Websphere Application Server V8 for Linux on System z SSL Setup & Performance Study

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Overview of cryptographic terms used

SSL/TLS – SSL (Secure Socket Layer) and its successor TLS (Transport Layer Security) are protocols for encrypting data transfers over a network

RSA - asymmetric algorithm used for public-key cryptography. The RSA key size (e.g. 2048 bits) defines the security strength of the algorithm.

AES – symmetric algorithm used for data encryption/decryption during network data transmission after the SSL connection is established

CPACF – System z **CP A**ssist for **C**ryptographic **F**unction is a feature on the Central Processor unit to accelerate symmetric cryptographic and hash functions

CEX – System z **C**rypto **Ex**press feature provides support for asymmetric cryptographic operations in secure and clear key mode in case of SSL and TLS

Linux on System z end-to-end project:
Websphere Application Server (WAS) V8 SSL setup & performance study

Setup study:

- Scenario 1: WAS V8 SSL setup for securing network communications
- Scenario 2: IBM HTTP Server (IHS) SSL + WAS setup for securing network communications
- usage of System z cryptographic hardware features (CPACF, CEX)

Performance study:

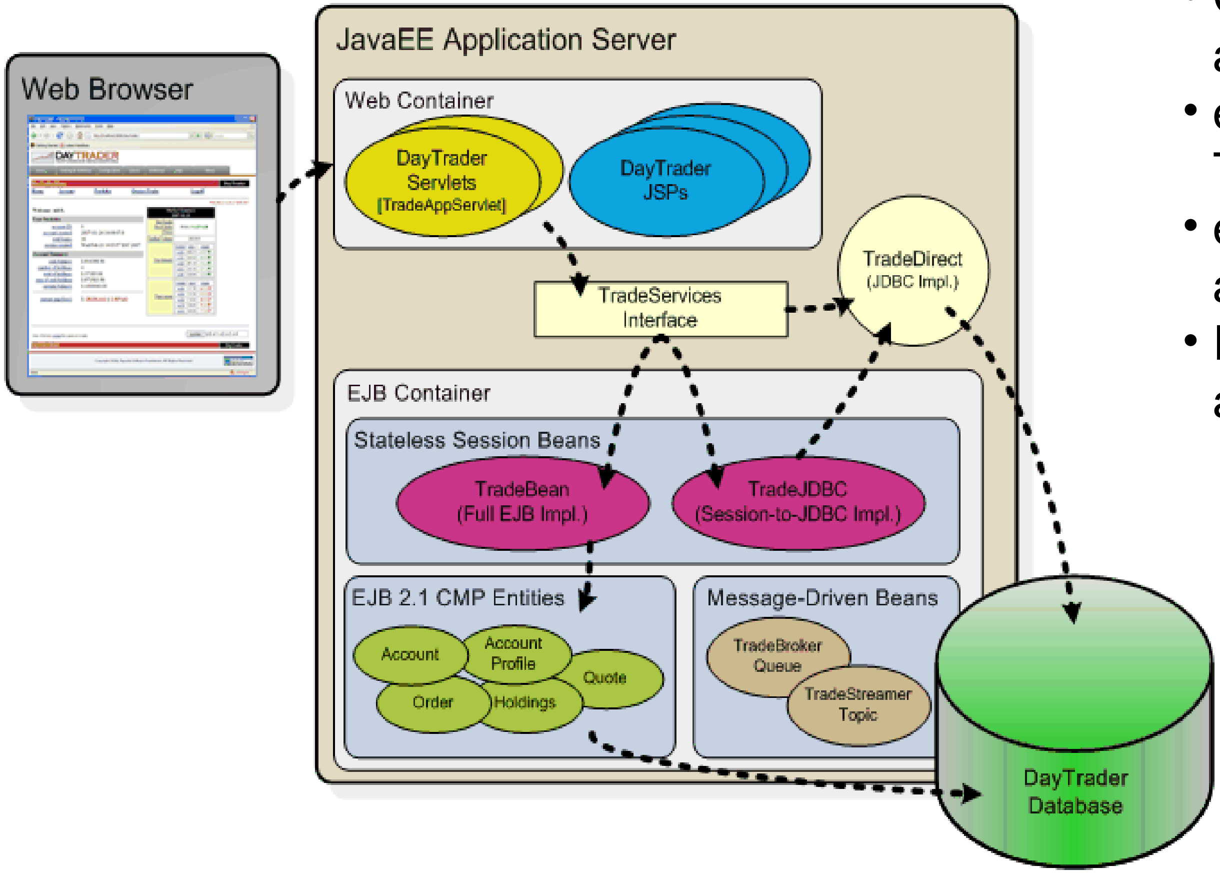
- SSL cryptographic operations in software mode only
- SSL cryptographic operations supported by CPACF
- SSL cryptographic operations supported by CPACF **and** CEX
  - CEX configured as SSL Accelerator (CEX3**A**)
  - CEX configured as cryptographic Co-Processor (CEX3**C**)
- results for different SSL RSA key sizes (2048 and 4096 bits)

Overview of the used System z cryptographic hardware

System z cryptographic hardware feature	symmetric crypto operations	asymmetric crypto operations	hash functions MACs	random number generation	secure key crypto
CPACF	DES 3DES AES		SHA-1 SHA-2 CMAC	pseudo RNG	
Crypto Express Accelerator		RSA			
Crypto Express Coprocessor		RSA ECC (via CCA)		true RNG	via CCA

