction, passing the ECIInteractionSpec and two Record objects.
9. Read the data from the output record.

```
package com.ibm.cics.server.examples.wlp;

                        import java.io.ByteArrayInputStream;
                        import java.io.ByteArrayOutputStream;
                        import java.io.IOException;
                        import java.io.InputStream;
                        import java.io.OutputStream;

                        import javax.annotation.Resource;
                        import javax.resource.cci.Connection;
                        import javax.resource.cci.ConnectionFactory;
                        import javax.resource.cci.Interaction;
                        import javax.resource.cci.Record;
                        import javax.resource.cci.Streamable;
                        import javax.servlet.ServletException;
                        import javax.servlet.annotation.WebServlet;
                        import javax.servlet.http.HttpServlet;
                        import javax.servlet.http.HttpServletRequest;
                        import javax.servlet.http.HttpServletResponse;

                        import com.ibm.connector2.cics.ECIInteractionSpec;

                        /**
                        * Servlet implementation class JCAServlet
                        */
                        @WebServlet("/JCAServlet")
                        public class JCAServlet extends HttpServlet
                        {
                        private static final long serialVersionUID = 4283052088313275418L;

                        // 1. Use JNDI to look up the connection factory
                        @Resource(lookup = "eis/defaultCICSConnectionFactory")
                        private ConnectionFactory cf;

                        protected void doGet(HttpServletRequest request, HttpServletResponse
                        response)
                        throws ServletException, IOException
                        {
                        try
                        {
                        // 2. Get the connection object from the connection factory
                        Connection conn = cf.getConnection();

                        // 3. Get an interaction object from the connection
                        Interaction interaction = conn.createInteraction();

                        // 4. Create a new ECIInteractionSpec
                        ECIInteractionSpec is = new ECIInteractionSpec();

                        // 5. Use the set methods on ECIInteractionSpec
                        // to set the properties of execution.
                        // Change these properties to suit the target program
                        is.setCommareaLength(20);
                        is.setFunctionName("PROGNAME");
                        is.setInteractionVerb(ECIInteractionSpec.SYNC_SEND_RECEIVE);

                        // 6. Create a record object to contain the input data and populate
                        data
                        // Change the contents to suit the data required by the program
                        RecordImpl in = new RecordImpl();
                        byte[] commarea = "COMMAREA contents".getBytes();
                        ByteArrayInputStream inStream = new ByteArrayInputStream(commarea);
                        in.read(inStream);

                        // 7. Create a record object to contain the output data
                        RecordImpl out = new RecordImpl();

                        // 8. Call the execute method on the interaction
                        interaction.execute(is, in, out);

                        // 9. Read the data from the output record
                        ByteArrayOutputStream outStream = new ByteArrayOutputStream();
                        out.write(outStream);
                        commarea = outStream.toByteArray();
                        }
                        catch (Exception e)
                        {
                        // Handle any exceptions by wrapping them into an IOException
                        throw new IOException(e);
                        }
                        }

                        // A simple class which extends Record and Streamable representing a
                        commarea.
                        public class RecordImpl implements Streamable, Record
                        {
                        private static final long serialVersionUID = -947604396867020977L;

                        private String contents = new String("");

                        @Override
                        public void read(InputStream is)
                        {
                        try
                        {
                        int total = is.available();
                        byte[] bytes = null;
                        if (total > 0)
                        {
                        bytes = new byte[total];
```

```
                        is.read(bytes);
                        }
                        // Convert the bytes to a string.
                        contents = new String(bytes);
                        }
                        catch (Exception e)
                        {
                        // Log the exception
                        e.printStackTrace();
                        }
                        }

                        @Override
                        public void write(OutputStream os)
                        {
                        try
                        {
                        // Output the string as bytes
                        os.write(contents.getBytes());
                        }
                        catch (Exception e)
                        {
                        // Log the exception
                        e.printStackTrace();
                        }
                        }

                        @Override
                        public String getRecordName()
                        {
                        // Required by Record, unused in this sample
                        return "";
                        }
                        @Override
                        public void setRecordName(String newName)
                        {
                        // Required by Record, unused in this sample
                        }
                        @Override
                        public void setRecordShortDescription(String newDesc)
                        {
                        // Required by Record, unused in this sample
                        }
                        @Override
                        public String getRecordShortDescription()
                        {
                        // Required by Record, unused in this sample
                        return "";
                        }
                        @Override
                        public Object clone() throws CloneNotSupportedException
                        {
                        // Required by Record, unused in this sample
                        return super.clone();
                        }
                        }
                        }
```

## Results

You have successfully linked to a program in CICS using the ECI resource adapter.

*Using the JCA local ECI resource adapter with channels and containers*

To use channels and containers with the JCA local ECI resource adapter, the input and output records must be instances of ECIChannelRecord.

When the ECIChannelRecord is passed to the execute() method of ECIInteraction, the method uses the ECIChannelRecord itself to create a channel and converts the entries inside the ECIChannelRecord into containers before passing them to CICS.

This example shows how to build an input and output record for use by the JCA local resource adapter using the put() and get() methods on the ECI ChannelRecord.

```
ECIChannelRecord in = new
                    ECIChannelRecord("CHANNELNAME");
                    byte[] bitData = "Container with BIT data".getBytes();
                    String charData = "Container with CHAR data";
                    in.put("BITCONTAINER", bitData);
                    in.put("CHARCONTAINER", charData);
                    ECIChannelRecord out = new ECIChannelRecord("CHANNELNAME");

                    interaction.execute(is, in, out);

                    bitData = (byte[]) out.get("BITCONTAINER");
                    charData = (String) out.get("CHARCONTAINER");
```

BIT and CHAR containers are created depending on the type of the entry:

- A BIT container is created when the entry data is of type byte[] or an object that implements the Streamable interface. No code page conversion takes place.
- A CHAR container is created when the entry data is of type String. String data is encoded by Unicode and is converted to the encoding of the container. Data read from this container by **`EXEC CICS GET CONTAINER`** will be converted according to Using containers for code page conversion.

When creating the ECIChannelRecord, the name must be a valid CICS channel name. Once created the getRecordName() method obtains the name of the channel. When adding containers to the ECIChannelRecord, the container names must be valid CICS container names. Once created the KeySet() method retrieves the names of all the containers.

*Using the JCA local ECI resource adapter with COMMAREA*
To use COMMAREA with the JCA local ECI resource adapter, the input and output records must be instances of classes that implement `javax.resource.cci.Record` and `javax.resource.cci.Streamable`.

This example shows how to build an input and output record for use by the local ECI resource adapter using the read() and write() methods on the Streamable interface:

```
RecordImpl in = new RecordImpl();
                    byte[] commarea = "COMMAREA contents".getBytes();
                    ByteArrayInputStream inStream = new ByteArrayInputStream(commarea);
                    in.read(inStream);
                    RecordImpl out = new RecordImpl();

                    interaction.execute(is, in, out);

                    ByteArrayOutputStream outStream = new ByteArrayOutputStream();
                    out.write(outStream);
                    commarea = outStream.toByteArray();
```

To retrieve a byte array from the output record, use the write method on the Streamable interface using a **`java.io.ByteArrayOutputStream`** object. The toByteArray() method on **`ByteArrayOutputStream`** provides the output data from the COMMAREA in the form of a byte array.

To provide more function for your specific JEE components, you can write implementations of the Record interface that allow you to set the contents of the record using the constructor. In this way you avoid use of the **`java.io.ByteArrayInputStream`** used in the example.

Rational Application Developer provides the J2C tooling that allows you to build implementations of the Record interface from specific native language structures such as COBOL copybooks, with in-built support for data marshalling between Java and non-Java data types.

### *Unit of work management with JCA*

Transaction Management, when using the CICS local ECI resource adapter, is provided by a CICS Liberty JVM server.

Calls to other CICS programs using the CICS local ECI resource adapter are integrated with CICS unit of work (UOW) management. This allows the UOW to be controlled through either syncpoint commands or a JTA transaction.

Calls to a program in a remote CICS region result in a DPL call using a mirror transaction. This mirror task UOW is coordinated by the calling UOW if a Java transaction context is being used, this means the called program is unable to issue syncpoint calls as it is restricted to the DPL command subset. If the calling program has no JTA transaction context then the mirror task UOW is invoked using the

SYNCONRETURN option. In this scenario the called program is able to issue syncpoint commands as its UOW is not coordinated by the calling program.

For more details refer to Programming considerations for distributed program link , "Unit of work (UOW) services" on page 79 and "Java Transaction API (JTA) " on page 130.

### *Enabling trace for the JCA local ECI resource adapter*

A detailed trace mechanism is provided for the JCA local ECI resource adapter. Enabling trace can be useful for problem solving in applications using the resource adapter.

- JCA local ECI resource adapter trace is enabled by SJ domain trace level 4 (SJ = 4 or SJ = ALL).
- Trace from the resource adapter will be included in the JVM server trace output in zFS with the component identifier `com.ibm.cics.wlp.jca.local.eci.adapter`.

### *Restrictions of the JCA local ECI resource adapter*

Some API calls that are available on the CICS Transaction Gateway ECI resource adapter are not supported by the CICS TS JCA local ECI resource adapter.

#### Restricted methods

These API calls are not supported by the JCA local ECI resource adapter

- ECIInteractionSpec class methods setExecuteTimeout(), getExecuteTimeout(), setReplyLength(), getReplyLength(), setTranName(), getTranName()
- CICSConnectionSpec class methods setPassword(), getPassword(), setUserid(), getUserid(), addPropertyChangeListener(), removePropertyChangeListener(), firePropertyChange
- ECIConnection class method getLocalTransaction()
- ECIChannelRecord class method values()
- CICSUserInputException
- The constructor ECIConnectionSpec(String username, String password). ECIConnectionSpec() has been added as an alternative
- The constructor ECIInteractionSpec(int verb, int timeout, String prog, int commLen, int repLen). ECIInteractionSpec(int verb, String prog, int commLen) has been added as an alternative

These calls are not supported when using the IBM CICS SDK for Java to develop web applications. In order to allow portability of existing ECI JCA applications into a Liberty JVM server these methods will continue to function but any settings of transaction, timeout, reply length and transaction name will have no effect. Setting the transaction ID through ECIInteractionSpec.setTPNName() only uses the specified transaction when linking to a remote program (DPL). Linking to a local program will continue to use the current transaction.

#### Non-managed environments

JCA local ECI only supports managed connection factories (those created via the server.xml configuration). Non-managed connections created using instances of a ManagedConnectionFactory, are not supported.

#### Exception handling

Exception handling may differ slightly between the CICS Transaction Gateway ECI resource adapter and the CICS TS JCA local ECI resource adapter. Any CICS errors will propagate to the ECI local resource adapter as a CICSException, as they do with the JCICS API. The resource adapter will wrap these exceptions in a ResourceException. To help identify the CICS fault, the CICSException will be set as the cause of the Exception and can be accessed using the getCause() method of java.lang.Throwable.

## Asynchronous calls

Asynchronous calls are not fully asynchronous in the JCA local ECI resource adapter. A call using the SYNC_SEND interaction verb will block until the program completes, then the results can be gathered via a subsequent call using the SYNC_RECEIVE interaction verb, using the same ECIInteraction.

## Unsupported CICS Transaction Gateway functions

These CICS Transaction Gateway functions are not supported in the CICS TS local ECI resource adapter.

- Remote connections to a CICS Transaction Gateway server
- Identity propagation
- Cross component trace (XCT)
- Request monitoring user exits
- Trace from the resource adapter is controlled by CICS TS, use of the CICSLogTraceLevels is not supported.

# CICS remote development feature for Java

The CICS remote development feature for Java provides an ECI resource adapter for use in Liberty running on a developers workstation. The feature enables developers to rapidly test and debug Java applications that use JCA APIs to invoke programs in CICS TS. When ready, the application can be deployed into Liberty running in CICS without any further changes to the application.

The feature connects to a CICS region by using an IP interconnectivity (IPIC) connection that is defined by using the TCPIPSERVICE resource. The trace facility can be used to identify problems with the data sent and received from the program in CICS TS.

### *Configuring the IPIC connection*

Before you can test your Java application with a CICS region, an IPIC connection must be available. Contact your CICS system programmer to request a TCP/IP service that accepts IPIC requests from a Liberty profile by using the following details.

## About this task

The following procedure guides the CICS system programmer through the steps to define a TCP/IP service in CICS and install a sample user program for IPIC connections.

## Procedure

1. Install IPIC support in CICS by defining a **TCPIPSERVICE** resource with the following attributes:

*Table 33. Attributes for TCPIPSERVICE resource*

| TCPIPSERVICE resource attribute | Value required |
|---|---|
| **URM** | DFHISAIP |
| **Port number** | n |
| **Status** | OPEN |
| **Protocol** | IPIC |
| **Transaction** | CISS |
| **Backlog** | 0 |
| **Socketclose** | No |

2. Verify that the **TCPIPSERVICE** is in service by issuing the **CEMT INQUIRE TCPIPSERVICE(JCA)** command.

3. Install a sample program to test the IPIC connection.
   a) If you do not already have a copy, download the CICS Transaction Gateway Software Development Kit (SDK) and expand the archive file.
   b) Locate and copy the `cicsprograms/ec01.cpp` member to a COBOL source data set on z/OS.
   c) Compile the `EC01` sample program and copy the generated module into a load library that CICS can access.
   d) If the `autoinstall` program is not enabled, define and install a program definition for EC01.
   e) Test the EC01 program by issuing the **`CECI LINK PROG(EC01) COMMAREA(' ')`**.

      Check that the **`RESPONSE`** is `NORMAL`.

### Results

IPIC support is now available for use in the CICS region.

## *Setting up your local Java test environment*

Before you can test your Java application with a CICS region, you must check that the required tools are installed and also configure your local work environment.

### About this task

To create a local work environment where you can test your Java applications with a CICS region, complete the following steps.

### Procedure

1. Download and install the Eclipse IDE for Java EE Developers with WebSphere Developer Tools (WDT). Then, install a local WebSphere Liberty server instance, create the Hello World JavaServer Pages (JSP) and test by deploying the Hello World web application on the server.

   For more information, see *Get Started* available at Open Liberty.
2. Install the JCA remote ECI resource adapter from the Liberty Repository. You can install a feature from the repository by using the **`installUtility`** command:

```
<liberty_install>/bin/installUtility install
--acceptLicense jcaRemoteEci-1.0
```

3. Add the `usr:jcaRemoteEci-1.0` , `localConnector-1.0` , and `webProfile-6.0` features to the `server.xml` file.
   For example, in Eclipse expand the **WebSphere Liberty** project and then expand **servers** . Double-click **defaultServer** to edit `server.xml` . Click the **source** tab and add the following features:

```
<featureManager>
...
<feature>usr:jcaRemoteEci-1.0</feature>
<feature>localConnector-1.0</feature>
<feature>webProfile-6.0</feature>
...
</featureManager>
```

4. Add a **`connectionFactory`** and **`properties.com.ibm.cics.wlp.jca.remote.eci`** to `server.xml`.

   The **`connectionFactory`** jndiName is used by the application to create a connection. The **`properties.com.ibm.cics.wlp.jca.remote.eci`** is used to configure the JCA remote ECI resource adapter and at a minimum must specify **`serverName`** with the host name and port number of the IPIC connection defined by the TCPIPSERVICE resource.

   **Note:** You might need to specify extra parameters. For example, to use Secure Sockets Layer (SSL) and a user ID and password. Table 1 lists the available parameters. Table 2 lists the ECI resource adapter deployment parameters that are not supported by the JCA remote ECI resource adapter. For more information, see ECI resource adapter deployment parameters.

```
<server>
...
<connectionFactory id="com.ibm.cics.wlp.jca.local.eci" jndiName="eis/ECI">
<properties.com.ibm.cics.wlp.jca.remote.eci serverName="tcp://
hostname
:
port"/>
</connectionFactory>
...
</server>
```

Table 1 shows the JCA remote ECI resource adapter properties that are supported.

*Table 34. Supported JCA remote ECI resource adapter properties*

| JCA object: property | Notes |
|---|---|
| **applid** | |
| **applidQualifier** | This property is required. |
| **cipherSuites** | |
| **ipicHeartbeatInterval** | |
| **ipicSendSessions** | This property default is 5. |
| **keyRingClass** | |
| **keyRingPassword** | |
| **password** | |
| **socketConnectTimeout** | |
| **serverName** | This property is required. |
| **traceLevel** | |
| **traceRequest** | |
| **userName** | |

Table 2 shows CICS Transaction Gateway ECI resource adapter deployment parameters that are not supported by the JCA remote ECI resource adapter.

*Table 35. JCA remote ECI resource adapter properties that are not supported*

| JCA object: property |
|---|
| **interceptPlugin** |
| **portNumber** |
| **tPNName** |
| **tranName** |

### *Testing the example Java EE JCAServlet application*

Add the example Java EE JCAServlet application and then verify that the Java EE application can call a sample program in CICS.

#### About this task

Complete the following steps to add the Java EE JCAServlet application. Then, verify that the Java EE JCAServlet application can call the EC01 sample program in CICS.

## Procedure

1. Create a JCAServlet class in the Hello World web application.

   Expand the **Hello World** project and then expand **Java Resource** . Right-click **New** and select **Servlet**.

   - For **`Java package`** , enter `com.ibm.ctg.samples.liberty`
   - For **`Class name`** , enter `JCAServlet`

   Then, click **Finish**.
2. Edit `JCAServlet.java` and replace all of the code with the CICS example `JCAServlet.java` from GitHub.

   For more information, see JCAServlet.java.
3. Expand the **Hello World** project and then expand **Java Resources** > **src** > **com.ibm.ctg.samples.liberty** . Right-click the **JCAServlet.java** application and select **Run As** > **Run on server**.
4. The Liberty server is started and a message is displayed on the Liberty server console that indicates the URL, which you can click to run the Java EE application. The following is an example of a message, which might be displayed.

   ```
   [AUDIT ] CWWKT0016I: Web application available
   (default_host):
   http://localhost:9080/GenappCustomerSearchWeb/
   ```

## Results

You can now test and debug the Java EE application in your local Liberty server.

### *Configuring the trace function in your local Liberty profile*

Before you can trace your Java web application in your local Liberty profile, you must configure your local work environment.

## About this task

Complete the following steps to configure the trace function in your local Liberty profile.

## Procedure

Add the `traceRequests="ON"` parameter to the connection factory in your `server.xml` file to enable tracing.

With `traceRequests="ON"` specified, when you send another application request, the Eclipse console shows the request and the response that your application sends and receives from CICS.

The following example shows a request that is sent to CICS and the response received from CICS.

```
Starting DataFlowsMonitor log stream at
Thu Apr 07 14:21:54 BST 2016[00000000001]:
com.ibm.ctg.monitoring.DataFlowsMonitor:eventFired called with
event = RequestEntry
FlowType = EciSynconreturn Fully qualified APPLID = No APPLID
CtgCorrelator =
1Program = EC01Server =
TCP://WINMVS2C.HURSLEY.IBM.COM:27723PayLoad = COMMAREA is 20
bytes00000000 00000000 00000000 00000000 00000000
'????????????????????'
```

```
[00000000001]:
com.ibm.ctg.monitoring.DataFlowsMonitor:eventFired called with
event = ResponseExit
FlowType = EciSynconreturn Fully qualified APPLID = No APPLID
CtgCorrelator =
1OriginData - Transaction Group ID = 1B114040
40404040 40402EF0 F0F0F0F0 F0F0F2D0 8F53F115 220100Program = EC01Server =
TCP://WINMVS2C.HURSLEY.IBM.COM:27723PayLoad = COMMAREA is 20
```

```
bytesF0F761F0 F461F1F6 40F1F47A F2F17AF5 F4000000
'??a??a??@??z??z?????'CtgReturnCode = 0CicsReturnCode = 0
```

### Results

You can now trace your application to help identify any problems.

### *Configuring a secure SSL connection*

You can secure the IPIC connection from the JCA remote ECI resource adapter to CICS by using SSL.

### About this task

Complete the following steps to configure a secure SSL connection.

Completing this setup provides SSL with trusted Certificates exported from both MVS and the local client. An MVS user ID and password are also required for authentication.

### Procedure

1. Set up a CICS RACF® environment.

   For more information, see Configuring SSL server authentication on the CICS server .
2. Set up the client security.

   For more information, see Configuring SSL server authentication on the client.
3. Configure the client authentication.

   For more information, see Configuring SSL client authentication.
4. Configure the IPIC connection on CICS.

   For more information, see Configuring the IPIC connection on CICS .
5. Modify your `server.xml` to use the local **`KeyRingClass`** that was created in Step 2 and send your user ID and password.

   ```
   <connectionFactory id="com.ibm.cics.wlp.jca.local.eci"
   jndiName="eis/ECI">
   <properties.com.ibm.cics.wlp.jca.remote.eci
   serverName="ssl://hostname:port"
   keyRingClass="C:\Users\IBM_ADMIN\Documents\CICS\JCA\ctgclientkeyring.jks"
   keyRingPassword="password"
   userName="user_ID"
   password="*******"
   applid="JCASSL"
   applidQualifier="ABCDEFGH"
   />
   </connectionFactory>
   ```

### Results

The JCA remote ECI resource adapter secures requests to CICS by using SSL and the key ring, user ID, and password that are specified in `server.xml`.

## Developing microservices with MicroProfile

Eclipse MicroProfile defines a programming model for developing microservice applications in an Enterprise Java environment. It is an open source project under The Eclipse Foundation to bring microservices to the Enterprise Java community. MicroProfile is supported by Liberty.

MicroProfile defines a number of specifications for building microservices that are resilient, secure and easy to monitor.

*Table 36. Included in Eclipse MicroProfile 1.2*

| Specification | Description |
|---|---|
| JSR 346: Contexts and Dependency Injection for Java EE 1.1 | CDI defines a set of services that manage the injection and lifecycle of objects in an Enterprise Java runtime. |
| JSR 339: JAX-RS 2.0: The Java API for RESTful Web Services | JAX-RS is a Java API for RESTful Web Services. |
| JSR 353: Java API for JSON Processing | JSON-P is a Java API for processing JSON. |
| Eclipse MicroProfile Config 1.1 | Config is a Java API and SPI for managing application configuration. |
| Eclipse MicroProfile Fault Tolerance 1.0 | Fault Tolerance provides strategies for coping with failures when calling external services. |
| Eclipse MicroProfile Health Check 1.0 | Health Check allows components to report their liveliness to the wider system. |
| Eclipse MicroProfile Health Metrics 1.0 | Health Metrics provide a unified way for applications to expose monitoring data. |
| Eclipse MicroProfile JWT Propagation 1.0 | JWT Propagation allows JSON Web Token (JWT) to be used for authentication and authorization with Java EE role-based access control (RBAC). |

## Restrictions

- CDI is used extensively in the MicroProfile APIs, however Liberty does not support CDI in OSGi web applications that are packaged in enterprise bundle archives (EBAs). Instead, package applications that use MicroProfile in web application archives (WARs) or enterprise application archives (EARs).
- MicroProfile Fault Tolerance 1.0 is designed to manage calls that are made to other services. It is not designed to manage updates to resources in a transactional context. CICS resources should not be updated in methods annotated `@Bulkhead`, `@CircuitBreaker`, `@Fallback`, `@Timeout` or `@Retry`. CICS cannot guarantee that these updates will be recovered when exceptions occur, even when JTA is used.
- When the feature `mpJwt-1.0` is enabled in the `server.xml` of a Liberty JVM server, all authentications must be done by using JWT bearer tokens. To use any other form of authentication, a separate Liberty JVM server must be used.

## Service architectures in CICS Liberty JVM servers

### Monolithic architecture

Monolithic architecture implements the application in a single unit. Internally the logic can be modular, but externally the application is either entirely available, or not available at all. Monoliths perform well compared to microservices and are less complex when managing security and transaction context. Scaling monoliths involves adding instances of the entire application, individual parts cannot be scaled.

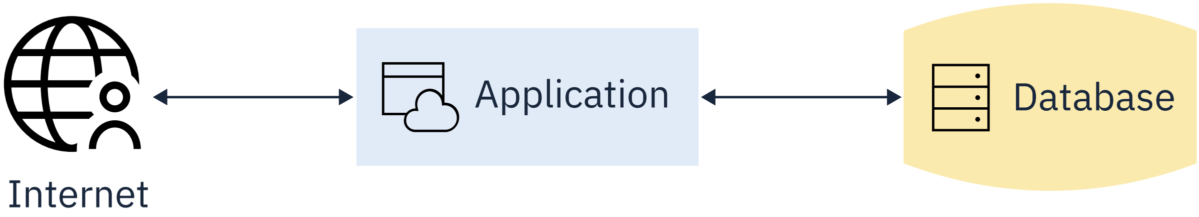


*Figure 28. Monolithic architecture*

## Backing services

Backing services allow the back end data and programs to be decoupled from the main application. By making the data and programs into separate applications, they are called using a platform agnostic communication method, for example HTTP, socket, message queues, and so on. Instead of the main application holding all the logic for communicating with these sources, some responsibility is given to these services.

In CICS, z/OS Connect is used to expose CICS programs as backing services through a REST API. In the example, the application uses JDBC to communicate with a database. SMTP is used to send emails and HTTP is used to call a CICS program through z/OS Connect.

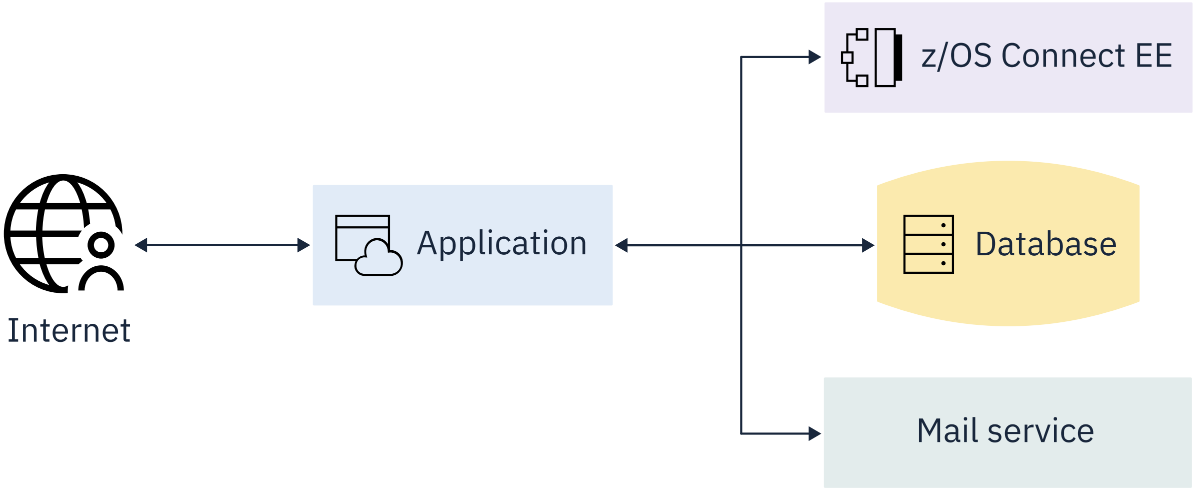


*Figure 29. Backing services*

### Hosted services

Services are hosted in CICS to further decouple the main application from the various components. Similar to backing services, more function is exposed in CICS through CICS Web Services, or in CICS Liberty with applications using technologies including servlets, JAX-RS and JAX-WS.

JAX-RS is a popular technology for creating RESTful web services, JAX-WS is used to create remote procedure call (RPC) oriented web services.

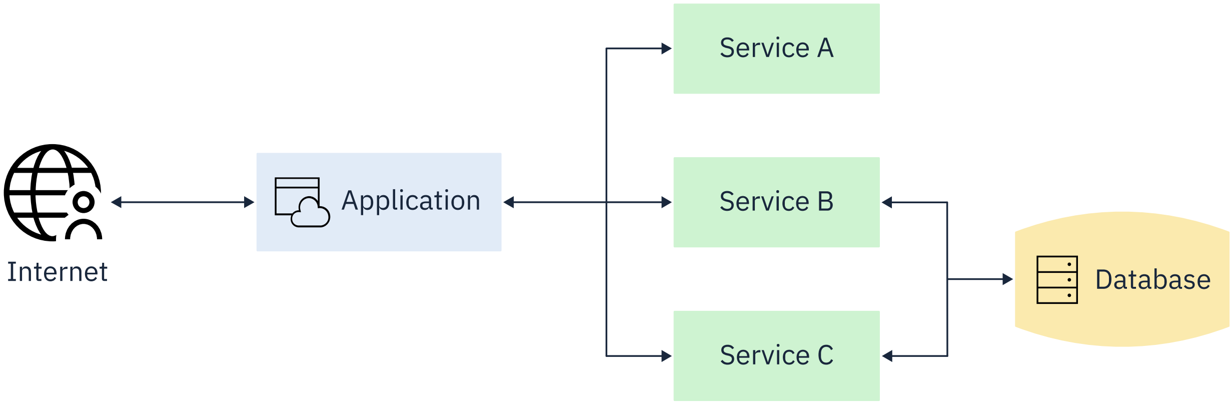


*Figure 30. Hosted services*

**Note:** Both REST and RPC are equally valid options for communication in microservices. REST focuses on resource management. RPC focuses on actions. A microservice architecture does not mandate REST,RPC, or any other technology.

## Microservices

A full microservice architecture is an interconnected web of isolated services with no single central point, though there can be dedicated entry points. Services can communicate with one another as required. Scaling microservices involves adding instances of the parts that require scaling. Microservices are more resilient to failures than monoliths.

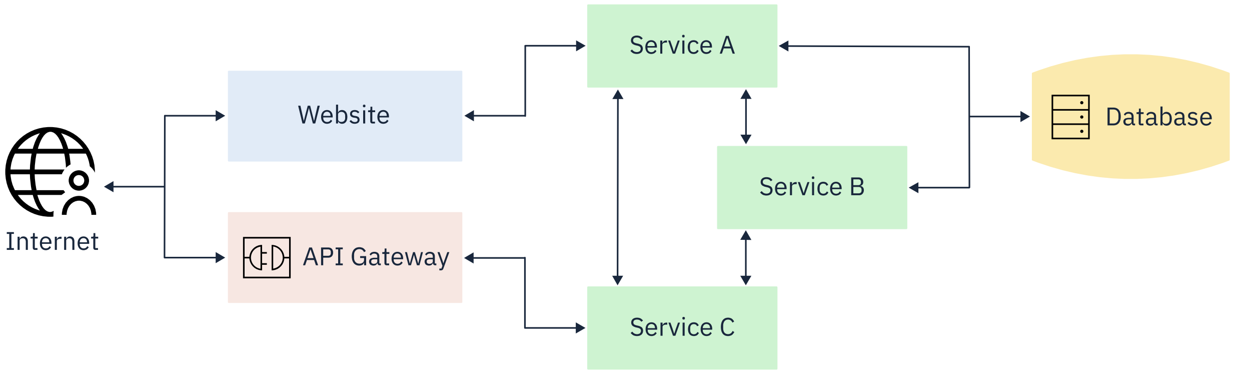


*Figure 31. Microservices*

### Scaling services in CICS

Services can be scaled in several ways in CICS, depending on region topology and setup. Microservices are typically isolated into a single container. In CICS, a service or set of services could be isolated within a region or JVM server. Scaling can be achieved by running multiple CICS regions hosting the same service or set of services. You can also scale the JVM server by increasing the number of threads.

### Securing microservices

Where possible, microservices should be kept off public networks. API gateways can be used to provide controlled access to microservices. MicroProfile offers a method for using Open ID Connect (OIDC) based JSON Web Tokens (JWT) for role based access control (RBAC) of microservice endpoints. Security tokens offer lightweight and interoperable propagation of user identities across different services.

MicroProfileJWT Authentication 1.0 provides functionality to authenticate and authorize users based on a JWT bearer token. The token can be injected into the service code and used to propagate the identity across the microservice network. Propagation of the JWT can be done manually by including the JWT as a bearer token in the Authorization HTTP header on the outbound request. Alternatively, Liberty can automatically propagate the JWT by configuring a `webTarget` element in `server.xml` with an `authnToken` configured, for example:

```
<webTarget uri="http://microservice.example.ibm.com/protected/*" authnToken="mpjwt" />
```

**Important:** JWT identities are not automatically mapped to a user registry and will not be propagated into the CICS task user ID. To enable identity mapping, add `mapToUserRegistry=”true”` configuration attribute to the `<mpJwt>` element in `server.xml`.

For more information on configuring MicroProfile JWT Authentication in Liberty see Configuring the MicroProfile JSON Web Token.

### Data consistency in microservices

Microservices cannot easily make use of distributed transactions. Instead, alternative transaction strategies are used, such as the saga pattern, where events are published after an updated in a service. For example, if service A and service B have updates that should both happen, the following sequence occurs:

1. A updates into a pending state
2. A sends a message to B
3. B updates into a complete state
4. B sends a message to A
5. A updates into a complete state

### When to use microservices

Microservices are best applied where an application can be deconstructed into smaller, isolated, services. A microservice allows for controlled scaling, independent deployment, and more autonomous development. The architecture of microservices can create extra complexity, particularlyin deployment and data consistency. Communicating over protocols such as HTTP produces a larger performance cost compared to calling in memory. Components can be made more resilient to failure by allowing them to scale individually. Monitoring solutions become more important to aid diagnosis of unhealthy services when managing a microservice architecture.

## Spring Boot applications

You can develop Spring Boot applications for use with CICS. There are two approaches to developing Spring Boot applications. The approach that you choose depends upon whether you want to integrate your Spring Boot application with aspects of Java EE such as Security, Transactions, DataSources and

Java Message Service (JMS), or whether you prefer to use standard Spring configuration and templates with little or no integration with Java EE.

If you build and deploy your Spring Boot application as a JAR, then you can only integrate with JCICS. To achieve greater integration with Java EE and Liberty, build and deploy your Spring Boot application as a WAR file and follow the best practices that are described in topic Building and deploying Spring Boot applications. Each subtopic describes an important aspect of integration and how to ensure Spring Boot integrates with Java EE, Liberty, and CICS capabilities.

## JCICS and JCICSX in Spring Boot applications

You can use JCICS or JCICSX in both Spring Boot WAR and Spring Boot JAR applications to call CICS services.

This is contrary to other integration aspects of Java EE and Liberty that are only available when the Spring Boot application is deployed as a WAR. Although you can resolve your Spring Boot dependencies against JCICS or JCICSX by using only the com.ibm.cics.server or com.ibm.cics.jcicsx artifact on Maven Central, a more consistent approach is to use the bill of materials (BOM) file. This ensures you resolve against consistent versions of a range of CICS artifacts as shown in the examples below.

**Note:** The following instructions use the JCICS library as an example but also apply to JCICSX.

Avoid binding the JCICS library into your application as this is provided by the CICS runtime.

If you are using Maven, you can achieve this by compiling against the JCICS library or by using `<scope>provided</scope>`. Or, if you are using the CICS TS BOM, the `<scope>import</scope>` on the `<dependency>` element automatically defers the scope value to the CICS BOM. The CICS BOM applies the `provided` scope, which ensures JCICS is only included at build time. It is not embedded in your application where it might potentially conflict with the version that is used by the CICS runtime. For example,

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>com.ibm.cics</groupId>
            <artifactId>com.ibm.cics.ts.bom</artifactId>
            <version>5.6-20200609123739</version>
            <type>pom</type>
            <scope>import</scope>
        </dependency>
    </dependencies>
</dependencyManagement>
```

If you are using Gradle, you can take advantage of the CICS TS BOM by coding a `compileOnly` directive with the `enforcedPlatform` qualifier. Doing so infers version information from the BOM and ensures that references to the contained artifacts are consistent and compatible. Thereafter, to declare a dependency on the JCICS library (`com.ibm.cics.server`) or any other CICS artifact from the BOM, a version qualifier is not required, simply code the appropriate dependency statement.

For example,

```
dependencies {
    compileOnly enforcedPlatform('com.ibm.cics:com.ibm.cics.ts.bom:5.6-20200609123739')
    compileOnly("com.ibm.cics:com.ibm.cics.server")  //dependency on JCICS
}
```

**Note:** See Maven Central for the latest version number for appropriate for your release of CICS.

For more CICS-provided dependencies you can resolve with Maven and Gradle, see “Managing Java dependencies using Gradle or Maven” on page 46.

## JPA in Spring Boot applications

Developers can use the Java Persistence API (JPA) to create object-oriented versions of relational database entities to use in their applications.

To use JPA in your Spring Boot application, first add a JPA artifact to your dependencies in your Spring Boot application. For example:

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-data-jpa</artifactId>
</dependency>
```

Java EE's implementation of JPA and Spring data's implementation of JPA both require configuration to define the connection to the database repository that is used by the application.

Just like using JDBC you can use the **`spring.datasource.jndi-name`** property that is defined in `application.properties` to configure the connection to the datasource being used and this will be used dynamically by the JPA EntityManager. Alternatively the data source can also be defined in an @Bean annotated dataSource() method, by performing a JNDI lookup of a data source defined in Liberty.

## Security in Spring Boot applications

You have three options when you are using Spring Boot security in CICS.

1. You can use Spring Boot security without integrating with Liberty or CICS security. This option is useful if you are taking an existing Spring Boot application and deploying it unchanged in CICS.
2. You can use Java EE security to authenticate web requests by using any of the Liberty-supported registry types. You can configure it in the standard Java EE method by using a `<security-constraint>`and `<login-config>` in the application's `web.xml`. This option is useful if you want to authenticate users by using any of the supported Liberty registry types, and then control transaction authorization by using CICS security. For more information, see Authenticating users in a Liberty JVM server

   **Note:** You must ensure that `web.xml` is stored in `src/main/webapp/WEB-INF/`
3. You can integrate Spring Boot security with Java EE security by using Java EE container pre-authentication. It allows you to authenticate users via an external system in order to provide a validated user ID and set of roles to Spring Boot security. To do this, you need to modify the application and create an `@Configuration` annotated class that extends WebSecurityConfigurerAdapter in order to name the roles to be propagated into Spring security. In addition, you then need to configure the standard Java EE security settings in the applications `web.xml` and `<application-bnd>` or EJBROLE profiles if you are using SAF authorization. Use this option if you want to authenticate users by using any of the supported Liberty registry types, and you want to authorize requests by using Java EE role-based access to individual methods

## Transactional integration and Spring Boot applications

You can achieve transactional integration when you are developing Spring Boot applications for use with CICS Liberty. The effect of transactional integration between Spring Boot and CICS is to ensure that the CICS Unit of Work (UOW) is coordinated by Liberty's transaction manager. Using the Java Transaction API (JTA) you can coordinate CICS, Liberty, and third-party resource managers, such as a type 4 database driver connection, together as one global transaction. For more information about JTA support in CICS, see Java Transaction API (JTA).

JTA is available for use in a Spring Boot WAR application in various ways:

- Spring Boot's @Transactional annotation: This annotation, which is specified at the class or method level denotes the code segment to be contained within a single global transaction.
- Spring templates: The Spring framework provides two templates for use with programmatic transaction management: the TransactionTemplate and the PlatformTransactionManager interface.

- UserTransaction: It is also possible to use the JTA UserTransaction interface within a Spring Boot application by obtaining the UserTransaction initial context of the hosting Application server (Liberty) through a JNDI lookup. For example, `ctx.lookup("java:comp/UserTransaction");`. The developer can employ a Bean-managed approach to transactions by explicitly coding UserTransaction 'start' and 'end' calls around the resources to be managed.

## Threading and Concurrency in Spring Boot applications

The Spring Framework provides abstractions for asynchronous execution of tasks by using the TaskExecutor interface. Executors are the Java SE name for the concept of thread pools. Spring’s TaskExecutor interface is identical to the java.util.concurrent.Executor interface. The TaskExecutor was originally created to give other Spring components an abstraction for thread pooling where needed. Spring includes a number of pre-built implementations of TaskExecutor but it is the DefaultManagedTaskExecutor that is most useful for integration with CICS as it looks up the application server's defaultExecutor - which in CICS Liberty is designed to provide CICS enabled threads.

### About this task

To run asynchronous tasks in your Spring Boot application by using CICS enabled threads, there are two options. You can either set an Asynchronous Executor for the whole application, or you can choose to specify an AsyncExecutor on a per method basis. If all the tasks you spawn asynchronously require CICS services, then setting the Asynchronous Executor for the whole application is the simplest approach. Otherwise, you need to specify the Asynchronous Executor to use for each and every method where you require asynchronous capability. Here, we demonstrate the whole application approach.

### Procedure

1. On your main Spring Boot Application class add the @EnableAsync annotation, implement the interface AsyncConfigurer, and override the getAsyncExecutor() and AsyncUncaughtExceptionHandler methods. Ensure you return an instance of the DefaultManagedTaskExecutor in the getAsyncExecutor() method as this obtains new threads from Liberty's defaultExecutor, which in turn is configured to return CICS enabled threads. For more information about the AsyncConfigurer, see the AsyncConfigurer in the Spring Boot documentation. For usage examples, see EnableAsync in the Spring Boot documentation.

```
@SpringBootApplication
@EnableAsync
public class MyApplication implements AsyncConfigurer
{

    public static void main(String[] args)
    {
        SpringApplication.run(MyApplication.class, args);
    }

    @Override
    @Bean(name = "CICSEnabledTaskExecutor")
    public Executor getAsyncExecutor()
    {
        return new DefaultManagedTaskExecutor();
    }

    @Override
    public AsyncUncaughtExceptionHandler getAsyncUncaughtExceptionHandler()
    {
        return new CustomAsyncExceptionHandler();
    }
}

public class CustomAsyncExceptionHandler implements AsyncUncaughtExceptionHandler
{
    @Override
    public void handleUncaughtException(Throwable throwable, Method method, Object... obj)
    {
        System.out.println("Exception Cause - " + throwable.getMessage());
        System.out.println("Method name - " + method.getName());
        for (Object param : obj)
        {
            System.out.println("Parameter value - " + param);
        }
    }
}
```

2. Add the @Async annotation to either: a class in your application if you wish to run all methods on that class asynchronously, or to individual methods that you wish to run asynchronously. i.e.`@Async("CICSEnabledTaskExecutor")`
3. Add the concurrent-1.0 feature to `server.xml`

## JDBC in Spring Boot applications

You can use Spring Data JDBC to implement JDBC based repositories. It allows you to access DB2 and other data sources from your Spring Boot application.

Spring Data JDBC is conceptually simpler than JPA, for more information on how it differs from JPA, see: Reference documentation in the Spring Boot documentation. To use JDBC in your Spring Boot application, add a JDBC artifact to your dependencies in your Spring Boot application to make the necessary Java libraries available. For example, in Maven:

```
<dependency>
    <groupId>org.springframework.boot</groupId>
    <artifactId>spring-boot-starter-data-jdbc</artifactId>
</dependency>
```

Or in Gradle, (implementation"`org.springframework.boot:spring-boot-starter-data-jdbc`")

To use JDBC in a Spring Boot application, you can define a Liberty dataSource in the `server.xml` just as you would if using JDBC in a Java EE application. This data source can then be located by using a JNDI lookup that references the jndiName attribute on the dataSource element, and then used by the Spring Boot JdbcTemplate object by using one of the following methods:

1. Performing a JNDI lookup of the data source in an @Bean annotated dataSource() method and returning the data source.
2. Naming the data source in the **`spring.datasource.jndi-name`** in the Spring application properties. Spring Boot creates the JdbcTemplate using the data source that is named in `application.properties`.

**Note:** In option 2, it is also possible to configure all the data source attributes necessary to connect a Spring application to the required data source from within the `application.properties` file. The attributes are all defined in Common application properties in the Spring Boot documentation. However, this ties the application directly the data source and using JNDI is a more flexible approach.

## JMS in Spring Boot applications

You can use JMS in Spring Boot applications to send and receive messages by using reliable, asynchronous communication by using messaging providers such as IBM MQ.

To use JMS in your Spring Boot application, add a JMS artifact to your dependencies in your Spring Boot application to make the necessary Java libraries available. For example, in Maven,

```
<dependency>
    <groupId>org.springframework.integration</groupId>
    <artifactId>spring-integration-jms</artifactId>
</dependency>
<dependency>
    <groupId>javax.jms</groupId>
    <artifactId>javax.jms-api</artifactId>
    <scope>provided</scope>
</dependency>
```

or in Gradle,

```
implementation("org.springframework.integration:spring-integration-jms")
compileOnly("javax.jms:javax.jms-api")
```

To send and receive messages by using a JMS messaging provider, you can define a JMS connection factory in the Liberty `server.xml` as you would if you were using JMS in a Java EE application. This connection factory can then be used to reference a remote IBM MQ queue manager by using a JmsTemplate object and either:

1. Performing a JNDI lookup of the connection factory in an @Bean annotated connectionFactory() method and returning the connection factory.
2. Naming the connection factory in the spring.jms.jndi-name in the Spring application properties. Spring Boot then creates the JmsTemplate by using the connection factory that is named in the `application.properties`.

**Note:** In option 2, it is also possible to configure all the connection factory attributes necessary to connect a Spring application to the required queue manager from within the `application.properties` file. The attributes are all defined in Common application properties. However, this ties the application directly the queue manager and by using JNDI is a more flexible approach.

A message driven POJO (MDP) is used to handle incoming messages in Spring Boot. An @EnableJms annotation is used in the Spring Boot Configuration class to enable discovery of methods annotated @JmsListener. The @JMSListener annotation marks a method to be the target of a JMS message listener that receives incoming messages.

If you want these MDPs to be able to use the JCICS API, then you need to bind the Liberty TaskExecutor to the JmsListenerContainerFactory. This can be achieved as follows:

```
@Bean
public TaskExecutor taskExecutor()
{
    return new DefaultManagedTaskExecutor();
}

@Bean
public JmsListenerContainerFactory<?> myFactory(ConnectionFactory connectionFactory)
{
    DefaultJmsListenerContainerFactory factory = new DefaultJmsListenerContainerFactory();
    factory.setConnectionFactory(connectionFactory);
    factory.setTaskExecutor(taskExecutor());
    return factory;
}
```

**Note:** This requires the use of the jndi-1.0 and concurrent-1.0 Liberty features.

The Spring Boot @Transactional annotation can also be used on the @JMSListener annotated method to signify that the receiving of the message from the queue and the CICS UOW are to be coordinated by using the same container-managed JTA global transaction.

## Building and deploying Spring Boot applications

You can build your Spring Boot applications for use in CICS with Maven or with Gradle.

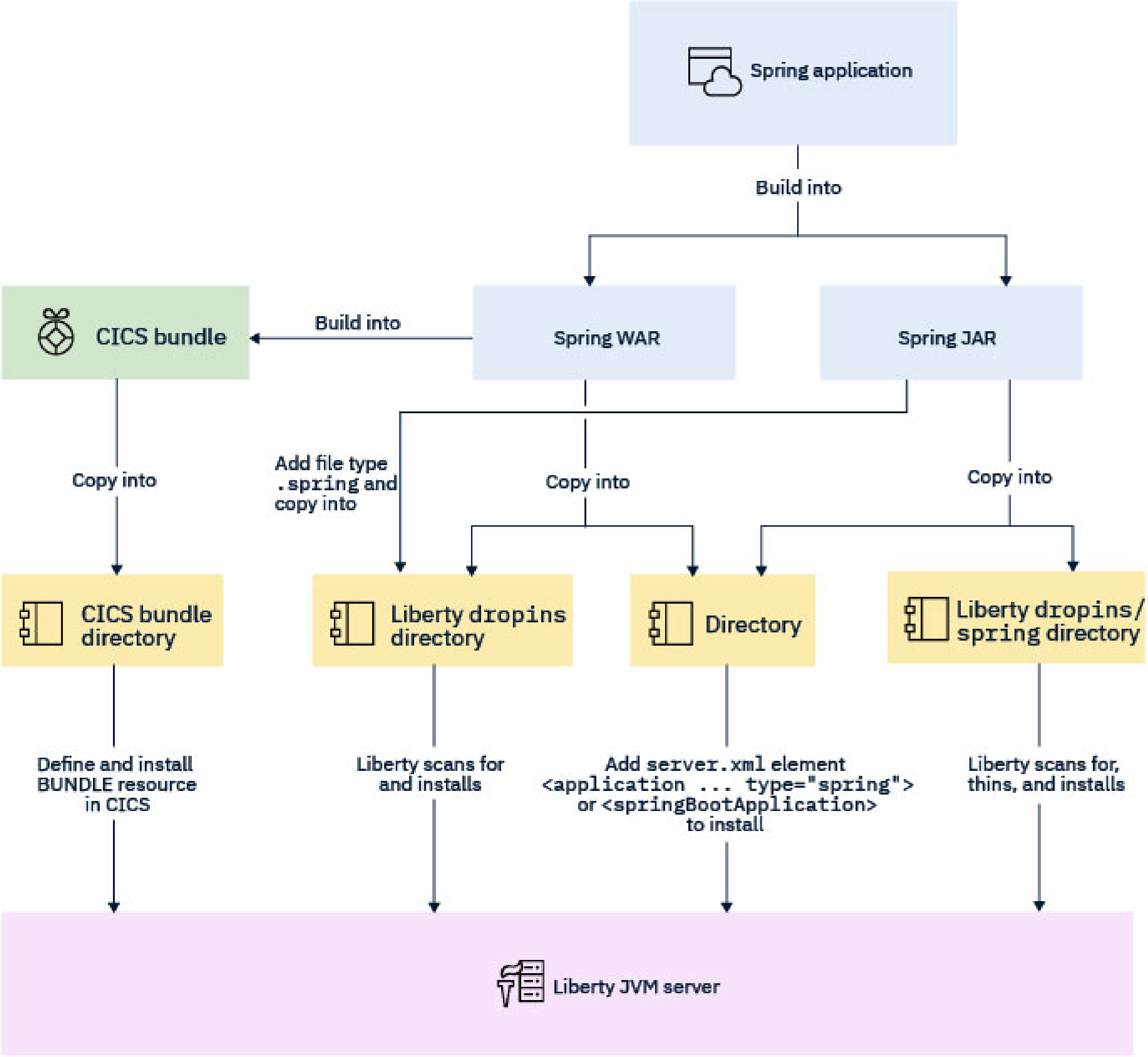
### Building Spring Boot applications as WAR or JAR files

You can build Spring Boot applications as a web application archive (WAR) or a Java Archive (JAR) file. Build your Spring boot application as a WAR if you are looking to integrate Spring Framework transactional management or Spring Boot Security in CICS. See Table 37 on page 172. When built as a WAR, a Spring Boot application can be deployed and managed by using CICS bundles in the same way as other CICS Liberty applications. When built as a JAR the springBoot-1.5 or springBoot-2.0 feature must be installed and the JAR must be deployed by using either a Liberty application element with the `type="spring"` attribute or by using the dropins directory. However, if you have an existing application that you simply want to deploy into CICS without using CICS integration, you can package it as a JAR. Only one JAR file can be deployed into a Liberty JVM server at a time but multiple WAR files can be co-hosted.

*Table 37. Spring Boot integration*

| Capability | Spring Boot applications built into: | |
|---|---|---|
| | WAR | JAR |
| CICS JCICS API | Yes | Yes |
| CICS link to Spring Bean | Yes | Yes |
| Java Persistance API (JPA) | Yes | No |
| Spring security integration with CICS | Yes | No |
| Spring transaction integration with CICS | Yes | No |
| Java Database Connectivity (JDBC) | Yes | No |
| Threading and concurrency | Yes | No |
| Java Message Service (JMS) | Yes | No |

The following diagram displays the different options that you can take to run your Spring Boot application on CICS.



Spring application
Build into
CICS bundle
Build into
Spring WAR
Spring JAR
Copy into
Add file type
.spring and
copy into
Copy into
Copy into
CICS bundle directory
Liberty dropins directory
Directory
Liberty dropins/ spring directory
Define and install BUNDLE resource in CICS
Liberty scans for and installs
Add server.xml element <application ... type="spring"> or <springBootApplication> to install
Liberty scans for, thins, and installs
Liberty JVM server

### Additional notes for building WARs

Before building, you must set the packaging type of your Spring Boot application as a deployable WAR. Your main application class must extend the SpringBootServletInitializer and override the configure method. You must also declare the Spring Boot embedded web container (typically Tomcat) as a provided dependency in your build script so that it can be replaced with Liberty's web-container at run time. In this example a main method is provided so that the application can also be built as a stand-alone JAR if required.

```
@SpringBootApplication
public class MyApplication extends SpringBootServletInitializer
{
    @Override
    protected SpringApplicationBuilder configure(SpringApplicationBuilder application)
    {
        return application.sources(MyApplication.class);
    }

    public static void main(String[] args)
    {
        SpringApplication.run(MyApplication.class, args);
    }
}
```

For detailed information about creating a deployable WAR file with Gradle or Maven, see Create a deployable WAR file in the Spring Boot documentation.

For more information about building applications with Maven and Gradle, see Managing Java dependencies using Maven or Gradle

## Liberty web server plug-in

The web server plug-in allows the forwarding of HTTP requests from a supported web server, on to one or more Liberty application servers.

There are three main reasons why you would want to use the web server plug-in.

- It provides integration with a web server for the serving of static content.
- It allows termination of the SSL endpoint in the web server when using HTTPS.
- It enables load balancing and failover of HTTP requests across a group of Liberty servers.

The web server plug-in is configured by generating a `plugin-cfg.xml` file on the Liberty server that is copied to the machine hosting the web server. The plug-in takes inbound requests and checks them against the configuration data contained within this file and forwards incoming HTTP requests to the URI and host of the configured Liberty servers.

The procedure for generating `plugin-cfg.xml` with a Liberty profile server uses the `generatePluginConfig` operation, that is exposed by the `com.ibm.ws.jmx.mbeans.generatePluginConfig` MBean provided by Liberty. This JMX MBean can either be invoked remotely using the JConsole utility supplied with the IBM Java SDK in combination with the Liberty server `restConnector-1.0` feature or by developing a custom JMX application to invoke the required operation on the MBean. For further details on using JMX in a CICS Liberty server see “ Java Management Extensions API (JMX) ” on page 142.

Further detailed information on setting up a web server plug-in can be found in the WAS Knowledge Center, see Adding a plug-in configuration to a web server.

## Context and Dependency Injection (CDI)

Context and Dependency Injection (CDI) provides a common mechanism to inject component such as Enterprise JavaBeans (EJBs) or managed beans into other components such as JavaServer Pages (JSPs) or other EJBs.

CDI support is provided by Liberty, and is configured in the Liberty server configuration files (`server.xml` and included files) through the features that are described in Table 38 on page 174.

*Table 38. Liberty features that provide CDI support*

| Feature Name | CDI Specification Level | Specification Levels |
|---|---|---|
| `cdi-1.0` | CDI 1.0<br>**Note:** CDI 1.0 support in Liberty is stabilized. For more information, see Stabilized Liberty features and feature capabilities. | • Java EE 6.0 - Web Profile |
| `cdi-1.2` | CDI 1.2 | • Java EE 7.0 - Web Profile<br>• Java EE 7.0 - Full Profile<br>• Eclipse MicroProfile 1.0<br>• Eclipse MicroProfile 1.2 |
| `cdi-2.0` | CDI 2.0 | • Java EE 8.0 - Web Profile<br>• Java EE 8.0 - Full Profile<br>• Eclipse MicroProfile 1.2<br>• Eclipse MicroProfile 3.0<br>• Eclipse MicroProfile 4.1 |

CDI beans can be packaged in any of the following archive types: JARs, EJB JARs, or WARs. Any location on the application class path can contain CDI beans. For CDI beans to be registered into the container, the archive they are contained in must be declared as a *bean archive*. In CDI 1.0, only *explicit bean archives* are supported. CDI 1.1 introduces support for two types of bean archives, *explicit bean archives* and *implicit bean archives*.

*Explicit bean archives* must contain a `beans.xml` file, which must be at:

- `META-INF/beans.xml` for JAR types
- `WEB-INF/beans.xml`, or `WEB-INF/classes/META-INF/beans.xml` for WAR types.

The `beans.xml` file can be empty, or can contain XML data that is described by either the CDI 1.0 or CDI 1.1 schemas.

**Note:** CDI versions 1.2 and 2.0 use the version 1.1 schema.

*Implicit bean archives* must contain one or more bean classes with a *bean defining* annotation, or session bean.

Liberty provides a configuration option on whether implicit bean archives are enabled. In the CICS default `server.xml` template file, implicit bean archives are disabled. If implicit bean archives are enabled in Liberty, every application is scanned for the presence of CDI beans, causing unnecessary CPU usage. On a platform where CPU is chargeable, a more efficient approach is to disable implicit bean archives, and define applications that contain CDI beans as explicit bean archives by adding a `beans.xml` file.

Implicit bean archives can be enabled through the following configuration:

```
<cdi12 enableImplicitBeanArchives="true" />
```

**Related information**

https://www.cdi-spec.org/

Contexts and Dependency Injection behavior changes between releases

Administering Contexts and Dependency Injection applications on Liberty

# Accessing data from Java applications

You can write Java applications that can access and update data in Db2 and VSAM. Alternatively, you can link to programs in other languages to access Db2, VSAM, and IMS.

You can use any of the following techniques when writing a Java application to access data in CICS. The CICS recovery manager maintains data integrity.

## Accessing relational data

You can write a Java application to access relational data in Db2 by using any of the following methods:

- A JCICS **LINK** command to link to a program that uses Structured Query Language (SQL) commands to access the data.
- Where a suitable driver is available, use Java Data Base Connectivity (JDBC) or Structured Query Language for Java (SQLJ) calls to access the data directly. Suitable JDBC drivers are available for Db2. For more information about using JDBC and SQLJ application programming interfaces, see Using JDBC and SQLJ to access Db2 data from Java programs .
- JavaBeans that use JDBC or SQLJ as the underlying access mechanism. You can use any suitable Java integrated development environment (IDE) to develop such JavaBeans.

## Accessing DL/I data

To access DL/I data in IMS, your Java application must use a JCICS **LINK** command to link to an intermediate program that issues EXEC DLI commands to access the data.

## Accessing VSAM data

To access VSAM data, a Java application can use either of the following methods:

- The JCICS file control classes to access VSAM directly.
- A JCICS **LINK** command to link to a program that issues CICS file control commands to access the data.

# Interacting with structured data from Java

CICS Java programs often interact with data that was originally designed for use with other programming languages. For example, a Java program might link to a COBOL program by using a COMMAREA defined in a COBOL copybook, or read a record from a VSAM file where the data is defined by using an assembler language DSECT.

## Importing structured data into Java

You can use an importer to generate Java classes that facilitate the interaction with structured record data from other languages. The importers map the data types that are contained in the language structure source so that your Java application can easily set and get individual fields in the underlying record structure.

You can use IBM Record Generator for Java or the Rational Java EE Connector (J2C) Tools to interact with data to produce a Java class so that you can pass data between Java and other programs in CICS.

## IBM Record Generator for Java V3.0.0

IBM Record Generator for Java is a stand-alone utility that generates Java helper classes based on the associated-data (ADATA) files that are produced from compiling COBOL copybooks or assembler DSECTs. These Java helper classes can then be used in a Java application to marshal data to and from the COBOL-specific or assembler language-specific record structures.

For more information, see IBM Record Generator for Java V3.0.0.

### Rational J2C Tools

The Rational J2C Tools, resource adapters, and file importers enable you to create J2C artifacts that you can use to create enterprise applications that connect to enterprise information systems such as CICS. To use the Rational J2C Tools, you require Rational Application Developer for WebSphere Software or IBM Developer for z Systems.

The J2C Tools CICS/IMS Data Binding wizard generates Java classes that map to COBOL, PL/I, or C application program data structures, by using a customizable Eclipse based wizard. These helper classes can then be used in a Java application to marshal data to and from the language-specific record structures.

For more information, see Connecting to enterprise information systems in Rational Application Developer for WebSphere Software product documentation.

**Related information**

IBM Redbooks: IBM CICS and the JVM server: Developing and Deploying Java Applications

Building Java records from COBOL with the IBM Record Generator for Java

COBOL Importer overview in Rational Application Developer for WebSphere Software product documentation

Generating Java Records from COBOL with Rational J2C Tools

## Developing Java applications to use the JZOS Toolkit API in an OSGi JVM server

The IBM JZOS Toolkit consists of classes in package `com.ibm.jzos`, which is distributed with the IBM Java SDKs for z/OS in a single JAR file `ibmjzos.jar`.

These classes give Java applications on z/OS direct access to traditional z/OS data sets and files and access to z/OS system services and converter classes for mapping byte array fields into Java data types.

### Before you begin

If the JZOS Toolkit API is not downloaded to your workstation, then transfer the `ibmjzos.jar` file from the relevant version of the IBM Java SDK on z/OS to your workstation.

**Important:** If you are using IBM CICS Explorer or an Eclipse-based IDE running version 2022-03 or later, your default compiler compliance level must match the Java version of the target runtime to which the application or sample is deployed to avoid issues. You can change this setting in IBM CICS Explorer by selecting Preferences, then Java, and then Compiler.

### Procedure

1. Set the Target platform. To prepare to use the JCICS API in your development environment, set the Eclipse Target Platform to ensure it can resolve locally. In an OSGi development environment Target Platform definitions are used to define the plug-ins that applications in the workspace is built against. For CICS Explorer use the Eclipse menu, **Windows** > **Preferences** > **Plug-in Development** > **Target Platform**. Click **Add**, and from the supplied templates select the CICS TS release for your runtime environment. Don't forget to apply the target platform to your workspace.
2. Create an OSGi wrapper bundle for the JZOS Toolkit. If you have the IBM CICS SDK for Enterprise Java (Liberty) plug-in, then select **File** > **Import** > **Java Archive into an OSGi bundle** to create a new OSGi Bundle Project. Ensure that the newly created bundle exports all the available JZOS Toolkit packages that are required by the Java application such as `com.ibm.jzos`, `com.ibm.jzos.fields`, or `com.ibm.jzos.wlm`. This ensures that these packages are available to be imported by other OSGi projects in the Eclipse workspace.

   For example

```
Export-Package: com.ibm.jzos,
  com.ibm.jzos.fields
```

3. Create a CICS Java application.
   a) Create an OSGi Bundle Project in Eclipse by using the wizard **File** > **New** > **Other Plug-in Project**.
   b) Create a Java package `com.ibm.cicsdev.jzos.sample` and add a class ZFilePrint.
   c) Copy in the following code example, which opens an MVS data set pointed to by the `//INPUT DD` and writes the output to a CICS temporary storage queue.

```
package com.ibm.cicsdev.jzos.sample;

import com.ibm.jzos.ZFile;
import com.ibm.jzos.ZUtil;
import com.ibm.cics.server.TSQ;

public class ZFilePrint
{
    public static void main(String[] args) throws Exception
    {
        ZFile zFile = new ZFile("//DD:INPUT", "rb,type=record,noseek");
        TSQ tsqQ = new TSQ();
        tsqQ.setName("JZOSTSQ");

        try
        {
            byte[] recBuf = new byte[zFile.getLrecl()];
            int nRead;
            String encoding = ZUtil.getDefaultPlatformEncoding();

            while ((nRead = zFile.read(recBuf)) >= 0)
            {
                String line = new String(recBuf, 0, nRead, encoding);
                tsqQ.writeString(line);
            }
        }
        finally
        {
            zFile.close();
        }
    }
}
```

4. Add the following Import-Package statements to the bundle manifest for the JCICS and JZOS packages. The JCICS import should follow best practice to specify a range of versions the application operates with. Typically this range will go up to, but not include, the next API breaking change. For JCICS that would be version 2.0.0, so the range `com.ibm.cics.server;version="[1.401.0,2.0.0)"` is used in the example as this is the minimum level that is required to support the JCICS `TSQ.writeString()` method. The JZOS package is not taken from a versioned bundle. It is displayed to the runtime from the underlying JAR file with no version, and so `com.ibm.jzos` can be listed without a referenced version, which allows any available version (including 0.0.0) to be chosen.

```
Manifest-Version: 1.0
Bundle-ManifestVersion: 2
Bundle-Name: com.ibm.cicsdev.jzos.sample
Bundle-SymbolicName: com.ibm.cicsdev.jzos.sample
Bundle-Version: 1.0.0
Bundle-RequiredExecutionEnvironment: JavaSE-1.7
Import-Package: com.ibm.cics.server;version="[1.401.0,2.0.0)",
 com.ibm.jzos
```

5. Add a CICS-MainClass: definition to the bundle manifest to register a **MainClass** service for your `com.ibm.cicsdev.jzos.sample.ZFilePrint` class.

   This allows the Java class to be linked to using a CICS program definition. Your manifest now looks similar to the following example:

```
Manifest-Version: 1.0
Bundle-ManifestVersion: 2
Bundle-Name: com.ibm.cicsdev.jzos.sample
```

```
Bundle-SymbolicName: com.ibm.cicsdev.jzos.sample
Bundle-Version: 1.0.0
Bundle-RequiredExecutionEnvironment: JavaSE-1.7
Import-Package: com.ibm.cics.server;version="[1.401.0,2.0.0)",
 com.ibm.jzos
CICS-MainClass: com.ibm.cicsdev.jzos.sample.ZFilePrint
```

### Results

The application is now ready to be tested, and can be deployed into a CICS OSGi JVM server by using a CICS Bundle Project as follows:

1. Create a CICS Bundle Project in Eclipse and add the OSGi Bundle Project by using the menu **New OSGi Bundle Project Include**.
2. Deploy to zFS by using the menu **Export Bundle Project to z/OS UNIX file system**.
3. Create a CICS BUNDLE definition that references this zFS location and install it.
4. Create a CICS PROGRAM definition that names the CICS-MainClass: `com.ibm.cicsdev.jzos.sample.ZFilePrint` in the `JVMClass` attribute and install it.
5. Before you run the application, you need to define an MVS DD in the CICS JCL referencing a valid MVS data set and then restart your CICS region. For instance

   ```
   //INPUT    DD DISP=SHR,DSN=CICS.USER.INPUT
   ```

6. If you need to run the application from a 3270 console, create a TRANSACTION definition that references the PROGRAM defined in step 4.

