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System - Managed CF Structure Duplexing

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Overview

System-Managed Coupling Facility (CF) Structure Duplexing (generally referred to as "CF Duplexing" throughout this paper) is designed to provide a general purpose, hardware assisted, easy-to-exploit mechanism for duplexing CF structure data. This can provide a robust recovery mechanism for failures such as loss of a single structure or CF, or loss of connectivity to a single CF, through rapid failover to the other structure instance of the duplex pair.

Benefits of System-Managed CF Structure Duplexing can include:

- ***Availability***
  Faster recovery of structures by having the data already in the second CF when a failure occurs. Furthermore, if a potential IBM, vendor, or customer CF exploitation were being prevented due to the effort required to provide alternative recovery mechanisms such as structure rebuild, log recovery, etc., System-Managed CF Structure Duplexing could provide the necessary recovery solution.
- ***Manageability and Usability***
  Provides a consistent procedure to set up and manage structure recovery across multiple exploiters
- ***Configuration Benefits***
  Enables the use of internal CFs for all resource sharing and data sharing environments

As there are benefits to be derived from System-Managed CF Structure Duplexing, there are also costs associated with its exploitation. These costs are dependent upon which structures are being duplexed and how those structures are being accessed by applications executing in a particular Parallel Sysplex® environment.

Costs of System-Managed CF Structure Duplexing can include:
- *Increased z/OS® CPU utilization*
- *Increased coupling facility CPU utilization*
- *Increased coupling facility link utilization*

A cost/benefit analysis should be performed for each structure prior to enabling it for System-Managed CF Structure Duplexing. This paper presents the background information and a methodology necessary for performing such an analysis.

Evolution of Parallel Sysplex Recovery

Before System-Managed CF Structure Duplexing, z/OS had several potential mechanisms for providing recovery in hard failure scenarios, each with its own availability characteristics:

1. ***No Recovery***
   Some structures provide no recovery mechanism whatsoever for hard failures. Whatever data is placed in the CF structure, along with whatever processing is dependent on that data, is therefore unrecoverable in a failure scenario. Prior to System-Managed CF Structure Duplexing, CICS® Shared Temporary Storage structures and Websphere MQ Shared Queue (non-persistent messages) structures were two examples of this. Typically, these structures contain either Read-Only or "scratch-pad" data in which recovery is not a major issue.

2. ***Disk Backup***
   Some structures recover from hard failures by maintaining another hardened copy of the data on another medium such as disk. For example, data in a directory-only cache or store-thru cache structure is hardened on disk, and is therefore recoverable from disk in the event of loss of the CF structure. System Logger's use of staging data sets to maintain a second copy of the logstream data from the time it is written to the CF until it is offloaded is another example. Such structure exploiters typically incur a substantial mainline performance cost to write their updates synchronously to disk.

3. ***User-managed rebuild***
   User-managed rebuild was introduced along with initial Coupling Facility support in MVS/ESA™ SP5.1.0. This process allowed MVS™ to coordinate a structure rebuild process with all of the active connected users of the structure, in which those connectors participate in the steps of allocating a new structure instance, propagating the necessary structure data to the new structure, and switching over to using the new structure instance. User-Managed Rebuild typically uses either an in-storage copy or a log to provide the data needed for structure recovery.

   User-managed rebuild provides both a planned reconfiguration capability and, in most cases, a robust failure recovery capability for CF structure data, but often requires significant amounts of support from the structure connectors. In some cases, it is either impossible to recover, or requires an elongated recovery process for the structure connectors to reconstruct the structure data. This happens when the structure is lost in conjunction with one or more of the active connectors to the structure, and the connectors' protocol for rebuilding the structure requires each of the active connectors to provide some portion of the data in order to reconstruct the complete contents of the structure that was lost.

   Without System-Managed CF Structure Duplexing, these structures require "Failure Isolation," separating the structure and its connectors into different servers, perhaps requiring the presence of one or more standalone CFs in the configuration. There is a demand to be able to use an ICF-only configuration in both a Resource Sharing and Data Sharing environment. The issue of failure isolation, of being able to effectively repopulate a structure if a structure on a CF image together with one of its connectors should be lost due to an (unlikely) hardware failure, currently limits internal CF usage for certain data sharing *structures. System-Managed CF Structure Duplexing resolves these failure isolation issues and can enable the use of ICF-only configurations for duplexed data sharing structures.*

4. ***User-managed duplexing***
   Some structures can recover from hard failures through user-managed duplexing failover. For example, changed data in a duplexed DB2® group buffer pool (GBP) cache structure can be recovered in this way. Such structure exploiters may obtain both very good mainline performance (taking advantage of the exploiter's intimate knowledge of the nature of the data contained in the structure and its usage, and of the exploiter's pre-existinsting serialization protocols that protect updates to the data, as performance optimizations) and excellent availability in failure situations due to the rapid duplexing failover capability.

   User-managed duplexing support was introduced on OS/390 R6. It allowed OS/390 to coordinate a duplexing structure rebuild process with all of the active connected users of the structure, in which those connectors participate in the steps of allocating a new structure instance, propagating the necessary structure data to the new structure, but then keeping both structure instances allocated indefinitely. Having thus created a duplexed copy of the structure, the connectors may then proceed to duplex their ongoing structure updates into both structure instances, using their own unique serialization or other protocols for ensuring synchronization of the data in the two structure instances.

   User-managed duplexing addresses the shortcoming noted above for user-managed rebuild, in which it is impossible or impractical for the structure exploiters to reconstruct the structure data when it is lost as a result of a failure. With user-managed duplexing, the exploiter can build and maintain a duplexed copy of the data in advance of any failure, and then when a failure occurs, simply switch over to using the unaffected structure instance in simplex mode. User-managed duplexing thus provides a very robust failure recovery capability, but because it is a user-managed process, it requires significant exploiter support from the structure connectors.

   In addition, user-managed duplexing is limited to cache structures only; list and lock structures are not supported.

5. ***System-managed rebuild***
   System-managed rebuild was introduced in OS/390 R8. This process allows OS/390 to internalize many aspects of the user-managed rebuild process that formerly required explicit support and participation from the connectors. OS/390 will internally allocate the new structure and propagate the necessary structure data to the new structure, then switch over to using the new structure instance.

   System-managed rebuild is only able to propagate the data to the new structure by directly copying it, so that system-managed rebuild provides only a planned reconfiguration capability. It is not capable of rebuilding the structure in failure scenarios, and thus does not provide a robust failure recovery mechanism at all. However, by internalizing many of the "difficult" steps in the rebuild process into OS/390 and taking them out of the hands of the connectors, system-managed rebuild greatly simplifies the requirements on the structure exploiters, drastically reducing the cost for the exploiters to provide a planned-reconfiguration rebuild capability.

6. ***System-Managed CF Structure Duplexing***
   None of the above approaches are ideal. Several of them have significant performance overheads associated with them during mainline operation (for example, the cost of synchronously hardening data out to disk in addition to the CF in a store-thru cache model); some of them compromise availability in a failure scenario by involving a potentially lengthy rebuild or log recovery process during which the data is unavailable (for example, log merge and recovery for an unduplexed DB2 group buffer pool cache). Furthermore, some of these recovery approaches involve considerable development effort on the part of the CF exploiters to provide the appropriate level of recovery, as each exploiter implements its own unique recovery mechanisms.

   System-Managed CF Structure Duplexing is designed to address these problems by creating a duplexed copy of the structure prior to any failure and maintaining that duplexed copy during normal use of the structure by transparently replicating all updates to the structure in both copies, and provides a robust failure recovery capability through failover to the unaffected structure instance. This results in:

   - *An easily exploited common framework for duplexing the structure data contained in any type of CF structure, with installation control over which structures are/are not duplexed.*
   - *High availability in failure scenarios by providing a rapid failover to the unaffected structure instance of the duplexed pair with very little disruption to the ongoing execution of work by the exploiter and application.*

System-Managed CF Structure Duplexing thus is designed to provide the "best of all possible worlds" — robust failure recovery capability via the redundancy of duplexing, and low exploitation cost via system-managed, internalized processing. Structure failures, CF failures, or losses of CF connectivity can be handled by:

1. *Masking the observed failure condition from the active connectors to the structure, so that they do not perform any unnecessary recovery actions,*
2. *Switching over to the structure instance that did not experience the failure, and*
3. *Re-establishing a new duplex copy of the structure, if appropriate, as the Coupling Facility becomes available again, or on a third CF in the Parallel Sysplex.*

System messages are generated as the structure falls back to simplex mode for monitoring and automation purposes. Until a new duplexed structure can be established, the structure operates in simplex mode, and can be recovered using whatever existing recovery techniques are supported by the exploiter (such as user-managed rebuild).

System-Managed CF Structure Duplexing's main focus is providing this robust recovery capability for structures whose users do not support user-managed duplexing and/or do not support user-managed rebuild.

Anatomy of a Duplexed CF Operation

When z/OS receives a CF exploiter's update request for a duplexed CF structure (for example, writing database data to the CF, or obtaining a lock in the CF), z/OS will first split the exploiter's request into two distinct CF requests, one destined for each of the two structure instances. The two requests are launched serially by a routine running disabled on a z/OS CP. z/OS tries to launch these two requests at as close to the same time as possible so that the CF commands can execute at the two CFs with the maximum amount of parallelism, but (as discussed later in this document) sometimes configuration issues can interfere with z/OS's ability to do this successfully.

Once the two commands arrive at their respective CFs, they need to coordinate their execution so that the update to the duplexed structure is synchronized between the two structure instances. In effect, the commands must be made to execute in "lockstep" with one another to preserve the logical appearance to the CF exploiter that there is a single consistent copy of the data. To do this, the CFs will exchange signals with one another over a CF-to-CF coupling link, a new configuration requirement for System-Managed CF Structure Duplexing. The CF commands may suspend and later resume their execution while they wait for the arrival of the necessary duplexing signals from the "peer" duplexed command executing in the other CF. Once again (as discussed later in this document), configuration issues may interfere with the ability of these CF-to-CF signals to be exchanged efficiently, or with the ability of the CF commands to resume execution in a timely manner after the arrival of a synchronization signal for which it was waiting. Once both of the duplexed commands have exchanged all the required signals and completed execution, they each return their individual command responses to the z/OS system that originated them.

As is true for simplex requests, z/OS can process the completion of duplexed requests in either a CPU-synchronous or a CPU-asynchronous manner. z/OS can either spin synchronously on the originating CPU polling for the completion of both operations, or it can give up control to process other work and eventually observe the completion of the two CF operations asynchronously. In z/OS 1.2 and above, the decision of whether requests are completed synchronously or asynchronously is largely under the control of a new conversion algorithm (see Washington Systems Center Flash 10159 for additional information http://www.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/FLASH10159) that takes into account the observed service times of the requests in comparison with the speed of the processor that originated the requests.

Regardless of how the requests are completed, z/OS inspects each of the responses, validates that the results are consistent between the two CFs, and then merges the results of the operations into a single consolidated request response. It is this consolidated response that is presented back to the CF exploiter, whose mainline request processing is therefore completely unaware of whether the structure being used is operating in simplex or duplex mode. (System-Managed CF Structure Duplexing is largely transparent to the exploiter, as far as the execution of mainline CF commands is concerned. However, z/OS does provide a notification to the exploiters of structure transitions into and out of the duplexed state so that the exploiter can react to this in other ways. For example, exploiters might have other mechanisms for providing data backup/redundancy that would need to operate only when their structure was operating in simplex mode.)

When to Configure System-Managed CF Structure Duplexing

While there is value in System-Managed CF Structure Duplexing, IBM does not recommend its use in all situations, nor should it necessarily be used for all of the structures that support it. A cost/benefit evaluation must first take place. There is a performance cost associated with the additional work that z/OS needs to do to send and receive two CF requests instead of one, and with the additional CF-to-CF communication involved in synchronizing updates to the two structure instances. These costs have to be weighed against the benefits of structure recovery and operational simplicity that duplexing can provide.

Some structures will obtain more benefit from System Managed duplexing than others.

1. *Structures that don't support user-managed rebuild for recovery purposes should obtain the most benefit. These are the structures in Appendix C that have* ***NO*** *in the User Managed Rebuild column (highlighted in red).*
2. *Some logging functions that currently use disk for staging datasets to duplicate data in structures. In some cases, the performance degradation when using disk is so great that staging datasets are not implemented. Using system-managed duplexing instead of stating datasets makes duplication more practical and thus improves availability. Generally, these are the structures in Appendix C that have "****Logger****" in the Structure column.*
3. *Structures which require failure-isolation from exploiting z/OS images in order to be able to rebuild must be located in a failure-isolated (e.g. Standalone) CF when in simplex mode, but can be located on an internal CF if CF Duplexing is used for them. These are the structures in Appendix C that have FAIL-ISOL in the User Managed Rebuild column (highlighted in yellow). Note that prior to CF Duplexing, logger structures generally required either the use of staging data sets or that the structure was failure-isolated from exploiting z/OS images in order to be fully recoverable, which is why these structures are highlighted in yellow twice in Appendix C.*

A staged approach to enabling system-managed duplexing allows the installation to assess the costs and benefits at each increment. First implement duplexing for those structures that don't support user-managed rebuild at all (case 1 above), assess their performance and operational characteristics, then proceed through case 2 and 3 above, assessing the performance and capacity requirements at each step.