* green – used in this project

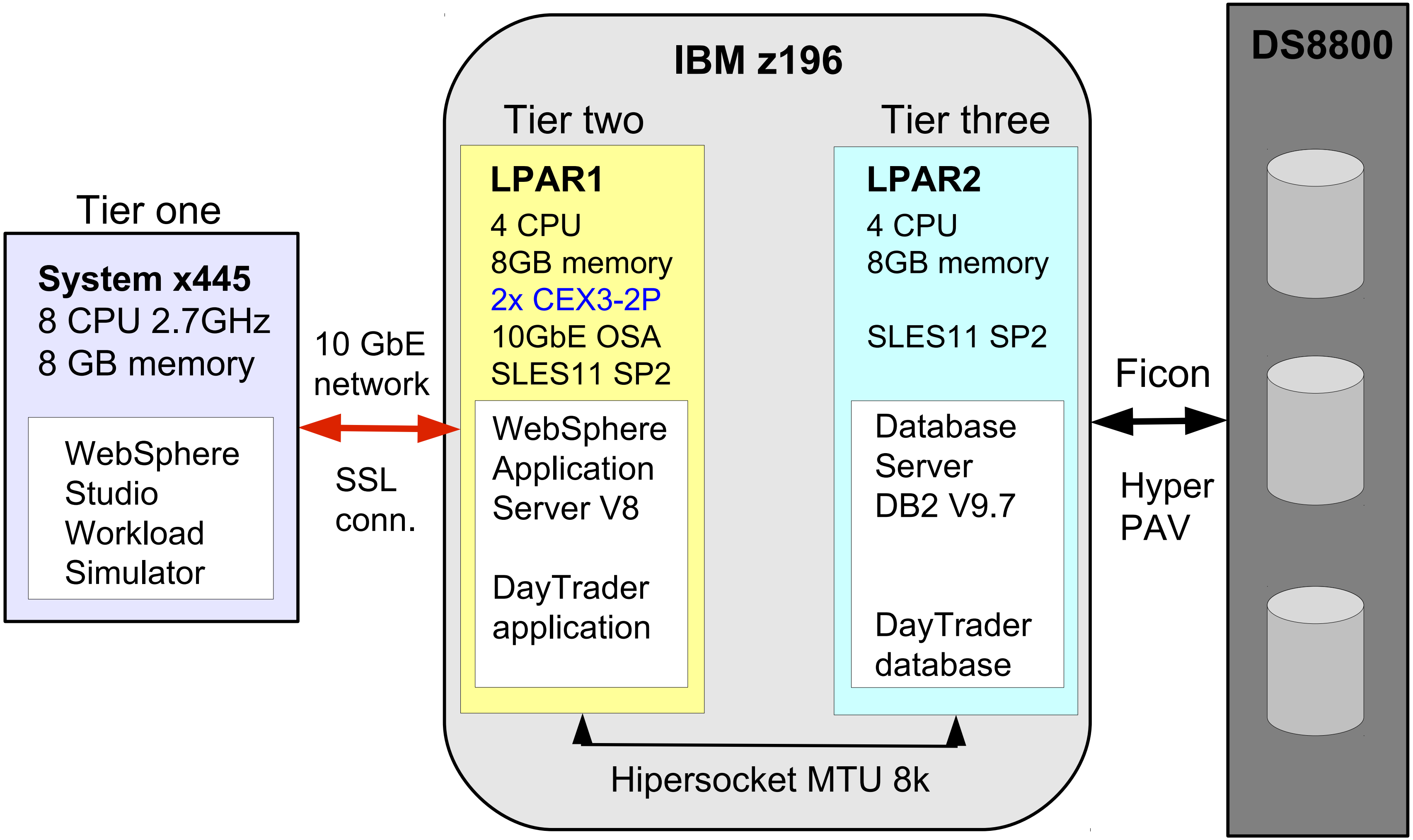
DayTrader benchmark application



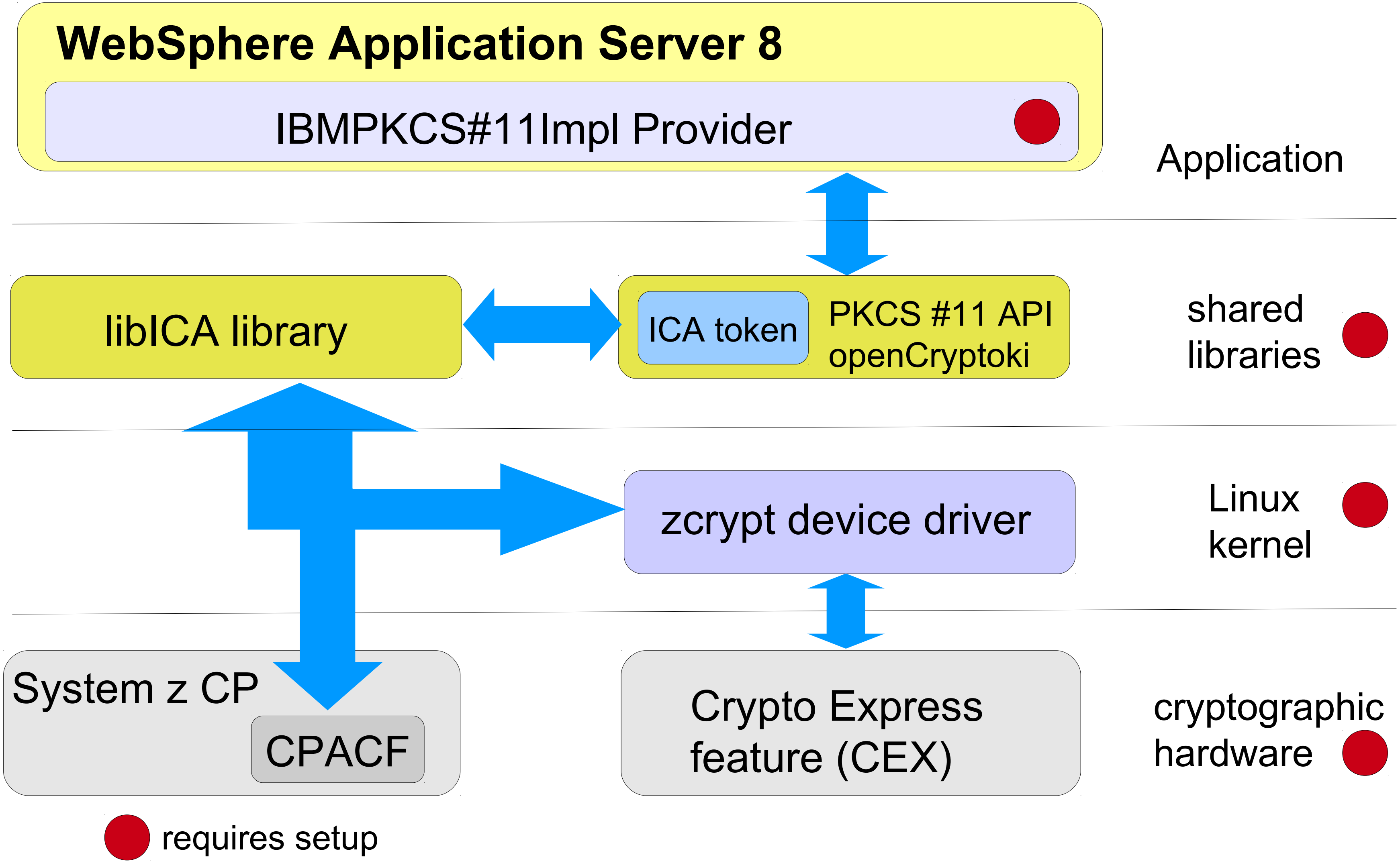
- Open Source benchmark application
- emulates an Online Stock Trading System
- end-to-end Java EE web application
- IBM WAS is a Java EE application server

http://geronimo.apache.org/GMOxDOC30/daytrader-a-more-complex-application.html

Scenario 1:
IBM WAS with internal HTTP transport – setup overview



IBM WAS with internal HTTP transport – cryptographic overview



WebSphere Application Server 8

IBMPKCS#11Impl Provider ●

Application

libICA library

ICA token

PKCS #11 API openCryptoki

shared libraries ●

zcrypt device driver

Linux kernel ●

System z CP

CPACF

Crypto Express feature (CEX)

cryptographic hardware ●

● requires setup

Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (1)

Enable System z cryptographic hardware

- **CPACF**

- CP Assist for Cryptographic Functions is available to the IBM System z Processor Unit (PU)
- must be enabled per feature code
- accessible from all LPARs

- **CEX**

- additional crypto feature
- Crypto Express cards can be shared among selected LPARs
- LPARs must be assigned to CEX cards using the SE or HMC customize image profiles task

Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (2)

Linux packages required:

- ***openCryptoki***
- ***openCryptoki-64bit***

- PKCS #11 API implementation for Linux
- interface between cryptographic hardware and user space applications

- ***libica***

- library for IBM Cryptographic Architecture (libICA)
- provides interface library routines used by modules to interface with IBM cryptographic hardware

Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (3)

IBM Linux on System z zcrypt device driver

- required when one or more System z *Crypto Express (CEX)* features are accessible in a LPAR or z/VM guest
- zcrypt device driver must be loaded (SLES11: rcz90crypt start)

- *lszcrypt** command shows the status of the available CEX features

```
# lszcrypt -V
card02: CEX3A      online
card03: CEX3A      online
```

- *chzcrypt** command controls any available CEX features

```
# chzcrypt -d 02
# lszcrypt -V
card02: CEX3A      offline
card03: CEX3A      online
```

* s390-tools package

Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (4)

