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Digital Certificates Demystified

Alyson Comer
IBM Corporation
System SSL Development
Endicott, NY
Email: comera@us.ibm.com

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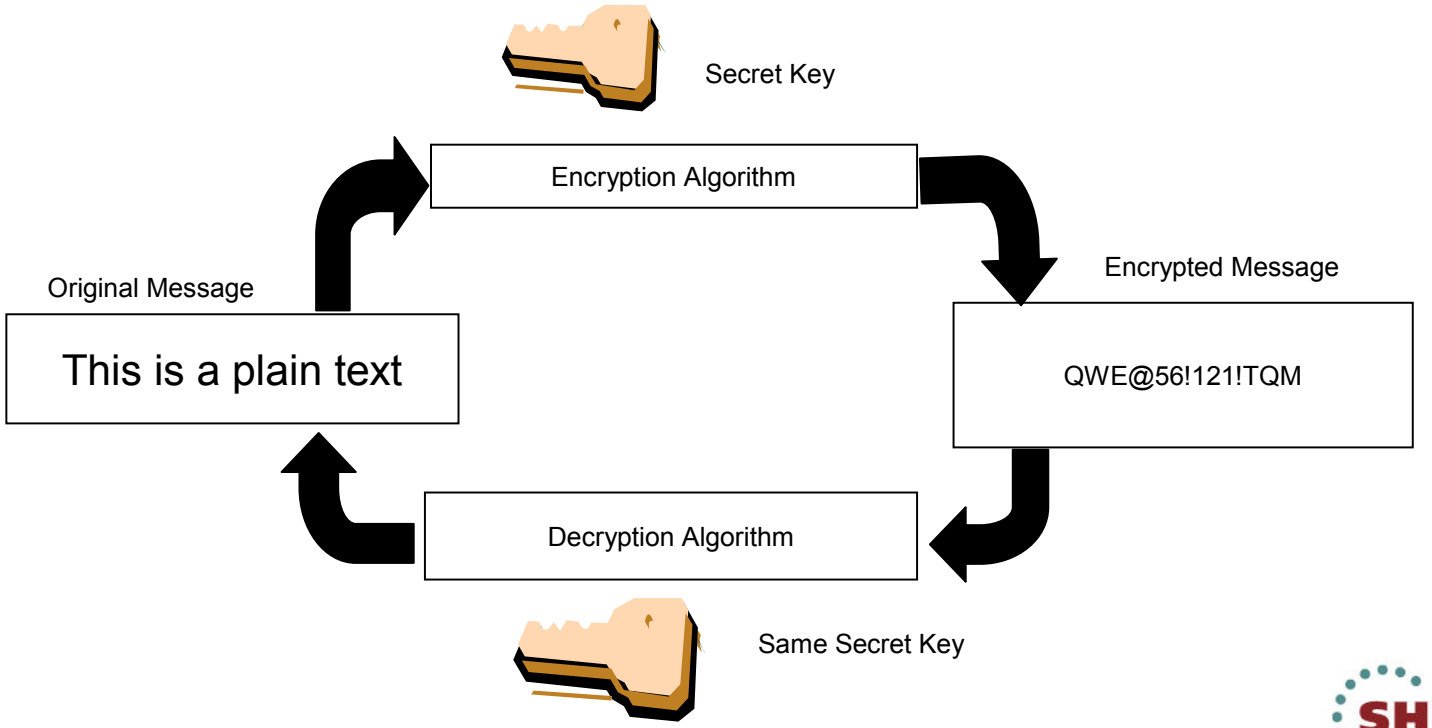
Agenda

- **Cryptography**
- What are **Digital Certificates**
- Certificate **Types** and **Contents**
- Certificate **Formats**
- Certificate **Validation**
- Certificates and **SSL**
- Certificate **Life Cycle**
- **RACDCERT** Command
- Using **RACDCERT** for **SSL** certificates
- **z/OS PKI Services**