More details on how to determine the cost of System-Managed CF Structure Duplexing are found later in this document.

System Logger

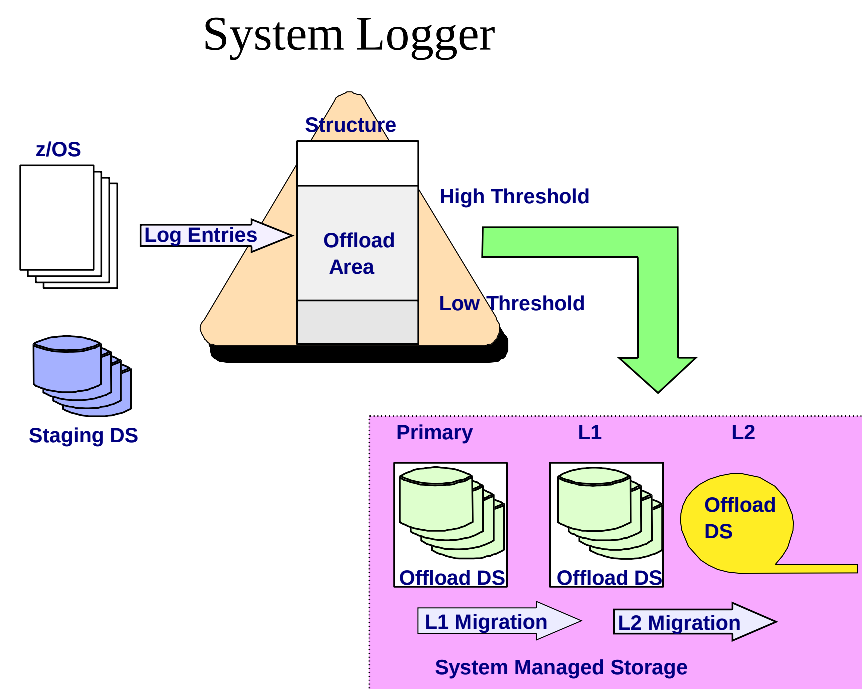
The System Logger is designed to provide its own backup copy of log data written to a CF structure for recovery capability. The Logger keeps its backup copy of the structure data either in local buffers (data spaces associated with the IXGLOGR address space) or in log stream staging data sets. This allows the Logger to provide recovery of log data in the event of many types of CF, structure, or system failures.

System-Managed CF Structure Duplexing provides an alternative to the previous means of providing recovery for log stream data. It is designed to provide greater recoverability opportunities over Logger local buffer duplexing.

The chart shows the types of storage used by the z/OS system logger. Primary storage consists of a data space in the same z/OS image as the System Logger, and a staging data set. Data is then offloaded to the Offload Data Set, then migrated to tape through HSM.

A benefit from System-Managed CF Structure duplexing from the System Logger will come from eliminating staging data sets as a requirement for availability. There are two major users of staging data sets: RRS and CICS. RRS has recommended that its data be backed by staging data sets to obtain better recoverability characteristics than using data spaces. IBM recommends a CF structure, and not DASD-Only logging, to provide the ability to restart a resource manager on a different partition.

CICS generally does not recommend the use of logger staging data sets due to the performance cost. However, there are cases when staging data sets are recommended.



These are:

- *The Coupling Facility is volatile (no internal battery backup or UPS)*
- *A Coupling Facility is not failure-isolated from the z/OS connector on different servers.*
- *A structure failure resulted in the only copy of log data being in z/OS local storage buffers*
- *DASD-only logging is implemented. For DASD-only log streams, staging data sets are the primary (interim) storage.*

STG_DUPLEX(YES) and DUPLEXMODE(COND) for the forward recovery and system log logstreams is recommended to cause the system logger to automatically allocate staging data sets if the Coupling Facility is not failure isolated.

Staging data sets must be used in a GDPS® disaster recovery environment to initiate a disk remote copy of the data to the remote site without waiting for the system logger structure to write the data to an offload dataset. More information on duplexing with GDPS can be found in a later section in this document.

VTAM Generic Resources

VTAM® Generic Resources provide a single system image to the Parallel Sysplex cluster for the end user at session logon time. A single generic name is presented to the z/OS Communication Server, where the session is then routed to one of the active session managers that has this generic name defined. Availability is improved, because when a member of the Parallel Sysplex fails, users can log on again using the same generic application name. The sessions are reestablished with another member of the sysplex.

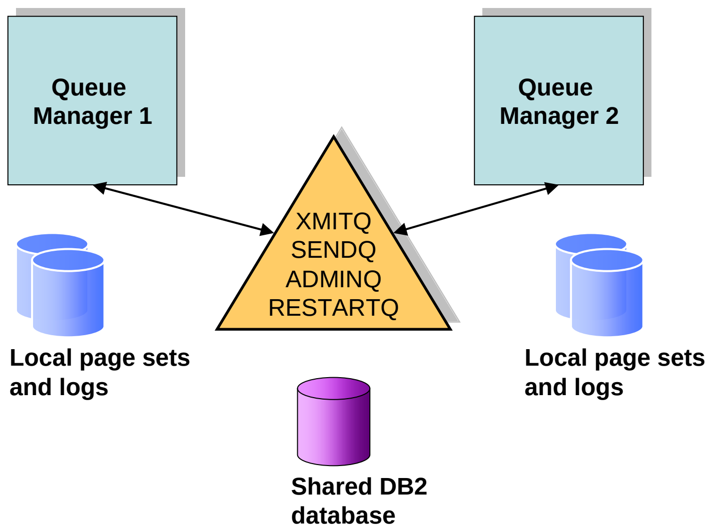
Taken in isolation, the VTAM Generic Resource structure can be rebuilt quickly, but if there are many structures that need to be rebuilt at the same time such as in a loss of connectivity situation, it can take a couple of minutes to complete VTAM Generic Resource structure rebuild. During this time while the Generic Resource structure is unavailable, users would be unable to log off a session or establish a session to the session manager, even if a specific name is used. LU requests are queued until the rebuild completes.

The end user impact of this depends on how VTAM generic resources are used within an installation.

Since the VTAM Generic Resource structure gets updated only when session status changes, there is no significant cost to duplexing the structure.

WebSphere MQ

WebSphere MQ has support for shared queues for messages stored in Coupling Facility structures. Applications running on multiple queue managers in the same queue-sharing group anywhere in the Parallel Sysplex cluster can access the same shared queues. This provides high availability, high capacity, and pull workload balancing. It is designed so that work can continue without interruption if an individual application instance or queue manager should fail or be recycled, as other instances of the same application accessing the same shared queues can continue to do the work. Throughput is no longer constrained by the capability of a single queue manager, as multiple queue managers can access the same shared queues. Automatic pull workload balancing can be achieved as the least constrained application instance will process the most messages.



Since non-persistent messages are not logged on disk, a loss of connectivity or a failure of the shared queue structure or the Coupling Facility would result in the loss of the shared (non-persistent) MQ message queue. In addition, all queue managers connected to the shared queue would fail together with non-persistent messages on their local queues. Similarly, if there is a loss of connectivity to the MQ administration structure or the structure or CF fails, then all queue managers using that structure would fail. System-Managed CF Structure Duplexing supplies higher availability for the non-persistent messages by providing higher availability for the CF structures containing them. Although some may chose to not duplex the shared queues due to performance impact, it is highly recommended to duplex the administration structure.

IMS

IMS™ supports many structures, depending upon the environment that is implemented. The value obtained from System-Managed CF Structure Duplexing differs for each of these environments.

IMS Full Function Data Sharing. The full function data sharing support as provided since IMS V5 requires up to three structures:

- *IRLM Lock*
- *OSAM Cache*
- *VSAM Cache*

The OSAM and VSAM Cache structures are implemented with either a "Directory-only" or a "Store-through" model. As data is written to the IMS local buffer pool, structure, it is designed to be simultaneously written to disk as well (and optionally to the OSAM structure). This is designed to make recovery easy in the loss of these structures as IMS would be able to access the data from disk and rebuild the structures as needed. Recovery of the IRLM lock structure for IMS (as well as for DB2) is fast; on the order half a minute. Because of these rapid recovery characteristics, outside of enabling the failure-isolation environment as recommended by IRLM, System-Managed CF Structure Duplexing provides little additional value in this environment.

IMS Shared Fast Path: IMS Fast Path Data Entry Data Bases (DEDB) come with the options of configuring them as DEDBs with SDEPs, and DEDBs with VSO (Sequential DEPendants, and Virtual Storage Option). While the shared DEDB/SDEP databases only require use of the (IRLM) Lock structure, DEDB/VSO does have its own structure to support data sharing with System-Managed CF Structure Duplexing implications.

IMS can manage duplexing for the DEDB/VSO structures. The VSO structure uses the "Write-Into" model. As records get updated, the data is asynchronously written into the structure, but not disk. At system checkpoints, updated data is then hardened to disk. The issue then is that if a structure or Coupling Facility should fail, the data on disk can not be assumed to be valid and a database recovery process is needed. This involves going to the last image copy and applying the logs, and can take hours. To help with this, IMS has implemented support for IMS-managed duplexing of DEDB/VSO structures on an area by area basis since IMS V6. If one structure would become unavailable, the IMS managed duplexed structure is still available for reads and updates in simplex mode. To get back to duplex mode, an IMS /VUNLOAD command is issued followed by a /STA Area command. IMS does not stop data sharing during this process. The /VUNLOAD command puts the data back to disk. The /STA Area command puts the data back into the two structures. All data is available during this time.

Compare this time-consuming IMS recovery procedure with System-Managed CF Structure Duplexing, where the duplexed structure may be automatically reestablished as the backup Coupling Facility comes online. There are no IMS commands required with System-Managed CF Structure Duplexing. Also, the VSO structure recovery will be consistent with other IMS database and system structures which currently support rebuild. Therefore there is no need for multiple operational recovery procedures. System-Managed CF Structure Duplexing provides the benefit of much easier system management characteristics compared with IMS managed VSO duplexing.

Shared Message Queues: Shared Message Queue (SMQ) implementation requires several structures, including the SMQ list structure holding the Message Queue itself, and the System Logger structures managed by the Common Queue Server (CQS) component used for recovery of the SMQ.

Recovery of the SMQ structure is similar to a database recovery process. It involves:

1. *Reallocating the structure*
2. *Restoring the structure from the disk image copy in the structure checkpoint data set*
3. *Applying changes from the System Logger structure*

Recovery of SMQ structures requires the user to take periodic "structure checkpoints" to disk. Activity to the structure is quiesced during this time, which may be several seconds, depending on the size of the structure. In the event that an SMQ structure is lost (or connectivity to it is lost), recovery is needed. The most recent structure checkpoint data set (SRDS) is used to restore the structure contents to the time of the structure checkpoint. Then the outstanding updates in the logs are applied.

This process can take a period of time, depending upon how many updates took place since the last SMQ checkpoint. For small structures it can take seconds, but for larger structures in a busy environment it can take significantly longer. Typically, it takes 1 minute to recover every 2-3 minutes of data. So, if 45 minutes of CQS log must be read after restoring the structure from the structure recovery data set, it takes a minimum of 15 minutes to read the log and finish the structure recovery. While SMQ recovery is occurring, all message activity in the IMSplex is quiesced.

System-Managed CF Structure Duplexing is designed to reduce the need (or desire) to take frequent structure checkpoints. While the chance of a loss of connectivity, a structure failure, or a CF failure is small, the impact of such a failure has to be weighed against the cost of duplexing the structure.

CICS

CICS TS Version 2.2 exploits system-managed rebuild function to allows the z/OS to manage the planned reconfiguration of Coupling Facility structures used for shared temporary storage, Coupling Facility data tables (CFDTs), and named counter server pools without recycling the CICS systems using them. Prior to this release of CICS, you could only move these structures by using server functions to UNLOAD to a sequential data set and then RELOAD elsewhere from the data set. This switch caused errors in CICS such that restart, an unacceptable outage in some situations, was recommended.

While z/OS is rebuilding a structure, requests for access to the structure are delayed until the rebuild is complete. The shared temporary storage and CFDT servers issue CF requests asynchronously, and therefore a rebuild simply delays such requests. Rebuild might take from a few seconds for a small structure to tens of seconds for a large structure. The only potential effect is that the transaction making the delayed request might get purged, either because of an apparent deadlock (by the DTIMOUT value) or by an operator command. The effects of this depend upon how sensitive the environment is to short stall conditions. Most environments would quickly recover. Some high volume, high stress environments may see significant backup in transactions which would take a longer time to recover. For this environment, the much faster recovery offered by System-Managed CF Structure Duplexing would greatly add to overall availability.

While System-Managed Rebuild supports the moving of structures from one Coupling Facility to another by copying data from the "old" to the "new" structure, it does not by itself support the recovering of a structure if the original is unavailable to all systems as in the case of a CF or structure failure. Although CICS TS V1.1 provided the ability to recover a CFDT, Temporary Storage or Named Counter structure, this was time consuming and would require starting and stopping the CICS Coupling Facility Server address space several times. Because of its complexity, this function was rarely used.

