Intro To Crypto
Share 14569
Anaheim, CA
March, 2014

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- **Share 14569**
- **Anaheim, CA**
- **March, 2014**

Agenda – Intro to Crypto

- **Some background**
  - Laws & Regulations
  - Crypto Standards
- **Crypto Functions**
- **Crypto Hardware**
- **Master Keys**
- **ICSF**
- **Linux**

Laws and Regs

- **Health Insurance Portability and Accountability Act of 1996 (HIPAA)**
- **California Senate Bill 1386**
- **Gramm-Leach Bliley Act (GLBA)**
- **Sarbanes-Oxley (SOX)**
- **Payment Card Industry Standards (PCI)**

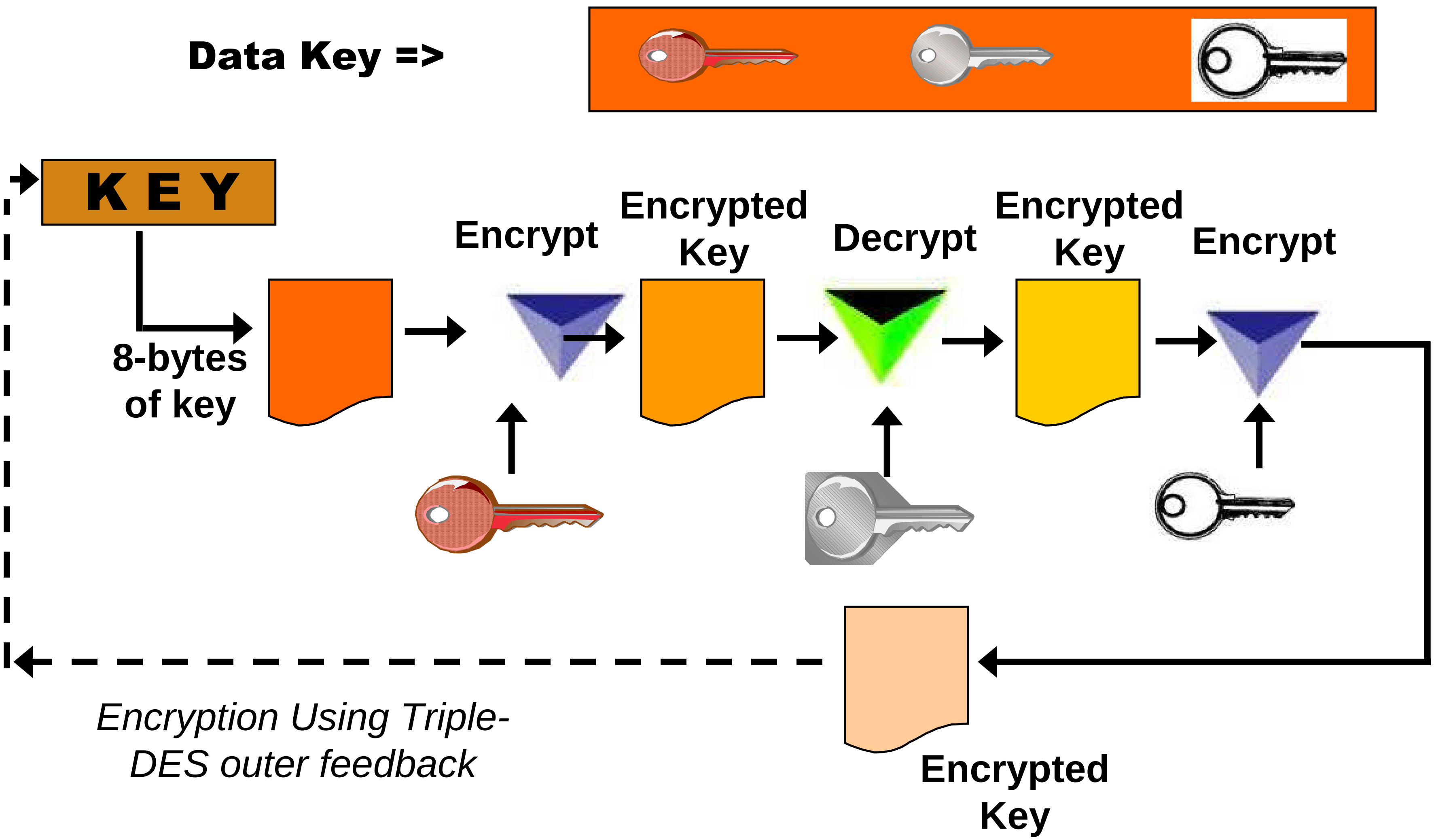
Cryptographic Standards

- **CCA (Common Cryptographic Architecture)**
- **PKCS (Public-Key Cryptography Standards)**
- **INTEL CDS (Common Data Security Architecture)**
- **OCSF (Open Cryptographic Services)**
- **ANSI (American National Standards Association)**
- **ISO (International Organization for Standardization)**
- **FIPS (Federal Information Processing Standards)**

Crypto Functions

- **Data Confidentiality**
  - Symmetric – DES/TDES, AES
  - Asymmetric – RSA, Diffie-Hellman, ECC
- **Data Integrity**
  - Modification Detection
  - Message Authentication
  - Non-repudiation
- **Financial Functions**
- **Key Security & Integrity**

Data Confidentiality – DES/TDES



Encryption Using Triple-DES outer feedback

Data Confidentiality - AES

- **Rijndael Algorithm**
  - –Block Cipher (16-byte blocks)
  - –128-, 192, 256-bit Key Length
  - –Multiple Rounds
  - –Four Steps per Round (Byte Substitution, Shift Row, Mix Column, Add Round Key)