CP Assist for Cryptographic Function (CPACF) support

- IBM WAS and IHS use the openCryptoki and libICA library on behalf to access System z cryptographic hardware
- *icainfo* (libica package) command lists supported CPACF ciphers

```
# icainfo
The following CP Assist for Cryptographic Function (CPACF) operations are
supported by libica on this system:
SHA-1:         yes
SHA-256:       yes
SHA-512:       yes
DES:           yes
TDES-128:      yes
TDES-192:      yes
AES-128:       yes
AES-192:       yes
AES-256:       yes
PRNG:          yes
CCM-AES-128:   yes
CMAC-AES-128:  yes
CMAC-AES-192:  yes
CMAC-AES-256:  yes
```

Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (5)

slot manager daemon for openCryptoki (pkcsslotd) – ICA token

- daemon must be running (e.g. rcpkcsslotd start)
- 'PKCS#11 cryptographic ICA token' must be initialized using the *pkcsconf* command (openCryptoki package)
- display token info shows a not yet initialized token below

```
# pkcsconf -t
Token #0 Info:
Label: IBM ICA PKCS #11
Manufacturer: IBM Corp.
Model: IBM ICA
Serial Number: 123
Flags: 0x880045 (RNG|LOGIN_REQUIRED|CLOCK_ON_TOKEN|
USER_PIN_TO_BE_CHANGED|SO_PIN_TO_BE_CHANGED)
Sessions: 0/-2
R/W Sessions: -1/-2
PIN Length: 4-8
Public Memory: 0xFFFFFFFF/0xFFFFFFFF
Private Memory: 0xFFFFFFFF/0xFFFFFFFF
Hardware Version: 1.0
Firmware Version: 1.0
Time: 13:32:27
```

Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (6)

slot manager daemon for openCryptoki (pkcsslotd) – ICA token

- command sequence to **initialize** the 'PKCS#11 cryptographic ICA token'

- initialize the ICA token (-c specifies the ICA token slot)

```
# pkcsconf -c 0 -I
```

- set a new Security Officer (SO) PIN

```
# pkcsconf -c 0 -P
```

- initialize and set a new User PIN

```
# pkcsconf -c 0 -u
# pkcsconf -c 0 -p
```

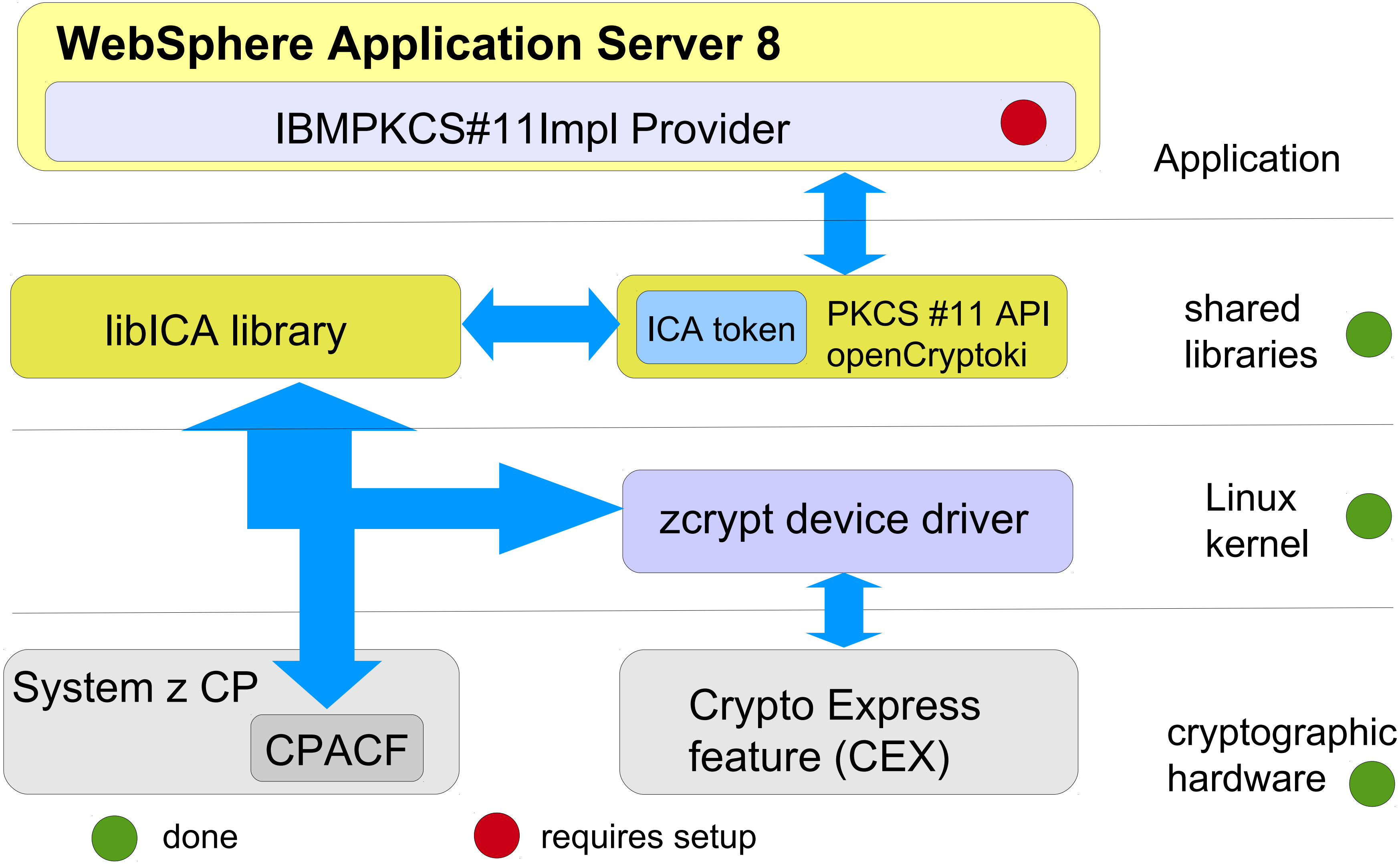
Configure Linux on System z cryptographic hardware support for IBM WAS V8 SSL (7)

slot manager daemon for openCryptoki – pkcsslotd

- list the fully initialized 'PKCS#11 cryptographic ICA token'

```
# pkcsconf -t
Token #0 Info:
Label: IBMICATOK
Manufacturer: IBM Corp.
Model: IBM ICA
Serial Number: 123
Flags: 0x44D (RNG|LOGIN_REQUIRED|USER_PIN_INITIALIZED|
CLOCK_ON_TOKEN|TOKEN_INITIALIZED)
Sessions: 0/-2
R/W Sessions: -1/-2
PIN Length: 4-8
Public Memory: 0xFFFFFFFF/0xFFFFFFFF
Private Memory: 0xFFFFFFFF/0xFFFFFFFF
Hardware Version: 1.0
Firmware Version: 1.0
Time: 15:37:35
```

IBM WAS with internal HTTP transport – cryptographic overview



Configure IBMPKCS11Impl Provider for IBM WAS V8 SSL support (1)

- update the IBMPKCS11Impl Provider *Java Security properties file* ({WAS home dir}/java/jre/lib/security/java.security)

- add the IBMPKCS11Impl Provider at the top of list provider list
- attach the path to the file holding the PKCS#11 token information

```
#
# List of providers and their preference orders (see above):
#
security.provider.1=com.ibm.crypto.pkcs11impl.provider.IBMPKCS11Impl /etc/cex3config.cfg
security.provider.2=com.ibm.crypto.fips.provider.IBMJCEFIPS
security.provider.3=com.ibm.crypto.provider.IBMJCE
security.provider.4=com.ibm.jsse.IBMJSSEProvider
security.provider.5=com.ibm.jsse2.IBMJSSEProvider2
security.provider.6=com.ibm.security.jgss.IBMJGSSProvider
security.provider.7=com.ibm.security.cert.IBMCertPath
security.provider.8=com.ibm.security.cmskeystore.CMSProvider
…
```

