IBM Americas, ATS, Washington Systems Center

# Database Encryption
## Share 11488
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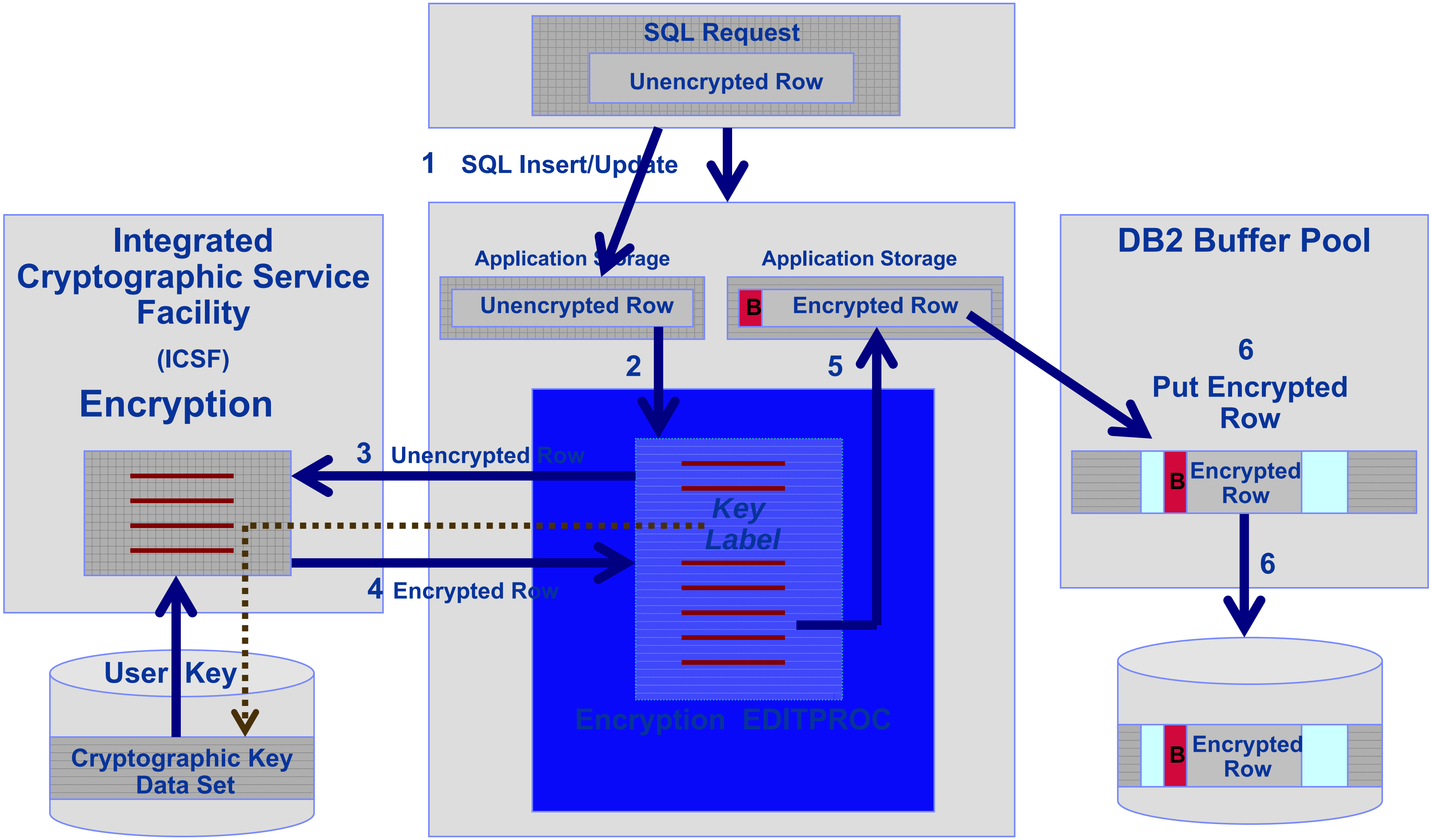
# Database Encryption

- **DB2 Built-In Functions**
- **IMS Data Encryption Tool for IMS & DB2 Databases (5799-P03)**
- **Other database encryption support**
  - Encrypting Tape
  - Encrypting DASD
  - Network encryption