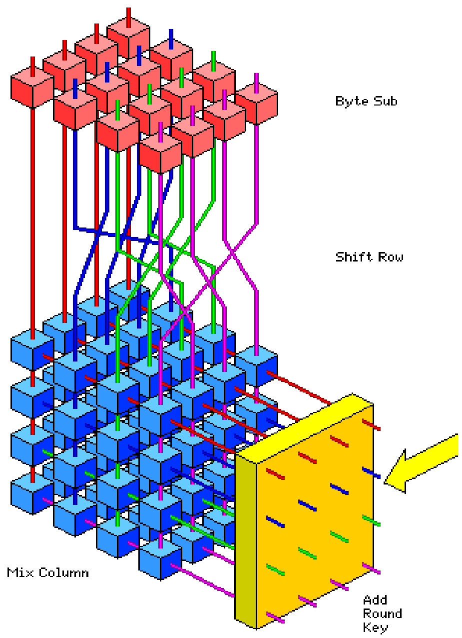
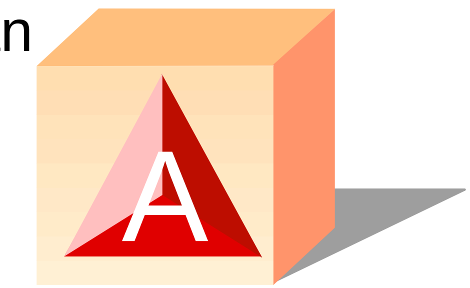
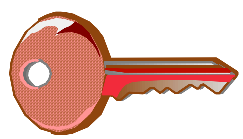


Image from http://www.esat.kuleuven.ac.be/~rijmen/rijndael/

Public Key Architecture - PKA

- **Asymmetric Keys**
  - –RSA, Rivest Shamir and Adleman
  - –Diffie-Hellman
  - –Elliptic Curve (ECC)





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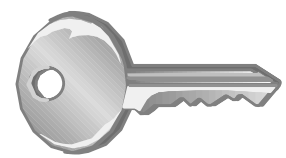
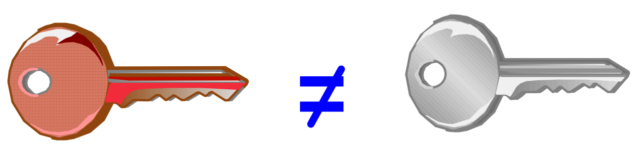


Encipher Key ≠ **Decipher Key**

Generating RSA Keys

- **RSA Keys consists of two parts, a modulus (N) and an exponent (E for the public key; D for the private key)**
  - Public Key => N E
  - Private Key => N D
- **The modulus is calculated by multiplying two prime numbers (P & Q) together**
  - P = 5 Q = 11 (in reality, these should be very large prime numbers, 100s of digits long)
  - N = P x Q => 5 x 11 = 55
- **Next, select an odd number, E, that will be the exponent for the public key**
  - Good values include 3 or 65537 (64K+1)
- **Public Key => N E => 55 3**
- **Finally, calculate the exponent for the private key, D, where**

  1 = (D * E) MOD ((P-1)(Q-1))
- **In our example, solve for 1 = (D * 3) MOD 40 => D = 27!**
- **Private Key => N D => 55 27**



Encipher the Message ‘IBM’ (9 2 13)

Public Key (N E) => 55 3

Private Key (N D) => 55 27

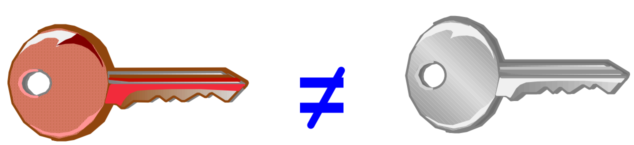
Convert characters to numeric (a=1, b=2, c=3, etc.)

‘I’ = 9; ‘B’ = 2; ‘M’ = 13

ciphertext = (cleartextE) Mod N**

- **For ‘I’** (9**3) MOD 55 => 729 MOD 55 = 14
- **For ‘B’** (2**3) MOD 55 => 8 MOD 55 = 8
- **For ‘M’** (13**3) MOD 55 => 2197 MOD 55 = 52

Ciphertext is 14 8 52



Decipher the message 14 8 52

Public Key (N E) => 55 3

Private Key (N D) => 55 27

Cleartext = (ciphertextD) MOD N**

- **For 14 14**27 MOD 55 = 9**

  (14**27 = 8819763977946281130444984418304)

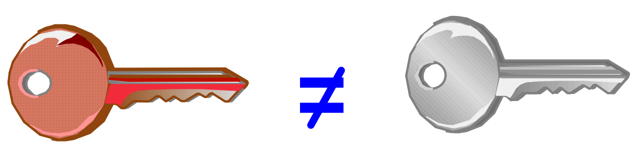
- **For 8 8**27 MOD 55 = 2**

  (8**27 = 2417851639229258349412352)

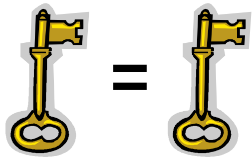
- **For 52 52**27 mod 55 = 13**

  (52**27 = 2.1482769967144679013436706816572e+46)

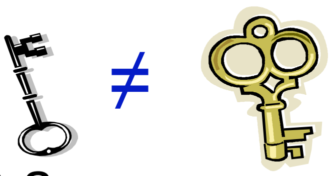
- **My decrypted message is 9 2 13 => “I” “B” “M”**



Why Symmetric and Asymmetric Keys?