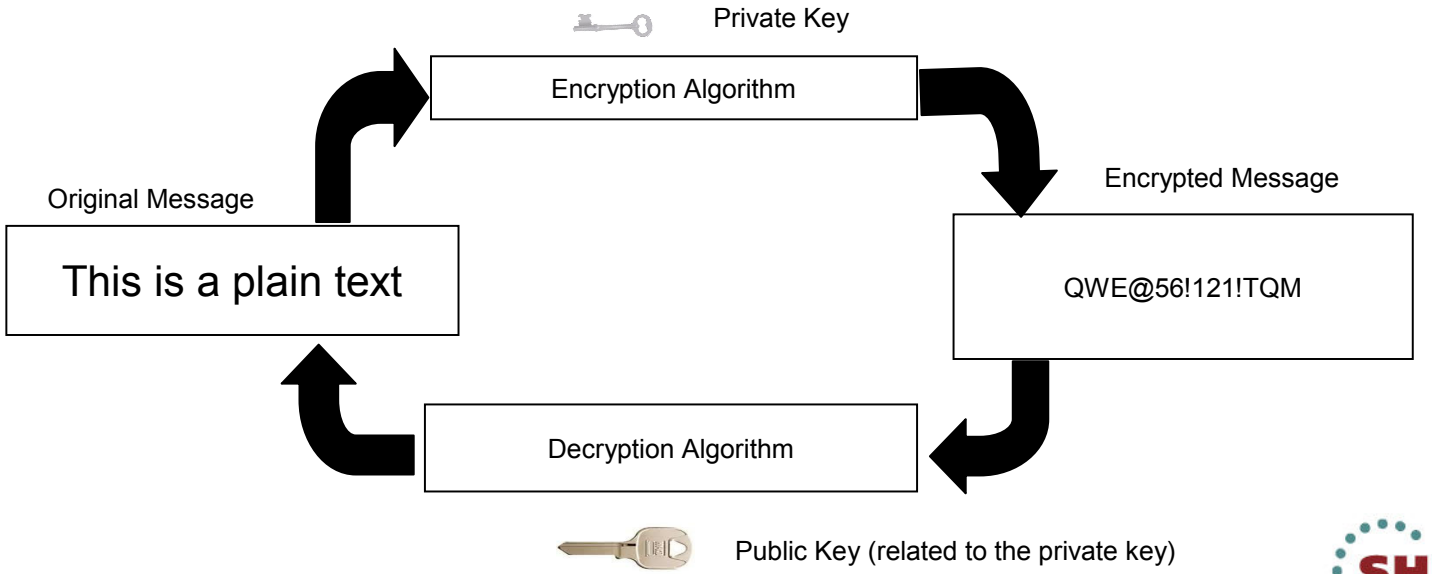
Symmetric Encryption

- **Provide data confidentiality**
- **Same key** used for both encryption and decryption
- **Fast**, used for bulk encryption/decryption
- **Securely sharing** and exchanging the key between both parties is a major issue
- **Common algorithms**: DES, Triple DES, AES