When started, your Java class `ZFilePrint` reads the defined MVS data set by using the JZOS Toolkit API and then write the contents to a CICS temporary storage queue using the JCICS API.

## Accessing IBM MQ from Java programs

Java programs that run in CICS can use either the IBM MQ classes for Java, or the IBM MQ classes for JMS, to access IBM MQ. IBM MQ classes for JMS are the preferred interfaces to IBM MQ from a Java application that runs in CICS. (The IBM MQ classes for Java continue to be supported but newer applications should use IBM classes for JMS.

For an overview of how CICS works with IBM MQ, see CICS and IBM MQ.

IBM MQ classes for Java encapsulate the Message Queue Interface (MQI), the native IBM MQ API. The classes use a similar object model to the C++ and .NET interfaces to IBM MQ. In addition, you can exploit the full range of features of IBM MQ beyond the features that are available through JMS. IBM MQ classes for JMS implement the JMS interfaces for IBM MQ as the messaging system.

Three different JVM server environments in CICS support access to the IBM MQ classes:

- A CICS integrated-mode Liberty JVM server. This JVM server supports IBM MQ classes for JMS. It provides managed JMS connection factories and MDB support, and integrated CICS transactions and security. IBM MQ classes for Java are not supported.
- A CICS standard-mode Liberty JVM server. This JVM server supports IBM MQ classes for JMS. It provides managed JMS connection factories and MDB support but without integrated CICS transactions. IBM MQ classes for Java are not supported.
- An OSGi JVM server. This JVM server supports IBM MQ classes for JMS. It supports non-managed JMS connection factories with integrated CICS transactions and security. IBM MQ classes for Java are also supported, in bindings-mode only.

In addition, there are three different ways of connecting to IBM MQ from CICS:

- MQ client mode: a TCP/IP network connection to an IBM MQ queue manager
- MQ bindings mode: a local cross memory interface to the queue manager, using the IBM MQ RRS adapter

- CICS-MQ adapter and MQCONN: a local cross memory interface to the queue manager, using the CICS-MQ adapter

Table 39 on page 179 shows which JVM servers support which IBM MQ classes, and through which connectivity options.

*Table 39. Summary of CICS support for access to IBM MQ from a Java application*

| **MQ connectivity** | **CICS standard-mode Liberty JVM server** | **CICS integrated-mode Liberty JVM server** | **OSGi JVM server** |
|---|---|---|---|
| Client mode | • IBM MQ classes for JMS: JMS 1.1 and JMS 2.0<br>• IBM MQ classes for Java: not supported<br>For more information, see "Using IBM MQ classes for JMS in a CICS Liberty JVM server" on page 179 | • IBM MQ classes for JMS: JMS 1.1 and JMS 2.0<br>• IBM MQ classes for Java: not supported<br>For more information, see "Using IBM MQ classes for JMS in a CICS Liberty JVM server" on page 179 | Not supported |
| Bindings mode | • IBM MQ classes for JMS: JMS 1.1 and JMS 2.0<br>• IBM MQ classes for Java: not supported<br>For more information, see "Using IBM MQ classes for JMS in a CICS Liberty JVM server" on page 179 | Not supported | • IBM MQ classes for JMS: not supported<br>• IBM MQ classes for Java: supported<br>For imore nformation, see "Using IBM MQ classes for Java in an OSGi JVM server " on page 186 |
| CICS-MQ adapter and MQCONN | Not applicable | Not applicable | • IBM MQ classes for JMS: JMS 1.1 and JMS 2.0<br>• IBM MQ classes for Java: not supported<br>For information, see "Using IBM MQ classes for JMS in an OSGi JVM server" on page 182 |

## Using IBM MQ classes for JMS in a CICS Liberty JVM server

Java programs running in a CICS Liberty JVM server can use JMS to access IBM MQ. When the IBM MQ JMS feature is installed in a CICS Liberty JVM server, JMS requests are processed by the MQ messaging provider. Support for the JMS 2.0 feature gives access to the classic (JMS 1.1) and simplified (JMS 2.0) interfaces. CICS must be connected to a level of IBM MQ queue manager that supports the appropriate level of JMS and is using a suitable version of the IBM MQ classes for JMS.

For an introduction, see How it works: IBM MQ classes for JMS. For information about how IBM MQ implements JMS, see Using IBM MQ classes for JMS in the IBM MQ documentation, including IBM MQ classes for JMS JavaDoc and information about messages, application functions, and accessing MQ features in Writing IBM MQ classes for JMS applications. To compare levels of JMS specification, see Java Message Service Specification.

In a CICS Liberty environment, the IBM MQ messaging provider supports JMS connections to be made to an IBM MQ queue manager as follows:

- In a CICS integrated-mode Liberty JVM server, JMS applications can only connect to a queue manager using MQ client mode transport. The use of MQ bindings mode is not supported. This type of CICS Liberty JVM server provides JMS support, with integrated CICS transactions and security.

- In a CICS standard-mode Liberty JVM server, JMS applications can connect to a queue manager using either MQ bindings mode or client mode transports. This type of CICS Liberty JVM server provides JMS support, without integrated CICS transactions.

Your Java application communicates with IBM MQ in one of two ways:

- Through message-driven beans (MDBs)
- Through a servlet that uses a JMS connection factory

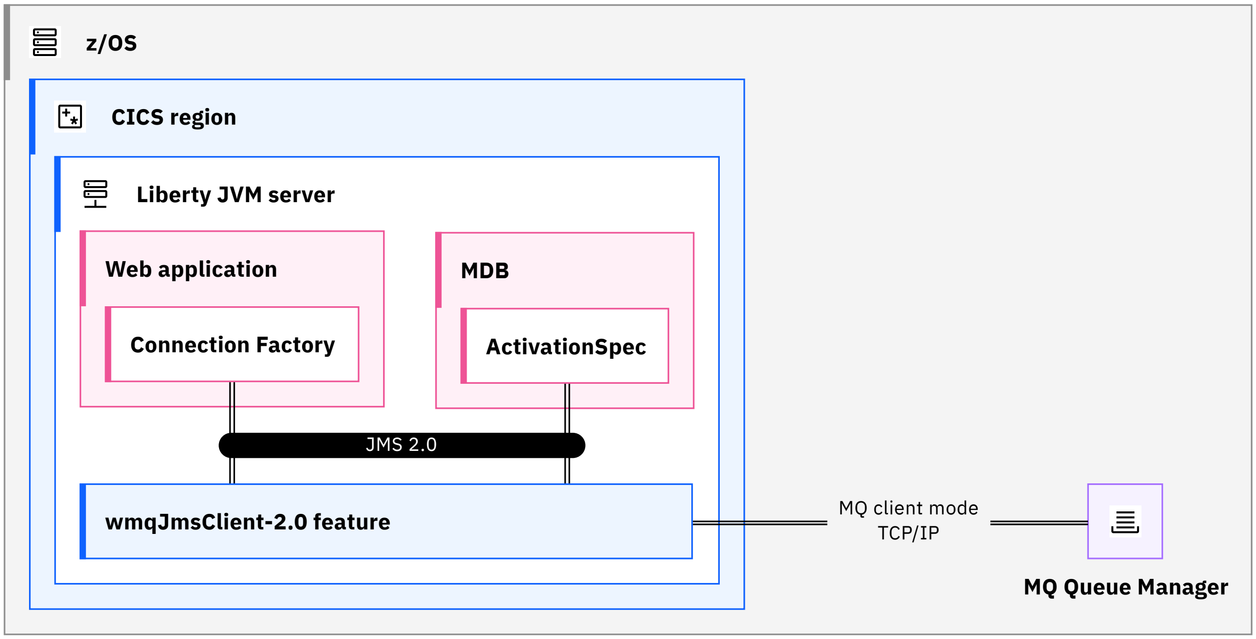


*Figure 32. Applications connecting to IBM MQ using JMS and running in a CICS Liberty JVM server*

## Things to check

- Your intended connection to IBM MQ is supported by your version of the CICS Liberty JVM server. See Table 39 on page 179 in " Accessing IBM MQ from Java programs " on page 178.
- The level of JMS that is supported by the IBM MQ queue manager that CICS connects to. IBM MQ for z/OS Version 7.1 only supports JMS 1.1. IBM MQ Version 8.0 and above support both JMS 1.1 and JMS 2.0.
- If you use bindings mode transport (supported only by CICS standard-mode Liberty) :
  - JMS applications that connect to an IBM MQ queue manager using bindings mode must specify a different queue manager to the queue manager that is specified on any CICS MQCONN resource installed in the same CICS region.
  - Both Liberty and IBM MQ are deployed on the same server.
- Any CICS tasks started using the CICSExecutorService must connect to a queue manager using client mode transport.
- There are some programming restrictions, described in "JMS programming considerations (Liberty JVM server)" on page 182.

## Where next?

To use JMS in an application, you must:

- Ensure that you have access to the IBM MQ classes for JMS in your development environment, either as a component of IBM MQ product or as a JAR file from FixCentral (see Using IBM MQ classes for JMS for information on how to do this.)
- Develop your application to use either managed JMS connection factory or message-driven beans (MDBs). For more information, see "Programming with IBM MQ classes for JMS with a Liberty JVM server " on page 181.
- Add your application to a CICS bundle project, export to zFS, and install it into the Liberty JVM server.
- Configure the CICS Liberty JVM server environment. In addition to configuring the `server.xml`, you must set up the IBM MQ resource adapter, which is needed to connect to IBM MQ from Liberty. For more information, see Configuring a Liberty JVM server to support JMS.

## Programming with IBM MQ classes for JMS with a Liberty JVM server

To use JMS in your CICS Java application to exchange messages with IBM MQ, you have two options. You can either use a message-driven bean (MDB) that receives incoming messages from an IBM MQ queue manager or a servlet that uses a JMS connection factory to send and receive JMS messages.

### Using a JMS connection factory

For a tutorial that shows how to develop this type of application, see CICS Developer Center: Developing an MQ JMS application for CICS Liberty. It includes links to a sample servlet and supporting code that you can download.

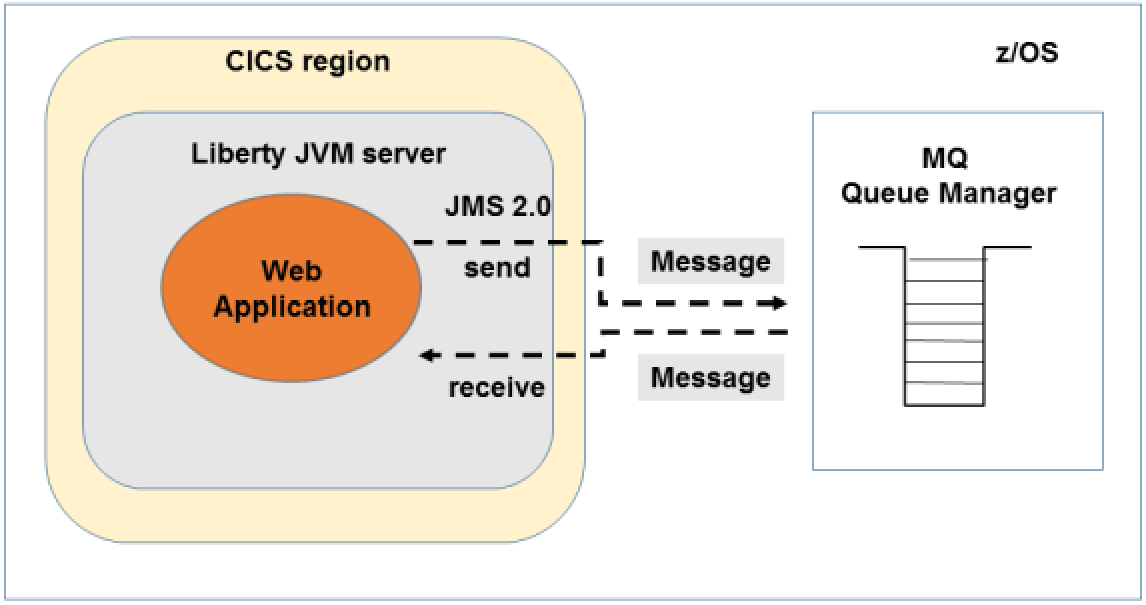


*Figure 33. Accessing IBM MQ through a Java application that uses JMS connection factory*

### Using message-driven beans (MDBs)

In this form of programming, the `onMessage()` method in the MDB is invoked when a message arrives on the queue that is associated with the MDB. A `javax.jms.Message` object is then passed as input to the MDB for further processing. An MDB is a type of EJB, so it can use either container-managed or bean-managed Java transactions

CICS Developer Center: Developing an MQ JMS application for CICS Liberty in the CICS developerCenter is a tutorial of how to develop this kind of application. It includes links to a sample servlet and supporting code that you can download.

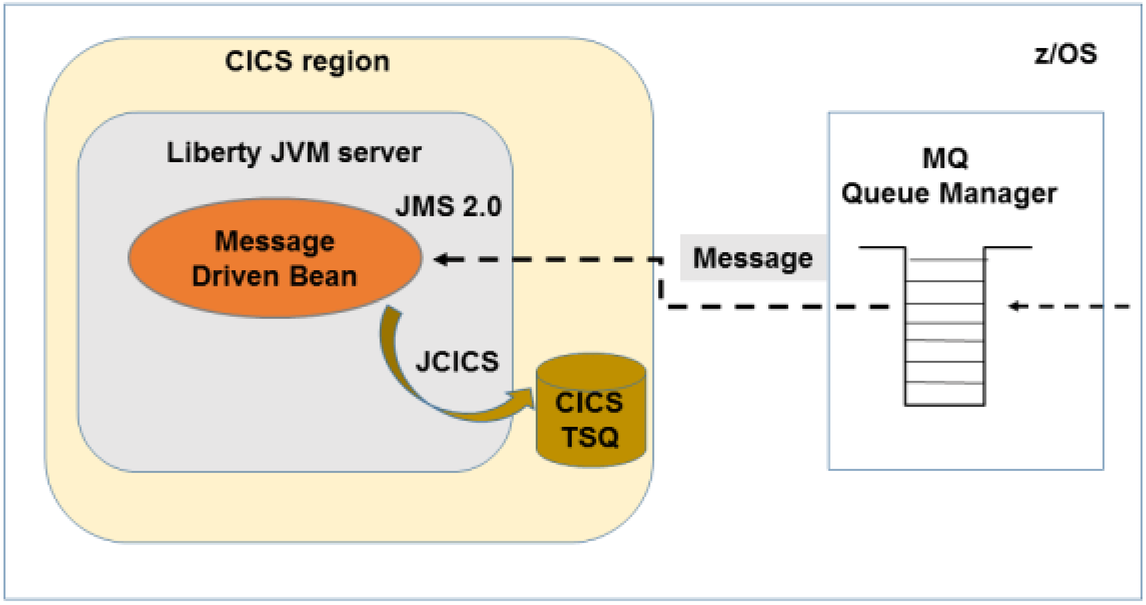


*Figure 34. Accessing IBM MQ through a Java application that uses MDBs*

### JMS programming considerations (Liberty JVM server)

- Any work submitted to the `CICSExecutorService` using the `runAsCICS()` method that work must not include any JMS requests.
- The CICS transaction ID under which the MDB request runs defaults to CJSU, which is the JVM server unclassified request processor. This can be modified per JVM server using the system property `com.ibm.cics.jvmserver.unclassified.tranid`.
- When you use JMS in a Liberty JVM server, messages sent and received by the IBM MQ classes for JMS are coordinated using the Liberty Transaction Manager. For updates to recoverable resources that are managed by CICS to be coordinated in the same unit-of-work, the application must use the Java Transaction API (JTA), either explicitly through the `UserTransaction.begin()` method or implicitly using an EJB container-managed transaction. To complete a UOW, use the `UserTransaction` `commit()` or `rollback()` methods. Using the EXEC CICS SYNCPOINT command (in a mixed-language application), or the `commit()` and `rollback()` methods on the following objects to commit or roll back the UOW is not supported:
  - `javax.jms.Session` (JMS 1.1 API)
  - `javax.jms.JmsContext` (JMS 2.0 API)
  - `com.ibm.cics.server.Task`

  For more information about JTA, see Java Transaction API (JTA).

## Using IBM MQ classes for JMS in an OSGi JVM server

Java programs running in an OSGi JVM server can use JMS to access IBM MQ. When a CICS Java application makes JMS requests, the requests are processed by the MQ messaging provider. Support is provided for using the classic (JMS 1.1) and simplified (JMS 2.0) interfaces, provided that CICS is connected to a level of IBM MQ queue manager that supports the appropriate level of JMS and is using a suitable version of the IBM MQ classes for JMS.

For an introduction, see How it works: IBM MQ classes for JMS. For information about how IBM MQ implements JMS, see Using IBM MQ classes for JMS in the IBM MQ documentation, including IBM MQ classes for JMS JavaDoc and information about messages, application functions, and accessing MQ features in Writing IBM MQ classes for JMS applications. To compare levels of JMS specification, see Java Message Service Specification

In a CICS environment, the IBM MQ classes for JMS allow connections to be made through an OSGi JVM server. This supports non-managed JMS connection factories, with integrated CICS transactions and security. If you want to use managed JMS connection factories or MDBs in your application, use a CICS Liberty JVM server instead.

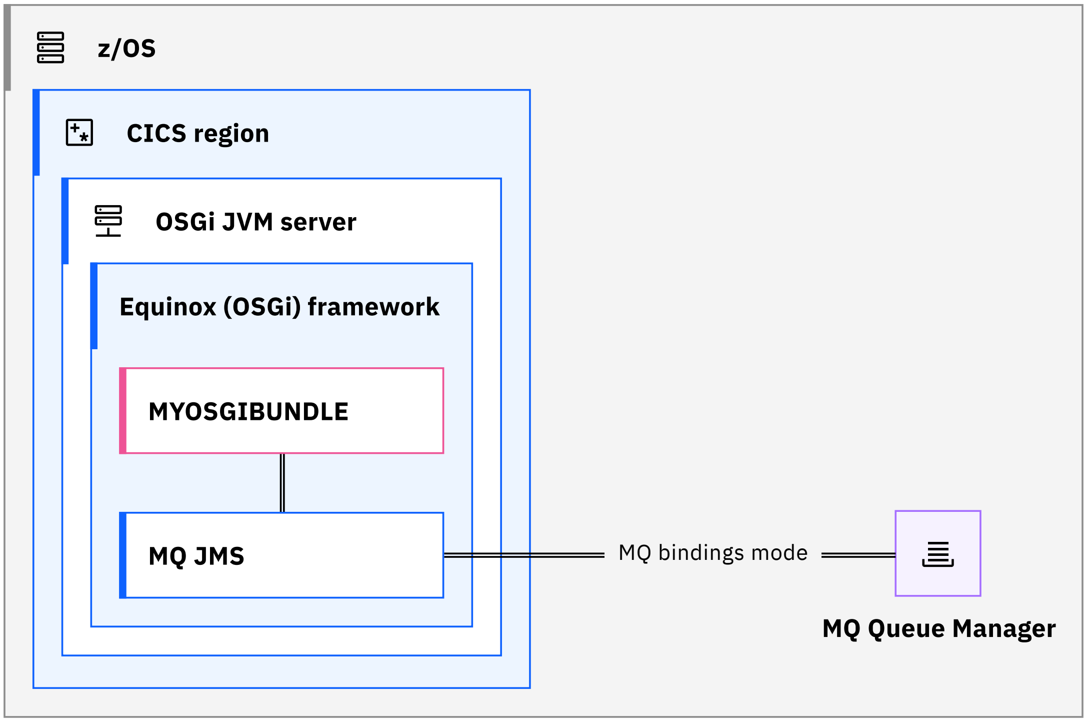


*Figure 35. Applications connecting to IBM MQ using JMS and running in a CICS OSGi server*

## Things to check

- The connection to IBM MQ. With an OSGi JVM server, only bindings mode connections to a local queue manager are supported.
- The level of JMS that is supported by the IBM MQ queue manager that CICS connects to. IBM MQ for z/OS Version 7.1 only supports JMS 1.1. IBM MQ Version 8.0 and above support both JMS 1.1 and JMS 2.0.
- You have defined a CICS MQCONN resource.
- There are some programming restrictions, described in “Programming with IBM MQ classes for JMS with an OSGi JVM server” on page 184.

## Where next?

To use JMS in an application, you must:

- Ensure that you have access to the IBM MQ classes for JMS in your development environment, either as a component of IBM MQ product or as a JAR file from FixCentral (see Using IBM MQ classes for JMS in the IBM MQ documentation for information on how to do this.)
- Develop your application to use non-managed JMS connection factory. For more information, see “Programming with IBM MQ classes for JMS with an OSGi JVM server” on page 184.
- Add your application to a CICS bundle project, export to zFS, and install it into the OSGi JVM server.
- Configure the CICS-MQ adapter. to connect to IBM MQ. For more information, see Setting up the CICS-MQ adapter.

- Configure the CICS OSGi server environment. For more information, see Configuring an OSGi JVM server to support JMS.

## Programming with IBM MQ classes for JMS with an OSGi JVM server

To use JMS in your CICS Java application to exchange messages with IBM MQ, you use a JMS connection factory.

for a tutorial that shows how to develop this type of application, see CICS Developer Center: Using MQ JMS in a CICS OSGi JVM server.

### JMS programming considerations (OSGi JVM server)

- Use of any of the XA connection factories, for example `com.ibm.mq.jms.MQXAConnectionFactory`, is not supported.
- Messages sent and received by the IBM® MQ classes for JMS in a JVM server environment are always associated with the CICS® unit of work (UOW) that is active on the current thread. That UOW can only be completed by calling the commit or rollback methods on the `com.ibm.cics.server.Task` object, or by the CICS task ending normally in which case the UOW is implicitly committed. (There is one exception to this, described in the next item in this list.) The values of the transacted and acknowledgeMode arguments are ignored when calling any of the `Connection.createSession`, or `ConnectionFactory.createContext` methods. Additionally, the following methods are not supported and calling them results in an `IllegalStateException` in the session case:
  - `javax.jms.Session.commit()`
  - `javax.jms.Session.recover()`
  - `javax.jms.Session.rollback()`

  and an `IllegalStateRuntimeSession` in the JMS context case:
  - `javax.jms.JMSContext.commit()`
  - `javax.jms.JMSContext.recover()`
  - `javax.jms.JMSContext.rollback()`
- The exception to the transactionality described above is this: if a session or JMS context is created using one of the following mechanisms:
  - `Connection.createSession(false, Session.AUTO_ACKNOWLEDGE)`
  - `Connection.createSession(Session.AUTO_ACKNOWLEDGE)`
  - `ConnectionFactory.createContext(JMSContext.AUTO_ACKNOWLEDGE)`

  then the behavior of that session, or JMS context, is as follows:
  - Any messages that are sent are transferred outside of the CICS UOW. That is, they are available on the target destination immediately, or when the provided delivery delay interval has completed.
  - Any non-persistent messages are received outside of the CICS UOW, unless the `syncPointAllGets` property is specified on the connection factory that created the session or JMS context.
  - Persistent messages are always received inside the CICS UOW.

  In a mixed-language application, an **`EXEC CICS SYNCPOINT`** command issued from a non-Java™ program will commit the whole unit of work, including the updates made to IBM MQ by a Java program.
- JMS provides support for a number of different listener interfaces such as `javax.jms.MessageListener`, `javax.jms.ExceptionListener` and, if using JMS 2, the `javax.jms.CompletionListener`. All of these interfaces result in MQ JMS using multiple threads which is not supported in a CICS environment. Attempting to register one of these listeners results in either a JMSException or a JMSRuntimeException.
- MQ JMS builds on the native support for IBM MQ in CICS so it makes use of the existing IBM MQ security support which is described in Security considerations for using IBM MQ with CICS . As a result,

any attempt to create either a connection or JMS context object while specifying a user id or password results in either a JMSException or JMSRuntimeException.

- A CICS MQCONN resource must be defined. The name of the queue manager, or queue sharing group, to which MQ JMS connects is taken from this MQCONN definition. Attempting to programmatically specify a queue manager, or queue sharing group has no effect.
- The following approaches can be used to create and configure the IBM MQ implementations of connection factories and destinations:
  - Using JNDI to retrieve administered objects
  - Using the IBM JMS extensions
  - Using the IBM MQ JMS extensions

  Most users of JMS use a JNDI repository to locate a pre-configured set of connection factories and destinations. CICS does not provide a JNDI implementation, and the use of LDAP is not possible in an OSGi environment.

  For details of the available options, and an example of how to register an initial context factory and the IBM MQ object factories with OSGi using the start method of a bundle adapter, see Creating and configuring connection factories and destinations.

  The connection between CICS and a IBM MQ queue manager is policed using the user ID of the CICS address space. Resource access to a queue is authorized by the transaction user ID. Specifying a user ID and password with a connection factory is therefore not supported.
- Any applications that make use of MQ JMS in CICS should make sure that all JMS resources are recreated from an MQConnectionFactory each time the application is run. I.e. application code should not store instances of sessions, message consumers, or any other MQ JMS objects in static variables so that they can be shared between runs of the application. This restriction exists because the CICS-MQ adapter tidies up any resources such as queue input handles when r the transaction that created them completes. Trying to use one of these resources in another run of the same, or any other, transaction results in JMS exceptions.
- From a JMS specification perspective, the IBM MQ classes for JMS treat a JVM server as a Java EE and Jakarta EE compliant application server, that always has a JTA transaction in progress. For example, you can never call `javax.jms.Session.commit()` in CICS, because the JMS specification states that you cannot call it in a JEE EJB, or Web container, while a JTA transaction is in progress. This results in restrictions to the JMS API in CICS.

The following restrictions apply to the classic JMS API (JMS 1.1):

- `javax.jms.Connection.createConnectionConsumer(javax.jms.Destination, String, javax.jms.ServerSessionPool, int)` always throws a JMSException
- `javax.jms.Connection.createDurableConnectionConsumer(javax.jms.Topic, String, String, javax.jms.ServerSessionPool, int)` always throws a JMSException.
- All three variants of `javax.jms.Connection.createSession` always throw a JMSException if the connection already has an existing session active.
- `javax.jms.Connection.createSharedConnectionConsumer(javax.jms.Topic, String, String, javax.jms.ServerSessionPool, int)` always throws a JMSException.
- `javax.jms.Connection.createSharedDurableConnectionConsumer(javax.jms.Topic, String, String, javax.jms.ServerSessionPool, int)` always throws a JMSException.
- `javax.jms.Connection.setClientID()` always throws a JMSException.
- `javax.jms.Connection.setExceptionListener(javax.jms.ExceptionListener)` always throws a JMSException.
- `javax.jms.Connection.stop()` always throws a JMSException.
- `javax.jms.MessageConsumer.setMessageListener(javax.jms.MessageListener)` always throws a JMSException.
- `javax.jms.MessageConsumer.getMessageListener()` always throws a JMSException.

- `javax.jms.MessageProducer.send(javax.jms.Destination, javax.jms.Message,javax.jms.CompletionListener)` always throws a JMSException.
- `javax.jms.MessageProducer.send(javax.jms.Destination, javax.jms.Message, int, int, long, javax.jms.CompletionListener)` always throws a JMSException.
- `javax.jms.MessageProducer.send(javax.jms.Message, int, int, long, javax.jms.CompletionListener)` always throws a JMSException.
- `javax.jms.MessageProducer.send(javax.jms.Message,javax.jms.CompletionListener )` always throws a JMSException.
- `javax.jms.Session.run()` always throws a JMSRuntimeException.
- `javax.jms.Session.setMessageListener(javax.jms.MessageListener)` always throws a JMSException.
- `javax.jms.Session.getMessageListener()` always throws a JMSException.

The following restrictions apply to the simplified JMS API (JMS 2.0):

- – `javax.jms.JMSContext.createContext(int)` always throws a JMSRuntimeException.
  – `javax.jms.JMSContext.setClientID(String)` always throws a JMSRuntimeException.
  – `javax.jms.JMSContext.setExceptionListener(javax.jms.ExceptionListener)` always throws a JMSRuntimeException.
  – `javax.jms.JMSContext.stop()` always throws a JMSRuntimeException.
  – `javax.jms.JMSProducer.setAsync(javax.jms.CompletionListener)` always throws a JMSRuntimeException.
  – `javax.jms.JMSConsumer.getMessageListener()` always throws a JMSRuntimeException.
  – `javax.jms.JMSConsumer.setMessageListener(javax.jms.MessageListener)` always throws a JMSRuntimeException.

### CICS abends during the processing of JMS requests

The use of IBM MQ classes for JMS and the bindings mode transport results in the issuing of IBM MQ MQI commands. CICS abends issued during processing of the MQI command are not converted into Java exceptions, and therefore are not catchable by a CICS Java application.

In this situation, the CICS transaction abends and rolls back to the last syncpoint.

## Using IBM MQ classes for Java in an OSGi JVM server

Java programs running in an OSGi JVM server can use the IBM MQ classes for Java, provided by IBM MQ, to access IBM MQ. The IBM MQ classes for Java provide a Java variant of the Message Queue Interface (MQI) that allows a CICS application to put and get messages to queues, using the MQ connection that is maintained by CICS. Support for use of IBM MQ classes for Java in CICS applications is provided from IBM MQ for z/OS 7.1.

In a CICS environment, the classes supplied by IBM MQ allow only connections to MQ in bindings mode. Any attempt to use connections to a remote queue manager in client mode results in an exception. In bindings mode, the call request is transformed into an IBM MQ MQI call, and is processed as normal by the existing CICS-MQ adapter. The converted requests flow into the CICS-MQ adapter in exactly the same way as MQI requests from any other program (for example, a COBOL program). So there are no operational differences between Java programs and other programs accessing IBM MQ.

To use the IBM MQ classes for Java in your application, you must:

- Ensure that you have access to the MQ classes for Java in your development environment. Unless you have IBM MQ installed on your workstation, get these from IBM MQ SupportPacs which entitle you to download the IBM MQ clients free of charge.
- Add your application to a CICS bundle project, export to zFS, and install it into the JVM server.

- Configure the CICS JVM server environment with the correct levels of the IBM MQ Java and native libraries. These must match the level of IBM MQ libraries that are specified in the CICS STEPLIB. For more information, see Configuring an OSGi JVM server to support IBM MQ classes for Java.

For information about the IBM MQ classes for Java, see Using IBM MQ classes for Java in the IBM MQ documentation. A list of the classes is in IBM MQ classes for JMS JavaDoc in the IBM MQ documentation. For a tutorial, see CICS Developer Center: Using MQ JMS in a CICS OSGi JVM server.

### Committing a unit of work involving WebSphere MQ requests

Messages sent and received by the IBM MQ classes for Java in a CICS JVM server environment are always associated with the CICS unit of work (UOW).

The UOW can only be completed by calling the commit or rollback methods on the `com.ibm.cics.server.Task` object, or by the CICS task ending normally, in which case the UOW is implicitly committed. Use of the transaction control methods on MQQueueManager is not supported.

For a mixed language application, an **`EXEC CICS SYNCPOINT`** command issued from a non- Java program will commit the whole unit of work, including the updates made to IBM MQ by a Java program.

### CICS abends during the processing of IBM MQ requests

The use of IBM MQ classes for Java results in the issuing of a IBM MQ MQI command. CICS abends issued during processing of the MQI command are not converted into Java exceptions, and therefore are not catchable by a CICS Java application.

In this situation, the CICS transaction will abend and roll back to the last syncpoint.

## Connectivity from Java applications in CICS

Java programs in the CICS environment can open TCP/IP sockets and communicate with external processes. You can use Java programs as a gateway to connect to other enterprise applications that might not be available to CICS programs in other languages. For example, you can write a Java program to communicate with a remote servlet or database.

In some cases, this connectivity is integrated with CICS to provide enterprise qualities of service, such as distributed transactions and identity propagation. In other cases, you can use connectivity without distributed transactions and other services provided by CICS. Depending on the type of connectivity you require, third party vendor products might be available which enable connectivity with enterprise applications that are not natively supported by CICS.

Generally, JVMs in the CICS environment are similar in capability to batch mode JVMs. A batch mode JVM runs as a stand-alone process outside the CICS environment, and is typically started from a UNIX System Services command line or with a JCL job. Most applications that can work in a batch mode JVM can also run in a JVM in CICS to the same extent. For example, if you write a batch mode Java application to communicate with a non-IBM database using a third-party JDBC driver, then the same application is likely to work in a JVM in CICS. If you want to use vendor supplied code such as non-IBM JDBC drivers in a JVM in CICS , consult with your vendor to determine whether they support their code running in a JVM in CICS.

For more information about Java application behavior in CICS , see “ Java runtime environment in CICS ” on page 37.

Batch mode applications that run in a JVM in the CICS environment do not usually exploit the capabilities of CICS. For example, if a Java program in CICS updates records in a non-IBM database using a third-party JDBC driver, CICS is not aware of this activity, and does not attempt to include the updates in the current CICS transaction.

# JCA local ECI support

You can deploy JCA ECI applications into a Liberty JVM server that is configured to use the JCA local ECI resource adapter. This topic applies to CICS integrated-mode Liberty only.

For information on developing applications refer to "Java EE Connector Architecture (JCA)" on page 145. To find out more about porting existing CICS Transaction Gateway applications, refer to "Porting JCA ECI applications into a Liberty JVM server" on page 147. For information on configuring JCA, see "Configuring the JCA local ECI resource adapter" on page 147.

The JCA ECI programming interfaces provided by the CICS TS JCA local ECI resource adapter are documented in Javadoc that is generated from the class definitions. The Javadoc is available at JCA local ECI Javadoc information.

The libraries and OSGi bundle required for application development are provided by the IBM CICS SDK for Java.

# Packaging existing applications to run in a JVM server

If you are running Java applications in pooled JVMs, you can move them to run in a JVM server. Because a JVM server can handle multiple requests for Java applications in the same JVM, you can reduce the number of JVMs that are required to run the same workload. You must package the Java application as one or more OSGi bundles. You can use one of three methods to package the application:

## Moving applications to a JVM server

If you are running Java applications in pooled JVMs, you can move them to run in a JVM server. Because a JVM server can handle multiple requests for Java applications in the same JVM, you can reduce the number of JVMs that are required to run the same workload.

### Before you begin

Ensure that the application is threadsafe and is packaged as one or more OSGi bundles. The OSGi bundles must be deployed in a CICS bundle to zFS and specify the correct target JVMSERVER resource.

The Java developer can use the CICS SDK for Java that is included with CICS Explorer to repackage a Java application using OSGi. For more information on how to migrate applications that use third party JARs, see Upgrading the Java environment .

### About this task

You can either use an existing JVM server or create a JVM server for your application. Do not move an application to a JVM server where the thread limit and usage are already high, because you might introduce locking contentions in the JVM server.

### Procedure

1. Create or update a JVM server:
   - If you decide to create a JVM server, see Configuring a Liberty JVM server . Many of the settings in a JVM profile for a pooled JVM do not apply to JVM servers. The only option that you might want to copy from the pooled JVM profile to the DFHOSGI profile is the `LIBPATH_SUFFIX` option.
   - If you use an existing JVM server, you might have to increase the THREADLIMIT attribute on the JVMSERVER resource to handle the additional application or update the options in the JVM server profile. If you change the JVM profile, restart the JVM server to pick up the changes.
2. Create a BUNDLE resource that points to the deployed bundle in zFS.

   When you install the BUNDLE resource, CICS loads the OSGi bundles into the OSGi framework in the JVM server. The OSGi framework resolves the OSGi bundles and registers the OSGi services.

Use CICS Explorer to check that the BUNDLE resource is enabled. You can also use the OSGi Bundles and OSGi Services views to check the state of the OSGi bundles and services.

3. Update the PROGRAM resource for the application:

   a) Ensure that the EXECKEY attribute is set to CICS .

      All JVM server work runs in CICS key.

   b) Remove the JVM profile name and enter the name of the JVMSERVER resource.

   c) Ensure that the JVMCLASS attribute matches the OSGi service of the Java application.

   d) Reinstall the PROGRAM resource for the application.

   The PROGRAM resource uses the OSGi service to make an OSGi bundle available to other CICS applications outside the JVM server.

### Results

When the Java application is called, it runs in the JVM server.

### What to do next

You can use the JVM server view in CICS Explorer and CICS statistics to monitor the JVM server. If the performance is not optimal, adjust the thread limit.

## Converting an existing Java project to a plug-in project

If you have an existing Java project, you can convert it to an OSGi plug-in project. The OSGi bundle can run in a pooled JVM environment and a JVM server.

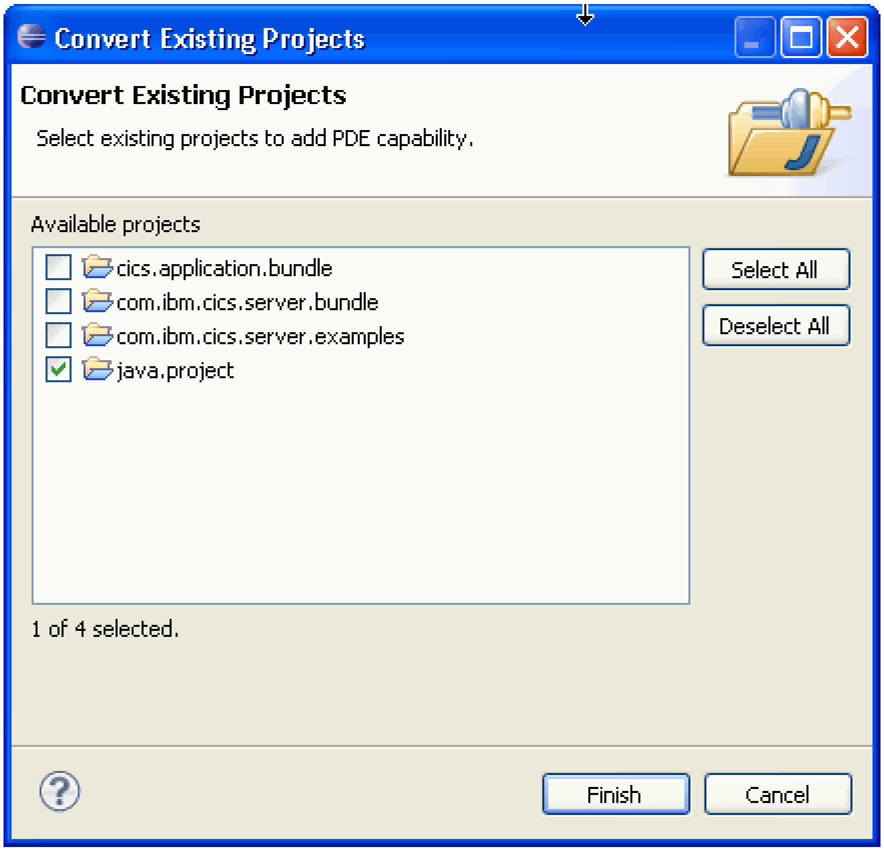
### About this task

This task assumes that you have an existing Java project in your workspace, and you want to convert it to an OSGi plug-in project.

### Procedure

1. In the Package Explorer view, right-click the Java project that you want to convert to a plug-in project, and click **Configure** > **Convert to Plug-in Projects**.

   The Convert Existing Projects dialog is displayed.



Convert Existing Projects

Convert Existing Projects

Select existing projects to add PDE capability.

Available projects

- ☐ cics.application.bundle
- ☐ com.ibm.cics.server.bundle
- ☐ com.ibm.cics.server.examples
- ☑ java.project

1 of 4 selected.

The dialog contains a list of all the Java projects in your workspace. The one you chose to convert is selected. You can change your selection, or select more than one Java project to convert to a plug-in project.

2. Click **Finish**.

   The Java project is converted to a plug-in project. The project name does not change, but the project now includes a manifest file and a build properties file.

3. Required: You must now edit the plug-in manifest file and add the JCICS API dependencies. If you do not perform these steps, you will be able to export and install the bundle, but it will not run.

   **Note:** In CICS versions before CICS TS version 4.2 you had to add the Java class library, `dfjcics.jar`, to the Java build path. With CICS TS version 4.2, OSGi manages the build path for you. Before you perform the following steps you must edit the current build path and remove any references to `dfhjcics.jar`. If you do not remove all references to `dfhjcics.jar`, a `NoSuchMethodException` error occurs at run time.

   a) In the Package Explorer view, right-click the project name and click **Plug-in Tools** > **Open Manifest**.

      The manifest file opens in the manifest editor.

   b) **Important**: In CICS versions before CICS TS version 4.2, the Java class library, known as JCICS, is supplied in the `dfjcics.jar` JAR file. In CICS TS version 4.2 the library is supplied in the `com.ibm.cics.server.jar` file. If your project manifest contains the declaration: **`Import-Package: dfhjcics.jar;`** you must remove the declaration before continuing with the remaining steps.

   c) Select the **Dependencies** tab and in the Imported Packages section, click **ADD**.

      The Package Selection dialog opens.

   d) Select the package `com.ibm.cics.server` and click **OK**.

      The package is displayed in the Imported Packages list.

   e) Optional: Repeat the previous step to install the following package, if it is required for your application:

**`com.ibm.record`**
The Java API for legacy programs that use IByteBuffer from the Java Record Framework that came with VisualAge. Previously in the `dfjcics.jar` file.

f) Select **File** > **Save** to save the manifest file.

### Results

You have successfully converted your existing Java project to a plug-in project.

### What to do next

You must now update the manifest file to add a CICS-MainClass declaration. For more information, see the related link.

## Importing the contents of a JAR file into an OSGi plug-in project

You can create a plug-in project from an existing JAR file. This method is useful when the application is already threadsafe and no refactoring or recompiling is required. The OSGi bundle can run in a pooled JVM environment and a JVM server.

### About this task

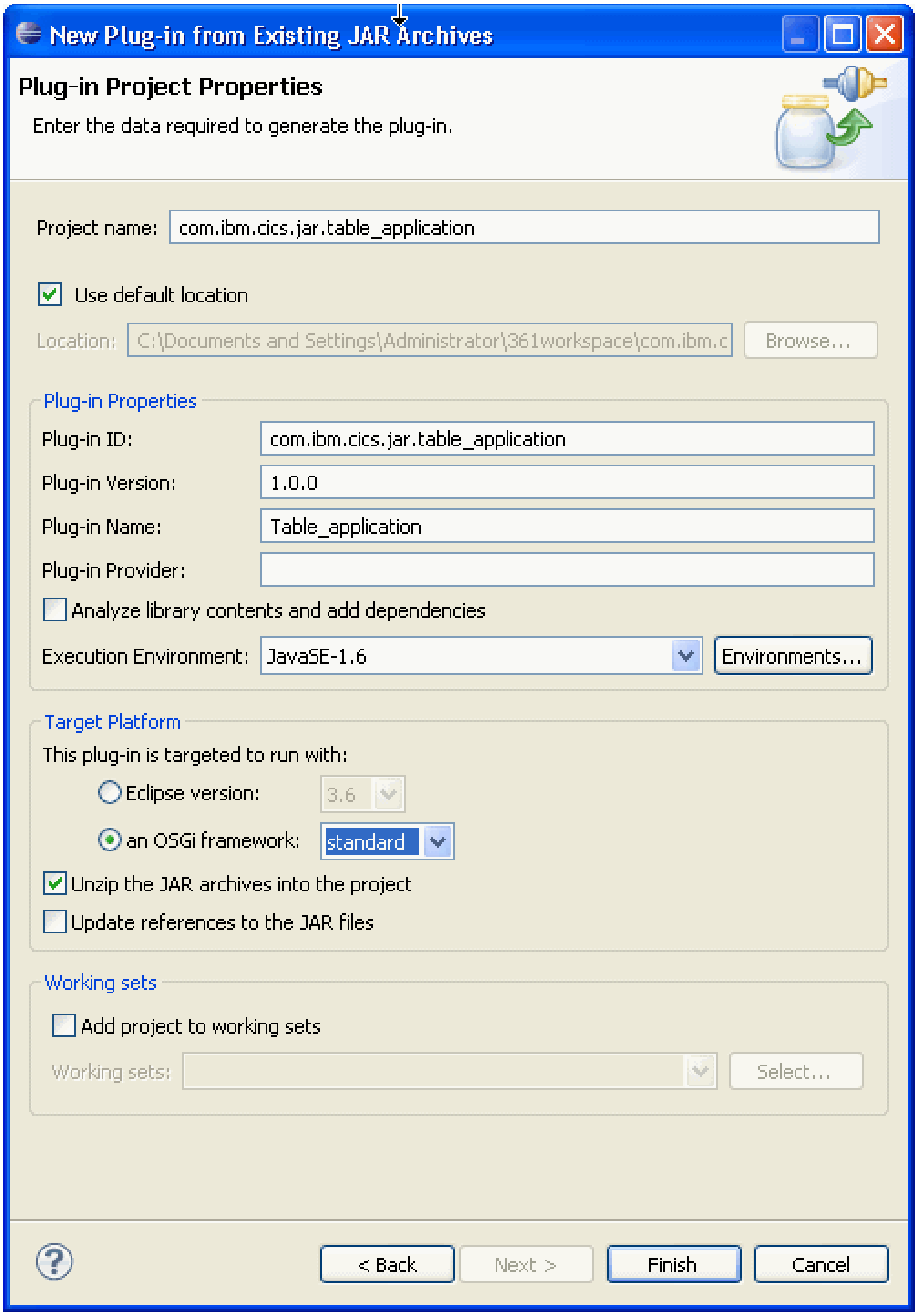
This task creates a new OSGi plug-in project from an existing JAR file. The JAR file must be on your local file system.

### Procedure

1. On the Eclipse menu bar, click **File** > **New** > **Project** to open the New wizard.
2. Expand the **Plug-in Development** folder and click **Plug-in from Existing JAR Archives**. Click **Next**.

   The JAR selection dialog opens.
3. Locate the JAR file to convert. If the file is in your Eclipse workspace, click **Add**. If the file is in a folder on your computer, click **Add External** and browse to the JAR file. Select the required file and click **Open** to add it in the Jar selection dialog. Click **Next**.

   The Plug-in Project Properties dialog opens.



New Plug-in from Existing JAR Archives

Plug-in Project Properties

Enter the data required to generate the plug-in.

Project name: com.ibm.cics.jar.table_application

☑ Use default location

Location: C:\Documents and Settings\Administrator\361workspace\com.ibm.c

Plug-in Properties

Plug-in ID: com.ibm.cics.jar.table_application

Plug-in Version: 1.0.0

Plug-in Name: Table_application

Plug-in Provider:

□ Analyze library contents and add dependencies

Execution Environment: JavaSE-1.6

Target Platform

This plug-in is targeted to run with:

○ Eclipse version: 3.6

● an OSGi framework: standard

☑ Unzip the JAR archives into the project

□ Update references to the JAR files

Working sets

□ Add project to working sets

Working sets:

4. In the **Project name** field, enter the name of the project that you want to create. A project name is mandatory.
5. Complete the following fields in the Plug-in Properties section as required:

   **Plug-in ID**

   The plug-in ID is automatically generated from the project name; however, you can change the ID if you want to.

   **Plug-in Name**

   The plug-in name is automatically generated from the project name; however, you can change the name if you want to.

**Execution Environment**
This field specifies the minimum level of JRE required for the plug-in to run. Select the Java level that matches the execution environment in your CICS runtime target platform.

6. In the Target Platform section, select **an OSGI framework** and select **standard** from the menu.
7. Ensure that **Unzip the JAR archives into the project** is selected and click **Finish**.

   Eclipse creates the plug-in project in the workspace.
8. Required: You must now edit the plug-in manifest file and add the JCICS API dependencies. If you do not perform these steps, you will be able to export and install the bundle, but it will not run.

   a) In the Package Explorer view, right-click the project name and click **Plug-in Tools** > **Open Manifest**.

      The manifest file opens in the manifest editor.

   b) Select the **Dependencies** tab and in the Imported Packages section, click **ADD**.

      The Package Selection dialog opens.

   c) Select the package `com.ibm.cics.server` and click **OK**.

      The package is displayed in the Imported Packages list.

   d) Optional: Repeat the previous step to install the following package, if it is required for your application:

      **`com.ibm.record`**
      The Java API for legacy programs that use IByteBuffer from the Java Record Framework that came with VisualAge. Previously in the `dfjcics.jar` file.

   e) Select **File** > **Save** to save the manifest file.

### Results

You have created an OSGi plug-in project from an existing JAR file.

### What to do next

You must now update the manifest file to add a CICS-MainClass declaration. For more information, see the related link.

## Importing a binary JAR file into an OSGi plug-in project

You can create a plug-in project from an existing binary JAR file. This method is useful in situations where there are licensing restrictions or where the binary file cannot be extracted. However, an OSGi bundle that contains a JAR file is not supported in a pooled JVM environment.

### About this task

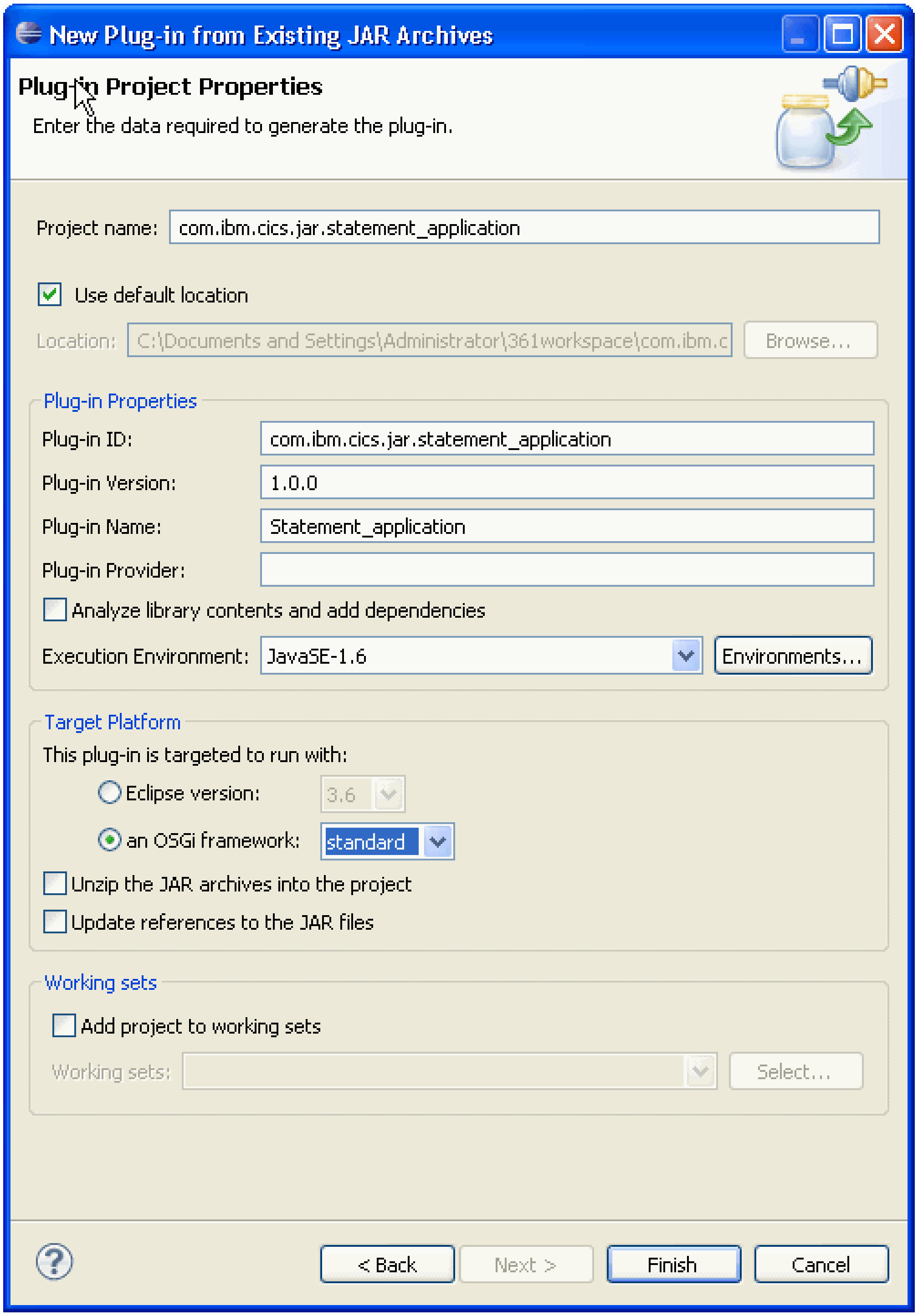
This task creates a new OSGi plug-in project from an existing binary JAR file. The JAR file must be on your local file system.

### Procedure

1. On the Eclipse menu bar click **File** > **New** > **Project** to open the New wizard.
2. Expand the **Plug-in Development** folder and click **Plug-in from Existing JAR Archives**. Click **Next**.

   The JAR selection dialog opens.
3. Locate the JAR file to convert. If the file is in your Eclipse workspace, click **Add**. If the file is in a folder on your computer, click **Add External** and browse to the JAR file. Select the required file and click **Open** to add it in the Jar selection dialog. Click **Next**.

   The Plug-in Project Properties dialog opens.



New Plug-in from Existing JAR Archives

Plug-in Project Properties

Enter the data required to generate the plug-in.

Project name: com.ibm.cics.jar.statement_application

☑ Use default location

Location: C:\Documents and Settings\Administrator\361workspace\com.ibm.c

Plug-in Properties

Plug-in ID: com.ibm.cics.jar.statement_application

Plug-in Version: 1.0.0

Plug-in Name: Statement_application

Plug-in Provider:

□ Analyze library contents and add dependencies

Execution Environment: JavaSE-1.6

Target Platform

This plug-in is targeted to run with:

○ Eclipse version: 3.6

● an OSGi framework: standard

□ Unzip the JAR archives into the project

□ Update references to the JAR files

Working sets

□ Add project to working sets

Working sets:

4. In the **Project name** field, enter the name of the project that you want to create. A project name is mandatory.
5. Complete the following fields in the Plug-in Properties section as required:

   **Plug-in ID**

   The plug-in ID is automatically generated from the project name; however, you can change the ID if you want to.

   **Plug-in Name**

   The plug-in name is automatically generated from the project name; however, you can change the name if you want to.

**Execution Environment**
This field specifies the minimum level of JRE required for the plug-in to run. Select the Java level that matches the execution environment in your CICS runtime target platform.

6. In the Target Platform section, select **an OSGI framework** and select **standard** from the menu.
7. Ensure that **Unzip the JAR archives into the project** is not selected and click **Finish**.

   Eclipse creates the plug-in project in the workspace. The project contains the binary JAR file but the project is not supported in a pooled JVM environment.
8. Required: You must now edit the plug-in manifest file and add the JCICS API dependencies. If you do not perform these steps, you will be able to export and install the bundle, but it will not run.
   a) In the Package Explorer view, right-click the project name and click **Plug-in Tools** > **Open Manifest**.

      The manifest file opens in the manifest editor.

   b) Select the **Dependencies** tab and in the Imported Packages section, click **ADD**.

      The Package Selection dialog opens.

   c) Select the package `com.ibm.cics.server` and click **OK**.

      The package is displayed in the Imported Packages list.

   d) Optional: Repeat the previous step to install the following package, if it is required for your application:

      **`com.ibm.record`**
      The Java API for legacy programs that use IByteBuffer from the Java Record Framework that came with VisualAge. Previously in the `dfjcics.jar` file.

   e) Select **File** > **Save** to save the manifest file.

## Results

You have successfully created the plug-in project in the workspace.

## What to do next

You must now update the manifest file to add a CICS-MainClass declaration. For more information, see the related link.

# Writing Java classes to redirect JVM stdout and stderr output

Use the USEROUTPUTCLASS option in a JVM profile to name a Java class that intercepts the `stdout` stream and `stderr` stream from the JVM. You can update this class to specify your choice of time stamps and record headers, and to redirect the output.

CICS supplies sample Java classes, `com.ibm.cics.samples.SJMergedStream` and `com.ibm.cics.samples.SJTaskStream`, that you can use for this purpose. Sample source is provided for both these classes in the directory `/usr/lpp/cicsts/cicsts56/samples/com.ibm.cics.samples`. The `/usr/lpp/cicsts/cicsts56` directory is the installation directory for CICS files on z/OS UNIX. This directory is specified by the **USSDIR** parameter in the DFHISTAR installation job. The sample classes are also shipped as a class file, `com.ibm.cics.samples.jar`, which is in the directory `/usr/lpp/cicsts/cicsts56/lib`. You can modify these classes, or write your own classes based on the samples.

Controlling the location for JVM output, logs, dumps and trace has information about:

- The types of output from JVMs that are and are not intercepted by the class that is named by the USEROUTPUTCLASS option. The class that you use must be able to deal with all the types of output that it might intercept.
- The behavior of the supplied sample classes. The `com.ibm.cics.samples.SJMergedStream` class creates two merged log files for JVM output and for error messages, with a header on each record that contains applid, date, time, transaction ID, task number, and program name. The log files are created by using transient data queues, if they are available; or z/OS UNIX files, if the transient data queues are not

available, or cannot be used by the Java application. The `com.ibm.cics.samples.SJTaskStream` class directs the output from a single task to z/OS UNIX files, adding time stamps and headers, to provide output streams that are specific to a single task.

For a JVM server to use an output redirection class, you must create an OSGi bundle that contains your output redirection class. You must ensure that the bundle activator registers an instance of your class as a service in the framework and sets the property `com.ibm.cics.server.outputredirectionplugin.name=`*`class_name`*. You can use the constant `com.ibm.cics.server.Constants.CICS_USER_OUTPUT_CLASSNAME_PROPERTY` to get the property name. The following code excerpt shows how you might register your service in the bundle activator:

```
Properties serviceProperties = new Properties();
    serviceProperties.put(Constants.CICS_USER_OUTPUT_CLASSNAME_PROPERTY,
MyOwnStreamPlugin.class.getName());
    context.registerService(OutputRedirectionPlugin.class.getName(), new MyOwnStreamPlugin(),
serviceProperties);
```

You can either add the OSGi bundle to the `OSGI_BUNDLES` option in the JVM profile, or ensure that the bundle is installed in the framework when the first task is run. Whichever method you use, you must still specify the class in the `USEROUTPUTCLASS` option.

If you decide to write your own classes, you need to know about:

- The `OutputRedirectionPlugin` interface
- Possible destinations for output
- Handling output redirection errors and internal errors

## The output redirection interface

CICS supplies an interface called `com.ibm.cics.server.OutputRedirectionPlugin` in `com.ibm.cics.server.jar`, which can be implemented by classes that intercept the stdout and stderr output from the JVM. The supplied samples implement this interface.

The following sample classes are provided:

- A superclass `com.ibm.cics.samples.SJStream` that implements this interface
- The subclasses `com.ibm.cics.samples.SJMergedStream` and `com.ibm.cics.samples.SJTaskStream`, which are the classes named in the JVM profile

Like the sample classes, ensure that your class implements the interface `OutputRedirectionPlugin` directly, or extends a class that implements the interface. You can either inherit from the superclass `com.ibm.cics.samples.SJStream`, or implement a class structure with the same interface. Using either method, your class must extend `java.io.OutputStream`.

The `initRedirect()` method receives a set of parameters that are used by the output redirection class or classes. The following code shows the interface:

```
package com.ibm.cics.server;

import java.io.*;

public interface OutputRedirectionPlugin {

  public boolean initRedirect( String inDest,
                               PrintStream inPS,
                               String inApplid,
                               String inProgramName,
                               Integer inTaskNumber,
                               String inTransid
                              );
  }
```

The superclass `com.ibm.cics.samples.SJStream` contains the common components of `com.ibm.cics.samples.SJMergedStream` and `com.ibm.cics.samples.SJTaskStream`. It contains an `initRedirect()` method that returns `false`, which effectively disables output redirection unless this method is overridden by another method in a subclass. It does not implement a `writeRecord()` method, and such a method must be provided by any subclass to control the output redirection process. You can use this method in your own class structure. The initialization of output redirection can also be performed using a constructor, rather than the `initRedirect()` method.

The **`inPS`** parameter contains either the original `System.out` print stream or the original `System.err` print stream of the JVM. You can write logging to either of these underlying logging destinations. You must not call the `close()` method on either of these print streams because they remain closed permanently and are not available for further use.

## Possible destinations for output

The CICS-supplied sample classes direct output from JVMs to a directory that is specific to a CICS region; the directory name is created using the applid associated with the CICS region. When you write your own classes, if you prefer, you can send output from several CICS regions to the same z/OS UNIX directory or file.

For example, you might want to create a single file containing the output associated with a particular application that runs in several different CICS regions.

Threads that are started programmatically using Thread.start() are not able to make CICS requests. For these applications, the output from the JVM is intercepted by the class you have specified for USEROUTPUTCLASS, but it cannot be redirected using CICS facilities (such as transient data queues). You can direct output from these applications to z/OS UNIX files, as the supplied sample classes do.

## Handling output redirection errors and internal errors

If your classes use CICS facilities to redirect output, they should include appropriate exception handling to deal with errors in using these facilities.

For example, if you are writing to the transient data queues CSJO and CSJE, and using the CICS-supplied definitions for these queues, the following exceptions might be thrown by TDQ.writeData:

- IOErrorException
- LengthErrorException
- NoSpaceException
- NotOpenException

If your classes direct output to z/OS UNIX files, they should include appropriate exception handling to deal with errors that occur when writing to z/OS UNIX. The most common cause of these errors is a security exception.

The Java programs that will run in JVMs that name your classes on the USEROUTPUTCLASS options should include appropriate exception handling to deal with any exceptions that might be thrown by your classes. The CICS-supplied sample classes handle exceptions internally, by using a Try/Catch block to catch all throwable exceptions, and then writing one or more error messages to report the problem. When an error is detected while redirecting an output message, these error messages are written to `System.err`, making them available for redirection. However, if an error is found while redirecting an error message, then the messages which report this problem are written to the file indicated by the STDERR option in the JVM profile used by the JVM that is servicing the request. Because the sample classes trap all errors in this way, this means that the calling programs do not need to handle any exceptions thrown by the output redirection class. You can use this method to avoid making changes to your calling programs. Be careful that you do not send the output redirection class into a loop by attempting to redirect the error message issued by the class to the destination which has failed.

# Chapter 4. Deploying applications to a JVM server

To deploy a Java application to a JVM server, the application must be packaged appropriately to install and run successfully. You can use the IBM CICS SDKs, or the CICS-provided Gradle or Maven plug-in to package and deploy the application.

You have a number of options for deploying Java applications:

- Deploy one or more CICS bundles that include the OSGi bundles for the application into a JVM server that is running an OSGi framework.
- Deploy one or more CICS bundles that include one or more WAR files into a Liberty JVM server.
- Deploy one or more CICS bundles that include Enterprise Bundle Archive (EBA) files into a Liberty JVM server.
- Deploy one or more CICS bundles that include EAR files into a Liberty JVM server.
- Deploy an application bundle that comprises the CICS bundles and OSGi bundles into a platform.

CICS provides two ways for you to deploy applications in CICS bundles:

- The IBM CICS SDK for Java and the IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer
- The Gradle or Maven plug-in that deploys bundles through the CICS bundle deployment API

For a complete list of deployment methods that CICS supports for different application and packaging types, see Design choices for Java in CICS.

## Deploying OSGi bundles in a JVM server

To deploy a Java application in a JVM server, you must install the OSGi bundles for the application in the OSGi framework of the target JVM server.

### Before you begin

The CICS bundle that contains the OSGi bundles for the application must be deployed to zFS. The target JVM server must be enabled in the CICS region.

### About this task

A CICS bundle can contain one or more OSGi bundles. Because the CICS bundle is the unit of deployment, all the OSGi bundles are managed together as part of the BUNDLE resource. The OSGi framework also manages the lifecycle of the OSGi bundles, including the management of dependencies and versioning.

Ensure that all OSGi bundles that comprise a Java application component are deployed in the same CICS bundle. If there are dependencies between OSGi bundles, deploy them in the same CICS bundle. When you install the CICS BUNDLE resource, CICS ensures that all the dependencies between the OSGi bundles are resolved.

If you have dependencies on an OSGi bundle that contains a library of common code, create a separate CICS bundle for the library. In this case, it is important to install the CICS BUNDLE resource that contains the library first. If you install the Java application before the CICS bundles that it depends on, the OSGi framework is unable to resolve the dependencies of the Java application.

Do not attempt to install a CICS bundle that contains an OSGi bundle into a Liberty JVM server, as this configuration is not supported. Instead, you can either package the OSGi bundle together with your web application in an enterprise bundle archive (EBA), or you can use the WebSphere Liberty bundle repository to make the OSGi bundle available to all web applications in the Liberty JVM server.

**If you're using CICS Explorer:** You can use the IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer to deploy bundles by following instructions in this topic.

**If you're using Gradle or Maven:** You can package and deploy applications in CICS bundles by using the CICS-provided Gradle or Maven plug-in, provided the CMCI JVM server is configured to use the CICS bundle deployment API.

This tutorial provides step-by-step instructions on how to build a CICS bundle from an existing Java application that is already built by Gradle or Maven.

## Procedure

1. Create a BUNDLE resource that specifies the directory of the bundle in zFS:

   a) In the CICS SM perspective, click **Definitions** > **Bundle Definitions** in the CICS Explorer menu bar to open the Bundles Definitions view.

   b) Right-click anywhere in the view and click **New** to open the New Bundle Definition wizard.

   Enter the details for the BUNDLE resource in the wizard fields.

   c) Install the BUNDLE resource.