- **Symmetric**
  - –plus - less resource intensive
  - –minus - requires key to be shared securely



- **Asymmetric**
  - –plus - its strength, can be used to establish a secret between two parties
  - –minus - expensive, regarding performance

Hash and Key Lengths

- **Why do we care about lengths a of keys and hashes?**
  - The longer a key the lower the probability to guess the right key
  - The longer a hash the lower the probability to guess a matching text for a given hash
  - Key and hash sizes that are considered secure change over time
- **Crypto Cryptography is not security, it is only low probability!? - But "Low" is "VERY LOW"!**
- **Examples of sizes:**

MegaMillions (March, 2012) @ $640Million	**1 In 176,000,000**
DES: 2^{56} different keys	**1 in 72,057,594,037,927,936**
AES-128: 2^{128} different keys	**38 digits**
number of atoms in the earth	**about $1.33*10^{50}$**
number of atoms in our solar system	**about $1.2*10^{57}$**
AES-192: 2^{192} different keys	**58 digits**
AES-256/SHA-256: 2^{256} different keys/hashes	**77 digits**
number of atoms in the universe	**about 10^{82}**
SHA-512: 2^{512} different hashes	**154 digits**

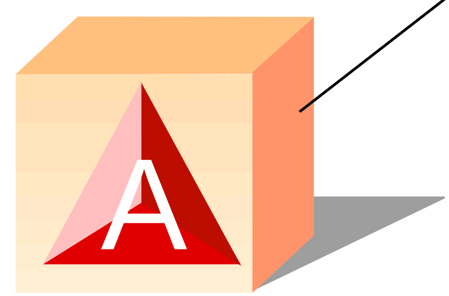
- **Key lengths for symmetric keys are not comparable to those of asymmetric keys**
- **E.g. only a "few" numbers out of 2^{1024} 1024-bit numbers are valid keys for RSA**

Data Integrity – Modification Detection

Has the message changed?

Message

Message | MD



Hash Algorithm

- **Characteristics of a good hash**
  - Can't recreate the message from the hash
  - Two different messages are statistically unlikely to generate the same hash value

Hash Example

- **SHA-256("The quick brown fox jumps over the lazy dog")**

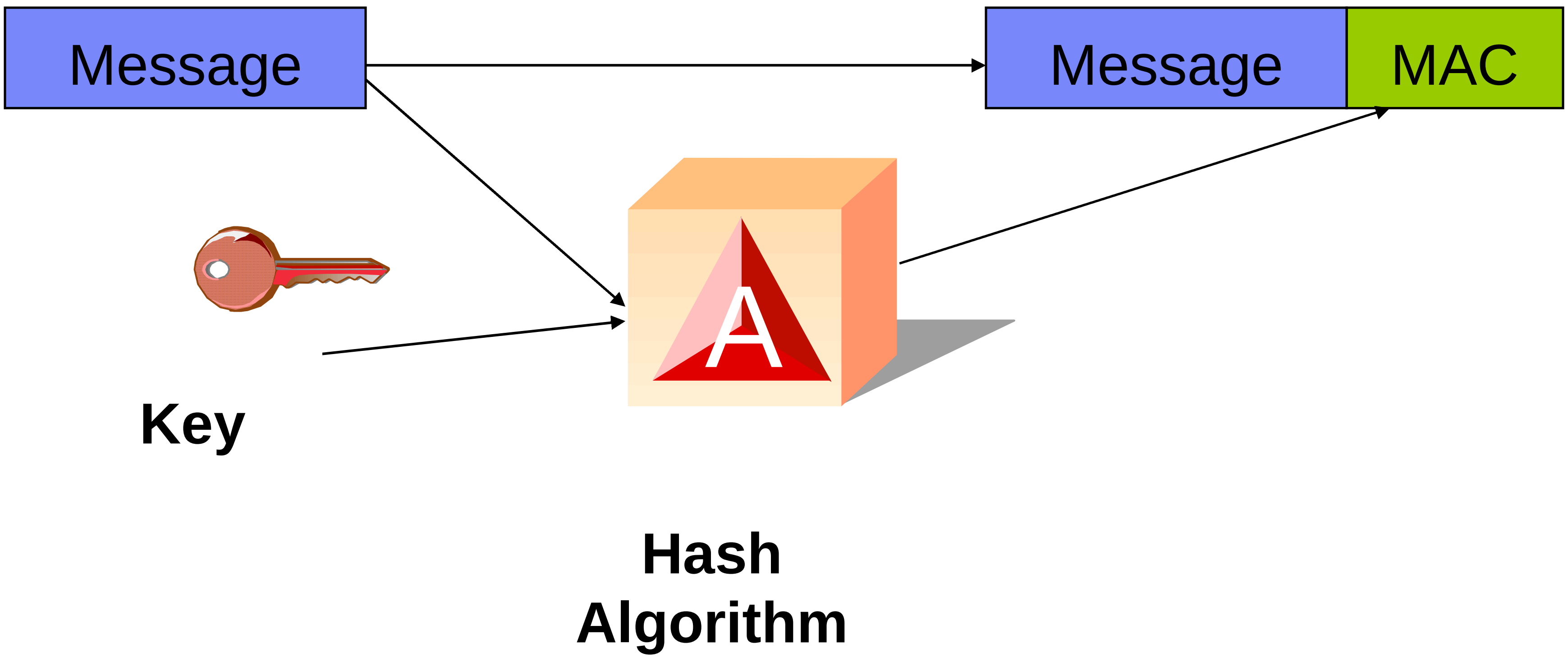
  35051FE3 F32E625D E54EE6B9 1F7F8B41 88D4292D 3E295A5B 9C8D7003 B72E06C1