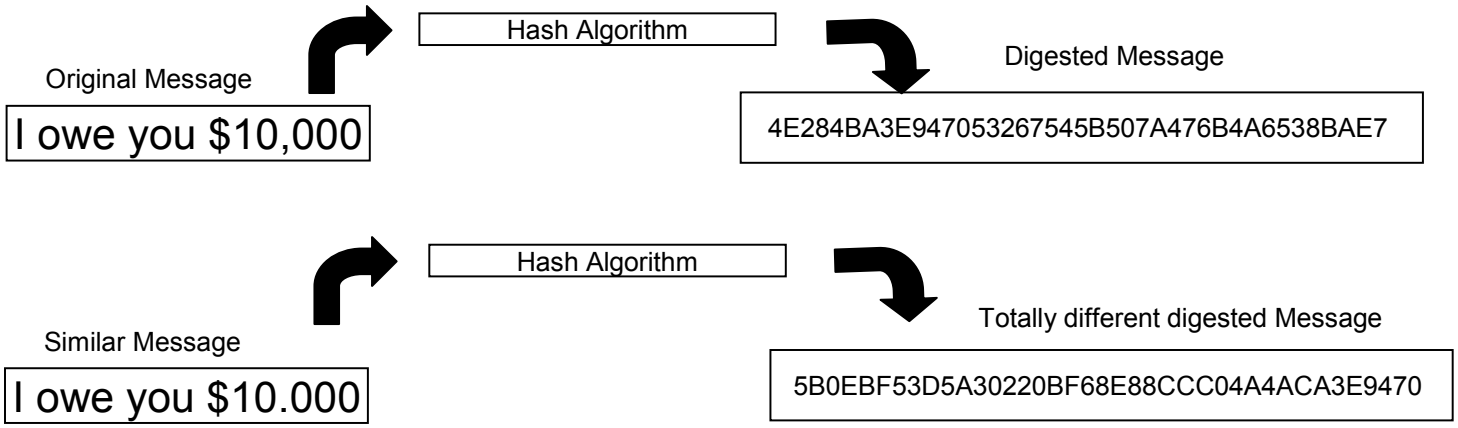
Asymmetric Encryption

- **Public / private key pairs** - 2 different keys
- A public key and a related private key are **numerically associated** with each other.
- Provide data **confidentiality**, **integrity** and **non-repudiation**
- **Data encrypted/signed using one** of the keys may only be **decrypted/verified using the other** key.
- **Slow,** Very expensive computationally
- **Public key is freely distributed** to others, private key is securely kept by the owner
- **Common algorithms**: RSA, DSA, ECC



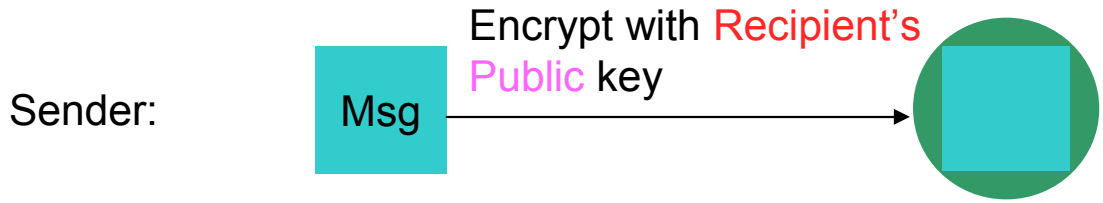
Message Digest (Hash)

- A **fixed-length** value generated from variable-length data
- Unique:
  - The same input data always generates the same digest value
  - Tiny change in data causes wide variation in digest value
  - Theoretically impossible to find two different data values that result in the same digest value
- **One-way**: can't reverse a digest value back into the original data
- **No keys involved** – Result determined only by the algorithm
- Play a part in data integrity and origin authentication
- **Common algorithms**: SHA1, SHA256, SHA384

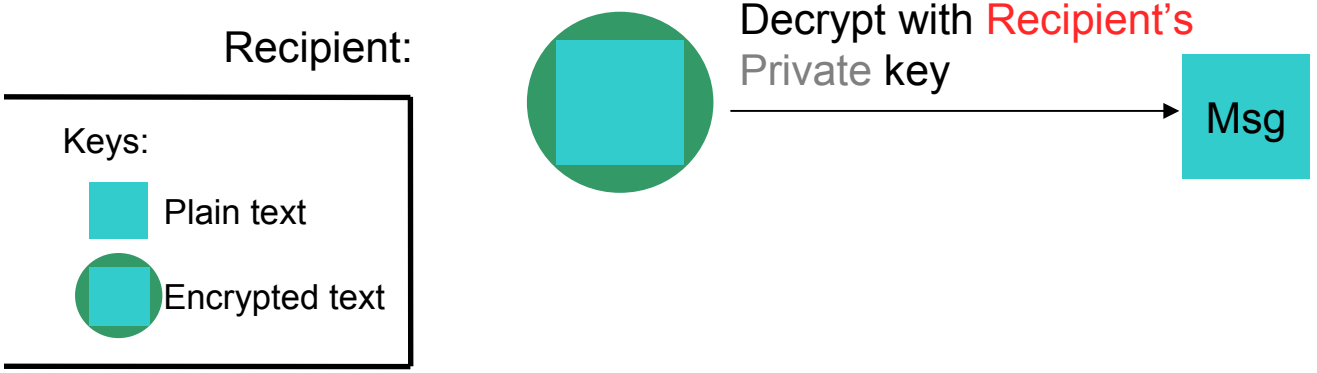


Encryption (for confidentiality)