It is possible to manage recovery of the Named Counters manually. For example, one method would be for CICS to read an existing database to get the "highest key value" and using that as a starting point. One can then update the file every 100 entries. If there is a duplicate entry in the database then the application would ask for another number until it didn't get a duplicate record.

System-Managed CF Structure Duplexing support in CICS TS Version 2.2 is designed to provide a rapid and simple recovery mechanism for all of these structures.

An additional benefit of System-Managed CF Structure Duplexing is application flexibility. Until now, the CFDTs and TS structures contain mostly "scratch-pad" information which are not critical to recover.

BatchPipes

BatchPipes® OS/390 offers a way to connect jobs so that data from one job can move through processor storage or, in a pipeplex, through a CF structure to another job without going to disk or tape. BatchPipes is designed to allow two or more jobs that formerly ran serially to run concurrently, helping to reduce the number of physical I/O operations by transferring data through processor storage rather than transferring data to and from disk or tape, and may also help to reduce tape mounts and use of disk.

If a BatchPipes subsystem running in a pipeplex detects a structure failure or loses connection to the coupling facility structure, the subsystem cannot service the jobs using cross-systems pipes. BatchPipes does not support automatic structure rebuild. As such, if there is a CF or SYSASFPxxxx structure failure, or a loss of connectivity to the structure, all other jobs with connections to the pipe receive an I/O error. This might cause those jobs to ABEND. Most likely it would required those jobs to be re-run from the last job that hardened the data on disk.

System-Managed CF Structure Duplexing is designed to isolate any loss of connectivity, CF failure, or structure failure incidents from the pipes connectors. This provides availability benefits through rapid failover recovery for these types of errors.

GDPS Considerations

It is not possible to guarantee consistency between a Coupling Facility structure and data on disk. Even if duplexing CF structures (either User or System managed) across two sites for disaster recovery purposes, the surviving instance of the duplexed structure in the recovery site may not be usable because it may not be consistent with the secondary copy of mirrored disk. To ensure that a subsystem did not use old data that may be residing on a CF structure after a takeover, GDPS "forces" the structures and have the subsystems rebuild the structures using consistent data on disk.

- *It is not predictable how a disaster that affects only a single site will affect the coupling facilities and duplexing. For some connectivity failure situations, XCF/CFRM may need to revert your duplexed structures to a simplex state. This means that one instance of the duplexed structures in the subject coupling facilities will be dropped and one instance will survive. There is no guarantee that the instance in the target recovery site will be the instance that will survive the failure.*
- *You may have a disaster in the site with the primary disks and there may be surviving instances of one or more of your duplexed structures in the recovery site where the secondary disks are. Whether any surviving instance of CF structures, duplexed or not, are usable is dependent on whether the structures are consistent with the disk data that will be used. If the data on the secondary disk were frozen at time 't' but the primary disk and duplexed structures continued to be updated beyond time t, then the disk data to bed used for recovery purposes will not consistent with the CF structures and these structures can not be used for disaster recovery purposes. To be able to use any surviving instance of structures following a disaster in conjunction with mirrored copy of disk, the disk and CF data must be known to be consistent with each other.*

Having a usable instance of certain application-related structures (such as DB2 Group Buffer pools) together with mirrored disk data that is time-consistent with the structures has the potential to greatly reduce recovery times. For example, for DB2, you can eliminate the time required for GRECP recovery which can be lengthy. Refer to GDPS Family - An Introduction to Concepts and Capabilities, SG24-6374 available at http://www.redbooks.ibm.com/abstracts/sg246374.html?Open for further information concerning GDPS support for structures duplexed across sites for disaster recovery purposes.

Finally, if CF structures are duplexed across sites, even when used in conjunction with the GDPS HyperSwap™ capability, chances are that continuous availability may not be attainable for compound, multi-component failures such as a complete site disaster. When there is such a failure event, the sequence of events (what fails first, what happens next, and so on) will vary greatly from one failure to another. The recovery actions taken by the operating systems across the sysplex, the sysplex exploiting subsystems and GDPS, if present, will be very timing dependent. Although there can be failure scenarios where continuous availability may be attainable in conjunction with GDPS HyperSwap (HyperSwap capability is needed for continuous availability of the data), one should not count on this and set service level requirements for such failures based on the assumption of continuous application availability.

Migrating to System-Managed CF Structure Duplexing

As with any system change, planning must take place to help obtain a successful transition. One example of a detailed migration plan with the user tasks is shown below:

1. *Determine which CF structures in the installation can exploit System-Managed CF Structure Duplexing, and decide, on a case-by-case basis, whether or not to enable duplexing for those structures. Note that structures can be migrated from simplex to duplex and back again one at a time, dynamically, allowing these decisions to be re-evaluated from time to time.*
2. *Evaluate the CF configuration (storage, links, processor capacity) and make any necessary configuration changes to accommodate the new structure instances resulting from System-Managed CF Structure Duplexing. For additional details concerning CF configuration, see section "Hardware Configuration."*
3. *Evaluate z/OS CPU requirements. Additional z/OS CPU will be required to drive two CF requests instead of one, and to reconcile the responses coming back. Some of this cost may be offset by System-Managed CF Structure Duplexing, eliminating the need for maintaining other in-storage or on-DASD copies of the CF structure data.*
4. *Install the new hardware/LIC requirements for System-Managed CF Structure Duplexing.*
   a. *Coupling Facilities must be on a IBM eServer™ zSeries®, G5/G6 Server, or R06*
   b. *CF-to-CF links*
   c. *Driver 26 (CFCC 11) with the latest level of maintenance for G5/G6 Servers and R06 Coupling Facilities, or Driver 3G (CFCC 12) with the latest level of maintenance for IBM eServer zSeries.*
5. *Migrate to CFCC Level 11 or Level 12 for System-Managed CF Structure Duplexing. The migration to these CFLEVELs may add some additional CF structure storage requirements. The size of some structures will have to increase as soon as these CFCC levels are installed and structures are allocated. This increase in storage requirement occurs for both simplexed and duplexed structure, regardless of hardware platform (G5/G6 or zSeries) used for the CF. The effects of this can be determined by using the CF Sizer, available at* ibm.com/servers/eserver/zseries/cfsizer.
6. *Install and migrate to z/OS R1.2 or higher. As a prerequisite for System-Managed CF Structure Duplexing, all systems in the Parallel Sysplex must be upgraded to R1.2 or later with APAR OW41617, and appropriate APARs listed in the CFDUPLEXING PSP bucket. APAR OW45976 is needed to support sender links on the Coupling Facilities*
7. *Format a new set of CFRM Couple Data Sets which are System-Managed CF Structure Duplexing capable. APAR OW41617 enables the XCF Couple Dataset format utility to process the SMDUPLEX keyword needed to implement the new CFRM CDS version. After all systems are at V1.2 or higher, bring the new CDSes into use as the primary and alternate CFRM CDSes for the configuration. This can be done nondisruptively via the SETXCF COUPLE,ACOUPLE and SETXCF COUPLE,PSWITCH operator commands.*

   Sample Couple Dataset Format Utility input:
   ```
   DATA     TYPE(CFRM)
   ITEM     NAME(POLICY)  NUMBER(6)
   ```

```
ITEM     NAME(CF)              NUMBER(8)
ITEM     NAME(STR)             NUMBER(50)
ITEM     NAME(CONNECT)         NUMBER(32)
ITEM     NAME(SMREBLD)         NUMBER(1)
ITEM     NAME(SMDUPLEX)        NUMBER(1)
```

Format LOGR couple data sets using the SMDUPLEX(1) keyword. LOGR would then need to deallocate and reallocate the structure before it can be duplexed. You must also update the logstream definition in the System Logger policy for the structures you want to duplex with the LOGGERDUPLEX parameter.

Bring the new LOGR couple data sets into use by adding one as a new alternate, PSWITCH to make it the primary, and then bring the second into the configuration as the alternate.

8. *Note that once the above steps have been taken, it is not possible to fall back nondisruptively to a downlevel CFRM or LOGR CDS which is not System-Managed CF Structure Duplexing-capable. Doing so will require a sysplex-wide IPL of all systems using CFRM or LOGR, with the downlevel CFRM or LOGR CDSes specified for use in the COUPLExx parmlib member. This does not imply that the System-Managed CF Structure Duplexing function cannot be turned on and off nondisruptively once an uplevel, System-Managed CF Structure Duplexing-capable CFRM CDS is in use in the sysplex. The System-Managed CF Structure Duplexing function can be started and stopped for particular structure instances, in a nondisruptive manner, through either the modification of the CFRM policy DUPLEX parameter or the SETXCF START|STOP,REBUILD,DUPLEX command, while the uplevel CFRM CDS remains in use. The uplevel CFRM CDS may even be brought into use and remain in use indefinitely even when all structures are DUPLEX(DISABLED), and are thus not eligible to be duplexed.*

   In addition, the new format of the LOGR and CFRM Couple Data Sets are not understood by an operating system lower than z/OS 1.2. Falling back to a previous version would first require a fallback to the previous CDS level.

9. *Install and migrate to the new CF-exploiting product/subsystem software levels required for System-Managed CF Structure Duplexing. Each product or subsystem will define its own unique migration rules for exploiting System-Managed Duplexing, but in general, structures should not be defined in the CFRM policy as duplexed before all of the exploiting connectors on all systems have been upgraded to the level that supports System-Managed CF Structure Duplexing. Once a structure is duplexed, downlevel connectors that do not provide the support for System-Managed CF Structure Duplexing will be unable to connect to the duplexed structure..*

10. *Modify the CFRM policy to control the placement (via the CF preference list) and DUPLEX parameter indication, for the structures which will be duplexed via System-Managed CF Structure Duplexing, and activate this CFRM policy. The existing DUPLEX parameter on the CFRM administrative policy STRUCTURE definition is broadened to control System-Managed CF Structure Duplexing:*

    - *DUPLEX(ENABLED) - z/OS will automatically attempt to start and maintain duplexing for the structure at all times*
    - *DUPLEX(ALLOWED) - Duplexing may be manually started/stopped for the structure, but z/OS will not start duplexing automatically*

- *DUPLEX(DISABLED) - Duplexing is not allowed for the structure*

Note that it is possible to define a CFRM policy which permits duplexing to be performed for one or more CF structures (DUPLEX(ALLOWED) or DUPLEX(ENABLED)), and activate that CFRM policy, today. This is because the DUPLEX policy keyword is already supported for User-Managed Duplexing, it is simply being broadened to pertain to System-Managed CF Structure Duplexing as well. However, the CFRM CDS itself must also be upgraded to the level that supports System-Managed CF Structure Duplexing, as described above, in order for the DUPLEX specification to pertain to and support a System-Managed CF Structure Duplexing rebuild.

11. *Monitor and evaluate actual CF structure placement and performance for duplexed structures. Make any necessary tuning changes indicated by this.*
12. *Familiarize oneself with, and make automation changes with respect to the additional information returned by the D XCF,STR,STRNAME=xxxxxx command.*
13. *Understand and document the recovery procedures and behaviors for CF structure failures, CF failures, CF losses of connectivity, and system and sysplex outages, involving CFs containing duplexed structures. This is important so that the operations staff will be familiar with the operation of the sysplex, incorporating the set of duplexed structures during failure scenarios.*
14. *Understand differences in CF monitoring and performance procedures. This includes:*
    - *Managing and monitoring the additional hardware resources related to System-Managed CF Structure Duplexing (e.g. CF to CF links),*
    - *Monitoring and tuning the performance of the duplexed structures themselves*
    - *Additional structures being reported on in the system monitors (e.g. RMF™)*

Once the CFRM CDS and policy migration steps have been taken, duplexing can be started for the desired structures. Again, this can be staged, structure by structure, dynamically and nondisruptively, through CFRM policy changes.

Managing and Monitoring

Starting Duplexing

There are two ways to start duplexing:

- *Activate a new CFRM policy with DUPLEX (ENABLED) for the structure. If the "OLD" structure is currently allocated, then z/OS will automatically initiate the process to establish duplexing as soon as you activate the policy. If the structure is not currently allocated, then the duplexing process will be initiated automatically when the structure is allocated. This method attempts to reestablish duplexing automatically in the case of a failure, and also will periodically attempt to establish duplexing for structure that were not previously duplexed in accordance with the CFRM policy specification.*
- *Activate a new CFRM policy with DUPLEX (ALLOWED) for the structure. This method allows the structures to be duplexed, however the duplexing must be initiated by a command - the system will not automatically duplex the structure. Duplexing may then be manually started via the existing SETXCF START,REBUILD,DUPLEX operator command or the IXLREBLD STARTDUPLEX programming interface. This method also requires that duplexing be manually reestablished in the event of a failure.*

For a production environment, the first method is recommended as it lends itself to a controlled change-management environment, and the change is permanent across sysplex-wide IPLs. Both methods should be used in the Test environment to build experience before going into production. A “hybrid” approach whereby DUPLEX(ENABLED) is used for some structures, and DUPLEX(ALLOWED) is used for others, is also discussed later in this document. An example of a CFRM policy entry follows:

```
STRUCTURE NAME(DB2GRP_LOCK1)
DUPLEX(ENABLED)    /*SM CF Structure Duplexing Enabled*/
MINSIZE(32768)     /* Minimum Size */
INITSIZE(32768)    /* Initial Size */
SIZE(65536)        /* Maximum Size */
ALLOWAUTOALT(YES)  /* Enable Auto Alter */
FULLTHRESHOLD(80)  /* Structure Full Monitoring threshold */
REBUILDPERCENT(1)
PREFLIST(CF01,CF02)
ENFORCEORDER(YES)  /* Always follow PrefList. Not valid w/ ExclList */
```

Stopping Duplexing

Duplexing may be manually stopped via the existing SETXCF STOP,REBUILD,DUPLEX operator command or IXLREBLD STOPDUPLEX programming interface.