   You can either install the resource in an enabled or disabled state:

   - If you install the resource in a DISABLED state, CICS installs the OSGi bundles in the framework and resolves the dependencies, but does not attempt to start the bundles.
   - If you install the resource in an ENABLED state, CICS installs the OSGi bundles, resolves the dependencies, and starts the OSGi bundles. If the OSGi bundle contains a lazy bundle activator, the OSGi framework does not attempt to start the bundle until it is first called by another OSGi bundle.
2. Optional: Enable the BUNDLE resource to start the OSGi bundles in the framework if the resource is not already in an ENABLED state.
3. Click **Operations** > **Bundles** in the CICS Explorer menu bar to open the Bundles view. Check the state of the BUNDLE resource.

   - If the BUNDLE resource is in an ENABLED state, CICS was able to install all the resources in the bundle successfully.
   - If the BUNDLE resource is in a DISABLED state, CICS was unable to install one or more resources in the bundle.

   If the BUNDLE resource failed to install in the enabled state, check the bundle parts for the BUNDLE resource. If any of the bundle parts are in the UNUSABLE state, CICS was unable to create the OSGi bundles. Typically, this state indicates that there is a problem with the CICS bundle in zFS. You must discard the BUNDLE resource, fix the problem, and then install the BUNDLE resource again.
4. Click **Operations** > **Java** > **OSGi Bundles** in the CICS Explorer menu bar to open the OSGi Bundles view. Check the state of the installed OSGi bundles and services in the OSGi framework.

   - If the OSGi bundle is in the STARTING state, the bundle activator has been called but not yet returned. If the OSGi bundle has a lazy activation policy, the bundle remains in this state until it is called in the OSGi framework.
   - If the OSGi bundles and OSGi services are active, the Java application is ready.
   - If the OSGi service is inactive it is possible that CICS detected an OSGi service with that name already exists in the OSGi framework.
   - If you disable the BUNDLE resource, the OSGi bundle moves to the RESOLVED state.
   - If the OSGi bundle is in the INSTALLED state, either it has not started or it failed to start because the dependencies in the OSGi bundle could not be resolved.
5. “Invoking a Java application in a JVM server” on page 204

## Results

The BUNDLE is enabled, the OSGi bundles are successfully installed in the OSGi framework, and any OSGi services are active. The OSGi bundles are available to other bundles in the framework.

### What to do next

You can make the Java application available to other CICS applications outside the OSGi framework, as described in "Invoking a Java application in a JVM server" on page 204.

## Deploying a Java EE application in a CICS bundle to a Liberty JVM server

You can deploy a Java EE application that is packaged as a CICS bundle in a Liberty JVM server.

### Before you begin

The Java EE application, either in the form of WAR files, EAR files or an EBA file, must be deployed as a CICS bundle in zFS. The target JVM server must be enabled in the CICS region.

For general information about creating Java applications, see "Developing applications using the IBM CICS SDKs" on page 39 or "Managing Java dependencies using Gradle or Maven" on page 46.

If you have dependencies on an OSGi bundle that contains a library of common code, install the bundle into the Liberty bundle repository, see "Deploying OSGi bundles in a JVM server" on page 199.

### About this task

The CICS application model is to package Java application components in CICS bundles and deploy them to zFS. By installing the CICS bundles, you can manage the lifecycle of the application components.

A Java EE application can contain:

- One or more WAR files that provide the presentation layer and business logic of the application
- An OSGi Application Project, exported to an EBA file, which contains a web-enabled OSGi Bundle Project to provide the presentation layer and a set of further OSGi bundles that provide the business logic
- An Enterprise Application Archive (EAR) file containing one or more WAR files that provide the presentation layer and business logic

**If you're using CICS Explorer:** You can use the IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer to deploy bundles by following instructions in this topic.

**If you're using Gradle or Maven:** You can package and deploy applications in CICS bundles by using the CICS-provided Gradle or Maven plug-in, provided the CMCI JVM server is configured to use the CICS bundle deployment API.

This tutorial provides step-by-step instructions on how to build a CICS bundle from an existing Java application that is already built by Gradle or Maven.

### Procedure

1. Create a BUNDLE resource that specifies the directory of the bundle in zFS:
   a) In the CICS SM perspective in CICS Explorer, click **Definitions** > **Bundle Definitions** in the CICS Explorer menu bar to open the Bundles Definitions view.
   b) Right-click anywhere in the view and click **New** to open the New Bundle Definition wizard.

      Enter the details for the BUNDLE resource in the wizard fields.
   c) Install the BUNDLE resource.

      You can install the resource in an enabled or disabled state:

      - If you install the resource in a DISABLED state, CICS does not attempt to install the Java EE applications into the Liberty server.
      - If you install the resource in an ENABLED state, CICS installs the Java EE applications (WAR, EAR, EBA files) in the `${server.output.dir}/installedApps` directory and adds an `<application>` entry into `${server.output.dir}/installedApps.xml`.

2. Optional: Enable the BUNDLE resource to start the Java EE applications in the Liberty server, if the resource is not already in an ENABLED state.
3. Click **Operations** > **Bundles** in the CICS Explorer menu bar to open the Bundles view. Check the state of the BUNDLE resource.

   - If the BUNDLE resource is in an ENABLED state, CICS installed all the resources in the bundle successfully and all Liberty applications included in the bundle have started.
   - If the BUNDLE resource is in an ENABLING state, CICS is currently installing all the resources in the bundle or one or more Liberty application included in the bundle are still installing or starting.
   - If the BUNDLE resource is in a DISABLED state, CICS was unable to install one or more resources in the bundle. This might happen if a Liberty application included in the bundle failed to start, or the application did not install in Liberty before the timeout. The timeout is configured by the JVM system property `com.ibm.cics.jvmserver.wlp.bundlepart.timeout`.

   If the BUNDLE resource failed to install in the enabled state, check the bundle parts for the BUNDLE resource. If any of the bundle parts are in the UNUSABLE state, a message is issued to explain the cause of the problem. For example, this state can indicate that there is a problem with the CICS bundle in zFS, or the associated JVMSERVER resource is not available. You must discard the BUNDLE resource, resolve the reported issue, and then install the BUNDLE resource again.
4. Optional: To run Java EE application requests on an application transaction, you can create URIMAP and TRANSACTION resources.

   Defining a URI map is useful if you want to control security to the application, because you can map the URI to a specific transaction and use transaction security. Typically, these resources are created as part of the CICS bundle and are managed with the application. However, you can choose to define these resources separately if preferred.

   a) Create a TRANSACTION resource for the application that sets the PROGRAM attribute to DFHSJTHP.

      This CICS program handles the security checking of inbound Java EE requests to the Liberty JVM server. If you set any remote attributes, they are ignored by CICS because the transaction must always attach in the local CICS region.

   b) Create a URIMAP resource that has a USAGE type of JVMSERVER. Set the TRANSACTION attribute to the name of the application transaction and set the SCHEME attribute to HTTP or HTTPS.

      You can also use the USERID attribute to set a user ID. This value is ignored if the application security authentication mechanisms are used. If no authentication occurs and no user ID is set on the URI map, the work runs under CICS default user ID.

### Results

The CICS resources are enabled, and the Java EE applications are successfully installed into the Liberty JVM server.

### What to do next

You can test that the Java application is available through a web client. To update or remove the application, see Administering Java applications.

## Deploying Java EE applications directly to a Liberty JVM server

You can deploy Java EE applications by defining the `application` element in `server.xml`, or by copying the application into a previously defined `dropins` directory.

### Before you begin

The JVM server must be configured to use Liberty technology.

## About this task

Java EE applications can be packaged as a Web Archive (WAR), a Enterprise Bundle Archive (EBA), or a Enterprise Application Archive (EAR).

Liberty provides two methods to install Java EE applications:

- You can add an `application` element in `server.xml`.
- Alternatively you can copy the application into the `dropins` directory of the Liberty JVM server. If you use `dropins`, CICS is will always run under the transaction CJSA and will not benefit from extra qualities of service such as CICS security.

**Note:**

- Do not use both techniques to deploy the same application into the same JVM server.
- If you accept the defaults that are provided by CICS autoconfigure, the `dropins` directory is not automatically created.

## Procedure

- **To deploy an application by adding it to the server configuration file:**

  You must configure the following attributes for the application element in the `server.xml`:

  - `id` - Must be unique and is used internally by the server.
  - `name` - Must be unique.
  - `type` - Specifies the type of application. The supported types are WAR, EBA, and EAR.
  - `location` - Specifies the location of the application. The location can be an absolute path or a URL.

  For example:

  ```
  <application
      id="com.ibm.cics.server.examples.wlp.tsq.app"
      name="com.ibm.cics.server.examples.wlp.tsq.app"
      type="eba"
      location="${server.output.dir}/path_to_app"/>
  ```

- **To create the `dropins` directory and deploy applications to it:**

  a) To enable `dropins`, you need to add configuration that is similar to the following example to your `server.xml`:

  ```
  <applicationMonitor dropins="dropins" dropinsEnabled="true" pollingRate="5s"
  updateTrigger="disabled"/>
  ```

  For more information, see Controlling dynamic updates.

  b) Use FTP to transfer the exported file in binary mode to the `dropins` directory. The directory path is `WLP_USER_DIR/servers/server_name/dropins`, where `server_name` is the value of the `com.ibm.cics.jvmserver.wlp.server.name` property. If the property is not set, the property is `defaultServer`.

## Results

The Liberty JVM server installs the application.

## What to do next

Access the Java EE application from a web browser to ensure that it is running correctly. To remove the application file, delete the WAR, EBA or EAR file from the `dropins` directory. If it was deployed with an application element, remove that element from `server.xml`.

# Deploying common libraries to a Liberty JVM server

Deploy the common libraries according to whether it is supplied as DLL files, JAR files or OSGi bundles.

## Procedure

- For common libraries supplied as DLL files, copy the files to a directory that is referred to by the `LIBPATH_SUFFIX` option of the JVM profile.

  For more information about LIBPATH_PREFIX and LIBPATH_SUFFIX, see Symbols used in the JVM profile.
- For common libraries supplied as OSGi bundle JAR files, copy the JAR files to a directory that is referred to in a bundleRepository definition in the `server.xml` file.

  For more information, see *Bundle repository* in Manually tailoring server.xml.
- For common libraries supplied as JAR files but not OSGi bundles, copy the JAR files to a directory that is referred to in a global library definition in the `server.xml` file.

  For more information, see *Global/shared library* in Manually tailoring server.xml.

# Invoking a Java application in a JVM server

There are many ways to call a Java application that is running in a JVM server. The method used will depend upon the characteristics of the JVM server.

## About this task

You can invoke a web application running in a Liberty JVM server by using a HTTP request with a specific URL. Web applications cannot be driven directly from **EXEC CICS LINK** or **EXEC CICS START**. If you have Enterprise Java applications that are implemented as Plain Old Java Objects (POJOs) and packaged in a WAR or an EAR, you can invoke their business logic components by using **EXEC CICS LINK** or **EXEC CICS START**.

To invoke a Java application that is running in an OSGi JVM server, you can either issue **EXEC CICS LINK** to a `PROGRAM` defined by Java, or **EXEC CICS START** a `TRANSACTION` that has a target `PROGRAM` defined by Java. The `PROGRAM` definition specifies a JVMSERVER, and the name of a CICS generated OSGi service you want to invoke. Such linkable OSGi services are created by CICS when you install an OSGi bundle that includes a `CICS-MainClass` header in its manifest. The `CICS-MainClass` header identifies the main method of the Java class in the OSGi bundle that you want to act as an entry-point to the application.

An OSGi service is a well-defined interface that is registered in the OSGi framework. OSGi bundles and remote applications use the OSGi service to call application code that is packaged in an OSGi bundle. An OSGi bundle can export more than one OSGi service. For more information, see Updating OSGi bundles in an OSGi JVM server.

Invoking Java function in a classpath based JVM server is usually performed as part of a specific capability of a JVM server, such as Batch, Axis2 and SAML. For these capabilities the DFHSJJI vendor interface is provided.

## Procedure

- For a web application developed as a web archive (WAR) file, as an enterprise application archive (EAR) file, or as an enterprise bundle archive (EBA) file containing web application bundle (WAB) files and running in a Liberty JVM server, invoke the application from the client browser by using a URL.

  For more information about invoking business logic components of Java EE applications, see “Preparing Java applications in a Liberty JVM server to be called by a CICS program” on page 123.
- For OSGi bundles that are deployed in an OSGi JVM server, follow these steps:

  a) Determine the symbolic name of the active OSGi service that you want to use in the OSGi framework.

Click **Operations** > **Java** > **OSGi Services** in CICS Explorer to list the OSGi services that are active.

b) Create a PROGRAM resource to represent the OSGi service to other CICS applications:

- In the JVM attribute, specify YES to indicate that the program is a Java program.
- In the JVMCLASS attribute, specify the symbolic name of the OSGi service. This value is case sensitive.
- In the JVMSERVER attribute, specify the name of the JVMSERVER resource in which the OSGi service is running.

c) You can call the Java application in either of two ways:

- Use a 3270 or **EXEC CICS START** request that specifies a transaction identifier. Create a TRANSACTION resource that defines the PROGRAM resource for the OSGi service.
- Use an **EXEC CICS LINK** request, an ECI call, or an EXCI call. Name the PROGRAM resource for the OSGi service when coding the request.

- For Axis2 or SAML function, see Configuring a JVM server for Axis2 and Configuring CICS for SAML.

### Results

You have created the definition to make your Java application available to other components. When CICS receives the request in the target JVM server, it invokes the specified Java class or Web application on a new CICS Java thread. If the associated OSGi service or Web application is not registered or is inactive, an error is returned to the calling program.

## Deploying a CICS non-OSGi Java application

The Java applications are included in a CICS bundle and can be deployed to a z/OS UNIX System Services (z/OS UNIX) file system using CICS Explorer, or using the CICS provided Gradle or Maven plug-in.

### About this task

This task outlines the steps to deploy a non-OSGi Java application. The process is the same as for an OSGi application; the only difference is that CICS uses the application JAR file instead of the bundle.

**If you're using CICS Explorer:** You can use the IBM CICS SDK for Java and the IBM CICS SDK for Enterprise Java (Liberty) in CICS Explorer to deploy bundles by following instructions in this topic. When you are not authorized to deploy the bundle directly to a z/OS file system, you can export the bundle as a compressed file. For more information, see Exporting a CICS bundle project to your local file system in the CICS Explorer product documentation

**If you're using Gradle or Maven:** You can package and deploy applications in CICS bundles by using the CICS-provided Gradle or Maven plug-in, provided the CMCI JVM server is configured to use the CICS bundle deployment API.

This tutorial provides step-by-step instructions on how to build a CICS bundle from an existing Java application that is already built by Gradle or Maven.

### Procedure

1. Convert the Java application to a plug-in project.

   Follow the instructions in "Converting an existing Java project to a plug-in project" on page 189.
2. Add the plug-in project to a CICS bundle.

   Follow the instructions in "Adding a project to a CICS bundle project" on page 44.
3. Deploy the bundle project to a z/OS Unix file system.

   Follow the instructions in Deploying a CICS bundle in the CICS Explorer product documentation.

### Results

The Java application is exported to z/OS UNIX. The exported bundle includes the application JAR files.

# Chapter 5. Setting up Java support

Perform the basic setup tasks to support Java in your CICS region and configure a JVM server to run Java applications.

### Before you begin

The Java components that are required for CICS are set up during the installation of the product. You must ensure that the Java components are installed correctly.

### About this task

CICS uses files in z/OS UNIX to start the JVM. You must ensure that your CICS region is configured to use the correct zFS directories, and that those directories have the correct permissions. After you configure CICS and set up zFS, you can configure a JVM server to run Java applications.

### Procedure

1. Set the JVMPROFILEDIR system initialization parameter to a suitable directory in z/OS UNIX where you want to store the JVM profiles that are used by the CICS region.

   For more information, see “Setting the location for the JVM profiles” on page 207.
2. Ensure that your CICS region has enough memory to run Java applications.

   For more information, see “Setting the memory limits for Java” on page 208.
3. Give your CICS region permission to access the resources that are held in z/OS UNIX, including your JVM profiles, directories, and files that are required to create JVMs.

   For more information, see “Giving CICS regions access to z/OS UNIX directories and files” on page 209.
4. Set up a JVM server.

   You can configure a JVM server to run different workloads. For more information, see “Setting up a JVM server” on page 211.
5. Optional: Enable a Java security manager to protect a Java application from performing potentially unsafe actions.

   For more information, see Enabling a Java security manager.
6. Set the `JAVA_DUMP_TDUMP_PATTERN` unformatted storage dump parameter.

   The dump is written to a sequential MVS data set, which can be changed by specifying a value for the environment variable `JAVA_DUMP_TDUMP_PATTERN`. Ensure that the CICS region user ID has UPDATE access to data sets matching this pattern, otherwise diagnostic data is lost. For more information, see Using dump agents on z/OS.

### Results

You set up your CICS region to support Java and created a JVM server to run Java applications.

### What to do next

If you are upgrading existing Java applications, follow the guidance in Upgrading. To start running Java applications in a JVM server, see Deploying applications to a JVM server.

## Setting the location for the JVM profiles

CICS loads the JVM profiles from the z/OS UNIX directory that is specified by the **`JVMPROFILEDIR`** system initialization parameter. You must change the value of the **`JVMPROFILEDIR`** parameter to a new location and copy the supplied sample JVM profiles into this directory so that you can use them to verify your installation.

### Before you begin

The USSHOME system initialization parameter must specify the root directory for CICS files on z/OS UNIX.

### About this task

The CICS-supplied sample JVM profiles are customized for your system during the CICS installation process, so you can use them immediately to verify your installation. You can customize copies of these files for your own Java applications.

The settings that are suitable for use in JVM profiles can change from one CICS release to another, so for ease of problem determination, use the CICS-supplied samples as the basis for all profiles. Check the upgrading information to find out what options are new or changed in the JVM profiles.

### Procedure

1. Set the JVMPROFILEDIR system initialization parameter to the location on z/OS UNIX where you want to store the JVM profiles used by the CICS region.

   The value that you specify can be up to 240 characters long.

   The supplied setting for the **`JVMPROFILEDIR`** system initialization parameter is `/usr/lpp/cicsts/cicsts56/JVMProfiles`, which is the installation location for the sample JVM profiles. This directory is not a safe place to store your customized JVM profiles, because you risk losing your changes if the sample JVM profiles are overwritten when program maintenance is applied. So you must always change **`JVMPROFILEDIR`** to specify a different z/OS UNIX directory where you can store your JVM profiles. Choose a directory where you can give appropriate permissions to the users who must customize the JVM profiles.
2. Copy the supplied sample JVM profiles from their installation location to the z/OS UNIX directory.

   When you install CICS, the sample JVM profiles are placed in a zFS directory. This directory is specified by the **`USSDIR`** parameter in the DFHISTAR installation job. The default installation directory is `/usr/lpp/cicsts/cicsts56/JVMProfiles`.

### Results

You have copied the sample JVM profiles to a zFS directory and configured CICS to use that directory. The sample JVM profiles contain default values so that you can use them immediately to set up a JVM server.

### What to do next

Ensure that CICS and Java have enough memory to run Java applications, as described in "Setting the memory limits for Java" on page 208. You must also ensure that the CICS region has access to the z/OS UNIX directories where Java is installed and the Java applications are deployed. For more information, see "Giving CICS regions access to z/OS UNIX directories and files" on page 209.

## Setting the memory limits for Java

Java applications require more memory than programs written in other languages. You must ensure that CICS and Java have enough storage and memory available to run Java applications.

### About this task

Java uses 24-bit (below-the-line) storage, 31-bit (above-the-line) storage, and 64-bit (above-the-bar) storage. The storage required for the JVM heap comes from the CICS region storage in MVS, and not the CICS DSAs.

### Procedure

1. Ensure that the z/OS **MEMLIMIT** parameter is set to a suitable value.

   This parameter limits the amount of 64-bit storage that the CICS address space can use. CICS uses the 64-bit version of Java and you must ensure that **MEMLIMIT** is set to a large enough value for both this and other use of 64-bit storage in the CICS region.

   See the following topics:

   - Calculating storage requirements for JVM servers
   - Estimating, checking, and setting MEMLIMIT in Improving performance

2. Ensure that the **REGION** parameter on the startup job stream is large enough for Java to run.

   Each JVM require some storage below the 16 MB line (24-bit storage) to run applications, including just-in-time compiled code, and working storage to pass parameters to CICS.

   For more instructions on estimating and setting the **REGION** parameter, see Estimating and setting REGION.

## Giving CICS regions access to z/OS UNIX directories and files

CICS requires access to directories and files in z/OS UNIX. During installation, each of your CICS regions is assigned a z/OS UNIX user identifier (UID). The regions are connected to an ESM group that is assigned a z/OS UNIX group identifier (GID). Use the UID and GID to grant permission for the CICS region to access the directories and files in z/OS UNIX.

### Before you begin

Ensure that you are either a superuser on z/OS UNIX, or the owner of the directories and files. The owner of directories and files is initially set as the UID of the system programmer who installs the product. The owner of the directories and files must be connected to the ESM group that was assigned a GID during installation. The owner can have that ESM group as their default group (DFLTGRP) or can be connected to it as one of their supplementary groups.

### About this task

z/OS UNIX System Services treats each CICS region as a UNIX user. You can grant user permissions to access z/OS UNIX directories and files in different ways. For example, you can give the appropriate group permissions for the directory or file to the ESM group to which your CICS regions connect. This option might be best for a production environment and is explained in the following steps.

### Procedure

1. Identify the directories and files in z/OS UNIX to which your CICS regions require access.

| JVM server options | Default directories | Permission | Description |
|---|---|---|---|
| JAVA_HOME | `/usr/lpp/java/J8.0_64` | read and execute | IBM 64-bit SDK for z/OS, Java Technology Edition directories |
| USSHOME | `/usr/lpp/cicsts/cicsts56` | read and execute | The installation directory for CICS files on z/OS UNIX. Files in this directory include sample profiles and CICS-supplied JAR files. |
| WORK_DIR | `/u/`*`CICS region userid`* | read, write, and execute | The working directory for the CICS region. This directory contains input, output, and messages from the JVMs. |

| JVM server options | Default directories | Permission | Description |
|---|---|---|---|
| JVMPROFILEDIR | *USSHOME*/JVMProfiles/ | read and execute | Directory that contains the JVM profiles for the CICS region, as specified in the **JVMPROFILEDIR** system initialization parameter. |
| WLP_USER_DIR | WORK_DIR/APPLID/ JVMSERVER/wlp/usr/ | read, write, and execute | Specifies the directory that contains the configuration files for the Liberty JVM server. WLP_USER_DIR needs additional x permissions (read, write, execute) if Liberty JVM server autoconfigure is used as CICS must be able to write to server.xml. |
| WLP_OUTPUT_DIR | WLP_USER_DIR/servers | read, write, and execute | Specifies the output directory for the Liberty JVM server. |

2. List the directories and files to show the permissions.

   Go to the directory where you want to start, and issue the following UNIX command:

   ```
   ls -la
   ```

   If this command is issued in the z/OS UNIX System Services shell environment when the current directory is the home directory of CICSHT##, you might see a list such as the following example:

   ```
   /u/cicsht##:>ls -la
   total 256
   drwxr-xr-x   2 CICSHT## CICSTS56     8192 Mar 15  2008 .
   drwx------   4 CICSHT## CICSTS56     8192 Jul  4 16:14 ..
   -rw-------   1 CICSHT## CICSTS56     2976 Dec  5  2010 Snap0001.trc
   -rw-r--r--   1 CICSHT## CICSTS56     1626 Jul 16 11:15 dfhjvmerr
   -rw-r--r--   1 CICSHT## CICSTS56        0 Mar 15  2010 dfhjvmin
   -rw-r--r--   1 CICSHT## CICSTS56      458 Oct  9 14:28 dfhjvmout
   /u/cicsht##:>
   ```

3. If you are using the group permissions to give access, check that the group permissions for each of the directories and files give the level of access that CICS requires for the resource.

   Permissions are indicated, in three sets, by the characters r, w, x and -. These characters represent read, write, execute, and none, and are shown in the left column of the command line, starting with the second character. The first set are the owner permissions, the second set are the group permissions, and the third set are other permissions.

   In the previous example, the owner has read and write permissions to dfhjvmerr, dfhjvmin, and dfhjvmout, but the group and all others have only read permissions.

4. If you want to change the group permissions for a resource, use the UNIX command chmod.
   The following example sets the group permissions for the named directory and its subdirectories and files to read, write, and execute. -R applies permissions recursively to all subdirectories and files:

   ```
   chmod -R g=rwx directory
   ```

   The following example sets the group permissions for the named file to read and execute:

   ```
   chmod g+rx filename
   ```

   The following example turns off the write permission for the group on two named files:

   ```
   chmod g-w filename filename
   ```

   In all these examples, g designates group permissions. If you want to correct other permissions, u designates user (owner) permissions, and o designates other permissions.

5. Assign the group permissions for each resource to the ESM group that you chose for your CICS regions to access z/OS UNIX. You must assign group permissions for each directory and its subdirectories, and for the files in them.

Enter the following UNIX command:

```
chgrp -R GID directory
```

*GID* is the numeric GID of the ESM group and *directory* is the full path of a directory to which you want to assign the CICS regions permissions.

For example, to assign the group permissions for the `/usr/lpp/cicsts/cicsts56` directory, use the following command:

```
chgrp -R GID /usr/lpp/cicsts/cicsts56
```

Because your CICS region user IDs are connected to the ESM group, the CICS regions have the appropriate permissions for all these directories and files.

### Results

You have ensured that CICS has the appropriate permissions to access the directories and files in z/OS UNIX to run Java applications.

When you change the CICS facility that you are setting up, such as moving files or creating new files, remember to repeat this procedure to ensure that your CICS regions have permission to access the new or moved files.

### What to do next

Verify that your Java support is set up correctly using the sample programs and profiles.

## Setting up a JVM server

To run Java applications, web applications, Axis2, or a CICS Security Token Service in a JVM server, you must set up the CICS resources and create a JVM profile that passes options to the JVM.

If you are configuring a CMCI JVM server, see Setting up CMCI for instructions instead. The CMCI JVM server is a special type of Liberty JVM server that provides support for the CMCI APIs. It is not used for hosting applications.

### About this task

A JVM server can handle multiple concurrent requests for different Java applications in a single JVM. The JVMSERVER resource represents the JVM server in CICS. The resource defines the JVM profile that specifies configuration options for the JVM, the program that provides values to the Language Environment enclave, and the thread limit. A JVM server can run different types of workload. A JVM profile is supplied for each different use of the JVM server:

- To run applications that are packaged as OSGi bundles, configure the JVM server with the `DFHOSGI.jvmprofile`. This profile contains the options to run an OSGi framework in the JVM server.
- To run applications that include Liberty in CICS, configure the JVM server with the `DFHWLP.jvmprofile`. This profile contains the options to run a web container that is based on Liberty technology. The web container also includes an OSGi framework and can therefore run applications that are packaged as OSGi bundles.
- To run SOAP processing for web services with the Axis2 SOAP engine, configure the JVM server with the `DFHJVMAX.jvmprofile`. This profile contains the options to run Axis2 in the JVM server.
- To run a CICS Security Token Service (STS), configure the JVM server with the `DFHJVMST.jvmprofile`. This profile contains the options to run an STS.

Any changes that you make to the profiles apply to all JVM servers that use it. When you customize each profile, make sure that the changes are suitable for all the Java applications that use the JVM server.

You can either configure JVM servers and JVM profiles with CICS online resource definition, or you can use the CICS Explorer to define and package JVMSERVER resources and JVM profiles in CICS bundles. For more information, see Working with bundles in the CICS Explorer product documentation.

### Results

The JVM server is configured and ready to run a Java workload.

### What to do next

Configure the security for your Java environment. Give appropriate access to application developers to deploy and install Java applications, and authorize application users to run Java programs and transactions in CICS.

## Configuring an OSGi JVM server

Configure the JVM server to run an OSGi framework if you want to deploy Java applications that are packaged in OSGi bundles.

### About this task

The JVM server contains an OSGi framework that handles the class loading automatically, so you cannot add standard class path options to the JVM profile. The supplied sample, DFHOSGI.jvmprofile, is suitable for an OSGi JVM server. This task shows you how to define a JVM server for an OSGi application from this sample profile.

You can define the JVM server either with CICS online resource definition or in a CICS bundle in CICS Explorer.

### Procedure

1. Create a JVMSERVER resource for the JVM server.
   a) Specify a name for the JVM profile for the JVM server.

      On the JVMPROFILE attribute of JVMSERVER, specify a 1 - 8 character name. This name is used for the prefix of the JVM profile, which is the file that holds the configuration options for the JVM server. You do not need to specify the suffix, .jvmprofile, here.

   b) Specify the thread limit for the JVM server.

      On the THREADLIMIT attribute of JVMSERVER, specify the maximum number of threads that are allowed in the Language Environment enclave for the JVM server. The number of threads depends on the workload that you want to run in the JVM server. To start with, you can accept the default value and tune the environment later. You can set up to 256 threads in a JVM server.
2. Create the JVM profile to define the configuration options for the JVM server.

   You can use the sample profile, DFHOSGI.jvmprofile, as a basis. This profile contains a subset of options that are suitable for starting the JVM server. All options and values for the JVM profile are described in "JVM profile validation and properties" on page 238. Follow the coding rules, including those for the profile name, in "Rules for coding profiles" on page 238.

   a) Set the location for the JVM profile.

      The JVM profile must be in the directory that you specify on the system initialization parameter, JVMPROFILEDIR. For more information, see "Setting the location for the JVM profiles" on page 207.

   b) Make the following changes to the sample profile:

      - Set JAVA_HOME to the location of your installed IBM Java SDK.
      - Set WORK_DIR to your choice of destination directory for messages, trace, and output from the JVM server.
      - Set TZ to specify the timezone for timestamps on messages from the JVM server. An example for the United Kingdom is TZ=GMT0BST,M3.5.0,M10.4.0.

   c) Save your changes to the JVM profile.

      The JVM profile must be saved as EBCDIC on the z/OS UNIX System Services file system.
3. Install and enable the JVMSERVER resource.

### Results

CICS creates a Language Environment enclave and passes the options from the JVM profile to the JVM server. The JVM server starts up and the OSGi framework resolves any OSGi middleware bundles. When the JVM server completes startup successfully, the JVMSERVER resource installs in the ENABLED state.

If an error occurs, for example CICS is unable to find or read the JVM profile, the JVM server fails to start. The JVMSERVER resource installs in the DISABLED state, and CICS issues error messages to the system log.

### What to do next

- Configure the location for JVM logs as described in Controlling the location for JVM output, logs, dumps and trace.
- Install OSGi bundles for the application in the OSGi framework of the JVM server, as described in Deploying OSGi bundles in a JVM server.
- Specify any directories that contain native C dynamic link library (DLL) files, such as Db2 or IBM MQ. You specify these directories on the LIBPATH_SUFFIX option in the JVM profile.
- Specify middleware bundles that you want to run in the OSGi framework. Middleware bundles are a type of OSGi bundle that contains Java classes to implement shared services, such as connecting to IBM MQ and Db2. You specify these bundles on the OSGI_BUNDLES option in the JVM profile.

## JVM profile example

Example JVM profile for an OSGi application.

The following excerpt shows an example JVM profile that is configured to start an OSGi framework that uses DB2 Version 11 and the JDBC 4.0 OSGi middleware bundle:

```
#**********************************************************************
#
#                         Required parameters
#                         -------------------
#
# When using a JVM server, the set of CICS options that are supported
JAVA_HOME=/usr/lpp/java/J8.0_64
WORK_DIR=.
LIBPATH_SUFFIX=/usr/lpp/db2v11/jdbc/lib
...
#**********************************************************************
#
#                    JVM server specific parameters
#                    ------------------------------
#
OSGI_BUNDLES=/usr/lpp/db2v11/jdbc/classes/db2jcc4.jar,\
             /usr/lpp/db2v11/jdbc/classes/db2jcc_license_cisuz.jar
OSGI_FRAMEWORK_TIMEOUT=60
#
#**********************************************************************
#
#                             JVM options
#                             -----------
# The following option sets the Garbage collection Policy.
#
-Xgcpolicy:gencon
#
#**********************************************************************
#
#                 Setting user JVM system properties
#                 ----------------------------------
#
# -Dcom.ibm.cics.some.property=some_value
#
#**********************************************************************
#
#              Unix System Services Environment Variables
#              ------------------------------------------
#
JAVA_DUMP_OPTS="ONANYSIGNAL(JAVADUMP,SYSDUMP),ONINTERRUPT(NONE)"
```

```
#
#
```

## Configuring OSGi package imports in CICS Java applications

The OSGi framework provides a comprehensive set of features for both application developers and JVM runtimes to control application modularity and declaration of dependencies.

Java applications that are deployed into CICS JVM servers need to be packaged as OSGi bundles. In the OSGi JVM server environment Java class loading is controlled by the embedded OSGi framework. For this reason, Java classes are not loaded by the traditional CLASSPATH configuration, instead, each OSGi bundle has its own class loader and is used in combination with the OSGi framework to resolve any dependencies. Dependencies are typically provided by other OSGi bundles, or from the underlying JRE by virtue of the OSGi system bundle.

Code that requires access to a Java package that is not included within its own OSGi bundle must explicitly import the package as part of the OSGi bundle definition. Imported packages are specified as a comma-separated list on the `Import-Package` statement in the OSGi manifest. Conversely, a bundle that is the provider of these required packages must explicitly export the package from its own OSGi bundle definition. Exported packages are listed on the `Export-Package` statement in the provider OSGi bundle manifest. When both OSGi bundles are deployed into the environment, the dependency can be resolved by the OSGi framework at runtime.

### Where are classes loaded from?

In an OSGi environment classes are loaded from the following locations, in search order:

1. The core JRE, or java.* packages
2. The parent class loader from the JVM boot class path (boot delegated packages)
3. Imported packages from other OSGi bundles, or from the OSGi framework system bundle
4. Required bundles (though best practice dictates Required bundles should be avoided)
5. The current OSGi bundle's class loader (including anything on the Bundle-classpath)
6. Bundle fragments
7. Dynamic Imports

### The JVM boot class path

Any `java.*` packages must be loaded by the JVM itself due to security restrictions in Java. Therefore, an OSGi bundle must not declare imports or exports for `java.*` packages - doing so is an error and installation of the bundle will fail. Class loading of `java.*` packages is implemented by delegation to the parent class loader of the JVM (referred to as *boot* delegation). Conversely, all other required packages such as `com.ibm.*` or Java SE components such as `javax.*` or `org.xml.sax` must be explicitly imported in the OSGi bundle manifest by using the relevant `Import-Package` statements.

### The OSGi framework

The system bundle is a special bundle that represents the OSGi framework and is used to export a variety of system components. Export definitions from the system bundle are treated like regular bundle exports - they can have version numbers and are used to resolve import definitions as part of the normal bundle resolution process. The advantage of this approach is that other bundles can provide alternative (newer) implementations of the same packages should it be necessary. By default, all `javax.*` packages are exported by the system bundle and so must be imported by using `Import-Package` statements in the application's bundle manifest. In addition, the CICS JVM server extends the list of exported system bundles by ensuring that key packages from the z/OS Java runtime are added to the default list exported by the system bundle. Examples of classes in this category are `com.ibm.jzos.fields.ByteArrayField` which is part of IBMJZOS and `javax.resource.cci.Record` which is part of JCA (Java Connector Architecture). Exports from the system bundle can be extended by adding additional packages to the system property org.osgi.framework.system.packages.extra. Note, all additional packages must already be available from the JRE classpath before they can be exposed by the OSGi system bundle.

If you need to determine what is exported from the system bundle, this can be queried by configuring the OSGi console using the following JVM server profile options, where port is a free TCP/IP port.

```
OSGI_CONSOLE=true
-Dosgi.console=port
-Dfile.encoding=ISO-8859-1
```

After restarting the JVM server, you can connect to this port using telnet and query the system bundle with the bundle 0 command, which produces a detailed listing:

```
>bundle 0
....
 Exported packages
   org.eclipse.core.runtime.adaptor; version="0.0.0"[exported]
   org.eclipse.core.runtime.internal.adaptor; version="0.0.0"[exported]
   org.eclipse.equinox.log; version="1.0.0"[exported]
.....
```

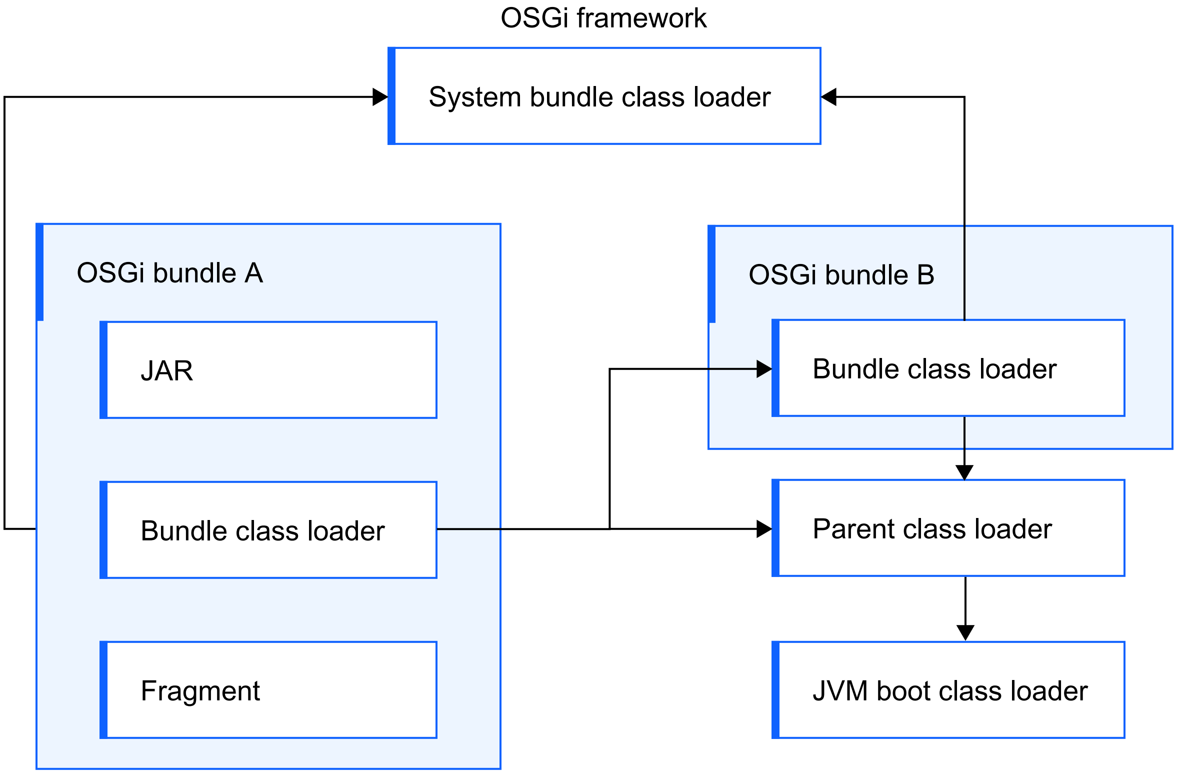


*Figure 36. OSGi package imports and class loaders*

## Imports from other bundles

OSGi bundles that are installed into the OSGi framework can export packages for import by any other installed bundle. In the CICS JVM server environment, the com.ibm.cics.server bundle is installed by CICS and provides the JCICS classes which wrapper the CICS API. In addition, if a third-party component is available as an OSGi bundle, it can also be installed as either:

- A middleware bundle using the JVM server OSGI_BUNDLES option. This is the usual approach for shared middleware components that do not need to be versioned without restarting the JVM server.
- An OSGi bundle deployed within a CICS bundle. This option is useful for a modularized application with separately versioned components that do not need to be shared between applications. This is because the same version of an OSGi bundle cannot be installed more than once into the OSGi framework and it

is usual for Java applications to be deployed in a single CICS bundle package to simplify deployment. If multiple CICS bundles contain duplicates of the same version of an OSGi bundle, then some of the CICS bundles will fail to install.

**Note:** If your application needs to import packages from a JAR that is not an OSGi bundle, then you can use the wrapping or injection techniques to create an OSGi bundle from the JAR, and export the required packages. You can then use either option in the list above to use this new OSGi bundle in your application. For more details on wrapping and injection refer to section 10.4 in IBM Redbook CICS and the JVM server – Developing and Deploying Java applications.

### Imports from the current bundle

All packages in the same OSGI bundle as the application are available to the bundle class loader. If your application requires access to classes from a JAR that is not OSGi enabled then this can be added to the bundle classpath using the `Bundle-ClassPath:` statement in the OSGI bundle manifest. This limits class loading of a JAR to the deployed bundle, and prevents sharing the JAR outside of the scope of the OSGi bundle.

**Note:** Since CICS TS V5.3, the OSGi framework defaults to using a last resort boot delegation strategy for packages not found through any of the above OSGi bundle dependency resolution mechanisms. This means that packages other than `java.*` can also be loaded from the JVM boot classpath once all other bundle class loaders have been searched. This behavior is controlled via the `osgi.compatibility.bootdelegation` system property and allows the OSGi runtime to be more tolerant if explicit dependencies were overlooked at development time. For strict OSGi compliance set this option to `false` and ensure all the packages used in your OSGi bundles are explicitly declared in the bundle manifest. For further details refer to JVM system properties.

## Configuring an OSGi JVM server to support JMS

You can configure an OSGi JVM server to support applications that use JMS.

### About this task

This task sets up the configuration for the OSGi JVM server to support applications that connect to IBM MQ using JMS. You configure CICS to connect to IBM MQ through the CICS-MQ adapter. The JMS bundles must be added to the set of middleware bundles that run in the OSGi framework within the JVM server. The framework must also have access to the associated set of IBM MQ native libraries.

Before you start, make sure that you review the considerations in Using IBM MQ classes for JMS in a CICS Liberty JVM server.

### Procedure

1. Set up the CICS-MQ adapter, as described in Setting up the CICS-MQ adapter.
2. Add the IBM MQ classes for JMS to the JVM server as an OSGi middleware bundle.

   Do this by including the following lines in the JVM profile of the JVM server:

   ```
   OSGI_BUNDLES=MQ_ROOT/OSGi/com.ibm.mq.osgi.allclientprereqs_VERSION.jar,\
   MQ_ROOT/OSGi/com.ibm.mq.osgi.allclient_VERSION.jar
   ```

   where *MQ_ROOT* is the `java/lib/` directory of the IBM MQ for z/OS® Unix System Services installation, for example, `/usr/lpp/V8R0M0/java/lib` and *VERSION* is the version of the IBM MQ classes for JMS used, for example, `8.0.0.0`.
3. Add the directory containing the IBM MQ classes for JMS native libraries to the `LIBPATH_SUFFIX` in the JVM profile of the JVM server.

   For example: `LIBPATH_SUFFIX=`*`MQ_ROOT`*.
4. Stop and restart the JVM server.

## Configuring an OSGi JVM server to support IBM MQ classes for Java

A JVM server is the runtime environment for Java applications. You can configure an OSGi JVM server to support applications that use IBM MQ classes for Java.

### About this task

To enable the OSGi JVM server to support applications that use IBM MQ classes for Java, IBM MQ for Java bundles need to be added to the set of middleware bundles that run in the OSGi framework within the JVM server. The framework must also have access to the associated set of native libraries.

### Procedure

1. Add the IBM MQ classes for Java to the JVM server as an OSGi middleware bundle.

   To add the classes, from IBM MQ Version 8.0, include the following lines in the JVM profile for the OSGi JVM server:

   ```
   OSGI_BUNDLES=<MQ_ROOT>/OSGi/com.ibm.mq.osgi.allclientprereqs_<VERSION>.jar,\
   <MQ_ROOT>/OSGi/com.ibm.mq.osgi.allclient_<VERSION>.jar
   ```

   For WebSphere MQ for z/OS Version 7.1, include the following line:

   ```
   OSGI_BUNDLES=<MQ_ROOT>/OSGi/com.ibm.mq.osgi.java_<VERSION>.jar
   ```

   where:

   - *MQ_ROOT* is the `java/lib/` directory of the IBM MQ for z/OS Unix System Services installation, for example, `/usr/lpp/V8R0M0/java/lib`.
   - *VERSION* is the version of the IBM MQ classes for Java that you are using, for example, `8.0.0.0`.
2. Add the directory containing the IBM MQ classes for Java native libraries to the LIBPATH_SUFFIX option in the JVM profile for the OSGi JVM server.

   For example:

   ```
   LIBPATH_SUFFIX=<MQ_ROOT>
   ```

   where *MQ_ROOT* is the `java/lib/` directory of the IBM MQ for z/OS Unix System Services installation, for example, `/usr/lpp/V8R0M0/java/lib`.

## Using Rational J2C data bindings in an OSGi JVM server

The J2C tooling in Rational Application Developer for WebSphere (RAD) can create CICS/IMS Java data bindings for accessing structured record data such as COBOL copybooks. J2C data bindings are created offline in the RAD environment, and then can be used in any Java runtime such as a CICS JVM server or WebSphere Application Server.

When used in CICS this scenario is an example of using OSGi enabled interfaces in the development environment that need to be added to the CICS JVM server environment. This is because the J2C tooling has a runtime dependency on the `marshall.jar` plug-in that is supplied with RAD. Perform the following steps to use the J2C data bindings in an OSGi JVM server.

1. Create the J2C data bindings using the wizard **File** > **New** > **J2C** > **CICS/IMS Java Data Binding** in RAD.
2. Import the required packages into your application by using the necessary OSGi `Import-Package` statements, for example: `Import-Package: com.ibm.etools.marshall, com.ibm.etools.marshall.util, javax.resource.cci`.
3. Locate the redistributable `marshall.jar` from your RAD installation. It is usually located in the `SDPShared\plugins\com.ibm.ccl.commonj.connector.metadata_nnn\runtime` folder.
4. Either wrapper the `marshall.jar` as an OSGi bundle and deploy to CICS as a middleware bundle, or add a `Bundle-ClassPath:` statement to the OSGI bundle manifest to make the packages in this JAR available to your application, as it is not provided by CICS or the z/OS Java SDK.

**Note:** The `Streamable` and `Record` interfaces from `javax.resource.cci` that are required by J2C are exported from the system bundle within the CICS JVM server environment. They do not need to be added in the same manner as used here for `marshall.jar`.

For more information, see Building Java Records from COBOL with Rational J2C tooling.

# Configuring a Liberty JVM server

Configure the Liberty JVM server if you want to deploy Java EE applications such as EJBs, JSP, JSF and servlets.

If you are configuring a CMCI JVM server, see Setting up CMCI for instructions instead. The CMCI JVM server is a special type of Liberty JVM server that provides support for the CMCI APIs. It is not used for hosting applications.

## About this task

You have two ways of configuring a Liberty JVM server:

**Autoconfigure**
CICS automatically creates and updates the configuration file for Liberty, `server.xml`, from templates that are supplied in the CICS installation directory. Autoconfigure gets you started quickly with a minimal set of configuration values in Liberty. To enable autoconfigure, set the JVM system property, **`-Dcom.ibm.cics.jvmserver.wlp.autoconfigure`** property to `true`. If you are defining the JVM server in a CICS bundle, set this option.

**Manually configuring**
This is the default setting. You supply the configuration files and all values. Manually configuring is appropriate where you want to remain in full control of the Liberty server configuration.

To define the JVM server, see Ways of defining CICS resources.

## Procedure

1. Create a JVMSERVER resource. If you want to create a JVMSERVER resource within a CICS bundle, see Artifacts that can be deployed in bundles.

   a) Specify a name for the JVM profile for the JVM server.

      On the JVMPROFILE attribute of JVMSERVER, specify a 1 - 8 character name. This name is used for the file name of the JVM profile, which is the file that holds the configuration options for the JVM server. You do not need to specify the file type, `.jvmprofile`, here.

   b) Specify the thread limit for the JVM server.

      On the THREADLIMIT attribute of the JVMSERVER, specify the maximum number of threads you want to allocate. The actual number of threads that are used depends on the workload that you run in the JVM server. To start with, you can accept the default value and tune the environment later. You can set up to 256 threads in a JVM server.

   c) Set the location for the JVM profile.

      The JVM profile must be in the directory that you specify on the system initialization parameter, **`JVMPROFILEDIR`**. For more information, see "Setting the location for the JVM profiles" on page 207.

2. Create the JVM profile to define the configuration options for the JVM server.

   You can use the sample profile, `DFHWLP.jvmprofile`, as a basis. This profile contains a subset of options that are suitable for starting the JVM server. All options and values for the JVM profile are described in "JVM profile validation and properties" on page 238. Follow the coding rules, including those for the profile name, in "Rules for coding profiles" on page 238.

   a) Make the following changes to the sample profile:

      - Set **`JAVA_HOME`** to the location of your installed IBM Java SDK.

- Set **`WORK_DIR`** to your choice of destination directory for messages, trace, and output from the JVM server.
- Set **`WLP_INSTALL_DIR`** to `&USSHOME;/wlp`
- Set **`TZ`** to specify the timezone for time stamps on messages from the JVM server. An example for the United Kingdom is `TZ=GMT0BST,M3.5.0,M10.4.0`
- Set **`-Dfile.encoding`** to ISO-8859-1, for example `-Dfile.encoding=ISO-8859-1`.
- (Optional) Set **`CICS_WLP_MODE`** to choose the level of integration between CICS and Liberty.

See Symbols used in the JVM profile for more information about JVM server options.

b) Save your changes to the JVM profile.

The JVM profile must be saved in EBCDIC file encoding on UNIX System Services and the file type must be `.jvmprofile`.

3. Create the Liberty server configuration.

Manually creating JVM servers is appropriate when the configuration files need to be carefully controlled. For more information, see "Manually creating a Liberty server" on page 222 and Manually tailoring server.xml.

**Important:** You should use autoconfigure if you are defining the JVM server in a CICS bundle, as the `server.xml` configuration file cannot be included with the JVM profile in a CICS bundle.

4. Install and enable the JVMSERVER resource.

## Results

The JVMSERVER reads the JVM profile and initializes itself based on the provided settings. If autoconfigure is enabled and a Liberty server configuration does not exist, it will be created. If autoconfigure is not enabled and there is no configuration, or the configuration is incorrect, the JVMSERVER will become DISABLED and report an appropriate failure. On subsequent start up, the JVMSERVER will use the existing configuration and launch the Liberty server instance. When the JVMSERVER completes startup successfully, the JVMSERVER resource installs in the ENABLED state.

If an error occurs, for example, CICS is unable to find or read the JVM profile, the JVM server fails to initialize. The JVM server is installed in the DISABLED state and CICS issues error messages to the system log. See Troubleshooting Liberty JVM servers and Java web applications for help. To confirm that Liberty successfully started within your JVM server, consult the `messages.log` file in the WLP_USER_DIR output directory on zFS.

⚠ **CAUTION:** Do not use the Liberty bin/server script to start or stop a Liberty server that is running in a JVM server.

**Note:** In CICS integrated-mode Liberty, the current number of threads indicated by the JVM server will return a positive value and can fluctuate even when no workload is running. This is because threads are pooled within Liberty for efficiency.

## What to do next

- Run the CICS Liberty default web application to verify the Liberty JVM server is running by using the following URL: `http://server:port/com.ibm.cics.wlp.defaultapp/`. For more information, see Configuring the CICS Default Web Application.
- Specify any directories that contain native C dynamic link library (DLL) files, such as IBM MQ. Middleware and tools that are supplied by IBM or by vendors might require DLL files to be added to the library path.
- Add support for security. See Configuring security for a Liberty JVM server.
- Install the Java EE applications (EAR files, WAR files, and EBA files), as described in Deploying a Java EE application in a CICS bundle to a Liberty JVM server.
- Liberty bootstrap properties can be placed in the JVM profile to achieve the same effect as using a Liberty bootstrap.properties file.

- By default, Liberty and OSGi caches are not cleared on start-up of the JVM server. If CICS maintenance has been applied since the JVM server last restarted, then the `--clean` option is used internally as a one-time operation to ensure caches are cleaned. If you subsequently encounter caching issues, or receive guidance from the IBM Service team to clean your server, this can be achieved by using one of two approaches:
  - Add `-Dcom.ibm.cics.jvmserver.wlp.args=--clean` to your JVM profile.
  - Add `-Dorg.osgi.framework.storage.clean=onFirstInit` to your JVM profile.

  In both cases, remove the option once the server has started to ensure subsequent restarts are not performance impacted.
- Be aware that by default, when Liberty is configured, two defaulted settings are applied but are not visible in `server.xml`. See CICS Liberty defaulted settings for more information.
- For more information on general Liberty set up see this overview on Liberty, Liberty overview.

## CICS standard-mode Liberty: Java EE Full Platform support without full CICS integration

Use the CICS embedded Liberty JVM server in standard mode to port and deploy Liberty applications from other platforms to CICS without changing your application. Standard mode is ideal for hosting applications that are written for and rely on the Java Enterprise Edition (Java EE) Full Platform, but do not require full integration with CICS. Applications running on CICS standard-mode Liberty can take advantage of Liberty services, management, and security, and benefit from the performance and capabilities of Java on z/OS, the z Systems platform, and close proximity to data in Db2 and IBM MQ.

CICS standard-mode Liberty is based on the Java EE 7 and Java EE 8 certified IBM WebSphere Application Server Liberty. Java EE extends the core Java SE by providing the APIs and environment for running multi-tiered, scalable, and secure network applications. Java EE includes the Web Profile, Enterprise JavaBeans, and Batch Applications for the Java Platform.

Manage the creation, life-cycle and configuration of CICS standard-mode Liberty using CICS JVM server technology. Applications running on CICS standard-mode Liberty do not have access to CICS resources by default, but can submit work to the `CICSExecutorService` using the `runAsCICS()` method. Work submitted to the `CICSExecutorService` has full access to the JCICS API, runs in a CICS unit-of-work under a CICS task, and is committed on completion of the thread. Work submitted to the `CICSExecutorService` does not have access to the Java EE APIs.

## Comparing CICS standard-mode Liberty and CICS integrated-mode Liberty

The two modes under which Liberty can run inside a JVM server are CICS standard-mode Liberty and CICS integrated-mode Liberty.

Both modes are configured by a single JVM profile option. See JVM server option CICS_WLP_MODE for details.

### CICS integrated-mode Liberty

In CICS integrated-mode Liberty, all web requests:

- Are fulfilled by CICS-enabled threads.
- Run under a CICS task.
- Provide access to CICS resources from Java web applications.

### CICS standard-mode Liberty

CICS standard-mode Liberty provides a Liberty server without automatic CICS integration. For example, this mode lacks the optimized performance of a dedicated CICS thread-pool. However, the following capabilities are retained:

- Life-cycle and administrative control over the Liberty server instance.

- CICS bundle application deployment.
- Programmatic opt-in to CICS-enabled threads, which provides access to CICS resources, CICS security, and native Db2 drivers.

## Side-by-side comparison

As the table highlights, it is more straightforward to migrate an application into CICS standard-mode Liberty than to CICS integrated-mode Liberty. This reflects the operation of Liberty outside of CICS, where there are no CICS-specific restrictions, or configurations. CICS standard-mode Liberty also offers increased zIIP-eligibility because native CICS-integration code does not run. Additionally, the reduction in CP cycles per request available in CICS standard-mode Liberty is because the native code is not bootstrapping into a CICS task environment for each request.

| Capability | CICS integrated-mode Liberty | CICS standard-mode Liberty |
|---|---|---|
| Supported feature set | Java EE 8 / Jakarta EE 8 Full Platform<br>Java EE 8 / Jakarta EE 8 Web Profile<br>Java EE 7 Full Platform<br>Java EE 7 Web Profile<br>Java EE 6 Web Profile | Java EE 8 / Jakarta EE 8 Full Platform<br>Java EE 8 / Jakarta EE 8 Web Profile<br>Java EE 7 Full Platform<br>Java EE 7 Web Profile<br>Java EE 6 Web Profile |
| Java CICS API (JCICS) | Yes | Yes under `runAsCICS()` API only |
| Native driver for Db2 | Yes | Yes under `runAsCICS()` API only |
| Ease of application migration to CICS Liberty | Moderate | Easy |
| Asynchronous operations and nested transactions | Some restrictions | Yes |
| CICS bundle deployment of application | Yes | Yes |
| CICS Liberty autoconfiguration available | Yes | Yes |
| JVM server creates and controls the Liberty server? | Yes | Yes |
| zIIP eligibility | Up to 90% | Up to 99% |
| CP | Integration overhead | Minimal overhead |
| CICS thread-pool optimizations | Yes | No |

As applications look to use CICS resources and integrate with CICS capabilities (for example, JDBC type 2), CICS standard-mode Liberty requires you to programmatically opt in to a CICS-enabled environment by using the `CICSExecutorService.runAsCICS()` API. As with CICS integrated-mode Liberty, more overhead and zIIP-eligibility reduction are the tradeoffs for running under CICS tasks. CICS standard-mode Liberty requires that your CICS resource work is isolated in discrete operations that can be run through the `runAsCICS()` API. You get the most out of CICS standard-mode Liberty by minimizing access to CICS and limiting that access to specific application components.

As the level of CICS integration increases, the cost of running in CICS standard-mode Liberty compared to CICS integrated-mode Liberty rises. Although both environments can put your workload into a CICS-enabled environment, CICS integrated-mode Liberty uses an internal thread-pool and other scalability optimizations compared to the one-shot CICS-enabled threads of CICS standard-mode Liberty. There is also one other important distinction - the one-shot threads used to satisfy `runAsCICS()` requests are not Enterprise Java capable. You cannot mix JCICS with Enterprise Java. Conversely, requests running in CICS integrated-mode Liberty (using the optimized thread-pool technology) can happily mix Enterprise Java APIs and JCICS APIs.

## JVM profile example

Example JVM profile for Liberty server.

The following excerpt shows an example JVM profile that is configured to automatically create the required configuration files and directory structure. It uses DB2 Version 11:

```
#**********************************************************************
# JVM profile: DFHWLP
#
JAVA_HOME=/java/java81_64/J8.1_64
WORK_DIR=.
#**********************************************************************
# JVM server parameters
#
OSGI_FRAMEWORK_TIMEOUT=60
#**********************************************************************
# Liberty JVM server
#
-Dcom.ibm.ws.logging.console.log.level=INFO
-Dcom.ibm.cics.jvmserver.wlp.autoconfigure=true
-Dcom.ibm.cics.jvmserver.wlp.server.http.port=12345
-Dcom.ibm.cics.jvmserver.wlp.server.host=*
-Dcom.ibm.cics.jvmserver.wlp.jdbc.driver.location=/usr/lpp/db2v11/jdbc
-Dfile.encoding=ISO-8859-1
WLP_INSTALL_DIR=&USSHOME;/wlp
WLP_USER_DIR=./&APPLID;/&JVMSERVER;
#**********************************************************************
# JVM options
-Xgcpolicy:gencon
-Xms128M
-Xmx256M
-Xmso128K
#**********************************************************************
# Unix System Services Environment Variables
TZ=CET-1CEST,M3.5.0,M10.5.0
```

## Manually creating a Liberty server

Manually creating a Liberty server in zFS for the JVM server.

### Procedure

1. Create the Liberty server directory structure in zFS for the JVM server.

   The JVM server expects configuration files to be in the *`WLP_USER_DIR`*`/servers/`*`server_name`* directory, where *WLP_USER_DIR* is the value of the `WLP_USER_DIR` option and *server_name* is the value of the **`com.ibm.cics.jvmserver.wlp.server.name`** property. The *server_name* property is always prefixed with -D. For more information on these server options, see JVM server options.

2. Create the Liberty server configuration in the *server_name* directory.

   As a minimum, you must create the `server.xml` file. You can base it on the template that is supplied as `wlp/templates/servers/defaultServer/server.xml` in the installation directory of Liberty. This file must be saved in the ASCII file encoding of ISO-8859-1 and tagged with this encoding using the UNIX command **`chtag -c ISO8859-1 -t <file>`**.

3. Edit the `server.xml` file for your installation.

   Update the `<httpEndpoint>` with the host name and port number. For information about configuring `server.xml` in a JVM server, see “Manually tailoring server.xml” on page 224. If you want to use security, see Configuring security for a Liberty JVM server.

**Attention:** The `server.xml` file configures a single Liberty JVM server. Do not attempt to share a `server.xml` file among two or more Liberty JVM servers.

## Configuring the CICS Default Web Application

The CICS Liberty Default Web Application can be used to verify that the Liberty server is running and view the server configuration. You can use it to view the JVM profile and server logs, and the Liberty `server.xml` and `messages.log` files.

### Before you begin

Without application security enabled, full access to the Default Web Application is available to all users. If you have autoconfigure enabled and run with CICS security (sec=yes), or you have manually configured your `server.xml` by adding the `cicsts:security-1.0` feature, your user ID requires additional permissions to run the application. For access to the Default servlet and basic information, you need to be in the `User` role. For access to the FileViewer servlet, you need to be in the `Administrator` role.

### Procedure

1. If you are using SAF authorization, and your `server.xml` contains the `<safAuthorization .../>` element, you need to create these profiles:

   a) To access the Default servlet, use the following example:

```
RDEFINE EJBROLE BBGZDFLT.com.ibm.cics.wlp.defaultapp.User UACC(NONE)
PERMIT BBGZDFLT.com.ibm.cics.wlp.defaultapp.User CLASS(EJBROLE) ID(WLPSVRS) ACCESS(READ)
SETROPTS RACLIST(EJBROLE) REFRESH
```

   b) To access the FileViewer servlet, use the following example:

```
RDEFINE EJBROLE BBGZDFLT.com.ibm.cics.wlp.defaultapp.Administrator UACC(NONE)
PERMIT BBGZDFLT.com.ibm.cics.wlp.defaultapp.Administrator CLASS(EJBROLE) ID(WLPSVRS) ACCESS(READ)
SETROPTS RACLIST(EJBROLE) REFRESH
```

2. Alternatively, if you do not have SAF authorization configured, then the default JEE role-based access is used.

   - CICS provides a default authorization definition as shown in the following configuration. Access to the Default servlet is granted through the `User` role to the special subject **`ALL_AUTHENTICATED_USERS`**, which means all users are authenticated. By default CICS does not provide access to the FileViewer servlet.

```
<authorization-roles id="com.ibm.cics.wlp.defaultapp">
    <security-role name="User">
        <special-subject type="ALL_AUTHENTICATED_USERS"/>
    </security-role>
</authorization-roles>
```

   - However, the default JEE role information can be customized in `server.xml` by adding an authorization element in the example that follows. This example extends the default configuration by adding `user2` into the `Administrator` role and giving access to the FileViewer servlet.

```
<authorization-roles id="com.ibm.cics.wlp.defaultapp">
    <security-role name="User">
        <user name="user1"/>
        <user name="user2"/>
    </security-role>
    <security-role name="Administrator">
        <user name="user2"/>
    </security-role>
</authorization-roles>
```

   In this case, `user1` can access the Default servlet but not the FileViewer servlet and `user2` can access the Default servlet and the FileViewer servlet.

## Results

You have successfully configured the CICS Default Web Application.

# Manually tailoring server.xml

If you want to make manual changes to your `server.xml`, there are some basic configurations you can apply. Your CICS region user ID needs to have both read and write access to the `server.xml` file.

## Rules for server configuration

Liberty allows customization of your `server.xml`. For details of the rules, see Server configuration.

## Configuring the HTTP endpoint

If you want web access to your application, update the `httpEndpoint` attribute with the host name and port numbers you require. For example:

```
<httpEndpoint host="winmvs2c.example.com" httpPort="28216" httpsPort="28217"
    id="defaultHttpEndpoint"/>
```

Use a port number that can be opened by the CICS region, either exclusively or as a shared port.

HTTPS is available only if SSL is configured as described in Configuring SSL (TLS) for a Liberty JVM server using a Java keystore.

For more information, see Liberty overview.

## Using environment variables in `server.xml`

Within `server.xml`, you can access and reference existing environment variables. See Using variables in configuration files.

These can include custom environment variables that you have already set up in a JVM profile. See Options for JVMs in a CICS environment.

## Adding features

Add the following features in the `<featureManager>` list of features.

- CICS feature `cicsts:core-1.0`. This feature installs the CICS system OSGi bundles into the Liberty framework. This feature is required to start a CICS integrated-mode Liberty JVM server. You can also define a SAF or other type of registry.
- CICS feature `cicsts:standard-1.0`. This feature is required to start a CICS standard-mode Liberty JVM server. The `cicsts:standard-1.0` feature does not have access to CICS resources by default. For more information see "CICS standard-mode Liberty: Java EE Full Platform support without full CICS integration" on page 220.

  **Note:** Specify either the `cicsts:core-1.0` or `cicsts:standard-1.0` feature. You cannot specify both features in `server.xml`.
- CICS security feature `cicsts:security-1.0`. This feature installs the CICS system OSGi bundles that are required for CICS Liberty security into the Liberty framework. This feature is required when CICS external security is enabled (**SEC**=YES in the SIT) and you want security in the Liberty server. To use the `cicsts:security-1.0` feature, you must also configure a user registry. For more information, see "User registry" on page 226.
- `jsp-2.3`. This feature enables support for servlet and JavaServer Pages (JSP) applications. This feature is required by Dynamic Web Projects (WAR files) and OSGi Application Projects that contain OSGi Bundle Projects with Web Support that are installed as CICS bundles.
- `cicsts:jdbc-1.0`. This feature enables applications to access Db2 through the JDBC DriverManager or DataSource interfaces.

Example:

```
<featureManager>
    <feature>cicsts:core-1.0</feature>
    <feature>cicsts:security-1.0</feature>
    <feature>jsp-2.3</feature>
    <feature>cicsts:jdbc-1.0</feature>
</featureManager>
```

For more information, see Liberty features.