# How does the Data Encryption Tool do encryption?

- **Via an EDITPROC, for every row processed by any SQL Utility for DB2 or IMS**
  - Encrypted row same length as clear row
  - No application changes required
  - One key per table or segment specified in the EDITPROC
  - Can use Clear Key, Secure Key or Protected Key
    - Protected key requires HCR7770 or later and CEX3

# DB2 Data Encryption Flow – Insert / Update



# How do the DB2 Built-In Functions do encryption?

- **Within the application, for every field that contains encrypted data**

  **ex. encrypt(data,'password for encryption',hint)**

  – 'Password for Encryption' is hashed to generate a unique key

  – Hint can be used as a  prompt for remembering the key

  – Encrypted field must be defined as VARCHAR (since it will contain binary data once its encrypted) and

  – The encrypted field will be longer (next multiple of 8 bytes + 24 bytes of MetaData + 32 bytes for optional hint field)

# Cryptographic Keys

- **Data Encryption Tool**
  - Clear Key or Secure Key or Protected Key
  - Key must be stored in the CKDS
  - When the table with an EDITPROC is in use, the key is available in the DB2 address space
- **DB2 BIF**
  - Clear key only (it’s calculated from the password for encryption in software) – so it’s available in the DB2 address space
  - Keys are not stored in a dataset, but the password for encryption is stored in the table

# Changing Cryptographic Keys

- **Data Encryption Tool**
  - Unload, change EDITPROC to reference new key, reload
  - Unload, change current key, DB2 restart, reload
- **DB2 BIF**
  - Under application control

# Encryption and Indexes

## Data Encryption Tool

- EDITPROC encrypts the entire row, so the data is encrypted, but the index is not
  - Bad for security, good for performance

| **INDEX** | **SSN NAME ADDRESS** |
|---|---|
| **223491398** | **F{(œ(•´ú□— GÿÞ#     □¥†‰jÍiÑÆ** |

## DB2 BIF

- Application encrypts the field, if that field is an index, then the index is encrypted
  - Good for security, bad for performance

| **INDEX** | **SSN NAME ADDRESS** |
|---|---|
| **F{(œ(•´ú** | **F{(œ(•´ú□— GÿÞ#     □¥†‰jÍiÑÆ** |

# Data Encryption Tool – Hardware Requirements

- **Clear Key**
  - z196/z114/z10/z9 CPACF (& PCIXCC z9/z890/z990 or CEXnC for CKDS*)
- **Secure Key**
  - z890/z990 Requires a PCIXCC or CEX2
  - z9 Requires a CEX2C
  - z10 Requires a CEX2C or CEX3C
  - z196/z114 Requires a CEX3C
- **Protected Key**
  - z10/z196/z114 Requires a CEX3C**

*Prior to HCR7750, a CEXnC is required to create and use a CKDS, beginning with HCR7751 ICSF supports a clear key only CKDS

**Protected Key support requires HCR7770 or higher

# DB2 BIFs - Hardware Requirements

- **z196/z114/z10/z9/z990/z890 (CPACF)**
  - Uses MSA instructions, not the ICSF APIs, but ICSF must be started to provide hashing support
  - TDES only

# Side-by-side Comparison

| | Column (DB2 Built-In Functions) | Row/Table (IBM Encryption Tool for IMS and DB2) |
|---|---|---|
| DB2 Support | ▪V8, V9, V10<br>▪Data in indexes is encrypted<br>▪Does not work w/DB2 Load Utility<br>▪Data type of encrypted columns must be FOR BIT DATA | ▪V7.x, V8.x, V9.x, v10.x<br>▪DB2 index data is not encrypted.<br>▪Works with all DB2 utilities |
| Application Change Required | ▪Application must change to invoke the BIFs for the columns that will be encrypted | ▪No application change, but each table will need to be recreated with an EDITPROC |
| Transaction Processing Overhead | ▪The cost overhead depends on hardware, DB2 and application access | ▪High overhead due to the amount of data encryptions |
| Key Management | ▪Application has responsibility for the encryption key | ▪Keys are managed by and accessed through ICSF |
| Pre-Reqs | ▪ICSF must be active<br>▪CPACF hardware | ▪ICSF must be active<br>▪Secure PCI card, unless running HCR7751 or later and clear key only CKDS |