When you need to stop duplexing structures, you must first decide which is to remain as the surviving simplex structure. Use the SETXCF STOP, REBUILD, STRNAME=xxxx,KEEP=OLD command to convert to using the primary structure as the simplex structure or with KEEP=NEW to leave the secondary as the simplex structure. z/OS will automatically stop duplexing when:

- *The CFRM policy changes to DUPLEX(DISABLED)*
- *Needed to allow a connect request to succeed*
- *Duplexing is "broken" as indicated by duplexed request response information*
- *A failure affects one of the structure instances*

When duplexing is stopped as a result of a failure affecting one of the structures (e.g. structure failure, CF failure, loss of connectivity), XES completely hides these failures from connectors so that stopping duplexing is the only recovery action taken. No loss of connectivity or structure failure events are presented to connectors. What happens next depends on the current setting of the DUPLEX policy parameter. If DUPLEX(ENABLED) is specified, the system will automatically try to re-establish duplexing the structure into the same CF with some caveats, or another CF if one is available. If DUPLEX(ALLOWED) is specified, re-duplexing does not occur automatically but must be done manually. If DUPLEX(DISABLED) is specified, then re-duplexing will not occur.

Operations and Displays

Several different command responses are affected by duplexing. One example includes the "D XCF,STR,STRNAME=str_name" command. An example of the output is shown below. This example is for a System-Managed CF Structure Duplexed JES2 Checkpoint. The changed responses are highlighted.

The "OLD" structure (or "Primary") is the first structure of the duplexed pair that got allocated. The "NEW" structure (or "Secondary") is the second structure of the duplexed pair that got allocated. All reads go only to the OLD/Primary structure, while all updates are reflected in both structure instances.

The D XCF,CF,CFNM=* command shows the duplexed structure in both Coupling Facilities.

D XCF,STR,STRNAME=JES2_CKPT1

```
IXC360I  12.10.16  DISPLAY XCF 931
STRNAME: JES2_CKPT1
 STATUS: REASON SPECIFIED WITH REBUILD START:
         POLICY-INITIATED
         DUPLEXING REBUILD
         METHOD        : SYSTEM-MANAGED
         AUTO VERSION  : B648FDD4 55CCED64
         REBUILD PHASE : DUPLEX ESTABLISHED
 POLICY INFORMATION:
  POLICY SIZE    : 60000 K
  POLICY INITSIZE: N/A
  POLICY MINSIZE : 0 K
  FULLTHRESHOLD  : 80
  ALLOWAUTOALT   : NO
  REBUILD PERCENT: N/A
  DUPLEX         : ENABLED
  PREFERENCE LIST: CF01     CF02
  ENFORCEORDER   : NO
  EXCLUSION LIST IS EMPTY

DUPLEXING REBUILD NEW STRUCTURE
-------------------------------
 ALLOCATION TIME: 11/28/2001 14:29:31
 CFNAME         : CF01
 COUPLING FACILITY: 002064.IBM.02.000000010A8B
                    PARTITION: A   CPCID: 00
 ACTUAL SIZE    : 60160 K
 STORAGE INCREMENT SIZE: 256 K
 PHYSICAL VERSION: B648FDF4 B3A04FA4
 LOGICAL  VERSION: B644170C B7F3E740
 SYSTEM-MANAGED PROCESS LEVEL: 8
 XCF GRPNAME    : IXCLO002
 DISPOSITION    : KEEP
 ACCESS TIME    : NOLIMIT
 MAX CONNECTIONS: 18
 # CONNECTIONS  : 4

DUPLEXING REBUILD OLD STRUCTURE
-------------------------------
 ALLOCATION TIME: 11/28/2001 14:29:31
 CFNAME         : CF02

CONNECTION NAME  ID VERSION  SYSNAME  JOBNAME  ASID  STATE
---------------- -- -------- -------- -------- ----  ----------------
 JES2_W02        05 00050062 W02      JES2     0031  ACTIVE NEW,OLD
 JES2_W03        06 0006004D W03      JES2     0032  ACTIVE NEW,OLD
 JES2_W04        03 0003009B W04      JES2     0031  ACTIVE NEW,OLD
```

Additional D CF command output information is provided to show additional information on the CF-to-CF connectivity and links. This includes CHPID number and type for each receiver and sender CF link.

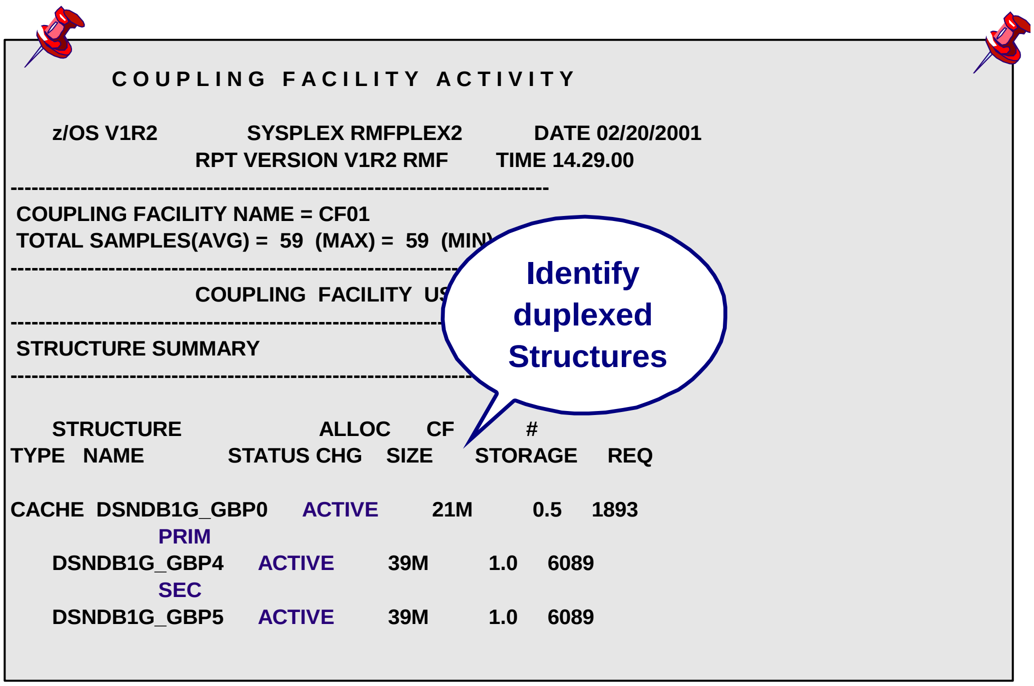
For example: (Note: This example shows only a single sender and receiver between the CFs, so there is a single point of failure in this configuration)

```
REMOTELY CONNECTED COUPLING FACILITIES

 CFNAME  COUPLING FACILITY
 ------  --------------------------
 CF02    SIMDEV.IBM.EN.ND0200000000
         PARTITION: 0  CPCID: 00
CHPIDS ON CF01 CONNECTED TO REMOTE FACILITY
          RECEIVER:   CHPID    TYPE
                      F1       CFR

          SENDER:     CHPID    TYPE
                      E1       CFS

 CF03     SIMDEV.IBM.EN.ND0100000000
          PARTITION: 0  CPCID: 00

CHPIDS ON CF01 CONNECTED TO REMOTE FACILITY
          RECEIVER:   CHPID    TYPE
                      F0       CFR

          SENDER:     CHPID    TYPE
                      E0       CFS

NOT OPERATIONAL CHPIDS ON TESTCF FF
```

Accounting and Measurement

RMF, in z/OS 1.2 Coupling Facility reporting enhancements, provides support to monitor and evaluate the actual CF structure placement and performance for duplexed structures, and thus for making any necessary tuning changes. This support is for both System-Managed and User (DB2) Managed duplexed structures.

The STATUS column of the Structure Summary Section has been extended to indicate the duplexing attributes for a specific structure:



- *ACTIVE PRIM*
  The structure is the rebuild-old (primary) structure in a duplexing rebuild process
- *ACTIVE SEC*
  The structure is the rebuild-new (secondary) structure in a duplexing rebuild process

The new duplexing related delay reasons are shown in Structure Activity Section:

- *PR WT: The amount of time that the system was holding one subchannel while waiting to get the other subchannel, to launch the duplexed operation.*
- *PR CMP: One of the two duplexed operations has completed, but the completed subchannel remains unavailable for use until the other operation completes*

New Delay Reasons

- peer subchannel wait contention
- waiting for peer completion

```
--------------------------------------------------------------------------------------
                         COUPLING  FACILITY  STRUCTURE  ACTIVITY
--------------------------------------------------------------------------------------

STRUCTURE NAME = DSNDB1G_GBP0      TYPE = CACHE          STATUS = ACTIVE PRIMARY
       # REQ    -------------- REQUESTS -------------   -------------- DELAYED REQUESTS ------------
SYSTEM   TOTAL          #    % OF  -SERV TIME(MIC)-   REASON    #   % OF  ---- AVG TIME(MIC) ----
NAME     AVG/SEC       REQ   ALL    AVG   STD_DEV           REQ   REQ  /DEL   STD_DEV  /ALL

RMF1      8621    SYNC    89    0.3   101.9    34.6    NO SCH   1    0.1   82.2     111.3   0.1
        4.79    ASYNC  8532   26.3   376.4   355.6    PR WT    4    0.1  285.8     440.2   0.2
              CHNGD    0     0.0   INCLUDED IN ASYNC  PR CMP   12    0.3   46.5     345.4   0.4
                                             DUMP      0    0.0    0.0      0.0    0.0
```

The CF-to-CF Activity Section shows a summary of basic counts for duplexing related operations only. In addition, the CF-to-CF section contains the information about the specific CF link types. This enhancement, the display CF link type information, has also been made in the existing subchannel activity section.

New CF to CF Activity Section

```
                    C O U P L I N G   F A C I L I T Y   A C T I V I T Y

  z/OS V1R2          SYSPLEX RMFPLEX2         DATE 02/20/2001        INTERVAL 001.00.000
                 RPT VERSION V1R2 RMF       TIME 14.29.00          CYCLE 01.000 SECONDS

------------------------------------------------------------------------------------------
COUPLING FACILITY NAME = ICF1
------------------------------------------------------------------------------------------
                                  CF TO CF ACTIVITY
------------------------------------------------------------------------------------------
      # REQ                ---------- REQUESTS ----------   ------------- DELAYED REQUESTS ------------
PEER     TOTAL       -- CF LINKS --           #   -SERVICE TIME(MIC)-       #    % OF  ------ AVG TIME(MIC) -----
CF       AVG/SEC     TYPE      USE            REQ     AVG    STD_DEV          REQ    REQ   /DEL    STD_DEV     /ALL

ICF2     86830       CFR        2       SYNC  86830   53.0     33.8    SYNC    19    0.2    4.5       2.7      14.5
         86.2
```

CF Link Type Information

Performance Impact of System-Managed CF Structure Duplexing

A Parallel Sysplex provides numerous benefits for the business. Like many things, there is a cost. This cost can be broken down into its factors:

1. *Software costs (pathlength) to manage a multi-system environment. This includes the additional work done by GRS serialization, JES2 shared Checkpoint, shared catalogs, etc.*
2. *Software costs to initiate and receive messages to and from a coupling facility.*
3. *Processor time needed to wait for synchronous messages to make the round trip to and from the CF. This time is a lost opportunity to process other instructions. This can be broken down into its components:*
   - *Time spent while the message is being prepared in the host hardware*
   - *Time spent while the message is traveling in the coupling link*
   - *Time spent while the message is being processed in the coupling facility*

System-Managed CF structure duplexing will impact these costs in a variety of ways.

Software costs to initiate and receive messages will increase. Simplex read operations will cost the same since z/OS will send a message to only one CF as before. The cost of Write operations (and any type of operation that modifies a structure) will increase, as the CF request has to be split, two messages sent, two messages received, and the results reconciled.

The CF response times from each duplexed (update) request will increase. Although the messages going to each of the two coupling facilities are overlapped for performance, there is additional time as each coupling facility coordinates the updates with its peer CF. For requests that are synchronous, a CP (engine) on the host system waits for both responses to come back before continuing processing. For example, a CP issuing 1000 CF requests/second with an average response time of 50 microseconds per request results in a CP cost of (1000 req/sec) * (.000 050 sec/req) = .05 or 5%. If the synchronous response time went up to 75 microseconds, this coupling cost would increase to 7.5%. Note that z/OS 1.2 has a new heuristic algorithm to convert long synchronous requests to asynchronous, to limit this cost. It is based on observations of actual CF service times, and considers the speed of the sending CEC to determine for each request whether it would be more CPU-efficient to process it synchronously or asynchronously.