Configure IBMPKCS11Impl Provider for IBM WAS V8 SSL support (2)

- sample PKCS#11 token configuration file

```
# cat /etc/cex3config.cfg
name = IBMICATOK                                  ← name of the ICA token label
description = config for IBM Crypto Express 3 (configured as an ICA token)
library = /usr/lib/pkcs11/PKCS11_API.so64         ← path to PKCS#11 library
SlotListIndex = 0                                 ← number of the PKCS#11 ICA token slot
disabledMechanisms = {
CKM_MD5
CKM_SHA_1
CKM_MD5_HMAC
CKM_SHA_1_HMAC
CKM_SSL3_MASTER_KEY_DERIVE
CKM_SSL3_KEY_AND_MAC_DERIVE
CKM_SSL3_PRE_MASTER_KEY_GEN                       ← list of PKCS#11 mechanisms to disable
}
```

IBM WAS V8 with internal HTTP transport - SSL setup (1)

Adding a user to the PKCS#11 group

- non-root users running WAS using the PKCS#11 API must belong to the pkcs11 group
- for example WAS running under a non-root user (e.g. wasadmin)
- root user is automatically added when *pkcs11_startup* command is called for the first time (SLES11: done in the in pkcsslotd startup script)

- sample: add the 'wasadmin' user to the pkcs11 group

```
# grep pkcs11 /etc/group
pkcs11:!:64:root
# usermod -G pkcs11 wasadmin
```

IBM WAS V8 with internal HTTP transport - SSL setup (2)

Update the Java JCE policy files

- IBM WAS ships its own Java environment (JRE) with strong but limited Java Cryptography Extension (JCE) policy files
  - limited RSA key sizes
  - limited cipher support (e.g. AES-128 vs AES-256)

- requires replacement of JAR files placed in the JRE's directory *jre/lib/security/*

For further details about JCE policy files, see:

http://www.ibm.com/developerworks/java/jdk/security/index.html
Select your Java version and search for IBM SDK Policy files.

IBM WAS V8 with internal HTTP transport - SSL setup (3)

Select a supported cipher suite for hardware acceleration

Example: AES-256 + RSA

- Hardware support depends on System z machine and Linux distribution level

- check that AES-256 is supported by CPACF (*icainfo* command)

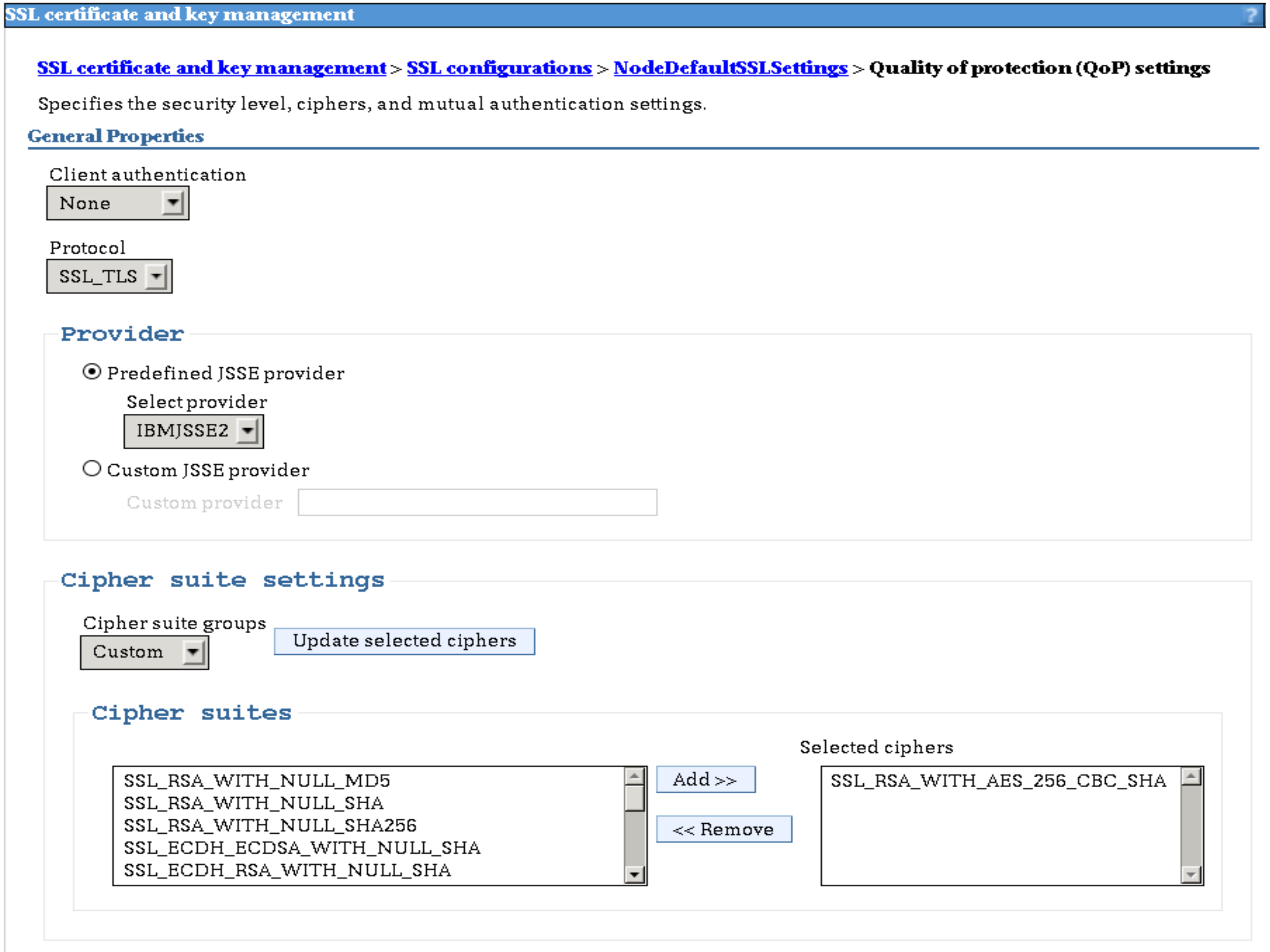
→ AES-256: **yes**

- RSA is supported with the CEX feature

WAS V8 cipher suite	IBM System z cryptographic stack support (SLES11 SP2)
SSL_RSA_WITH_AES_256_CBC_SHA	full support
SSL_DHE_RSA_WITH_AES_256_CBC_SHA	partially supported DHE-RSA in software; AES in hardware
SSL_RSA_WITH_AES_256_CBC_SHA256	not supported currently no support for SHA-256 in opencryptoki
SSL_ECDH_RSA_WITH_AES_256_CBC_SHA	ECDH-RSA not supported
SSL_ECDHE_RSA_WITH_AES_256_CBC_SHA	ECDHE-RSA not supported

IBM WAS V8 with internal HTTP transport - SSL setup (4)

Select a supported cipher suite for hardware acceleration



SSL certificate and key management

SSL certificate and key management > SSL configurations > NodeDefaultSSLSettings > Quality of protection (QoP) settings

Specifies the security level, ciphers, and mutual authentication settings.