- **SHA-256("The quick brown fox jumps over the lazy hog")**

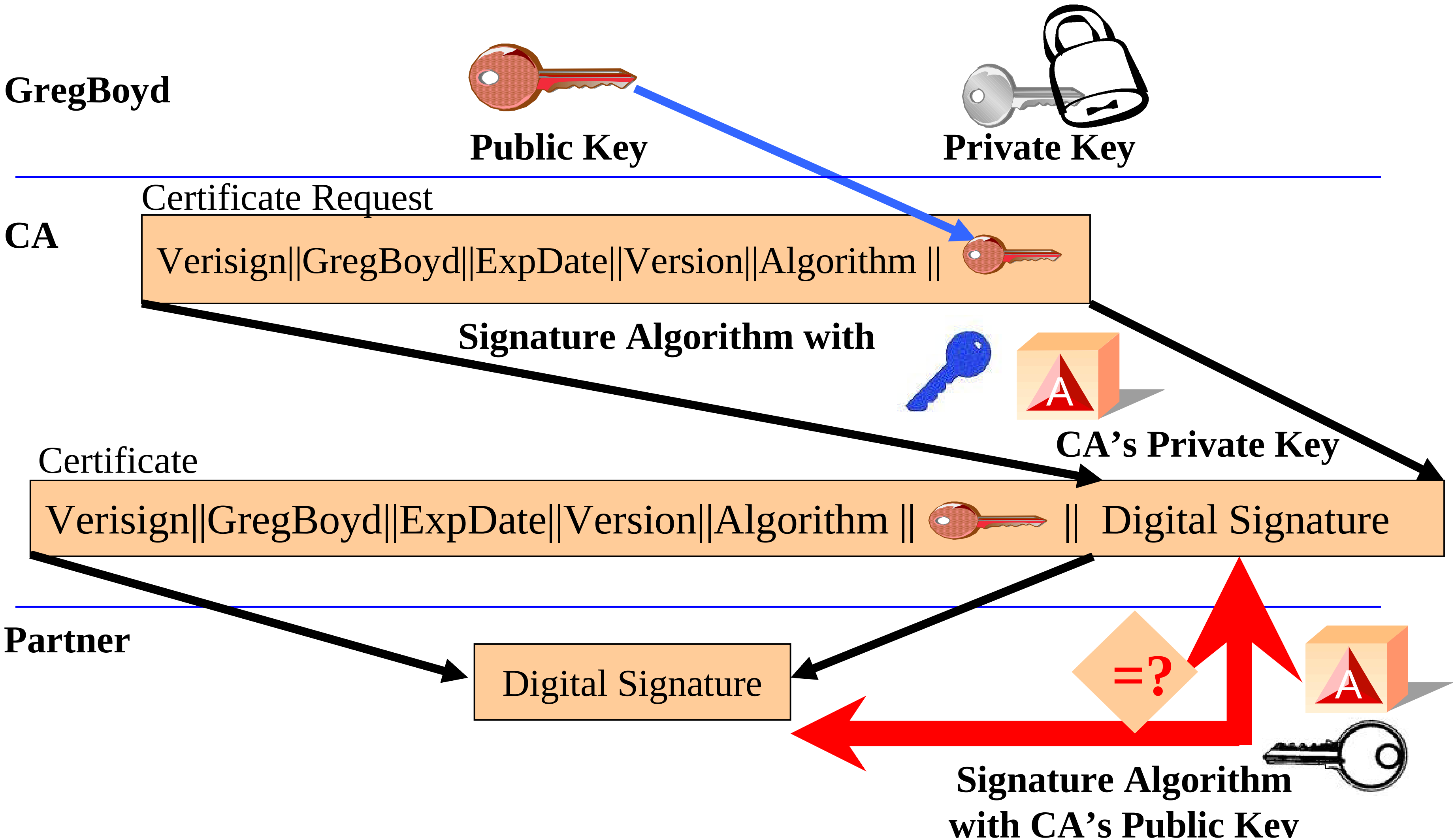
  390EBA67 48141EBC B2046317 64476A34 48F79E8F 0319CF0C 5D6551F8 24E4CC65

Data Integrity – Message Authentication

Did the message come from who I think it came from?

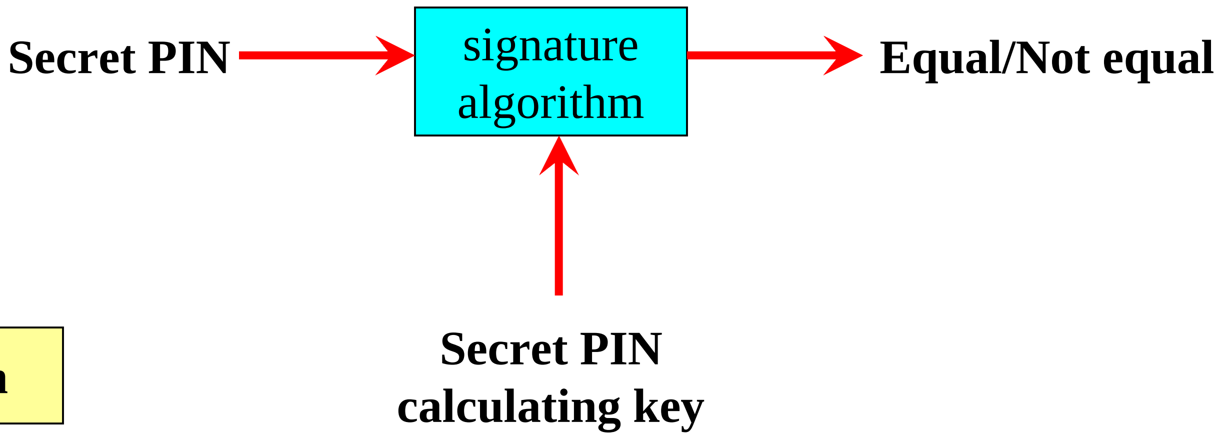


Data Integrity – Digital Certificates



Financial Services

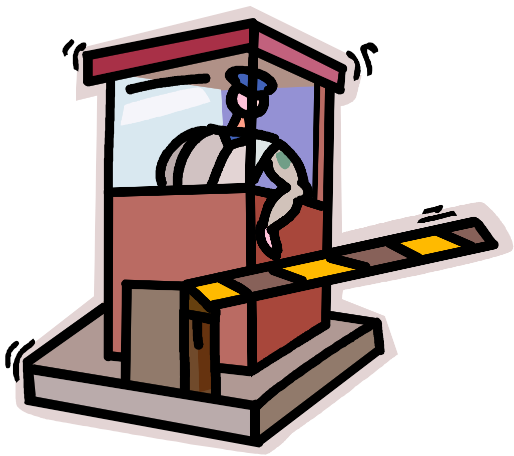
- **PIN Generation**
- **PIN Verification**
- **PIN Export/Import**