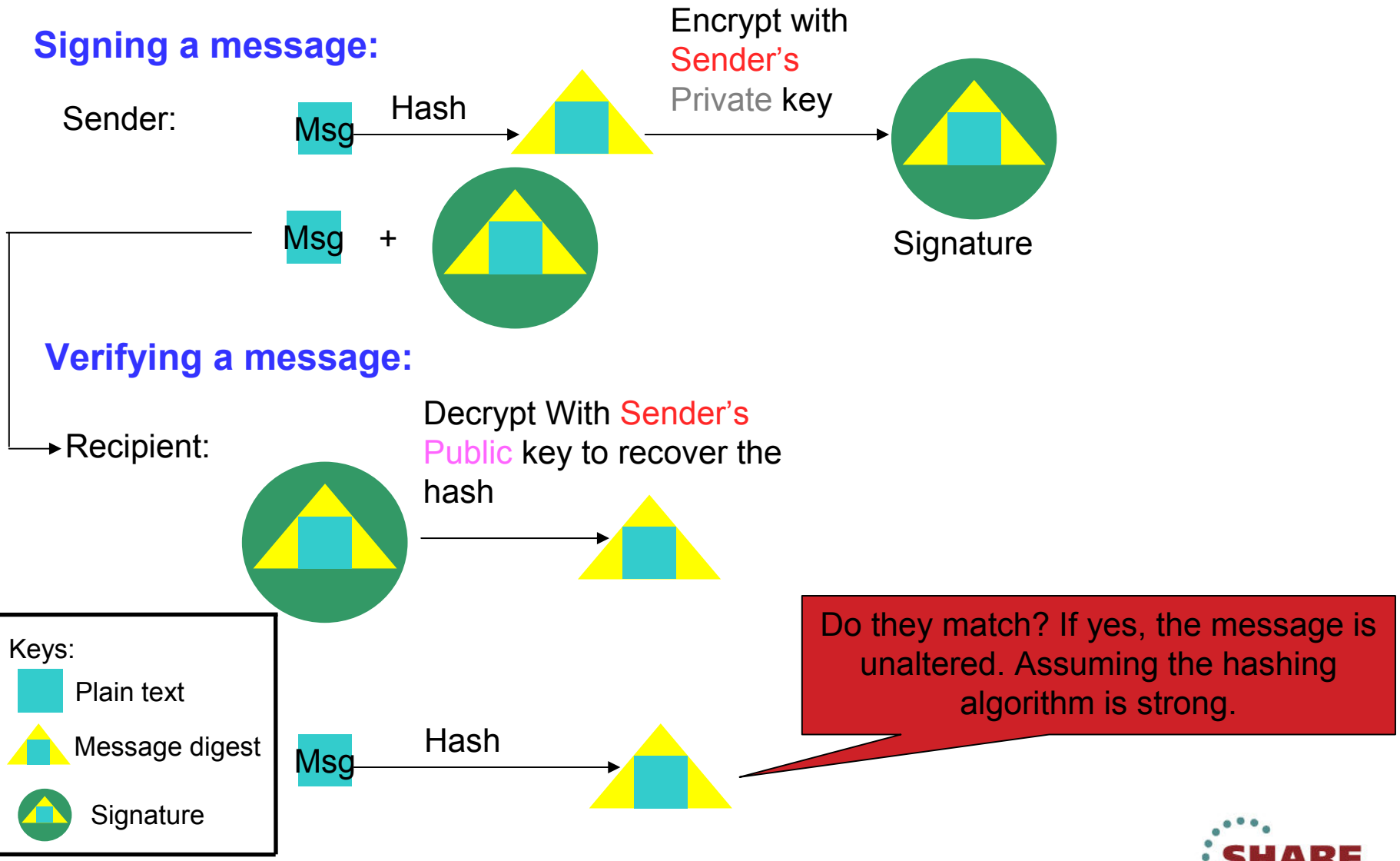
Encrypting a message:



Decrypting a message:



Signing (for integrity and non repudiation)



What is a Digital Certificate?

- A Digital Certificate is a digital document issued by a trusted third party which binds an end entity to a public key.

- **Digital document:**
  - Contents are organized according to ASN1 rules for X.509 certificates
  - Encoded in binary or base64 format
- **Trusted third party** aka **Certificate Authority** (CA):
  - The consumer of the digital certificate trusts that the CA has validated that the end entity is who they say they are before issuing and signing the certificate.
- **Binds the end entity to a public key:**
  - **End entity** - Any person or device that needs an electronic identity. Encoded in the certificate as the Subjects Distinguished Name (SDN). Can prove possession of the corresponding private key.
  - **Public key** - The shared half of the public / private key pair for asymmetric cryptography
  - **Digitally signed** by the CA

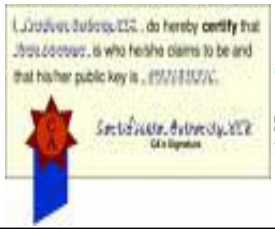
What is a Digital Certificate?