## CICS bundle deployed applications

If you want to deploy Liberty applications that use CICS bundles, the `server.xml` file must include the entry:

```
<include location="${server.output.dir}/installedApps.xml"/>
```

The included file is used to define CICS bundle deployed applications.

## Bundle repository

Share common OSGi bundles by placing them in a directory and referring to that directory in a `bundleRepository` element. For example:

```
<bundleRepository>
    <fileset dir="directory_path" include="*.jar"/>
</bundleRepository>
```

## Global/shared library

Share common JAR files between web applications by placing them in a directory and referring to that directory in a global/shared library definition.

```
<library id="global">
    <fileset dir="directory_path" include="*.jar"/>
</library>
```

The global/shared libraries cannot be used by OSGi applications in an EBA, which must use a bundle repository. For more information, see Providing global libraries for all Java EE applications or Shared libraries.

## Liberty server application and configuration update monitoring

The Liberty JVM server scans the `server.xml` file for updates. By default, it scans every 500 milliseconds. To vary this value, add an entry such as:

```
<config monitorInterval="5s" updateTrigger="polled"/>
```

It also scans the `dropins` directory to detect the addition, update, or removal of applications. If you install your web applications in CICS bundles, disable the `dropins` directory as follows:

```
<applicationMonitor updateTrigger="disabled" dropins="dropins"
dropinsEnabled="false" pollingRate="5s"/>
```

For more information, see Controlling dynamic updates.

### JTA transaction log

When the Java Transaction API (JTA) is used, the Liberty transaction manager stores its recoverable log files in the zFS filing system. The default location for the transaction logs is `${WLP_USER_DIR}/tranlog/`. This location can be overridden by adding a transaction element to `server.xml` such as

```
<transaction transactionLogDirectory="/u/cics/CICSPRD/DFHWLP/tranlog/"/>
```

### CICS default web application

The CICS default web application **`CICSDefaultApp`** is a configuration service that validates the Liberty JVM server has started. To make the application available, add the JVM profile option `com.ibm.cics.jvmserver.wlp.defaultapp=true` to your JVM profile, or if you are not using autoconfigure, add the `cicsts:defaultApp-1.0` feature to `server.xml`. Run the application by using the URL `http://<server>:<port>/com.ibm.cics.wlp.defaultapp/`.

```
<featureManager>
    <feature>cicsts:defaultApp-1.0</feature>
</featureManager>
```

### User registry

Unless you are using distributed identity mapping, you must define a SAF registry to use the CICS security feature:

```
<safRegistry enableFailover="false" id="saf"/>
```

For more information, see Configuring security for a Liberty JVM server by using distributed identity mapping or Java Database Connectivity 4.1.

### CICS JTA integration

If an XA transaction is used by Liberty, the CICS unit-of-work becomes subordinate to the XA transaction by default. You can opt out of this automatic integration of CICS with JTA by setting the JVM profile option `com.ibm.cics.jvmserver.wlp.jta.integration=false`. Alternatively you can manually set the **`cicsts_jta`** element directly in your `server.xml`.

```
<cicsts_jta integration="false"/>
```

### Modifying Lightweight Third-Party Authentication (LTPA) support

LTPA is configured by default when security is enabled for Liberty servers. LTPA enables web users to re-use their logged-in credentials across different applications or servers, using tokens signed by keys owned by the Liberty server. In secure deployment scenarios, you should modify the default password for the LTPA keys file to protect server security. You can also modify the expiry interval of the tokens, and change the default file location, which is required if sharing keys between multiple Liberty servers.

## Configuring Admin Center

The adminCenter-1.0 feature enables the Liberty Admin Center, a web-based graphical interface for deploying, monitoring, and managing Liberty servers. After creating a Liberty JVM server, configure the server.xml file.

### About this task

These steps outline how to set up Admin Center.

## Procedure

1. Open an editor on the `server.xml` file of the Liberty server, and configure the server for Admin Center. Add the adminCenter-1.0 feature to the feature manager.

   ```
   <featureManager>
      <feature>adminCenter-1.0</feature>
      <feature>websocket-1.1</feature>
   </featureManager>
   ```

   WebSocket provides a live view of the topology. Without the WebSocket feature, Admin Center web client periodically and frequently polls for changes.
2. Add the userid of all users of the Admin Center (SAF userid if registry), or add the RACF group, to the built-in administrator role.

   ```
   <administrator-role>
      <user>username</user>
   </administrator-role>
   ```

   For more information about the built-in administrator role, see Mapping the administrator role for Liberty on z/OS
3. Optionally, give Admin Center access to write to `server.xml` by adding the following to `server.xml`:

   ```
   <remoteFileAccess>
       <writeDir>${server.config.dir}</writeDir>
   </remoteFileAccess>
   ```

   In the Admin Center you can see and edit server.xml, as well as any include files such as the CICS `installedApps.xml` file.

   The design view lists and describes many other attributes of each element, providing a good way to understand the options available.

   **Note:**

   Some CICS augmented elements are not understood by a Liberty server and so those must be manually edited in the source view.

   Do not remove any of the essential CICS features, such as core-1.0. This disconnects the Liberty instance and the containing JVMSERVER resource.

## Results

Admin Center is now set up and ready to use. When you are using Admin Center, you should be aware that it is possible to **STOP** the server and applications. Any synchronization of resources should be seen as a convenience and not as a primary mechanism of control. The following behavior applies:

- A signal is sent to CICS when the Liberty server is stopped. This quiesces all of your JVM server workload with a DISABLE(PHASEOUT) of the JVMSERVER. There is no option in the Admin Center to use **FORCE** or **PURGE** commands.
- When stopping an application deployed as a CICS bundle, the parent CICS bundle is notified of the application **STOP** and moves to the corresponding DISABLED state.

# Auto-configuring a Db2 type 2 connection

Create a CICS-aware Db2 data source with type 2 connectivity by using the auto-configure property. This uses the `jdbc-4.0`, `jdbc-4.1`, `jdbc-4.2`, or `jdbc-4.3` feature.

## Before you begin

Configure your CICS region to connect to Db2. For more information, see Defining the CICS Db2 connection.

## About this task

You can create a Db2 DataSource with type 2 connectivity in the Liberty `server.xml`, which operates through the CICS DB2CONN, by using the JVM profile auto-configure property. The JNDI name is `jdbc/defaultCICSDataSource`.

If there is already a Db2 DataSource with type 2 connectivity with `id="defaultCICSDataSource"`, you are not able to use auto-configure to create a new one. For more information on creating one manually, see Manually configuring a Db2 DataSource with type 2 connectivity through CICS using the jdbc-4.0, jdbc-4.1 or jdbc-4.2 feature.

## Procedure

1. Enable auto-configure by setting **`-Dcom.ibm.cics.jvmserver.wlp.autoconfigure=true`** in the JVM profile.
2. Set the **`com.ibm.cics.jvmserver.wlp.jdbc.driver.location`** in the JVM profile to the location of the Db2 JDBC library.
   For example: `-Dcom.ibm.cics.jvmserver.wlp.jdbc.driver.location=/usr/lpp/db2v11/jdbc`
3. If the default schema is not the current userid, set the **`db2.jcc.currentSchema`** in the JVM profile to the name of the schema.
   For example: `-Ddb2.jcc.currentSchema=CICSDB2`
4. Install and enable the JVMSERVER resource.

## Results

A Db2 DataSource with type 2 connectivity is added to the Liberty server configuration file, `server.xml`.

```
<featureManager>
    ...
    <feature>jdbc-4.2</feature>
</featureManager>
```

```
<dataSource id="defaultCICSDataSource" jndiName="jdbc/defaultCICSDataSource" transactional="false">
    <jdbcDriver libraryRef="defaultCICSDb2Library"/>
    <properties.db2.jcc driverType="2"/>
    <connectionManager agedTimeout="0"/>
</dataSource>

<library id="defaultCICSDb2Library">
    <fileset dir="/usr/lpp/db2v11/jdbc/classes" includes="db2jcc4.jar db2jcc_license_cisuz.jar"/>
    <fileset dir="/usr/lpp/db2v11/jdbc/lib" includes="libdb2jcct2zos4_64.so"/>
</library>
```

# Manually configuring a Db2 type 2 connection with the Liberty JDBC features

A CICS Liberty JVM server can be configured to use a JDBC DataSource with type 2 connectivity through CICS to access Db2 databases from Java applications.

## Before you begin

You should configure your CICS region to connect to Db2. For more information, see Defining the CICS Db2 connection.

## About this task

This task explains how to define the elements that are required in `server.xml` to enable JDBC type 2 driver connectivity to a local Db2 database.

Java 17Java 21 To enable Db2 type 2 connectivity when you are running Java 17 or Java 21, add `LIBPATH_SUFFIX=/usr/lpp/db2v12/jdbc/lib` to the JVM profile.

## Procedure

1. Add the `jdbc-4.0`, `jdbc-4.1`, `jdbc-4.2`, or `jdbc-4.3` feature to the `server.xml` file.

   ```
   <featureManager>
       <feature>jdbc-4.2</feature>
   </featureManager>
   ```

2. Add a library element to the `server.xml` file to specify the location on zFS of the JDBC driver.

```
<library id="defaultCICSDb2Library">
    <fileset dir="/usr/lpp/db2v11/jdbc/classes" includes="db2jcc4.jar db2jcc_license_cisuz.jar"/>
    <fileset dir="/usr/lpp/db2v11/jdbc/lib" includes="libdb2jcct2zos4_64.so"/>
</library>
```

3. To access Db2 through a DataSource definition, a **`dataSource`** element is required. The **`jndiName`** attribute is required to define the JNDI name that is referenced by your application.

   **Note:** As of JDBC 4.3, the default **`dataSource`** *type* is `javax.sql.XADataSource`, which is not supported by the Db2 type 2 JDBC driver. The *type* must be set to `javax.sql.ConnectionPooledDataSource` or `javax.sql.DataSource` for Db2 type 2 data sources.

   You can set attributes for the **`dataSource`** by using a **`properties.db2.jcc`** element. The following example shows how to do this:

```
<dataSource id="defaultCICSDataSource" jndiName="jdbc/defaultCICSDataSource" transactional="false">
    <jdbcDriver libraryRef="defaultCICSDb2Library"/>
    <properties.db2.jcc driverType="2"/>
    <connectionManager agedTimeout="0"/>
</dataSource>
```

   `transactional="false"` is required to allow CICS to manage the transactions.

   `driverType="2"` is required to use the type 2 connectivity to Db2.

   `agedTimeout="0"` is required to disable Liberty connection pooling. Liberty connection pooling is not required as the DB2CONN resource provides Db2 connection pooling.

## Results

The Liberty server is configured to allow access to Db2 databases by using JDBC type 2 connectivity through a CICS DB2CONN resource.

# Manually configuring a Db2 type 4 connection

A CICS Liberty JVM server can be configured to use a JDBC DataSource with type 4 connectivity to access Db2 databases from Java applications.

## Before you begin

The Liberty Db2 DataSource with type 4 connectivity does not use the CICS Db2 connection resource. However, if you do not have APARs PI18798 and PI18799 applied, you need to add the Db2 SDSNLOAD and SDSNLOD2 libraries to the CICS STEPLIB concatenation.

## About this task

This task explains how to manually define the elements that are required in the `server.xml` configuration file to enable JDBC type 4 driver connectivity to a local or remote Db2 database. Updates that are made to a Db2 database that uses type 4 connectivity do not use the CICS Db2 connection resource. They are not part of a two-phase commit transaction unless the DataSource connection is of type `javax.sql.XADataSource`, and they are made within a JTA user transaction. For more information, see Acquiring a connection to a database.

## Procedure

1. Add the `jdbc-4.0`, `jdbc-4.1`, `jdbc-4.2`, or `jdbc-4.3` feature to the featureManager element. This enables use of the **`dataSource`** and **`jdbcDriver`** elements that are used later in the `server.xml`file.

```
<featureManager>
    <feature>jdbc-4.2</feature>
</featureManager>
```

2. Add **`dataSource`** and **`jdbcDriver`** elements. The **`dataSource`** element must refer to a library definition that specifies the library from which the JDBC driver components (the Db2 JDBC jar and native DLL files) are to be loaded. Typical definitions might look like this:

```
<dataSource jndiName="jdbc/defaultCICSDataSource">
    <jdbcDriver libraryRef="db2Lib"/>
    <properties.db2.jcc driverType="4"
        serverName="winmvs2c.hursley.ibm.com"
        portNumber="41100"
        databaseName="DSNV11P2"
        user="DBUSER"
        password="{xor}Lz4sLCgwLTs="/>
</dataSource>

<library id="db2Lib">
    <fileset dir="/usr/lpp/db2v11/jdbc/classes" includes="db2jcc4.jar
        db2jcc_license_cisuz.jar" />
</library>
```

If you do not have APARs PI18798 and PI18799 applied, you need to add a fileset entry for the Db2 native library to the library configuration, for example:

```
<fileset dir="/usr/lpp/db2v11/jdbc/lib" />
```

The **`dataSource`** specifies the **`jndiName`** attribute that is referenced by your application program when you are establishing a connection to that data source. The required properties are set in the **`properties.db2.jcc`** element as follows:

**driverType**

Description: Database driver type, must be set to 4 to use the pure Java driver.

Default value: 4

Required: false

Data type: int

**serverName**

Description: The host name of server where the database is running. This is the SQL DOMAIN value of the Db2 DISPLAY DDF command.

Default value: localhost

Required: false

Data type: string

**portNumber**

Description: Port on which to obtain database connections. This is the TCPPORT value of the Db2 DISPLAY DDF command.

Default value: 50000

Required: false

Data type: int

**databaseName**

Description: specifies the name for the data source. This is the LOCATION value of the Db2 DISPLAY DDF command.

Required: true

Data type: string

**user**

Description: The user ID used to connect to the database.

Required: true

Data type: string

**password**

Description: The password of the user ID used to connect to the database. The value can be stored in clear text or encoded form. It is recommended that you encode the password. To do so, use the securityUtility tool with the encode option, see securityUtility command.

Required: true

Data type: string

### Results

The Liberty server, when started, is configured to allow access to Db2 databases through a JDBC type 4 connectivity. For more information, see Java Database Connectivity 4.1.

## Manually configuring a Db2 DataSource or the DriverManager interface with type 2 connectivity through CICS using the `cicsts:jdbc-1.0` feature

A CICS Liberty JVM server can be configured to use JDBC type 2 connectivity through CICS, providing Java applications with either a **`javax.sql.DataSource`** or a **`java.sql.DriverManager`** interface to access Db2 databases.

### Before you begin

Configure your CICS region to connect to Db2. For more information, see Defining the CICS Db2 connection.

### About this task

Although you can configure CICS Liberty to access Db2 with type 2 connectivity using the **`cicsts:jdbc-1.0`** feature, the preferred method is to use the Liberty `jdbc-4.x` features. For more information, see Manually configuring a Db2 DataSource with type 2 connectivity through CICS using the jdbc-4.0, jdbc-4.1 or jdbc-4.2 feature. However, if you want to use the DriverManager interface, you must use the **`cicsts:jdbc-1.0`** feature as described in the following procedure.

### Procedure

1. Add the `cicsts:jdbc-1.0` feature to the featureManager element.

   This enables use of the **`cicsts_jdbcDriver`** and **`cicsts_dataSource`** elements, used later in the `server.xml` file.

   ```
   <featureManager>
       <feature>cicsts:jdbc-1.0</feature>
   </featureManager>
   ```

2. Add a **`cicsts_jdbcDriver`** element. This enables JDBC type 2 connectivity with the **`java.sql.DriverManager`** or **`javax.sql.DataSource`** interface.

   The **`cicsts_jdbcDriver`** element must refer to a library definition that specifies the library from which the JDBC driver components (the Db2 JDBC jar and native dll files) are to be loaded. Typical definitions might look like this:

```
<cicsts_jdbcDriver libraryRef="defaultCICSDb2Library"/>
<library id="defaultCICSDb2Library">
    <fileset dir="/usr/lpp/db2v11/jdbc/classes" includes="db2jcc4.jar db2jcc_license_cisuz.jar"/>
    <fileset dir="/usr/lpp/db2v11/jdbc/lib" includes="libdb2jcct2zos4_64.so"/>
</library>
```

**Note:** Only one **cicsts_jdbcDriver** element is required. If more than one is specified, only the last **cicsts_jdbcDriver** element in the server.xml file is used and the others are ignored.

If you require only **java.sql.DriverManager** support, the preceding steps are sufficient.

3. To access Db2 using the DataSource interface, a **cicsts_dataSource** element is required, but the preferred method for DataSource access is to use the Liberty jdbc-4.x features, as described in Manually configuring a Db2 DataSource with type 2 connectivity through CICS using the jdbc-4.0, jdbc-4.1 or jdbc-4.2 feature. A **cicsts_dataSource** requires a jndiName attribute to define the JNDI name that is referenced by your application. A definition might look like this:

```
<cicsts_dataSource id="defaultCICSDataSource" jndiName="jdbc/defaultCICSDataSource"/>
```

   **Tip:** The DataSource class that is used is **com.ibm.db2.jcc.DB2SimpleDataSource**, which implements **javax.sql.DataSource**.

4. Optional: You can set attributes for the **cicsts_dataSource** by using a **properties.db2.jcc** element. The following example shows how to do this:

```
<cicsts_dataSource id="defaultCICSDataSource" jndiName="jdbc/defaultCICSDataSource">
    <properties.db2.jcc currentSchema="DB2USER" fullyMaterializeLobData="true" />
</cicsts_dataSource>
```

   Some of the attributes, which can be specified on the **properties.db2.jcc** element are not valid for DataSources with type 2 connectivity. If these invalid attributes are specified, they are ignored and a warning message is issued. The following attributes are not valid:

   - *driverType*
   - *serverName*
   - *portNumber*
   - *user*
   - *password*
   - *databaseName*

### Results

The Liberty JVM server can connect to Db2 databases with JDBC type 2 connectivity through a CICS DB2CONN resource.

**Note:** Dynamic updates of the cicsts_dataSource and its components are not supported. Updating the configuration while the Liberty server is running can result in Db2 application failures. You should recycle the server to activate any changes.

## Configuring a Liberty JVM server to support JMS

You configure a CICS Liberty JVM server to support applications that use JMS. The Liberty JVM server can be either CICS standard-mode Liberty or CICS integrated-mode Liberty but there are differences in the configuration, depending on which you use and the type of connection that you use to IBM MQ.

### About this task

This task sets up the server.xml for the CICS Liberty JVM server to support applications that connect to IBM MQ through the IBM MQ classes for JMS. To connect to IBM MQ from Liberty, you need the IBM MQ resource adapter at Version 9.0.1 or later. Liberty does not contain the IBM MQ resource adapter so you must get it from Fix Central (see Installing the resource adapter in Liberty). The Liberty features that are referenced in the configuration steps are described in detail in Liberty features.

Before you start, make sure that you review the considerations in Using IBM MQ classes for JMS in a CICS Liberty JVM server.

## Procedure

1. Add the `wmqJmsClient-2.0` feature to the `server.xml` file.

   Adding the `wmqJmsClient-2.0` feature enables the Liberty server to load the necessary IBM MQ bundles that let you define the JMS resources, such as the connection factory and activation specification properties.

   If you want to perform a JNDI lookup, then you must also add the `jndi-1.0` feature.

   ```
   <featureManager>
       <feature>wmqJmsClient-2.0</feature>
       <feature>jndi-1.0</feature>
   </featureManager>
   ```

2. If you want to configure JMS applications to connect to IBM MQ in bindings mode (supported only in CICS standard-mode Liberty), add the `zosTransaction-1.0` feature:

   ```
   <featureManager>
       <feature>zosTransaction-1.0</feature>
   </featureManager>
   ```

3. Specify the location in zFS of the IBM MQ resource adapter on the `variable` element of the `server.xml` file:

   ```
   <variable name="wmqJmsClient.rar.location" value="/path/to/wmq/rar/wmq.jmsra.rar"/>
   ```

   On the `value` attribute, specify the absolute path to the IBM MQ resource adapter file, `wmq.jmsra.rar`.

4. If you are using a JMS connection factory to connect to the IBM MQ queue manager, add the connection factory definitions to the `server.xml` file.

   You must have information about the IBM MQ system: the name of the queue manager, the host name of its system, the port that the queue manager is listening on, and the channel to the queue manager. The connection factory is not applicable if your application communicates with IBM MQ through message-driven beans.

   For more information about the IBM MQ properties, see the Configuring JMS connection factories in the Liberty documentation.

   - For a client mode connection to IBM MQ, add the following elements:

     ```
     <jmsConnectionFactory jndiName="jms/wmqCF" connectionManagerRef="ConMgr6">
         <properties.wmqJms transportType="CLIENT"
             hostName="localhost" port="1414"
             channel="SYSTEM.DEF.SVRCONN" queueManager="QM1"/>
     </jmsConnectionFactory>

     <connectionManager id="ConMgr6" maxPoolSize="10"/>
     ```

     The value of 10 on `maxPoolSize` is used as an example only. Set `maxPoolSize` to the maximum number of concurrent users of the connection factory.

   - For a bindings mode connection to IBM MQ (supported only in CICS standard-mode Liberty), add the following elements:

     ```
     <jmsConnectionFactory jndiName="jms/qm1" connectionManagerRef="ConMgr6">
         <properties.wmqJms transportType="BINDINGS" queueManager="QM1"/>
     </jmsConnectionFactory>

     <connectionManager id="ConMgr6" maxPoolSize="10"/>
     ```

     The value of “10” on `maxPoolSize` is used as an example only. Set `maxPoolSize` to the maximum number of concurrent users of the connection factory.

5. Add the queue definitions to the `server.xml` that are referenced by the `jmsConnectionFactory` or `jmsActivationSpec`:

```
<jmsQueue id="jms/queue1" jndiName="jms/queue1">
    <properties.wmqJms baseQueueName="QUEUE1" baseQueueManagerName="QM1"/>
</jmsQueue>
```

6. If you are configuring JMS applications to connect in bindings mode, use the `wmqJmsClient` element in the `server.xml` file to specify the location of the IBM MQ native libraries.

   ```
   <wmqJmsClient nativeLibraryPath="/opt/mqm/java/lib64"/>
   ```

7. If you use message-driven beans, add the **`mdb-3.2`** feature to `server.xml`. This feature is not applicable if you use a connection factory.

   ```
   <featureManager>
       <feature>mdb-3.2</feature>
   </featureManager>
   ```

   Then define a `jmsActivationSpec` in the Liberty `server.xml` that references the `jmsQueue` element, the IBM MQ channel, queue manager, host, port, and transport type. For more information about the IBM MQ properties, see the Configuring JMS connection factories in the Liberty documentation.

   - For a client mode connection, add a `jmsActivationSpec` element as follows:

     ```
     <jmsActivationSpec id="MQ.JMS.mdb.app/MQ.JMS.mdbEJB/MessageDrivenBean">
         <properties.wmqJms transportType="CLIENT"
             destinationRef="jms/queue1" destinationType="javax.jms.Queue"
             hostName="localhost" port="1414"
             channel="SYSTEM.DEF.SVRCONN" queueManager="QM1"/>
     </jmsActivationSpec>
     ```

     The jmsActivationSpec `id` attribute must be in the format of *application name/module name/bean name*.

   - For a bindings mode connection (supported only in CICS standard-mode Liberty), add a `jmsActivationSpec` element as follows:

     ```
     <jmsActivationSpec id="MQ.JMS.mdb.app/MQ.JMS.mdbEJB/MessageDrivenBean">
         <properties.wmqJms transportType="BINDINGS"
             destinationRef="jms/queue1" destinationType="javax.jms.Queue"
             queueManager="QM1"/>
     </jmsActivationSpec>
     ```

     The jmsActivationSpec `id` attribute must be in the format of *application name/module name/bean name*.

### Results

You have configured a CICS Liberty JVM server to support applications that use JMS.

## CICS Liberty defaulted settings

When Liberty is configured, by default, two configuration settings are applied but are not visible in `server.xml`.

### Defaulted configuration settings

If you wish to use different settings than the two non-visible defaulted settings, you can specify them in `server.xml`. The two settings are:

- **`<applicationManager autoExpand="true"/>`** This setting causes application file archives to be automatically expanded into the `${server.config.dir}`/apps directory on first use. This avoids expansion of file archives into the Liberty work area on server startup, reducing zFS file I/O and making more efficient use of the Java shared class cache. If you wish to override this setting and switch it off, then you should place the XML element: `<applicationManager autoExpand="false"/>` in your `server.xml` file.

- **`<transaction recoverOnStartup="true" waitForRecovery="true"/>`** These settings specify that following a server failure, transaction recovery should occur at server startup, and the server should wait for recovery to complete before permitting further transactional work. See Configuring the transaction service startup for more information.

## Configuring a JVM server for Axis2

Configure the JVM server to run Axis2 if you want to run Java web services or process SOAP requests in a pipeline.

### About this task

Axis2 is a Java SOAP engine that can process web service requests in provider and requester pipelines. When you configure a JVM server to run Axis2, CICS automatically adds the required JAR files to the class path.

You can define the JVM server either with CICS online resource definition or in a CICS bundle.

### Procedure

1. Create a JVMSERVER resource for the JVM server.
   a) Specify a name for the JVM profile for the JVM server.

      On the JVMPROFILE attribute of JVMSERVER, specify a 1 - 8 character name. This name is used for the prefix of the JVM profile, which is the file that holds the configuration options for the JVM server. You do not need to specify the suffix, .jvmprofile, here.

   b) Specify the thread limit for the JVM server.

      On the THREADLIMIT attribute of JVMSERVER, specify the maximum number of threads that are allowed in the Language Environment enclave for the JVM server. The number of threads that are required depend on the workload that you want to run in the JVM server. To start with, you can accept the default value and then tune the environment. You can set up to 256 threads in a JVM server.
2. Create the JVM profile to define the configuration options for the JVM server.

   You can use the sample profile, DFHJVMAX.jvmprofile, as a basis. This profile contains a subset of options that are suitable for starting the JVM server. All options and values for the JVM profile are described in "JVM profile validation and properties" on page 238. Follow the coding rules, including those for the profile name, in "Rules for coding profiles" on page 238.

   a) Set the location for the JVM profile.

      The JVM profile must be in the directory that you specify on the system initialization parameter, JVMPROFILEDIR. For more information, see "Setting the location for the JVM profiles" on page 207.

   b) Make the following changes to the sample profile:

      - Set JAVA_HOME to the location of your installed IBM Java SDK.
      - Set JAVA_PIPELINE to run Axis2.
      - Set CLASSPATH_SUFFIX to specify classes for Axis2 applications and SOAP handlers that are written in Java.
      - Set WORK_DIR to your choice of destination directory for messages, trace, and output from the JVM server.
      - Set TZ to specify the timezone for timestamps on messages from the JVM server.An example for the United Kingdom is TZ=GMT0BST,M3.5.0,M10.4.0.

   c) Save your changes to the JVM profile.

      The JVM profile must be saved as EBCDIC on the z/OS UNIX System Services file system.
3. Install and enable the JVMSERVER resource.

## Results

CICS creates a Language Environment enclave and passes the options from the JVM profile to the JVM server. The JVM server starts up and loads the Axis2 JAR files. When the JVM server completes startup successfully, the JVMSERVER resource installs in the ENABLED state.

If an error occurs, for example CICS is unable to find or read the JVM profile, the JVM server fails to start. The JVMSERVER resource installs in the DISABLED state and CICS issues error messages to the system log.

## What to do next

- Specify any directories that contain native C dynamic link library (DLL) files, such as Db2 or IBM MQ. You specify these directories on the LIBPATH_SUFFIX option in the JVM profile.
- Configure CICS to run web service requests in the JVM server, as described in Using Java with web services.

# JVM profile example

Example JVM profile configured to start Axis2.

The following excerpt shows an example JVM profile that is configured to start Axis2:

```
#**********************************************************************
#
#                         Required parameters
#                         -------------------
#
# When using a JVM server, the set of CICS options that are supported
JAVA_HOME=/usr/lpp/java/J8.0_64
WORK_DIR=.
LIBPATH_SUFFIX=/usr/lpp/db2910/lib
...
#**********************************************************************
#
#                    JVM server specific parameters
#                    ------------------------------
#
JAVA_PIPELINE=YES
#
#**********************************************************************
#
#                             JVM options
#                             -----------
# The following option sets the Garbage collection Policy.
#
-Xgcpolicy:gencon
#
#**********************************************************************
#
#                 Setting user JVM system properties
#                 ----------------------------------
#
# -Dcom.ibm.cics.some.property=some_value
#
#**********************************************************************
#
#              Unix System Services Environment Variables
#              ------------------------------------------
#
JAVA_DUMP_OPTS="ONANYSIGNAL(JAVADUMP,SYSDUMP),ONINTERRUPT(NONE)"
#
#
```

## Configuring a JVM server for a CICS Security Token Service

Configure the JVM server to run a CICS Security Token Service if you want to validate and process SAML tokens.

### About this task

The supplied sample DFHJVMST.jvmprofile is suitable for a JVM server that runs a CICS Security Token Service.

You can define the JVM server either with CICS online resource definition or in a CICS bundle. For more help with using the CICS Explorer to create and edit resources in CICS bundles, see Working with bundles in the CICS Explorer product documentation.

Java 11Java 17Java 21 Running a SAML JVM server with Java 11, Java 17 or Java 21 is not supported.

### Procedure

Create a JVMSERVER resource for the JVM server.

a) Specify a name for the JVM profile for the JVM server.

On the JVMPROFILE attribute, specify a 1 - 8 character name. This name is used for the prefix of the JVM profile, which is the file that holds the configuration options for the JVM server. You do not need to specify the suffix .jvmprofile.

b) Specify the thread limit for the JVM server.

The number of threads depends on the workload that you want to run in the JVM server. To start with, you can accept the default value and then tune the environment later. You can set up to 256 threads in a JVM server.

c) Create the JVM profile to define the configuration options for the JVM server.

The JVM profile must be in the directory that you specify on the system initialization parameter, JVMPROFILEDIR. You can use the sample profile, DFHJVMST.jvmprofile, as a basis. This profile contains a subset of options that are suitable for starting the JVM server. You can either copy DFHJVMST.jvmprofile from the installation directory into the directory that you specify on JVMPROFILEDIR, or select it in CICS Explorer and save to the target directory.

All options and values for the JVM profile are described in "JVM profile validation and properties" on page 238. Follow the coding rules in "Rules for coding profiles" on page 238.

Make the following changes to the sample profile:

- Set JAVA_HOME to the location of your installed IBM Java SDK.
- Set WORK_DIR to your choice of destination directory for messages, trace, and output from the JVM server.
- Set SECURITY_TOKEN_SERVICE to YES.
- Set TZ to specify the timezone for timestamps on messages from the JVM server. An example for the United Kingdom is TZ=GMT0BST,M3.5.0,M10.4.0.

d) Save your changes to the JVM profile

The JVM profile must be saved as EBCDIC on the USS file system.

### Results

When you install and enable the JVMSERVER resource, CICS creates a Language Environment enclave and passes the options from the JVM profile to the JVM server. The JVM starts up and the OSGi framework resolves any OSGi middleware bundles. When the JVM server completes startup successfully, the JVMSERVER resource installs in the ENABLED state.

If an error occurs, for example CICS is unable to find or read the JVM profile, the JVM server fails to initialize. The JVMSERVER resource installs in the DISABLED state and CICS issues error message.

### What to do next

You can further customize the JVM server, for example:

- Specify any directories that contain native C dynamic link library (DLL) files, such as Db2 or IBM MQ. You specify these directories on the LIBPATH_SUFFIX option.
- For more information see Configuring the CICS Security Token Service.

## JVM profile validation and properties

JVM profiles contain a set of options and system properties that are passed to the JVM when it starts. Some JVM profile options are specific to the CICS environment and are not used for JVMs in other environments. CICS validates that the JVM profile is coded correctly when you start the JVM server.

The JVM options are described in "Options for JVMs in a CICS environment" on page 240. CICS provides sample profiles for each JVM server configuration that is supported by CICS. These sample profiles have default values for the most common JVM options. The sample profiles are stored in zFS in `/usr/lpp/cicsts/cicsts56/JVMProfiles/`.

You can also specify z/OS UNIX System Services environment variables in a JVM profile. For more information see Symbols used in the JVM profile. Name and value pairs that are not valid JVM options are treated as z/OS UNIX System Services environment variables, and are exported. z/OS UNIX System Services environment variables specified in a JVM profile apply only to JVMs created with that profile.

Examples of environment variables include the `WLP_INSTALL_DIR` variable for the Liberty profile, and the TZ variable for changing the time zone of the JVM.

The Java class libraries include other system properties that you can set in a JVM profile. For example, applications might also have their own system properties. The IBM Java documentation is the primary source of Java information. For more information about the JVM system properties, see Using system property command-line options.

### Rules for coding profiles

JVM profiles are text files encoded in EBCDIC when stored on the USS file system. When JVM profiles are created in a CICS bundle, they can be edited on a workstation using any text editor. They must be converted to EBCDIC when they are transferred to USS. CICS Explorer performs this conversion automatically when exporting a CICS bundle project to USS.

**Case sensitivity**

All parameter keywords and operands are case-sensitive, and must be specified exactly as shown in Options for JVMs in a CICS environment, JVM system properties, or Node.js profile and command line options.

**Comments**

To add comments or to comment out an option instead of deleting it, begin each line of the comment with a # symbol. Comment lines are ignored when the file is read by the launcher.

Blank lines are also ignored. You can use blank lines as a separator between options or groups of options.

The profile parsing code removes inline comments. An inline comment is defined as follows:

- The comment starts with a # symbol
- It is preceded with one or more spaces (or tabs)
- It is not contained in quoted text

*Table 40. Inline comment examples*

| Code | Result |
|---|---|
| `MYVAR=myValue # Comment` | MYVAR=myValue |

*Table 40. Inline comment examples (continued)*

| Code | Result |
|---|---|
| `MYVAR=#myValue # Comment` | MYVAR=#myValue |
| `MYVAR=myValue "# Quoted comment" # Comment` | MYVAR=myValue "# Quoted comment" |

**Continuation**

For options the value is delimited by the end of the line in the text file. If a value that you are entering or editing is too long for an editor window, you can break the line to avoid scrolling. To continue on the next line, terminate the current line with the backslash character and a blank continuation character, as in this example:

```
STDERR=/example/a/long/path/which/you/would/like\
 /to/break/over/a/line
```

Do not put more than one option on the same line.

**Including files**

Use `%INCLUDE=<file_path>` to include a file in your profile. The file can contain common system-wide configuration that can be maintained separate to the profile. This enables configuration that is common to several profiles to be shared, giving more control and providing easier maintenance for profiles.

The following rules apply:

- `<file_path>` must be a fully qualified file in zFS.
  - Avoid use of relative directories at the start of `<file_path>` such as `.` and `..`. They are interpreted by UNIX System Services as relative to the Language Environment current working directory, which can change in processing.
  - If `<file_path>` does not exist, or if the CICS region user ID does not have read access to `<file_path>` message DFHSJ1308 is issued.
- `<file_path>` can contain symbols, for example `&USSCONFIG;`.
  - Symbols `&DATE;` and `&TIME;` are not allowed due to the formatting for these being set via the time zone option (TZ) that can be before or after the `%INCLUDE` directive.
- The contents of `<file_path>` replace the %INCLUDE directive.
- A profile can contain any number of %INCLUDE directives.
- Cyclic references result in message `Skipping duplicate`. For example, Profile-A can include Profile-B, and Profile-B include Profile-C; but if Profile-B includes Profile-A the directive is ignored.

**Multiple instances of options**

If more than one instance of the same option is included in a profile, the value for the last option found is used, and previous values are ignored.

**UNIX System Services directory paths**

Do not use quotation marks when specifying values for zFS files or directories in a profile.

## Rules specific to JVM profiles

**Appending values**

Use the + character before a variable to append the value specified to the existing value of that variable using a comma separator, for example:

```
LIBERTY_INCLUDE_XML=/path/file1
+LIBERTY_INCLUDE_XML=/path/file2
```

This is the equivalent to:

```
LIBERTY_INCLUDE_XML=/path/file1,/path/file2
```

**CEDA**

The CEDA panels accept mixed case input for the JVMPROFILE field irrespective of your terminal UCTRAN setting. However, you must enter the name of a JVM profile in mixed case when you use CEDA from the command line or when you use another CICS transaction. Ensure that your terminal is correctly configured with uppercase translation suppressed. You can use the supplied CEOT transaction to alter the uppercase translation status (UCTRAN) for your own terminal, for the current session only.

**Class path separator character**

Use the `:` (colon) character to separate the directory paths that you specify on a class path option, such as `CLASSPATH_SUFFIX`.

**Name of a profile**

- The name of a JVM profile can be up to eight characters in length.
- JVM profiles on the file system must have the file extension `.jvmprofile`. The file extension is set to lowercase and must not be changed (only applies to JVM profiles).
- The name can be any name that is valid for a file in z/OS UNIX System Services. Do not use a name beginning with DFH, because these characters are reserved for use by CICS.
- Because profiles are UNIX files, case is important. When you specify the name in CICS, you must enter it using the same combination of uppercase and lowercase characters that is present in the z/OS UNIX file name.

**Referencing environment variables**

Environment variables can be referenced in other variables in the JVM profile using the symbol notation syntax. For more information , see Symbols used in the JVM profile.

**Storage sizes**

When specifying storage-related options in a JVM profile, specify storage sizes in multiples of 1024 bytes. Use the letter K to indicate KB, the letter M to indicate MB, and the letter G to indicate GB. For example, to specify 6 291 456 bytes as the initial size of the heap, code **`-Xms`** in one of the following ways:

```
-Xms6144K
-Xms6M
```

## Options for JVMs in a CICS environment

The options in a JVM profile are used by CICS to start JVM servers. Some options are specific to CICS, but you can also specify environment variables and Java system properties.

### Coding rules

When you specify JVM options, make sure that you follow the coding rules. For more information, see "Rules for coding profiles" on page 238.

### Format

The format of options can vary:

- Options in a JVM profile either take the form of a keyword and value, separated by an equal sign (=), for example `JAVA_PIPELINE=TRUE`, or they begin with a hyphen, for example `-Xmx16M`.
- Keyword value pairs are either CICS variables such as `JAVA_PIPELINE=TRUE`, or if not recognized as CICS options, they are treated as z/OS UNIX System Services environment variables, and are exported.

- Options that begin with `-D` in a JVM profile are JVM system properties. Options that begin with `-X` are treated as JVM command-line options. Any option that begins with `-` is passed to the JVM after any substitution symbols have been expanded. For more information, see "JVM system properties" on page 253.

### *Symbols used in the JVM profile*

You can use built-in substitution symbols in any variable or JVM server property specified in the JVM profile. The values of these symbols are determined at JVM server startup, so you can use a common profile for many JVM servers and CICS regions.

**Note:**

Environment variables that have been previously defined in the profile can also be used as substitution variables using the syntax `&myvar;`

The following symbols are supported:

**&APPLID;**
When you use this symbol, the APPLID of the CICS region is substituted at run time. In this way, you can use the same profile for all regions, and still have region-specific working directories or output destinations. The APPLID is always in uppercase.

**&BUNDLE;**
When you use this symbol, the symbol is replaced with the name of the CICS bundle from which the JVM server is being installed.

**&BUNDLEID;**
When you use this symbol, the symbol is replaced with the ID of the CICS bundle from which the JVM server is being installed.

**&CONFIGROOT;**
When you use this symbol, the absolute path of the directory where the JVM profile is located is substituted at run time. For JVM servers that are defined in CICS bundles, the JVM profiles are by default located in the root directory for the bundle. For JVM servers that are defined by other methods, the JVM profiles are in the directory that is specified by the JVMPROFILEDIR system initialization parameter.

**&DATE;**
When you use this symbol, the symbol is replaced with the current date in the format *Dyymmdd* at run time.

**&JVMSERVER;**
When you use this symbol, the name of the JVMSERVER resource is substituted at run time. Use this symbol to create unique output or dump files for each JVM server.

**&TIME;**
When you use this symbol, the symbol is replaced with the JVM start time in the format *Thhmmss* at run time.

**&USSCONFIG;**
When you use this symbol, the symbol is replaced with the value of the USSCONFIG system initialization parameter that is the directory for CICS configuration files.

**&USSHOME;**
When you use this symbol, the symbol is replaced with the value of the USSHOME system initialization parameter. You can specify this symbol to automatically pick up the home directory for z/OS UNIX where CICS supplies its libraries for Java and the Liberty profile.

Built-in symbols are only substituted during the parsing phase of a JVM profile, they are not available to your applications directly. If you wish to set them as environment variables you can assign them in your JVM profile like this: e.g. `APPLID=&APPLID;`.

## Custom variables

Environment variables that have been previously defined in the profile, e.g. MYVAR=HELLO, can also be used as substitution variables e.g. MYVAR2=&MYVAR;

### *JVM server profile options*

JVM server options, how they apply to different uses of a JVM server, and their descriptions are listed.

## How options apply to different uses of a JVM server

The following table indicates whether an option is required, optional, or not supported for a particular use of a JVM server.

*Table 41. JVM server options and how they apply to different uses of a JVM server*

| Option | OSGi | Liberty | Axis2 | STS |
|---|---|---|---|---|
| _DFH_UMASK | Optional | Optional | Optional | Optional |
| CICS_WLP_MODE | Not supported | Optional | Not supported | Not supported |
| CLASSPATH_PREFIX | Not supported | Not supported | Optional | Optional |
| CLASSPATH_SUFFIX | Not supported | Not supported | Optional | Optional |
| DIAGS_ARCHIVE_DIR | Optional | Optional | Optional | Optional |
| DIAGS_TEMP_DIR | Optional | Optional | Optional | Optional |
| DISPLAY_JAVA_VERSION | Optional | Optional | Optional | Optional |
| IDENTITY_PREFIX | Optional | Optional | Optional | Optional |
| JAF_REGISTRATION | Optional | Not supported | Optional | Optional |
| JAVA_DUMP_TDUMP_PATTERN | Optional | Optional | Optional | Optional |
| JAVA_HOME | Required | Required | Required | Required |
| JAVA_PIPELINE | Not supported | Not supported | Required | Not supported |
| JAXB_REGISTRATION | Required | Not supported | Optional | Optional |
| JNDI_REGISTRATION | Optional | Not supported | Optional | Optional |
| JVMLOG | Optional | Optional | Optional | Optional |
| JVMTRACE | Optional | Optional | Optional | Optional |
| LIBERTY_INCLUDE_XML | Not supported | Optional | Not supported | Not supported |
| LIBERTY_PRODUCT_EXTENSIONS | Not supported | Optional | Not supported | Not supported |
| LIBPATH_PREFIX | Optional - use only under the guidance of IBM service personnel. | Optional - use only under the guidance of IBM service personnel. | Optional - use only under the guidance of IBM service personnel | Optional - use only under the guidance of IBM service personnel. |
| LIBPATH_SUFFIX | Optional | Optional | Optional | Optional |
| LOG_FILES_MAX | Optional | Optional | Optional | Optional |
| LOG_LEVEL | Optional | Optional | Optional | Optional |
| LOG_PATH_COMPATIBILITY | Optional | Optional | Optional | Optional |

*Table 41. JVM server options and how they apply to different uses of a JVM server (continued)*

| Option | OSGi | Liberty | Axis2 | STS |
|---|---|---|---|---|
| OSGI_BUNDLES | Optional | Not supported | Not supported | Not supported |
| OSGI_CONSOLE | Optional | Not supported | Not supported | Not supported |
| OSGI_FRAMEWORK_TIMEOUT | Optional | Optional | Not supported | Not supported |
| PRINT_JVM_OPTIONS | Optional | Optional | Optional | Optional |
| PRINT_PROFILE | Optional | Optional | Optional | Optional |
| PURGE_ESCALATION_TIMEOUT | Optional | Optional | Optional | Optional |
| SCRIPT_TIMEOUT_SECS | Optional | Optional | Optional | Optional |
| SECURITY_TOKEN_SERVICE | Not supported | Not supported | Not supported | Required |
| STDERR | Optional | Optional | Optional | Optional |
| STDIN | Optional | Optional | Optional | Optional |
| STDOUT | Optional | Optional | Optional | Optional |
| USEROUTPUTCLASS | Optional | Not supported | Optional | Optional |
| WLP_INSTALL_DIR | Not supported | Required | Not supported | Not supported |
| WLP_LINK_TIMEOUT | Not supported | Optional | Not supported | Not supported |
| WLP_OUTPUT_DIR | Not supported | Optional | Not supported | Not supported |
| WLP_USER_DIR | Not supported | Optional | Not supported | Not supported |
| WORK_DIR | Optional | Optional | Optional | Optional |
| WSDL_VALIDATOR | Optional | Not supported | Optional | Optional |
| ZCEE_INSTALL_DIR | Not supported | Optional | Not supported | Not supported |

## JVM server options and descriptions

Default values, where applicable, are the values that CICS uses when the option is not specified. The sample JVM profiles might specify a value that is different from the default value.

**Note:** You can still use options that are previously documented as YES|NO but TRUE|FALSE is the preferred syntax. TRUE|FALSE is case-insensitive.

**_DFH_UMASK={007|*number*}**

Sets the UNIX System Services process UMASK that applies when JVMSERVER files are created. This value is a three digit octal. For example, the default value of 007 allows the intended `read/write/execute` permissions of owner and group to be respected, while preventing `read/write/execute` being given to `other` when a file is created. The supplied value must fall within the range of `000` (least restrictive) to 777 (most restrictive). UMASK applies for the lifetime of the JVM.

For security, it is best practice to allocate z/OS user IDs to groups. Permissions can be applied at a group level, rather than on an individual basis.

**CICS_WLP_MODE={INTEGRATED|STANDARD}**

For a Liberty JVM server, choose the level of integration between CICS and Liberty.

Specify the INTEGRATED mode to use CICS integrated-mode Liberty. The Liberty JVM server runs with CICS enabled threads, respects CICS security, integrates with a CICS unit of work, and makes the Java class library for CICS (JCICS) API available for your Java web applications. If this option is omitted or not valid, the default of INTEGRATED is used.

Specify the STANDARD mode to use CICS standard-mode Liberty. The Liberty JVM server runs in a mode that is more standard to all Liberty supported platforms. This mode allows you to port and deploy your Liberty applications from other platforms to CICS without change. The JVM server retains control of the Liberty server and manages the server creation, lifecycle, and configuration. However, threads are not CICS enabled by default and do not run within a CICS transaction context. CICS unit of work integration, CICS security integration, and the JCICS API are not directly available from your Java application.

**CLASSPATH_PREFIX, CLASSPATH_SUFFIX=*classpathnames***

Use these options to specify directory paths, Java archive files, and compressed files to be searched by a JVM that is not OSGi enabled. For example, it is used for Java web services. Do not set a class path if you want to use an OSGi framework because the OSGi framework handles the class loading for you. If you use these options to specify the standard class path for Axis2, you must also specify JAVA_PIPELINE=TRUE to start the Axis2 engine.

`CLASSPATH_PREFIX` adds class path entries to the beginning of the standard class path, and `CLASSPATH_SUFFIX` adds them to the end of the standard class path. You can specify entries on separate lines by using a \ (backslash) at the end of each line that is to be continued.

Use the `CLASSPATH_PREFIX` option with care. Classes in `CLASSPATH_PREFIX` take precedence over classes of the same name that are supplied by CICS and the Java run time and the wrong classes might be loaded.

CICS builds a base class path for a JVM by using the `/lib` subdirectories of the directories that are specified by the **USSHOME** system initialization parameter and the `JAVA_HOME` option in the JVM profile. This base class path contains the Java archive files that are supplied by CICS and by the JVM. It is not visible in the JVM profile. You do not specify these files again in the class paths in the JVM profile.

Use a colon (:) not a comma to separate multiple items that you specify by using the `CLASSPATH_PREFIX` or `CLASSPATH_SUFFIX` options.

**DIAGS_ARCHIVE_DIR=*pathname***

Specifies where the diagnostics archive tar file is stored when the the PERFORM JVMSERVER (*jvmserver-name*) JVM GATHER DIAGNOSTICS command completes. See Using the PERFORM JVMSERVER SPI to gather JVM diagnostics. Defaults to `${WORKDIR}/diagnostics/archives`.

**DIAGS_TEMP_DIR=*pathname***

Specifies where the diagnostics archive tar file is initially created and where trace information is stored as the PERFORM JVMSERVER (*jvmserver-name*) JVM GATHER DIAGNOSTICS command runs. See Using the PERFORM JVMSERVER SPI to gather JVM diagnostics. Defaults to `/tmp`.

**DISPLAY_JAVA_VERSION={TRUE|FALSE}**

If this option is set to TRUE, when a JVM is started by an application, CICS writes message DFHSJ0901 to the MSGUSER log, showing the version and build of the IBM Software Developer Kit for z/OS, Java Technology Edition that is in use.

**IDENTITY_PREFIX={TRUE|FALSE}**

To establish the origin of JVM server output, all `STDOUT`, and `STDERR` entries that are routed to JES are written with a prefix string of the JVM server name, which is useful if multiple JVM servers are sharing a JES destination. This behavior can be disabled by setting `IDENTITY_PREFIX=FALSE`, which disables use of the prefix string.

**JAF_REGISTRATION={TRUE|FALSE}**

Specifies that the Jakarta Activation framework (JAF) registration JAR files are automatically added to the JVM runtime environment to support the usage of JAF by Java applications. This option is ignored for Liberty JVM servers. It is possible to opt out of the automatic addition of these files by setting `JAF_REGISTRATION=FALSE`. If this function is not required, opting out can prevent potential clashes with newer JAR files, can keep the JVM footprint smaller, and avoids unnecessary class loading. Before Java 11, this technology is included as part of the JRE.

**JAVA_DUMP_TDUMP_PATTERN=**

A z/OS UNIX System Services environment variable that specifies the file name pattern to be used for transaction dumps (TDUMPs) from the JVM. Java TDUMPs are written to a data set destination in the event of a JVM abend.

**JAVA_HOME=`/usr/lpp/java/`*`javadir`*`/`**

Specifies the installation location for IBM 64-bit SDK for z/OS, Java Technology Edition in z/OS UNIX. This location contains subdirectories and Java archive files that are required for Java support.

The supplied sample JVM profiles contain a path that was generated by the **`JAVADIR`** parameter in the DFHISTAR CICS installation job. The default for the **`JAVADIR`** parameter is `java/J8.0_64/`, which is the default installation location for the IBM 64-bit SDK for z/OS, Java Technology Edition. This value produces a `JAVA_HOME` setting in the JVM profiles of `/usr/lpp/java/J8.0_64/`.

**JAVA_PIPELINE={TRUE|FALSE}**

Adds the required Java archive files to the class path so that a JVM server can support web services processing in Java standard SOAP pipelines. The default value is FALSE. If you set this value, the JVM server is configured to support Axis2 instead of OSGi. You can add more JAR files to the class path by using the `CLASSPATH` options.

**Note:** The options JAVA_PIPELINE=TRUE and SECURITY_TOKEN_SERVICE=TRUE are not compatible.

**JAXB_REGISTRATION={TRUE|FALSE}**

Specifies that the Jakarta XML Binding API (JAXB) registration JAR files are automatically added to the JVM runtime environment to support the usage of JAXB by Java applications. This option is ignored for Liberty JVM servers. It is possible to opt out of the automatic addition of these files by setting `JAXB_REGISTRATION=FALSE`. If this function is not required, opting out can prevent potential clashes with newer JAR files, can keep the JVM footprint smaller, and avoids unnecessary class loading. Before Java 11, this technology is included as part of the JRE.

**JNDI_REGISTRATION={TRUE|FALSE}**

Specifies that the `JNDI` registration JAR files are automatically added to the JVM runtime environment to support the usage of the `JNDI` by Java applications. This option is ignored for Liberty JVM servers. It is possible to opt out of the automatic addition of these files by setting `JNDI_REGISTRATION=FALSE`. If this function is not required, opting out can prevent potential clashes with newer JAR files, can keep the JVM footprint smaller, and avoids unnecessary class loading.

**JVMLOG={`{&APPLID;.&JVMSERVER;.}Dyyyymmdd.Thhmmss.dfhjvmlog`|*filename*|JOBLOG|//DD:*data_definition*}**

Specifies the name of the z/OS UNIX file or JES DD to which JVM server logging is written during operation of a JVM server. If you do not set a value for this option, CICS automatically creates unique log files for each JVM server.

If `JVMLOG` is left to default or is a relative file name, the output location depends on the `LOG_PATH_COMPATIBILITY` option. If `LOG_PATH_COMPATIBILITY=FALSE`, the files are placed in the `WORK_DIR/applid/jvmserver` directory. If `LOG_PATH_COMPATIBILITY=TRUE`, the files are placed in the `WORK_DIR` directory.

If an absolute file name is specified for `JVMLOG`, CICS creates any directories within the path that do not exist.

If the file exists, output is appended to the end of the file. To create unique output files for each JVM server, use the `JVMSERVER` and `APPLID` symbols in your file name, as demonstrated in the sample JVM profiles. If `JVMLOG` is left to default, CICS uses the `APPLID` and `JVMSERVER` symbols, and the date and timestamp when the JVM server started to create unique output files.

To route to a JES DD, specify the data definition name from JES by using the syntax //DD:*data_definition*.

If this option is set to `JOBLOG`, `JVMLOG` is routed to the current `stdout` location.

**JVMTRACE={{&APPLID;.&JVMSERVER;.}Dyyyymmdd.Thhmmss.dfhjvmtrc|*filename*|JOBLOG|//DD:*data_definition*}**

Specifies the name of the z/OS UNIX file or JES DD to which JVM server tracing is written during operation of a JVM server. If you do not set a value for this option, CICS automatically creates unique trace files for each JVM server.

If JVMTRACE is left to default or is a relative file name, the output location depends on the LOG_PATH_COMPATIBILITY option. If LOG_PATH_COMPATIBILITY=FALSE, the files are placed in the WORK_DIR/applid/jvmserver directory. If LOG_PATH_COMPATIBILITY=TRUE, the files are placed in the WORK_DIR directory.

If an absolute file name is specified for JVMTRACE, CICS creates any directories within the path that do not exist.

If the file exists, output is appended to the end of the file. To create unique output files for each JVM server, use the JVMSERVER and APPLID symbols in your file name, as demonstrated in the sample JVM profiles. If JVMTRACE is left to default, CICS uses the APPLID and JVMSERVER symbols, and the date and timestamp when the JVM server started to create unique output files.

To route to a JES DD, specify the data definition name from JES by using the syntax //DD:*data_definition*.

If this option is set to JOBLOG, JVMTRACE is routed to the current stdout location.

**LIBERTY_INCLUDE_XML=*filenames***

Specifies a file, or a comma-separated list of files, to be added to the server.xml as <include> elements.

Use the + character before a variable to append a comma and the value that is specified to the existing value of that variable, for example:

```
LIBERTY_INCLUDE_XML=/path/file1
+LIBERTY_INCLUDE_XML=/path/file2
```

This is the equivalent to:

```
LIBERTY_INCLUDE_XML=/path/file1,/path/file2
```

**LIBERTY_PRODUCT_EXTENSIONS=*name;location***

Allows installation of a users own product extension into a Liberty server.

The *name* is a unique name for the product extension. It is used also as the feature prefix. The *location* is the absolute location of the directory on zFS where the product extension is located and maintained.

You can add multiple product extensions by using a comma to separate them. Alternatively, you can use an append syntax.

```
LIBERTY_PRODUCT_EXTENSIONS=product1;/u/product1, product2;/u/product2

OR

LIBERTY_PRODUCT_EXTENSIONS=product1;/u/product1
+LIBERTY_PRODUCT_EXTENSIONS=product2;/u/product2
```

**Warning:** Do not name your product extension cicsts because it clashes with core JVM server support and gives unpredictable results.

Do not name your product extension usr because Liberty looks for the extensions in the ${wlp.usr.dir}/extension directory instead of your own directory.

**LIBPATH_PREFIX, LIBPATH_SUFFIX=*pathnames***

Specifies directory paths to be searched for native C dynamic link library (DLL) files that are used by the JVM, and that have the extension .so in z/OS UNIX. This includes files that are required to run the JVM and extra native libraries that are loaded by application code or services.

The base library path for the JVM is built automatically by using the directories that are specified by the **USSHOME** system initialization parameter and the JAVA_HOME option in the JVM profile. The base library path is not visible in the JVM profile. It includes all the DLL files that are required to run the JVM and the native libraries that are used by CICS.

You can extend the library path by using the LIBPATH_SUFFIX option. This option adds directories to the end of the library path after the base library path. Use this option to specify directories that contain any additional native libraries that are used by your applications. Also, use this option to specify directories that are used by any services that are not included in the standard JVM setup for CICS. For example, the additional native libraries might include the DLL files that are required to use the Db2 JDBC drivers.

The LIBPATH_PREFIX option adds directories to the beginning of the library path before the base library path. Use this option with care. If DLL files in the specified directories have the same name as DLL files on the base library path, they are loaded instead of the supplied files.

Use a colon, not a comma, to separate multiple items that you specify by using the LIBPATH_PREFIX or LIBPATH_SUFFIX option.

DLL files that are on the library path for use by your applications must be compiled and linked with the XPLink option. Compiling and linking with the XPLink option provides optimum performance. The DLL files that are supplied on the base library path and the DLL files that are used by services such as the Db2 JDBC drivers are built with the XPLink option.

**LOG_FILES_MAX={0|*number*}**

Specifies the number of old log files that are kept on the system. A default setting of 0 ensures that all old versions of the log file are retained. You can change this value to specify how many old log files you want to remain on the file system.

If **LOG_PATH_COMPATIBILITY=TRUE**, **LOG_FILES_MAX** is ignored.

If **STDOUT**, **STDERR**, **JVMLOG**, and **JVMTRACE** use the default scheme, or if customized, they include the *&DATE;.&TIME;* pattern, then only the newest *number* of each log type is kept on the system. If your customization does not include any variables, which make the output unique, then the files are appended to, and there is no requirement for deletion. Only files with the .dfhjvmtrc, .dfhjvmlog, .dfhjvmout or .dfhjvmerr will be deleted.

The clean-up does not apply if the output variables are customized to route output to DD:// or JOBLOG.

**LOG_LEVEL={INFO|WARNING|ERROR|NONE}**

Provides control over the logged information that is returned in the dfhjvmlog file. A value of NONE suppresses all output and the file is empty. Any other value indicates the lowest log type that is written to the dfhjvmlog file. For example, selecting WARNING gives log entries of WARNING level and above.

**LOG_PATH_COMPATIBILITY={TRUE|FALSE}**

The default value for this behavior is LOG_PATH_COMPATIBILITY=FALSE, which provides a consolidated log output behavior. The new behavior places the **JVMSERVER** log files in the same output directory structure as used by existing subcomponents of the **JVMSERVER**, for example: the OSGi framework, and the Liberty server. To revert to behavior from previous releases, set the parameter to LOG_PATH_COMPATIBILITY=TRUE, and the **JVMSERVER** log directories are created in the original location.

**OSGI_BUNDLES=*pathnames***

Specifies the directory path for middleware bundles that are enabled in the OSGi framework of an OSGi JVM server. These OSGi bundles contain classes to implement system functions in the framework, such as connecting to IBM MQ or Db2. If you specify more than one OSGi bundle, use commas to separate them.

**OSGI_CONSOLE={TRUE|FALSE}**

Adds the required OSGi bundles to the OSGi framework to enable the OSGi console. You must also set the following properties in the JVM profile: `-Dosgi.console=host:port` and `-Dosgi.file.encoding={ISO-8859-1|US-ASCII|ASCII}`. The default value is FALSE. If you want to look at the state of OSGi bundles and services, see Troubleshooting Java applications.

**OSGI_FRAMEWORK_TIMEOUT={60|*number*}**

Specifies the number of seconds that CICS waits for the OSGi framework to initialize or shut down before it times out. You can set a value in the range 1 - 60000 seconds. The default value is 60 seconds. If the OSGi framework takes longer to start than the specified number of seconds, the JVM server fails to initialize, and a DFHSJ0215 message is issued by CICS. Error messages are also written to the JVM server log files in zFS. If the OSGi framework takes longer to shut down than the specified number of seconds, the JVM server fails to shut down normally.

**PRINT_JVM_OPTIONS={TRUE|FALSE}**

If this option is set to TRUE, whenever a JVM starts, the options that are passed to the JVM at start are also printed to SYSPRINT. The output is produced every time a JVM starts with this option in its profile. You can use this option to check the contents of the class paths for a particular JVM profile, including the base library path and the base class path that are built by CICS, which are not visible in the JVM profile.

**PRINT_PROFILE={TRUE|FALSE}**

If this option is set to TRUE, the options, system properties, and environment variables from the profile that are passed to the JVM server and application are output to SYSPRINT.

**PURGE_ESCALATION_TIMEOUT={15|*time*}**

Specifies the interval in seconds between the disable actions that CICS performs when a JVM server encounters a TCB failure or a runaway task. After each timeout, CICS escalates to the next disable action (for example, from phaseout to purge), until the JVM server has been recycled.

CICS performs the following steps in sequence:

1. CICS disables the JVMSERVER resource with the PHASEOUT option to allow existing work in the JVM to complete where possible and prevent new work from using the JVM.
2. If the PHASEOUT operation fails to disable the JVMSERVER within the interval specified by the `PURGE_ESCALATION_TIMEOUT` JVM server option, CICS escalates to the next disable action PURGE until the JVMSERVER is disabled.

   For a Liberty JVM server, there is a minimum of 60-second timeout from phaseout to purge.
3. If the PURGE operation fails to disable the JVMSERVER within the interval, CICS escalates to the next disable action FORCEPURGE.
4. If the FORCEPURGE operation fails to disable the JVMSERVER within the interval, CICS escalates to KILL.
5. After the JVMSERVER is successfully disabled, message DFHSJ1008 is issued.
6. CICS attempts to re-enable the resource to create a new JVM.

**SCRIPT_TIMEOUT_SECS={300|*number*}**

Specifies the number of seconds that the PERFORM JVMSERVER (*jvmserver-name*) JVM GATHER DIAGNOSTICS command is permitted to run before it is considered to have malfunctioned, after which execution is abandoned. See Using the PERFORM JVMSERVER SPI to gather JVM diagnostics. Defaults to 300 seconds.

**SECURITY_TOKEN_SERVICE={TRUE|FALSE}**

If this option is set to TRUE, the JVM server can use security tokens. If this option is set to FALSE, Security Token Service support is disabled for the JVM server.

**Note:** The options SECURITY_TOKEN_SERVICE=TRUE and JAVA_PIPELINE=TRUE are not compatible.

**STDERR={`{&APPLID;.&JVMSERVER;.}Dyyyymmdd.Thhmmss.dfhjvmerr`|*filename*|JOBLOG|//DD:*data_definition*}**

Specifies the name of the z/OS UNIX file or JES DD to which the `stderr` stream is redirected. If you do not set a value for this option, CICS automatically creates unique trace files for each JVM server.

If STDERR is left to default or is a relative file name, the output location depends on the `LOG_PATH_COMPATIBILITY` option. If `LOG_PATH_COMPATIBILITY=FALSE`, the files are placed in the `WORK_DIR/applid/jvmserver` directory. If `LOG_PATH_COMPATIBILITY=TRUE`, the files are placed in the `WORK_DIR` directory.

If an absolute file name is specified for STDERR, CICS creates any directories within the path that do not exist.

If the file exists, output is appended to the end of the file. To create unique output files for each JVM server, use the `JVMSERVER` and `APPLID` symbols in your file name, as demonstrated in the sample JVM profiles. If STDERR is left to default, CICS uses the `APPLID` and `JVMSERVER` symbols, and the date and timestamp when the JVM server started to create unique output files.

To route to a JES DD, specify the data definition name from JES by using the syntax //DD:*data_definition*.

If this option is set to `JOBLOG`, STDERR is routed to SYSOUT if defined, or to a dynamic SYS*nnn* if not.

If you specify the USEROUTPUTCLASS option on a JVM profile, the Java class that is named on that option handles the `System.err` requests instead. The z/OS UNIX file that is named by the STDERR option might still be used if the class named by the USEROUTPUTCLASS option cannot write data to its intended destination; for example, when you use the supplied sample class `com.ibm.cics.samples.SJMergedStream`. You can also use the file if output is directed to it for any other reason by a class that is named by the USEROUTPUTCLASS option.

**STDIN=*filename***

Specifies the name of the z/OS UNIX file from which the `stdin` stream is read. CICS does not create this file unless you specify a value for this option.

**STDOUT={`{&APPLID;.&JVMSERVER;.}Dyyyymmdd.Thhmmss.dfhjvmout`|*filename*|JOBLOG|//DD:*data_definition*}**

Specifies the name of the z/OS UNIX file or JES DD to which the `stdout` stream is redirected. If you do not set a value for this option, CICS automatically creates unique trace files for each JVM server.

If STDOUT is left to default or is a relative file name, the output location depends on the `LOG_PATH_COMPATIBILITY` option. If `LOG_PATH_COMPATIBILITY=FALSE`, the files are placed in the `WORK_DIR/applid/jvmserver` directory. If `LOG_PATH_COMPATIBILITY=TRUE`, the files are placed in the `WORK_DIR` directory.

If an absolute file name is specified for STDOUT, CICS creates any directories within the path that do not exist.

If the file exists, output is appended to the end of the file. To create unique output files for each JVM server, use the `JVMSERVER` and `APPLID` symbols in your file name, as demonstrated in the sample JVM profiles. If STDOUT is left to default, CICS uses the `APPLID` and `JVMSERVER` symbols, and the date and timestamp when the JVM server started to create unique output files.