The Read/Write ratios are different for each exploiter. Projecting the cost of System-Managed CF Structure Duplexing in terms of host effect (coupling cost), CF utilization, and CF Link utilization will therefore require an analysis of each structure based on the cost currently being paid for that structure in simplex mode and the read/write ratio. The appropriate duplexing costs can then be applied to reflect the duplexed write (update) requests. Many customers have tools that calculate these costs for their simplex case today. For those that need to estimate their current simplex costs, Appendix A contains a methodology that can be followed.

Depending upon which structures are being duplexed and how they are being invoked by the applications, System-Managed CF Structure Duplexing impacts include:

- *z/OS CPU utilization:*
  For those operations that update the structure ...
  1. *Instead of paying the software cost to send and receive one CF message, two messages are being sent and two responses received with the results reconciled*
  2. *Additional pathlength is required to overlap the sending of the messages.*
  3. *For synchronous messages, the host has to wait until both messages return. This has the effect of increasing the synchronous response time, directly affecting host CPU utilization. Some requests may be converted to asynchronous (new function in z/OS 1.2) to reduce the impact*
- *Coupling Facility CPU utilization:*
  For those operations that update the structure ...
  1. *The coupling facility containing the original ("old," or "Primary") structure continues to process requests as when running in simplex mode*
  2. *The coupling facility containing the new structure now has to process requests that update the duplexed structure. The impact of processing these requests may have already been planned for to handle a CF rebuild situation in a simplex environment.*
  3. *Additional CF usage for both CFs is incurred to handle the CF-to-CF communication to coordinate the updates. This communication is done to ensure that both images of a structure remain synchronized with each other.*
- *Coupling Facility link usage:*
  For those operations that update the structure ...
  1. *There will be additional traffic on the links due to the additional requests to the new (or "secondary") structure.*
  2. *The CF-to-CF communication requires CF links.*
  3. *Since the z/OS-to-CF response times increase due to the CF to CF communication, the z/OS CF link subchannel utilization will increase*

It should be noted that CF storage requirements need not increase. Although a new structure is now required on the second CF, this space should have already been planned for to handle the CF rebuild situation.

It needs to be stressed again that the impact of these effects is on a structure by structure basis, and is directly related to the amount of duplexing being done within each structure. For example, a cache structure may have 80% read accesses. Therefore, the System-Managed CF Structure Duplexing costs will apply to only the other 20% of its accesses that update the structure. It is up to each installation to determine the cost/benefit relationship before enabling System-Managed CF duplexing for a particular structure.

Structure Type	Host CPU Busy	CF CPU Busy	CF Link Subch Busy	Percent update
UM GBPs	2x	2x	2x	1% to 100%, avg. 20%
SM Lock	4x	5x	8x	100%
SM List	3x	4x	6x	Near 100%

Since User-Managed CF structure duplexing for DB2 Group Buffer Pool duplexing is similar to System-Managed CF Structure Duplexing in terms of both what it is used for and its external interface, data for projecting GBP duplexing is included. The cost of User-Managed CF Structure Duplexing for DB2 Group Buffer Pools is generally less because all of the synchronization costs are already paid through IRLM locking that also occurs in simplex mode, whereas for System-Managed CF Structure Duplexing the synchronization is obtained through additional CF-to-CF communication that does not occur in simplex mode.

An example of applying these numbers can be seen below:

Here, the host CPU capacity cost for the SIMPLEX version of the UM GBPs is shown to be 5%. To calculate the cost impact of User-Managed (DB2 Group Buffer Pool) Duplexing one would take 20% of the simplex cost (reflecting the portion of activity to the structure that is updated and must be duplexed) and multiply that portion by 2. This would result in a total overhead equal to 1.2 times the SIMPLEX cost. In this example, this results in a total cost of 6% (thus, a growth of 1% above the simplex cost). Similarly, if a lock structure has a simplex cost of 2%, the duplexing impact would be found by multiplying 100% of the simplex cost by 4, yielding a total after-duplex cost of 8%.

Host CPU Capacity	Simplex	CF Duplex Multiplier	Duplex
UM GBPs	5%	1.2x	6%
SM Lock	2%	4x	8%
SM List	1%	3x	3%
Non-Duplexed	2%	n/a	2%
Total	10%		19%

It is very important to note that when using the simplex CPU cost calculation as a basis for determining what the projected CPU cost of CF Duplexing will be, care must be taken to apply the appropriate multipliers to the different components of the total CPU cost. For example:

- *The cost of handling asynchronous operations is increased by a factor of 2 - 2.5x by CF Duplexing.*
- *The cost of handling lock contention is not increased at all by CF Duplexing (that is, a factor of 1x).*
- *The cost of handling synchronous operations is increased by a factor of 3 - 4x, as shown in the table above.*

In the above example, it was assumed that essentially the entire lock structure and list structure simplex cost contribution came from synchronous operations, and that the contribution of asynchronous operations and of handling lock contention were negligible. Therefore, the multiplier of 3 - 4x was applied to the entire simplex cost. However, if a significant portion of the simplex cost had come from asynchronous operations or from handling lock contention, this would not have been appropriate; we would have had to separately apply a multiplier of 3 - 4x to the component of the simplex cost from synchronous operations, a multiplier of 1x to the component of the simplex cost from handling lock contention, and a multiplier of 2 - 2.5x to the component of the simplex cost from asynchronous operations.

The duplexing impact on CF CPU Busy and CF Link Subchannel Busy can be estimated in an analogous manner.

Avg CF CPU Busy	**Simplex**	**Impact**	**Duplex**
UM GBPs	15%	1.2x	18%
SM Lock	5%	5x	25%
SM List	4%	4x	16%
Non-Duplexed	6%	n/a	6%
Total	30%		65%

For example, if CF01 required 5% of the CPU to process a simplexed Lock structure, then if it is duplexed, both CF01 and CF02 will each require 25% of the CPU to manage the structure.

Avg CF Link Sub ch Busy	**Simplex**	**Impact**	**Duplex**
UM GBPs	5%	1.2x	6%
SM Lock	2%	8x	16%
SM List	1%	6x	6%
Non-Duplexed	3%	n/a	3%
Total	10%		31%

Interpreting the Results

The increase in CF CPU usage is split between each of the two coupling facilities. Similarly, the increase in CF Link Subchannel usage is split between the links going to each of the coupling facilities. After System-Managed CF Structure Duplexing is turned on, some relocation of CF structures may be necessary to rebalance the coupling facility CPU and CF link subchannel utilization.

In both simplex and duplexed environments, the best performance occurs when the coupling facility is less than 50% CPU busy. At utilizations higher than this, significant queuing within the CF can occur, elongating response time and increasing z/OS CPU usage for synchronous activity. With this guideline in mind, some installations may have already planned spare CF CPU capacity (white space) for recovery situations. In these cases, less white space may be planned for after duplexing. The CPU capacity white space that would have been needed during a failure scenario is already being used on an ongoing basis with System-Managed CF Structure Duplexing.

In the simplex environment it is recommended that average Coupling Facility storage usage not exceed 50%. When planning for a failure situation, this is to allow a CF to rebuild all the structures on the other CF. With duplexed structures, the backup structures are preallocated, so the 50% rule is no longer applicable. There is no increase in CF storage required due to having duplexed structures, provided that the 50% rule was followed. The storage capacity white space that would have been needed for rebuild purposes is already being used on an ongoing basis with System-Managed CF Structure Duplexing.

The link subchannel utilization and response times, affecting z/OS CPU requirements, are directly dependent upon the coupling technology employed. This includes coupling facility technology as well as link technology. As seen in customer studies, (See Appendix B: Host Effects of Technology in a Parallel Sysplex), significant performance benefits to the z/OS partitions can be obtained by migrating to more efficient technologies. This holds true whether structures are Simplex or Duplexed.

Utilizing newer technology increases the coupling efficiency by improving the response times. It should be remembered that with System-Managed CF Structure Duplexing you can only go as fast as your slowest CF partition and link, because each operation waits for its peer to complete. For sysplexes with a mixture of coupling facility CPU and link technologies, duplexing efficiency will be determined by the slowest component.

More information on link types can be found in "Coupling Facility Configuration Options" available at: ibm.com/servers/eserver/zseries/library/techpapers/gf225042.html.

Recovery Benefits - Duplexing “Failover”

One of the major benefits of System-Managed CF Structure Duplexing is its ability to rapidly recover from situations where there is a loss of connectivity to a Coupling Facility or a CF failure. In an environment was configured to illustrate this, a CICS/DB2 workload was run with 24 structures spread across two coupling facilities. A loss of connectivity to one of the CFs resulted in all structures in that CF being rebuilt or recovered via duplexing failover. The results were:

Configuration	Time	Ratio
Simplex structures	117 sec	1
Simplex structures, UM duplexed GBPs	84 sec	0.72
SM duplexed structures, UM duplexed GBPs	28 sec	0.24

This experiment did not include the case where the DB2 Group Buffer Pool structures had to be rebuilt from logs as they would have if they failed while in simplex mode). Experience suggests that the ratio time for log recovery would be 10 times longer than the rebuild case, or about 40 times slower than the SM+UM case above. It should be noted as well that recovery times are affected by the number and size of structures that must be recovered, thus larger configurations would result in bigger differences between the scenarios.

Hardware Configuration Considerations and Recommendations

This section describes specific configuration options and considerations associated with System-Managed CF Structure Duplexing and provides specific recommendations for each of those configuration options.

Distance Considerations

Prior to z/OS 1.2, a rule of thumb said that coupling overhead increases by 1% for every kilometer over 3 Km that a coupling facility is away from the host system. This is due to the response time increase caused by the longer time needed for the signals to travel back and forth between the host and CF - so-called "propagation delays." With the synchronous to asynchronous message conversion in z/OS 1.2, CF communications are converted to asynchronous to limit the overhead in this environment. Although the coupling overhead will now not increase as rapidly with host to CF distances, response times still will. Since the CF link and subchannel remain allocated for the interval as reported by the response time, increasing the distances between host and CF causes the link and subchannel utilization to increase. Another effect of increased distances is the added time needed to send a signal and get its response back, increasing the subchannel utilization on the link. Increased subchannel and link utilization would also affect the path busy conditions for shared links and subchannel queuing. These effects are true for simplex as well as duplexed structures.

With duplexed structures, as the distances between two coupling facilities increase, the response time needed for the CFs to exchange signals also increases. As well as increasing the response time for the duplexed command (using subchannels and link resources leading to path busy in the z/OS to CF link), it also ties up the subchannels in the CF-to-CF link. Another effect of increased CF-to-CF distances is that while the coupling facility CPU is free to process other requests, the task is still active in the coupling facility while waiting for the response from its duplexed partner. To compensate for this, 48 tasks are available in CFCC Level 12 for an increased multiprocessing level over earlier releases.

For a GDPS Peer to Peer Remote Copy (PPRC) configuration, also called "Metro Mirror," System-Managed CF Structure Duplexing can still provide the same benefits in terms of improved structure data availability that it does in a non-GDPS configuration. However, in a GDPS configuration, System-Managed CF Structure Duplexing may incur substantial distance effects as described above, especially when one of the coupling facilities is located in one site and the other coupling facility is located in the other site (that is, when the CF-to-CF links are inter-site long links). This distance effect is undesirable, and in a GDPS site failover situation, if GDPS "Enhanced Recovery Support" is not configured, the duplexed copies of the CF structure data are not preserved for use in any event, so GDPS really derives no value from having one copy of the CF structure data resident in each of the two sites.

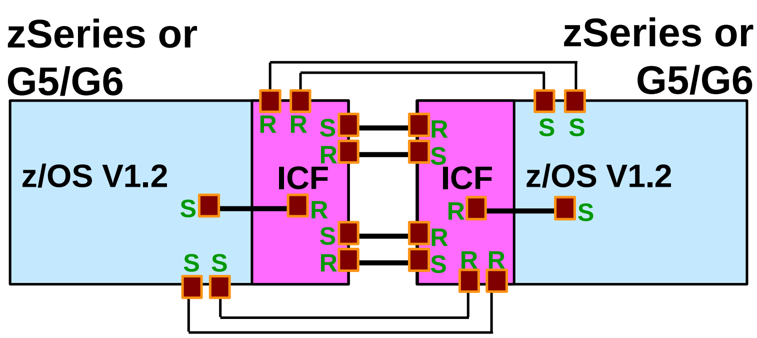
Recommendation: As z/OS to CF and CF-to-CF distances increase, monitor the coupling facility link/subchannel and path-busy status. If more than 10% of all requests are being delayed on the CF link due to subchannel or path busy condition, either migrate to peer mode links to increase the number of subchannels from two to seven for each link, or configure additional link(s).

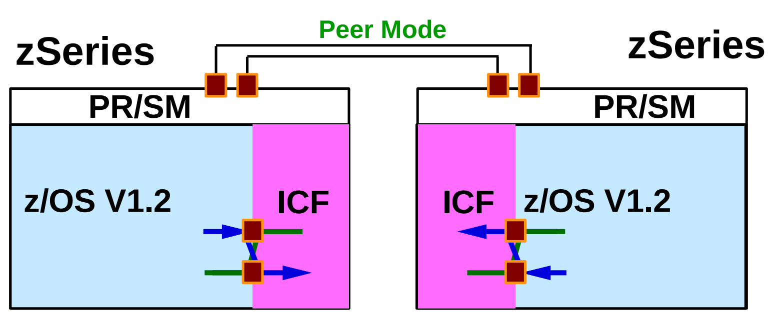
Recommendation: In a GDPS/PPRC multi-site configuration, do not duplex CF structure data between coupling facilities located in different sites. If desired, duplex the structures between two coupling facilities located at the same site. CF structure data is not preserved in GDPS site failover situations, regardless of duplexing.