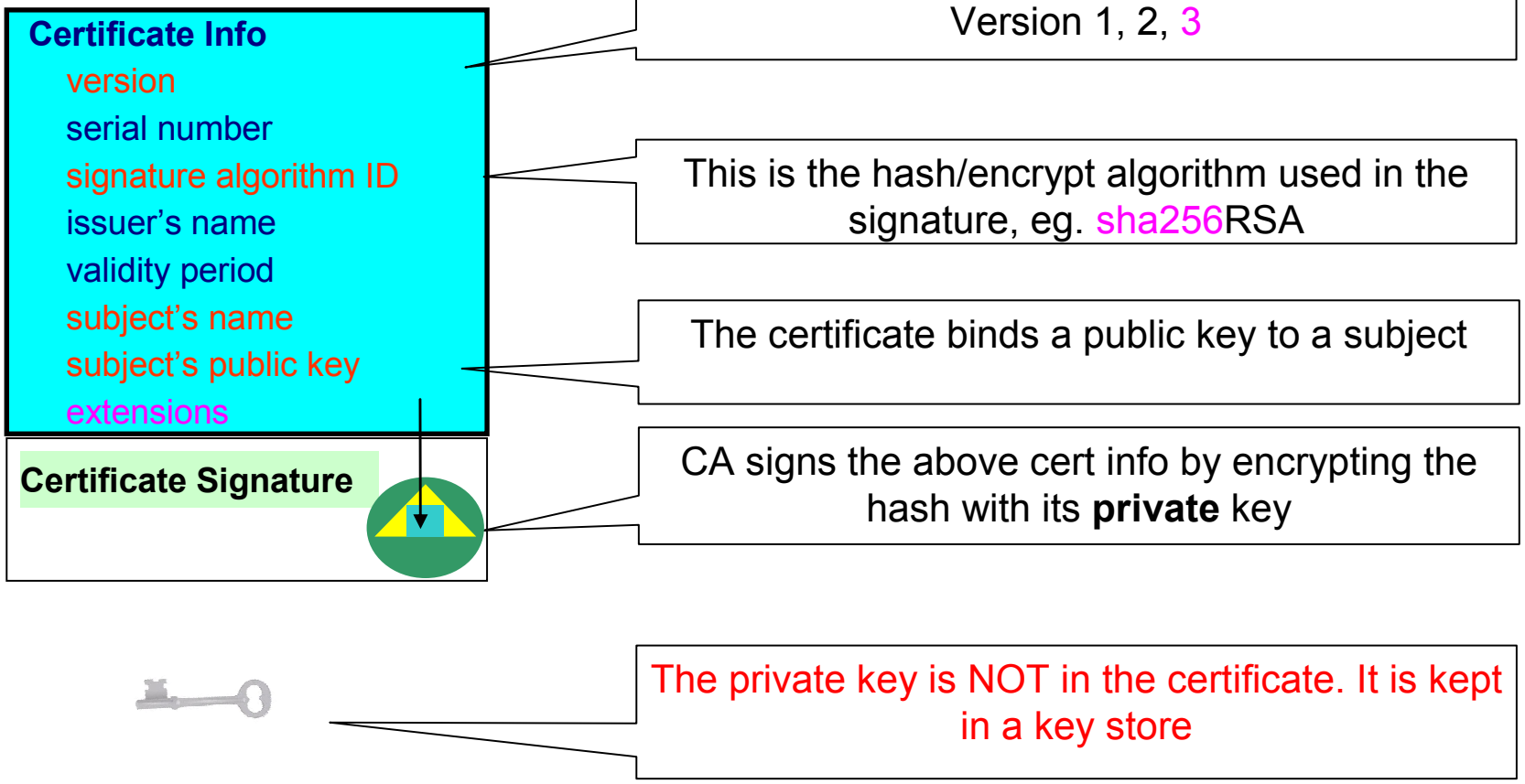
- Best way to think of it is as an **ID card**, like driver licenses or passport
- To **establish your identity** or credential to be used in electronic transactions
- Digital certificate technology has been in existence for over 25 years
- Packaging of the information is commonly known as the X.509 digital certificate. X.509 defines the format and contents of a digital certificate.
  - **IETF RFC 5280**
- Have evolved over time to not only bind basic identity information to the public key but also how public key can be used, additional identity data, revocation etc.
- Generally a digital certificate provides identity to a person or a server

How is Digital Certificate used?