To route to a JES DD, specify the data definition name from JES by using the syntax //DD:*data_definition*.

If this option is set to `JOBLOG`, STDOUT is routed to SYSPRINT if defined, or to a dynamic SYS*nnn* if not.

If you specify the USEROUTPUTCLASS option on a JVM profile, the Java class that is named on that option handles the `System.out` requests instead. The z/OS UNIX file that is named by the STDOUT option might still be used if the class named by the USEROUTPUTCLASS option cannot write data to its intended destination; for example, when you use the supplied sample class `com.ibm.cics.samples.SJMergedStream`. You can also use the file if output is directed to it for any other reason by a class that is named by the `USEROUTPUTCLASS` option.

**USEROUTPUTCLASS=*classname***

Specifies the fully qualified name of a Java class that intercepts the output from the JVM and messages from JVM internals. You can use this Java class to redirect the output and messages from your JVMs, and you can add timestamps and headers to the output records. This is not supported for Liberty. If the Java class cannot write data to its intended destination, the files that are named in the `STDOUT` and `STDERR` options might still be used.

Specifying the `USEROUTPUTCLASS` option has a negative effect on the performance of JVMs. For best performance in a production environment, do not use this option. However, this option can be useful to application developers who are using the same CICS region because the JVM output can be directed to an identifiable destination.

For more information about this class and the supplied samples, see Controlling the location for JVM output, logs, dumps and trace.

**WLP_INSTALL_DIR={&USSHOME;/wlp|*directory_path*}**

Specifies the Liberty installation directory. The default location for Liberty is the z/OS UNIX home directory for CICS in a subdirectory called `wlp`. The default installation directory is `/usr/lpp/cicsts/cicsts56/wlp`.

To set the correct file path, you can either:

- Use the &USSHOME; symbol to set the default file path and append the `wlp` directory.
- Specify the installation directory of an alternative Liberty version. In this case, CICS verifies the level of Liberty requested by:
  - Enforcing a minimum version of Liberty. If you attempt to launch a version of Liberty that is below the minimum level that CICS supports, an exception is thrown and the Liberty JVM server does not start. The exception message - written to JVMLOG and STDERR - indicates the version of Liberty being launched and the minimum version accepted: `Liberty version XX.X.X.X not supported. Minimum version is YY.Y.Y.Y`.
  - Issuing a warning if the version of Liberty being launched is greater than the maximum version of Liberty supported by CICS. The warning is written to JVMLOG and Liberty continues to launch. This might happen if CICS does not yet offer support for this level of Liberty or if you have not applied the companion CICS service APAR. If you encounter this warning, it is prudent to confine your use of such versions to test, prototype, or development systems.

  The minimum and maximum supported Liberty versions are reassessed regularly and are changed, if appropriate, by the quarterly CICS Liberty fixpack APAR.

In addition to the *&USSHOME;* environment variable, you can also supply other environment variables and system properties to configure the Liberty JVM server. The environment variables are prefixed with WLP, and the system properties are described in "JVM system properties" on page 253.

**WLP_LINK_TIMEOUT={30000|*number*}**

Specifies the number of milliseconds that CICS waits to dispatch a request to invoke an application in the Liberty JVM server before it times out. If you specify 0, CICS waits indefinitely. The default value is 30000 milliseconds. If the task has no been dispatched to the Liberty JVM server after the specified number of milliseconds, the EXEC CICS LINK command fails and CICS issues DFHSJ1006 message.

**WLP_OUTPUT_DIR=$WLP_USER_DIR/servers**

Specifies the directory that contains output files for the Liberty profile. By default, the Liberty profile stores logs, the work area, configuration files, and applications, for the server in a directory that is named after the server.

This environment variable is optional. If you do not specify it, CICS defaults to *`$WORK_DIR/&APPLID;`*`/`*`&JVMSERVER;`*`/wlp/usr/servers`, replacing the symbols with runtime values.

If this environment variable is set, the output logs and work area are stored in `$WLP_OUTPUT_DIR/`*`server_name`*.

**WLP_USER_DIR={`&APPLID;/&JVMSERVER;/wlp/usr/`|*directory_path*}**

Specifies the directory that contains the configuration files for the Liberty JVM server.
This environment variable is optional. If you do not specify it, CICS uses *`&APPLID;`*`/`*`&JVMSERVER;`*`/wlp/usr/` in the working directory, replacing the symbols with runtime values.
Configuration files are written to `servers/`*`server_name`*.

**WORK_DIR={.|`/tmp`|*directory_name*}**

Specifies the working directory on z/OS UNIX that the CICS region uses for activities that are related to JVMSERVER. The CICS JVMSERVER uses this directory as the route of configuration and output. A period (.) is defined in the supplied JVM profiles, indicating that the home directory of the CICS region user ID is to be used as the working directory. This directory can be created during CICS installation. If the directory does not exist or if `WORK_DIR` is omitted, `/tmp` is used as the z/OS UNIX directory name.

You can specify an absolute path or relative path to the working directory. A relative working directory is relative to the home directory of the CICS region user ID. If you do not want to use the home directory as the working directory for activities that are related to Java, or if your CICS regions are sharing the z/OS user identifier (UID) and so have the same home directory, you can create a different working directory for each CICS region.

If you specify a directory name that uses the &APPLID; symbol (whereby CICS substitutes the actual CICS region APPLID), you can have a unique working directory for each region, even if all the CICS regions share the set of JVM profiles. For example, if you specify:

```
WORK_DIR=/u/&APPLID;/javaoutput
```

each CICS region that uses that JVM profile has its own working directory. Ensure that the relevant directories are created on z/OS UNIX, and that the CICS regions are given read, write, and run access to them.

You can also specify a fixed name for the working directory. In this situation, you must also ensure that the relevant directory is created on z/OS UNIX, and access permissions are given to the correct CICS regions. If you use a fixed name for the working directory, the output files from all the JVM servers in the CICS regions that share the JVM profile are created in that directory. If you use fixed file names for your output files, the output from all the JVM servers in those CICS regions is appended to the same z/OS UNIX files. To avoid appending to the same files, use the JVMSERVER symbol and the APPLID symbols to produce unique output and dump files for each JVM server.

Do not define your working directories in the CICS installation directory on z/OS UNIX, which is the home directory for CICS files as defined by the **USSHOME** system initialization parameter.

**WSDL_VALIDATOR={TRUE|FALSE}**

Enables validation for SOAP requests and responses against their definition and schema. This option is ignored for Liberty JVM servers. For more information, see Validating SOAP messages. It is possible to turn off this option by setting WSDL_VALIDATOR=FALSE. Opting out can prevent potential clashes with newer JAR files, wasted storage, and slower start.

**ZCEE_INSTALL_DIR={*directory_name*}**

Provides the location of the z/OS Connect Enterprise Edition feature installation. For z/OS Connect Enterprise Edition V2.0, the default is `/usr/lpp/IBM/zosconnect/v2r0/runtime`. For z/OS Connect Enterprise Edition V3.0, the default is `/usr/lpp/IBM/zosconnect/v3r0/runtime`.

### *JVM command-line options*

JVM command-line options, with descriptions.

## List of command-line options

**Note:** This list is not exhaustive. It is a list of useful IBM® JVM options. Options that include -X are specific to the IBM JVM.

**-agentlib**

Specifies whether debugging support is enabled in the JVM.

For more information, see Debugging a Java application. For more information about the Java Platform Debugger Architecture (JPDA), see Oracle Technology Network Java website.

**-Xcompressedrefs**

Java 1.7.1 sets compressed references by default. This setting instructs the virtual machine (VM) to store all references to objects, classes, threads, and monitors as 32-bit values, rather than 64-bit values. The use of compressed references improves the performance of many applications because objects are smaller, resulting in less frequent garbage collection, and improved memory cache usage. However, this is at the expense of a large initial allocation of 31-bit storage.

Before Java 1.7.1, the use of compressed references was optional. To balance the use of `-Xcompressedrefs` in a JVM server, and to offset the large initial 31-bit storage allocation, a JVM server automatically sets the `-XXnosuballoc32bitmem` option. The effect of this option is to avoid a large initial allocation in favor of incremental allocations as required. For many applications, this behavior is an adequate balance between performance and storage use. For applications that use many references, reducing the available 31-bit storage (or if operating within a 31-bit storage constrained environment) then the use of `-Xnocompressedrefs` might be preferable - consider using this option if you are constrained on 31-bit storage.

**-Xnocompressedrefs**

The use of `-Xnocompressedrefs` might be preferable for applications that use many references that reduce the available 31-bit storage (or if operating within a 31-bit storage constrained environment).

**-Xms**

Specifies the initial size of the heap. Specify storage sizes in multiples of 1024 bytes. Use the letter K to indicate KB, the letter M to indicate MB, and the letter G to indicate GB. For example, to specify 6,291,456 bytes as the initial size of the heap, code **`-Xms`** in one of the following ways:

```
-Xms6144K
-Xms6M
```

Specify *size* as a number of KB or MB. For information, see JVM command-line options in IBM SDK.

**-Xmso**

Sets the initial stack size for operating system threads.

For more information about the **`-Xmso`** JVM option and the default value, see -Xmso.

**-Xmx**

Specifies the maximum size of the heap. This fixed amount of storage is allocated by the JVM during JVM initialization.

Specify *size* as a number of KB or MB.

**-Xscmx**

Specifies the size of the shared class cache. The minimum size is 4 KB: the maximum and default sizes are platform-dependent.

Specify *size* as a number of KB or MB. For information, see JVM command-line options in IBM SDK.

**-Xshareclasses**

Specify this option to enable class data sharing in a shared class cache. The JVM connects to an existing cache or creates a cache if one does not exist. You can have multiple caches and you can specify the correct cache by adding a suboption to the **`-Xshareclasses`** option. For more information, see Class data sharing between JVMs in IBM SDK.

**-XX:[+|-]EnableCPUMonitor**

This defaults to **`-XX:-EnableCPUMonitor`** when running in a JVM server, however, if you want to use the enhanced JMX CPU-monitoring capabilities, it should be set to **`-XX:+EnableCPUMonitor`**. Enabling this option will incur an increased CPU usage.

### *JVM system properties*

JVM system properties provide configuration information specific to the JVM and its runtime environment. You provide JVM system properties by adding them to the JVM profile. At run time, CICS reads the properties from the JVM profile, and passes them to the JVM.

## Property prefix

System properties must be set by using a -D prefix. For example, the correct syntax for **`com.ibm.cics`** is **`-Dcom.ibm.cics`**.

**`com.ibm.cics`** indicates that the property is specific to the IBM JVM in a CICS environment.
**`com.ibm`** indicates a general JVM property that is used more widely.
**`java.ibm`** also indicates a general JVM property that is used more widely.

For information about general properties, see "JVM profile validation and properties" on page 238.

## Property coding rules

Properties must be specified according to a set of coding rules. For more information about the rules, see "Rules for coding profiles" on page 238.

## Applicability of properties to different uses of JVM server

For a generic JVM server, three types are available: OSGi, Liberty, and Classpath. Classpath JVM servers can be further refined to Axis2-capable, Security Token Server (STS)-capable, Batch-capable, and Mobile-capable. The following table shows the options that apply to each specific capability. The table also indicates whether a property is supported for a particular use of a JVM server. Some properties are read-only. Changing a read-only property might result in runtime environment failure. For details about these properties, see "Read-only properties" on page 256.

*Table 42. Options by JVM server use*

| System property | OSGi | Liberty | Classpath |
|---|---|---|---|
| com.ibm.cics.json.enableAxis2Handlers | Not supported | Not supported | Supported |
| com.ibm.cics.jvmserver.applid | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.cics.product.name | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.cics.product.version | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.configroot | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.controller.timeout | Supported | Supported | Not supported |
| com.ibm.cics.jvmserver.local.ccsid | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.name | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.override.ccsid | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.supplied.ccsid | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.threadjoin.timeout | Supported | Supported | Not supported |
| com.ibm.cics.jvmserver.trace.filename | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.trace.format | Supported | Supported | Supported |

*Table 42. Options by JVM server use (continued)*

| System property | OSGi | Liberty | Classpath |
|---|---|---|---|
| com.ibm.cics.jvmserver.trace.specification | Supported | Supported | Supported |
| com.ibm.cics.jvmserver.trigger.timeout | Supported | Supported | Not supported |
| com.ibm.cics.jvmserver.unclassified.tranid | Supported | Supported | Not supported |
| com.ibm.cics.jvmserver.unclassified.userid | Supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.args | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.autoconfigure | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.bundlepart.timeout | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.defaultapp | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.executor.corethreads | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.install.dir | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.jdbc.driver.location | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.jta.integration | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.latebinding | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.optimize.static.resources | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.optimize.static.resources.extra | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.security.subject.create | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.config.dir | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.host | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.reserve.thread.percentage | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.http.port | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.https.port | Not supported | Supported | Not supported |

Table 42. Options by JVM server use (continued)

| System property | OSGi | Liberty | Classpath |
|---|---|---|---|
| com.ibm.cics.jvmserver.wlp.server.keystore.location | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.keystore.type | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.name | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.server.output.dir | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.wab | Not supported | Supported | Not supported |
| com.ibm.cics.jvmserver.wlp.xml.format | Not supported | Supported | Not supported |
| com.ibm.cics.sts.config | Not supported | Not supported | Supported (STS only) |
| com.ibm.ws.logging.console.log.level | Not supported | Supported | Not supported |
| com.ibm.ws.zos.core.angelName | Not supported | Supported | Not supported |
| com.ibm.ws.zos.core.angelRequired | Not supported | Supported | Not supported |
| com.ibm.ws.zos.core.angelRequiredServices | Not supported | Supported | Not supported |
| console.encoding | Supported | Supported | Supported |
| file.encoding | Supported | Supported | Supported |
| java.security.manager | Supported | Not supported | Supported |
| java.security.policy | Supported | Not supported | Supported |
| org.osgi.framework.storage.clean | Supported | Supported | Not supported |
| org.osgi.framework.system.packages.extra | Supported | Supported | Not supported |
| osgi.compatibility.bootdelegation | Supported | Supported | Not supported |

## Properties applicable to CMCI JVM server only

The CMCI JVM server is a Liberty server that can be configured either in the WUI region of a CICSPlex SM environment or a single CICS region for an SMSS environment. It is an optional component of the CICS management client interface (CMCI), a system management API for use by HTTP client applications such as IBM® CICS Explorer®. The CMCI JVM server provides enhanced support for CMCI requests, such as the GraphQL API and the CICS bundle deployment API and is highly recommended for the CICSPlex SM environment.

*Table 43. Options by CMCI JVM server use*

| System property |
|---|
| com.ibm.cics.jvmserver.cmci.bundles.dir |
| com.ibm.cics.jvmserver.cmci.deploy.timeout |
| com.ibm.cics.jvmserver.cmci.max.file.size |
| com.ibm.cics.jvmserver.cmci.max.request.size |
| com.ibm.cics.jvmserver.cmci.user.agent.allow.list |
| com.ibm.cics.jvmserver.cmci.user.agent.allow.list.monitor.interval |
| com.ibm.cics.jvmserver.cmci.user.agent.allow.list.reject.text |
| com.ibm.cics.jvmserver.wlp.saf.profilePrefix |

## Read-only properties

**com.ibm.cics.json.enableAxis2Handlers**

Indicates that a JVM requires the ability to run Axis2 handler programs when processing JSON data. This property is only relevant to a JVM that has `JAVA_PIPELINE=YES` specified and is configured to support JSON pipelines. This option is not relevant to z/OS Connect in CICS, and should be enabled only if the capability is required. Enabling this option ensures that Axis2 Handler programs can run during a JSON workload but there is likely to be a performance penalty and some of the capabilities of mapping level 4.2 and later WSBind files will not be available for use.

**com.ibm.cics.jvmserver.applid**

Specifies the CICS region application identifier (APPLID). This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.cics.product.name**

Specifies the name of the CICS product under which Liberty is running. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.cics.product.version**

Specifies the version of the CICS product under which Liberty is running. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.configroot**

Specifies the location where configuration files, such as the JVM profile of a JVM server, can be found. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.local.ccsid**

Specifies the code page for file encoding when the JCICS API is used. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.name**

Specifies the name of the JVM server. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.supplied.ccsid**

Specifies the default CCSID for the local CICS region. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.trace.filename**

Specifies the name of the JVM server trace file. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.wlp.install.dir**

Specifies the location of the Liberty installation. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.wlp.server.config.dir**
Specifies the location of the Liberty configuration directory. This is a read-only property. You can use this property in an application but you should not change it.

**com.ibm.cics.jvmserver.wlp.server.output.dir**
Specifies the location of the Liberty output directory where you can find Liberty logs. This is a read-only property. You can use this property in an application but you should not change it.

## Properties that can be changed

**com.ibm.cics.jvmserver.cmci.bundles.dir=*<bundles_directory>***

**Note:** This property is intended only for the CICS bundle deployment API.

Specifies the bundles directory on zFS that stores the CICS bundles pushed to the API.

**com.ibm.cics.jvmserver.cmci.deploy.timeout={`120000`|*timeout_limit*}**

**Note:** This property is intended only for the CICS bundle deployment API.

Specifies the timeout limit for deploying a CICS bundle, in milliseconds. This includes the time for all bundle lifecycle actions, including disable, discard, install and enable. Use only numeric characters when you change this value.

**com.ibm.cics.jvmserver.cmci.max.file.size={`52428800`|*max_file_size*}**

**Note:** This property is intended only for the CICS bundle deployment API.

Specifies the maximum size allowed for the uploaded CICS bundle, in bytes.

**com.ibm.cics.jvmserver.cmci.max.request.size={`104857600`|*max_request_size*}**

**Note:** This property is intended only for the CICS bundle deployment API.

Specifies the maximum size allowed for a multipart or form-data request, in bytes.

**com.ibm.cics.jvmserver.cmci.user.agent.allow.list={*file_path*}**

**Note:** This property is intended only for the CMCI JVM server

Specifies the location of the client allowlist file and enables allowlist processing in the CMCI JVM server.

**com.ibm.cics.jvmserver.cmci.user.agent.allow.list.monitor.interval={*time*|`10s`}**

**Note:** This property is intended only for the CMCI JVM server

Specifies the interval of Liberty cache file monitoring checks performed by the CMCI JVM server to refresh the cache of user-agent allowlist values obtained from the client allowlist file.

**com.ibm.cics.jvmserver.cmci.user.agent.allow.list.reject.text={*text*}**

**Note:** This property is intended only for the CMCI JVM server

Specifies a custom response message to return to the user when a request to connect to the CMCI is rejected because the system management client that is used is not in the client allowlist.

**com.ibm.cics.jvmserver.controller.timeout={*time*|`90000ms`}**

This value should be greater than the Liberty bundlepart timeout value, otherwise bundleparts can incorrectly time out. Use only numeric characters when you change this value.

⚠ **Warning:** This property is subject to change at any time.

**com.ibm.cics.jvmserver.override.ccsid=**

⚠ **Warning:** This property is intended for advanced users.

It overrides the code page for file encoding when the JCICS API is used. By default, JCICS uses the value of the **`LOCALCCSID`** system initialization parameter as the file encoding. If you choose to override this value, set the code page in this property. Use an EBCDIC code page. You must ensure that your applications are consistent with the new code page, or errors might occur. For more information about valid CCSIDs, see LOCALCCSID system initialization parameter.

**com.ibm.cics.jvmserver.threadjoin.timeout={*time*|30000ms}**
Controls the timeout value when requests that are waiting for threads are queuing for service. Use only numeric characters when you change this value.

**com.ibm.cics.jvmserver.trace.format={FULL|SHORT|ABBREV}**
Controls the format of the trace, which can be varied for your own purposes. You must set it to SHORT when you send diagnostic information to IBM service.

**com.ibm.cics.jvmserver.trace.specification={filter_text}**

⚠ **Warning:** Use this property only under IBM service guidance. This property is subject to change at any time.

Specifies a JVM server trace filter string that allows finer-grained control over package and class trace from the JVM server. *{filter_text}* is a colon separated string of clauses that sets the trace level of one or more specified components. If not specified, the default value is equivalent to **com.ibm.cics.*=ALL**.

The SJ domain trace flag remains the main switch, but this trace specification allows for extra filtering of specific components.

For any class or package, the most specific filter clause applies. Each filter clause can be set to one of the following levels:

{ALL, DEBUG, ENTRYEXIT, EVENT, INFO, WARNING, ERROR, NONE}

Example 1:

```
com.ibm.cics.jvmserver.trace.specification=com.ibm.cics.*=NONE
```

A single filter clause that suppresses all output.

Example 2:

```
com.ibm.cics.jvmserver.trace.specification=com.ibm.cics.*=NONE:com.ibm.cics.wlp.*=ALL
```

This example has two filter clauses. The first filter clause suppresses all trace. The second filter clause is more specific for all packages under the **com.ibm.cics.wlp** component and ensures that all of their trace output is written.

Example 3:

```
com.ibm.cics.jvmserver.trace.specification=com.ibm.cics.wlp.impl.CICSTaskWrapper=NONE:com.ib
m.cics.wlp.impl.CICSTaskInterceptor=NONE
```

This example has two filter clauses. All trace is written, except trace that is produced from the specific CICSTaskWrapper and CICSTaskInterceptor classes of the **com.ibm.cics.wlp.impl** package.

**com.ibm.cics.jvmserver.trigger.timeout={*time*|500ms}**
Use only numeric characters when you change this value.

⚠ **Warning:** Use this property only under IBM service guidance. This property is subject to change at any time.

**com.ibm.cics.jvmserver.unclassified.tranid={transaction_id}**
Specifies the default transaction that is used for unclassified work that is run in a JVM server.

- In a Liberty JVM server, unclassified work runs under transaction CJSU, unless you specify the `com.ibm.cics.jvmserver.unclassified.tranid` property.
- In an OSGI JVM server, unclassified work runs under transaction CJSA, unless you specify the `com.ibm.cics.jvmserver.unclassified.tranid` property.

The user must ensure that the transaction ID specified is defined to CICS, by duplicating the CJSA or CJSU transaction.

**com.ibm.cics.jvmserver.unclassified.userid={user_id}**
Allows users to change the default user ID under which unclassified work is run as a CICS task in a JVM server. If not specified, the CICS default user ID is used. The user ID specified must be defined to RACF® and have the necessary permissions to run the work.

Unclassified work is any request that is not identified by the HTTP classification component of Liberty; for example, JMS, inbound JCA, EJB requests, and so on.

**com.ibm.cics.jvmserver.wlp.args=**

Provides a way to set Liberty server options during start-up. For a list of server options, see the 'options' section in Server command options.

The `--clean` option is used to clear the Liberty and OSGi caches. By default, the `--clean` option is not set. If CICS maintenance was applied since the JVM server last restarted, then the `--clean` option is used internally as a one-time operation to ensure caches are cleaned.

⚠ **Warning:** This property is typically used under IBM service guidance.

**com.ibm.cics.jvmserver.wlp.autoconfigure={`false`|`true`}**
Specifies whether CICS creates the necessary Liberty directories, `server.xml` and other configuration files within WLP_USER_DIR if they do not exist.

**com.ibm.cics.jvmserver.wlp.bundlepart.timeout={`time`|`60000ms`}**
Controls the timeout value that is used by CICS Liberty during bundlepart installation. If the operation times out, the bundlepart - and by association, the bundle - is moved to the disabled state.

When Liberty acknowledges the installation phase, the bundlepart stays in an enabling state until Liberty fully starts the application. The timeout does not affect bundleparts that reach this state. Use only numeric characters when you change this value.

**Important:** This value should be greater than the Liberty configuration monitor interval, otherwise bundleparts can incorrectly time out.

**com.ibm.cics.jvmserver.wlp.defaultapp={`false`|`true`}**

Instructs CICS to add the `defaultApp-1.0` feature to `server.xml`, which installs the default CICS web application that can be used to verify that the Liberty server is installed and started correctly.

**Tip:** This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.executor.corethreads={*thread_number*|`wlp`}**
Set *thread_number* to an integer between 4 and 256 to override the value of `coreThreads` for the Liberty `<executor>` element in `server.xml`. By default, the CICS capped algorithm is used if the property is omitted.

Alternatively, set `com.ibm.cics.jvmserver.wlp.executor.corethreads=wlp` to use Liberty's default `coreThreads` algorithm.

⚠ **Warning:** Use this property only under IBM Support guidance. This property is subject to change at any time.

**com.ibm.cics.jvmserver.wlp.jdbc.driver.location={*file_path*}**
Specifies the location of the directory that contains the Db2 JDBC drivers. The location must contain the Db2 JDBC driver `classes` and `lib` directories. If the autoconfigure property **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**, when the JVM server is enabled, the existing example configuration in `server.xml` is replaced with the default configuration and any user updates are lost.

**com.ibm.cics.jvmserver.wlp.jta.integration={`false`|`true`}**
Enables CICS integration with the Java Transaction API (JTA). When transactions that are created through the JTA interface are in effect, the CICS unit of work is subordinate to the Java Transaction Manager.

**Tip:** This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.latebinding={NONHTTP|COMPATIBILITY}**

**Warning:** Use this property only under IBM service guidance. This property is subject to change at any time.

**com.ibm.cics.jvmserver.wlp.optimize.static.resources={false|true}**

Enables requests for static content to be processed on a non-CICS thread. The following types of file are recognized as static: `.css` `.gif` `.ico` `.jpg` `.jpeg` `.js` and `.png`.

**com.ibm.cics.jvmserver.wlp.reserve.thread.percentage={percent|10}**

Reserves a percentage of the threadlimit of the Liberty JVM server for use by OSGi Applications. The value can be between 1% and 50%.

**com.ibm.cics.jvmserver.wlp.optimize.static.resources.extra=**

Specifies a custom list of extra static resources for optimization. Items must be comma-separated, and begin with a period, for example: `.css`, `.gif`, `.ico`.

**Tip:** This value is only respected when **`com.ibm.cics.jvmserver.wlp.optimize.static.resources=true`**.

**com.ibm.cics.jvmserver.wlp.saf.profilePrefix=*{my_prefix}***

Specify the prefix for SAF profiles in the EJBROLE class. The default value is the APPLID of the region that contains the CMCI JVM server.

**Note:** This property is intended only for the CMCI JVM server

**com.ibm.cics.jvmserver.wlp.security.subject.create={true|*false*}**

Allows the user to turn off Java Subject creation when performing a LINK to Liberty.

If your application does not perform security role checking, setting `com.ibm.cics.jvmserver.wlp.security.subject.create=false` gives a performance boost. The value of this setting is specific to each JVMSERVER that you LINK to.

RunAs role behavior is unchanged.

**com.ibm.cics.jvmserver.wlp.server.host={*|*hostname*|*IP_address*}**

Specifies the name or IP address in IPv4 or IPv6 format of the host for HTTP requests to access the web application. The Liberty JVM server uses * as the default value. This value is not appropriate for running a web application in CICS, so either use this property to provide a different value or update the `server.xml` file.

**Tip:** This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.server.http.port={9080|*port_number*}**

Specifies a port to accept HTTP requests for a Java web application. CICS uses the default value that is supplied by Liberty. The Liberty JVM server does not use a TCPIPSERVICE resource. Ensure that the port number is free or shared on the z/OS system.

**Tip:** This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.server.https.port={9443|*port_number*}**

Specifies a port to accept HTTPS requests for a Java web application. CICS uses the default value that is supplied by Liberty. The Liberty JVM server does not use a TCPIPSERVICE resource, so ensure that the port number is free or shared on the z/OS system.

**Tip:** This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.server.keystore.location={zFS | *location_url*}**

CICS generates a default Liberty keystore element with the ID of *defaultKeyStore*. The location of the default keystore is in zFS for Liberty and in SAF for CMCI. Use this property to explicitly request either a zFS based keystore, a SAF-based keystore, and to override the user ID and key ring values.

***zFS***

Specifies that Liberty creates the default zFS based Java keystore. *zFS* is the default except for the CMCI JVM server, which updates the zFS keystore location to SAF.

***location_url***

A SAF-based keystore is configured by using a *location_url* value with the following format.

*scheme*://*userid*/*keyring*

The *scheme* can be one of the following values: `safkeyring`, `safkeyringhw`, or `safkeyringhybrid`. For more information about SAF key ring formats, see the System Authorization Facility (SAF) security guide in the IBM Semeru Runtime® Certified Edition for z/OS documentation.

Examples:

- `safkeyring:///KEYRING.CICS1` specifies that CICS accesses the RACF key ring KEYRING.CICS1 by using the CICS region user ID.
- `safkeyring://USER1/KEYRING.CICS1` specifies that CICS accesses the RACF key ring KEYRING.CICS1 by using the user ID USER1.
- `safkeyring` or `safkeyring:///` specifies that the values from **`KEYRING`** SIT parameter are used to create the keystore.

Java 11 Use `safkeyringjce`, `safkeyringjcecca`, or `safkeyringjcehybrid` for the *scheme* when running Java 11.

This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.server.keystore.type=*keystore_type***

This property overrides the keystore type that is configured by CICS. By default, the keystore type is inferred from the **`com.ibm.cics.jvmserver.wlp.server.keystore.location`** property and only needs to be configured if you don't want to accept the default.

Some examples of valid keystore types are `JCERACFKS`, `JCECCARACFKS`, `JCEHYBRIDRACFKS`, or `PKCS12`.

For more information about keystore types, see Keystores in the IBM WebSphere Application Server for z/OS Liberty documentation.

This property is used only when **`com.ibm.cics.jvmserver.wlp.autoconfigure=true`**.

**com.ibm.cics.jvmserver.wlp.server.name={`defaultServer`|*server_name*}**

Specifies the name of the Liberty server. You should not need to specify this property as it affects the location of the Liberty server configuration and output files and directories.

**com.ibm.cics.jvmserver.wlp.wab={`false`|`true`}**

Controls the Liberty feature `wab-1.0` in `server.xml`. If you want to use Java EE 8 in standard or integrated-mode Liberty, you must set this option to `com.ibm.cics.jvmserver.wlp.wab=false`, and then add the required Java EE 8 features.

If you want to use EBA files, you must set this option to `com.ibm.cics.jvmserver.wlp.wab=true`.

**com.ibm.cics.jvmserver.wlp.xml.format={`false`|`true`}**

Enables CICS to format the white space in `server.xml` for improved readability.

**com.ibm.cics.sts.config=*path***

Specifies the location and name of the STS configuration file.

**com.ibm.ws.logging.console.log.level={`INFO`|`AUDIT`|`WARNING`|`ERROR`|`OFF`}**

Controls which messages Liberty writes to the JVM server stdout file. Liberty console messages are also written to the Liberty `messages.log` file independent of the setting of this property.

**com.ibm.ws.zos.core.angelName=*named_angel***

Specifies a named angel process for the Liberty JVM server to connect to. If you do not specify **`com.ibm.ws.zos.core.angelName`**, when required, the default angel process is used for Liberty JVM server startup.

**com.ibm.ws.zos.core.angelRequired={`false`|`true`}**

Indicates whether an angel process is required for Liberty JVM server startup.

**com.ibm.ws.zos.core.angelRequiredServices=*zos_authorized_services***

The value for this property must be a comma-separated list of valid angel process services. All service names must be 8 characters or less and symbols are not valid. This property must be specified with com.ibm.ws.zos.core.angelRequired property set to true. See Enabling z/OS authorized services on Liberty for z/OS for a description of the z/OS authorized services that a Liberty Server can use.

**Warning:** If this property is used, all of the services that are specified must be available. If any of the services that are listed are not available, message CWWKB0133E is written to `messages.log` and Liberty terminates. An authorized service is not available if its RACF profile is not created or, if it is created, the CICS region user ID is not granted READ access to that profile. See Enabling z/OS authorized services on Liberty for z/OS for a description of the RACF profiles that must be created.

**console.encoding=**

Specifies the encoding for JVM server output files.

**file.encoding=**

Specifies the code page for reading and writing characters by the JVM. By default, a JVM on z/OS uses the EBCDIC code page IBM1047 (or cp1047).

- In a profile that is configured for OSGi, you can specify any code page that is supported by the JVM. CICS tolerates any code page because JCICS uses the local CCSID of the CICS region for its character encoding.
- In a profile that is configured for the Liberty JVM server, the supplied default value is ISO-8859-1. You can also use UTF-8. Any other code page is not supported.
- In a profile that is configured for Axis2, you must specify an EBCDIC code page.

**java.security.manager={default| "" | |*other_security_manager*}**

Specifies the Java security manager to be enabled for the JVM. To enable the default Java security manager, include this system property in one of the following formats:

- `java.security.manager=default`
- `java.security.manager=""`
- `java.security.manager=`

All these statements enable the default security manager. If you do not include the **`java.security.manager`** system property in your JVM profile, the JVM runs with Java security disabled.

**java.security.policy=**

Describes the location of extra policy files that you want the security manager to use to determine the security policy for the JVM. A default policy file is provided with the JVM in `/usr/lpp/java/J8.0_64/lib/security/java.policy`, where the `java/J8.0_64` subdirectory names are the default values when you install the IBM 64-bit SDK for z/OS, Java Technology Edition. The default security manager always uses this default policy file to determine the security policy for the JVM, and you can use the **`java.security.policy`** system property to specify any policy files that you want the security manager to take into account, in addition to the default policy file.

To enable CICS Java applications to run successfully when Java security is active, specify, as a minimum, an extra policy file that gives CICS the permissions it requires to run the application.

For information about enabling Java security, see Enabling a Java security manager.

**org.osgi.framework.storage.clean={`onFirstInit`}**
This option is specific to OSGi-enabled JVM servers, including Liberty. It specifies whether and when the storage area for the OSGi framework should be cleaned. If no value is specified, the framework storage area is not cleaned. **`onFirstInit`** flushes the bundle cache when the framework instance is first initialized: that is, when the JVM server is enabled. Framework storage cleaning is not necessary under normal operations.

**org.osgi.framework.system.packages.extra=**
This option is specific to OSGi-enabled JVM servers, including Liberty, which allows extensions of the JRE and custom Java packages to be exposed through the OSGi framework for subsequent bundle import resolution. JVM vendors might provide different extensions in the JRE. In an IBM JVM server, the option is augmented to include the set of packages which CICS chooses to expose from the IBM JRE. You can set this property to define additional packages, if required. For further information, see OSGi Alliance Specifications.

**osgi.compatibility.bootdelegation={`false`|`true`}**
This option is specific to the Equinox implementation of OSGi. It applies to OSGi-enabled JVM servers, including Liberty. When set to *true*, the OSGi framework employs a last resort boot delegation strategy for packages that are not found through the normal OSGi bundle dependency resolution mechanism. This option allows the OSGi run time to be more tolerant if explicit dependencies were overlooked at development time. As a last resort algorithm, a small amount of overhead is incurred compared to direct resolution (where the package is explicitly listed in the Import-Package bundle header).

For strict OSGi compliance, increased portability, and optimum performance, set this option to *false* and ensure all the packages that are used in your OSGi bundles are explicitly declared in the bundle `MANFEST.MF`.

### *Setting the time zone for a JVM server*

The TZ environment variable specifies the "local" time of a system. You can set this for a JVM server by adding it to the JVM profile. If you do not set the TZ variable, the system defaults to UTC. Once the TZ variable is set, a JVM automatically transitions to and from daylight savings time as required, without a restart or further intervention.

When setting the time zone for a JVM server or Node.js application, you should be aware of the following issues:

- The TZ variable in your JVM or Node.js profile should match your local MVS system offset from GMT. For more information on how to display and set your local MVS system offset, see TIMEZONE statement in z/OS Communications Server: IP Configuration Reference and Adjusting local time in a sysplex in z/OS MVS Setting Up a Sysplex.
- Customized time zones are not supported and will result in failover to UTC or a mixed time zone output in the JVMTRACE file (for JVM servers) or TRACE file (for Node.js applications).
- If you see LOCALTIME as the time zone string, there is an inconsistency in your configuration. This can be between your local MVS time and the TZ you are setting, or between your local MVS time and your default setting in the JVM or Node.js profile. The output will be in mixed time zones although each entry will be correct.

## Using the POSIX time zone format

The POSIX time zone format has a short form and a long form. You can use either to set the TZ environment variable, but using the short form reduces the chance of input errors.

Long form examples with daylight saving (Greenwich Mean Time, Central European Time, Eastern Standard Time):

```
TZ=GMT0BST,M3.5.0,M10.4.0
TZ=CET-1CEST,M3.5.0,M10.5.0
TZ=EST5EDT,M3.2.0,M11.1.0
```

Short form examples with daylight saving (Greenwich Mean Time, Central European Time, Eastern Standard Time):

```
TZ=GMT0BST
TZ=CET-1CEST
TZ=EST5EDT
```

Examples with no daylight saving (Malaysian Time, China Standard Time, Singapore Time):

```
TZ=MYT-8
TZ=CST-8
TZ=SGT-8
```

To find out what time zone your system is running on, log on to USS and enter `echo  $TZ`. The result is the long form of the value your TZ environment variable should be set to.

```
/u/user:>echo $TZ
GMT0BST,M3.5.0,M10.4.0
```

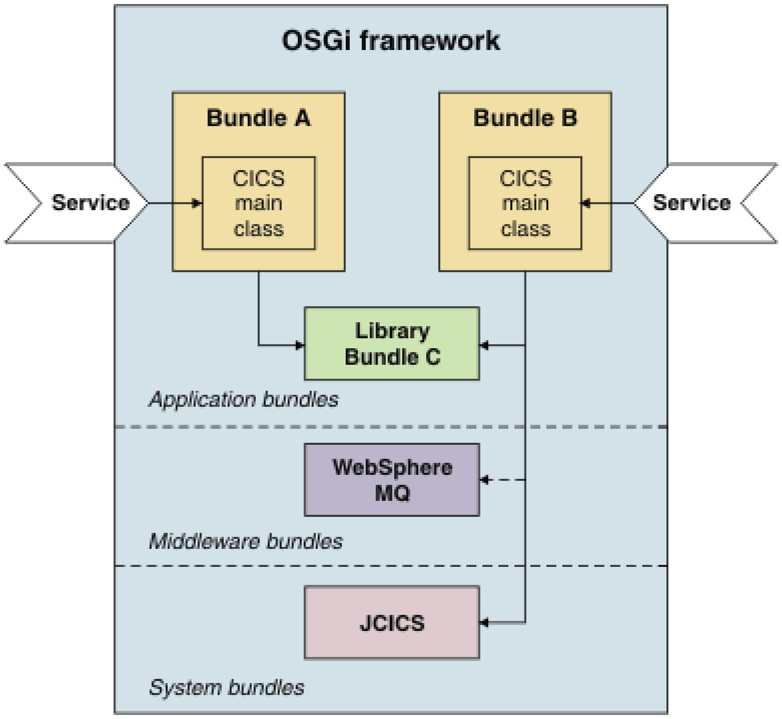
For a more detailed breakdown of the POSIX time zone format, see POSIX and Olson time zone formats on the IBM developerWorks® site.

# Chapter 6. Updating OSGi bundles in a JVM server

The process for updating OSGi bundles in the OSGi framework depends on the type of bundle and its dependencies. You can update OSGi bundles for applications without restarting the JVM server. However, updating a middleware bundle requires a restart of the JVM server.

## About this task

In a typical JVM server, the OSGi framework contains a mixture of OSGi bundles as shown in the following diagram.



Bundle A and Bundle B are separate Java applications that are packaged as OSGi bundles in separate CICS bundles. Both applications have a dependency on a common library that is packaged in Bundle C. Bundle C is separately managed and updated. In addition, Bundle B has a dependency on an IBM MQ middleware bundle and the JCICS system bundle.

Bundle A and B can both be independently updated without affecting any of the other bundles in the framework. However, updating Bundle C can affect both the bundles that depend on it. Any exported packages in Bundle C remain in memory in the OSGi framework, so to pick up changes in Bundle C, Bundles A and B also have to be updated in the framework.

Middleware bundles contain framework services and are managed with the life cycle of the JVM server. For example, you might have native code that you want to load once in the framework or you might want to add a driver to access another product such as IBM MQ.

System bundles are provided by CICS to manage the interaction with the OSGi framework. These bundles are serviced by IBM as part of the product. An example of a system bundle is the `com.ibm.cics.server.jar` file, which provides most of the JCICS API to access CICS services.

# Updating OSGi bundles in an OSGi JVM server

If a Java developer provides an updated version of an OSGi bundle, you can either replace the CICS bundle that refers to it completely, or phase in a new version of the OSGi bundle.

### About this task

The update method to use depends on the following factors:

- Whether service outages can be tolerated during the update.
- Whether CICS resource changes can be tolerated during the update.

## Using CICS bundle PHASEIN to dynamically update an OSGi bundle without updating CICS resources

Use this update method to phase in a new version of an OSGi bundle when service outages and CICS resource changes cannot be tolerated during the update.

### Before you begin

The new version of the JAR file for the OSGi bundle must be present in the same zFS directory as the old version of the OSGi bundle, that is, the same directory as the associated `osgibundle bundlepart` file. By default, this directory is the directory that is named in the BUNDLE resource definition. This new version of the OSGi bundle must have a higher version than the one that is currently installed in the OSGi framework, and the version must be in the version range that was defined when the OSGi bundle reference was added to the CICS bundle project.

### Procedure

To phase in a new version of an OSGi bundle in an OSGi JVM server, use the following steps.

1. In the **Bundles** view in CICS Explorer, right-click the CICS bundle that contains the OSGi bundle, click **Phase In**, then click **OK**. The new version of the OSGi bundle is phased in, new versions of any services that are implemented by the new version of the OSGi bundle are installed into the OSGi framework, and any old versions of the services are removed from the OSGi framework.
2. In the **OSGi Services** view in CICS Explorer check that all OSGi services for the new version of the OSGi bundle are all in the active state.
3. In the **OSGi Bundles** view in CICS Explorer check that the new version of the OSGi bundle is listed and is in the active state.

### Results

The new version of the OSGi bundle is used for all new service requests. Existing requests continue to use the old version. The symbolic version of the OSGi bundle increases, indicating that the Java code is updated.

### What to do next

If you are satisfied that the new version of the OSGi service is working well, there is no more to do. Optionally, you can delete the old version of the OSGi JAR file from zFS, but it is not compulsory. It might also be useful to retain the OSGi JAR file so that you can restore that version if problems arise with the new version.

If you are not satisfied with the new version of the OSGi service and want to restore the old version, use the following steps.

1. Delete the new version of the OSGi bundle JAR from zFS.

2. In the **Bundles** view of CICS Explorer, right-click the CICS bundle that contains the OSGi bundle, click **Phase In**, then click **OK**. Because the old version of the OSGi bundle is now the one with the highest version on zFS, it is reinstalled into the OSGi framework and the defective new version removed.
3. In the **OSGi Services** view in CICS Explorer, check that only the OSGi services for the old version of the OSGi bundle are listed, and are all in the active state.
4. In the **OSGi Bundles** view in CICS Explorer, check that only the old version of the OSGi bundle is listed and is in the active state.

If there is a CICS cold, warm, or emergency restart, the new version of the OSGi bundle is automatically restored. You do not need to change any CICS resource definitions to ensure that this happens.

## Phasing in an OSGi bundle with CICS resource changes

Use this update method to phase in a new version of an OSGi bundle when service outages cannot be tolerated during the update process. New CICS resources are created during the update.

### Before you begin

A CICS bundle that contains the new version of an OSGi bundle is already defined and exported to zFS. The new version of the OSGi bundle must have a higher version specified in the OSGi bundle manifest than the version that is currently installed in the OSGi framework. You can have both OSGi bundles running in the framework at the same time.

### Procedure

To phase in a new version of an OSGi bundle in an OSGi JVM server, use the following steps.

1. In the **Bundle Definitions** view in CICS Explorer, right-click anywhere and click **New** to create a BUNDLE resource to pick up the new CICS bundle project on zFS.
2. In the **Bundle Definitions** view in CICS Explorer, right-click the BUNDLE resource that you created in the previous step and click **Install**. Select the install target, then click **OK** to install the OSGi bundles and services in the CICS bundle into the OSGi framework.
3. Check the status of the OSGi bundles in the **OSGi Bundles** view in CICS Explorer. Two versions of the OSGi bundle are listed with a state of active.
4. In the **OSGi Services** view in CICS Explorer, check the OSGi services that are implemented by both versions of the OSGi bundle are all in the active state. The OSGi services that reference the OSGi bundle with the highest semantic version are used for any new service invocations.

### Results

The updated OSGi bundle is available in the OSGi framework along with the old version of the OSGi bundle.

The new version of the OSGi bundle is used for all new service requests. Existing requests continue to use the old version.

### What to do next

When you are satisfied that the new version of the OSGi service is working well, use the following steps to remove the old version from the OSGi framework:

1. Disable the BUNDLE resource that points to the old version of the OSGi bundle. In the **Bundles** view in CICS Explorer, right-click the old BUNDLE, click **Disable**, then click **OK**. The old version of any services that are implemented by the OSGi bundle are removed from the OSGi framework; only the new versions of the services are now listed in the **OSGi Services** view. In the **OSGi Bundles** view, the old OSGi bundle state is now in resolved.
2. Discard the BUNDLE resource that points to the old version of the OSGi bundle. In the **Bundles** view in CICS Explorer, right-click the old BUNDLE, click **Discard**, then click **OK**. In the **OSGi Bundles** view,

the OSGi bundle from the OSGi framework is removed, and only the new version of the OSGi bundle is listed.

To ensure that the new version of the OSGi bundle is installed if there is a cold start of a CICS region, make sure that you update any CICS group lists (GRPLIST system initialization parameter) that reference the CSD groups that contain the BUNDLE definition for the old version, to reference the CSD groups that contain the new BUNDLE definition that you created in Step 1 of the procedure.

If you want to restore the old version of the OSGi bundle, use the previous two steps to disable and discard the BUNDLE resource that points at the new version of the OSGi bundle. The old version of the service is listed in the **OSGi Services** view in CICS Explorer, and it is used for any new service invocations.

## Replacing OSGi bundles in an OSGi JVM server

Use this update method when service outages can be tolerated during the update process. No new CICS resources are created, but you might need to update the existing BUNDLE resource definition.

### Before you begin

To replace the CICS bundle completely, an updated CICS bundle that contains the new version of the OSGi bundle must be present in zFS.

### Procedure

To replace an existing OSGi bundle in an OSGi JVM server with a new version of the OSGi bundle, use the following steps.

1. In the **Bundles** view in CICS Explorer, disable and discard the BUNDLE resource for the CICS bundle that you want to update. The OSGi services that are part of that CICS bundle are removed from the OSGi framework and are not listed in the **OSGi Services** view of CICS Explorer.

   **Note:** No services that are implemented by the OSGi bundle are available in the OSGi framework from this point until the completion of step 3, so any users of these services suffer a service outage.
2. Optional: Edit the BUNDLE resource definition if the updated CICS bundle is deployed in a different directory in zFS.
3. In the **Bundles** view in CICS Explorer, install the BUNDLE resource definition to pick up the changed OSGi bundle. The OSGi bundles and services in the CICS bundle are installed in the OSGi framework.
4. Check the status of the OSGi bundle in the **OSGi Bundles** view in CICS Explorer. The new version of the OSGi bundle is listed with a state of active.
5. In the **OSGi Services** view in CICS Explorer, check that the new version of all the OSGi services that are implemented by the new version of the OSGi bundle are in the active state.

### Results

The new version of the OSGi bundle is used for all new service requests. Existing requests continue to use the old version. The symbolic version of the OSGi bundle increases, indicating that the Java code is updated.

# Updating bundles that contain common libraries

OSGi bundles that contain common libraries for use by other OSGi bundles must be updated in a specific order.

### Before you begin

An updated CICS bundle that contains the new version of the OSGi bundle must be present in zFS. If you manage common libraries in a separate CICS bundle, you can manage the lifecycle of these libraries separately from the applications that depend on them.

## About this task

Typically, an OSGi bundle specifies a range of supported versions in a dependency on another OSGi bundle. Using a range provides more flexibility to make compatible changes in the framework. When you are updating bundles that contain common libraries, the version number of the OSGi bundle increases. However, the running applications are already using a version of the bundle that satisfies the dependencies. To obtain the most recent version of the library, you must refresh the OSGi bundles for the applications. It is therefore possible to update specific applications to use different versions of the library, and leave other applications to run on an older version.

When you update an OSGi bundle that contains common libraries, you can completely replace the CICS BUNDLE resource. However, if classes are not loaded in the library, the dependent bundles might receive errors. Alternatively, you can install a new version of the library and run it in the framework alongside the original version. If the OSGi bundles have different version numbers, the OSGi framework can run both bundles concurrently.

## Procedure

To replace an existing OSGi bundle in an OSGi JVM server:

1. Define and install a CICS BUNDLE resource that points to the new version of the CICS bundle, which contains the OSGi bundle that defines the common libraries. CICS defines the new version of the OSGi bundle in the OSGi framework. The existing OSGi bundles continue to use the previous version of the library.
2. Check the status of the OSGi bundles in the **OSGi Bundles** view in CICS Explorer (**Operations** > **Java** > **OSGi Bundles**). The list shows two entries for the same OSGi bundle symbolic name with different versions that are running in the framework.
3. To obtain the new version of the library in a dependent Java application, use one of the following methods:

   - Replace the CICS bundle for the Java application.

     a. Disable and discard the CICS BUNDLE resource for the Java application.

     b. Reinstall the CICS BUNDLE resource for the Java application.

   - Phase in a new version of the Java application.

     a. Ask the Java developer to update the version information for the OSGi bundle. The new version of the OSGi bundle must have a higher version specified in the OSGi bundle manifest and be within the version range specified when the OSGi Bundle Project was added to the CICS bundle. Optionally, the new version of the OSGi bundle could also have its dependencies modified to specifically require the new version of the OSGi bundle that defines the common libraries.

     b. Copy the JAR for the new version of OSGi bundle to the root directory of the CICS BUNDLE resource.

     c. In the **Operations** > **Bundles** view in CICS Explorer, right-click the CICS bundle that contains the OSGi bundle, click **Phase In**, then click **OK** to phase in the new version of the OSGi bundle.

   When the OSGi bundle is loaded in the framework, it obtains the latest version of the common libraries.
4. Check the status of the CICS BUNDLE resource in the **Bundles** view in CICS Explorer (**Operations** > **Bundles**).

## Results

You have updated an OSGi bundle that contains common libraries and updated a Java application to use the latest version of the libraries.

## Updating OSGi middleware bundles

To update the middleware bundles that are running in an OSGi framework, you must stop and restart the JVM server.

### About this task

OSGi middleware bundles are installed in the OSGi framework during the initialization of the JVM server. If you want to update a middleware bundle, for example to apply a patch or use a new version, you must stop and restart the JVM server to pick up the changed bundle.

You can manage the lifecycle of the JVM server and edit the JVM profile by using CICS Explorer.

### Procedure

1. Ensure that the new version of the middleware bundle is in a directory on zFS to which CICS has read and execute access. CICS also requires read access to the files.
2. If the zFS directory or file name is different from the values that are specified in the JVM profile, edit the `OSGI_BUNDLES` option in the JVM profile for the JVM server.
   a) Open the **JVM Servers** view in CICS Explorer to find out the name and location of the JVM profile in zFS.

      You must be connected with a region or CICSplex selected to see the JVMSERVER resources.

   b) Open the **z/OS UNIX Files** view and browse to the directory that contains the JVM profile.

   c) Edit the JVM profile to update the `OSGI_BUNDLES` option.
3. Disable the JVMSERVER resource to shut down the JVM server.

   Disabling the JVMSERVER also disables any BUNDLE resources that contain OSGi bundles that are installed in that JVM server.
4. Enable the JVMSERVER resource to start the JVM server with the updated JVM profile.

   The JVM server starts up and installs the new version of the middleware bundle in the OSGi framework. CICS also enables the BUNDLE resources that were disabled and installs the OSGi bundles and services in the updated framework.

### Results

The OSGi framework contains the updated middleware bundles and the OSGi bundles and services for Java applications that were installed before you shut down the JVM server.

# Chapter 7. Removing OSGi bundles from a JVM server

If you want to remove OSGi bundles from the JVM server, use the CICS Explorer to disable and discard the BUNDLE resource.

## About this task

The BUNDLE resource provides life-cycle management for the collection of OSGi bundles and OSGi services that are defined in the CICS bundle. Removing OSGi bundles from the OSGi framework does not automatically affect the state of other installed OSGi bundles and services. If you remove a bundle that is a prerequisite for another bundle, the state of the dependent bundle does not generally change until you explicitly refresh that bundle. An exception is in the use of singleton bundles. If you uninstall a singleton bundle that other bundles depend on, the dependent bundles cannot use the services of the uninstalled bundle. The reported status of the CICS BUNDLE resource might not accurately reflect the status of the OSGi bundle.

## Procedure

1. Click **Operations** > **Java** > **OSGi Bundles** to find out which BUNDLE resource contains the OSGi bundle.
2. Click **Operations** > **Bundles** to disable the BUNDLE resource.

   CICS disables each resource that is defined in the CICS bundle. For OSGi bundles and services, CICS sends a request to the OSGi framework in the JVM server to unregister any OSGi services and moves the OSGi bundles into a resolved state. Any in-flight transactions complete, but any new links to the OSGi service from CICS applications return with an error.
3. Discard the BUNDLE resource.

   CICS sends a request to the OSGi framework to remove the OSGi bundles from the JVM server.

## Results

You have removed the OSGi bundles and services from the OSGi framework.

## What to do next

If you have PROGRAM resources pointing to OSGi services that are no longer in the OSGi framework, you might want to disable and discard the PROGRAM resources.

# Chapter 8. Updating Enterprise Java applications in a Liberty JVM server

There are three methods to update Enterprise Java applications in a Liberty JVM server: refresh the CICS bundles, update the applications in the drop-ins folder, and use `<application>` elements.

## About this task

The process to update Enterprise Java applications in a Liberty server depends on how the applications are deployed:

- Applications deployed in CICS bundles

  In this scenario, the application must be added as a bundle part to a CICS bundle project using CICS Explorer and then exported to z/OS File System (zFS). It is then installed into CICS using a BUNDLE definition that refers to the exported project.
- Applications deployed directly to the Liberty `drop-ins` folder

  In this scenario, the Java archive is copied directly to a previously defined `drop-ins` directory.
- Applications deployed in an `<application>` element into `server.xml`

  In this scenario, a reference to the application is added into `server.xml`, together with further application attributes and descriptive elements.

## Procedure

Applications deployed in CICS bundles

- To refresh the CICS bundle, a bundle that contains the Enterprise Java application must already be installed and enabled in the CICS region. For more information, see Deploying a Java EE application in a CICS bundle to a Liberty JVM server.
  a) In the **Bundles** view in CICS Explorer, disable the BUNDLE resource for the CICS bundle that you want to update.

     **Note:** The applications that are part of that CICS bundle are removed from the Liberty server run time and are not available from this point until the last step completes. Any users of these services suffer a service outage.
  b) Export the new version of the CICS bundle that contains the Enterprise Java application to the same zFS location as the old version.
  c) In the **Bundles** view in CICS Explorer, enable the BUNDLE resource definition to pick up the Enterprise Java application. The applications are reinstalled into the Liberty server.
  d) Check the status of the CICS bundle in CICS Explorer. The CICS bundle is listed with a state of active.

  When the new version of the Enterprise Java application becomes active, it is used for all new requests.

Applications deployed directly to the Liberty `drop-ins` folder

- To use the `drop-ins` directory with a Liberty server, the `server.xml` configuration must be updated to enable this function. For more information, see Deploying Java EE applications directly to a Liberty JVM server.
  a) Export the new version of the archive (WAR, EAR, or EBA) from your Eclipse environment.

     **Note:** The applications that are part of that CICS bundle are removed from the Liberty server run time. Any users of these services suffer a service outage.
  b) Copy this new archive into the `drop-ins` directory, replacing the original version.

The Liberty server scans the directory, uninstalls the previous version, and installs the new version.

When the new version of the Enterprise Java application becomes active, it is used for all new requests.

Applications deployed in an `<application>` element into `server.xml`

- To allow applications to be dynamically updated, the `updateTrigger` attribute of the `<applicationMonitor>` element must be set to `polled`. For more information, see Controlling dynamic updates.

  a) Export the new version of the archive (WAR, EAR, or EBA) from your Eclipse environment.

     **Note:** The applications that are part of that CICS bundle are removed from the Liberty server run time. Any users of these services suffer a service outage.

  b) Copy this new archive into the location specified in your `<application>` element.

     The Liberty server scans the file for modification and if a change is detected, it uninstalls the previous version and installs the new version.

  When the new version of the Enterprise Java application becomes active, it is used for all new requests.

# Chapter 9. Managing the thread limit of JVM servers

JVM servers are limited in the number of threads that they can use to run Java applications. The CICS region also has a limit on the number of threads, because each thread uses a T8 TCB. You can adjust the thread limit using CICS statistics to balance the number of JVM servers in the region against the performance of the applications running in each JVM server.

## About this task

Each JVM server can have a maximum of 256 threads to run Java applications. In a CICS region you can have a maximum of 2000 threads. If you have many JVM servers running in the CICS region (for example, more than seven), you cannot set the maximum value for every JVM server. You can adjust the thread limit of each JVM server to balance the number of JVM servers in the CICS region against the performance of the Java applications.

The thread limit is set on the JVMSERVER resource, so set an initial value and use CICS statistics to adjust the number of threads when you test your Java workloads.

## Procedure

1. Enable the JVMSERVER resources and run your Java application workload.
2. Collect JVMSERVER resource statistics using an appropriate statistics interval.

   You can use the **Operations** > **Java** > **JVM Servers** view in CICS Explorer, or you can use the DFH0STAT statistics program.
3. Check how many times and how long a task waited for a thread.

   The "JVMSERVER thread limit waits" and "JVMSERVER thread limit wait time" fields contain this information.

   - If the values in these fields are high and many tasks are suspended with the JVMTHRD wait, the JVM server does not have enough threads available. Increasing the number of threads can increase the processor usage, so check you have enough MVS resource available.
   - If the values in these fields are low and the peak number of tasks is below the maximum number of threads available, you can free up threads for other JVM servers by reducing the thread limit.
4. To check the availability of MVS resource, use the dispatcher TCB pool and TCB mode statistics to assess the T8 TCB usage across the CICS region.

   Each thread in a JVM server uses a T8 TCB and you are limited to 2000 in a region. T8 TCBs cannot be shared between JVM servers, although all TCBs are in a THRD TCB pool. If the number of waiting TCBs and processor usage is low, it indicates that there is enough MVS resource available.
5. To adjust the number of threads that can run in the JVM server, change the THREADLIMIT value on the JVMSERVER resource.
6. Run the Java application workload again and use the statistics to check that the number of waiting tasks has reduced.

## What to do next

To tune the performance of your JVM servers, see Improving JVM server performance.

# Chapter 10. Security for Java applications

You can secure Java applications to ensure that only authorized users can deploy and install applications, and access those applications from the web or through CICS. You can also use a Java security manager to protect the Java application from performing potentially unsafe actions.

You can add security at different points in the Java application lifecycle:

- Implement security checking for defining and installing Java application resources. Java applications are packaged in CICS bundles, so you must ensure that users who are allowed to install applications in the JVM server can install this type of resource.
- Implement security checking for application users to ensure that only authorized users can access an application.
- Implement security checking for CICS Java tasks that are started using the CICSExecutorService. All such CICS tasks run under the CJSA transaction and the default user ID.
- Implement security restrictions on the Java API by using a Java security manager.

Java applications can run in an OSGi framework or a Liberty server. Liberty is designed to host web applications and includes an OSGi framework. The security configuration for a Liberty server is different, because Liberty has its own security model.

To configure security for OSGi applications, use CICS resource security to authorize which users can manage the lifecycle of the JVMSERVER and the Java applications. Use CICS transaction security to determine who can access the application.

## Configuring security for OSGi applications

Use CICS resource security to authorize which users can manage the lifecycle of the JVMSERVER and the Java applications. Use CICS transaction security to determine who can access the application.

### Procedure

- Authorize application developers and system administrators to create, view, update, and remove JVMSERVER and BUNDLE resources as appropriate. The JVMSERVER resource controls the availability of the JVM server. The BUNDLE resource is a unit of deployment for the Java application and controls the availability of the application.
- Authorize users to run the application by ensuring the relevant user ID is allowed to attach the transaction under which the application will run.

### Results

You have successfully configured security for Java applications that run in an OSGi framework.

## Configuring security for a Liberty JVM server

You can use the CICS Liberty security feature to authenticate users and authorize access to web applications through Java Platform, Enterprise Edition roles (Java EE roles), providing integration with CICS transaction and resource security. You can also use CICS resource security to authorize the appropriate users to manage the lifecycle of both the JVMSERVER resource and Java web applications that are deployed in a CICS BUNDLE resource. In this topic, authentication verifies the identity of a given user, typically by requiring the user to enter a username and password. Authorization then grants access control permissions based on the identity of the authenticated user.

## Before you begin

1. Ensure that the CICS region is configured to use SAF security and is defined with SEC=YES as a system initialization parameter. If CICS security is turned off (SEC=NO), you can still use Liberty security by manually configuring the `server.xml` file as described in "6" on page 279.
2. Authorize application developers and system administrators to create, view, update, and remove JVMSERVER and BUNDLE resources to deploy web applications into a Liberty JVM server.

The JVMSERVER resource controls the availability of the JVM server, and the BUNDLE resource is a unit of deployment for the Java applications and controls the availability of the applications. The default behavior of the CICS TS security feature, `cicsts:security-1.0`, is to use the SAF registry. If you use an LDAP registry, a SAF registry is not created. For more information, see Configuring security for a Liberty JVM server by using distributed identity mapping. The basic user registry (which is also used by `quickStartSecurity`) is only suitable for simple security testing. Be aware that if you configure and run with basic user registry and you need to switch to `cicsts:security-1.0`, you need to delete the session tokens.

## About this task

This task explains how to configure security for a Liberty JVM server and integrate Liberty security with CICS security. For information about how to configure security for Link to Liberty, see Linking to Java applications in a Liberty JVM server by using the @CICSProgram annotation. For guidance on configuring security for the JCICSX remoting server, see "Configuring security for remote JCICSX API development" on page 299.

The default transaction ID for running web requests is CJSA. However, you can configure CICS to run web requests under a different transaction ID by using a URIMAP of type JVMSERVER. Typically, you might specify a URIMAP to match the generic context root (URI) of a web application to scope the transaction ID to the set of servlets that make up the application. Or you might choose to run each individual servlet under a different transaction with a more precise URI.

Calls to the JCICSX Liberty JVM server are run under transaction CJXA.

The default user ID for running web requests is the CICS default user ID. If a URIMAP is available and contains a static user ID, it is used in preference to the default user ID. If the web request contains a user ID in its security header, it takes precedence over all other mechanisms.

Tasks starting from Liberty that are not classified as web requests run under the CJSU transaction by default. Although there is no URIMAP style mechanism for these types of tasks, you can override the default transaction ID by using the JVM profile property of `com.ibm.cics.jvmserver.unclassified.tranid` and the default user ID by using the JVM profile property `com.ibm.cics.jvmserver.unclassified.userid`.

**Note:** The user ID requires permission to attach the specified transaction. For more information, see Transaction security.

## Procedure

1. Configure the Liberty angel process to provide authentication and authorization services to the Liberty JVM server, see The Liberty server angel process.

   **Tip:** If you have a named angel process, you need to configure your Liberty JVM server to connect to it by adding the following line to your JVM profile.

   ```
   -Dcom.ibm.ws.zos.core.angelName=<named_angel>
   ```

2. Optional: Enforce the requirement to connect to the Liberty angel process when the Liberty JVM server is being enabled by adding the following line to your JVM profile:

   ```
   -Dcom.ibm.ws.zos.core.angelRequired=true
   ```

   This option prevents the Liberty JVM server from starting if the angel process is unavailable.

It instructs CICS to call the Liberty angel check API to verify whether an angel process is available for Liberty JVM server startup.

If the angel process is unavailable, CICS reacts as follows:

- If the Liberty JVM server is being enabled through the CEMT transaction, a message is issued, and the Liberty JVM server is disabled.
- If the Liberty JVM server is being enabled by the **SET JVMSERVER** SPI command or by using the CMCI through the CICS Explorer, a message is issued, and the Liberty JVM server is disabled.
- If the Liberty JVM server is being enabled by the CICS CREATE SPI, by BAS, or from GRPLIST, a message is issued, and CICS will wait 30 seconds before retrying the Liberty angel check API call. If the angel process is unavailable on the fifth attempt, a WTOR message is issued, giving the operator the option to continue waiting or to disable the JVMSERVER resource.

3. Add the `cicsts:security-1.0` feature to the `featureManager` list in the `server.xml`,

```
<featureManager>
   ...
   <feature>cicsts:security-1.0</feature>
</featureManager>
...
```

4. Add the System Authorization Facility (SAF) registry to `server.xml` by using the following example:

```
<safRegistry id="saf" enableFailover="false"/>
```

5. Save the changes to `server.xml`.
6. Optional: Alternatively, if you are autoconfiguring the Liberty JVM server and the **SEC** system initialization parameter is set to YES in the CICS region, the Liberty JVM server is dynamically configured to support Liberty JVM security when the JVM server is restarted. For more information, see Configuring a Liberty JVM server.

   If the **SEC** system initialization parameter is set to NO, you can still use Liberty security for authentication or SSL support. If CICS security is turned off, and you want to use a Liberty security, you must configure the `server.xml` file manually:

   a. Add the `appSecurity-2.0` feature to the `featuremanager` list.
   b. Add a user registry to authenticate users. Liberty security supports SAF, LDAP, and basic user registries. For more information, see Configuring a user registry in Liberty.
   c. Add security-role definitions to authorize access to application resources, see "Authorizing users to run applications in a Liberty JVM server" on page 286.