General Properties

Client authentication: None

Protocol: SSL_TLS

Provider

● Predefined JSSE provider

Select provider: IBMJSSE2

○ Custom JSSE provider

Custom provider

Cipher suite settings

Cipher suite groups: Custom

Update selected ciphers

Cipher suites

- SSL_RSA_WITH_NULL_MD5
- SSL_RSA_WITH_NULL_SHA
- SSL_RSA_WITH_NULL_SHA256
- SSL_ECDH_ECDSA_WITH_NULL_SHA
- SSL_ECDH_RSA_WITH_NULL_SHA

Add >>

<< Remove

Selected ciphers

- SSL_RSA_WITH_AES_256_CBC_SHA

IBM WAS V8 with internal HTTP transport - SSL setup

Verify the SSL setup (1)

- try to access your application via SSL

```
# curl -k -v https://wasnode1.net:9443/daytrader    ← int. WAS SSL port
About to connect() to wasnode1.net port 9443 (#0)
Trying 10.x.x.x... connected
Connected to wasnode1.net (10.x.x.x) port 9443 (#0)
successfully set certificate verify locations:
CAfile: none
CApath: /etc/ssl/certs/
SSLv3, TLS handshake, Client hello (1):
SSLv3, TLS handshake, Server hello (2):
SSLv3, TLS handshake, CERT (11):
SSLv3, TLS handshake, Server finished (14):
SSLv3, TLS handshake, Client key exchange (16):
SSLv3, TLS change cipher, Client hello (1):
SSLv3, TLS handshake, Finished (20):
SSLv3, TLS change cipher, Client hello (1):
SSLv3, TLS handshake, Finished (20):
SSL connection using AES256-SHA                     ← used cipher suite
```

IBM WAS V8 with internal HTTP transport - SSL setup

Verify the SSL setup (2)

- Do we really use cryptographic hardware?

- *icastats* command shows libICA statistics during application execution

```
# icastats
 function | # hardware | # software
----------+------------+------------
    SHA-1 |         12 |           0      ← supported by CPACF
  SHA-224 |          0 |           0
  SHA-256 |          0 |           0
  SHA-384 |          0 |           0
  SHA-512 |          0 |           0
   RANDOM |         36 |           0      ← supported by CPACF(pseudo) or CEX3C(true)
 MOD EXPO |          7 |           0
  RSA CRT |         62 |           0      ← supported by CEX3A/C
  DES ENC |          0 |           0
  DES DEC |          0 |           0
 3DES ENC |          0 |           0
 3DES DEC |          0 |           0
  AES ENC |         94 |           0      ← supported by CPACF
  AES DEC |         93 |           0      ← supported by CPACF
 CMAC GEN |          0 |           0
 CMAC VER |          0 |           0
```

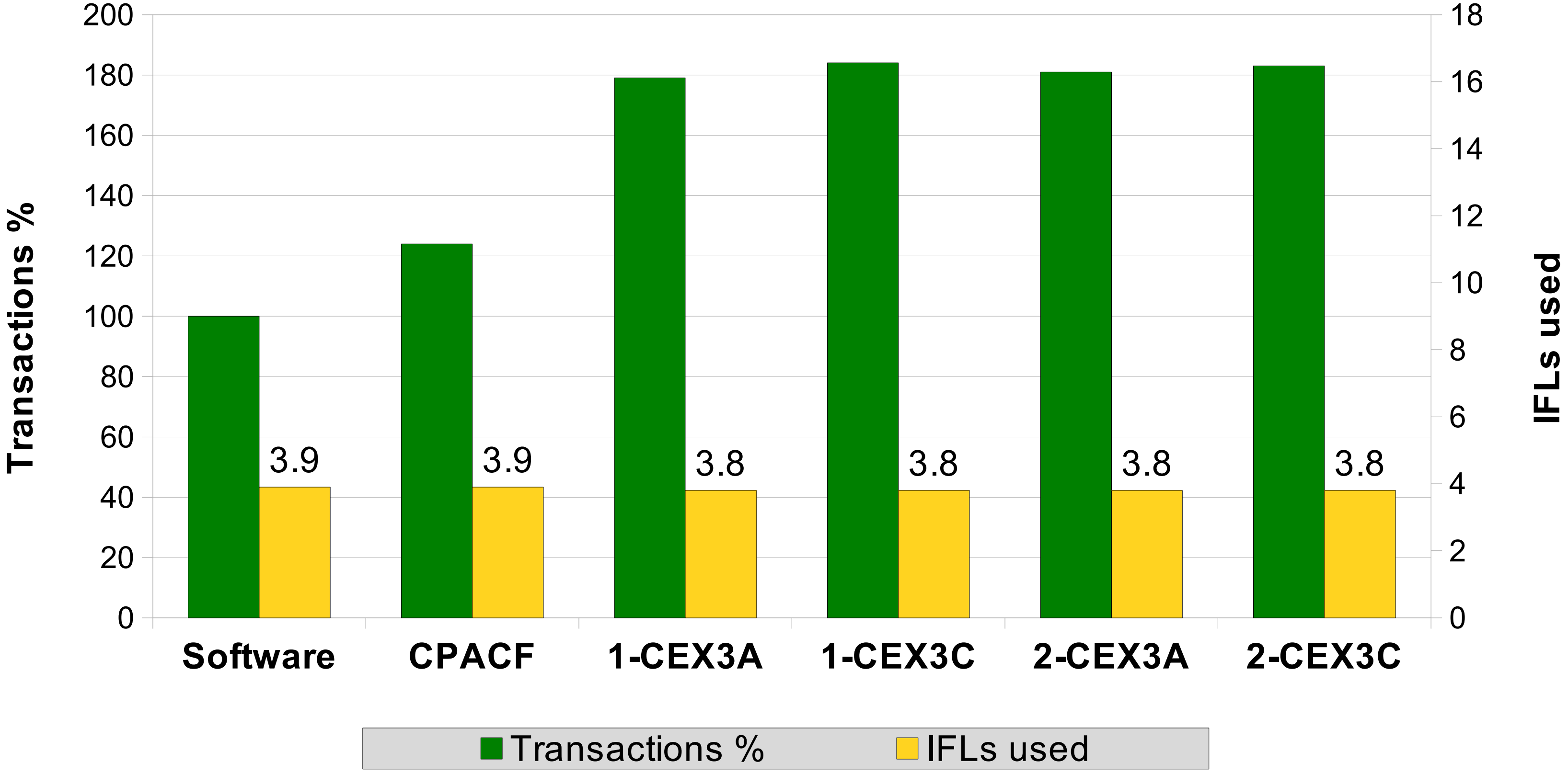
IBM WAS V8 with internal HTTP transport - SSL setup

Verify the SSL setup (3)