Authentication

Suite B

- **Symmetric Encryption**
  - AES w/key sizes of 128 and 256
- **Digital Signatures**
  - ECDSA – Elliptic Curve, Digital Signature Algorithm
- **Key Agreement**
  - ECDH – Elliptic Curve, Diffie Hellman
- **Message Digest**
  - SHA-2 (SHA-256 and SHA-384)



http://www.nsa.gov/ia/programs/suiteb_cryptography/

Clear Key / Secure Key / Protected Key

- **Clear Key – key <u>may</u> be in the clear, at least briefly, somewhere in the environment**
- **Secure Key – key value does not exist in the clear outside of the HSM (secure, tamper-resistant boundary of the card)**
- **Protected Key – key value does not exist outside of physical hardware, although the hardware may not be tamper-resistant**

Protected Key – How it works

- **Create a key, with the value 'ABCD' and store it as a secure key in the CKDS (i.e. encrypted under the Master Key, MK)**
  - E_{MK}(x'ABCD') => x'4A!2' written to the CKDS and stored with a label of MYKEY
- **Execute CSNBSYE (the clear key API to encrypt data), but pass it the key label of our secure key, MYKEY; and text to be encrypted of 'MY MSG '**
  - CALL CSNBSYE(….,

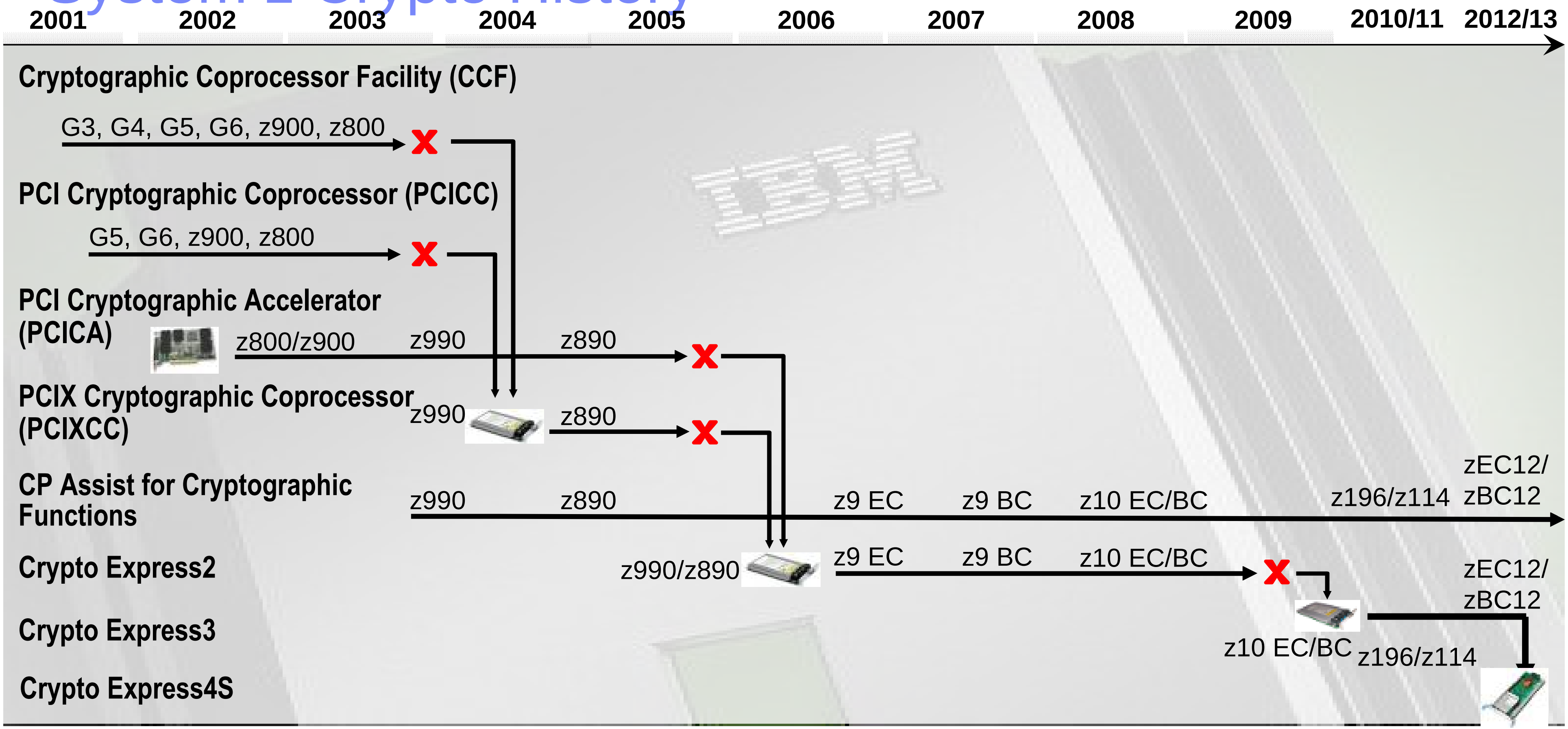
    MYKEY,

    'MY MSG ' ….)