## Results

The web container is automatically configured to use the z/OS Security feature of Liberty. A SAF registry is used for authentication, and Java EE roles are respected for authorization. Authorization constraints and security roles govern who can access the application. These are usually defined in the deployment descriptor (`web.xml`) of the application, but might also be defined as security annotations in the source-code. Typically, users and groups are mapped to roles by the applications *<application-bnd>* element in `server.xml`. Alternatively, if the*<safAuthorization>* element is configured in `server.xml`, the mappings are held in SAF (as EJBROLEs in RACF).

## What to do next

**Note:** You can also delegate authentication to another identity by configuring the RunAs specification for Liberty, see Configuring RunAs authentication in Liberty.

- Configure Liberty application security authentication rules; see "Authenticating users in a Liberty JVM server" on page 284.
- Define authorization rules for web applications; see "Authorizing users to run applications in a Liberty JVM server" on page 286 and "Authorization using SAF role mapping" on page 290.
- Modify the Liberty authentication cache.

For more information about using Secure Sockets Layer (SSL), see "Configuring SSL (TLS) for a Liberty JVM server using a Java keystore" on page 304.

# The Liberty angel process

The Liberty angel process is a started task that allows Liberty servers to use z/OS authorized services. It's long-lived and can be shared among your multiple Liberty servers. When you include the `cicsts:security-1.0` feature, the CICS Liberty JVM server uses the angel process to call z/OS authorized services such as System Authorization Facility (SAF).

## Named angels

A Liberty server can only connect to one angel process at server startup. However, all Liberty servers that are running on a z/OS image can share a single angel process. This is regardless of the level of code that the servers are running or whether they are running in a CICS JVM server. To achieve this, you need to use named angels.

If an angel process is not given a name, it becomes the default angel process. You can have only one default angel process. If you try to create another, it fails to start.

Optionally, you can name an angel process. Named angels allow multiple uniquely named angel processes to run on a single z/OS system, in addition to the default unnamed angel process.

A named angel has the same function as the default angel process, but it can be used for a selected group of Liberty servers. This provides the ability to isolate servers from one another, so that they can run different service levels or be managed independently.

For more information about named angel processes, see Named angel.

## Angel version interoperability

All Liberty servers that are running on a z/OS image can share a single angel process, regardless of the level of Liberty code that the servers are using. It's recommended that the angel process be upgraded before the Liberty servers that use its services, because it provides back-level support for earlier versions of Liberty servers. This ensures support is available for all authorized services potentially required by the Liberty servers.

**Important:** Install the latest version of the angel process, regardless of which product it is bundled with. The latest version might be bundled with other IBM software, and might supersede the version that is bundled with CICS.

You can identify the version of Liberty for the angel process and the Liberty JVM server that's running in CICS as shown in "Examples of identifying Liberty versions" on page 283.

## Running the angel process started task

1. Locate the JCL procedure for the **started** task in the USSHOME directory, for example: `/usr/lpp/cicsts56/wlp/templates/zos/procs/bbgzangl.jcl`
2. Modify and copy the JCL procedure to a JES procedure library. You can set **ROOT** to the value of USSHOME`/wlp`, for example: `ROOT=/usr/lpp/cicsts56/wlp`
3. Start the angel process. In the following examples, `[.identifier]` indicates an optional identifier that can be up to 8 characters.
   a. To start the angel process without naming it, use the following command:

   ```
   START BBGZANGL[.identifier]
   ```

   b. To start the angel process as a named angel process, code the NAME parameter on the operator START command. For example:

   ```
   START BBGZANGL[.identifier],NAME=<named_angel>
   ```

The angel process name is 1 - 54 characters inclusive, and must use only the following characters: A-Z 0-9 ! # $ + - / : < > = ? @ [ ] ^ _ ` { } | ~

**Note:** A Liberty server can use its own named angel process. One benefit of this isolation is that the angel process can be serviced without affecting any other Liberty server instances on the LPAR. The angel process must be running before the Liberty JVM server starts.

4. Start the Liberty JVM server. By default, the server connects to the unnamed angel process if one is available. To connect to a specific angel process, set the com.ibm.ws.zos.core.angelName property in the JVM server profile, for example:

```
-Dcom.ibm.ws.zos.core.angelName=named_angel
```

5. You can specify that CICS checks for the presence of a running angel process before enabling, by setting the com.ibm.ws.zos.core.angelRequired property in the JVM server profile to true. For example:

```
-Dcom.ibm.ws.zos.core.angelRequired=true
```

The server fails if the angel process is not available during startup. Use of this property allows a quicker and cleaner failure.

## Interacting with the angel process started task

In the following examples, [.identifier] indicates an optional identifier that can be up to eight characters.

- Display the Liberty JVM servers that are connected to the angel process use the following console command:

```
MODIFY BBGZANGL[.identifier],DISPLAY,SERVERS,PID
```

A list of job names and process identifiers (PID) are displayed:

```
15.48.45 STC82204  CWWKB0067I ANGEL DISPLAY OF ACTIVE SERVERS
15.48.45 STC82204  CWWKB0080I ACTIVE SERVER ASID 5c JOBNAME IYK3ZNA1 PID 83953428
15.48.45 STC82204  CWWKB0080I ACTIVE SERVER ASID 5c JOBNAME IYK3ZNA1 PID 33621002
```

Each Liberty JVM server runs under a unique PID, and is returned by the CICS command INQUIRE JVMSERVER.

- Stop the angel process.

```
STOP BBGZANGL[.identifier]
```

**Note:** The Liberty JVM server must be stopped before restarting or applying maintenance to the angel process.

## SAF profiles used by the angel process

This section describes the SAF profiles to which access is required for CICS processing. For information on the full set of SAF profiles defined by Liberty, refer to Enabling z/OS authorized services on Liberty for z/OS.

- The Liberty JVM server runs under the authority of the CICS region user ID. This user ID must be able to connect to the angel process to use authorized services. The user ID that the angel process runs under needs access to the SAF STARTED profile, for example:

```
RDEFINE STARTED BBGZANGL.* UACC(NONE) STDATA(USER(WLPUSER))
SETROPTS RACLIST(STARTED) REFRESH
```

- For the Liberty JVM server to connect to an angel process, create a profile for the angel (**BBG.ANGEL**, or **BBG.ANGEL.<namedAngelName>** if you are using a named angel process) in the **SERVER** class. Give the CICS region user ID (*cics_region_user*) authority to access it, for example, in RACF:

```
RDEFINE SERVER BBG.ANGEL UACC(NONE)
PERMIT BBG.ANGEL CLASS(SERVER) ACCESS(READ) ID(cics_region_user)
```

- For a Liberty server to use the z/OS authorized services, create a **SERVER** profile for the authorized module **BBGZSAFM** and give the CICS region user ID (*cics_region_user*) to the profile:

```
RDEFINE SERVER BBG.AUTHMOD.BBGZSAFM UACC(NONE)
PERMIT BBG.AUTHMOD.BBGZSAFM CLASS(SERVER) ACCESS(READ) ID(cics_region_user)
```

- Give the Liberty JVM server, under the authority of the CICS region user ID (*cics_region_user*), access to the SAF user registry and SAF authorization services (**SAFCRED**) in the **SERVER** class. For example, in RACF:

```
RDEFINE SERVER BBG.AUTHMOD.BBGZSAFM.SAFCRED UACC(NONE)
PERMIT BBG.AUTHMOD.BBGZSAFM.SAFCRED CLASS(SERVER) ACCESS(READ) ID(cics_region_user)
```

- Create a **SERVER** profile for the **IFAUSAGE** services (**PRODMGR**) and allow the CICS region user ID access to it. This allows the Liberty JVM server to register and unregister from **IFAUSAGE** when the CICS JVM server is enabled and disabled:

```
RDEFINE SERVER BBG.AUTHMOD.BBGZSAFM.PRODMGR UACC(NONE)
PERMIT BBG.AUTHMOD.BBGZSAFM.PRODMGR CLASS(SERVER) ACCESS(READ) ID(cics_region_user)
```

- Refresh the **SERVER** resource:

```
SETROPTS RACLIST(SERVER) REFRESH
```

The following table summarizes the SAF security profiles that are used by a Liberty server running in a CICS JVM server.

*Table 44. SAF profile table for CICS Liberty security*

| Class | Profile | Required for | CICS region user ID 1 | Unauthenticated user ID 2 | Authenticated user ID 3 |
|---|---|---|---|---|---|
| SERVER | BBG.ANGEL | Angel process registration at Liberty server startup | READ | | |
| SERVER | BBG.ANGEL.<namedAngelName> | Angel process registration at Liberty server startup | READ | | |
| SERVER | BBG.AUTHMOD.BBGZSAFM | Angel process registration at Liberty server startup | READ | | |
| SERVER | BBG.AUTHMOD.BBGZSAFM.SAFCRED | Angel process registration at Liberty server startup | READ | | |
| SERVER | BBG.AUTHMOD.BBGZSAFM.PRODMGR | Angel process registration at Liberty server startup | READ | | |

*Table 44. SAF profile table for CICS Liberty security (continued)*

| Class | Profile | Required for | CICS region user ID 1 | Unauthenticated user ID 2 | Authenticated user ID 3 |
|---|---|---|---|---|---|
| SERVER | `BBG.SECPFX.BBGZDFLT` 4 | Authentication or authorization | READ | | |
| APPL | `BBGZDFLT` 4 | Authentication or authorization | | READ | READ |
| EJBROLE | `BBGZDFLT.<resource>.<role>` 5 | Authentication or authorization | | | READ |

1. User ID that is associated with the CICS job or started task.
2. User ID used for unauthenticated requests in Liberty. The value is controlled by using the `unauthenticatedUser` attribute of the `<safCredentials>` element. This value defaults to `WSGUEST`.
3. User ID authenticated by the Liberty server.
4. `BBGZDFLT` is the default value for the security profile prefix that is set by using the `profilePrefix` attribute of the `<safCredentials>` element, for example: `<safCredentials profilePrefix="BBGZDFLT"/>`.
5. EJBROLE profiles are required if the `<safAuthorization>` element is configured. The default pattern for the profile is controlled by the SAF role mapper element, which defaults to `<safRoleMapper profilePattern="%profilePrefix%.%resource%.%role%"/>`.

For more information, see Process types on z/OS.

## Examples of identifying Liberty versions

### Example: Identifying the angel Liberty version from the started task system log

If the Liberty angel process is running Liberty 18.0.0.2 or above, the started task system log contains a message that indicates the Liberty version:

```
CWWKB0079I THE ANGEL BUILD LEVEL IS 18.0.0.2 20180619-0654 2018.7.0.0 20180619-0654
```

### Example: Identifying the version of a Liberty JVM server running in CICS from message DFHSJ1405

The version of a Liberty running in a CICS JVM server is available in the following message:

```
DFHSJ1405I 08/22/2018 17:04:39 IYK3ZDRI JVMSERVER EYUCMCIJ is running WebSphere Application Server
                            Version 18.0.0.2 Liberty - (18.0.0.2-cl180220180619-0403) process ID
67174497.
```

### Example: Identifying both Liberty versions by running scripts

Suppose that the angel JCL specifies the following ROOT parameter:

```
// SET ROOT='/usr/lpp/zosmf/wlp'
```

To find out what the version of Liberty for the angel process is, run the following script:

```
/usr/lpp/zosmf/wlp/bin/productInfo version --verbose
```

For a Liberty JVM server running in CICS, run the following script:

```
/usr/lpp/cicsts56/wlp/bin/productInfo version --verbose
```

```
WebSphereApplicationServer.properties:
        com.ibm.websphere.productId=com.ibm.websphere.appserver
        com.ibm.websphere.productOwner=IBM
        com.ibm.websphere.productVersion=16.0.0.3
        com.ibm.websphere.productName=WebSphere Application Server
        com.ibm.websphere.productInstallType=Archive
        com.ibm.websphere.productEdition=zOS
        com.ibm.websphere.productLicenseType=IPLA

WebSphereApplicationServerZOS.properties:
        com.ibm.websphere.productId=com.ibm.websphere.appserver.zos
        com.ibm.websphere.productOwner=IBM CORP
        com.ibm.websphere.productVersion=16.0.0.3             <== Liberty Version
        com.ibm.websphere.productName=WAS FOR Z/OS
        com.ibm.websphere.productPID=5655-WAS
        com.ibm.websphere.productQualifier=WAS Z/OS
        com.ibm.websphere.productReplaces=com.ibm.websphere.appserver
        com.ibm.websphere.productEdition=
        com.ibm.websphere.gssp=true

zOSMF.properties:
        com.ibm.websphere.productId=com.ibm.zoszmf
        com.ibm.websphere.productOwner=IBM
        com.ibm.websphere.productVersion=2.2.0
        com.ibm.websphere.productName=z/OSMF
        com.ibm.websphere.productPID=5650-ZOS
        com.ibm.websphere.productQualifier=z/OSMF
        com.ibm.websphere.productReplaces=com.ibm.websphere.appserver.zos
        com.ibm.websphere.productEdition=N/A
```

*Figure 37. Example output*

## Authenticating users in a Liberty JVM server

Although you can configure CICS security for all web applications that run in a Liberty JVM server, the web application will only authenticate users if it includes a security constraint. The security constraint is defined by an application developer in the deployment descriptor (web.xml) of the Dynamic Web Project or OSGi Application Project. The security constraint defines what is to be protected (URL) and by which roles.

A `<login-config>` element defines the way a user gains access to web container and the method used for authentication. The supported methods are either HTTP basic authentication, form based authentication or SSL client authentication. For further details on how to define application security for CICS see SSL security for Explorer connections in the CICS Explorer product documentation. Here is an example of those elements in web.xml:

```
<!-- Secure the application -->
<security-constraint>
    <display-name>com.ibm.cics.server.examples.wlp.tsq.web_SecurityConstraint</display-name>
        <web-resource-name>com.ibm.cics.server.examples.wlp.tsq.web</web-resource-name>
        <description>Protection area for com.ibm.cics.server.examples.wlp.tsq.web</description>
        <url-pattern>/*</url-pattern>
    </web-resource-collection>
    <auth-constraint>
        <description>Only SuperUser can access this application</description>
        <role-name>SuperUser</role-name>
    </auth-constraint>
    <user-data-constraint>
        <!-- Force the use of SSL -->
        <transport-guarantee>CONFIDENTIAL</transport-guarantee>
    </user-data-constraint>
</security-constraint>

<!-- Declare the roles referenced in this deployment descriptor -->
<security-role>
    <description>The SuperUser role</description>
    <role-name>SuperUser</role-name>
</security-role>

<!--Determine the authentication method -->
<login-config>
        <auth-method>BASIC</auth-method>
```

```
</login-config>
```

**Note:** If you use RequestDispatcher.forward() methods to forward requests from one servlet to another, the security check occurs only on the first servlet that is requested from the client.

Tasks that are authenticated in CICS using Liberty security can use the user ID derived from any of the Liberty application security mechanisms to authorize transaction and resource security checks in CICS. The CICS user ID is determined according to the following criteria:

1. Liberty application security authentication.

   Integration with the SAF user registry is part of the CICS Liberty security feature, unless distributed identity mapping is used. Any of the application security mechanisms supported by Liberty are supported in CICS, this includes HTTP basic authentication, form login, SSL client certificate authentication, identity assertion using a custom login module, JACC, JASPIC, or a Trust Association Interceptor (TAI). All SAF user IDs authenticated by Liberty must be granted read access to the Liberty JVM server APPL class profile. The name of this is determined by the profilePrefix setting in the safCredentials element in the Liberty server configuration file server.xml.

   ```
   <safCredentials profilePrefix="BBGZDFLT"/>
   ```

   The APPL class is also used by CICS terminal users to control access to specific CICS regions and your Liberty JVM server can use the same profile as the CICS APPLID depending upon your security requirements. If you do not specify this element, then the default profilePrefix of BBGZDFLT is used.

   You must define the APPLID and users must have access to the it. To configure and activate the BBGZDFLT profile in the APPL class:

   ```
   RDEFINE APPL BBGZDFLT UACC(NONE)
   SETROPTS CLASSACT(APPL)
   ```

   The users must be given read access to the BBGZDFLT profile in the APPL class in order to authenticate. To allow user AUSER to authenticate against the BBGZDFLT APPL class profile:

   ```
   PERMIT BBGZDFLT CLASS(APPL) ACCESS(READ) ID(AUSER)
   ```

   The Liberty SAF unauthenticated user id must be given read access to the APPL class profile. The SAF unauthenticated user id can be specified in the safCredentials element in the Liberty server configuration file server.xml.

   ```
   <safCredentials unauthenticatedUser="WSGUEST"/>
   ```

   If you do not specify the element, then the default unauthenticatedUser is WSGUEST. To allow the SAF unauthenticated user id WSGUEST read access to the BBGZDFLT profile in the APPL class:

   ```
   PERMIT BBGZDFLT CLASS(APPL) ACCESS(READ) ID(WSGUEST)
   ```

   If you use WSGUEST, then you should follow the steps to configure the SAF user registry as described in Setting up the System Authorization Facility (SAF) unauthenticated user.

   The WLP z/OS System Security Access Domain (WZSSAD) refers to the permissions granted to the Liberty server. These permissions control which System Authorization Facility (SAF) application domains and resource profiles the server is permitted to query when authenticating and authorizing users. The CICS region user ID must be granted permission within the WZSSAD domain to make authentication calls. To grant permission to authenticate, the CICS region ID must be granted READ access to the BBG.SECPFX.<APPL> profile in the SERVER class:

   ```
   RDEFINE SERVER BBG.SECPFX.BBGZDFLT UACC(NONE)
   PERMIT BBG.SECPFX.BBGZDFLT CLASS(SERVER) ACCESS(READ) ID(cics_region_user)
   ```

   For more details refer to Accessing z/OS security resources using WZSSAD.

2. If an unauthenticated subject is supplied from Liberty, then the USERID defined in the URIMAP will be used.
3. If no USERID is defined in the URIMAP the request will run under the CICS default user ID.

**Note:** Be aware that Liberty caches authenticated user IDs and, unlike CICS, does not check for an expired user ID within the cache period. You can configure the cache timeout by using the standard Liberty configuration process. Please see Configuring the authentication cache in Liberty.

## Authorizing users to run applications in a Liberty JVM server

You can use Enterprise Java application security roles to authorize access to Enterprise Java applications. Additionally, in a Liberty JVM server you can further restrict access to transactions (run as part of the application) by using CICS transaction and resource security.

### About this task

Your application is secured by providing an authorization constraint, the <auth_constraint> element, in the deployment descriptor (web.xml). If present, this ensures that access to your application is achieved only by a user that is a member of an authorized role. User or group membership to an Enterprise Java role is determined in one of two ways:

- Use an <application-bnd> element in the <application> element of your server.xml to describe the user/group to role mappings directly in XML.
- Use <safAuthorization> in your server.xml to allow users/groups role membership to be mapped by SAF (typically using EJBROLEs).

For more information, see Authorization using SAF role mapping.

Using CICS security allows you to re-use existing security procedures but requires that individual web applications are accessed from different URIMAPs. Using role-based security allows you to use existing standard Enterprise Java security definitions from another Enterprise Java application server. For more information, see “Authenticating users in a Liberty JVM server” on page 284.

If you want to use CICS transaction and resource authorization exclusively, or prefer to use finer-grained annotation-based role checking in code, you can defer the authorization decision to those components by using the special subject ALL_AUTHENTICATED_USERS role, as shown in the following example. If you deploy a Liberty application in a CICS bundle, CICS automatically configures this for you.

**Note:** Access checks are performed for the declarative security annotations and CICS transaction and resource security only after the configured constraints (web.xml) are verified

```
<application id="com.ibm.cics.server.examples.wlp.tsq.app"
    name="com.ibm.cics.server.examples.wlp.tsq.app" type="eba"
    location="${server.output.dir}/installedApps/com.ibm.cics.server.examples.wlp.tsq.app.eba">
    <application-bnd>
        <security-role name="cicsAllAuthenticated">
            <special-subject type="ALL_AUTHENTICATED_USERS"/>
        </security-role>
    </application-bnd>
</application>
```

Using this special subject, and giving the cicsAllAuthenticated role access to all URLs in your web applications deployment descriptor (web.xml), allows access to the web application using any authenticated user ID and authorization to the transaction must be controlled using CICS transaction security. If you deploy your application directly to the dropins directory, it is not configured to use CICS security as dropins does not support security.

If you are using safAuthorization then the <application-bnd> no longer acts as the source of user ID to role mapping. Instead, EJBROLEs in SAF determine which SAF users are in which roles (EJBROLEs). With safAuthorization the <application-bnd> is ignored. To achieve the same effect and allow all authenticated users to be authorized to run your application, the <auth-constraint> in web.xml must use the special role **, for example:

```
<auth-constraint>
        <description>special role for all authenticated users</description>
        <role-name>**</role-name>
</auth-constraint>
```

- The special role name ** is a shorthand for any authenticated user independent of role.
- The special role name * is a shorthand for all role names defined in the deployment descriptor.

When the special role name ** appears in an authorization constraint, it indicates that any authenticated user, independent of role, is authorized to perform the constrained requests. Special roles do not need an additional <security-role> declaration in web.xml.

To use CICS transaction or resource security you should follow the following steps:

### Procedure

1. Define a URIMAP of type JVMSERVER for each web application. Typically, you might specify a URIMAP to match the generic context root (URI) of a web application to scope the transaction ID to the set of servlets that make up the application. Or you may choose to run each individual servlet under a different transaction with a more precise URI.
2. Authorize all users of the web application to use the transaction specified in the URIMAP using CICS transaction or resource security profiles.

## Authorizing applications by using OAuth 2.0

OAuth 2.0 is an open standard for delegated authorization. The OAuth authorization framework enables a user to grant a third-party application access to information that is stored with another HTTP service without sharing their access permissions or the full extent of their data.

WebSphere Liberty supports OAuth 2.0, and can be used as an OAuth service provider endpoint and an OAuth protected resource enforcement endpoint. Liberty supports persistent OAuth 2.0 services. See Configuring persistent OAuth 2.0 services. Clients can be defined locally with the localStore and client elements. The following procedure uses local clients to enable OAuth 2.0 authorization.

### Before you begin

SAF security is a common use-case in CICS, and this procedure uses SAF in the examples.

Ensure that the CICS region is configured to use SAF security and is defined with SEC=YES as a system initialization parameter.

Optionally, you can grant an administrator user access to the SAF EJBROLE BBGZDFLT.com.ibm.ws.security.oauth20.clientManager. The security role clientManager controls access to the management interfaces, allowing local clients to be queried, and persistent local clients to be created. The administrator user controls OAuth 2.0 local clients.

Configure the Liberty angel process to provide authentication and authorization services to the Liberty JVM server. See The Liberty server angel process.

For more information about OAuth, see oauth-2.0.

### About this task

The following procedure covers how to:

- Create an OAuth 2.0 service provided in a Liberty JVM server.
- Create a locally configured client.
- Use this local client to grant an OAuth 2.0 token to a relying party application, also known as a third-party web application.
- Use this token to access protected resources in an application.

**Restriction:** Db2 JDBC type 2 connectivity is not supported for persistent OAuth 2.0 services.

## Procedure

1. Configure an OAuth 2.0 service provider.
   a) Add the `oauth-2.0` and the `cicsts:security-1.0` features to the `featureManager` element in `server.xml`.

   ```
   <featureManager>
       ...
       <feature>oauth-2.0</feature>
       <feature>cicsts:security-1.0</feature>
   </featureManager>
   ...
   ```

   b) Configure an OAuth 2.0 provider in `server.xml`.

   ```
   <oauthProvider id="myProvider">
   </oauthProvider>
   ```

2. Configure a local client for the relying party application. Local clients define the details of the relying party application, including the name, secret password, and redirect URI of the application.
   a) Define a meaningful local client name and create a secret password that is used by the server for authorization. The local client application listens on a URI, and the server supplies authorization codes.
   b) Configure an OAuth 2.0 local client in the `oauthProvider` element of `server.xml`, supplying the local client ID, secret password, and the redirect URI.

```
<oauthProvider id="myProvider">
    <localStore>
        <client id="myClient" redirect="https://client.example.ibm.com/webApp/redirect"
secret="mySecret" />
    </localStore>
</oauthProvider>
```

   **Important:**

   Although it is not shown in this example, it is important to encode passwords and limit access to `server.xml` configuration. Passwords can be encoded by using the Liberty `securityUtility`, found in USS_HOME`/wlp/bin/securityUtility`. For more information, see securityUtility command.

   **Note:** More than one local client can be configured in the `localStore` element.

3. When the relying party application requires access to protected resources on the server, the user must authorize access to these resources first.
   a) The relying party application requires the user to authenticate with the server, and select the type of access for the relying party application by linking or redirecting the user to the authorization endpoint:

   ```
   https://hostname:port/oauth2/endpoint/provider_name/authorize
   ```

   or

   ```
   https://hostname:port/oauth2/declarativeEndpoint/provider_name/authorize
   ```

   Additional parameters are required in the query parameters of the URL. For the local client that was configured in step 2, the following GET request is required (all one line):

```
https://zos.example.ibm.com/oauth2/endpoint/myProvider/authorize?response_type=code
   &client_id=myClient&client_secret=mySecret&redirect_uri=https://client.example.ibm.com/webApp/redirect
```

After the user selects the access for the relying party application, they are redirected back to the relying party application using the redirect URI:

```
https://client.example.ibm.com/webApp/redirect?code=access_code
```

The relying party application must store this access code to request an OAuth token.

**Note:** For local clients, the user must exist in a user register in the Liberty JVM server. For more information about authenticating users in Liberty JVM servers, see Authenticating users in a Liberty JVM server.

b) The relying party application requests an OAuth 2.0 token by sending a POST request to the server:

```
https://hostname:port/oauth2/endpoint/provider_name/token
```

The relying party application sends the authorization code that is received from the authorization endpoint, the local client ID, and the secret password in the POST data (`grant_type` is all one line):

```
POST https://zos.example.ibm.com/oauth2/endpoint/myProvider/token HTTP/1.1
Content-Type: application/www-form-urlencoded

grant_type=authorization_code&code=code&client_id=myClient
   &client_secret=mySecret&redirect_url=https://client.example.ibm.com/webApp/redirect
```

This returns a JSON document that contains the token.

4. Use the token to access protected resources.

a) Add the token to the `Authorization` header on the HTTP request.

```
Authorization: Bearer <token>
```

### Results

Users are able to authorize third-party applications to access their protected resources in a Liberty JVM server through OAuth 2.0 authorizations flows. The Liberty JVM server can configure the provider of these tokens and create locally configured clients.

Several methods to grant tokens are available. For more information, see OAuth 2.0 service invocation.

## Configuring persistent OAuth 2.0 services

WebSphere Liberty supports persisting OAuth 2.0 local clients and tokens to a database. With persistent OAuth 2.0, an authorized local client can continue to access OAuth 2.0 services after a restart.

### Before you begin

SAF security is a common use-case in CICS, and this procedure uses SAF in the examples.

- Gain the necessary access to create tables and read/write to these tables in a database and configure it in the Liberty `server.xml`.
- Grant access to the SAF EJBROLE BBGZDFLT`.com.ibm.ws.security.oauth20.clientManager` to an administrator user to control OAuth 2.0 local clients.
- Create an OAuth 2.0 provider in the Liberty `server.xml`. For more information, see Authorization using OAuth 2.0.

### About this task

The following steps create a persistent OAuth 2.0 local client. This local client is used to grant OAuth 2.0 tokens.

**Restriction:** Db2 JDBC type 2 connectivity is not supported for persistent OAuth 2.0 services.

### Procedure

1. Create the necessary tables using IBM Db2 for persistent OAuth services as a guide.
2. Create a persistent local client by sending a POST request to the URL:

   ```
   https://hostname:port/oauth2/endpoint/provider_name/registration
   ```

   Use the JSON document which is described in the first table in Configuring an OpenID Connect Provider to accept client registration requests; for example:

   ```
   {
       "client_id": "client_id",
       "client_secret": "client_secret",
       "grant_types": [ "authorization_code", "refresh_token" ],
       "redirect_uris": [ "https://client.example.ibm.com/webApp/redirect" ]
   }
   ```

### Results

A persistent OAuth 2.0 local client is created. When this local client is used to produce tokens, the tokens are persisted to the database. If the server restarts, the persistent local client and tokens remain valid.

## Authorization using SAF role mapping

Mapping Java EE roles to users and groups can be achieved in different ways. In distributed systems, a basic registry or LDAP registry would typically be used in conjunction with an application specific `<application-bnd>` element, to map users from those registries into *roles*. The deployment descriptor of the application determines which roles can access which parts of the application.

### About this task

On z/OS, there is an additional registry type, the System Authorization Facility (SAF) registry. A Liberty JVM server implicitly uses this type for authentication when the `cicsts:security-1.0` feature is installed unless configured to use LDAP. You can choose to make use of SAF authorization. When using SAF authorization, user to role mappings are used to map roles to EJBROLE resource profiles using the SAF role mapper. The server queries SAF to determine if the user has the required READ access to the EJBROLE resource profile.

In a Liberty JVM server, if you want to use Java EE roles without SAF authorization, you cannot use CICS bundles to install your applications. This is because a CICS bundle installed application automatically creates an `<application-bnd>` element and uses the `ALL_AUTHENTICATED_USERS` special-subject, which prevents you from defining the element yourself. Instead, you must create an `<application>` element in `server.xml` directly and configure the `<application-bnd>` with the roles and users you require.

If, however, you choose to use Java EE roles and SAF authorization, you can continue to use CICS bundles to lifecycle your web applications. The `<application-bnd>` is ignored by Liberty in favor of using the role mappings determined by the SAF registry. Role mappings are determined by virtue of a user belonging to an EJB role.

**Tip:** When SAF authorization is enabled, EJB roles in RACF are used for role mapping instead of the roles in `server.xml`. Therefore, special subjects such as `ALL_AUTHENTICATED_USERS` and `EVERYONE`, or users can not be defined in `server.xml` in this case.

**Tip:** It is advisable to create or update your EJB roles before starting the CICS region. Liberty issues a `RACROUTE REQUEST=LIST` with `GLOBAL=NO` in order to support a minimum version of z/OS. The address space will not see updates until it is restarted (or started).

### Procedure

1. Add the `<safAuthorization id="saf"/>` element to your `server.xml`. If you are using the `cicsts:distributedIdentity-1.0` feature, this is defined for you.

2. Optional: You can add `racRouteLog="ASIS"` to the element in the previous step.

   This allows you to see the RACF EJBROLE logging from Liberty.
3. Create the EJB roles in RACF, with reference to the prefix scheme described.
4. Add users to those EJB roles.

   By default, if SAF authorization is used, the application uses the pattern `<profile_prefix>.<resource>.<role>` to determine if a user is in a role. The `profile_prefix` defaults to `BBGZDFLT` but can be modified using the `<safCredentials>` element. For example, you can set it to the `APPL_ID` of a region. If you want multiple regions to share identical security configuration, you can set `<profile_prefix>` to the same value for those regions. For more information, see Accessing z/OS security resources using WZSSAD.

   The role mapping preferences can be modified using the `<safRoleMapper>` element in the `server.xml`, for example:

   ```
   <safRoleMapper profilePattern="myprofile.%resource%.%role%" toUpperCase="true"/>
   ```

   Users can then be authorized to a particular EJB role using the following RACF commands, where `WEBUSER` is the authenticated user ID.

   ```
   RDEFINE EJBROLE BBGZDFLT.MYAPP.ROLE UACC(NONE)
   PERMIT BBGZDFLT.MYAPP.ROLE CLASS(EJBROLE) ACCESS(READ) ID(WEBUSER)
   ```
5. Optional: If you are deploying the CICS servlet examples and want to use the Java EE role security with SAF authorization, create a SAF `EJBROLE` for each servlet that you have deployed. For example, if you use the default APPL class of `BBGZDFLT`, define the following `EJBROLE` security definitions using RACF commands:

```
RDEFINE EJBROLE BBGZDFLT.com.ibm.cics.server.examples.wlp.hello.war.cicsAllAuthenticated UACC(NONE)
RDEFINE EJBROLE BBGZDFLT.com.ibm.cics.server.examples.wlp.tsq.app.cicsAllAuthenticated UACC(NONE)
RDEFINE EJBROLE BBGZDFLT.com.ibm.cics.server.examples.wlp.jdbc.app.cicsAllAuthenticated UACC(NONE)
SETROPTS RACLIST(EJBROLE) REFRESH
```

   Give read access to the defined roles for each web user ID that requires authorization:

```
PERMIT BBGZDFLT.com.ibm.cics.server.examples.wlp.hello.war.cicsAllAuthenticated
       CLASS(EJBROLE) ID(user) ACCESS(READ)
PERMIT BBGZDFLT.com.ibm.cics.server.examples.wlp.tsq.app.cicsAllAuthenticated
       CLASS(EJBROLE) ID(user) ACCESS(READ)
PERMIT BBGZDFLT.com.ibm.cics.server.examples.wlp.jdbc.app.cicsAllAuthenticated
       CLASS(EJBROLE) ID(user) ACCESS(READ)
SETROPTS RACLIST(EJBROLE) REFRESH
```

### Results

You can authorize access to web applications using CICS Security, Java EE role security, or both by defining the roles and the users in the roles.

## Configuring security for a Liberty JVM server with the Enterprise Java security API

Java EE 8 introduces a portable, flexible, and standardized security model with the Java EE security API 1.0. A Liberty JVM server can be configured to respect the new security configuration through the inclusion of the Liberty appSecurity-3.0 feature.

The Java EE security API 1.0 specification covers three principles:

1. Authentication mechanism: provided by the HttpAuthenticationMechanism interface for the servlet container
2. Identity store: an attempt to standardize the JAAS LoginModule
3. Security context: an access point for programmatic security

## Authentication mechanism

An authentication mechanism is a way that is used to obtain a username and password from the user to be processed later by the Java Security API. There are two standard options for authentication, both take advantage of the annotations that are introduced by the Java EE security 1.0 API.

### HTTP basic authentication

Basic authentication displays the browser's native login dialog before the user can access the protected resource.

```
@BasicAuthenticationMechanismDefinition(realmName="user-realm")
@WebServlet("/home") @DeclareRoles({"user"})
@ServletSecurity(@HttpConstraint(rolesAllowed = "user"))
public class HomeServlet extends HttpServlet {
    ...
}
```

### Form-based authentication

You can use form-based authentication to replace the browser’s built-in dialog with your own custom HTML form. You can create an application config class with annotations as follows:

```
@FormAuthenticationMechanismDefinition(
    loginToContinue = @LoginToContinue(
        loginPage = "/login",
        errorPage = "/error"
    )
)
@ApplicationScoped
public class ApplicationConfig {
    ...
}
```

## Identity store

A component acts as a DAO (Data Access Object) for accessing user information, including their usernames, passwords, and associated roles. A number of identity store types are introduced by the Java EE security API 1.0, including:

### Database identity store

A database identity store is used to retrieve user information from a relation database.

```
@DatabaseIdentityStoreDefinition(
dataSourceLookup = "jdbc/sec",
    callerQuery = "#{'select password from USR where USERNAME = ?'}",
    groupsQuery = "#{'select ugroup from USR where USERNAME = ?'}",
    hashAlgorithm = Pbkdf2PasswordHash.class,
    priorityExpression = "#{100}",
    hashAlgorithmParameters = {
        "Pbkdf2PasswordHash.Iterations=3072",
        "Pbkdf2PasswordHash.Algorithm=PBKDF2WithHmacSHA512",
        "Pbkdf2PasswordHash.SaltSizeBytes=64"
    }
)
```

### Lightweight Directory Access Protocol (LDAP) identity store

LDAP is a common way of organizing a user's access to different systems across a single organization. LDAP realizes the idea of Single-Sign On, where a user has a single username and password, and then uses it across all different systems that are used to perform the everyday business of a specific organization.

```
@WebServlet("/home")
@ServletSecurity(@HttpConstraint(rolesAllowed = "user"))
@LdapIdentityStoreDefinition(
    url = "ldap://localhost:33389/",
    callerBaseDn = "ou=user,dc=jsr375,dc=net",
    groupSearchBase = "ou=group,dc=jsr375,dc=net"
)
public class HomeServlet extends HttpServlet{
    ...
}
```

URL: The URL of the LDAP server to use for authentication.

callerBaseDn: Base distinguished name for callers in the LDAP store.

groupSearchBase: Search base for looking up groups.

**Custom identity store**

In addition to the built-in identity stores found in Java EE security API 1.0, a user can implement their own identity store and control exactly where to obtain user information. This can be achieved by creating a custom identity store class, then creating an HTTP authentication mechanism associated with this custom identity store.

### Security context

The security context object is used to programmatically check a user's authority to access a specific resource. This is useful when you need to perform custom behavior. In this example, the user is forwarded to another page only if they have access to it:

```
@WebServlet("/home")
public class HomeServlet extends HttpServlet {
    @Inject
    private SecurityContext securityContext;
    @Override
    protected void doGet(HttpServletRequest req, HttpServletResponse resp)
        throws ServletException, IOException {
        if (securityContext.hasAccessToWebResource("/anotherServlet", "GET")) {
            req.getRequestDispatcher("/anotherServlet").forward(req, res);
        } else {
            req.getRequestDispatcher("/logout").forward(req, res);
        }
    }
}
```

For more information about the Java EE 8 security API, see Java EE Security API in the Liberty documentation.

## Authenticating by using a database identity store

You can use the @DatabaseIdentityStoreDefinition interface to retrieve user credentials from a database for authentication.

### About this task

Follow these steps to authenticate by using a database identity store.

### Procedure

1. Add the `appSecurity-3.0` feature to `server.xml` before you start the server.
2. Ensure that CDI annotation file scanning is enabled. CICS disables it by default in `server.xml`.

   You can ensure CDI annotation file scanning is enabled by checking the following line is not present in `server.xml`: `<cdi12 enableImplicitBeanArchives="false"/>`.
3. Create a table in the database and set up `server.xml`.
   For example, to create a Db2 table using SQL:

   ```
   CREATE TABLE PXX.USR (
       USERNAME      VARCHAR ( 256 ) NOT NULL,
       PASSWORD      VARCHAR ( 256 ) NOT NULL,
       UGROUP        VARCHAR ( 256 ) NOT NULL
   ) IN SECU.TSSE;
   CREATE UNIQUE INDEX INDXUSRS ON PXX.USR (USERNAME);
   ```

The password in the database must be encrypted. An example of inserting an encrypted password into a database can be found here: Database Setup

a) Add the jdbc-4.2 feature in `server.xml`:

```
<feature>jdbc-4.2</feature>
```

b) Set `jndiName` in `server.xml`, for example:

```
<dataSource id="DefaultDataSource" jndiName="jdbc/sec">
    <jdbcDriver libraryRef=<xxx>"/>
    ...
</dataSource>
```

4. Determine whether to use SAF for the CICS task user ID.

a) If you do not want to push the database identity onto the CICS task, you can remove the default safRegistry setting in `server.xml`. This makes the CICS task run under the default CICS user ID.

b) If you want CICS tasks to run under specific SAF users mapped from your database identity store, you need to take the following steps:

i) Configure SAF in `server.xml` by setting the following SAF elements.

```
<safCredentials mapDistributedIdentities="true" profilePrefix=<xxx>"/;
<safAuthorization id="saf"/>
<safRoleMapperprofilePattern=“<xxx>.%resource%.%role%" toUpperCase="false;
```

ii) Issue the RACMAP command. The general RACMAP command of mapping a distributed user ID to a SAF user ID is in the format of:

```
RACMAP ID(userid)
MAP
WITHLABEL('label-name')
USERDIDFILTER(NAME('distributed-identity-user-name'))
REGISTRY(NAME('distributed-identity-registry-name'))
```

Use `defaultRealm` in `REGISTRY(NAME(<nnn>))`, and use `<username_in_DBIS>` in `USERDIDFILTER(NAME(<nnn>))`, for example:

```
RACMAP ID(JATM12) MAP WITHLABEL('authorisedUser:JATM12')
USERDIDFILTER(NAME('authorisedUser')) REGISTRY(NAME('defaultRealm'))
```

**Note:** If you deploy the application in a CICS bundle, the security role `"cicsAllAuthenticated"` is automatically set in the `installedApps.xml` as follows:

```
<application ...>
    <application-bnd>
        <security-role name="cicsAllAuthenticated">
            <special-subject type="ALL_AUTHENTICATED_USERS"/>
        </security-role>
    </application-bnd>
</application>
```

The security role `"cicsAllAuthenticated"` takes precedence over the group name that is stored in the database identity store and an HTTP 403 error occurs. There are two options you take:

i) Deploy your database identity store application with a direct `<application>` element in `server.xml`.

ii) Deploy within a CICS bundle, but use safAuthorization to bypass the CICS-generated `<application-bnd>` which overrides the group information stored in the Custom Identity Store.

## Results

You have successfully configured the database identity store.

## Authenticating by using a custom identity store

You can use a custom identity store to implement your own identity store and control exactly where to obtain user information.

### About this task

Follow these steps to authenticate by using a custom identity store.

### Procedure

1. Add the `appSecurity-3.0` feature to `server.xml` before you start the server.
2. Ensure that CDI annotation file scanning is enabled. CICS disables it by default in `server.xml`.

   You can ensure that CDI annotation file scanning is enabled by checking the following line is not present in `server.xml`: `<cdi12 enableImplicitBeanArchives="false"/>`.
3. Create Java classes to process the custom identity store logic and build them into a WAR file.

   a) Create a custom identity store object, by creating a class that implements the IdentityStore interface, as shown in the following example:

```
@ApplicationScoped
public class MyIdentityStore implements IdentityStore {
    public CredentialValidationResult validate(UsernamePasswordCredential userCredential)
{
        if (userCredential.compareTo("authorisedUser", "tomtom")) {
            return new CredentialValidationResult("authorisedUser",
                new HashSet<String>(asList("user")));
        }
        return INVALID_RESULT;
    }
}
```

   b) Create an HTTP authentication mechanism associated with this identity store, which is used with the identity store class that is created in the previous step:

```
@ApplicationScoped
public class MyAuthMechanism implements HttpAuthenticationMechanism {

    @Inject
    private IdentityStoreHandler idStoreHandler;

    public AuthenticationStatus validateRequest(HttpServletRequest req,
        HttpServletResponse res, HttpMessageContext context) {
        CredentialValidationResult result = idStoreHandler.validate(
            new UsernamePasswordCredential(
                req.getParameter("name"),
                req.getParameter("password")));
        if (result.getStatus() == CredentialValidationResult.Status.VALID) {
            return context.notifyContainerAboutLogin(result);
        } else {
            return context.responseUnauthorized();
        }
    }
}
```

   c) Create a servlet.

```
@WebServlet("/home")
@ServletSecurity(@HttpConstraint(rolesAllowed = "user"))
public class Servlet extends HttpServlet {...}
```

4. Determine whether to use SAF for the CICS task userid.

   a) If you do not want to push the custom identity onto the CICS task, you can remove the default safRegistry setting in `server.xml`. This makes the CICS task run under the default CICS userid.

   b) If you want CICS tasks to run under specific SAF users mapped from your custom identity store, you need to take the following steps:

i) Configure SAF in `server.xml` by setting the following SAF elements.

```
<safCredentials mapDistributedIdentities="true" profilePrefix="<xxx>"/>
<safAuthorization id="saf"/>
<safRoleMapperprofilePattern="<xxx>.%resource%.%role%" toUpperCase="false"/>
```

ii) Issue the RACMAP command. The general RACMAP command of mapping a distributed userid to a SAF userid is in the format of:

```
RACMAP ID(userid)
MAP
WITHLABEL('label-name')
USERDIDFILTER(NAME('distributed-identity-user-name'))
REGISTRY(NAME('distributed-identity-registry-name'))
```

Use "`defaultRealm`" in `REGISTRY(NAME('<nnn>'))`, and use "`<username_in_CIS>`" in `USERDIDFILTER(NAME('<nnn>'))`, for example:

```
RACMAP ID(JATM12) MAP WITHLABEL('authorisedUser:JATM12')
USERDIDFILTER(NAME('authorisedUser')) REGISTRY(NAME('defaultRealm'))
```

**Note:** If you deploy the application within a CICS bundle, the security role `"cicsAllAuthenticated"` is automatically set in `installedApps.xml` as follows:

```
<application ...>
    <application-bnd>
        <security-role name="cicsAllAuthenticated">
            <special-subject type="ALL_AUTHENTICATED_USERS"/>
        </security-role>
    </application-bnd>
</application>
```

It takes precedence over the group name that is stored in the custom identity store and an HTTP 403 error occurs. There are two options you can take:

i) Deploy your custom identity store application with a direct `<application>` element in `server.xml`.

ii) Deploy within a CICS bundle, but use safAuthorization to bypass the CICS-generated `<application-bnd>` which overrides the group information stored in the custom identity store.

### Results

You have successfully configured the custom identity store.

## Configuring security for a Liberty JVM server by using an LDAP registry

Liberty uses a user registry to authenticate a user and retrieve information about users and groups to perform security-related operations, including authentication and authorization. Default CICS Liberty security uses the SAF registry. However, many transactions that run on CICS are initiated by users who authenticate their identities on distributed application servers, so CICS also supports the use of a Lightweight Directory Access Protocol (LDAP) registry in Liberty. To use LDAP, it is necessary to manually configure the `server.xml`.

### Before you begin

- Ensure that the CICS region is configured to use SAF security and is defined with SEC=YES as a system initialization parameter.
- Authorize application developers and system administrators to create, view, update, and remove JVMSERVER and BUNDLE resources to deploy web applications into a Liberty JVM server. The JVMSERVER resource controls the availability of the JVM server, and the BUNDLE resource is a unit of deployment for the Java applications and controls the availability of the applications.

## About this task

This task explains how to configure LDAP security for a Liberty JVM server, and integrate Liberty security with CICS security. Distributed identity mapping can be used to associate a SAF user ID with a distributed identity. You can use the CICS distributed identity mapping feature to set up distributed identity mapping. A user can then log on to a CICS web application with their distributed identity, as authenticated by an LDAP server. Filters that are defined in the z/OS security product (RACMAP) determine the mapping of this identity to a SAF user ID. This SAF user ID can then be used to authorize access to web applications through JEE application role security, providing integration with CICS transaction and resource security. You can map a SAF user ID to one or more distributed identities.

The default transaction ID for running any web request is CJSA. You can configure CICS to run web requests under a different transaction ID by using a URIMAP of type JVMSERVER. You can specify a URIMAP to match the generic context root (URI) of a web application to scope the transaction ID to the set of servlets that make up the application. Or you can choose to run each individual servlet under a different transaction with a more precise URI.

There are three scenarios for this task:

- Scenario 1 – Distributed identity mapping with SAF authorization
- Scenario 2 – Distributed identity mapping without SAF authorization
- Scenario 3 – LDAP for authentication and authorization

## Procedure

1. **Distributed identity mapping with SAF authorization**

   You can use the CICS distributed identity mapping feature, `cicsts:distributedIdentity-1.0` to enable LDAP distributed identities to be mapped to SAF user IDs. When used with the CICS security feature `cicsts:security-1.0`, Liberty LDAP security is used for authentication and JEE application role security from EJB role mappings are respected for authorization. CICS transactions run under the mapped SAF user ID providing integration with CICS transaction and resource security.

   a. Configure the WebSphere Liberty angel process to provide authentication and authorization services to the Liberty JVM server, for more information see The Liberty server angel process.

   b. Add the `cicsts:security-1.0` and the `cicsts:distributedIdentity-1.0` feature to the featureManager list in the `server.xml`.

   ```
   <featureManager>
      ...
      <feature>cicsts:security-1.0</feature>
      <feature>cicsts:distributedIdentity-1.0</feature>
   </featureManager>
   ...
   ```

   c. Configure Liberty to use LDAP authentication by defining the LDAP server in the `server.xml`, for example:

   ```
   <ldapRegistry id="ldap"
       host="host.domain.com" port="389"
       ldapType="IBM Tivoli Directory Server"
       baseDN="ou=users,dc=domain,dc=com"
       ignoreCase="true">
   </ldapRegistry>
   ```

   Full details on configuring LDAP user registries with Liberty are available in Configuring LDAP user registries in Liberty.

   d. Remove the safRegistry element, if present. Save the changes to the `server.xml`.

   e. Make the necessary RACF definitions, including setting up the RACMAPs to map distributed identities to SAF user IDs as which are described in Configuring LDAP user registries in Liberty and providing access for these user IDs to the appropriate EJBROLEs as described in "Authorization using SAF role mapping" on page 290. CICS configures SAF authorization and the mapDistributedIdentities attributes in the safCredentials configuration element for you.

When the `cicsts:distributedIdentity-1.0` feature is used with the `cicsts:security-1.0` feature, Liberty LDAP security is used for authentication, and JEE application role security from EJB role mappings are respected for authorization. CICS transactions run under the RACMAP mapped user ID providing integration with CICS transaction and resource security.

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2. **Distributed identity mapping without SAF authorization**

   It is possible to allow CICS transactions to run under a RACMAP mapped user ID while respecting the roles configured in the application's `<application-bnd>` element. This might be useful when migrating work from distributed Liberty to CICS Liberty. Be aware that if CICS bundles are used, a user-defined `<application-bnd>` is overwritten by the CICS-generated `<application-bnd>`. SAF authorization using role mapping is preferred, for more information see "Authorization using SAF role mapping" on page 290 for more details.

   a. Configure the WebSphere Liberty angel process to provide authentication and authorization services to the Liberty JVM server, for more information, see The Liberty server angel process.

   b. Add the `cicsts:security-1.0` and the `ldapRegistry-3.0` feature to the featureManager list in the `server.xml`.

   ```
   <featureManager>
      ...
      <feature>cicsts:security-1.0</feature>
      <feature>ldapRegistry-3.0</feature>
   </featureManager>
   ...
   ```

   c. Configure Liberty to use LDAP authentication by defining the LDAP server in the `server.xml`, for example:

   ```
   <ldapRegistry id="ldap"
       host="host.domain.com" port="389"
       ldapType="IBM Tivoli Directory Server"
       baseDN="ou=users,dc=domain,dc=com"
       ignoreCase="true">
   </ldapRegistry>
   ```

   Full details on configuring LDAP user registries with the Liberty are available in Configuring LDAP user registries in Liberty.

   d. Configure Liberty to use distributed identity filters to map the distributed identities to SAF user IDs by setting the `mapDistributedIdentities` attribute in the `safCredentials` configuration element to `true` in the `server.xml`.

   e. Remove the safRegistry element, if present. Save the changes to the `server.xml`.

   f. Make the necessary RACF definitions, including setting up the RACMAPs to map distributed identities to SAF user IDs as which are described in Configuring LDAP user registries in Liberty.

   g. If JEE application role security from EJB roles is required for authorization then refer to the topic "Authorization using SAF role mapping" on page 290.

   Applications use Liberty LDAP security for authentication, and JEE application role security in an `<application-bnd>` element are respected for authorization of the distributed identity. In CICS, transactions run under the RACMAP mapped user ID, providing integration with CICS transaction and resource security.

   What to do next

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3. **LDAP for authentication and authorization**

   LDAP security can be used in a CICS Liberty JVM server for both authentication and authorization using JEE application role security. URIMAP definitions can then be used to set the user ID under which transactions run. The `mapDistributedIdentities` attribute is not set in this scenario.

This scenario might be useful if migrating a distributed application into a CICS Liberty JVM server, without requiring any significant security resource changes.

a. Add the `cicsts:security-1.0` and the `ldapRegistry-3.0` feature to the featureManager list in the `server.xml`.

```
<featureManager>
   ...
   <feature>cicsts:security-1.0</feature>
   <feature>ldapRegistry-3.0</feature>
</featureManager>
...
```

b. Configure Liberty to use LDAP authentication by defining the LDAP server in the `server.xml`, for example:

```
<ldapRegistry id="ldap"
    host="host.domain.com" port="389"
    ldapType="IBM Tivoli Directory Server"
    baseDN="ou=users,dc=domain,dc=com"
    ignoreCase="true">
</ldapRegistry>
```

Full details on configuring LDAP user registries with Liberty are available in Configuring LDAP user registries in Liberty.

c. Remove the safRegistry element, if present. Save the changes to the `server.xml`.

d. If JEE application role security from EJB roles is required for authorization then refer to the topic “Authorization using SAF role mapping” on page 290.

Applications use Liberty LDAP security for authentication, and JEE application role security in an `<application-bnd>`element are respected for authorization. In CICS transactions run under the URIMAP or CICS DFLTUSER user ID as appropriate.

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### What to do next

This applies to all three scenarios:

- Modify the Liberty authentication cache.
- Set up URIMAP definitions to map web application URIs to transaction IDs.

This applies to scenarios 1 and 2:

- Set up CICS transaction security definitions to authorize access to URIs based on the mapped user ID.

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## Configuring security for remote JCICSX API development

The JCICSX server is a remote Liberty JVM server in a CICS region. With the JCICSX API, it allows developers to run Java applications on their local workstation as if they were run in CICS, without deploying the applications to CICS. When remote connection is established from a JCICSX development client in the developer's local JVM to a JCICSX server, the remote server can authenticate users and authorize them with access based on their identities to ensure security. It also prevents users from interfering with remote tasks started by other users.

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### What authentication and authorization options are available?

The JCICSX server *authenticates* users to verify their identity. When planning how to authenticate JCICSX users, you have a few options to consider. First, you need to decide which user registry is used to store the user identity information. This topic covers the configuration of two registry options: using user identities from SAF (`safRegistry`) and embedding user identities directly in your `server.xml` (`basicRegistry`).

After configuring where the server is to find user identities, those users can be *authorized* to use the JCICSX server application. By default, the JCICSX server allows all users who are able to be authenticated with the server to access its services. However, this is customizable. The JCICSX server defines the Enterprise Java role JCICSXUSER, which can be used to customize access. This is achieved by mapping a role, which provides access to the application, to a group of users. Also, this role mapping can either be recorded in SAF (`safAuthorization`) or embedded directly in your `server.xml`.

**Note:** You must have a SAF registry to use SAF authorization.

Therefore, as shown in Figure 38 on page 301, the following authentication and authorization options are available for your remote JCICSX server:

- Using a basic user registry for authentication and `server.xml` for role mapping.
- Using a SAF registry for authentication and `server.xml` for role mapping.
- Using a SAF registry for authentication and SAF authorization for role mapping.

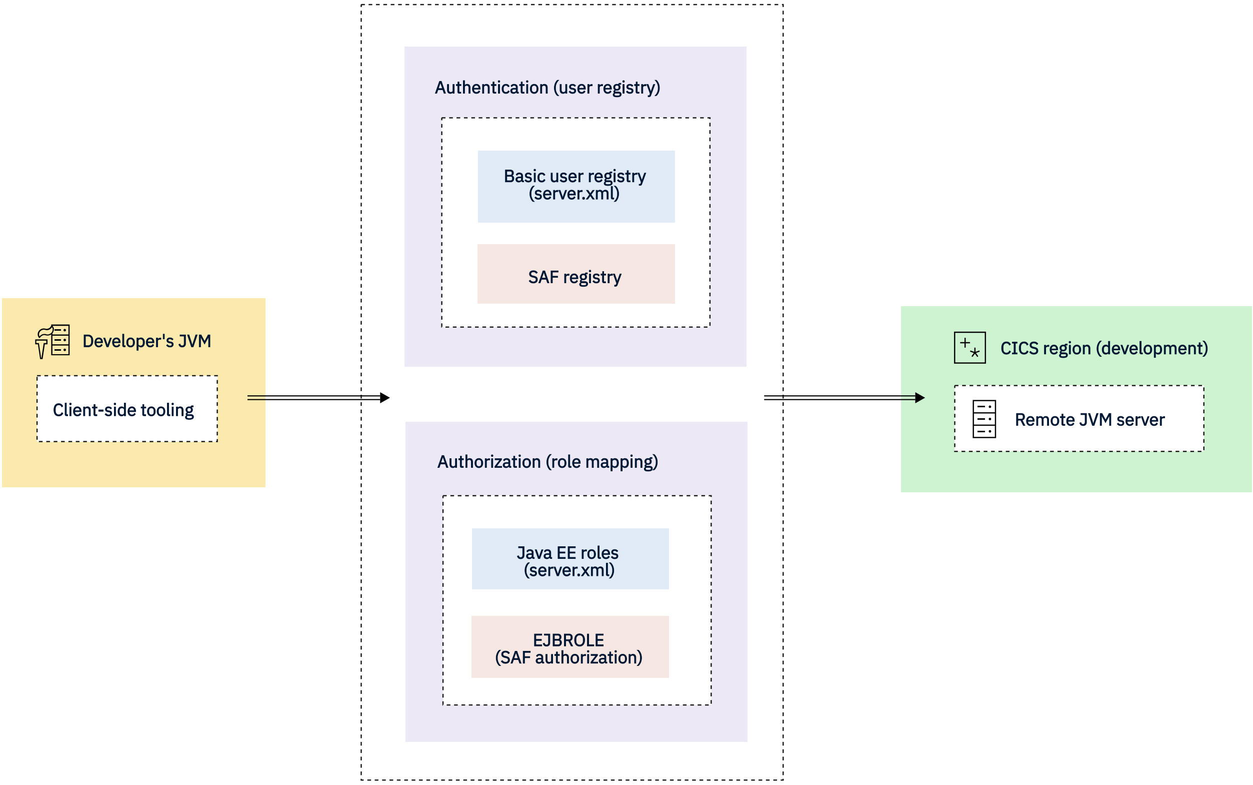


*Figure 38. Authentication and authorization of remote JCICSX server*

## What options to choose?

From a logistical standpoint, it's simple to configure authentication and authorization directly in your `server.xml`. Therefore, it can be a convenient option if you are setting up the JCICSX server in a private development region. However, it has limitations at larger scales because the `server.xml` configuration is difficult to share. While it's more complicated to set up SAF for authentication and authorization, which involves the creation of EJB roles (EJBROLEs) in RACF, you can take advantage of existing information in your SAF database if you already have one. For example, you can authorize existing groups that are defined in SAF to use JCICSX, without having to specify them again. You can also share that information across multiple instances of JCICSX server running in different CICS regions, without having to configure each region independently.

**Note:** Any security configuration that you specify in the JCICSX server's `server.xml` must co-exist with the security requirements of other applications you have deployed into that server. For example, if you have an application that requires SAF authorization be enabled, you cannot specifically disable it for the JCICSX server and enable SAF authorization in the same Liberty server. In this case, you can create another JVM server that's dedicated to running the JCICSX server in your CICS region to work around this. If you don't create a separate server for JCICSX, you must follow instructions in "Scenario 3: Set up security in all my CICS regions, granting access to specific people" on page 303 to set up SAF authorization for the server.

In addition, when the client starts a session with the JCICSX server, a new CICS task is created to run under transaction CJXA and URI map DFHJXSU. Subsequent JCICSX requests for that session will run under the same task, and must be issued by the same user. Transaction CJXA is a category 2 transaction. If you have transaction attach security turned on, you also need to permit users to run transaction CJXA.

See "Typical scenarios and procedures" on page 302 for a discussion on how you might configure authentication and authorization for a number of typical scenarios.

## Typical scenarios and procedures

Three scenarios are provided to cover the options described before.

- "Scenario 1: Allow all users to try it out in a single region with no authentication" on page 302
- "Scenario 2: Allow users to sign on using SAF identities, granting access to authenticated or specific users" on page 303
- "Scenario 3: Set up security in all my CICS regions, granting access to specific people" on page 303

## Scenario 1: Allow all users to try it out in a single region with no authentication

To allow developers to test applications quickly in a development region, you can configure the remote JCICSX server to use no authentication. This task configures all security settings in `server.xml`.

### Before you begin

Ensure that you have set up a Liberty JVM server to serve as the JCICSX server, by adding the JCICSX server feature (`cicsts:jcicsxServer-1.0`) to the `server.xml` file of your Liberty JVM server:

```
<featureManager>
    <feature>cicsts:jcicsxServer-1.0</feature>
</featureManager>
```

For more information, see Java development using JCICSX.

### Procedure

1. If your server is not configured with the `appSecurity-2.0` feature to use Liberty security, no further configuration is needed. Any user can access the server with no credentials provided. For more information about `appSecurity`, see "Configuring security for a Liberty JVM server" on page 277.
2. If your server is configured with the `appSecurity-2.0` feature to use Liberty security:

   a. By default, the server only accepts authentication with a valid certificate. To allow users to be authenticated with a username and password, add the following line to the `server.xml` file:

   ```
   <webAppSecurity allowFailOverToBasicAuth="true"/>
   ```

   Otherwise, users get a 403 error when they access the server with a username and password.

   b. Create a basic user registry to authenticate users in `server.xml`. For instructions, see Configuring a basic user registry for Liberty.

   c. By default, the server allows all the authenticated users defined in your user registry to access the servlet. Override the default setting to allow all users by adding the following snippet to `server.xml`:

   ```
   <authorization-roles id="com.ibm.cics.wlp.jcicsxserver">
     <security-role name="JCICSXUSER">
       <special-subject type="EVERYONE"/>
     </security-role>
   </authorization-roles>
   ```

   It changes the `special-subject` type from `ALL_AUTHENTICATED_USERS` to EVERYONE so that any user can access the servlet no matter what usernames or passwords they provide. If you don't specify the EVERYONE special subject, unauthenticated users who access the server get a 401 error.

3. If you are using transaction attach security, grant the CICS default user ID access to run the CJXA transaction.

**Result**

You have now configured remote JCICSX server to use no authentication for a CICS region.

## Scenario 2: Allow users to sign on using SAF identities, granting access to authenticated or specific users

This is convenient if you already have a SAF registry to manage user identities. In this scenario, you use the SAF registry for authentication and configure role mapping in `server.xml` so that you don't need to configure new SAF EJBROLEs.

**Before you begin**

Ensure that you have set up a Liberty JVM server to serve as the JCICSX server, by adding the JCICSX server feature (`cicsts:jcicsxServer-1.0`) to the `server.xml` file of your Liberty JVM server:

```
<featureManager>
    <feature>cicsts:jcicsxServer-1.0</feature>
</featureManager>
```

For more information, see Java development using JCICSX.

**Procedure**

1. Enable CICS security, which integrates Liberty security, for the JCICSX server and configure it to use the SAF registry. For instructions, see "Configuring security for a Liberty JVM server" on page 277.
2. By default, the server only accepts authentication with a valid certificate. To allow users to be authenticated with a username and password, add the following line to the `server.xml` file:

   ```
   <webAppSecurity allowFailOverToBasicAuth="true"/>
   ```

   Otherwise, users get a 403 error when they access the server with a username and password.
3. After users are authenticated, all the authenticated users are allowed to use the application by default. If you want to restrict the application to specific users, bind users to the JCICSXUSER security role in `server.xml`:

   ```
   <authorization-roles id="com.ibm.cics.wlp.jcicsxserver">
     <security-role name="JCICSXUSER">
       <user name="USER"/>
     </security-role>
   </authorization-roles>
   ```
4. If you are using transaction attach security, grant the CICS default user ID access to run the CJXA transaction.

**Result**

You now have configured the remote JCICSX server to authenticate users using the SAF registry and to authorize them access to the service using role mapping in Enterprise Java.

## Scenario 3: Set up security in all my CICS regions, granting access to specific people

In this scenario, you configure the JCICSX servers in all CICS regions that run under the default profile prefix to use SAF for authentication and authorization to grant specific user or user groups access. This is because SAF authorization makes it easy to share security settings across multiple CICS regions. When using SAF authorization, user to role mappings are used to map roles to EJBROLE resource profiles using the SAF role mapper. The server queries SAF to determine if the user has the required READ access to the EJBROLE resource profile. It's also convenient in that you can authorize an existing user group to use the JCICSX server by creating an EJBROLE.

**Before you begin**

Ensure that you have set up a Liberty JVM server to serve as the JCICSX server, by adding the JCICSX server feature (`cicsts:jcicsxServer-1.0`) to the `server.xml` file of your Liberty JVM server:

```
<featureManager>
    <feature>cicsts:jcicsxServer-1.0</feature>
</featureManager>
```

For more information, see Java development using JCICSX.

**Procedure**

1. Enable CICS security, which integrates Liberty security, for the JCICSX server and configure it to use the SAF registry. For instructions, see “Configuring security for a Liberty JVM server” on page 277.
2. By default, the server only accepts authentication with a valid certificate. To allow users to be authenticated with a username and password, add the following line to the `server.xml` file:

   ```
   <webAppSecurity allowFailOverToBasicAuth="true"/>
   ```

   Otherwise, users get a 403 error when they access the server with a username and password.
3. Add the`<safAuthorization>` element to `server.xml`, to use SAF authorization for role mapping:

   ```
   <safAuthorization id="saf"/>
   ```

4. Create the EJBROLE in RACF using the following RACF command:

   ```
   RDEFINE EJBROLE BBGZDFLT.com.ibm.cics.wlp.jcicsxserver.JCICSXUSER UACC(NONE)
   ```

   where BBGZDFLT is the default profile prefix, so this security configuration applies to all CICS regions that run under the default profile prefix. The profile prefix can be modified, making it easy for regions with the same profile prefix to share security settings. For more information, see “Authorization using SAF role mapping” on page 290.
5. Grant users READ access to those EJBROLE:

   ```
   PERMIT BBGZDFLT.com.ibm.cics.wlp.jcicsxserver.JCICSXUSER CLASS(EJBROLE) ACCESS(READ)
   ID(<user|group>)
   ```

6. If you are using transaction attach security, grant the CICS default user ID access to run the CJXA transaction.

**Result**

You have configured the remote JCICSX servers in all CICS regions running under the default profile prefix to authenticate users using the SAF registry and to authorize specific users or user groups with access to the services.