- *lszcrypt* command shows statistics for any available Crypto Express cards

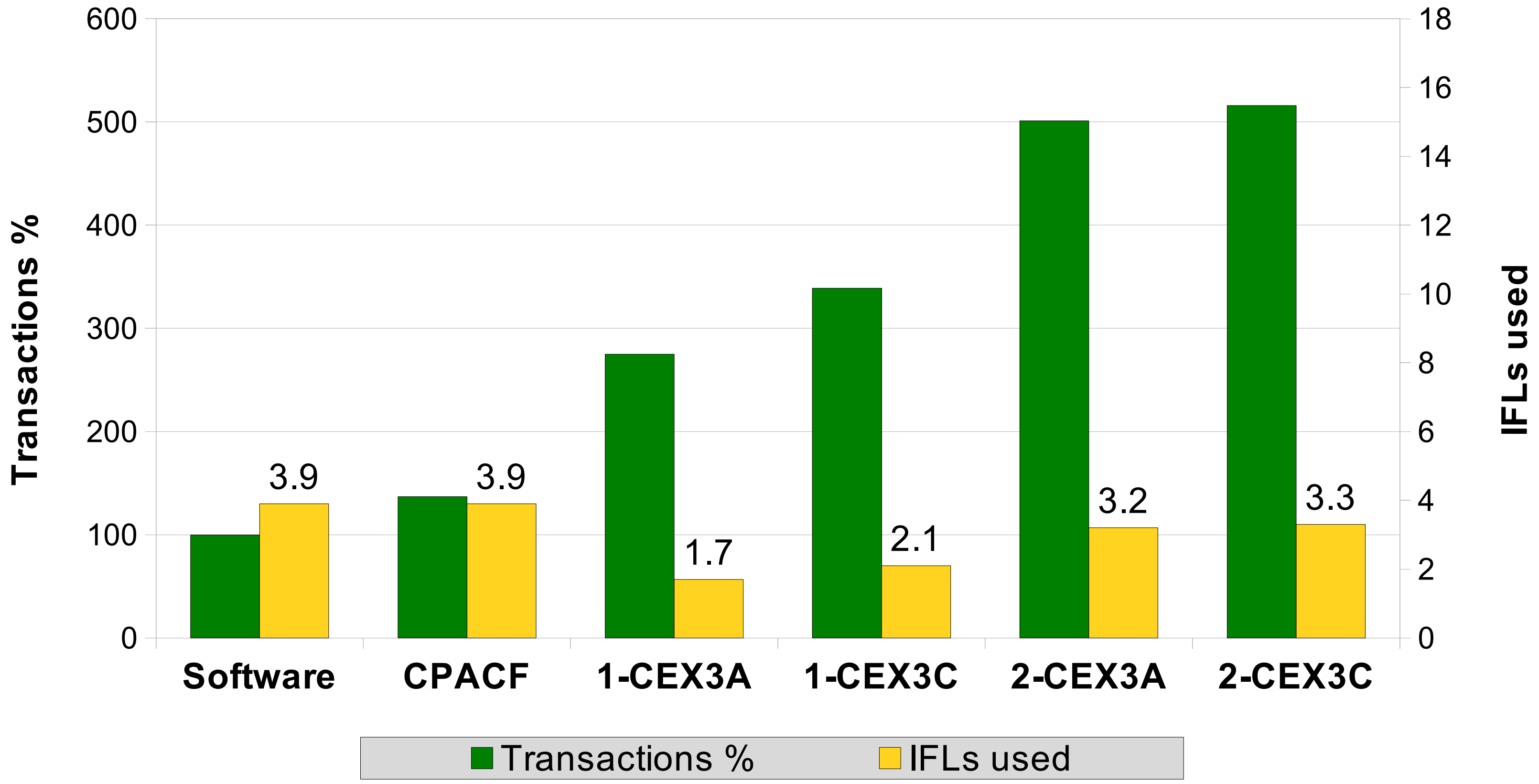
```
- no parameters given shows available CEX cards
# lszcrypt
card02: CEX3A
card03: CEX3A


- verbose level 1 shows status for the CEX cards
# lszcrypt -V
card02: CEX3A       online
card03: CEX3A       online


- verbose level 2 shows request count for the CEX cards
# lszcrypt -VV
card02: CEX3A       online  hwtype=9  depth=8 request_count=369228
card03: CEX3A       online  hwtype=9  depth=8 request_count=373015
```

Result for scenario 1: WAS only - RSA key 2048 bits
SSL transaction throughput (normalized)

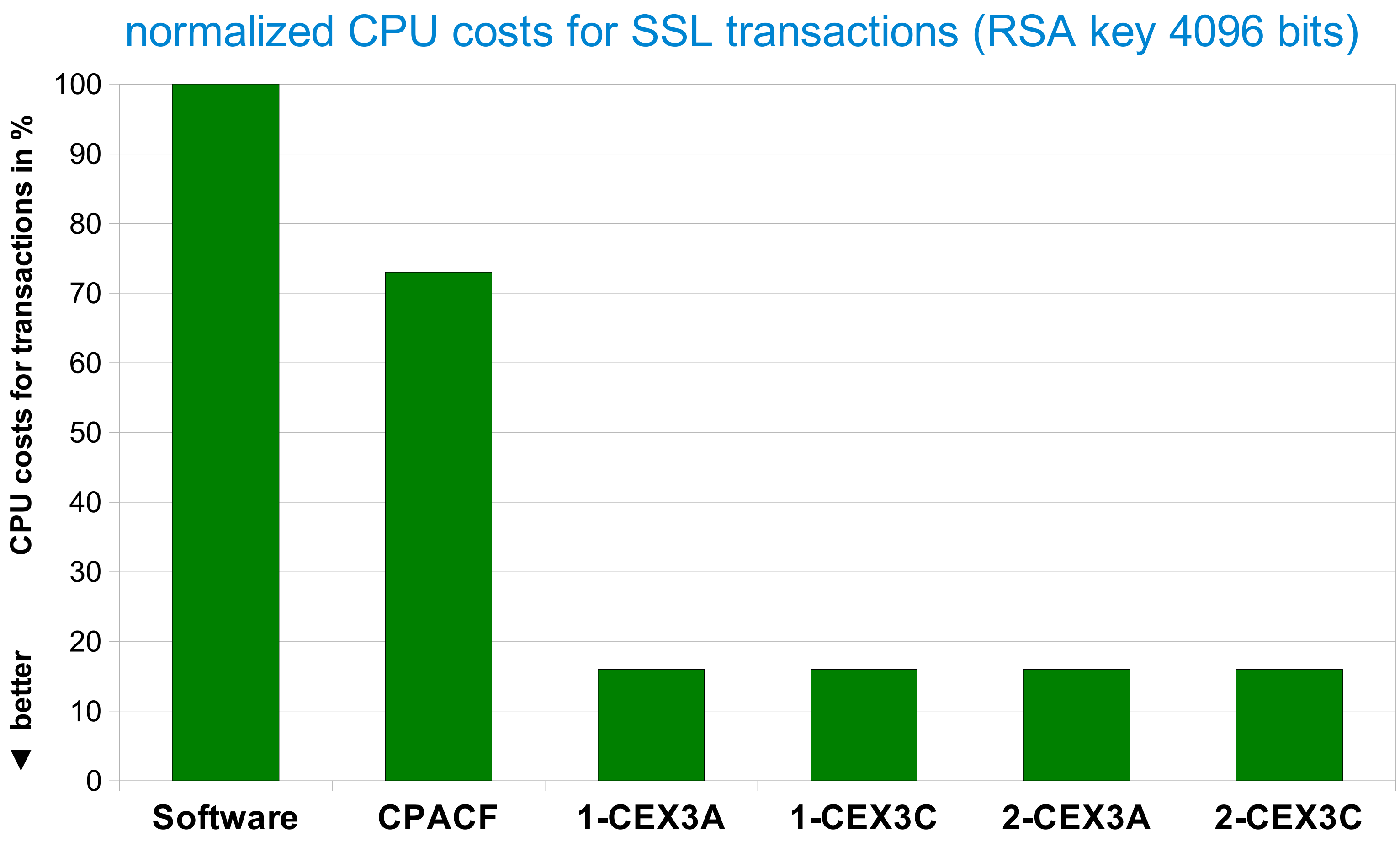


- transaction throughput nearly doubles with CEX3 cards
- more than 20% throughput increase with CPACF
- CPUs almost fully utilized for all test cases
- all CEX3 test cases include CPACF feature