Protected Key – How it works (cont …)

- **ICSF will read MYKEY from the CKDS and pass the key value x'4A!2' to the CEX3**
- **Inside the CEX3, recover the original key value and then wrap it using the wrapping key**
  - D_{MK}(x' 4A!2') => x' ABCD'
  - E_{WK}(x'ABCD') => x'*94E'
- **ICSF will pass the wrapped key value of x'*94E' to the CPACF, along with the message to be encrypted**
- **In the CPACF, we'll retrieve the wrapping key, WK**
  - D_{wk}(x'*94E') => x'ABCD'
  - $E_{x'ABCD'}$('MY MSG ') => ciphertext of x'81FF18019717D183'

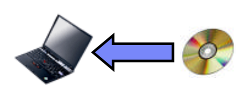
System z Crypto History



- Cryptographic Coprocessor Facility – Supports “Secure key” cryptographic processing
- PCICC Feature – Supports “Secure key” cryptographic processing
- PCICA Feature – Supports “Clear key” SSL acceleration
- PCIXCC Feature – Supports “Secure key” cryptographic processing
- CP Assist for Cryptographic Function allows limited “Clear key” crypto functions from any CP/IFL
  - NOT equivalent to CCF on older machines in function or Crypto Express2 capability
- Crypto Express2 – Combines function and performance of PCICA and PCICC
- Crypto Express3 – PCIe Interface, additional processing capacity with improved RAS
- Crypto Express4S - IBM Standard PKCS #EP11

System z Clear Key Crypto Hardware – z10(EC *(GA3)* & BC *(GA2)*),, *z196/z114, zEC12, zBC12*

- **CP Assist for Crypto Function (CPACF)**
  - **DES (56-, 112-, 168-bit), new chaining options**
  - **AES-128, AES-192, AES-256, new chaining options**
  - **SHA-1, SHA-256, SHA-512 (SHA-2)**
  - **PRNG**
  - **Protected Key**



- **Single CPACF per CP on zEC12 & z9**

TechDoc WP100810 – A Synopsis of System z Crypto Hardware

System z Secure Key Crypto Hardware

- **Secure Key DES/TDES**
- **Secure Key AES**
- **Financial (PIN) Functions**
- **Key Generate/Key Management**
- **Random Number Generate and Generate Long**
- Protected Key Support (CEX3 on z10)
- **SSL Handshakes, ECDSA support (CEX3 on z196)**
- EP11 (CEX4S)

TechDoc WP100810 – A Synopsis of System z Crypto Hardware

Master Keys

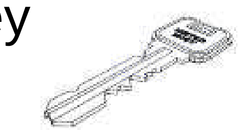
- **Stored within the secure hardware boundary of the cryptographic coprocessor**

- **ICSF uses five master keys to protect operational keys**
  - DES Master Key (DES-MK aka SYM-MK) - 128 bit key (or now 256-bit)
    - Protects DES/TDES (symmetric) application keys

  - AES Master Key (AES-MK) - 256 bit key
    - Protects AES (symmetric) application keys

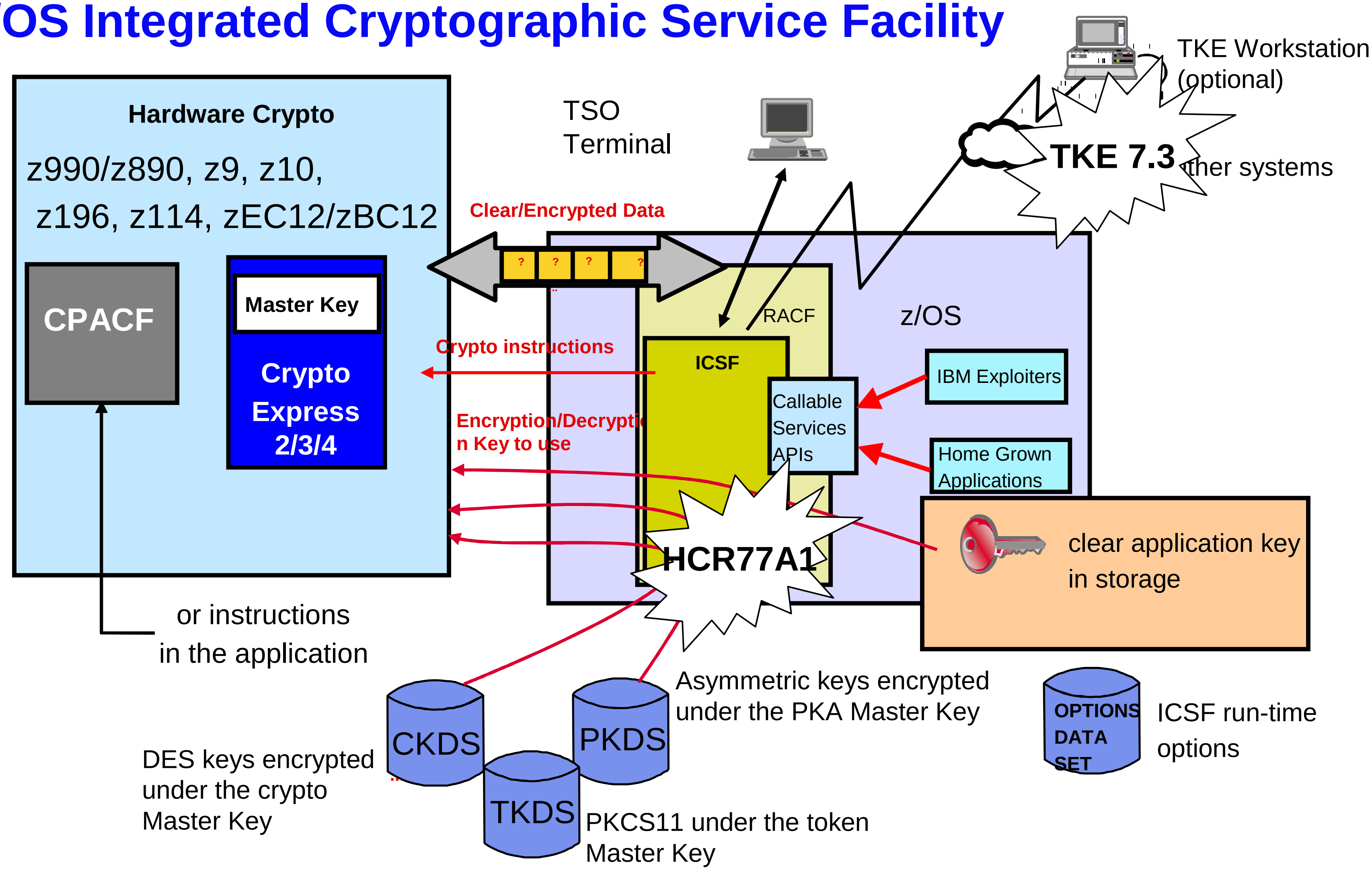
  - Asymmetric-keys master key (RSA-MK aka ASYM-MK) - 192 bit key
    - Protects RSA (asymmetric) private keys