## Configuring SSL (TLS) for a Liberty JVM server using a Java keystore

You can configure a Liberty JVM server to use SSL for data encryption, and optionally authenticate with the server by using a client certificate. Certificates can be stored in a Java keystore or in a SAF key ring such as in RACF.

### About this task

Enabling SSL in a Liberty JVM server requires adding the **`transportSecurity-1.0`** Liberty feature, a keystore, and an HTTPS port. CICS automatically creates and updates the `server.xml` file. Autoconfiguring always results in the creation of a Java keystore.

It is important to understand that any web request to a Liberty JVM server uses the JVM support for TCP/IP sockets and SSL processing, not CICS sockets domain.

### Procedure

- To use autoconfigure to configure SSL, complete the following steps:
  a) Ensure autoconfigure is enabled in the JVM profile by using the JVM system property **`-Dcom.ibm.cics.jvmserver.wlp.autoconfigure=true`**.
  b) Set the SSL port by setting the JVM system property **`-Dcom.ibm.cics.jvmserver.wlp.server.https.port`** in the JVM profile.
  c) Restart the JVM server to add the necessary configuration elements to `server.xml`.

### Results

SSL for a Liberty JVM server is successfully configured.

## Configuring SSL (TLS) for a Liberty JVM server using RACF

You can configure a Liberty JVM server to use SSL for data encryption, and optionally authenticate with the server by using a client certificate. Certificates can be stored in a Java keystore or in a SAF key ring such as a RACF keyring.

### About this task

Enabling SSL in a Liberty JVM server requires adding the **`transportSecurity-1.0`** Liberty feature, a keystore, and an HTTPS port. You edit the `server.xml` file to add the required elements and values. You must follow the manual procedure if you want to use a RACF key ring.

It is important to understand that any web request to a Liberty JVM server uses the JVM support for TCP/IP sockets and SSL processing, not CICS sockets domain.

### Procedure

- To manually configure SSL, you need to create a signing certificate. Use this signing certificate to create a server certificate. Then, export the signing certificate to the client web browser where it is used to authenticate the server certificate.
  a) Create a certificate authority (CA) certificate (signing certificate). An example, using RACF commands, follows:

```
RACDCERT GENCERT
  CERTAUTH
  SUBJECTSDN(CN('CICS Sample Certification Authority')
   O('IBM')
   OU('CICS'))
   SIZE(2048)
  WITHLABEL('CICS-Sample-Certification')
```

  The SIZE of the certificate should be a minimum of 2048 bits. For more information, see the RACF RACDCERT GENCERT (Generate certificate) command.

  b) Create a server certificate that uses the signing certificate from step 2, where `<userid>` is the CICS region user ID. The `hostname` is the host name of the server that the Liberty server HTTPS port is configured to use.

```
RACDCERT ID(<userid>)
GENCERT
  SUBJECTSDN(CN('<hostname>')
   O('IBM')
   OU('CICS'))
   SIZE(2048)
   SIGNWITH (CERTAUTH LABEL('CICS-Sample-Certification'))
  WITHLABEL('<userid>-Liberty-Server')
```

  The SIZE of the certificate should be a minimum of 2048 bits. For more information, see the RACF RACDCERT GENCERT (Generate certificate) command.

  c) Connect the signing certificate and server certificate to a RACF key ring.

You can use RACF with the following command, and replace the value of <keyring> with the name of the key ring you want to use. Replace the value of <userid> with the CICS region user ID.

```
RACDCERT ID(<userid>) CONNECT(RING(<keyring>)
       LABEL('CICS-Sample-Certification')
       CERTAUTH)

RACDCERT ID(<userid>) CONNECT(RING(<keyring>)
       LABEL('<userid>-Liberty-Server'))
```

Export the signing certificate to a CER file:

```
RACDCERT CERTAUTH EXPORT(LABEL('CICS-Sample-Certification'))
       DSN('<userid>.CERT.LIBCERT')
       FORMAT(CERTDER)
       PASSWORD('password')
```

FTP the exported certificate in binary to your workstation, and import it into your browser as a certificate authority certificate.

d) Edit the `server.xml` file and add the SSL feature, and the keystore. Set the HTTPS port (value is 9443 in the following example) and restart your CICS region. The SAF key ring must be specified in the URL form `safkeyring://<userid>/<keyring>`.

If you are running Java 11, the location must be `location="safkeyringjce://<userid>/<keyring>"`.

The <userid> value must be set to the CICS region user ID and the <keyring> value must be set to the name of the key ring. The password field is not used for accessing the SAF key ring and must be set to `password`.

```
<featureManager>
  ...
       <feature>transportSecurity-1.0</feature>
</featureManager>
...
<httpEndpoint host="*" httpPort="9080" httpsPort="9443"
    id="defaultHttpEndpoint"/>
...
.
<keyStore filebased="false" id="racfKeyStore"
        location="safkeyring://<userid>/<keyring>"
        password="password"
        readOnly="true"
        type="JCERACFKS"/>
<ssl id="defaultSSLConfig" keyStoreRef="racfKeyStore"
      sslProtocol="SSL_TLS"
      serverKeyAlias="<userid>-Liberty-Server" />
```

### Results

SSL for a Liberty JVM server is successfully configured.

## Configuring SSL (TLS) for remote JCICSX API development

When configuring a Liberty JVM server in CICS for remote JCICSX API development, you can configure it to use SSL for data encryption.

### About this task

To enable the remote development functionality of the JCICSX API, a Liberty JVM server is required in CICS to receive requests from the developer's local Liberty JVM server. To enable SSL communication between the remote Liberty JVM server in CICS and the local Liberty JVM server on the developer's machine, the remote server must be configured to use SSL and its certificate must be trusted by the local Liberty server.

## Before you begin

- Configure the remote Liberty JVM server for user authentication and authorization. For instructions, see "Configuring security for remote JCICSX API development" on page 299
- Enable SSL in the Liberty JVM server in CICS. For instructions, see "Configuring SSL (TLS) for a Liberty JVM server using a Java keystore" on page 304.
- Ensure that a local Liberty JVM server is configured to make remote JCICSX requests. This is usually done by the application developer on their local machine. For instructions, see **Extra configuration for remote development (local workstation)** in Java development using JCICSX.

## Procedure

- **For system programmers, configure the remote Liberty JVM server as follows:**

  As a system programmer, you need to generate a certificate for the remote Liberty JVM server with its host name registered.

  a) **Register the host name of the remote server in the `server.xml` file.**

     By default the host name of the Liberty server is `localhost`. In this case your SSL connection will fail because the certificate will be registered to `localhost` while your client will be trying to connect to the host name of your CICS region. To override the default `localhost` host name, add the `defaultHostName` variable to your `server.xml` file:

     ```
     <variable name="defaultHostName" value="your-hostname"/>
     ```

     where *your-hostname* is the host name of the remote Liberty JVM server. For more information, see Setting the default host name of a Liberty server.

  b) **Generate a new copy of the remote Liberty JVM server's public certificate.**

     After setting the default host name of your server, you must regenerate the certificate for it.

     a. Stop the Liberty JVM server.
     b. Delete the Java keystore that stores the certificates. It is the `key.p12` file located in `{server.config.dir}/resources/security`.
     c. Start the liberty server.
     d. Verify that a new `key.p12` file is regenerated.

  c) **Verify that the host name is correct in the certificate using OpenSSL or the Java keytool utility:**

     – If you're using OpenSSL, input this command to show the certificates of the remote Liberty JVM server:

     ```
     $ openssl s_client -showcerts -connect remotejcicsxserver.com:portNo
     ```

     – If you're using the Java keytool utility:

       a. Navigate to the folder of the keystore on the remote Liberty server at: `{server.config.dir}/resources/security`.
       b. If the local Liberty server is at 19.0.0.3 or later, which is the minimum version required to use the client-side tooling of remote JCICSX development, and that autoconfigure is enabled for the remote Liberty server to use SSL, the remote Liberty server will have created a keystore using default values. In this case, use this command to show the certificates stored in the auto-created Java keystore:

          ```
          keytool -list -keystore key.p12 -storepass defaultPassword -storetype PKCS12 -v
          ```

          Otherwise, substitute values in for `storepass` and `storetype` according to your custom configuration.
       c. In the output, verify that `CN = your-hostname` shows the host name of the remote JVM server, instead of the default `localhost` value. Otherwise, repeat Step "2" on page 307.

- **For application developers, configure the local Liberty JVM server to trust the remote server's public certificate as follows:**

  By default, the local Liberty JVM server might refuse to connect to the remote Liberty JVM server because it does not trust the public certificate that the remote Liberty provides during the SSL handshake. Therefore, the application developer must download a copy of the certificate from the remote Liberty server and add it to the truststore used by the local Liberty server.

  a) Download a copy of the public certificate from the remote Liberty JVM server:

     **To use OpenSSL:**

     a. Run the following command to show the certificates of the remote server, where *your-hostname* and *your-port* are the host name and port number of your remote Liberty JVM server:

        ```
        openssl s_client -showcerts -connect your-hostname:your-port
        ```

     b. From the output, copy the first certificate. Include the following lines and the information between these lines:

        ```
        "-----BEGIN CERTIFICATE-----"
        "-----END CERTIFICATE-----"
        ```

     c. Paste the certificate into a new file with a `.cer` extension, for example, `publicKey.cer`.

        **Note:** Note: Be sure not to include additional lines in this file; otherwise the certificate won't be added to you local Liberty truststore successfully.

     **If you have access to the remote Liberty server, you can also use the Java keytool utility to download the certificate:**

     a. Navigate to the keystore on your remote Liberty JVM server. The file path is `{server.config.dir}/resources/security/key.p12`.

     b. Use the Java keytool utility to create a public certificate:

        ```
        keytool -rfc -export -keystore key.p12 -alias default -file /your/save/location/
        public-remote.cer -v -storepass yourKeyStorePassword -storeType yourType
        ```

        where *yourType* is the keystore type, which defaults to PKCS12. For more information, see Liberty default keystore type changed to PKCS12.

  b) Navigate to the folder of the keystore on the local Liberty JVM server: `{server.config.dir}/resources/security`.

  c) Import the public certificate that the system programmer downloaded into the truststore of the local Liberty, using the following command:

     ```
     keytool -importcert -file /cert/location/public-remote.cer -keystore key.p12 -storepass
     localPassword -storetype yourType -trustcacerts -v
     ```

     where *yourType* is the keystore type, which defaults to PKCS12. For more information, see Liberty default keystore type changed to PKCS12.

  d) Restart the local Liberty JVM server to pick up the new certificate.

## What to do next

The application developer can add a JCICSX resource to the local Liberty JVM server to check whether the connection is working. Samples can be found at JCICSX samples in GitHub.

## Setting up SSL (TLS) client certificate authentication in a Liberty JVM server

SSL client certificate authentication allows the client and server to provide certificates to the opposite party for mutual verification. It is often used in situations where an extra level of authentication is required because of security concerns.

### Before you begin

You must complete the task Configuring SSL (TLS) for a Liberty JVM server using RACF. If you do not already have your CICS Liberty security set up, you must complete Configuring security for a Liberty JVM server before proceeding.

### About this task

The following setup information assumes that you are using RACF keystores to store your certificates for SSL client certificate authentication.

### Procedure

1. Create a personal certificate using a signing certificate and associate the personal certificate with a RACF user ID.

   Then, export the personal certificate to a data set in CER format and then FTP in binary to your work station. Import the personal certificate to the web browser as a personal certificate. When the certificate is imported into the web browser, it can supply an SSL client certificate and connect to the HTTPS port in the Liberty server. Use the following RACF command, where `<clientuserid>` is the RACF user ID and `<hostname>` is the host name of the client computer.

   ```
   RACDCERT ID(<clientuserid>)
   GENCERT
     SUBJECTSDN(CN('<hostname>')
      O('IBM')
      OU('CICS'))
      SIZE(2048)
      SIGNWITH (CERTAUTH LABEL('CICS-Sample-Certification'))
     WITHLABEL('<clientuserid>-certificate')
   ```

   Export the personal certificate as you have done earlier in this step.

   ```
   RACDCERT ID(<clientuserid>)
     EXPORT(LABEL('<clientuserid>-certificate'))
      DSN('USERID.CERT.CLICERT')
      FORMAT(PKCS12DER)
      PASSWORD('password')
   ```

   Update the `server.xml` SSL element to support SSL client certificate authentication:

   ```
     <ssl id="defaultSSLConfig" keyStoreRef="racfKeyStore"
        sslProtocol="SSL_TLS"
        serverKeyAlias="<userid>-Liberty-Server"
        clientAuthenticationSupported="true"/>
   ```

   Additionally, if you want to ensure all clients must supply a valid SSL client certificate, add the **`clientAuthentication`** attribute to the SSL element as follows:

   ```
     <ssl id="defaultSSLConfig" keyStoreRef="racfKeyStore"
        sslProtocol="SSL_TLS"
        serverKeyAlias="<userid>-Liberty-Server"
        clientAuthenticationSupported="true"
        clientAuthentication="true"/>
   ```

2. You can authenticate a web request in CICS under the identity of the client user ID in step 2. Then, deploy the web application with a `login-config` element for CLIENT-CERT in the `web.xml`. The `web.xml` file can be found inside the source files for the web application that you are deploying.

```
<login-config>
        <auth-method>CLIENT-CERT</auth-method>
</login-config
```

Instead, if you want to allow failover to HTTP basic authentication if SSL client certificate authentication is not configured, add the webAppSecurity element to `server.xml`.

```
<webAppSecurity allowFailOverToBasicAuth="true" />
```

3. Finally, set up CICS transaction security to authorize access to the CICS transaction based on the authenticated client user ID.

   For further information, see "Authorizing users to run applications in a Liberty JVM server" on page 286.

## Using the syncToOSThread function

You can use the syncToOSThread function of Liberty in a CICS Liberty JVM server. SyncToOSThread enables a Java subject, authenticated by Liberty, to be synchronized with the operating system (OS) thread identity. Without syncToOSThread, the operating system thread identity defaults to be the CICS region user ID, this is the identity used to authorize access to resources outside of CICS control such as zFS files. With syncToOSThread in effect, the user's subject is used to access these operating system resources.

### About this task

Enabling syncToOSThread requires the Liberty appSecurity-1.0 and zosSecurity-1.0 features. These features are included with the cicsts:security-1.0 feature. You must also define the syncToOSThread configuration element in the Liberty `server.xml` and add a special `<env-entry/>` to the application's deployment descriptor (`web.xml`). In addition, the SAF registry must be used for authentication, the angel process must be up and running, and the server must be connected to the angel process. For more information about the angel process, see Process types on z/OS.

### Procedure

1. Configure the syncToOSThread configuration element in the Liberty `server.xml` and add the required `<env-entry/>` to each web application's deployment descriptor by following steps 1 and 2 in Enabling syncToOSThread for applications
2. Grant the Liberty server permission to perform syncToOSThread operations by configuring SAF with either of the following profiles:

   - Grant the CICS region user ID CONTROL access to the `BBG.SYNC.<`*`profilePrefix`*`>` profile in the FACILITY class, where *`<profilePrefix>`* is specified on the `<safCredentials />` element. This allows the Liberty server to synchronize any Java subject with the OS thread identity:

     ```
     PERMIT BBG.SYNC.<profilePrefix> ID(<serverUserId>) ACCESS(CONTROL) CLASS(FACILITY)
     ```

   - Grant the CICS region user ID READ access to the `BBG.SYNC.<`*`profilePrefix`*`>` profile in the FACILITY class. Additionally, grant the CICS region user ID READ access to one or more `BBG.SYNC.<`*`AuthUserid/`*`>` profiles in the SURROGATE class, one for each authenticated user ID to be synchronized with the OS identity:

     ```
     PERMIT BBG.SYNC.<profilePrefix> ID(<serverUserId>) ACCESS(READ) CLASS(FACILITY)
     PERMIT BBG.SYNC.<AuthUserid> ID(<serverUserId>) ACCESS(READ) CLASS(SURROGAT)
     ```

   **Restriction:** A servlet configured as the welcome page in `web.xml`, does not support the syncToOSThread function.

# Enabling a Java security manager

By default, Java applications have no security restrictions placed on activities requested of the Java API. To use Java security to protect a Java application from performing potentially unsafe actions, you can enable a security manager for the JVM in which the application runs.

## About this task

The security manager enforces a security policy, which is a set of permissions (system access privileges) that are assigned to code sources. A default policy file is supplied with the Java platform. However, to enable Java applications to run successfully in CICS when Java security is active, you must specify an additional policy file that gives CICS the permissions it requires to run the application.

You must specify this additional policy file for each kind of JVM that has a security manager enabled. CICS provides some examples that you can use to create your own policies.

**Notes:** Enabling a Java security manager is not supported in a Liberty JVM server.

- The OSGi security agent example creates an OSGi middleware bundle called `com.ibm.cics.server.examples.security` in your project that contains a security profile. This profile applies to all OSGi bundles in the framework in which it is installed.
- The `example.permissions` file contains permissions that are specific to running applications in a JVM server, including a check to ensure that applications do not use the `System.exit()` method.
- CICS must have read and execute access to the directory in zFS where you deploy the OSGi bundle.

For applications that run in the OSGi framework of a JVM server:

## Procedure

1. Create a plug-in project in the IBM CICS SDK for Java and select the supplied OSGi security agent example.
2. In the project, select the `example.permissions` file to edit the permissions for your security policy.
   a) Validate that the CICS zFS and Db2 installation directories are correctly specified.
   b) Add other permissions as necessary.
3. Deploy the OSGi bundle to a suitable directory in zFS such as `/u/bundles`.
4. Edit the JVM profile for the JVM server to add the OSGi bundle to the `OSGI_BUNDLES` option before any other bundles:

   ```
   OSGI_BUNDLES=/u/bundles/com.ibm.cics.server.examples.security_1.0.0.jar
   ```
5. Add the following Java property to the JVM profile to enable security.

   ```
   -Djava.security.policy=all.policy
   ```
6. Add the following Java environment variable to the JVM profile to enable security in the OSGi framework:

   ```
   org.osgi.framework.security=osgi
   ```
7. To allow the OSGi framework to start with Java 2 security, add the following policy:

   ```
   grant { permission java.security.AllPermission; };
   ```
8. Save your changes and enable the JVMSERVER resource to install the middleware bundle in the JVM server.
9. Optional: Activate Java 2 security.
   a) To activate a Java 2 security policy mechanism, add it to the appropriate JVM profile. You must also edit your Java 2 security policy to grant appropriate permissions.
   b) To use JDBC or SQLJ from a Java application with a Java 2 security policy mechanism active, use the IBM Data Server Driver for JDBC and SQLJ.
   c) To activate a Java 2 security policy mechanism, edit the JVM profile.

d) Edit the Java 2 security policy to grant permissions to the JDBC driver, by adding the lines that are shown in Example 1. In place of db2*xxx*, specify a directory below which all your Db2 libraries are located. The permissions are applied to all the directories and files below this level. This enables you to use JDBC and SQLJ.

e) Edit the Java 2 security policy to grant read permissions, by adding the lines that are shown in Example 2. If you do not add read permission, running a Java program produces AccessControlExceptions and unpredictable results. You can use JDBC and SQLJ with a Java 2 security policy.

**Example 1:**

```
grant codeBase "file:/usr/lpp/db2xxx/-" {
  permission java.security.AllPermission;
};
```

**Example 2:**

```
grant {

// allows anyone to read properties
permission java.util.PropertyPermission "*", "read";

};
```

## Results

When the Java application is called, the JVM determines the code source for the class and consults the security policy before granting the class the appropriate permissions.

# Chapter 11. Improving Java performance

You can take various actions to improve the performance of Java applications and the JVMs in which they run.

### About this task

In addition to fine-tuning CICS itself, you can further improve the performance of Java applications in the following ways:

- Ensuring that the Java applications are well written
- Tuning the Java Runtime Environment (JVM)
- Tuning the language in which the JVM runs

### Procedure

1. Determine the performance goals for your Java workload.

   Some of the most common goals include minimizing processor usage or application response times. After you decide on the goal, you can tune the Java environment.
2. Analyze your Java applications to ensure that they are running efficiently and do not generate too much garbage.

   IBM has tools that can help you to analyze Java applications to improve the efficiency and performance of particular methods and the application as a whole.
3. Tune the JVM server.

   You can use statistics and IBM tools to analyze the storage settings, garbage collection, task waits, and other information to tune the performance of the JVM.
4. Tune the Language Environment enclave in which a JVM runs.

   JVMs use MVS storage, obtained by calls to MVS Language Environment services. You can modify the runtime options for Language Environment to tune the storage that is allocated by MVS.
5. Optional: If you use the z/OS shared library region to share DLLs between JVMs in different CICS regions, you can tune the storage settings.

## Determining performance goals for your Java workload

Tuning CICS JVMs to achieve the best overall performance for a given application workload involves several different factors. You must decide what the preferred performance characteristics of your Java workload are. When you establish these characteristics, you can determine what parameters to change and how to change them.

The following performance goals for Java workloads are most common:

**Minimum overall processor usage**

This goal prioritizes the most efficient use of the available processor resource. If a workload is tuned to achieve this goal, the total use of the processor across the entire workload is minimized, but individual tasks might experience high processor consumption. Tuning for the minimum overall processor usage involves specifying large storage heap sizes for your JVMs to minimize the number of garbage collections.

**Minimum application response times**

This goal prioritizes ensuring that an application task returns to the caller as rapidly as possible. This goal might be especially relevant if there are Service Level Agreements to be achieved. If a workload is tuned to achieve this goal, applications respond consistently and quickly, though a higher processor usage might occur for garbage collections. Tuning for minimum application response times involves keeping the heap size small and possibly using the gencon garbage collection policy.

**Minimum JVM storage heap size**

This goal prioritizes reducing the amount of storage used by JVMs. You can reduce the amount of storage that is used in the JVM, by reducing the JVM heap size.

**Note:** Reducing the JVM heap size might result in more frequent garbage collection events.

Other factors can affect the response times of your applications. The most significant of these is the Just In Time (JIT) compiler. The JIT compiler optimizes your application code dynamically at run time and provides many benefits, but it requires a certain amount of processor resource to do this.

# Analyzing Java applications using IBM Health Center

To improve the performance of a Java application, you can use IBM Health Center to analyze the application. This tool provides recommendations to help you improve the performance and efficiency of your application.

## About this task

IBM Health Center is available in the IBM Support Assistant Workbench. These free tools are available to download from IBM as described in the Getting Started guide for IBM Health Center. Try to run the application in a JVM on its own. If you are running a mixed workload in a JVM server, it might be more difficult to analyze a particular application.

## Procedure

1. Add the required connection options to the JVM profile of the JVM server.

   The IBM Health Center documentation describes what options you must add to connect to the JVM from the tool.
2. Start IBM Health Center and connect it to your running JVM.

   IBM Health Center reports JVM activity in real time so wait a few moments for it to monitor the JVM.
3. Select the **Profiling** link to profile the application.

   You can check the time spent in different methods. Check the methods with the highest usage to look for any potential problems.

   **Tip:** The **Analysis and Recommendations** tab can identify particular methods that might be good candidates for optimization.
4. Select the **Locking** link to check for locking contentions in the application.

   If the Java workload is unable to use all the available processor, locking might be the cause. Locking in the application can reduce the amount of parallel threads that can run.
5. Select the **Garbage Collection** link to check the heap usage and garbage collection.

   The **Garbage Collection** tab can tell you how much heap is being used and how often the JVM pauses to perform garbage collection.

   a) Check the proportion of time spent in garbage collection.

      This information is presented in the Summary section. If the time spent in garbage collection is more than 2%, you might need to adjust your garbage collection.

   b) Check the pause time for garbage collection.

      If the pause time is more than 10 milliseconds, the garbage collection might be having an effect on application response times.

   c) Divide the rate of garbage collection by the number of transactions to find out approximately how much garbage is produced by each transaction.

      If the amount of garbage seems high for the application, you might have to investigate the application further.

## What to do next

After you have analyzed the application, you can tune the Java environment for your Java workloads.

# Garbage collection and heap expansion

Garbage collection and heap expansion are an essential part of the operation of a JVM. The frequency of garbage collection in a JVM is affected by the amount of garbage, or objects, created by the applications that run in the JVM.

## Allocation failures

When a JVM runs out of space in the storage heap and is unable to allocate any more objects (an allocation failure), a garbage collection is triggered. The Garbage Collector cleans up objects in the storage heap that are no longer being referenced by applications and frees some of the space. Garbage collection stops all other processes from running in the JVM for the duration of the garbage collection cycle, so time spent on garbage collection is time that is not being used to run applications. For a detailed explanation of the JVM garbage collection process, see Generational Concurrent Garbage Collector.

When a garbage collection is triggered by an allocation failure, but the garbage collection does not free enough space, the Garbage Collector expands the storage heap. During heap expansion, the Garbage Collector takes storage from the maximum amount of storage reserved for the heap (the amount specified by the `-Xmx` option), and adds it to the active part of the heap (which began as the size specified by the `-Xms` option). Heap expansion does not increase the amount of storage required for the JVM, because the maximum amount of storage specified by the `-Xmx` option has already been allocated to the JVM at startup. If the value of the `-Xms` option provides sufficient storage in the active part of the heap for your applications, the Garbage Collector does not have to carry out heap expansion at all.

At some point during the lifetime of the JVM, the Garbage Collector stops expanding the storage heap, because the heap has reached a state where the Garbage Collector is satisfied with the frequency of garbage collection and the amount of space freed by the process. The Garbage Collector does not aim to eliminate allocation failures, so some garbage collection can still be triggered by allocation failures after the Garbage Collector has stopped expanding the storage heap. Depending on your performance goals, you might consider this frequency of garbage collection to be excessive.

## Garbage collection options

You can use different policies for garbage collection that make trade-offs between throughput of the application and the overall system, and the pause times that are caused by garbage collection. Garbage collection is controlled by the `-Xgcpolicy` option:

**`-Xgcpolicy:optthruput`**
This policy delivers high throughput to applications but at the cost of occasional pauses, when garbage collection occurs.

**`-Xgcpolicy:gencon`**
This policy helps to minimize the time that is spent in any garbage collection pause. Use this garbage collection policy with JVM servers. You can check which policy is being used by the JVM server by inquiring on the JVMSERVER resource. The JVM server statistics have fields that tell you how many major and minor garbage collection events occur and what processor time is spent on garbage collection.

When you use this policy, it is also worth considering the `-Xgc:concurrentScavenge` setting - which is not a default setting - if your system has a large heap and is response-time sensitive. In these situations it can help to reduce garbage collection pause times. For more information, see -Xgc:concurrentScavenge.

**`-XX:+HeapManagementMXBeanCompatibility`**
This policy is set by default if you are using Java 8 SR5 and above. The policy ensures consistent garbage collection statistics with previous levels of Java. For more information, see -XX:[+|-]HeapManagementMXBeanCompatibility.

**`-XX:-HeapManagementMXBeanCompatibility`**
You can choose to opt in to using this policy. The policy enables the default heap changes in Java 8 SR5 and above, however in some cases, the garbage collection statistics might indicate

the heap usage to be greater than the maximum heap size. For more information, see -XX:[+|-]HeapManagementMXBeanCompatibility.

You can change the garbage collection policy by updating the JVM profile. For details of all the garbage collection options, see Specifying garbage collection policy in IBM SDK.

# Improving JVM server performance

To improve the performance of applications that run in a JVM server, you can tune different parts of the environment, including the garbage collection and the size of the heap.

## About this task

CICS provides statistics reports on the JVM server, which include details of how long tasks wait for threads, heap sizes, frequency of garbage collection, and processor usage. You can also use additional IBM tools that monitor and analyze the JVM directly to tune JVM servers and help with problem diagnosis. You can use the statistics to check that the JVM is performing efficiently, particularly that the heap sizes are appropriate and garbage collection is optimized.

## Procedure

1. Check the amount of processor time that is used by the JVM server.

   Dispatcher statistics can tell you how much processor time the T8 TCBs are using. JVM server statistics tell you how long the JVM is spending in garbage collection and how many garbage collections occurred. Application response times and processor usage can be adversely affected by the JVM garbage collection.
2. Ensure that there is enough available storage capacity in the CICS address space. The CICS address space contains the Language Environment heap size that is required by the JVM server.
3. Tune the garbage collection and heap in the JVM.

   A small heap can lead to very frequent garbage collections, but too large a heap can lead to inefficient use of MVS storage. You can use IBM Health Center to visualize and tune garbage collection and adjust the heap accordingly.

## What to do next

For more detailed analysis of memory usage and heap sizes, you can use the Memory Analyzer tool in IBM Support Assistant to analyze Java heap memory using system dump or heap dump snapshots of a Java process.

To start one or more JVM servers in a CICS region, you must ensure that enough storage capacity is available for the JVM to use, excluding any storage capacity that is allocated to CICS.

# Examining processor usage by JVM servers

You can use the CICS monitoring facility to monitor the processor time that is used by transactions running in a JVM server. CICS-enabled threads in a JVM server run on T8 TCBs.

## About this task

You can use the DFH$MOLS utility to print the SMF records or use a tool such as CICS Performance Analyzer to analyze the SMF records.

## Procedure

1. Turn on monitoring in the CICS region to collect the performance class of monitoring data.
2. Check the performance data group DFHTASK.

   In particular, you can look at the following fields:

| Field ID | Field name | Description |
|---|---|---|
| 283 | MAXTTDLY | The elapsed time for which the user task waited to obtain a T8 TCB, because the CICS region reached the limit of available threads. The thread limit is 2000 for each CICS region and each JVM server can have up to 256 threads. |
| 400 | T8CPUT | The processor time during which the user task was dispatched by the CICS dispatcher domain on a CICS T8 mode TCB. When a thread is allocated a T8 TCB, that same TCB remains associated with the thread until the processing completes. |
| 401 | JVMTHDWT | The elapsed time that the user task waited to obtain a JVM server thread because the CICS system had reached the thread limit for a JVM server in the CICS region. This does not apply to Liberty JVM servers. |

3. To improve processor usage, reduce or eliminate the use of tracing where possible.

   a) In a production environment, consider running your CICS region with the CICS main system trace flag set off.

      Having this flag on significantly increases the processor cost of running a Java program. You can set the flag off by initializing CICS with SYSTR=OFF, or by using the CETR transaction.

   b) Ensure that you activate JVM trace only for special transactions.

      JVM tracing can produce large amounts of output in a very short time, and increases the processor cost. For more information about controlling JVM tracing, see Diagnostics for Java.

4. Do not use the `USEROUTPUTCLASS` option in JVM profiles in a production environment.

   Specifying this option has a negative effect on the performance of JVMs. The `USEROUTPUTCLASS` option enables developers using the same CICS region to separate JVM output, and direct it to a suitable destination, but it involves the building and invocation of additional class instances.

## Calculating storage requirements for JVM servers

To run a JVM server successfully in a CICS region, you must ensure that enough free MVS storage is available for both the JVM and its deployed applications to use.

### About this task

The storage that is required for a JVM server, and the Java applications in it, does not come from CICS-managed storage areas such as the DSA, EDSA, or GDSA. Some storage areas are managed by the Language Environment handling requests, such as **`malloc()`** issued by C code. The remaining storage areas are managed directly by the JVM, by using z/OS storage management requests such as **`IARV64`**. Both of these storage area management types use storage from the available MVS private areas. It is important to ensure that sufficient non-allocated private area region storage is available in the 24-bit, 31-bit, and 64-bit addressing areas. CICS cannot use its short-on-storage mechanism when private area region storage is running low.

The major Java components that allocate MVS storage areas are as follows:

- Java heap
- Loading of Java classes
- JIT compilation caches
- Native stack
- Java monitors
- Java threads
- UNIX shared libraries

The Java heap is a contiguous pre-allocated block of 64-bit storage that is used to store the runtime data area for all objects and arrays. It is managed by the JVM garbage collection process, and its size can only be modified if the JVM is restarted. The other JVM storage areas are more dynamic in size and their size can vary depending on usage. In addition, on top of the storage areas that are allocated by the JVM, you must also consider other components that use MVS private area and interact with the JVM such as JDBC type 2 drivers, IBM MQ Java adapter, or third-party tools.

To estimate the amount of storage used by the JVM in the different MVS private storage areas, you can use the following procedure:

## Procedure

1. Calculate your 24-bit storage.

   Each JVM thread requires 4 KB of 24-bit storage. A single JVM server can start more than 50 background daemon threads; this number does not include the number of CICS-managed JVM server threads defined by the JVMSERVER THREADLIMIT attribute. If you are using a Liberty JVM server, the number of daemon threads can be 100 or greater.

   UNIX System Services temporarily requires 256 KB of contiguous 24-bit storage during the process of creating a new thread. The minimum 24-bit requirement is calculated as follows:

   ```
   256KB + (4KB * number_of_threads)
   ```

2. Calculate your 31-bit storage.

   Multiple JVM components can allocate storage from the 31-bit MVS private area that includes loading of Java classes, CICS control blocks, Java thread stack, the JIT compiler, and the USS dynamic link library (DLL) files used by the JVM.

   a) Java class loading

   By default, CICS JVM servers with -Xmx (heap) values of 57GB or less use Java compressed references. Compressed references instruct the JVM to create smaller objects, and having smaller objects can improve performance. Using compressed references causes the Java objects, classes, threads, and monitors to be loaded into the LE HEAP31 storage area in 31-bit storage. If you have insufficient space in 31-bit storage, class loading fails, causing termination of the JVM. Setting the JVM command line option `–Xnocompressedrefs` disables the use of compressed references and instead loads the Java classes into 64-bit storage.

   b) JIT Compiler

   The JIT compiler is responsible for continuous optimization, by compiling Java byte code. Executable code is stored in the JIT code cache, and static data is stored in the JIT data cache. Prior to z/OS, Version 2 Release 3 and Java 8 SR5 the code cache is stored in 31-bit storage, whereas the data cache is stored in 64-bit storage. Depending on the number of Java applications, and the amount of JIT activity, the 31-bit JIT code cache can expand dynamically to a maximum size determined by the JVM setting `-Xcodecachetotal`. This defaults to 128 MB. If the cache becomes full, the JIT process stops but the JVM continues to operate with reduced potential performance. If you are using z/OS, Version 2 Release 3, you can free up more space in the 31-bit private area by upgrading to Java 8 SR5, which supports residency mode for 64-bit applications (RMODE64) for the JIT code cache. This stores the compiled JIT code in the 64-bit private area.

   c) UNIX shared libraries

   The shared library region is a z/OS® feature that enables address spaces to improve the performance of the loading of UNIX System Services dynamic link library (DLL) files, and to share the associated real storage. The shared library function is disabled by default in CICS JVM servers, but is supported by the IBM Java SDK. When the first JVM process that uses shared libraries is started in the region, the shared library region reserves storage in the 31-bit high private area. For more information, see Tuning the z/OS shared library region.

   **Note:**

As an approximate guideline if using Java 8 SR5 and a single application, the first JVM server to start within a CICS region can allocate anywhere between 51M to 115M of 31-bit MVS private area depending on configuration and workload.

The subsequent JVM servers have a lower footprint and can allocate anywhere between 8M and 73M, as the JVM DLL files need to only be loaded once.

These figures do not include the UNIX shared library region, the value of which must also be added to the 31-bit storage if enabled.

3. Calculate your 64-bit storage.

   Multiple JVM components can allocate storage from the 64-bit MVS private area that includes the Java heap, native thread stack, Java classes, JIT compiler output, and Java monitors. The amount of 64-bit storage that is required can be estimated as a minimum of 2 GB, with additional storage required for larger workloads or more complex configurations.

   To more accurately estimate 64-bit storage, you need to consider:

   - The maximum Java heap value, set by using `-Xmx`
   - The maximum number of all threads in the JVM. Each thread requires a minimum of 3 MB of Language Environment stack storage, including 1 MB of stack. This accounts for the minimum 1 MB native stack storage, 1 MB of reserve storage and the 1 MB Language Environment control block that is required to support each thread. See Identifying Language Environment storage needs for JVM servers
   - Storage for the Java classes, JIT caches, and Language Environment 64-bit heaps. You can add a best guess of 300 MB - 500 MB depending on workload and configuration

   **Note:**

   The Java shared class cache uses UNIX shared memory which does not count towards the CICS region's address space MEMLIMIT.

   The resulting figure needs to be rounded up to the next GB to account for the way that CICS GDSA expansion views guarded storage.

4. Run the sample statistics program DFH0STAT to provide values used to estimate MVS storage.

   View the MVS user region and extended user region storage report for information about the use of 24-bit and 31-bit MVS storage.

   View the Storage above 2 GB report for information about the use of 64-bit MVS storage.

   - Note the values for **1** `Current Unallocated Total`, which indicate the current amount of unallocated 24-bit (user region) and 31-bit (extended user region) storage.
   - Note the value for **2** `MEMLIMIT minus Current Address Space active`, which indicates the current amount of 64-bit storage available to the CICS region.

```
MVS User Region and Extended User Region
_________________________________________________________
                                                    User Region               Extended User
Region

______________________________________________________
  Last Monitor Sample Time . . . . . . . . . . . :  03/11/2022  16:22:13      03/11/2022
16:22:13
  State. . . . . . . . . . . . . . . . . . . . . :                Normal
Normal
  Current Unallocated Total. . . . . . . . . . . :                5,956K
392,956K         1
  LWM Unallocated Total. . . . . . . . . . . . . :                5,956K
392,956K
  Current Unallocated Largest Contiguous Area. . :                5,956K
392,168K
  LWM Unallocated Largest Contiguous Area. . . . :                5,956K
392,168K
  Last date and time SOS . . . . . . . . . . . . :
  Current Tasks Waiting Because SOS. . . . . . . :
0                         0
  Peak Tasks Waiting Because SOS . . . . . . . . :
0                         0
  Total Waits Because SOS. . . . . . . . . . . . :
0                         0
  Time Tasks Waited Because SOS. . . . . . . . . :        00:00:00.00000
00:00:00.00000
```

```
Storage ABOVE 2GB
_________________________
  MEMLIMIT Size. . . . . . . . . . . . . :               15,360M
  MEMLIMIT Set By. . . . . . . . . . . . :                  JCL

  Current Address Space active (bytes) :      1,143,996,416
  Current Address Space active . . . . :             1,091M
  Peak Address Space active. . . . . . :             1,091M

  MEMLIMIT minus Current Address Space active. . . . . . . :           14,269M    2
  MEMLIMIT minus allocated to Private Memory Objects . . . :           13,144M
  MEMLIMIT minus bytes usable within Private Memory Objects:           14,269M
  Number of Private Memory Objects . . . . . . . . . . . . :                33
    ....minus Current GDSA extents . . . . . . . . . . . . :                32
  Bytes allocated to Private Memory Objects. . . . . . . . :            2,216M  =
2,323,644,416
    ....minus Current GDSA allocated . . . . . . . . . . . :            1,192M  =
1,249,902,592
  Bytes hidden within Private Memory Objects . . . . . . . :            1,125M  =
1,179,648,000
    ....minus Current GDSA hidden. . . . . . . . . . . . . :            1,124M  =
1,178,599,424
      ....minus CICS Internal Trace Table hidden . . . . . :              130M
  Bytes usable within Private Memory Objects . . . . . . . :            1,091M  =
1,143,996,416
  Peak bytes usable within Private Memory Objects  . . . . :            1,806M  =
1,893,728,256
  Current GDSA Allocated . . . . . . . . . . . . . . . . . :            1,024M  =
1,073,741,824
  Peak GDSA Allocated. . . . . . . . . . . . . . . . . . . :            1,024M
```

5. Start the JVM server and run a representative Java workload.

   Observe how the values for each private storage area available change, and make sure that the private storage areas are not constrained.

## What to do next

Set your Java memory limits based on the estimate you got. For instructions, see Setting the memory limits for Java.

# Tuning JVM server heap and garbage collection

Garbage collection in a JVM server is handled by the JVM automatically. You can tune the garbage collection process and heap size to ensure that application response times and processor usage are optimal.

## About this task

The garbage collection process affects application response times and processor usage. Garbage collection temporarily stops all work in the JVM and can therefore affect application response times. If you set a small heap size, you can save on memory, but it can lead to more frequent garbage collections and more processor time spent in garbage collection. If you set a heap size that is too large, the JVM makes inefficient use of MVS storage and this can potentially lead to data cache misses and even paging. CICS provides statistics that you can use to analyze the JVM server. You can also use IBM Health Center, which provides the advantage of analyzing the data for you and recommending tuning options.

## Procedure

1. Collect JVM server and dispatcher statistics over an appropriate interval. The JVM server statistics can tell you how many major and minor garbage collections take place and the amount of time that elapsed performing garbage collection. The dispatcher statistics can tell you about processor usage for T8 TCBs across the CICS region.
2. Use the dispatcher TCB mode statistics for T8 TCBs to find out how much processor time is spent on JVM server threads.

   The "Accum CPU Time / TCB" field shows the accumulated processor time taken for all the TCBs that are, or have been, attached in this TCB mode. The "TCB attaches" field shows the number of T8 TCBs that have been used in the statistics interval. Use these numbers to work out approximately how much processor time each T8 TCB has used.
3. Use the JVM server statistics to find the percentage of time that is spent in garbage collection.

   Divide the time of the statistics interval by how much elapsed time is spent in garbage collection. Aim for less than 2% of processor usage in garbage collection. If the percentage is higher, you can increase the size of the heap so that garbage collection occurs less frequently.
4. Divide the heap freed value by the number of transactions that have run in the interval to find out how much garbage per transaction is being collected.

   You can find out how many transactions have run by looking at the dispatcher statistics for T8 TCBs. Each thread in a JVM server uses a T8 TCB.
5. Optional: Write the verbosegc log data to a file, which can be done with the parameter **`-Xverbosegclog:`***path_to_file*. This data can be analyzed by another ISA tool - Garbage Collection and Memory Visualizer.

   The JVM writes garbage collection messages in XML to the file that is specified in the STDERR option in the JVM profile. For examples and explanations of the messages, see Troubleshooting and support.

   **Tip:** You can use the file in the Memory Analyzer tool to perform more detailed analysis.

## Results

The outcome of your tuning can vary depending on your Java workload, the maintenance level of CICS and of the IBM SDK for z/OS, and other factors. For more detailed information about the storage and garbage collection settings and the tuning possibilities for JVMs, see Troubleshooting and support.

IBM Health Center and Memory Analyzer are two IBM monitoring and diagnostic tools for Java that are supplied by the IBM Support Assistant workbench. You can download these tools free of charge from the IBM Support Assistant web site.

## Tuning the JVM server startup environment

If you are running multiple JVM servers, you can improve performance by tuning the JVM startup environment.

### About this task

When a JVM server starts, the server has to load a set of libraries in the `/usr/lpp/cicsts/cicsts56/lib` directory. If you start a large number of JVM servers at the same time, the time taken to load the required libraries might cause some JVM servers to time out, or some JVM servers might take an excessively long time to start. To reduce JVM server startup time, you should tune the JVM startup environment.

### Procedure

1. Create a shared class cache for the JVM servers to load the libraries a single time.

   To use a shared class cache, add the **`-Xshareclasses`** option to the JVM profile of each JVM server. For more information see Class data sharing between JVMs in IBM SDK.
2. Increase the timeout value for the OSGi framework.

   The DFHOSGI.jvmprofile contains the `OSGI_FRAMEWORK_TIMEOUT` option that specifies how long CICS waits for the JVM server to start and shut down. If the value is exceeded, the JVM server fails to initialize or shut down correctly. The default value is 60 seconds, so you should increase this value for your own environment.

# Language Environment enclave storage for JVMs

A JVM server has both static and dynamic storage requirements, primarily in 64-bit storage. It may use a significant amount of 31-bit storage.

**Note:** The amount of 31-bit storage used will depend on several factors:

- The configuration parameters
- The design and use of other products
- The design of the JVM
- The Java workload.

For example, the use of **`-Xcompressedrefs`** might improve performance, but requires 31-bit storage and should always be used with **`-XXnosuballoc32bitmem`** to ensure that the JVM dynamically allocates 31-bit storage for compressed references based on demand. For more information about of these options, see Default settings for the JVM in IBM SDK. *Just-in-time compilation* (JIT) also requires 31-bit storage for the compiled class code.

A JVM runs as a z/OS UNIX System Services process in a Language Environment enclave that is created using the Language Environment preinitialization module, **`CELQPIPI`**.

JVM storage requests are handled by Language Environment, which in turn allocates z/OS storage based on the defined runtime options.

The Language Environment runtime options are set by DFHAXRO. The default values provided by these programs for a JVM enclave are shown in Table 45 on page 322:

*Table 45. Language Environment runtime options used by CICS for the JVM enclave*

| Language Environment runtime options | Example JVM server values |
|---|---|
| Heap storage | `HEAP64(256M,4M,KEEP,4M,1M,FREE,1K,1K,KEEP)` |
| Library heap storage | `LIBHEAP64(5M,3M)` |

*Table 45. Language Environment runtime options used by CICS for the JVM enclave (continued)*

| Language Environment runtime options | Example JVM server values |
|---|---|
| Library routine stack frames that can reside anywhere in storage | `STACK64(1M,1M,16M)` |
| Optional heap storage management for multithreaded applications (64 bit) | `HEAPPOOLS64(ALIGN)` |
| Optional heap storage management for multithreaded applications (31 bit) | `HEAPPOOLS(ALIGN)` |
| Amount of storage reserved for the out-of-storage condition and the initial content of storage when allocated and freed | `STORAGE(NONE,NONE,NONE)` |

**Note:** For current JVM server values, refer to the DFHAXRO member in Library SDFHSAMP.

Language Environment runtime options, such as HEAP64, work on the principle of an initial value for that type of storage: for example, 256 MB 64-bit. When HEAP64 cannot contain a new request, an increment is allocated of the specified size (4 MB above) or of the request size plus control information, whichever is larger. Extra increments are allocated as required to meet demand. When an increment is empty, Language Environment will either KEEP or FREE the z/OS storage based on the runtime value.

For full information about Language Environment runtime options, see z/OS Language Environment Customization.

Where possible, the 31-bit and 64-bit initial size should cover the total 31-bit and 64-bit storage requirements, although a few increments is acceptable. This reduces both overall z/OS storage requirements and CPU time, compared to when there are many increments.

The HEAP64 31-bit increment size should not be set to less than 1M and the FREE option should be used. In the previous example, the 31-bit parameters were set to 4M, 1M, and FREE.

Language Environment 31-bit and 64-bit HEAP usage can be seen by activating the RPTO(ON) and RPTS(ON) options in DFHAXRO. An Language Environment storage report is produced when the JVM server is stopped.

You can override the Language Environment runtime options by modifying and recompiling the sample program DFHAXRO, which is described in "Modifying the enclave of a JVM server with DFHAXRO" on page 327. This program is set on the JVMSERVER resource, so you can use different names, which is why there are different options for individual JVM servers, if required.

The amounts of storage required for a JVM in a Language Environment enclave might require changes to installation exits, IEALIMIT or IEFUSI, which you use to limit the **REGION** and **MEMLIMIT** sizes. A possible approach is to have a Java owning region (JOR), to which all Java program requests are routed. Such a region runs only Java workloads, minimizing the amount of CICS DSA storage required and allowing the maximum amount of MVS storage to be allocated to JVMs.

# Identifying Language Environment storage needs for JVM servers

After identifying the actual storage needs, it is possible to determine whether the supplied **DFHAXRO** options need to be modified or not. This allows values to be chosen that either avoid the need for incremental storage allocations, or reduce the number to an acceptable level.

## About this task

The HEAP64 runtime option in DFHAXRO controls the heap size of the Language Environment enclave for a JVM server. This option includes settings for 64-bit, 31-bit, and 24-bit storage. You can use your own program instead of DFHAXRO if preferred. The program must be specified on the JVMSERVER resource.

## Procedure

1. Set the RPTO(ON) and RPTS(ON) options in DFHAXRO.

   These options are in comments in the supplied source of DFHAXRO. Specifying these options causes Language Environment to report on the storage options and to write a storage report showing the actual storage used.
2. Disable the JVMSERVER resource.

   The JVM server shuts down and the Language Environment enclave is removed.
3. Enable the JVMSERVER resource.

   CICS uses the Language Environment runtime options in DFHAXRO to create the enclave for the JVM server. The JVM also starts up.
4. Run your Java workloads in the JVM server to collect data about the storage that is used by the Language Environment enclave.
5. Remove the RPTO(ON) and RPTS(ON) options from DFHAXRO.
6. Disable the JVMSERVER resource to generate the storage reports.

   The storage reports include a suggestion for the initial Language Environment enclave heap storage. The entry "Suggested initial size" in the 64-bit user heap statistics contains the suggested value and is equal to the total amount of Language Environment enclave heap storage that was used by the JVM server.

## Results

The storage reports are saved in an `stderr` file in z/OS UNIX, or can also go to your CICS JES output if you are using the **JOBLOG** or **DD://** routing syntax. The directory depends on whether you have redirected output for the JVM in the JVM profile. If no redirection exists, the file is saved in the working directory for the JVM. If no value is set for WORK_DIR in the profile, the file is saved in the `/tmp` directory.

Use the information in the storage reports to select a suitable value for the Language Environment enclave heap storage in the **DFHAXRO HEAP64** option. Storage requirements might change from one CICS execution to the next, and are typically not the same for different CICS systems that share the one DFHAXRO, thus requiring a compromise.

The normal aim is to set the HEAP64 initial allocations to the suggested sizes to avoid or reduce the number of increments. The more increments that are used, the more likely that the ratio of z/OS storage compared to actively used Language Environment storage increases. Many increments can also cause an increase in the amount of CPU time that is used by Language Environment to manage the HEAP64 storage requests. Java allocates the JVM Heap as a Memory Object via IARV64 and not through a Language Environment storage request. If a Java migration is performed with an initial allocation that includes **-Xmx**, it normally doubles the storage that is used for the Java Heap, and might result in MEMLIMIT being too small.

Allocating many increments might produce the effect of a Storage Leak, which manifests as a continual increase in z/OS storage over time. In practice, this is more likely to be Storage Creep, which is characterized by an increase in both z/OS allocated storage and Language Environment free storage. A Storage Leak shows a continual increase in both z/OS and Language Environment used storage. 31-bit HEAP64 storage is allocated in z/OS subpool 1 whereas JIT storage is allocated in z/OS subpool 2 in 2MB increments.

The effect of the revised options should be evaluated at least one time and adjusted as required. Tuning should also be repeated at suitable intervals to assess the effect of any changes to storage usage due to application changes and other changes. Tuning should also be repeated whenever the CICS or Java release changes as storage usage patterns might change.

**Note:** If you increase the 31 bit **HEAP64** initial size, you must also change **HEAPP** to avoid over-allocating **HEAPPOOLS** 31-bit storage. In the example below, the HEAPPOOLS percentage values should be reduced from 10% to 1%.

HEAPPOOLS and HEAPPOOLS64 are active in the default DFHAXRO and can be effective when configured, but the correct values are dependent on the workload and hence precise tuning might be difficult.

STACK64 should be checked to ensure that the maximum storage used is not close to the defined limit, which is typically 16 MB. Exceeding the limit will results in runtime errors.

What is not obvious from LE RPTSTG output is that, while using STACK64(1M,1M,16M) provides a safe value for JVM thread stack expansion, it can result in a large **MEMLIMIT** being required to avoid CICS SOS Above the Bar during GDSA expansion. With the 16M maximum, 20 MB is allocated per JVM thread in three Memory Objects - one of 16+1 MB, one of 2 MB and one of 1 MB. Only 3 MB is initially usable, and of out this 1MB is allocated for the native stack, 1MB for the LE control block and 1MB for the reserve stack, leaving 16MB as guarded stack storage and another 1MB as guarded reserve stack storage. Only the 3MB of usable allocated storage is counted towards the z/OS IARV64 **MEMLIMIT** check. However, CICS counts all 20 MB to decide whether it can expand the GDSA by a multiple of GB without exceeding **MEMLIMIT**. A single JVM server can legitimately use more than 200 threads, and 200 threads equates to 4,000MB towards the CICS **MEMLIMIT** check. Therefore, reducing the STACK64 maximum to a lower value that still permits some expansion can help towards reducing the **MEMLIMIT** size and the possibility of SOS Above the Bar.

### Example

The following example is **RPTOPTS** output based on these DFHAXRO options:

```
HEAPPOOLS(ALIGN,8,10,32,10,128,10,256,10,1024,10,2048,10,0,10,0,10,0,10,0,10,0,10,0,10)
HEAPPOOLS64(ALIGN,8,4000,32,2000,128,700,256,350,1024,100,2048,50,3072,50,4096,50,8192,
            25,16384,10,32768,5,65536,5)
HEAP64(256M,4M,KEEP,4194304,1048576,KEEP,1024,1024,KEEP)
LIBHEAP64(3M,3M,FREE,16384,8192,FREE,8192,4096,FREE)
STACK64(1M,1M,16M)
THREADSTACK64(OFF,1M,1M,128M)
```

The following example is partial **RPTSTG** output:

```
STACK64 statistics:
Initial size:                                  1M
Increment size:                                1M
Maximum used by all concurrent threads:        1M
Largest used by any thread:                    1M - no change required
Number of increments allocated:                0
THREADSTACK64 statistics:
Initial size:                                  1M
Increment size:                                1M
Maximum used by all concurrent threads:        0M
Largest used by any thread:                    0M - not used
Number of increments allocated:                0
64bit User HEAP statistics:
Initial size:                                  256M
Increment size:                                4M
Total heap storage used:                       730857472
Suggested initial size:                        697M - use this
Successful Get Heap requests:                  783546
Successful Free Heap requests:                 780785
Number of segments allocated:                  135 - too many increments
Number of segments freed:                      0
31bit User HEAP statistics:
Initial size:                                  4194304
Increment size:                                1048576
Totalheap storage used (suggested initial size):  137165672 - use this
Successful Get Heap requests:                  1345332
Successful Free Heap requests:                 1345260
Number of segments allocated:                  125 - too many increments
Number of segments freed:                      0
64bit Library HEAP statistics:
Initial size:                                  3M
Increment size:                                3M
Total heap storage used:                       4640032
Suggested initial size:                        5M
Successful Get Heap requests:                  113381
Successful Free Heap requests:                 112860
Number of segments allocated:                  1 - low, so no change required
Number of segments freed:                      0
31bit Library HEAP statistics:
Initial size:                                  16384
Increment size:                                8192
Total heap storage used (suggested initial size): 520
Successful Get Heap requests:                  33725
Successful Free Heap requests:                 33725
```

```
Number of segments allocated:                     1 - low, so no change required
Number of segments freed:                         0

Suggested Percentages for current CellSizes:
HEAPP(ALIGN,8,1,32,1,128,1,256,1,1024,1,2048,1,0)
```

When reviewing **RPTSTG** output, remember that the **HEAP64** increment sizes are for the minimum amount of storage that Language Environment allocates, and any increment could be substantially bigger than that value. Hence it is not possible to accurately determine how much z/OS storage was used when 1 or more increments have been allocated. The actual number of increments is reported for 64bit HEAP (that is, 135), for 31bit **HEAP** the actual number of increments is one less than is shown (that is, 124 not 125).

Because of the way that Language Environment's storage management works when increments are used, the amount of 31-bit and 64-bit z/OS storage allocated may be significantly higher than shown in **RPTSTG** "maximum used".

The suggested **DFHAXRO** changes are:

```
* Heap storage
DC     C'HEAP64(700M,'         Initial 64bit heap - change (Note 1)
DC     C'4M,'                   64bit Heap increment
DC     C'KEEP,'                 64bit Increments kept
DC     C'128M,'                 Initial 31bit heap - change (Note 2)
DC     C'2M,'                   31bit Heap increment - change (Note 3)
DC     C'FREE,'                 31bit Increments freed - change (Note 4)
DC     C'1K,'                   Initial 24bit heap
DC     C'1K,'                   24bit Heap increment
DC     C'KEEP) '                24bit Increments kept

* Heap  pools
DC     C'HP64(ALIGN) '
DC     C'HEAPP(ALIGN,8,1,32,1,128,1,256,1,1024,1,2048,1,0) ' - change (Note 5)

* Library Heap storage
DC     C'LIBHEAP64(3M,3M) '     Initial 64bit heap - do not change (Note 6)

* 64bit stack storage
DC     C'STACK64(1M,1M,16M) ' - consider a change (Note 7)
```

**Note:**

1. As shown by **RPTSTG** output 64bit "Suggested initial size" plus a small increase.
2. As shown by **RPTSTG** output 31bit "Suggested initial size" but with a small reduction as we are using FREE.
3. The 31-bit **HEAP** increment may be better as a value of 2M instead of 1M.
4. Optionally, using 31-bit **HEAP  FREE** may result in less z/OS storage being allocated to map the "Total heap storage used" than with KEEP.
5. As recommended by **RPTSTG** output after the **HEAPPOOLS** statistics, but may benefit from further optimization. The default of 10% of the 31-bit Heap initial size of 128MB is likely to result in an excessive amount of storage being allocated. A minimum of 6 pools each of 10% of the initial heap size of 128MB causes 77MB to be allocated. This will be included in the "Total heap storage used" value (because the **HEAPPOOLS** storage extents are allocated there), irrespective of what percentage of the pool s is productively used. Using **HEAPPOOLS** cell sizes greater than 256 bytes might result in inefficient use of Language Environment HEAP storage.
6. Only one increment was required, which is not a problem.
7. The largest used was 1MB. Reducing the maximum of 16M to a value such as 8 MB or even lower would significantly reduce the amount of STACK64 storage that CICS counts towards **MEMLIMIT** when checking to see whether it can allocate a new GDSA extent. STACK64 changes should be tested thoroughly before migrating them into a production environment.

This is an example of using 31-bit **HEAP  FREE** on another run of the same JVM server. The "Number of segments" shows the number of  **GETMAIN**s and **FREEMAIN**s performed, which was low for the time that the JVM server was active. The difference of 2 shows that the enclave terminated with only the initial allocation plus one increment, which is likely to be less than the "Total heap storage" and shows the effectiveness of FREE. "Total heap storage used" was higher, but any total often changes from one run of a JVM server to another, hence basing changes on only one set of **RPTSTG** may not provide the best possible settings.

```
31bit User HEAP statistics:
Initial size: 134217728
Increment size: 2097152
Total heap storage used (suggested initial size): 154056664
Successful Get Heap requests: 3253239
Successful Free Heap requests: 3253176
Number of segments allocated: 149
Number of segments freed: 147
```

It is important to read the Language Environment Debugging Guide in order to correctly interpret **RPTSTG** output.

## Modifying the enclave of a JVM server with DFHAXRO

DFHAXRO is a sample program that provides a default set of runtime options for the Language Environment® enclave in which a JVM server runs. For example, it defines storage allocation parameters for the heap and stack. It is not possible to provide default runtime options that are optimized for all workloads. Consider identifying actual storage usage, and override the defaults as required, to optimize the ratio of used storage to allocated storage.

### About this task

You can update the sample program to tune the Language Environment enclave or you can base your own program on the sample. The program is defined on the JVMSERVER resource and is called during the CELQPIPI preinitialization phase of the Language Environment enclave that is created for a JVM server.

You must write the program in assembly language and it must not be translated with the CICS® translator. The options are specified as character strings, comprising a 2-byte string length followed by the runtime option. The maximum length for all Language Environment runtime options is 255 bytes, so use the abbreviated version of each option and restrict your changes to a total of under 200 bytes (allowing space for the mandatory options imposed by the JVMSERVER).

### Procedure

1. Copy the DFHAXRO program to a new location to edit the runtime options, and rename the module if required.

   If maintenance is applied to your CICS region, you might want to reflect the changes in your program. The source for DFHAXRO is in the CICSTS56.CICS.SDFHSAMP library.
2. Edit the runtime options, using the abbreviation for each option.

   The z/OS Language Environment Programming Guide has complete information about Language Environment runtime options.

   - Use the HEAP64 option to specify the initial heap allocation for the 64-bit, 31-bit and 24-bit storage Language Environment heap areas.

     For example the following HEAP64 settings `HEAP64(256M,4M,KEEP,4M,1M,FREE,1K,1K,KEEP)` sets the initial 64-bit heap to 256 MB with further storage getmained in 4 MB increments, the initial 31-bit storage heap to 4 MB with 1 MB increments, and the initial 24-bit storage heap to 1 KB with 1 KB increments.
   - The POSIX option is forced on by CICS.
3. Use the RPTO(ON) and RPTS(ON) values to report on the LE options and LE storage usage.

   The output that is produced is written to the Enclave `stderr` stream at Enclave termination.

   **Tip:**

   It is possible to see the Language Environment storage growing over time as application workload increases. While this growth might look like a storage leak, in most instances, the growth and the total amount of storage can be corrected by tuning the Language Environment HEAP64 runtime option 64-bit and 31-bit parameters based on the following procedure.

4. Use the DFHASMVS procedure to compile the program, deploy into the RPL and restart the JVM server.
5. Analyze the LE storage report produced to see if any of the LE user heaps show allocation using a high number of increments.

   Using many increments typically increases the amount of CPU time for storage requests. The more segments that are allocated, the more likely it is that storage fragmentation occurs.
6. If any of the user heap statistics show more than 20 segments have been allocated, increase the initial size or the increment size in the relevant LE runtime option.
7. When tuning is complete, edit the runtime options and disable the reporting of the LE options and LE storage report. Compile the program, deploy into the RPL and restart the JVM server.

   Example LE storage report for LE user heap statistics:

```
64bit User HEAP statistics:
  Initial size:                                              256M
  Increment size:                                              4M
  Total heap storage used:                               47842496
  Suggested initial size:                                     46M
  Successful Get Heap requests:                              8214
  Successful Free Heap requests:                             8052
  Number of segments allocated:                                 0
  Number of segments freed:                                     0
31bit User HEAP statistics:
  Initial size:                                           4194304
  Increment size:                                         1048576
  Total heap storage used (sugg. initial size):           8583912
  Successful Get Heap requests:                               338
  Successful Free Heap requests:                               69
  Number of segments allocated:                                 6
  Number of segments freed:                                     0
24bit User HEAP statistics:
  Initial size:                                              1024
  Increment size:                                            1024
  Total heap storage used (sugg. initial size):                 0
  Successful Get Heap requests:                                 0
  Successful Free Heap requests:                                0
  Number of segments allocated:                                 0
  Number of segments freed:                                     0
```

### Results

When you enable the JVMSERVER resource, CICS creates the Language Environment enclave by using the runtime options that you specified in the DFHAXRO program. CICS checks the length of the runtime options before it passes them to Language Environment. If the length is greater than 255 bytes, CICS does not attempt to start the JVM server and writes error messages to CSMT. The values that you specify are not checked by CICS before they are passed to Language Environment.

## Tuning the z/OS shared library region

The shared library region is a z/OS feature designed to improve performance when loading UNIX System Services dynamic link library (.so) files. The primary exploiter of this feature is the Java SDK for z/OS, but it can be used by any product that sets the shared library bit on their shared object (.so) files.

CICS JVM servers and Node.js applications disable the shared library region by default. Doing so usually increases the available MVS 31-bit private area virtual storage within the CICS region. To enable the shared library region, you must explicitly set the variable `_BPXK_DISABLE_SHLIB=NO` in the JVM profile or Node.js profile.

Enabling the shared library region across multiple CICS regions can provide a performance benefit related to the one-time allocation of the associated real storage, compared to each region loading each library individually. However, if your z/OS image has many different JVM versions in use, all using the shared library region, a larger amount of virtual storage is needed in all regions to hold the different versions of the shared libraries. That increase is significant because each address space must reserve an equivalent amount of MVS high private area storage onto which it maps the shared library region. Thus, a region's private storage allocation is usually larger than if it was loading only the specific libraries required.

For more information about private storage, see High private area.

Additionally, executable code in the shared library region is allocated on a megabyte boundary, allowing a single-page table to be shared, similar to LPA. A tradeoff is that the coarse-grained allocation consumes more storage than direct loading of libraries.

Individual address spaces allocate their private storage when the first process using shared libraries is started in the region. Take care that all processes within your address space opt in or opt out of the shared library region consistently. If you choose to use the shared library region, the amount of storage that is allocated is controlled by the **SHRLIBRGNSIZE** parameter in z/OS, which is in the BPXPRMxx member of SYS1.PARMLIB. The minimum is 16 MB, and the z/OS default is 64 MB. To determine the amount of storage that is allocated, bring up your normal workload on the z/OS system, then issue the command `D OMVS,L` to display the library statistics. Adjust the **SHRLIBRGNSIZE** parameter large enough to accommodate all the libraries, but not so large that excessive storage is reserved.

**Note:** Native libraries are loaded once per address space. Running multiple JVM servers and Node.js applications within the same CICS region will not incur additional load costs regardless of the shared library region setting, providing they use the same version of the IBM SDK, Java Technology Edition and IBM SDK for Node.js - z/OS respectively.

# Chapter 12. Troubleshooting Java applications

If you have a problem with a Java application, you can use the diagnostics that are provided by CICS and the JVM to determine the cause of the problem.

## About this task

CICS provides some statistics, messages, and tracing to help you diagnose problems that are related to Java. The diagnostic tools and interfaces that are provided with Java can give you more detailed information about what is happening in the JVM than CICS because CICS is unaware of many of the activities in a JVM.

You can use freely available tools that perform real-time and offline analysis of a JVM, for example IBM Health Center. For full details, see IBM Monitoring and Diagnostic Tools for Java - Health Center.

For troubleshooting web applications that are running in a Liberty JVM server, see "Troubleshooting Liberty JVM servers and Java web applications" on page 335. For information about where to find log files see "Controlling the location for JVM output, logs, dumps and trace" on page 345.