# Enabling Protected Key

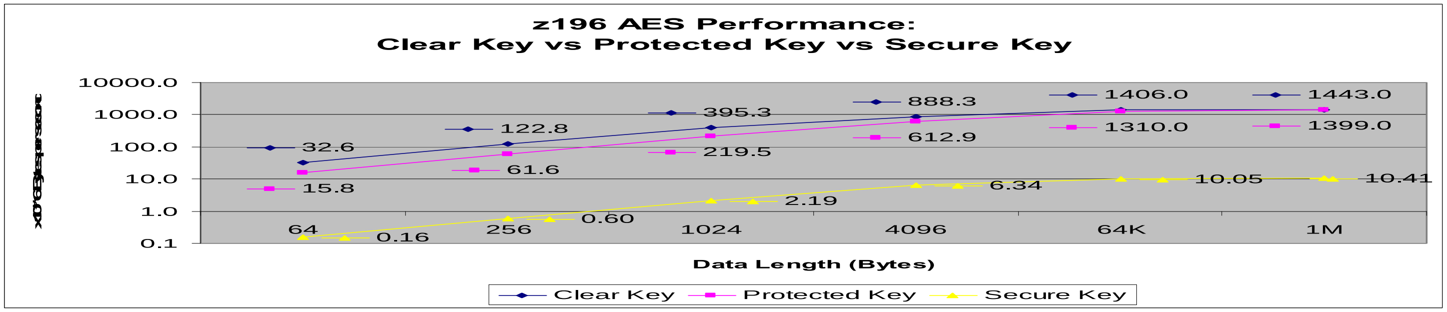
- **Install HCR7770 or later**
  - CSFINIT replaces CSFMMAIN
- **Install Crypto Express3 on z10 with Driver 79 or on z196/z114**
  - With master keys loaded
- **Install RACF (OA29193) and SAF (OA29194) APARs**
- **Create secure keys which will be used as protected keys**
- **Create/update RACF profiles for the keys, with SYMCPACFWRAP(YES)**

# z196 Crypto Performance

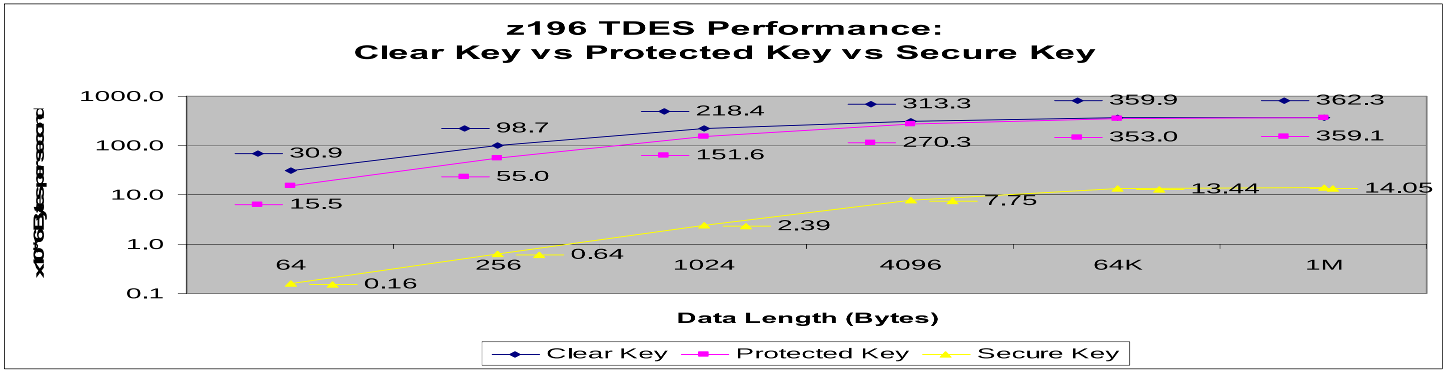
## From the Crypto Performance Whitepapers