Result for scenario 1: WAS only - RSA key 4096 bits SSL transaction throughput (normalized)

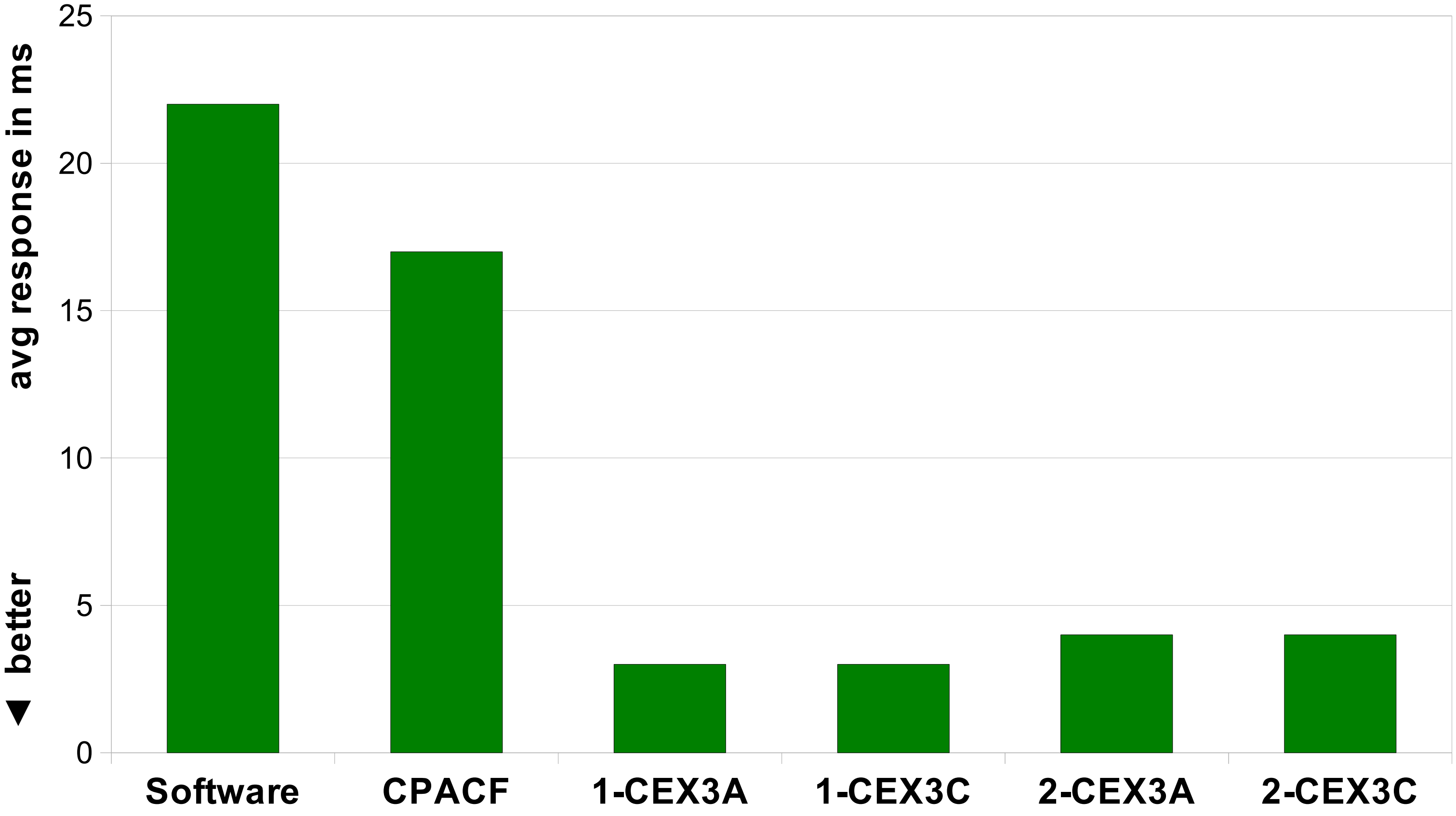


- transaction throughput increases up to 3x with one CEX3 card
- transaction throughput increases 5x with two CEX3 cards
- CPUs not fully utilized when CEX3 processors are used



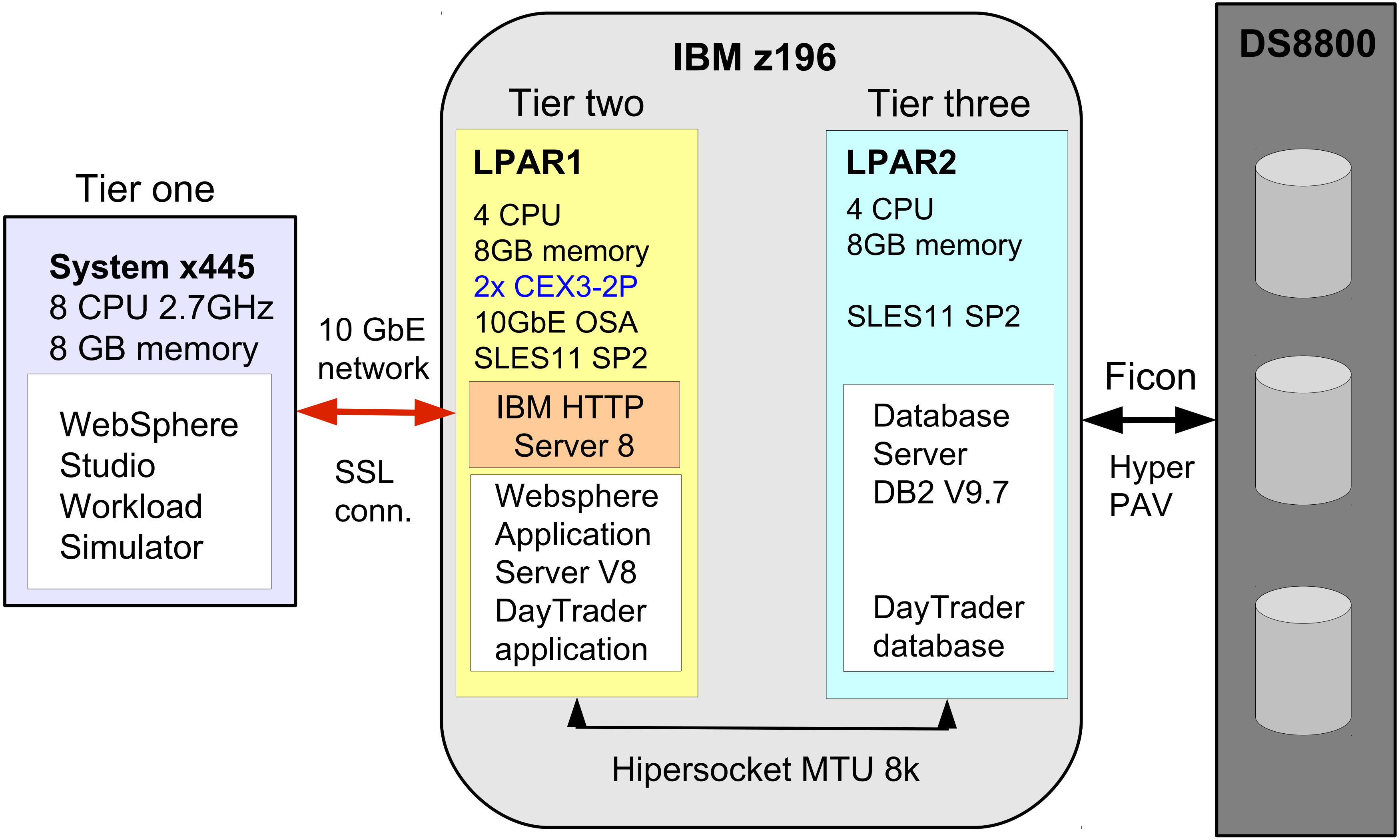
- use of System z cryptographic features reduces CPU costs at higher throughput rates
- pure software cryptographic operations are extremely CPU cost expensive

average response times for the SSL transactions (RSA key 4096 bits)