A new connectivity requirement for System-Managed CF Structure Duplexing is that there must be bi-directional CF-to-CF connectivity between each pair of CFs in which duplexed structure instances reside. With peer links between zSeries processors, this connectivity can be provided by a single bi-directional link (two with redundancy). Sender/receiver link connectivity between G5/G6 processors or between a zSeries and a G5/G6 processor requires two links for each CF, one in each direction (or two in each direction for redundancy).

CF-to-CF Links - Sharing and Redundancy

CF-to-CF links may either be dedicated or shared via MIF. They may be shared with z/OS-to-CF links between z/OS and CF images in the pair of CECs they connect. When the same physical link is shared as both a z/OS-to-CF link and a CF-to-CF link, the usage of the link as a CF-to-CF link may cause a small amount of path busy conditions to occur for the z/OS-to-CF usage of the link (even when that physical link is "dedicated" in so far as it is serving only one z/OS-to-CF link). This amount of path busy is generally not significant and causes no noticeable performance concerns. With InfiniBand links, multiple CHPIDs can be shared using the same physical link.





> Recommendation: Provide two or more physical CF-to-CF links (peer mode), or two or more physical CF-to-CF links in each direction (sender/receiver mode), between each pair of CFs participating in duplexing. The physical CF-to-CF links may be shared by a combination of z/OS-to-CF links and CF-to-CF links.

z/OS CPs - sharing and capacity

When z/OS drives duplexed requests to a duplexed CF structure, z/OS launches the two requests to the two coupling facilities serially, by a routine running disabled on a z/OS CP. When the z/OS processor is dedicated, these two duplexed requests will both be launched in as expeditious a fashion as possible, allowing for maximum parallelism in executing the duplexed request and yielding optimal CF duplexing performance.

When the z/OS processor is shared, there is a small chance that PR/SM™ will take control away from the z/OS partition on the processor during the window of time between launching one duplexed request and the other. The second request will not be launched until PR/SM re-dispatches the z/OS partition. When this occurs, one duplexed request may reach one of the CFs well before the other request has even been launched, causing a delay between the execution of the two duplexed commands. This results in less parallelism for the duplexed request, less optimal use of CF resources, and less optimal System-Managed CF Structure Duplexing performance overall. In general, the chances of a duplexed request falling into this window are small, as is the penalty associated with sharing of z/OS CPs for System-Managed CF Structure Duplexing.

The overall synchronous service time for a duplexed request, and the corresponding z/OS CP utilization, is significantly higher for duplexed requests as compared to simplex requests. The z/OS 1.2 sync/async conversion algorithm (see Washington Systems Center Flash 10159 for additional information) tends to react to this by preferentially converting the slower duplexed operations to asynchronous execution, more so than it converts simplex operations. Converting these requests to be processed asynchronously limits the increase in CPU consumption that would otherwise result from the z/OS processor waiting for synchronous completion of these requests but at the expense of further elongating the response time for these requests since asynchronously processed requests are subject to additional z/OS polling latencies. Given these considerations, a modest increase in the z/OS CPU utilization will be seen when operation is converted from simplex to duplexed. Increased CF service times and increased conversion of CF requests from synchronous to asynchronous execution will also be seen. In general, the increased CF service times have little effect on overall transaction response time for the workload, but is something that should be watched carefully.

> Recommendation: You may provide either dedicated or shared z/OS CPs when using System-Managed CF Structure Duplexing. Generally, it is not necessary to provide dedicated z/OS CPs to obtain good performance with CF Duplexing. Be prepared to provide additional z/OS CPU capacity when the workload's CF operations become duplexed.

z/OS-to-CF Links - sharing and redundancy

As in simplex mode, at least one (or two for redundancy) z/OS-to-CF link must be defined between each z/OS image using a coupling facility, and each CF image that it is using. Additional z/OS-to-CF links may be required for additional capacity.

In simplex mode, the sharing of z/OS-to-CF links between multiple LPARs via MIF can result in path busy conditions. These occur when there is contention for the physical resources of the link, between the various z/OS LPARs that are sharing the link. Each LPAR will handle these path busy conditions by redriving the requests over and over again until they succeed. This can substantially increase the CPU cost of accessing the coupling facility for the sharing z/OS partitions. For this reason, it is recommended that path busy conditions be limited to at most 10-20% of the total requests to a CF. If the occurrence of path busy conditions exceeds this amount, it should be addressed either by providing more shared links for use by the z/OS partitions, or preferably by dedicating links to the z/OS partitions using them. Path busy conditions do not occur with dedicated links.

The considerations for z/OS-to-CF links are similar for System-Managed CF Structure Duplexing. Sharing of links between multiple z/OS partitions can similarly cause contention for CF link resources and result in path busy conditions which must be redriven by z/OS. However, there are several factors which make this even more expensive in a duplexed environment. First, duplexed requests in general have longer service times and are thus active on a link for longer periods of time compared with a simplex request. Other things being equal, they are much more likely to experience path busy conditions and need to be redriven more frequently before the operation is successfully launched. Second, since a duplexed request starts two operations instead of just one, the likelihood of experiencing a path busy condition on at least one of them is substantially increased compared with a simplex request. Third, once the first CF request of a duplexed pair is successfully launched, any path busy conditions that occur during the starting of the second CF request of the pair will delay the second request from being started, causing a "skew" between the arrival and execution of the two duplexed commands at the CFs. This in turn results in less parallelism for the duplexed request, less optimal use of CF resources, and less optimal System-Managed CF Structure Duplexing performance overall.

> Recommendation: For redundancy, provide two or more z/OS-to-CF links from each system to each CF. Provide dedicated z/OS-to-CF links if possible. If z/OS-to-CF links are shared between z/OS partitions, the occurrence of path busy conditions should be limited to at most 10-20% of total requests. If path busy exceeds this guideline, either provide dedicated links, or provide additional shared links, to eliminate or reduce the contention for these link resources. Use peer links whenever possible.

Coupling Facility CP Utilization - capacity

CF requests get the best response times when the coupling facility CP utilization is limited to 50% or less. At higher utilizations, it becomes less likely that the CF processor(s) will be available to process incoming requests in a timely manner, degrading the CF request service time.

The recommendations for coupling facility CP utilization are similar for System-Managed CF Structure Duplexing. However, there are several factors which make high coupling facility CP utilization even more expensive in a duplexed environment. First, in order to obtain optimal CF duplexing performance, both CF commands must be received by their respective CFs and begin execution in a timely fashion. Any delay in executing either of the requests may ultimately result in delayed completion of the duplexed pair of requests as well as less optimal usage of CF resources. Second, as duplexed CF requests exchange signals in order to coordinate and synchronize their execution across the pair of CFs, the duplexed commands may need to suspend their execution while awaiting a signal from the other CF and then resume execution when the signal arrives. Any delay in resuming execution caused by excessive coupling facility CP utilization will ultimately result in delayed completion of the duplexed pair of requests and less optimal usage of CF resources.

> Recommendation: Provide sufficient coupling facility CP resources so that coupling facility CP utilization remains below 50% in all CF images. If coupling facility CP utilization exceeds this guideline, then
>
> *Provide additional CF processor resources to reduce the overall utilization.*
>
> *Try to rebalance or redistribute duplexed structures between CFs to reduce the utilization of an overutilized one.*
>
> *If you already have three or more CF engines on the server, try to limit the number of structures enabled for System-Managed CF duplexing. Select structures based on the hierarchy described on the section: "When to Configure System-Managed CF Structure Duplexing."*

Coupling Facility CPs - sharing

In simplex mode, running with shared coupling facility CPs can cause longer CF request service times compared to running CFs with dedicated engines. The reason for this is that the CF is not interrupt driven, it is a polling engine that is continuously looking for requests to process. When the CF is using a processor that is shared with other images, there are periods in time where the CP is unavailable to poll for and process any incoming work for that CF image simply because the shared CP happens to be doing work for another image at the time. This latency is what drives the average CF service times up with shared CPs. Since some requests experience this latency while others do not, another effect of shared Coupling Facility CPs is a large standard deviation on the response times as reported by RMF.

There is a configuration which allows shared coupling facilities to share CPs with little impact on performance for a "highly-favored" CF partition. For example, if CFHIGH and CFLOW share a CP, but CFHIGH runs with Dynamic CF Dispatch OFF and CFLOW runs with Dynamic CF Dispatch ON, then CFLOW interferes very little with CFHIGH. CFHIGH obtains reasonably good service times, while CFLOW obtains very poor service times due to the use of Dynamic CF Dispatching. In any case, if the CF does not contain System-Managed duplexed structures, it should have sufficient LPAR weight to be able to run on a CP at least 50% of the time (and upwards of 90% of the time when servicing response sensitive exploiters).

For System-Managed CF Structure Duplexing, the latency effect of shared coupling facility CPs is magnified even further. Processing of a duplexed operation requires several exchanges of coordination signals between the two CFs containing the duplexed structure instances. Each exchange requires the attention of the CF at the other end to perform certain activities and respond. If the CFs involved in duplexing are using shared engines, then the kind of shared CP latency described above can occur not only at the beginning of each request, but also at several points during the processing of each duplexed request. This makes the performance of shared-CP coupling facilities for CF duplexing much worse than with dedicated-CP coupling facilities. In extreme cases, the duplexed structures may even have difficulty maintaining their duplexed state. When this occurs, one or more structures may "break duplexing" spontaneously and revert to simplex mode.

If shared engines must be used, then it is recommended that the CF images involved in duplexing be configured to have at least one CP available to run on at least 95% of the time. This can be done by defining the image to be "highly favored" (given a high LPAR weight, be run with dynamic CF dispatch OFF and all other CF partitions sharing with this partition be run with dynamic CF dispatch ON). For example, you might configure a production CF image with Dynamic Dispatch OFF and an LPAR weight of 95 sharing 1 CP with a test CF image with Dynamic Dispatch ON and an LPAR weight of 5. This would ensure the production CF would have a CP available 95% of the time. Even so, it is possible to "break duplexing" in such a configuration. Degraded duplex request service times may be expected when shared coupling facility CPs are being used compared to when dedicated coupling facility CPs are being used.

Shared Coupling Facility CPs with insufficient weights may result in degraded performance, timeout messages from various applications (like DB2, IMS , VTAM) and loss of duplexing for some structures.
If the CF consists of dedicated CF CPs and CF CPs which are shared with z/OS CPs, the shared CF CPs must be weighted much higher (20 times) than the highest z/OS CPs. See the PR/SM Planning Guide for a further discussion of this configuration and recommendations for its definition and use.

Be careful when configurating Dynamic CF Expansion using a mix of dedicated engines and shared engines (e.g. 1 of each). One might like to do this as a kind of "reserve capacity" so that during peak activity when the dedicated CF engine gets very busy, the extra shared engine could be dispatched to pick up the extra load. When the shared engine starts to process requests, it will acquire CFCC latches for serialization. If PR/SM decides to dispatch another LPAR while the CF on the shared CP is holding onto those latches, the execution of requests on the dedicated CP will be disrupted. In extreme cases, the additional shared CP resource might actually do more harm than good by disrupting the dedicated engine!

Recommendation: Provide a configuration that ensures all production CFs participating in System-Managed CF Structure Duplexing always have at least one (physical) CP which is available 100% of the time. For example, this might be done by dedicating a CP to the production partition or a shared CP configuration with two physical CPs and the production CF has two logical CPs and the test CF has one logical CP.

Recommendation: If shared engines must be used, then it is recommended that the CF images involved with duplexing be configured to have at least one CP available to run on at least 95% of the time. Even so, it is possible to spontaneously “break duplexing” in such a configuration.

Recommendation: Do not configure CFs with Dynamic Dispatching turned ON for use with CF Duplexing, except in a test configuration in which performance is not critical.

Recommendation: In a test environment with a shared CP coupling Facility, give the CF a high weight in combination with Dynamic Dispatching turned ON.

Coupling Facility CPs - “balanced” capacity

Another issue related to coupling facility CPs for System-Managed CF Structure Duplexing is that of "balanced" capacity. Given the "lockstep" nature of the synchronization of the execution of duplexed commands, the completion of the duplexed operation is gated by the execution speed of the slower of the two operations.

When there is a mismatch in either raw processor speed (e.g. machine type of the CF), or overall coupling facility CPU capacity (e.g. number of coupling facility CPs, CF LPAR weights, shared vs. dedicated coupling facility CPs, etc.), the slower of the two CFs will tend to become a bottleneck. This can cause the overall service time for the duplexed requests to degrade and the duplexed requests may utilize the task and processor resources of the faster CF inefficiently because the duplexed commands are not able to execute at the "full potential" of the faster CF engines on which they are executing. These effects can be minimized by avoiding such imbalances in CF processor speed and capacity and by carefully following the recommendations above regarding overall "Coupling Facility CP Utilization."