http://www.ibm.com/systems/z/advantages/security/z10cryptography.html

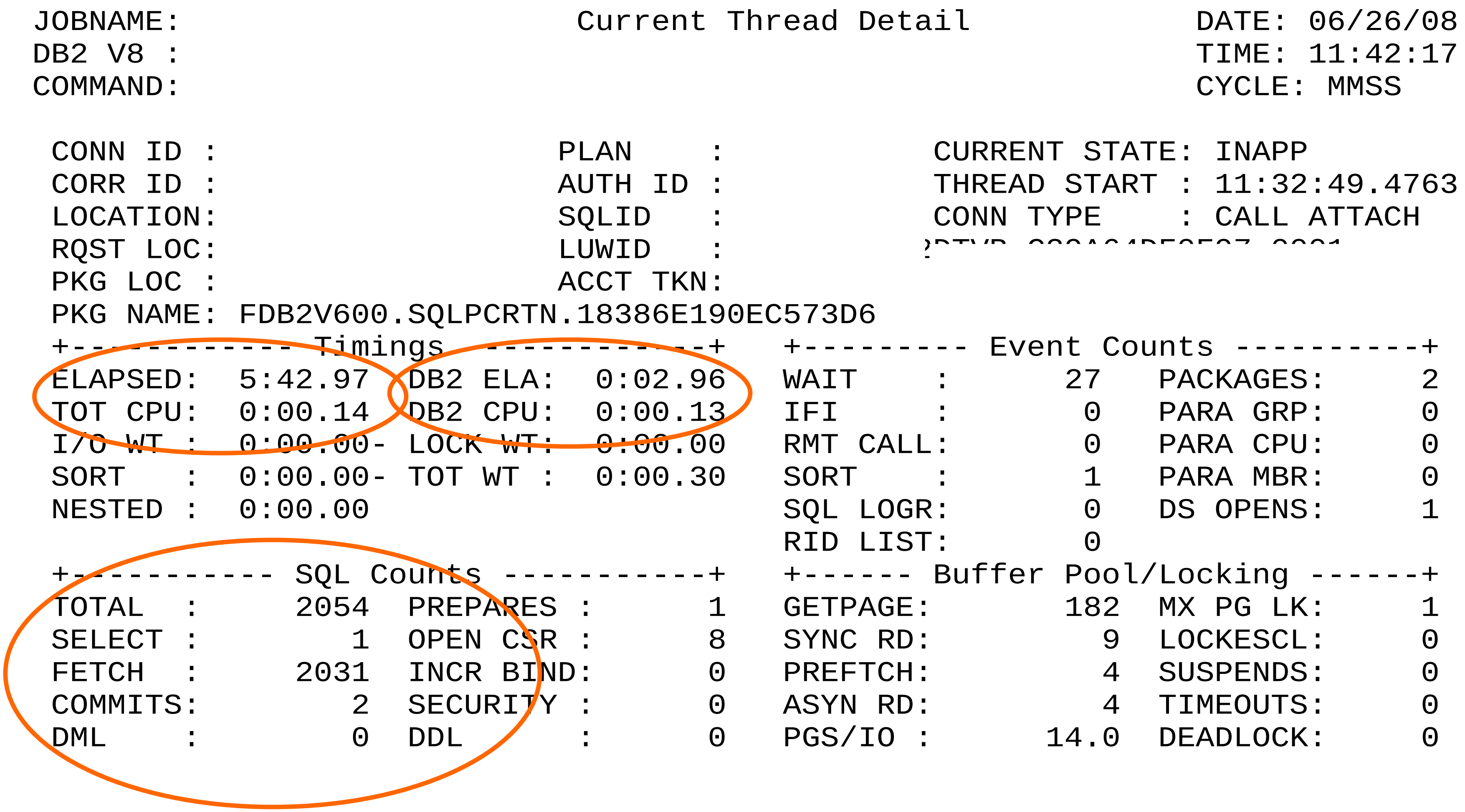
- **AES Encryption**



- **TDES Encryption**



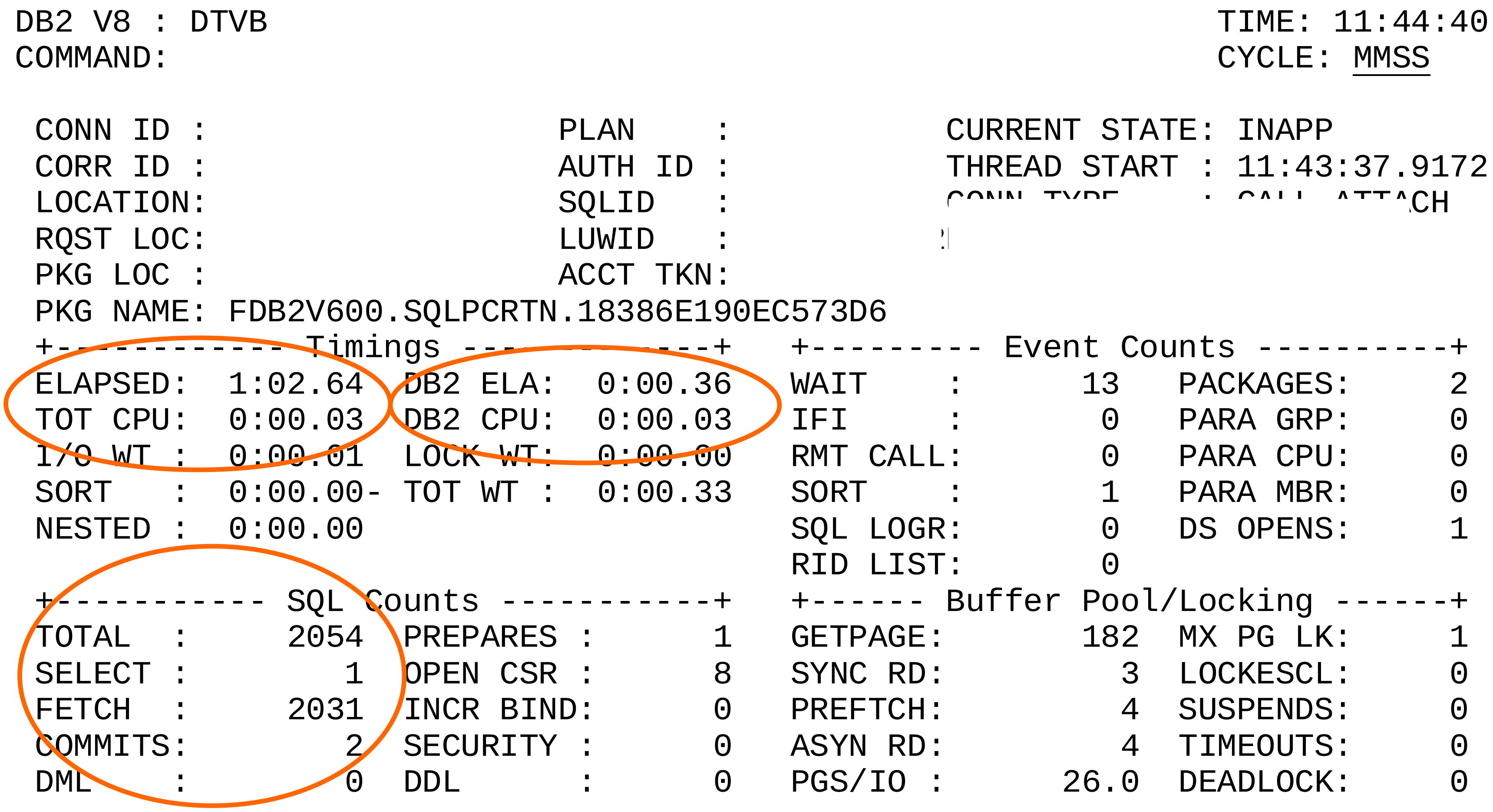
# Secure Key SQL Performance Results



```
JOBNAME:                     Current Thread Detail           DATE: 06/26/08
DB2 V8 :                                                     TIME: 11:42:17
COMMAND:                                                     CYCLE: MMSS

 CONN ID :                  PLAN     :           CURRENT STATE: INAPP
 CORR ID :                  AUTH ID :            THREAD START : 11:32:49.4763
 LOCATION:                  SQLID    :           CONN TYPE     : CALL ATTACH
 RQST LOC:                  LUWID    :
 PKG LOC :                  ACCT TKN:
 PKG NAME: FDB2V600.SQLPCRTN.18386E190EC573D6
 +------------ Timings ------------+  +--------- Event Counts ----------+
 ELAPSED:  5:42.97  DB2 ELA:  0:02.96  WAIT     :      27   PACKAGES:     2
 TOT CPU:  0:00.14  DB2 CPU:  0:00.13  IFI      :       0   PARA GRP:     0
 I/O WT :  0:00.00- LOCK WT:  0:00.00  RMT CALL:       0   PARA CPU:     0
 SORT   :  0:00.00- TOT WT :  0:00.30  SORT     :       1   PARA MBR:     0
 NESTED :  0:00.00                     SQL LOGR:       0   DS OPENS:     1
                                       RID LIST:       0
 +---------- SQL Counts -----------+  +------- Buffer Pool/Locking ------+
 TOTAL   :     2054  PREPARES :     1  GETPAGE:      182   MX PG LK:     1
 SELECT :        1  OPEN CSR :     8  SYNC RD:        9   LOCKESCL:     0
 FETCH   :     2031  INCR BIND:     0  PREFTCH:        4   SUSPENDS:     0
 COMMITS:        2  SECURITY :     0  ASYN RD:        4   TIMEOUTS:     0
 DML     :        0  DDL       :     0  PGS/IO :     14.0   DEADLOCK:     0
```