  - Elliptic Curve Master Key (ECC-MK) - 256 bit key
    - Protects ECC (asymmetric) private keys



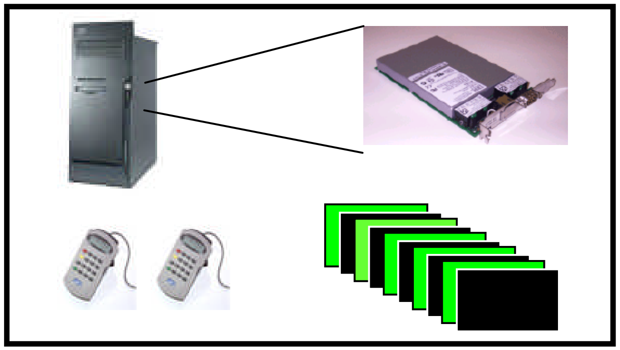
  - Enterprise PKCS #11 Master Key (P11-MK) - 256 bit key
    - Protects PKCS #11 keys

z/OS Integrated Cryptographic Service Facility



Access to the cryptographic services and keys can be controlled by RACF with the CSFSERV and CSFKEYS classes

Trusted Key Entry (TKE) Workstation

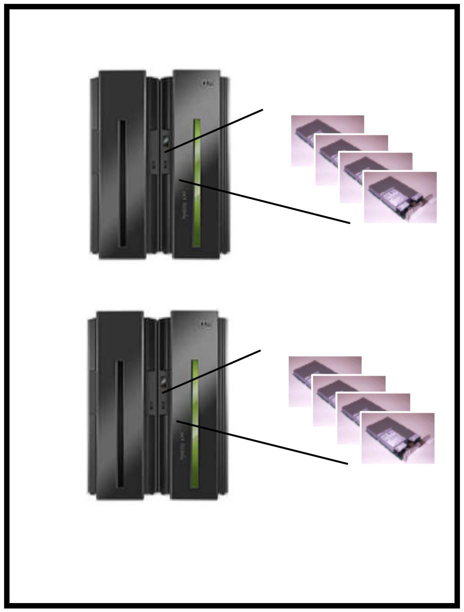


Components

- Workstation with a 4765 Cryptographic Coprocessor
- **TKE 7.2 LIC**
- **Smart card readers and smart cards**
  - Required if using Enterprise PKCS #11 LIC
  - Optional if using IBM CCA LIC

Purpose

- Used to manage multiple Cryptographic Coprocessors and keys on various generations of System z (zEC12, z196, z114 and z10 EC and BC) from a single point of control
  - Support requirements for standards
  - Simplification of tasks



Enhancements

- Support of new hardware or firmware functions
  - Support for Crypto Express4S defined as a CCA coprocessor
  - Required for Crypto Express4S defined as an Enterprise PKCS #11coprocessor
  - New DES operational keys
  - New AES CIPHER key attribute
  - Allow creation of corresponding keys
  - Support 4 smart card readers
- Support requirements for standards
  - Stronger key wrapping