## Procedure

1. If you are unable to start a JVM server, check that the setup of your Java installation is correct.

   Use the CICS messages and any errors in the `stderr` file for the JVM to determine what might be causing the problem.

   a) Check that the correct version of the Java SDK is installed and that CICS has access to it in z/OS UNIX.

      For a list of supported SDKs, see Changes to CICS support for application programming languages.

   b) Check that the **USSHOME** system initialization parameter is set in the CICS region.

      This parameter specifies the home for files on z/OS UNIX.

   c) Check that the **JVMPROFILEDIR** system initialization parameter is set correctly in the CICS region.

      This parameter specifies the location of the JVM profiles on z/OS UNIX.

   d) Check that the CICS region has read and run access to the z/OS UNIX directories that contain the JVM profiles.

   e) Check that the CICS region has write access to the working directory of the JVM.

      This directory is specified in the `WORK_DIR` option in the JVM profile.

   f) Check that the `JAVA_HOME` option in the JVM profiles points to the directory that contains the Java SDK.

   g) If you are using IBM MQ or Db2 DLL files, check that the 64-bit versions of these files are available to CICS.

   h) If you modify DFHAXRO to configure the Language Environment enclave, ensure that the runtime options do not exceed 200 bytes and that the options are valid.

      CICS does not validate the options that you specify before it passes them to Language Environment. Check SYSOUT for any error messages from Language Environment.

2. If your setup is correct, gather diagnostic information to determine what is happening to the application and the JVM.

   a) To obtain the diagnostics, you must use `PRINT_JVM_OPTIONS=TRUE`. The default for this option is `PRINT_JVM_OPTIONS=FALSE`, so if it is left to default no options for diagnostics are presented. When you specify `PRINT_JVM_OPTIONS=TRUE`, all the options that are passed to the JVM at startup, including the contents of the class paths, are printed to SYSPRINT. The information is produced every time a JVM is started with this option in its profile.

   b) Check the `dfhjvmout` and `dfhjvmerr` files for information and error messages from the JVM.

These files are in the directory that is specified by the `WORK_DIR/applid/jvmserver` option in the JVM profile. The files might have different names if the STDOUT and STDERR options were changed in the JVM profile.

3. If the application is failing or performing poorly, debug the application.
   - If you receive `java.lang.ClassNotFoundException` errors and the transaction abends with the AJ05 code, the application might not be able to access IBM or vendor classes in the OSGi framework. For more information about how to fix this problem, see Upgrading the Java environment.
   - Use the CEDX transaction to debug the application transaction. For a Liberty JVM server, if you are using a URI map to match the inbound application request to an application transaction, debug that transaction. If you use the default transaction CJSA, you must set the MAXACTIVE attribute to 1 on the DFHEDFTC transaction class (or DFHEDFTO transaction class if you use CEDY). This setting is required because a number of CJSA tasks might be running and you might debug the wrong transaction. Do not use CEDX on the CJSA transaction in a production environment.
   - To use a debugger with the JVM server, you must set some options in the JVM profile. For more information, see "Debugging a Java application" on page 350.
   - If you want to determine the status of OSGi bundles and services, use the OSGi console. Set the following properties in the JVM profile: `-Dosgi.file.encoding=ISO-8859-1`, and `-Dosgi.console=host:port` where `host` is the host name of the system the JVM server is running on, and `port` is a free port on the same system. While the `osgi.console.encoding` property was designed to allow the OSGi console to use a preferred encoding without putting the whole JVM into that encoding, an outstanding bug in the Equinox OSGi framework prevents its use, instead you must set the `file.encoding` value to an ASCII based encoding. If you are using an OSGi JVM server, add **`OSGI_CONSOLE=TRUE`** to the JVM profile. If you are using a Liberty JVM server, add the osgiConsole-1.0 feature to the `server.xml`. Connect to the OSGi console by using a Telnet session with the host and port properties you specified in the JVM profile.

     **Note:** If you type the `exit` command into the OSGi console, it will issue a system.exit(0) call to the environment that the JVMSERVER runs in. The command to disconnect your terminal from the OSGi console is `disconnect`. system.exit(0) is an abrupt stop of all threads and workload, and if left to continue processing, can leave the JVM and CICS in an indeterminate state. CICS is designed to perform an immediate shutdown in this eventuality to avoid subsequent complications. For this reason, it is important to control write access to both the JVM profile, and `server.xml`. A Liberty JVM server offers further protection by requiring inclusion of the osgiConsole-1.0 feature before the OSGi console is able to run. The OSGi console is primarily a development and debug aid, and is not expected to run in a production environment.

4. If you are getting out-of-memory errors, it might indicate that the JVM or CICS address space was not allocated enough storage, the application might have a memory leak, or the heap size might be insufficient.
   a) Use CICS statistics or a tool such as IBM Health Center to monitor the JVM. If the application has a memory leak, the amount of live data that remains after garbage collection gradually increases over time until the heap is exhausted.

      The JVM server statistics report the size of the heap after the last garbage collection and the maximum and peak size of the heap. For more information, see Analyzing Java applications using IBM Health Center.

   b) Run the storage reports for Language Environment to find out whether the amount of storage is sufficient.

      For more information, see Language Environment enclave storage for JVMs.

5. If you are getting encoding errors when you install or run a Java application, maybe you set up conflicting or an unsupported combination of code pages.
   - Java 21 With Java 21, JVMs on z/OS typically use UTF-8 for file encoding, but the JVM can use other code pages for file encoding if required.

- Java 8Java 11Java 17 With Java 8, Java 11 and Java 17, JVMs on z/OS typically use an EBCDIC code page for file encoding; the default for non-Liberty JVM servers is IBM1047 (or cp1047), but the JVM can use other code pages for file encoding if required.

CICS requires an EBCDIC code page to handle character data and all JCICS calls must use an EBCDIC code page. The code page is set in the **LOCALCCSID** system initialization parameter for the CICS region.

a) Check the JVM server logs to see whether any warning messages were issued relating to the value of **LOCALCCSID**.

   If this parameter is set to a non-EBCDIC code page, a code page that is not supported by the JVM, or an EBCDIC code page that is not supported (such as 930), the JVM server uses cp1047.

b) JCICS calls use the code page that is specified in the **LOCALCCSID** system initialization parameter.

   If your application expects a different code page, you get encoding errors. To use a different code page for JCICS, set the **-Dcom.cics.jvmserver.override.ccsid=** parameter in the JVM profile.

c) If you are using the **-Dcom.cics.jvmserver.override.ccsid=** parameter in the JVM profile, ensure that the CCSID is an EBCDIC code page.

   The application must use EBCDIC when it uses JCICS calls.

d) If you are running SOAP processing in an Axis2 JVM server, ensure that the **-Dfile.encoding** JVM property specifies an EBCDIC property.

   If you specify a non-EBCDIC code page, such a UTF-8, the web service request fails and the response contains corrupted data.

6. If you experience startup timeouts or timeouts under workload, there are various parameters that you can tune to help resolve the issue. The following give an indication of values you can tune:

   - Modify your **-Dcom.ibm.cics.jvmserver.threadjoin.timeout** setting to control how long an HTTP request waits to obtain a JVM server thread.
   - Increase the **THREADLIMIT** value on the JVMSERVER resource.
   - If **THREADLIMIT** is already set to the maximum permitted value, then you might be attempting to run more work than a single JVM server can handle. Consider balancing the workload between multiple JVM servers or multiple regions.

     Alternatively, your CICS system might be unresponsive because of other constraints. Follow the standard procedures to diagnose performance problems. See Improving the performance of a CICS system.

7. If your JVM server hangs in a disabling state after issuing DISABLED PHASEOUT then:

   - Review the JVMLOG to see if CICS is reporting any non-daemon threads which are still running. A PHASEOUT will not complete until all non-daemon threads have finished to allow work to drain from the JVM server. If non-daemon threads are still running, ensure your applications terminate them once they are no longer needed or set them as daemon when they are not performing an important function.
   - You can issue the SET JVMSERVER DISABLED command with PURGE, FORCEPURGE, or KILL options to disable the JVM server. These options may cause abends or CICS to terminate abnormally, so should be used cautiously.

## What to do next

If you cannot fix the cause of the problem, contact IBM support. Make sure that you provide the required information, as listed in the Collecting CICS troubleshooting data (CICS MustGather) for IBM Support for reporting Java problems.

# Diagnostics for Java

Many of the usual sources of CICS diagnostic information contain information that applies to Java applications. In addition to the information supplied by CICS, there are a number of interfaces specific to the JVM that you can use for problem determination.

## CICS diagnostic tools for Java

CICS has statistics and monitoring data that you can collect on running Java applications. When errors occur, transactions abend and messages are written to the appropriate log. See CICS messages for a list of the abends and messages that apply to the JVM (SJ) domain. Messages related to Java are in the format DFHSJxxxx.

You can also turn on tracing to produce additional diagnostic information. The trace points for the JVM domain are listed in JVM and Node.js runtime domain trace points.

When the first JVM is started in a CICS region after initialization, CICS issues message DFHSJ0207, showing the version of Java that is being used.

The Java SDK provides diagnostic tools and interfaces that give you more detailed information about what is happening in the JVM. Messages and diagnostic information from the JVM are written to the `stderr` log file for the JVM. If you encounter a Java problem, always consult this file. For example, if CICS issues a message to indicate that the JVM has abended, the `stderr` log file is the primary source of diagnostic information. "Controlling the location for JVM output, logs, dumps and trace" on page 345 tells you how to control the location of output from the JVM, and how to redirect messages from JVM internals and output from Java applications running in a JVM.

When you develop Java applications for CICS, it is important to consider the requirements for thread safety and transaction isolation in CICS. If a Java application works correctly on its first use, but does not behave correctly on subsequent uses, then the problem is likely to be due to isolation issues.

## OSGi diagnostic files

The OSGi framework produces diagnostic files in zFS that you can use to help troubleshoot problems with OSGi bundles and services in a JVM server:

**OSGi cache**

The OSGi cache is in the *$WORK_DIR*/*applid*/*jvmserver*/`configuration/org.eclipse.osgi` directory of the JVM server. *$WORK_DIR* is the working directory of the JVM server, *applid* is the CICS APPLID, and *jvmserver* is the name of the JVMSERVER resource. The OSGi cache contains framework metadata and other information that is required to run the framework. The cache is replaced when the JVM server starts up.

**OSGi logs**

If an error occurs in the OSGi framework, an OSGi log is created in the *$WORK_DIR*/*applid*/*jvmserver*/`configuration/` directory of the JVM server. The file extension is `.log`.

## JVM diagnostic tools

The CICS documentation provides information about some of the Java diagnostic tools and interfaces:

- "Activating and managing tracing for JVM servers" on page 349 describes how you can use the component tracing provided by the CETR transaction to trace the life cycle of the JVM server and the tasks running inside it. JVM servers do not use auxiliary or GTF tracing. Instead, the tracing is written to a file on zFS that is uniquely named for each JVM server.
- "Debugging a Java application" on page 350 describes how you can use a remote debugger to step through the application code for a Java application that is running in a JVM. CICS also provides a set of interception points (or plug-in) in the CICS Java middleware, which allows additional Java programs to be inserted immediately before and after the application Java code is run, for debugging, logging, or other purposes. For more information, see "The CICS JVM plug-in mechanism" on page 351.

Many more diagnostic tools and interfaces are available for the JVM. See Troubleshooting and support for information about further facilities that can be used for problem determination for JVMs. The following facilities provide useful diagnostic information:

- The internal trace facility of the JVM can be used directly, without going through the interfaces provided by CICS. For information about the system properties that you can use to control the internal trace facility and to output JVM trace information to various destinations, see Using CICS trace. You can use these system properties to output trace from any method or class within the JVM, and to find the value of any parameters and return types on the method call.
- If you experience memory leaks in the JVM, you can request a heap dump from the JVM. A heap dump generates a dump of all the live objects (objects still in use) that are in the heap of the JVM. You can also analyze memory leaks using the IBM Health Center and Memory Analyzer tools, which are both available with IBM Support Assistant. For more information about Java tools, see IBM Monitoring and Diagnostic Tools for Java - Health Center.
- The HPROF profiler, that is shipped with the IBM 64-bit SDK for z/OS, Java Technology Edition, provides performance information for applications that run in the JVM, so you can see which parts of a program are using the most memory or processor time.
- The JVM provides interfaces for monitoring, profiling, and RAS (Reliability, Availability, and Serviceability).

With all interfaces, options, or system properties available for the IBM JVM that are not specific to the CICS environment, use the IBM JVM documentation as the primary source of information.

# Troubleshooting Liberty JVM servers and Java web applications

If you have a problem with a Java web application, you can use the diagnostics that are provided by CICS and Liberty to determine the cause of the problem.

CICS provides statistics, messages, and tracing to help you diagnose problems that are related to running Java web applications in a Liberty JVM server. Liberty also produces diagnostics that are available in zFS. For general setup errors and application problems, see Troubleshooting and support.

## Avoiding problems

CICS uses the values of the region APPLID and the JVMSERVER resource name to create unique zFS file and directory names. Some of the acceptable characters have special meanings in the UNIX System Services shell. For example, the dollar sign ($) means the start of an environment variable name. Some of these characters can cause an `Exception` in the Equinox OSGi framework and prevent the JVM server from starting. Avoid using non-alphanumeric characters in the region APPLID and JVM server name. If you do use these characters, you might need to use the backslash (\) as an escape character in the UNIX System Services shell. For example, if you called your JVM server MY$JVMS and wanted to read the JVM system out file:

```
cat CICSPRD.MY\$JVMS.D20140319.T124122.dfhjvmout
```

## Unable to start Liberty JVM server

1. If you are unable to start a Liberty JVM server, check that your setup is correct; see Configuring a Liberty JVM server for more information. Use the messages in the CICS system log and the Liberty `messages.log` file that is located after `WLP_OUTPUT_DIR` to determine what might be causing the problem.
2. Check that the **`-Dfile.encoding`** JVM property in the JVM profile specifies either ISO-8859-1 or UTF-8. These are the two code pages that are supported by Liberty. If you set any other value, the JVM server fails to start.

## Local Liberty JVM server cannot connect to the remote Liberty JVM server for JCICSX when SSL is enabled (SRVE0777E)

You might receive this error after configuring your Liberty JVM server to use SSL for remote JCICSX API development:

```
Application Error
SRVE0777E: Exception thrown by application class
'com.ibm.cics.jcicsx.http.CICSContextProviderImpl.initialise:112'
com.ibm.cics.jcicsx.http.JCICSXException: Failed to retrieve server info
at com.ibm.cics.jcicsx.http.CICSContextProviderImpl.initialise(CICSContextProviderImpl.java:112)
at
com.ibm.cics.jcicsx.http.CICSContextProviderImpl.getCICSContext(CICSContextProviderImpl.java:85)
at com.ibm.cics.harness.TaskProducer.produceTask(TaskProducer.java:26)
at com.ibm.cics.harness.HarnessServletFilter.doFilter(HarnessServletFilter.java:36)
at com.ibm.ws.webcontainer.filter.FilterInstanceWrapper.doFilter(FilterInstanceWrapper.java:201)
at [internal classes]
Caused by: javax.ws.rs.ProcessingException: java.io.IOException: IOException invoking https://
remotejcicsxserver.com:portNum/jcicsxServer/info: HTTPS hostname wrong: should be
<remotejcicsxserver.com>
at org.apache.cxf.jaxrs.client.AbstractClient.checkClientException(AbstractClient.java:643)
at [internal classes]
at com.sun.proxy.$Proxy34.getInfo
at com.ibm.cics.jcicsx.http.CICSContextProviderImpl.initialise(CICSContextProviderImpl.java:101)
... 5 more
Caused by: java.io.IOException: IOException invoking https://remotejcicsxserver.com:portNum/
jcicsxServer/info: HTTPS hostname wrong: should be <remotejcicsxserver.com>
at sun.reflect.NativeConstructorAccessorImpl.newInstance0(NativeConstructorAccessorImpl.java:-2)
at sun.reflect.NativeConstructorAccessorImpl.newInstance(NativeConstructorAccessorImpl.java:62)
at
sun.reflect.DelegatingConstructorAccessorImpl.newInstance(DelegatingConstructorAccessorImpl.java:4
5)
at java.lang.reflect.Constructor.newInstance(Constructor.java:423)
at
org.apache.cxf.transport.http.HTTPConduit$WrappedOutputStream.mapException(HTTPConduit.java:1447)
... 8 more
Caused by: java.io.IOException: HTTPS hostname wrong: should be <remotejcicsxserver.com>
at sun.net.www.protocol.https.HttpsClient.checkURLSpoofing(HttpsClient.java:649)
at sun.net.www.protocol.https.HttpsClient.afterConnect(HttpsClient.java:573)
at
sun.net.www.protocol.https.AbstractDelegateHttpsURLConnection.connect(AbstractDelegateHttpsURLConn
ection.java:185)
at sun.net.www.protocol.http.HttpURLConnection.getInputStream0(HttpURLConnection.java:1564)
at sun.net.www.protocol.http.HttpURLConnection.getInputStream(HttpURLConnection.java:1492)
at java.net.HttpURLConnection.getResponseCode(HttpURLConnection.java:480)
at
sun.net.www.protocol.https.HttpsURLConnectionImpl.getResponseCode(HttpsURLConnectionImpl.java:347)
at
org.apache.cxf.transport.http.URLConnectionHTTPConduit$URLConnectionWrappedOutputStream$2.run(URLC
onnectionHTTPConduit.java:427)
... 8 more
```

**Explanation**

This error is returned when a host name is not specified for the Liberty JVM server running in CICS. If not specified, the host name on the remote Liberty server defaults to `localhost`. However, the server expects the host name to be that of the remote CICS region, in this case `remotejcicsxserver.com`. This is the correct host name your local Liberty server should have passed to the remote Liberty server through the certificate but `localhost` was passed instead.

**User action**

To identify the problem, find the current host name registered in the remote Liberty JVM server's certificates, in either of the following ways:

- Use the OpenSSL command to show the certificates of the remote Liberty JVM server:

  ```
  $ openssl s_client -showcerts -connect remotejcicsxserver.com:portNo
  ```

  The output might be like this:

```
CONNECTED(00000005)
depth=0 C = us, O = ibm, OU = defaultServer, CN = localhost
verify error:num=18:self signed certificate
verify return:1
depth=0 C = us, O = ibm, OU = defaultServer, CN = localhost
verify return:1
```

The CN value returned in the header of the result is the certificate name and host name (`localhost`) on the server.

- To use the Java keytool utility:

  1. Navigate to the folder of the keystore on the remote Liberty server at: `{server.config.dir}/resources/security`.
  2. If the local Liberty server is at 19.0.0.3 or later, which is the minimum version required to use the client-side tooling of remote JCICSX development, and that autoconfigure is enabled for the remote Liberty server to use SSL, the remote Liberty server will have created a keystore using default values. In this case, use this command to show the certificates stored in the auto-created Java keystore:

     ```
     keytool -list -keystore key.p12 -storepass defaultPassword -storetype PKCS12 -v
     ```

     Otherwise, substitute values in for `storepass` and `storetype` according to your custom configuration.

     You might get output like this, which shows `localhost` as the host name:

     ```
     Keystore type: PKCS12
     Keystore provider: IBMJCE


     Your keystore contains 1 entry


     Alias name: default
     Creation date: Jun 1, 2020
     Entry type: keyEntry
     Certificate chain length: 1
     Certificate[1]:
     Owner: CN=localhost, OU=defaultServer, O=ibm, C=us
     Issuer: CN=localhost, OU=defaultServer, O=ibm, C=us
     Serial number: dd89aa9
     Valid from: 6/1/20 5:41 PM until: 6/1/21 5:41 PM
     Certificate fingerprints:
              MD5:  AB:05:27:5E:55:3B:44:73:CA:65:61:11:D3:08:21:AC
              SHA1: 16:8E:73:61:49:A3:0E:C4:46:7D:77:87:F0:81:DD:C9:EB:28:92:CF
              SHA256:
     E7:68:BB:CC:6C:00:33:67:CF:A6:DA:9A:56:25:D5:05:8F:69:33:0C:3D:CE:1C:E4:03:E6:13:30:FD:E0:
     9F:E9
              Signature algorithm name: SHA256withRSA
              Version: 3


     Extensions:


     #1: ObjectId: 2.5.29.14 Criticality=false
     SubjectKeyIdentifier [
     KeyIdentifier [
     0000: e3 4f e5 04 ff 71 e7 64  1a da 06 2b cb e0 ec 35  .O...q.d.......5
     0010: 18 6f 2d 94                                        .o..
     ]
     ]


     #2: ObjectId: 2.5.29.17 Criticality=false
     SubjectAlternativeName [
     [DNSName: localhost]]
     ```

The host name being `localhost` in the certificate returned means no host name is specified on the remote Liberty JVM server. Follow instructions in Configuring SSL (TLS) for remote JCICSX API development to configure SSL correctly for the remote Liberty JVM server.

## Unable to authenticate a user when trying to access a protected web application in a CICS Liberty JVM server

CICS **JESMSGLG** log contains the message:

```
ICH420I PROGRAM DFHSIP FROM LIBRARY hlq.SDFHAUTH CAUSED THE
ENVIRONMENT TO BECOME UNCONTROLLED
BPXP014I ENVIRONMENT MUST BE CONTROLLED FOR DAEMON (BPX.DAEMON) PROCESSING.
```

The Liberty `messages.log` contains the message:

```
CWWKS1100A: Authentication did not succeed for user ID user.
An invalid user ID or password was specified.
```

The CICS Liberty JVM server security implementation uses the Liberty angel process to perform authorized security checks. If Liberty is unable to connect to the angel process, it fails over to using UNIX System Services security, which requires all members in the STEPLIB and DFHRPL concatenations to be program controlled.

**Attention:** The Liberty server connects only to the angel process at server startup. The JVM server needs to be restarted to complete authentication.

## Unable to authenticate a user with user ID and password, cannot access APPL-ID when trying to access a protected web application in a CICS Liberty JVM server

Liberty `messages.log` contains the message:

```
com.ibm.ws.security.saf.SAFServiceResult E CWWKS2909E:
A SAF authentication or authorization attempt was rejected because the server
is not authorized to access the following SAF resource:
APPL-ID APPL-ID. Internal error code 0x03008108.
```

The CICS Liberty JVM server security requires access to SAF security profiles in classes APPL and SERVER. If access is not granted, then Liberty is not able to authenticate the user ID and password. Details of how to configure this can be found here Authenticating users in a Liberty JVM server.

## Web application is not available after it is deployed to the `dropins` directory

If you receive a CWWK0221E error message in `dfhjvmerr`, check that you set the right values for the host name and port number in the JVM profile and `server.xml`. The port might be in use by another process and port sharing disabled. The host name might not be resolvable by the client.

## CICS CPU use increased after a Liberty JVM server is enabled

Liberty can be configured to regularly check for updates to both configuration and installed applications using the *<config>* and *<applicationMonitor>* elements in `server.xml`. If the configuration polling rate or application monitor interval is set too frequently it can cause excessive use of CPU and I/O.

For *<config>* you can reduce the frequency using the *monitorInterval* attribute. Do not set the *updateTrigger* attribute to disabled because CICS requires Liberty to pick up configuration changes within a few seconds.

For *<applicationMonitor>* you can reduce the frequency using the *pollingRate* attribute, change the *updateTrigger* attribute to `mbean`, or disable it.

For more information, see Controlling dynamic updates.

## Application not available

You copy a WAR file into the `dropins` directory but your application is not available. Check the Liberty `messages.log` file for error messages. If you receive the CWWKZ0013E error message, you already have a web application running in the Liberty JVM server with the same name. To fix this problem, change the name of the web application and deploy to the `dropins` directory.

## Web application returns `Context Root Not Found`

You enabled your Liberty JVM server and deployed your web application. The JVM server reports it is enabled, but when you are accessing your application, you receive `Context Root Not Found`. Accessing the web application a short time later results in success. This is a known timing window in which the server reports it is enabled while applications are still starting in the background. You are more likely to experience this condition in a multi-region environment that uses Sysplex Distributor or port sharing. You are also likely to experience this condition if you use automation to access the application triggered from the `enabled` status. If you are using Sysplex Distributor or port sharing, TCP/IP automation can be used to silence a port and then resume the port once the web application is available. Workarounds might involve the addition of a pause in automation scripts, or the application writing a flag to a known location when it is available.

## Web application is not requesting authentication

You configured security, but the web application is not requesting authentication.

1. Although you can configure CICS security for web applications, the web application uses security only if it includes a security restraint in the WAR file. Check that a security restraint was defined by the application developer in the `web.xml` file in the Dynamic Web Project.
2. Check that the `server.xml` file contains the correct security information. Any configuration errors are reported in `dfhjvmerr` and might provide some useful information. If you are using CICS security, check that the feature **`cicsts:security-1.0`** is specified in `server.xml`. If CICS security is switched off, check that you specified a basic user registry to authenticate application users.
3. Check that `server.xml` is configured either for `<safAuthorization>` to take advantage of EJBRoles, or for a local role mapping in an `<application-bnd>` element. The `<application-bnd>` element is found with in the `<application>` element in `server.xml` or `installedApps.xml`. The default security-role added by CICS for a local role mapping is **`cicsAllAuthenticated`**.

## Web application is returning an HTTP 403 error code

The web application is returning an HTTP 403 error code in the web browser because either your user ID is revoked or you are not authorized to run the application transaction.

1. Check the CICS message log for the error message ICH408I to see what type of authorization failure occurred. To fix the problem, make sure that the user ID has a valid password and is authorized to run the transaction.
2. If no ICH408I message is found check the `messages.log` file.
   - For the following message:

     ```
     CWWKS3005E: A configuration exception has occurred.
     No UserRegistry implementation service is available. Â
     Ensure that you have a user registry configured.
     ```

     You must ensure that you have configured a SAF registry in `server.xml`. For more information, see Manually tailoring server.xml.
   - For the following message, when distributed identity is in use:

     ```
     CWWKS9104A:Â Authorization failed for user alidist:defaultRealm
     while invoking LdapTests on /basic.
     The user is not granted access to any of the required roles: [testing].
     ```

     IfÂ `server.xml` is configured for **`<safAuthorization>`** or includes the `cicsts:distributedIdentity-1.0` feature, then ensure the appropriate EJBRoles for the RACMAPped user ID have been defined. For more information, see Authorization using SAF role mapping. If `server.xml` is not configured for **`<safAuthorization>`** and does not include the `cicsts:distributedIdentity-1.0` feature, then ensure that the appropriate distributed user ID is defined to have access to the appropriate role in an **`<application-bnd>`** element. For more information, see Authorizing users to run applications in a Liberty JVM server.
3. If the application is retuning an exception for the class `com.ibm.ws.webcontainer.util.Base64Decode`, check `dfhjvmerr` for error messages. If you

see configuration error messages, for example CWWKS4106E or CWWKS4000E, the server is trying to access configuration files that were created in a different encoding. This type of configuration error can occur when you change the **`file.encoding`** value and restart the JVM server. To fix the problem, you can either revert to the previous encoding and restart the JVM server, or delete the configuration files. The JVM server re-creates the files in the correct file encoding when it starts.

## Web application is returning an HTTP 500 error code

The web application is returning an HTTP 500 error in the web browser. If you receive an HTTP 500 error, a configuration error occurred.

1. Check the CICS message log for DFHSJ messages, which might give you more information about the specific cause of the error.
2. If you are using a URIMAP to run application requests on a specific transaction, make sure that the URIMAP specifies the correct transaction ID.
3. Make sure that the SCHEME and USAGE attributes are set correctly. The SCHEME must match the application request, either HTTP or HTTPS. The USAGE attribute must be set to JVMSERVER.

## Web application is returning an HTTP 503 error code

The web application is returning an HTTP 503 error in the web browser. If you receive an HTTP 503 error, the application is not available.

1. Check the CICS message log for DFHSJ messages for additional information.
2. Make sure that the TRANSACTION and URIMAP resources for the application are enabled. If these resources are packaged as part of the application in a CICS bundle, check the status of the BUNDLE resource.
3. The request might have been purged before it completed. The error messages in the log describe why the request was purged.

## Unable to access your web application by using distributed identity mapping

If you are using distributed identity mapping and see the following message in the `messages.log` file:

```
FFDC1015I: An FFDC Incident has been created: "com.ibm.ws.security.saf.SAFException:

CWWKS2905E: SAF service IRRSIA00_CREATE did not succeed because
user null was not found in the SAF registry.
SAF return code 0x00000008. RACF return code 0x00000008. RACF reason code 0x00000010.

FFDC1015I: An FFDC Incident has been created:
"javax.security.auth.login.CredentialException: could not create SAF credential
for <distid> DistId
```

Check the CICS message log for the error message ICH408I to see what type of authorization failure occurred. If it is `ICH408I USER(<userid>) GROUP(TSOUSER ) NAME(<name>) DISTRIBUTED IDENTITY IS NOT DEFINED: 776 cn= <distid> DistId,ou=users,dc=domain,dc=com LdapRegistry` you need to create the appropriate RACMAP for the distributed identity being used to access the application. The **`RACMAP QUERY`** command is useful for debugging. For example:

```
RACMAP QUERY USERDIDFILTER(NAME('ou=users,dc=domain,dc=com')) REGISTRY(NAME('LdapRegistry'))
```

## The web application is returning exceptions

The web application is returning exceptions in the web browser; for example, the application is retuning an exception for the class `com.ibm.ws.webcontainer.util.Base64Decode`.

1. Check `dfhjvmerr` for error messages.
2. If you see configuration error messages, for example CWWKS4106E or CWWKS4000E, the server is trying to access configuration files that were created in a different encoding. This type of configuration error can occur when you change the **`file.encoding`** value and restart the JVM server. To fix the

problem, you can either revert to the previous encoding and restart the JVM server, or delete the configuration files. The JVM server re-creates the files in the correct file encoding when it starts.

## Error message WTRN0078E `An attempt by the transaction manager to call start on a transactional resource has resulted in an error.`

The error code was XAER_PROTO. If you experience this error, the most likely scenario is that you have the default JTA integration in operation on your Liberty server, and your application uses a bean method declared as REQUIRES_NEW. For example, the use of REQUIRES_NEW inside an XA transaction is not supported by CICS: `@Transactional(value = TxType.REQUIRES_NEW) void yourMethod{}` You must alter the application before it will run.

## Error message DFHSJ1004 in MSGUSER, but no corresponding STDERR exception

A symptom of running out of zFS file system space could be a DFHSJ1004 with no corresponding STDERR exception. The message is sent because of the lack of space, but there is no exception in STDERR because there is no space to write a message to the files.

You can plan and monitor the size of your file system using the techniques detailed in Managing file systems in z/OS UNIX System Services Planning.

## Using the `productInfo` script to verify integrity of Liberty

You can verify the integrity of the Liberty installation after you install CICS or applying service, by using the `productInfo` script.

1. Change directory to the `CICS USSHOME` directory.
2. As productInfo uses Java, you must ensure that Java is included in your PATH. Alternatively, set the **`JAVA_HOME`** environment variable to the value of **`JAVA_HOME`** in your JVM profile, for example:

   ```
   export JAVA_HOME=/usr/lpp/java/J8.0_64
   ```

3. Run the `productInfo` script, supplying the validate option `wlp/bin/productInfo validate`. No errors should be reported. For more information about the Liberty **`productInfo`** script, see Verifying the integrity of Liberty profile installation.

## Using the `wlpenv` script to run Liberty commands

You might be asked by IBM service to run one or more of the Liberty supplied commands, such as **`productInfo`** or **`server dump`**. To run these commands, you can use the `wlpenv` script as a wrapper to set the required environment. The script is created and updated every time that you enable a Liberty JVM server after the JVM profile has been successfully parsed. Because the script is unique for each JVM server in each CICS region, it is created in the *WORK_DIR/APPLID/JVMSERVER* as specified by default in the JVM profile and is called `wlpenv`. *APPLID* is the value of the CICS region APPLID and *JVMSERVER* is the name of the JVMSERVER resource.

To run the **`wlpenv`** script in the UNIX System Services shell, change directory to the *WORK_DIR* as specified in the JVM profile and run the script with the Liberty command as an argument, for example:

```
./wlpenv productInfo version
```

```
./wlpenv server dump --archive=package_file_name.dump.pax --include=heap
```

For the **`server dump`** command, you do not supply the server name because it is set by the `wlpenv` script to the value set the last time the JVM server was enabled.

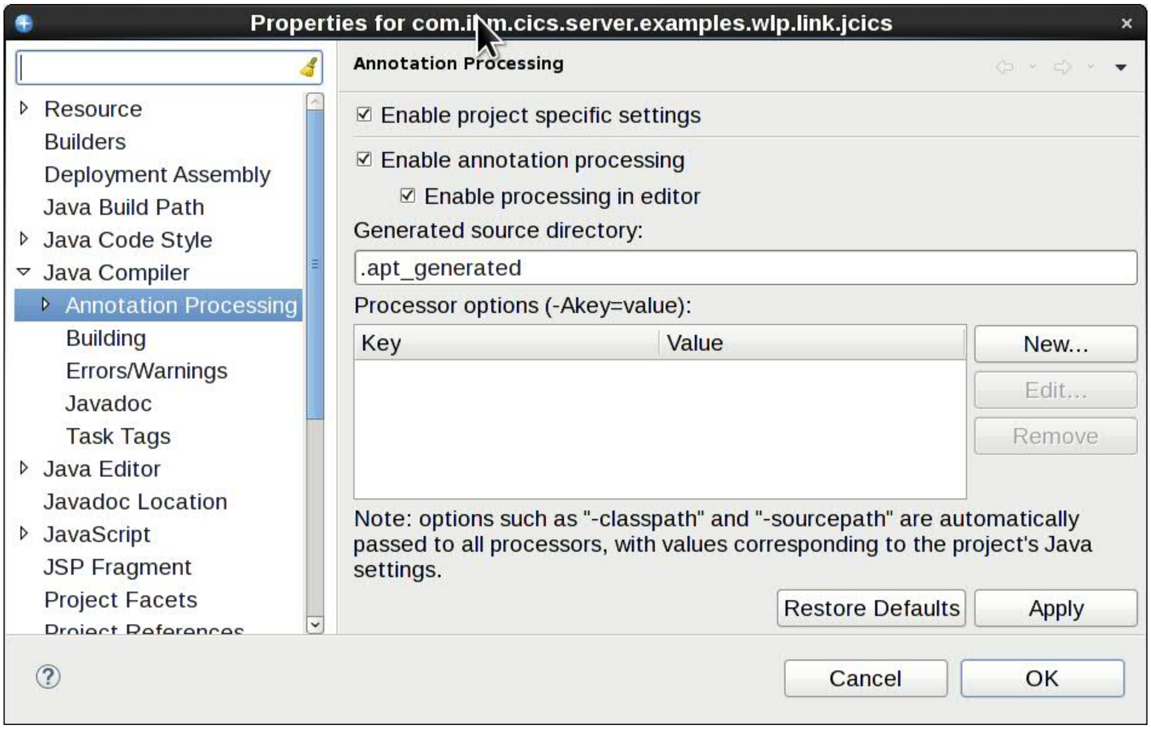
For more information about Liberty commands, see productInfo command and Generating a Liberty server dump from the command line.

## Troubleshooting invoking an Enterprise Java application

### EXEC CICS LINK command fails with RESP = PGMIDERR, RESP2 = 1

1. Check the application to determine whether the correct artifacts have been generated.

   a. Check that annotation processing is enabled on the source project.



Properties for com.ibm.cics.server.examples.wlp.link.jcics

Annotation Processing

☑ Enable project specific settings

☑ Enable annotation processing

☑ Enable processing in editor

Generated source directory: .apt_generated

Processor options (-Akey=value):

| Key | Value |
|---|---|

Note: options such as "-classpath" and "-sourcepath" are automatically passed to all processors, with values corresponding to the project's Java settings.

*Figure 39. Check annotation processing is enabled*

   b. Check if an `@CICSProgram` has been added to a Java method and that it compiles correctly.

   c. If your project contains a `web.xml`, check the version of the servlet specification it specifies. It must be at least version 2.5.

   d. Export the application and check for generated code in the `com.ibm.cics.server.invocation.proxy` package. For example, on a workstation, open the WAR or EAR file using an archive manager, or on z/OS use the `jar -tf` command, to examine the contents of the WAR or EAR file. If code has not been generated, check you have the latest version of the CICS Explorer, CICS build toolkit, or the annotation processor.

2. Review the CICS message log for messages similar to:

   - DFHSJ1204: A linkable service has been registered for class examples.TSQ.ClassOne method anotherMethod with program name LINKJCIN in JVMSERVER LINKJVM
   - DFHPG0101: Resource definition for LINKJCIN has been added.

   If these messages don't appear then:

   a. Ensure you have a Liberty JVM server in the enabled state.

   b. Ensure you have the `cicsts:link-1.0` feature configured in your `server.xml`. If it is configured you will see message `J2CA7001I: Resource adapter com.ibm.cics.wlp.program.link.connectorinstalled` in `messages.log`.

   c. If you are deploying your application using a CICS bundle, ensure the bundle is installed and enabled.

   d. Ensure the application is installed in Liberty, if it is, in the `messages.log` you will get a message including the name of the user's application. For example: `CWWKZ0001I: Application com.ibm.cics.test.javalink started.`

**`EXEC CICS LINK` command fails with RESP = PGMIDERR, RESP = 27**

This indicates that CICS tried to invoke an Enterprise Java application in Liberty but a timeout occurred before the application was successful. The most common cause for this issue is that there was no thread available in the JVM server. To resolve this, increase the JVM server thread limit or increase the value of WLP_LINK_TIMEOUT to allow the tasks to wait longer to acquire a thread. For more information see WLP_LINK_TIMEOUT in Symbols used in the JVM profile and Managing the thread limit of JVM servers.

**JCICS API call throws a CICSRuntimeException**

```
com.ibm.cics.server.CicsRuntimeException:
DTCTSQ_READNEXT: No JCICS context is associated with the current thread.
```

The most likely cause of this exception is that you created a JCICS object on one thread and tried to call its instance methods from a different thread. Change your application to construct the JCICS object on the same thread that calls its methods.

Patterns that lead to inadvertently using an object on a different thread include:

- Constructing a JCICS object in constructor of a `java.lang.Runnable` or `java.util.concurrent.Callable`. Construct the object in the `run()` method instead.
- Assigned JCICS objects to static variables. Use instance variables instead.
- Passing a JCICS object as a parameter to a method that is executed by another thread. The thread should construct JCICS object itself.

**Transaction abends AJ05 when using invoking an Enterprise Java application**

The following exceptions will be logged to the `dfhvjmerr` file:

```
com.ibm.cics.server.InvalidRequestException: CICS INVREQ Condition(RESP=INVREQ, RESP2=200)
java.lang.RuntimeException:
javax.transaction.RollbackException:
XAResource start association error:XAER_PROTO
```

Using JTA with Link to Liberty is only supported with CICS JTA integration disabled. Configure this by using `<cicsts_jta integration="false"/>` in `server.xml`.

## Java stack overflows

The Java error message `java.lang.StackOverflowError: operating system stack overflow` is typically seen when the thread exceeds the initial stack size for operating system threads. The size is set by the JVM option `-Xmso` in the JVM profile. This value might need to be increased if Java Platform Debugger Architecture (JPDA) is enabled.

## Unexpected ICH408I messages in log

These are standard audit messages. For more information, see Classes that control auditing for z/OS UNIX System Services in z/OS Security Server RACF Auditor's Guide.

You can prevent them from being issued by executing one of the following RACF commands

- `SETROPTS LOGOPTIONS(NEVER(IPCOBJ))`
- `SETROPTS LOGOPTION(DEFAULT(IPCOBJ))`

IPCOBJ is defined only for auditing z/OS UNIX security events, it is not used for authorization checking.

## Liberty Bundlepart hits timeout

In the JVM log or STDERR file, you see the message:

```
The application installed by bundlepart <symbolic-name> was not started
after 30000 milliseconds. Either a problem exists with the application, or the system is busy.
This timeout can be controlled by the System Property
'com.ibm.cics.jvmserver.wlp.bundlepart.timeout=n'
where n is the value of milliseconds to wait.
```

Check the Liberty `messages.log` for CWWKZ messages. CWWKZ messages might provide information on why the application has not started. If there are no CWWKZ messages for the application, make sure the `<config>` element is configured to use polling and has a monitor interval lower the timeout, for example:

```
<config updateTrigger="polled" monitorInterval="10s" />
```

If the monitor interval is less than the bundlepart timeout, you need to increase the timeout value. The timeout value is controlled by the JVM system property `com.ibm.cics.jvmserver.wlp.bundlepart.timeout`.

## CICS Explorer cannot export a bundle or find a project with error `Unable to find a built {project_type} with symbolic name {symbolic_name}.`

You might see the following validation errors when adding a project to your CICS bundle:

```
The bundle cannot be exported because CICS Explorer cannot find a built {project_type} with
symbolic name {symbolic_name}.
To resolve this, either install the IBM CICS SDK for Java EE, Jakarta EE and Liberty to build
the project or import the built {file_extension} project directly.
```

```
Unable to find a built OSGi Application Project with symbolic name {symbolic_name}.
To resolve this, either install LDT to find and validate projects in your workspace or add the
built EBA project into the root of the CICS bundle project.
```

```
Unable to find a {project_type} with symbolic name {symbolic_name}.
To resolve this, either import the {project_type} into your workspace or add the built
{file_extension} project into the root of the CICS bundle project.
```

Or this error when exporting a CICS bundle:

```
{symbolic_name} cannot be exported. Install the Liberty Developer Tools (LDT) from Eclipse
Marketplace.
```

```
The WAR, EAR or EBA cannot be exported. Install the IBM CICS SDK for Java EE, Jakarta EE and
Liberty.
```

**Why did it happen?**

For a project in the CICS bundle, CICS Explorer either finds the corresponding project in your workspace or validates whether a corresponding built binary file with the matching symbolic name exists so that the project can be exported with the bundle. One of the previous errors is returned if CICS Explorer fails to find such a built project.

Where:

**{project_type}**

Is the project type of the missing built project. It can be an OSGi Application Project or an Enterprise Application Project.

**{symbolic_name}**

Is the name of the missing built project, which is specified in the `cics.xml` file.

**{file_extension}**

Is the file format of the missing built project. It can be EBA or EAR.

**How to resolve the error?**

For an OSGi Application Project (EBA), follow instructions in the error messages to either install the IBM CICS SDK for Enterprise Java (Liberty), the Liberty Developer Tools (LDT), or both to validate and build the project, or add the corresponding built project to the root of your CICS bundle.

For an Enterprise Application Project (EAR) or a Dynamic Web Project (WAR), follow instructions in the error messages to install the IBM CICS SDK for Enterprise Java (Liberty), import the corresponding Enterprise Application Project or Dynamic Web Project into your workspace, or add the built EAR or WAR project to the root of your CICS bundle project.

### EBA application fails to install with a CWWKZ0005E or CWWKZ0021E messages

If Liberty fails to install an EBA, it produces either the CWWKZ0005E or CWWKZ0021E messages. This might be caused when the wab-1.0 feature is not installed. Ensure that the wab-1.0 feature is correctly installed.

Due to the stabilization of Liberty's OSGi support, WABs are not compatible with Java EE 8 features. The wab-1.0 feature can automatically be uninstalled if Java EE 8 features are also installed in the same Liberty server, causing any EBAs to be removed from the server with the above message. The JVM profile property com.ibm.cics.jvmserver.wlp.wab can be used to control whether the wab-1.0 feature is added to server.xml.

### Error message CWWKC2262E The server is unable to process the 4.0 version and the http://xmlns.jcp.org/xml/ns/javaee namespace

If the server is unable to process the 4.0 version and the http://xmlns.jcp.org/xml/ns/javaee namespace, this typically means that an application server, such as Tomcat has not been excluded from the build script. In Gradle, ensure that you have specified providedRuntime("org.springframework.boot:spring-boot-starter-tomcat"), while in Maven you have used the scope 'provided', for example:

```
<dependency>
<groupId>org.springframework.boot</groupId>
<artifactId>spring-boot-starter-tomcat</artifactId>
<scope>provided</scope>
</dependency>
```

## Controlling the location for JVM output, logs, dumps and trace

Output from Java applications that are running in a JVM server can be written to the z/OS UNIX files. The z/OS UNIX files are named by the STDOUT, STDERR, JVMLOG, and JVMTRACE options in the JVM profile or routed to the JES log. In a Liberty JVM server, Liberty server output can be found in messages.log relative to the configured log directory.

### Logs and Traces

By default, the output from Java applications that are running in a JVM server is written to the z/OS UNIX file system. The z/OS UNIX file system follows the file name convention DATE.TIME.<dfhjvmxxx> within the directory structure of $WORK_DIR/APPLID/JVMSERVER. Additional overrides can be used to route the output to the JES log. For more information, see Using a DD statement to route JVM server output to JES.

If you want to override the defaults, you can specify a zFS file name for the STDOUT, STDERR, JVMLOG, and JVMTRACE options. However, if you use a fixed file name, the output from all the JVMs that were created with that JVM profile is appended to the same file. The output from different JVMs is interleaved with no record headers. This situation is not helpful for problem determination.

If you customize these values, a better choice is to specify a variable file name for the STDOUT, STDERR, JVMLOG, and JVMTRACE options. The files can then be made unique to each individual JVM during the lifetime of the CICS region.

You can include the CICS region APPLID in the file name by using the *APPLID* symbol.

You can also include extra identifying information in file names. Other identifying information includes the *DATE* and *TIME* symbols.

*DATE* is replaced by the date the profile parses on JVM server start, in the form Dyymmdd.
*TIME* is replaced by the time the profile parses on JVM server start, in the format Thhmmss.
*JVMSERVER* is replaced by the name of the JVMSERVER resource.

Further customization can be achieved at the programmatic level that uses the USEROUTPUTCLASS option, which does not work with Liberty. The USEROUTPUTCLASS option, which is specified in the JVM profile, names a Java class. A Java class intercepts and redirects the output from the JVM to a custom location such as a CICS transient data queue. You can add time stamps and headers to the output records, and identify the output from individual transactions that are running in the JVM. CICS supplies sample classes that perform these tasks.

### Dumps

The location for the javacore (also known as a Java dump), heap and snaptrace outputs from the JVM is the working directory on z/OS UNIX named by the *JVMSERVER*'s `WORK_DIR` option in the JVM profile. These files are uniquely identified by a time stamp in their names. To override the default locations and names, you can use **`-Xdump:directory=<path>`** to specify a location for all dump types to be written to, and **`-Xdump:file=<filename>`** to specify the dump file names. For details about `-Xdump`, see -Xdump.

The more detailed Java system dumps are written to the data set named by the `JAVA_DUMP_TDUMP_PATTERN` option. You can use the *APPLID*, *DATE*, and *TIME*, and *JVMSERVER* symbols in this value to make the name unique to the individual JVM, as shown in the sample JVM profiles included with CICS. You can also use MVS symbols as supported by the IEATDUMP macro or dump agent tokens as supported by the JRE. For details about dump agent tokens see -Xdump and for details about MVS system symbols see What are system symbols?. You should ensure that the generated data set names are valid and can be allocated by the CICS region user ID otherwise first failure diagnostic information may be lost in the event of a system error.

**Note:** The terms **system dump** and **TDUMP** are occasionally used interchangeably. For clarification, **TDUMP** is a type of MVS system dump generated via IEATDUMP, producing an MVS transaction dump. Care should be taken to avoid confusing such MVS transaction dumps with CICS transaction dumps.

The JVM writes information to the `stderr` stream when it generates a javacore output or a system dump. For more information about the contents of javacore outputs and system dump files, see Troubleshooting and support.

## Using a DD statement to route JVM server output to JES

You can update the JVM server to redirect output to a specific location.

JVM server `STDOUT`, `STDERR`, `JVMLOG`, `JVMTRACE`, and `messages.log` output can be routed to the JES log. This allows JVM server log file output to be managed together with other CICS logs such as the `MSGUSR`.

Using the `JOBLOG` parameter results in `STDOUT`, `JVMLOG` and `JVMTRACE` being routed to `SYSPRINT` if defined or to a dynamic SYSnnn if not. If only `JVMTRACE=JOBLOG` is specified, `JVMTRACE` is routed to the current `stdout` location. `STDERR` is routed to `SYSOUT` if defined or to a dynamic SYSnnn if not, for example:

```
STDOUT=JOBLOG
STDERR=JOBLOG
JVMTRACE=JOBLOG
JVMLOG=JOBLOG
```

Output can also be routed to any MVS data definition (DD) defined to JES, for example if the CICS region JCL specifies the DD statements `JVMOUT`, `JVMERR`, and `MSGLOG`.

```
//JVMOUT   DD SYSOUT=*
//JVMERR   DD SYSOUT=*
//MSGLOG   DD SYSOUT=*    <--- redirects Liberty messages.log
```

If the DD statements configured in Liberty are not defined in CICS runtime JCL, these logs are automatically redirected to the specified DD output and are listed in CICS job output when Liberty is started.

The following JVM profile options can then be used in the JVM profile to route `stdout` and `stderr` streams to the `JVMOUT` and `JVMERR` destinations. If omitted, the JVM server will automatically create those destinations. A MSGLOG statement automatically redirects messages.log to JES without the need for any JVM profile configuration.

```
STDOUT=//DD:JVMOUT
STDERR=//DD:JVMERR
```

To establish the origin of the JVM server output, all stdout, and stderr entries that are routed to JES are written with a prefix string of the JVM server name, which is useful if multiple JVM servers are sharing a destination. This behavior can be disabled by using the JVM profile option IDENTITY_PREFIX, which if set to FALSE disables use of the prefix string.

It is not possible to route IBM Health Center messages to the CICS job log. Consider using zFS as the primary output location if you wish to see detailed IBM Health Center output.

If you choose not to specify a destination, the output will redirect to the zFS default file, however you can set it to send to specific zFS files. See "Controlling the location for JVM output, logs, dumps and trace" on page 345.

## Redirecting the JVM stdout and stderr streams

During application development, the USEROUTPUTCLASS option can be used by developers to separate out their own stdout and stderr entries in a CICS region, and direct them to an identifiable destination of their choice. You can use a Java class to redirect the output, and you can add time stamps and headers to the output records. Dump output cannot be intercepted by this method.

Specifying the USEROUTPUTCLASS option has a negative effect on the performance of JVMs. For best performance in a production environment, do not use this option.

Output that is written to System.out() or System.err(), either by an application or by system code, can be redirected by the output redirection class. The z/OS UNIX files that are named by the STDOUT and STDERR options in the JVM profile are still used for some messages that are issued by the JVM, or if the class named by the USEROUTPUTCLASS option is unable to write data to its intended destination. You must therefore still specify appropriate file names for these files.

To use the USEROUTPUTCLASS option, specify USEROUTPUTCLASS=[java class] in a JVM profile, naming the Java class of your choice. The class extends java.io.OutputStream. The supplied sample JVM profiles contain the commented-out option USEROUTPUTCLASS=com.ibm.cics.samples.SJMergedStream, which names the supplied sample class. Uncomment this option to use the com.ibm.cics.samples.SJMergedStream class to handle output from JVMs with that profile. CICS also supplies an alternative sample Java class, com.ibm.cics.samples.SJTaskStream.

For JVM servers, you package your output redirection class as an OSGi bundle to run the class in the OSGi framework. For more information, see Writing Java classes to redirect JVM stdout and stderr output.

**Note:** Output redirection samples function in OSGi and classpath JVM servers and not in a Liberty JVM server.

### The sample classes com.ibm.cics.samples.SJMergedStream and com.ibm.cics.samples.SJTaskStream

For Java application threads that can make CICS requests, you can intercept the output from the JVM and write it to a transient data queue. A log is created that correlates JVM activity with CICS activity.

You can add time stamps, task and transaction identifiers, and program names when the output is intercepted. You can therefore create a merged log file that contains the output from multiple JVMs. You can use this log file to correlate JVM activity with CICS activity. The sample class, com.ibm.cics.samples.SJMergedStream, is set up to create merged log files.

The com.ibm.cics.samples.SJMergedStream class directs output from the JVM to the transient data queues CSJO (for the stdout stream), and CSJE (for the stderr stream and internal messages). These transient data queues are supplied in group DFHDCTG, and they are redirected to CSSL, but you can redefine them if required.

By redirecting the output, the class adds a header to each record that contains the date, time, APPLID, TRANSID, task number, and program name. The result is two merged log files for JVM output and for error messages, in which the source of the output and messages can easily be identified.

The classes are shipped in the file `com.ibm.cics.samples.jar`, which is in the directory `/usr/lpp/cicsts/cicsts56/lib`, where `/usr/lpp/cicsts/cicsts56` is the installation directory for CICS files on z/OS UNIX. The source for the classes is also provided as samples, so you can modify the classes as you want, or write your own classes based on the samples. The classes are packaged as an OSGi bundle JAR. These classes can either be deployed into a CLASSPATH JVM server or as a middleware bundle that uses the OSGI_BUNDLES JVM server option in an OSGi JVM server. For more information, see Writing Java classes to redirect JVM stdout and stderr output.

Java applications that run on threads other than the ones that are attached by CICS are not able to make CICS requests. The output from the JVM cannot be redirected by using CICS facilities. The `com.ibm.cics.samples.SJMergedStream` class still intercepts the output and adds a header to each record. The output is written to the z/OS UNIX files `/`*`work_dir`*`/`*`applid`*`/stdout/CSJO` and `/`*`work_dir`*`/`*`applid`*`/stderr/CSJE` as referred to previously. If these files are unavailable, the output is written to the z/OS UNIX files named by the STDOUT and  STDERR options in the JVM profile.

As an alternative to creating merged log files for your JVM output, you can direct the output from a single task to z/OS UNIX files. You can also add time stamps and headers, to provide output streams that are specific to a single task. The sample class that is supplied with CICS, `com.ibm.cics.samples.SJTaskStream` is set up for this purpose. The class directs the output for each task to two z/OS UNIX files. One is for the `stdout` stream and one is for the `stderr` stream. The output entries within the streams are uniquely named by using a task number (in the format YYYYMMDD`.task.`*`tasknumber`*). The z/OS UNIX files are stored in directories called STDOUT and STDERR respectively. The process is the same for Java applications which run on threads that are attached by CICS, and Java applications that are running on other threads.

## Error handling

The length of messages that are given by the JVM can vary. The maximum record length for the CSSL queue (133 bytes) might not be sufficient to contain some of the messages you receive. If you receive more messages than the maximum record length for the queue, the sample output redirection class issues an error message. The text of the message might be affected.

If you find that you are receiving messages longer than 133 bytes from the JVM, redefine CSJO and CSJE as separate transient data queues. Make them extrapartition destinations, and increase the record length for the queue. You can allocate the queue to a physical data set or to a system output data set. You might find a system output data set more convenient in this case, because you do not then need to close the queue to view the output. For information about how to define transient data queues, see TDQUEUE resources. If you redefine CSJO and CSJE, ensure that they are installed as soon as possible during a cold start, in the same way as for transient data queues that are defined in group DFHDCTG.

If the transient data queues CSJO and CSJE cannot be accessed, output is written to the z/OS UNIX files `/`*`work_dir`*`/`*`applid`*`/stdout/CSJO` and `/`*`work_dir`*`/`*`applid`*`/stderr/CSJE`, where *work_dir* is the directory that is specified on the `WORK_DIR` option in the JVM profile, and *applid* is the APPLID identifier that is associated with the CICS region. If these files are unavailable, the output is written to the z/OS UNIX files named by the STDOUT and STDERR options in the JVM profile.

When an error is encountered by the sample output redirection classes, one or more error messages are given. If the error occurred while you processed an output message, then the error messages are directed to `System.err`, and are eligible for redirection. However, if the error occurred while you processed an error message, then the new error messages are sent to the file named by the STDERR option in the JVM profile, avoiding a recursive loop in the Java class. The classes do not return exceptions to the calling Java program.

### Control of Java-related dump options

The -Xdump option can be used in a JVM profile to specify dump options to the JVM.

Information about Java-related dump options can be found in Troubleshooting and support.

## CICS component tracing for JVM servers

In addition to the logging produced by Java, CICS provides some standard trace points in the SJ (JVM) and AP domains for 0, 1, and 2 trace levels. These trace points trace the actions that CICS takes in setting up and managing JVM servers.

You can activate the SJ and AP domain trace points at levels 0, 1, and 2 using the CETR transaction. For details of all the standard trace points in the SJ domain, see JVM and Node.js runtime domain trace points.

### SJ and AP component tracing

The SJ component traces exceptions and processing in SJ domain to the internal trace table. The AP component traces the installation of OSGi bundles in the OSGi framework. SJ level 3, 4, and 5 tracing produce Java logging that is written to a trace file in zFS. The name and location of the trace file is determined by the JVMTRACE option in the JVM profile.

SJ level 4 and 5 tracing produces verbose logging information in the trace file. If you want to use this trace level, you must ensure that there is enough space in zFS for the file. For more information about activating and managing trace, see “Activating and managing tracing for JVM servers” on page 349.

## Activating and managing tracing for JVM servers

You can activate JVM server tracing by turning on SJ and AP component tracing. Small amounts of trace are written to the internal trace table, but Java also writes out logging information to a unique file in zFS for each JVM server. This file does not wrap so you must manage its size in zFS.

### About this task

JVM server tracing does not use auxiliary or GTF tracing. CICS writes some information to the internal trace table. However, most diagnostic information is logged by Java and written to a file in zFS. This file is uniquely named for each JVM server. The default file name has the format `&DATE;.&TIME;.dfhjvmtrc` and is created by CICS in the `$WORK_DIR/&APPLID;/&JVMSERVER;` directory when you enable the JVMSERVER resource. You can change the name and location of the trace file in the JVM profile. If you delete or rename the trace file when the JVM server is running, CICS does not re-create the file and the logging information is not written to another file.

### Procedure

1. Use the CETR transaction to activate tracing for the JVM server.

   You can use two components to produce tracing and logging information for a JVM server:

   - Select the SJ component to trace the actions taken by CICS to start and stop the JVM server. The JVM logs diagnostic information in the zFS file.
   - Select the AP component to trace the installation of OSGi bundles.
2. Set the tracing level for the SJ and AP components:

   - SJ level 0 produces tracing for exceptions only, such as errors during the initialization of the JVM server or problems in the OSGi framework. SJ level 1 and level 2 produces more CICS tracing from the SJ domain. This tracing is written to the internal trace table.
   - SJ level 3 produces additional logging from the JVM, such as warning and information messages in the OSGi framework. This information is written to the trace file in zFS.

- SJ level 4, 5 and AP level 2 produce debug information from CICS and the JVM, which provides much more detailed information about the JVM server processing. This information is written to the trace file in zFS.

3. Each trace entry has a date and time stamp. You can change the name and the location of this trace file by using the `JVMTRACE` profile option.
4. If you are using the default `JVMTRACE` settings, when you enable the JVMSERVER resource CICS creates a new unique trace file for the life of the JVM.

   If you disable the JVMSERVER resource, you can delete the trace file or rename the file if you want to retain the information separately.
5. To manage the number of files you can set the LOG_FILES_MAX option to control the number of old trace files that are retained on the JVM server startup.

## Debugging a Java application

The JVM in CICS supports the Java Platform Debugger Architecture (JPDA), which is the standard debugging mechanism provided in the Java Platform.

### About this task

You can use any tool that supports JDPA to debug a Java application running in CICS. For example, you can use the Java Debugger (JDB) that is included with the Java SDK on z/OS. To attach a JPDA remote debugger, you must set some options in the JVM profile.

**Note:** The use of JPDA might require a larger stack size for operating system threads. The stack size for operating threads can be configured in the JVM profile with option `-Xmso`. You should review your existing profiles for artificially constrained lower values. The default stack size is now 1M, which matches the stack size of the 64bit JVM.

IBM provides monitoring and diagnostic tools for Java, including Health Center. IBM Health Center is available in the IBM Support Assistant Workbench. These free tools are available to download from IBM as described in the Getting Started guide for IBM Health Center.

### Procedure

1. Add the debugging option to the JVM profile to start the JVM in debug mode:

   ```
   -agentlib:jdwp=transport=dt_socket,server=y,address=port,suspend=n
   ```

   Select a free port to connect to the debugger remotely.

   If the JVM profile is shared by more than one JVM server, you can use a different JVM profile for debugging.

   **Note:** The default value for suspend is y. This value suspends the JVM and waits for the remote client debugger to attach before processing continues. Specifying a value of n will prevent the JVM server from suspending.
2. Add these properties to the JVM profile when debugging a Liberty JVM server to avoid hot-swap complications with Liberty trace. This will also indicate to Liberty that it should operate in a debug cognizant mode:

   ```
   -Dwas.debug.mode=true
   -Dcom.ibm.websphere.ras.inject.at.transform=true
   ```
3. Attach the debugger to the JVM.

   If an error occurs during the connection, for example the port value is incorrect, messages are written to the JVM standard output and standard error streams.
4. Using the debugger, check the initial state of the JVM. For example, check the identity of threads that are started and system classes that are loaded.

5. Set a breakpoint at a suitable point in the Java application by specifying the full Java class name and source code line number. If the debugger indicates that activation of this breakpoint is deferred, it is because the class might not yet have loaded.

   Let the JVM run through the CICS middleware code to the application breakpoint, at which point it suspends execution again.
6. Examine the source code of the loaded classes and variables and set further breakpoints to step through the code as required.
7. End the debug session. You can let the application run to completion, at which point the connection between the debugger and the CICS JVM closes. Some debuggers support forced termination of the JVM, which results in an abend and error messages on the CICS system console.

## The CICS JVM plug-in mechanism

In addition to the standard JPDA debug interfaces in the JVM, CICS provides a set of interception points (plug-ins) in the CICS Java middleware, which can be useful for debugging applications. You can use these plug-ins to insert additional Java programs immediately before and after the application Java code is run.

Information about the application, for example, class name and method name, is made available to the plug-ins. The plug-ins can also use the JCICS API to obtain information about the application, and can also be used in conjunction with the standard JPDA interfaces to provide additional debug facilities specifically for CICS. The plug-ins can also be used for purposes other than debugging, in a similar way to CICS user exits.

The Java exit is a CICS Java wrapper plug-in that provides methods that are called immediately before and after a Java program is invoked.

To deploy a plug-in, you package the plug-in as an OSGi bundle. For more information see Deploying OSGi bundles in a JVM server.

Two Java programming interfaces are provided.

Both interfaces are supplied in `com.ibm.cics.server.jar`, and are documented in the Javadoc.

The Java programming interfaces are:

- DebugControl: `com.ibm.cics.server.debug.DebugControl`. This programming interface defines the method calls that can be made to an implementation supplied by the user.
- Plugin: `com.ibm.cics.server.debug.Plugin`. This is a general purpose programming interface that you use for registering the plug-in implementation.

Here is an example of the DebugControl interface:

```
public interface DebugControl
{
    // called before an application object method or program main is invoked
    public void startDebug(java.lang.String className,java.lang.String methodName);

    // called after an application object method or program main is invoked
    public void stopDebug(java.lang.String className,java.lang.String methodName);

    // called before an application object is deleted
    public void exitDebug();

}
public interface Plugin
{
    // initaliser, called when plug-in is registered
    public void init();
}
```

Here is an example implementation of the DebugControl and Plugin interfaces:

```
import com.ibm.cics.server.debug.*;

public class SampleCICSDebugPlugin
```

```
    implements Plugin, DebugControl
{
    // Implementation of the plug-in initialiser
    public void init()
    {
        // This method is called when the CICS Java middleware loads and
        // registers the plug-in. It can be used to perform any initialization
        // required for the debug control implementation.
    }

    // Implementations of the debug control methods
    public void startDebug(java.lang.String className,java.lang.String methodName)
    {
        // This method is called immediately before the application method is
        // invoked. It can be used to start operation of a debugging tool. JCICS
        // calls such as Task.getTask can be used here to obtain further
        // information about the application.
    }

    public void stopDebug(java.lang.String className,java.lang.String methodName)
    {
        // This method is called immediately after the application method is
        // invoked. It can be used to suspend operation of a debugging tool.
    }

    public void exitDebug()
    {
        // This method is called immediately before an application object is
        // deleted. It can be used to terminate operation of a debugging tool.
    }

    public static void main(com.ibm.cics.server.CommAreaHolder ca)
    {
    }
}
```

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IBM CICS supplies some documentation that can be considered to be Programming Interfaces, and some documentation that cannot be considered to be a Programming Interface.

Programming Interfaces that allow the customer to write programs to obtain the services of CICS Transaction Server for z/OS, Version 5 Release 6 (CICS TS 5.6) are included in the following sections of the online product documentation:

- Developing applications
- Developing system programs
- CICS TS security
- Developing for external interfaces
- Application development reference
- Reference: system programming
- Reference: connectivity

Information that is NOT intended to be used as a Programming Interface of CICS TS 5.6, but that might be misconstrued as Programming Interfaces, is included in the following sections of the online product documentation:

- Troubleshooting and support
- CICS TS diagnostics reference

If you access the CICS documentation in manuals in PDF format, Programming Interfaces that allow the customer to write programs to obtain the services of CICS TS 5.6 are included in the following manuals:

- Application Programming Guide and Application Programming Reference
- Business Transaction Services

- Customization Guide
- C++ OO Class Libraries
- Debugging Tools Interfaces Reference
- Distributed Transaction Programming Guide
- External Interfaces Guide
- Front End Programming Interface Guide
- IMS Database Control Guide
- Installation Guide
- Security Guide
- CICS Transactions
- CICSPlex System Manager (CICSPlex SM) Managing Workloads
- CICSPlex SM Managing Resource Usage
- CICSPlex SM Application Programming Guide and Application Programming Reference
- Java Applications in CICS

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- Data Areas
- Diagnosis Reference
- Problem Determination Guide
- CICSPlex SM Problem Determination Guide

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