# Clear Key SQL Performance Results



```
DB2 V8 : DTVB                                                     TIME: 11:44:40
COMMAND:                                                          CYCLE: MMSS

 CONN ID :                  PLAN     :            CURRENT STATE: INAPP
 CORR ID :                  AUTH ID  :            THREAD START : 11:43:37.9172
 LOCATION:                  SQLID    :            CONN TYPE    : CALL ATTACH
 RQST LOC:                  LUWID    :
 PKG LOC :                  ACCT TKN:
 PKG NAME: FDB2V600.SQLPCRTN.18386E190EC573D6
 +------------ Timings ------------+   +---------- Event Counts ----------+
 ELAPSED:  1:02.64  DB2 ELA:  0:00.36   WAIT     :      13   PACKAGES:     2
 TOT CPU:  0:00.03  DB2 CPU:  0:00.03   IFI      :       0   PARA GRP:     0
 I/O WT :  0:00.01  LOCK WT:  0:00.00   RMT CALL:        0   PARA CPU:     0
 SORT   :  0:00.00- TOT WT :  0:00.33   SORT     :       1   PARA MBR:     0
 NESTED :  0:00.00                      SQL LOGR:        0   DS OPENS:     1
                                        RID LIST:        0
 +----------- SQL Counts -----------+   +------- Buffer Pool/Locking ------+
 TOTAL   :      2054  PREPARES :     1   GETPAGE:       182   MX PG LK:     1
 SELECT  :         1  OPEN CSR :     8   SYNC RD:         3   LOCKESCL:     0
 FETCH   :      2031  INCR BIND:     0   PREFTCH:         4   SUSPENDS:     0
 COMMITS:          2  SECURITY :     0   ASYN RD:         4   TIMEOUTS:     0
 DML     :         0  DDL      :     0   PGS/IO :      26.0   DEADLOCK:     0
```

# Secure vs. Clear Key: Database Load Results

Database utility loads of 200,000 rows yielded the following results:

| (In seconds) | Clear Key | Secure Key |
|---|---|---|
| CPU Time | 2 | 8 |
| Elapsed Time | 18 | 259 |