Recommendation: Provide "balanced" coupling facility CP capacity between CF images participating in CF Duplexing, if possible. Avoid such significant imbalances as one CF with shared CPs and the other CF with dedicated CPs, CFs with wildly disparate numbers of CPs, CFs of different machine types with very different raw processor speed, etc. In general, re-balancing of coupling facility CP capacities may be necessary for any processor upgrade affecting a CF, and should be part of the installation planning prior to production use of the new/upgraded processor.

If such imbalances are unavoidable, it may be possible to compensate for them in other ways. For example, consider providing more CPs in the slower CF than there are in the faster CF to compensate for the inherent difference in engine speed. Another option is to consider redistributing the simplex structures so as to push more of the simplex workload at the faster CF, leaving the more constrained, slower CF free to devote more of its capacity to servicing the duplexed requests.

DUPLEX(ALLOWED) vs DUPLEX(ENABLED) Considerations

When defining the CFRM policy for duplexed structures, one must define either DUPLEX(ALLOWED) or DUPLEX(ENABLED) to indicate that a structure is to be duplexed. Specifying or defaulting to DUPLEX(DISABLED) for a structure makes it ineligible to be duplexed. At least two CF images that are connected to one another with CF-to-CF links must also be specified in the preference list (PREFLIST) for the structure.

Specifying DUPLEX(ENABLED) is often desirable from an operational standpoint because it minimizes the amount of operator intervention required for duplexing a structure and makes sure that it remains duplexed whenever possible. . z/OS will automatically start duplexing for these structures and attempt to keep them duplexed (re-duplexing if needed) as best it can. On the other hand, DUPLEX(ALLOWED) requires manual intervention via the SETXCF command to decide when to start or stop duplexing a particular structure, giving the installation finer control over duplexing (and re-duplexing) the structure.

There are some workload availability considerations that come into play in deciding how to specify this attribute. If DUPLEX(ENABLED) is specified with three or more CFs in each structure’s preference list, then in the event of a CF failure or loss of CF connectivity all structures in the affected CF will revert to simplex mode and then immediately re-duplex into the other available CF in the preference list. If there are only two CFs in the structure’s preference list, then in the event of a CF failure or loss of CF connectivity, the structure will first revert to simplex mode and then as soon as the second CF is restored, it will re-duplex back into that restored CF. While reverting to simplex mode requires no propagation/copying of structure data and is generally quite fast and non-disruptive, re-duplexing the structure requires that z/OS copy the structure content into a newly-allocated secondary structure instance. Reduplexing the structure can be somewhat disruptive to the ongoing workload that is using the structure as structure activity is temporarily quiesced during this copy process.

An installation can choose to specify DUPLEX(ENABLED) for a particular structure and the structure will automatically maintain its duplexed state as best it can without manual intervention, but in the event of a failover to simplex mode there will be a temporary disruption in workload processing when the structure automatically tries to reestablish duplexing at the earliest possible opportunity. Alternatively, an installation can choose to specify DUPLEX(ALLOWED) for a particular structure, which will require more operator intervention to start and maintain duplexing over time, but in the event of a failover to simplex mode the installation can plan for and control when it will undertake the temporary workload disruption associated with re-duplexing the structure (also taking into consideration the risks associated with leaving the structure in simplex mode for some period of time, before it is eventually re-duplexed).

To summarize, the choice of DUPLEX(ALLOWED) vs. DUPLEX(ENABLED) amounts to an installation making the tradeoff between three competing considerations: avoiding manual intervention to start and maintain duplexing, avoiding unnecessary disruption caused by re-duplexing structures at inopportune times (such as during a workload peak), and avoiding risks associated with having structures remain in simplex mode any longer than necessary.

Recommendation: In general, the use of DUPLEX(ALLOWED) is recommended. With this option, minimal disruption to the workload occurs at the time of an unplanned failure (e.g. CF failure, loss of CF connectivity) which causes structures to revert to simplex mode.

If DUPLEX(ALLOWED) is used, the installation must carefully document the protocols for reestablishing duplexing once the CF-related failure has been recovered including determining *when* to undertake this processing so as to minimize the disruption of the workload caused by the re-duplexing process while at the same time considering that the structures are exposed to the possibility of even more disruptive recovery actions should a second failure occur while the structures are still operating in simplex mode.

An installation that wishes to minimize this “double failure” risk should make use of DUPLEX(ENABLED) as this option will tend to ensure that the structures remain duplexed as much of the time as possible without requiring manual intervention to do so. An installation using DUPLEX(ENABLED) should also maintain an alternative copy of the CFRM policy that is defined with DUPLEX(ALLOWED) for use during planned CF reconfiguration/maintenance actions.

A hybrid approach is also recommended. Specify DUPLEX(ENABLED) for those structures which *do not* support user-managed rebuild processing (or which have failure-isolation considerations that make user-managed rebuild impossible in certain failure scenarios), and specify DUPLEX(ALLOWED) for those structures which *do* support user-managed rebuild (and which do not have any special failure-isolation considerations). With this approach, if a failure occurs the only structures that will automatically and immediately re-duplex themselves are those for which duplexing provides the *only* robust structure recovery mechanism. The structures that are not as dependent on duplexing as a recovery mechanism will remain in simplex mode until the installation chooses a convenient time to manually re-duplex them. This alternative is a good compromise in terms of reducing the workload disruption of re-duplexing immediately after a failure while also mitigating the risks associated with leaving some structures in simplex mode for an extended period of time.

Structure Sizing Considerations for System-Managed CF Structure Duplexing

Each Coupling Facility release usually will have increased storage requirements relative to the same structure allocated in a previous level Coupling Facility. The amount of increase varies, dependent on new function in that release as well as the specific structure attributes, so there is no simple "rule of thumb" that can be used to estimate the amount of storage increase that may occur. The CFSIZER utility may be used to calculate the appropriate structure size for a given type of structure. Each of the two duplexed structure instances will require this amount of CF space. This is available in http://www.ibm.com/systems/support/z/cfsizer/.

When defining the CFRM policy size parameters (SIZE, INITSIZE, and MINSIZE) for a duplexed structure, the size values specified should define the size of one of the structure instances, not both added together.

Recommendation: Perform the appropriate structure sizing/re-sizing for duplexed structures.

Recommendation: Since *each* of the duplexed structure instances will require the calculated amount of CF space, you must plan for that amount of space in *each* of the CF instances in which a copy of the duplexed structure may reside. However, the CFRM policy values that you specify for structure size (e.g. SIZE, INITSIZE, and MINSIZE) should define the size of *one* of the structure instances, not both added together.

Summary

System-Managed CF Structure Duplexing is the next evolutionary step in the Parallel Sysplex architecture, providing value through:

- *Eliminating Staging Data Sets for the System Logger as a requirement for availability if a CF or Logger structure fails. This is expected to provide both CPU and response time benefit.*
- *System Management benefits by simplifying recovery procedures. A major benefactor of this is IMS Shared DEDB/VSO structures.*
- *Basic recovery for failed structures, failed CFs, and losses of CF connectivity. Without System-Managed Duplexing, many structures have no simple means to recover data. This includes BatchPipes, CICS Data Tables, Temporary Storage, and Named Counters structures.*
- *Faster recovery for structures that would otherwise require reading log data to recover. The IMS Shared Message Queue is one example of this.*

In addition, System-Managed CF Structure Duplexing is designed to help provide direct financial savings by potentially enabling the use of an ICF instead of a standalone model Coupling Facility to simplify the Parallel Sysplex configuration.

Consistent with z/OS's design points of Reliability/Availability/Serviceability, once the system is enabled for duplexing, migrating in and out of duplexing mode on a structure by structure basis is dynamic. It can be as simple as issuing an operator command or making a CFRM policy update. In addition, RMF reports on the performance and service characteristics of the environment for monitoring and tuning.

As with any technology, a cost / benefit analysis of System-Managed CF Structure Duplexing needs to be done for each exploiter to determine the value in each environment.

Appendix A: Calculating Simplex Resource Use

Host CPU Capacity

To measure the effect on host CPU capacity of each CF structure, one would need to calculate the amount of CPU time spent by the system on behalf of each structure. The following formula can be used:

CPU Time for coupling function = (CF Access Rate) * (Software + Hardware time)

The CF access rates and hardware times are easily determined from an RMF Structure Activity Report. For example, consider this hypothetical structure:

```
                                                 INTERVAL = 00.10.00


STRUCTURE NAME = BUSY_STR        TYPE = LIST
                # REQ    -------------- REQUESTS -------------
      SYSTEM    TOTAL                #      % OF  -SERV TIME(MIC)-
      NAME      AVG/SEC             REQ      ALL      AVG   STD_DEV

      SYSA        900K   SYNC     600K  66.7%     30.0      21.0
                 1500    ASYNC    300K  33.3%    250.0     155.7
                         CHNGD      0    0.0%  INCLUDED IN ASYNC
```

The synchronous hardware response time is 30 microseconds for 1000 synchronous requests per second (600K requests / 600 seconds) in this 10 minute interval. The asynchronous hardware response times are not used in a CPU time calculation as the host processor does not wait for these requests to finish. However, there are larger software costs (compared to synchronous operations) associated with starting and completing these requests.

Approximate software times for each type of request can be found in the table below. As these are machine dependent, sample times (in microseconds) are shown for mid-sized models in each family of servers. The values are scaled by the single processor speed of each model (total model capacity divided by number of CPs). Performance ratios for the processors shown and any other models are available from https://www-304.ibm.com/servers/resourcelink/lib03060.nsf/pages/lsprindex?OpenDocument/.

Host software times (in microseconds) for various types of requests to the coupling facility:

Model	LSPR MIPS (PCI)	Engine Speed	Synchronous Lock	Lock Contention	Synchronous List/Cache	Asynchronous
z800-002	309	155	14	440	24	112
z900 1C8	1562	195	12	379	20	96
z900 2C8	1886	236	10	316	17	80
z890 410	90	23	105	3303	178	834
z890 420	160	40	59	1863	100	470
z890 430	309	75	31	977	53	247
z890 440	387	97	25	782	42	197
z890 450	605	151	15	488	26	123
z890 460	738	185	13	409	22	103
z890 470	1282	321	7	235	12	59
z990 304	1568	392	6	189	10	48
z990 312	4119	342	7	220	12	55
z990 320	6267	313	8	249	13	62
z9 EC 704	2122	530	4	140	8	35
z9 EC 712	5546	462	5	164	9	42
z9 EC 720	8392	420	6	187	10	46
z10 EC 704	3192	798	2.7	93	5.3	23
z10 EC 712	8258	688	3.3	110	6	27
z10 EC 720	12514	626	4	125	7	32
z196 704	4320	1080	2.2	68.8	3.7	17.4
z114 z04	3139	784	3.6	114.4	6.2	28.9
z12 EC 405	1078	216	11	342	18	87
z12 EC 505	2809	562	4	132	7	33
z12 EC 605	4178	836	3	88	5	22
z12 EC 705	6628	1326	2	56	3	14
z12 BC A04	166	42	56	1759	93	446
z12 BC H04	433	108	22	688	53	174
z12 BC R04	1422	356	7	208	11	53
z12 BC z04	3543	886	3	83	4	21
z13 405	1118	224	10	330	17	84
z13 505	3306	661	4	112	6	28
z13 605	4690	938	2.5	79	4	20
z13 705	7392	1478	1.6	50	2.6	13

The Parallel Sysplex technology provides many benefits to the z Systems environment, including high availability, workload balancing, scalable growth, reduced cost of computing, ease of use, and investment protection of current applications. System-Managed CF Structure Duplexing enhances this by providing a general-purpose, hardware-assisted, easy-to-exploit mechanism for duplexing CF structure data, and providing a robust recovery mechanism for that duplexed CF structure data during failover situations.

If you are interested in a model not listed, calculate the "MIPS" per CP for that model and one in the table. For example:

BC	MIPS	Per CP
Z01	670	670
Z02	1245	622
Z03	1777	593
Z04	2270	554
Z05	2749	550
EC (E12)		
704	3227	807

If you want to compare to a BC Z05 to a EC 704, the engine speed of the BC is 807/550 or 1.47x faster, so factor all the numbers by 1.47

	Sync Lock	Lock Cont.	Sync Lst/Cache	Async
z10 EC 704	2.7	93	5.3	32
z10 BC Z05	4.0	137	7.8	47

Synchronous Lock	1.47 * 2.7 = 4.0
Syncc List / Cache	1.47 * 5.3 = 7.8
Lock Cont:	1.47 * 93 = 137
Async Time	1.47 * 32 = 47

Another component of CPU cost for coupling functions involves resolving lock contention (note the software cost of lock contention in the table above). Lock contention rates are identified at the far right of the lock structure activity report in RMF. Consider the extracted example below:

```
STRUCTURE NAME = LOCK_STR          TYPE = LOCK    INTERVAL = 00.10.00
              # REQ    -------------- REQUESTS -------------
    SYSTEM    TOTAL              #     % OF  -SERV TIME(MIC)-
    NAME      AVG/SEC            REQ    ALL      AVG   STD_DEV

   SYSA        900K   SYNC    900K  100%    28.0     21.0   Req. Delay
            1500   ASYNC          0.0%    0.0      0.0   -CONT 7198
                      CHNGD     0     0.0%  INCLUDED IN ASYNC

STRUCTURE NAME = LIST_STR        TYPE = LIST
              # REQ    -------------- REQUESTS -------------
    SYSTEM    TOTAL              #     % OF  -SERV TIME(MIC)-
    NAME      AVG/SEC            REQ    ALL      AVG   STD_DEV

    SYSA        30K   SYNC    15K   50.0%    30.0     31.0
             50.0  ASYNC  15K   50.0%   260.0    165.7
                      CHNGD     0    0.0%  INCLUDED IN ASYNC

STRUCTURE NAME = CACHE_STR        TYPE = CACHE
              # REQ    -------------- REQUESTS -------------
    SYSTEM    TOTAL              #     % OF  -SERV TIME(MIC)-
    NAME      AVG/SEC            REQ    ALL      AVG   STD_DEV

    SYSA        600K   SYNC    400K  66.7%    35.0     41.0
                1000   ASYNC    200K  33.3%   250.0    175.7
                       CHNGD     0    0.0%  INCLUDED IN ASYNC
```

```
REQUEST
CONTENTIONS
# REQ           240K
# REQ DELAYED   3601
- CONT          3600
- FALSE CONT    3000
```

Using the "-CONT" field and assuming a 10 minute interval, this results in (3600/ 600) = 6 contention events per second.