Linux on System z Crypto Stack

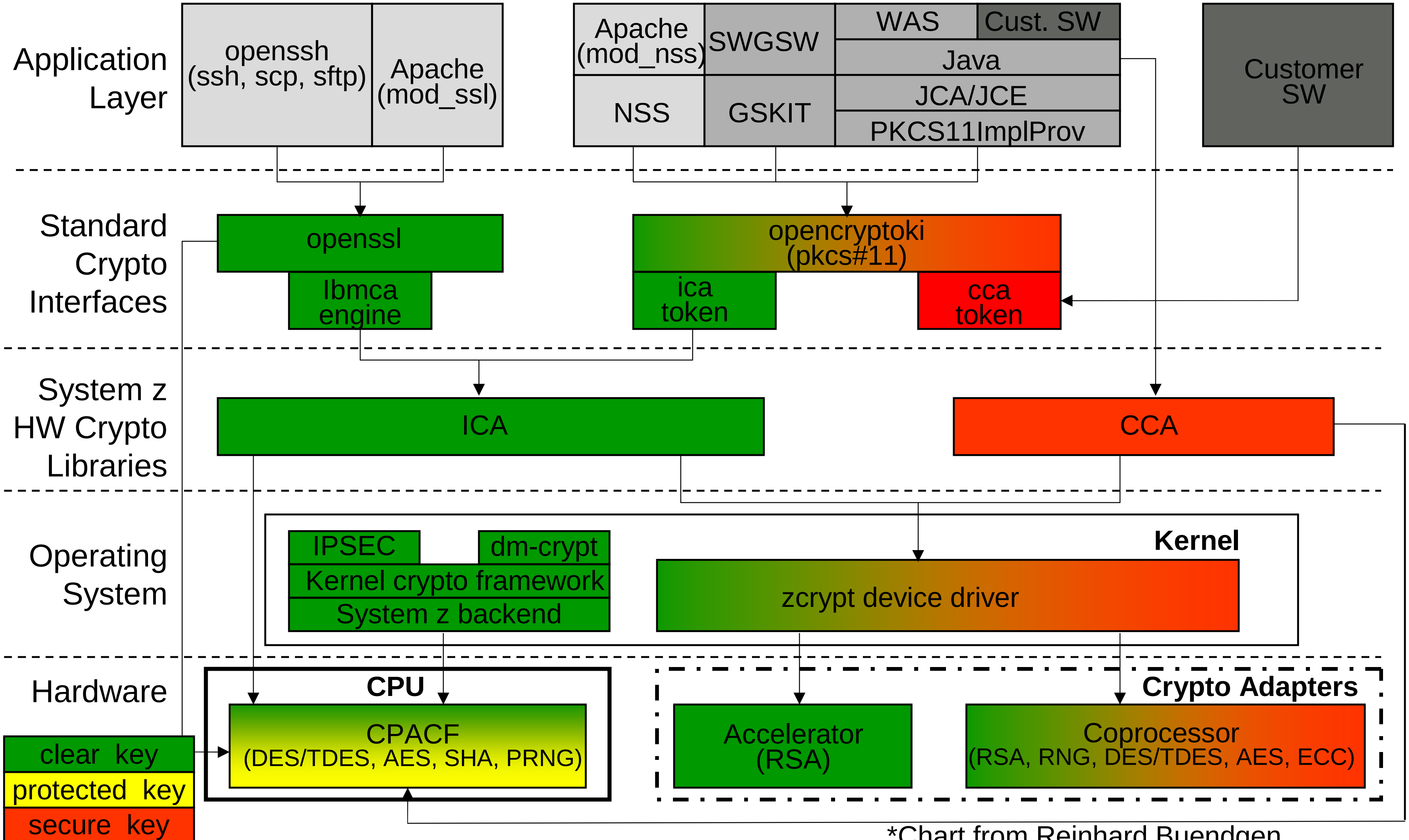


*Chart from Reinhard Buendgen

References

Cryptography Books

- Bruce Schneier, ‘Applied Cryptography Second Edition: Protocols, Algorithms, and Source Code in “C”’, Addison Wesley Longman, Inc., 1997
- Simon Singh, ‘The Code Book’, Anchor Books, 1999
- Niels Ferguson, Bruce Schneier, ‘Practical Cryptography’, Wiley Publishing, Inc. 2003

Standards

- www.ietf.org – Internet Engineering Task Force
- www.csrc.nist.gov – Computer Security Resource Center of NIST
- www.rsasecurity.com/rsalabs - Research site for RSA Security

Free Stuff

- www.scmagazine.com - SC Magazine
- www.counterpane.com – Bruce Schneier web site with monthly newsletter

ICSF Pubs

- **ICSF Overview**
  - z/OS 2.1 SC14-7505
  - z/OS 1.13 SA22-7519
- **ICSF Administrator's Guide**
  - z/OS 2.1 SC14-7506
  - z/OS 1.13 SA22-7521
- **ICSF Application Programmer's Guide**
  - z/OS 2.1 SC14-7508
  - z/OS 1.13 SA22-7522
- **ICSF Systems Programmer's Guide**
  - z/OS 2.1 SC14-7507
  - z/OS 1.13 SA22-7520

z/OS Web Download Site

- **http://www.ibm.com/systems/z/os/zos/tools/downloads/index.html**

IBM Resources (on the web)

- **Redbooks – www.redbooks.ibm.com 'Crypto'**
  – IBM zEnterprise EC12 Technical Introduction, SG24-8050
  – IBM zEnterprise EC12 Technical Guide, SG24-8049
- **ATS TechDocs Web Site www.ibm.com/support/techdocs (Search All Documents for keyword of 'Crypto')**
  – WP100810 – A Synopsis of System z Crypto Hardware
  – WP100647 – A Clear Key/Secure Key/Protected Key Primer

Linux Secure Key Crypto - Information & Download

- Crypto Cards Hardware Overview **-** http://www.ibm.com/security/cryptocards/
- PCI-E Cryptographic Coprocessor (CEX3) **-** http://www.ibm.com/security/cryptocards/pciecc/overview.shtml
- Crypto Product Summary – http://www.ibm.com/security/cryptocards/pcixcc/overproduct.shtml
- CCA Overview - http://www.ibm.com/security/cryptocards/pcixcc/overcca.shtml
- PCI-E Cryptograhpic Coprocessor Library - http://www.ibm.com/security/cryptocards/pciecc/library.shtml
- CCA Library Download – http://www.ibm.com/security/cryptocards/pciecc/ordersoftware.shtml
- Cryptographic Coprocessor Order Information - http://www.ibm.com/security/cryptocards/pciecc/order.shtml
- PCI-E Cryptographic Coprocessor Support - http://www.ibm.com/security/cryptocards/pciecc/support.shtml
- Cutting Edge Cryptography by Peter Spera, May/June 2007 IBM Systems Magazine - http://www.ibmsystemsmag.com/mainframe/mayjune07/features/14233p1.aspx

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