**As you can see from the LOAD and SQL examples, secure key is considerably more CPU intensive.**

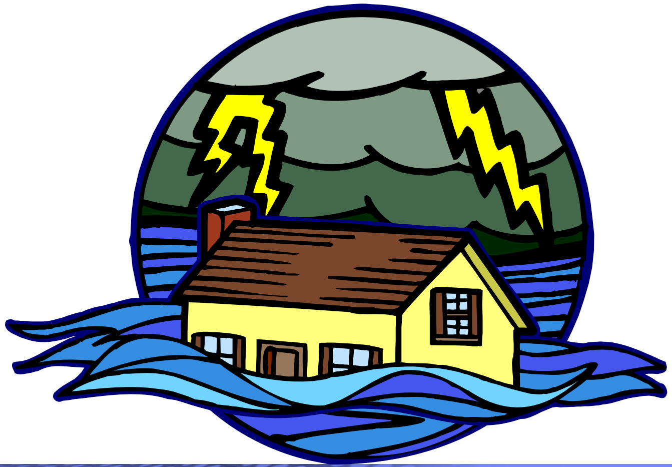
# Implementation–Example

| Table xxx | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Encrypted Tables xxDBA | | | | | Non Encrypted Tables xxNON | | | | |
| Utility | Elapsed Time | CPU Time | Init Date | Init Time | Utility | Elapsed Time | CPU Time | Init Date | Init Time |
| **Unload** | **00:01:37.86** | **00:01:46.02** | **Sept. 28** | **9:15 A** | **Unload** | **00:01:42.64** | **00:01:08.31** | **Sept. 28** | **9:15 A** |
| **Load** | **00:04:07.73** | **00:03:45.13** | **Sept. 28** | **11:30 A** | **Load** | **00:03:40.55** | **00:03:12.89** | **Sept. 28** | **11:30 A** |
| **REORG** | **00:19:56.46** | **00:03:33.44** | **Sept. 28** | **2:30 P** | **REORG** | **00:05:49.17** | **00:02:12.37** | **Sept. 28** | **2:30 P** |
| **Index Rebuild** | **00:03:50.03** | **00:01:32.04** | **Sept. 29** | **9:00 A** | **Index Rebuild** | **00:01:20.30** | **00:00:48.94** | **Sept. 29** | **9:00 A** |
| **Image Copy** | **00:07:05.19** | **00:00:08.10** | **Sept. 29** | **1:00 P** | **Image Copy** | **00:03:51.43** | **00:00:07.56** | **Sept. 29** | **1:00 P** |
| **Recover** | **00:07:05.19** | **00:00:08.10** | **Sept 29** | **2:15 P** | **Recover** | **00:03:51.43** | **00:00:07.56** | **Sept. 29** | **2:15 P** |
| **DSNTIAUL** | **00:05:42.22** | **00:04:31.99** | **Sept. 30** | **9:30 A** | **DSNTIAUL** | **00:05:23.32** | **00:03:52.42** | **Sept. 30** | **9:30 A** |

Your mileage may vary.

# Disaster Recovery Considerations

- **The major requirement is that the appropriate crypto hardware be available at the DR site**
  - Clear Key / Secure Key / Protected Key
  - Key lengths
- **For the data encryption tool, master keys must be available at the DR site**



# Decisions, Decisions …

- **Ownership (i.e. politics)**
  - Data Administrator - Data Encryption Tool
    - Sets up the EDITPROC and specifies the key to be used for the entire table
    - Key must be defined to/managed by ICSF (stored in the CKDS)
  - Application - DB2
    - Application logic determines which key to use for each field/column
    - Password is managed by the application
- **Security requirements**
- **Performance requirements**
- **Application/production support**
- **Space considerations**
- **Crypto hardware available**

# Data Encryption Tool – New Functions

- **Customizable UDF PM45364/UK72991**
  - No application changes
  - Minimally disruptive, columns encrypted in place
  - Indexes can be encrypted
  - All data types supported by UDFs can be encrypted
- **Customizable FIELDPROC PM55879/UK76423**
  - No application changes
  - Non-disruptive
  - Index can be encrypted
  - Same restrictions as EDITPROC

# IBM Tape Based Encryption

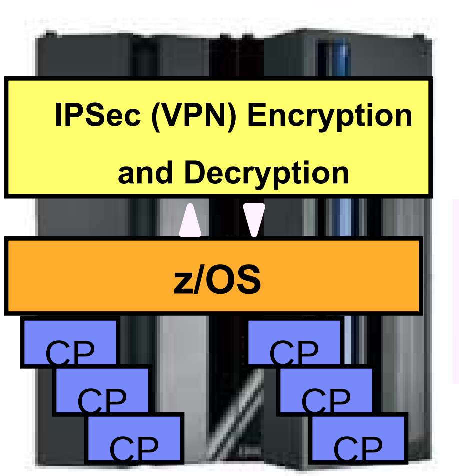
- LTO4 and LTO5 - Open Systems
- TS1120, TS1130, TS1140 - Open Systems and Mainframe
- AES-256 bit encryption
- All files on the tape are protected using a single key
  - Which is in turn encrypted using RSA (public/private key algorithms)
- TKLM, Tivoli Key Lifecycle Manager or in a z/OS environment, ISKLM IBM Security Key Lifecycle Manager is required for DS8000 and recommended for Tapes