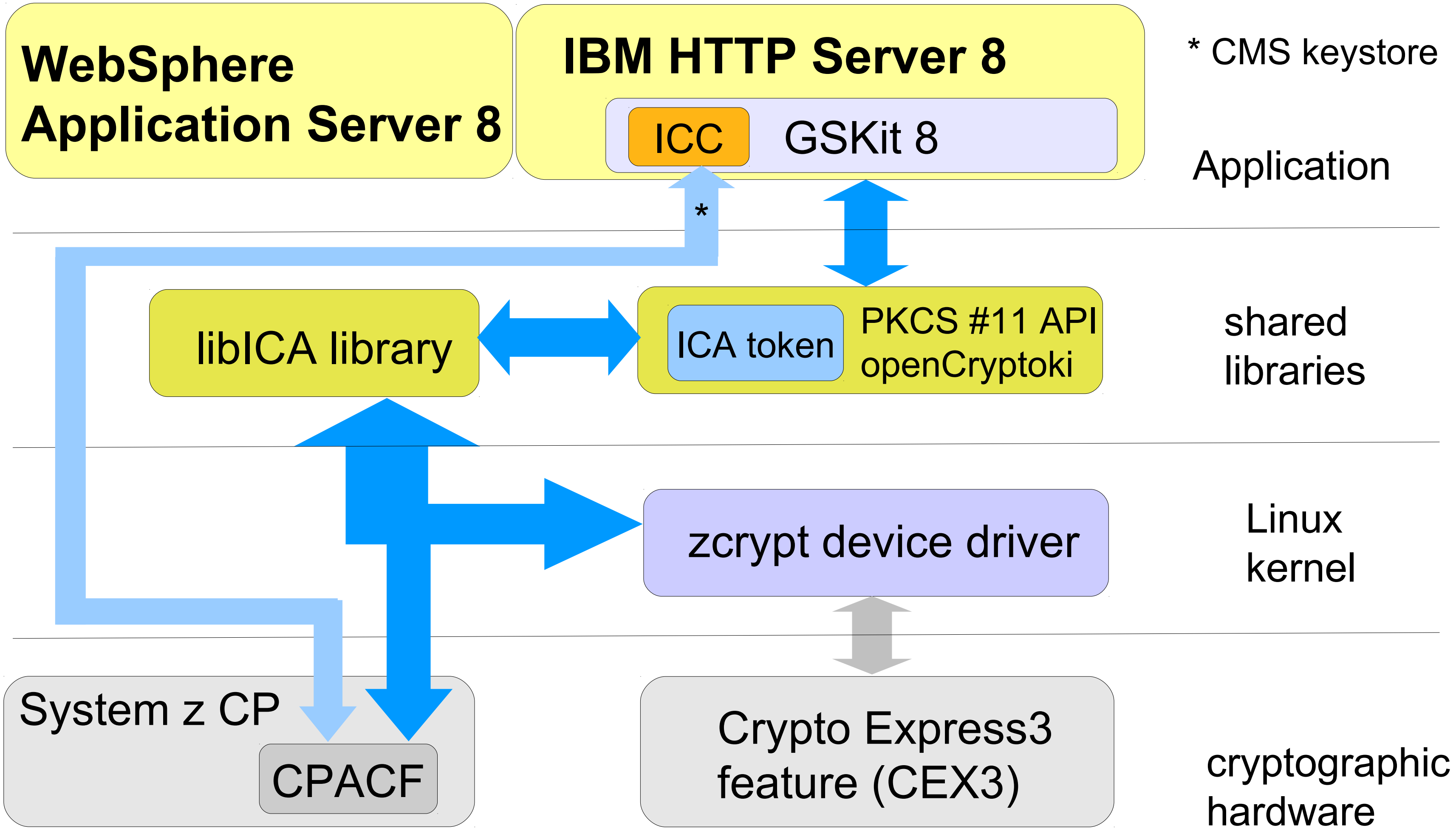


- avg response time below 5 ms for the CEX3 card setups
- transactions are processed faster with System z cryptographic hardware enabled on the application server

Scenario 2:
IBM WAS with IBM HTTP server – setup overview



IBM WAS with IBM HTTP server – cryptographic overview



Differences when using IBM HTTP Server instead of internal WAS HTTP transport

- zcrypt device driver handling is the same
- PKCS#11 (opencryptoki) ICA token configuration is the same

Differences:

- IHS uses the Global Secure ToolKit API (GSKit) instead of the IBMPKCS11ImplProvider
- SSL definitions are added to the IHS configuration file **/opt/IBM/HTTPServer/conf/httpd.conf**
- SSL certificates stored in the ICA token (PKCS12 keystore for WAS)

IBM WAS V8 with IBM HTTP server - SSL setup

Sample common SSL/TLS configuration for IHS version 8 (1)

```
# Example SSL(TLS) configuration
#
# added due to conflicting GSKit8 and openSSL libraries
LoadFile /usr/lib64/libcrypto.so                      ← added to prevent  SSL init failures
LoadModule ibm_ssl_module modules/mod_ibm_ssl.so
Listen 443
<VirtualHost wasnode1.net:443>
ServerName wasnode1.net
SSLEnable
SSLProtocolDisable SSLv2                              ← disable SSL protocol versions
SSLProtocolDisable SSLv3                                to force TLS usage
# cipher suite TLS_RSA_WITH_AES_256_CBC_SHA(35b)
# remove all ciphers first
SSLCipherSpec ALL NONE                                         ← reset cipher suites list
SSLCipherSpec ALL +TLS_RSA_WITH_AES_256_CBC_SHA                ← add cipher suites
</VirtualHost>
...
```

IBM WAS V8 with IBM HTTP server - SSL setup

Sample SSL/TLS PKCS#11 configuration for IHS version 8 (2)

```
...
# PKCS#11 configuration
KeyFile /opt/IBM/HTTPServer/ssl/key.kdb                        ← CMS keystore for signer
                                                               certificates

SSLServerCert IBMICATOK:ihscert                                ← use server certificate stored in
                                                               PKCS#11 ICA token

SSLStashfile /opt/IBM/HTTPServer/ssl/ibmicatok.sth             ← password file with stashed
                                                               PKCS#11 ICA token user PIN

SSLPKCSDriver /usr/lib/pkcs11/PKCS11_API.so64                  ← Fully qualified name of the
                                                               PKCS#11 library module
SSLDisable
SSLCachePortFilename /opt/IBM/HTTPServer/logs/siddport
# End of SSL configuration
```

Questions ?

- Further information
  - More detailed description is in the available White Paper (covers also the IBM HTTP Server setup)
    "IBM Websphere Application Server Version 8 for Linux on IBM System z -
    SSL Setup and Performance Study"
    http://www.ibm.com/developerworks/linux/linux390/perf/tuning_security.html#ssl
  - Linux on System z – Tuning hints and tips
    http://www.ibm.com/developerworks/linux/linux390/perf/index.html
  - Live Virtual Classes for z/VM and Linux
    http://www.vm.ibm.com/education/lvc/

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