Using the data from the structure activity report and the software table, the simplex host cost for each structure can be determined. Take, for example, an IBM eServer zSeries 800 (z800) Model 002 connected to a CF with three structures. The RMF report for the structures might look like the following:

From this example report, we can construct a worksheet for each structure using software times from the z800-002 row of the host software time table, and frequencies and hardware times from the RMF report. Note that times have been converted from microseconds to seconds for the "CPU Cost" column.

Structure	Frequency * (per sec)	(Software + (mics)	Hardware) (mics)	=	CPU Cost (sec)
Lock _Str	1500	* (14 +	28)	=	0.063
Lock Contention	12	* (440)		=	0.005
List_Str synch	25	* (24 +	30)	=	0.001
List_Str asynch	25	* (77)		=	0.002
Cache_Str synch	667	* (24 +	35)	=	0.039
Cache_Str asynch	333	* (77)		=	0.026
					====
				Total	0.136 Seconds

To calculate the CPU cost for coupling as a percentage of host capacity, one must divide the CPU time by the number of engines in the host. Thus, for this 2-way processor example, the total time is divided by two engines and then transformed into a percentage (by multiplying by 100). Thus, we have (0.136/2) = 0.068, or 6.8% simplex host coupling cost for the total of all three structures. Individually, the structure impact on host capacity cost would be calculated similarly yielding 3.4% for Lock_Str, 0.15% for List_Str, and 3.25% for Cache_Str.

CF CPU Capacity

Information needed to calculate the current contribution to CF CPU utilization of each structure in a coupling facility can be found in the Coupling Facility Usage Summary of RMF's CF Activity Report. An example is shown below, showing details of four of the structures on a coupling facility:

TYPE	STRUCTURE NAME	STATUS	CHG	ALLOC SIZE	% OF CF STORAGE	# REQ	% OF ALL REQ
LIST	DB2PROD_SCA	ACTIVE		25M	0.6%	7727	0.8%
	IXCDEF	ACTIVE		14M	0.3%	237681	25.9%
LOCK	DB2PROD_LOCK1	ACTIVE		125M	3.1%	246985	26.9%
	ISGLOCK	ACTIVE		128M	3.2%	358786	39.1%
(other structures not shown)							7.3%

and on the next page of the report we see:

```
COUPLING FACILITY      2064  MODEL 100  CFLEVEL   12

AVERAGE CF UTILIZATION  (% BUSY)   5.9  LOGICAL PROCESSORS:
DEFINED 2  EFFECTIVE 2.0
```

The coupling facility utilization for each structure can be approximated by allocating the total coupling facility usage proportionally between its structures based upon the number of requests. For example, if a lock structure gets 39% of the requests, then 39% of the CF usage is allocated to that structure.

Using the example above, one can calculate the contribution of each structure as:

Structure	**CF % Busy Contribution**
DB2PROD_SCA	.05%
IXCDEF	1.53%
DB2PROD_LOCK1	1.56%
ISGLOCK	2.31%

Coupling Facility Link Subchannel Busy

Coupling links connect the server running z/OS and the coupling facility, as well as the CF to CF for system-managed duplexing. Each link has either seven (with peer mode links), or two buffers available to send and receive signals. These buffers are associated with subchannels. When a message is being sent from a z/OS to a CF, the link is busy for the time needed to send the signals and responses over the connection, but the subchannel is allocated for the entire duration from the beginning of the first signal to the final response back. In an asynchronous message, the subchannel is busy for the entire duration of the request as well. The link subchannel utilization can be calculated as the product of the request rate per second and the service time per request.

Information needed to calculate the current contribution of each structure to CF link subchannel utilization can be found in the Structure Activity Report of RMF's CF Activity Report. As an example, consider the report shown earlier for Cache_Str. Using data extracted from that report, we can make the following calculations:

Total link subchannel busy time for Cache_Str
= (synch ops/sec * serv time) + (async ops/sec * serv time)
= (400K/600 * .000035) + (200K/600 * .000250)
= .023 + .083
= .106 seconds

If there were 2 links to the CF containing this structure, and each link had 2 subchannels, then the average simplex link subchannel utilization would be:

Average link subchannel utilization
= 100 * subchannel busy time per second / number of subchannels in use
= 100 * .106 / 4
= 2.6%

It is recommended to keep the average subchannel utilization below 30% busy. Going beyond this value may cause elongation of response times and therefore increased host CPU usage for the system.

Appendix B: Host effects of Technology in a Parallel Sysplex

The table below shows the effects that various servers, coupling facilities, and coupling links have on the host z/OS capacity cost of coupling. The host technologies are listed across the top, and the coupling technologies are listed down the side. The value at each intersection gives the approximate percentage of host capacity that is consumed for coupling functions. For example, a value of 10% would indicate that approximately 10% of the host capacity (or host MIPS) is consumed by the subsystem, operating system and hardware functions associated with coupling facility activity. The values in the chart are based on customer experiences where their major applications are involved in data sharing. Your actual results may vary depending on the amount of data sharing your applications are doing. All structures are assumed to be in Simplex mode.

This chart is based on 9 CF operations per MIPS. One can calculate your activity by simply summing the total req/sec of the two CFs and dividing by the used MIPS of the attached systems (that is, MIPS rating times CPU busy). Then, the values in the table would be linearly scaled. For example, if the customer was running 4.5 CF ops per MIPS then all the values in the table would be cut in half.

Host CF	z114	z196	zBC12	zEC12	z13
z10 BC ISC	17	21		24	
z10 BC 1x IFB	14	17		19	
z10 BC 12x	13	15		17	
z10 BC ICB4	-	-	-	-	
z10 EC ISC	17	21		24	
z10 EC 1x IFB	14	17		19	
z10 EC 12x	12	14		16	
z10 EC ICB	-	-	-	-	
z114 ISC3	17	21	1	24	
z114 1x IFB	14	17	1	21	22
z114 12x IFB	12	15	1	17	19
z114 12x IFB3	10	12	1	13	14
z196 ISC3	17	21	1	24	

z196 1x IFB	**13**	**16**	**1**	**18**	**21**
z196 12x IFB	**11**	**14**	**1**	**15**	**17**
z196 12x IFB3	**9**	**11**	**1**	**12**	**13**
zBC12 ISC3	**17**	**21**	**1**	**24**	
zBC12 1x IFB	**14**	**18**	**1**	**20**	**22**
zBC12 12x	**12**	**15**	**1**	**17**	**18**
zBC12 12x	**10**	**11**	**1**	**12**	**14**
zEC12 ISC3	**17**	**21**	**1**	**24**	
zEC12 1x IFB	**13**	**16**	**1**	**18**	**20**
zEC12 12x	**11**	**13**	**1**	**15**	**17**
zEC12 12x	**9**	**10**	**1**	**11**	**12**
z13 1x IFB	**14**	**17**	**1**	**19**	**20**
z13 12x IFB	**12**	**14**	**1**	**16**	**17**
z13 12x IFB3	**9**	**11**	**1**	**12**	**12**
z13 CS5					**11**

Note 1: Assumes 9 CF requests / MI for production workload
Note 2: The table does not take into consideration any extended distance effects or system managed duplexing.
Note 3: For 9 CF requests/MI, host effect values in the table may be considered capped at approximately 18% due to z/OS 1.2 feature Synchronous to Asynchronous CF Message Conversion. Configurations where entries are approaching 18% will see more messages converted to asynchronous. As synchronous service times degrade relative to the speed of the host processor, the overhead % goes up. This could happen, for example, where the CF technology stays constant but you upgrade the host technology. This can be seen in the table by the % value increasing. z/OS converts synchronous messages to asynchronous messages when the synchronous service time relative to the speed of the host processor exceeds a breakeven threshold. At this point it is cheaper to go asynchronous. When all CF operations are asynchronous, the overhead will be about 18%. By the time you have reached >=18% in the table, that corresponds to the time z/OS must have been converting almost every operation asynchronous.

More information on using this table can be found in “CF Configuration Options” ZSW01971USEN.

Appendix C: Structure Recovery Support

The following table summarizes various structures and their recovery support.

Subsystem	Structure	Structure Type	User Managed Rebuild	System Rebuild/ SM Duplex
Allocation	Shared Tape	List	YES YES	No
BatchPipes	Multi-system pipes	List		YES
Catalog	Enhanced Catalog Sharing	LIST	YES	No
CICS	DFHLOG - **Logger**	LIST	**FAIL-ISOL**	YES
CICS	DFHSHUNT - **Logger**	LIST	**FAIL-ISOL**	YES
CICS	FWD Recovery - **Logger**	LIST	**FAIL-ISOL**	YES
CICS	Temp Storage	LIST	NO	YES
CICS	Shared Data Tables	LIST	NO	YES
CICS	Named Counter	List	NO	YES
DB2	SCA	LIST	**FAIL-ISOL**	YES
DB2	GBP	CACHE	YES	NO* Supports User Managed Duplexing
DB2	IRLM LOCK	LOCK	YES **FAIL-ISOL**	YES
GRS	Star	Lock	YES	NO
IMS	IRLM LOCK	LOCK	YES **FAIL-ISOL**	YES
IMS	VSO	CACHE	NO	YES
IMS	OSAM	CACHE	YES	NO
IMS	VSAM	CACHE	YES	NO
IMS	CQS	LIST	YES	YES
IMS	CQS **Logger**	LIST	**FAIL-ISOL**	YES
IMS	CQS **Logger** (EMH)	LIST	**FAIL-ISOL**	YES
JES2	Checkpoint	List	NO	YES
z/OS Operlog	**Logger**	LIST	**FAIL-ISOL**	YES
z/OS Logrec	**Logger**	LIST	**FAIL-ISOL**	YES
RACF®	Shared DB	Cache	YES	NO
RRS	**Logger**	LIST	**FAIL-ISOL**	YES
DFSMS	HSM Common Recall Queue	LIST	NO	YES
DFSMS	RLS Cache	Cache	YES	NO
DFSMS	RLS Lock IGWLOCK00	Lock	**FAIL-ISOL**	YES
VTAM	Generic Resources	LIST	**FAIL-ISOL**	YES
VTAM	MNPS	LIST	**FAIL-ISOL**	YES
Websphere MQ	Administration	LIST	NO	YES
Websphere MQ	Application	LIST	NO	YES
WLM	IRD	Cache	NO	YES
WLM	Enclaves	List	NO	YES
XCF	Signaling	List	YES	NO

Appendix D: Performance Improvements

The IBM System z10 Enterprise Class server introduced Coupling Facility Control Code (CFCC) Level 16. Prior to CFCC Level 16, System-Managed Coupling Facility (CF) Structure Duplexing required two duplexing protocol exchanges to occur synchronously during processing of each duplexed structure request. CFCC Level 16 allows one of these protocol exchanges, the “Ready to Commit”, or RTC, to complete asynchronously with respect to the transaction. This allows faster duplexed request service time, with more benefits when the Coupling Facilities are further apart, such as in a multi-site Parallel Sysplex. It is enabled with the z/OS parameter ENABLE(DUPLEXCF16) set in SYSx.PARMLIB(COUPLExx).

More information about this can be found in the IBM Redbook: z/OS Version 1 Release 10 Implementation http://www.redbooks.ibm.com/redbooks/pdfs/sg247605.pdf

References

- Parallel Sysplex Internet site
  http://www.ibm.com/systems/z/advantages/pso/index.html
- Parallel Sysplex White Papers
  http://www.ibm.com/systems/z/advantages/pso/whitepaper.html
- GDPS Sysplex Internet site
  http://www.ibm.com/systems/z/advantages/gdps/
- Coupling Facility Performance: A Real World Perspective
  http://www.redbooks.ibm.com/redpapers/pdfs/redp4014.pdf
- z/OS Version 1 Release 10 Implementation
  http://www.redbooks.ibm.com/redbooks/pdfs/sg247605.pdf

as the amount of multiprogramming in the user’s job stream, the I/O configuration, the storage configuration, and the workload processed. Therefore, no assurance can be given that an individual user will achieve throughput improvements equivalent to the performance ratios stated here.

ZSW01975-USEN-12