# IBM DS8000 Disk Encryption - Characteristics

- **Customer data at rest is encrypted**
  - Data at rest = data on any disk or in any persistent memory
- **Customer data in flight is not encrypted**
  - Data in flight = on I/O interfaces or in dynamic memories (Cache, NVS)
    - If you can read/write to disk, you get access to clear-text data.
- **Uses Encrypting Disk**
  - Encryption hardware in disk (AES 128)
  - Runs at full data rate (146/300/450 GBs  15K RPM )- No measurable performance impact
- **Integrated with Tivoli Key Lifecycle Manager (TKLM) or IBM Security Key Lifecycle Manager (ISKLM)**
  - DS8000 automatically communicates with TKLM when configuring encryption group or at power on to obtain necessary encryption keys to access customer data
  - Each disk has an encryption key
    - Data is always encrypted on write and decrypted on read
    - Encryption key is wrapped with access credential and maintained within the disk
    - Access credential maintained by TKLM/ISKLM
    - Establishing a new encryption key causes cryptographic erasure
- **Key attack vectors prevented:**
  - Disk removed (repair, or stolen)
  - Box removed (retire, or stolen)

# zIIP Assisted IPSec (VPN) on z/OS

- Benefits of having secure channel end-point on z/OS
  - Security regulations compliance - No clear-text data on any network segments
  - End-to-end authentication of secure channel end-points
    - Both end-point authentication and message authentication
  - Key management and storage done on System z by z/OS
  - Compliance with end-to-end security regulations
- System z CPU cost is a concern
  - Encryption/decryption CPU cost can be a significant percentage of overall CPU cost for a given application
  - Especially the case for streaming workloads (file transfer type of workload)
- zIIP processors
  - Specialty processor on System z9 or later hardware
  - zIIPs priced lower than general purpose processors
  - No IBM software charges on zIIPs
- zIIP Assisted IPSec
  - Use zIIP processors for most IPSec encryption/decryption
  - Lower the cost of doing IPSec processing on z/OS



System z9 or later
z/OS CS V1R8 + PTFs
z/OS CS V1R9

# Closing Thoughts

- **Encryption has a cost**
  - –Crypto hardware more efficient with large blocks of data
- **Secure Key on a PCI Card – longer pathlength**
- **Clear Key exists in the DB2 Address Space, Protected Key and Secure Key are too, but they are stored encrypted under the Wrapping Key or Master Key**

# Data Encryption for DB2 - Reference Materials

- **SC18-9549 IBM Data Encryption Tool for IMS and DB2 Databases User Guide**
  - Includes an appendix on activating crypto on your hardware
- **ICSF Manuals**
  - SA22-7520 ICSF System Programmer's Guide
  - SA22-7521 ICSF Administrator's Guide
- **Redbooks**
  - DB2 UDB for z/OS Version 8 Performance Topics – SG24-6465
- **Articles**
  - IMS Newletter article: "Encrypt your IMS and DB2 data on z/OS" - ftp://ftp.software.ibm.com/software/data/ims/shelf/quarterly/fall2005.pdf

# Session #11488 Feedback

Questions ?!?
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  - @ibm_system_z
- Top Facebook pages related to System z:
  - Systemz Mainframe
  - IBM System z on Campus
  - IBM Mainframe Professionals
  - Millennial Mainframer
- Top LinkedIn Groups related to System z:
  - Mainframe Experts Network
  - Mainframe
  - IBM Mainframe
  - System z Advocates
  - Cloud Mainframe Computing
- YouTube
  - IBM System z

- Leading Blogs related to System z:
  - Evangelizing Mainframe (Destination z blog)
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  - Common Sense
  - Enterprise Class Innovation: System z perspectives
  - Mainframe
  - MainframeZone
  - Smarter Computing Blog
  - Millennial Mainframer