- **Prove Identity to a peer:**
  - Owner of the certificate can prove possession of the certificate's private key
  - Identity can be validated by checking it is signed by a trusted Certificate Authority
- **Prove authenticity of a digital document:**
  - Programs can be signed by code signing certificates
  - E-mail signatures
  - Certificates are signed by CA certificates
- **Establish a secure connection:**
  - Certificates contain a public key which allows protocols such as SSL and TLS to exchange session keys

What is in a Digital Certificate?



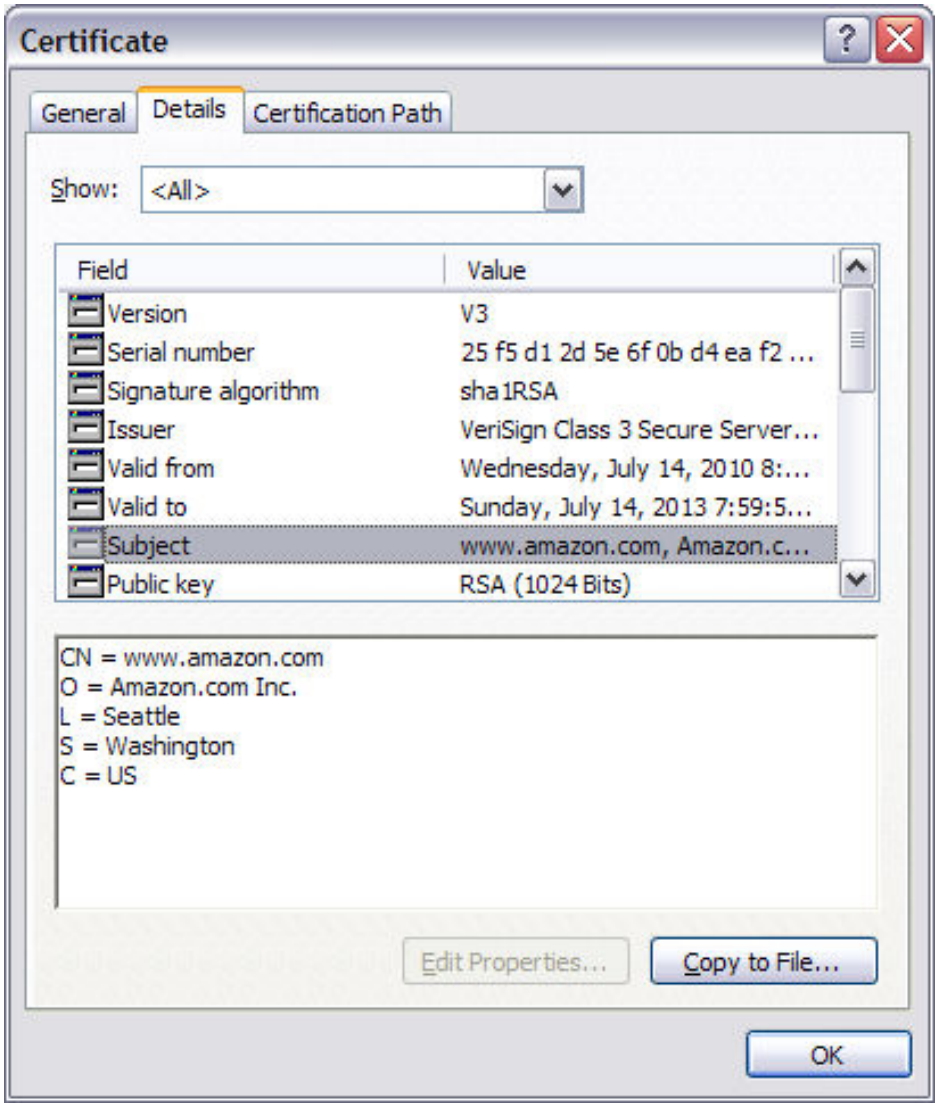


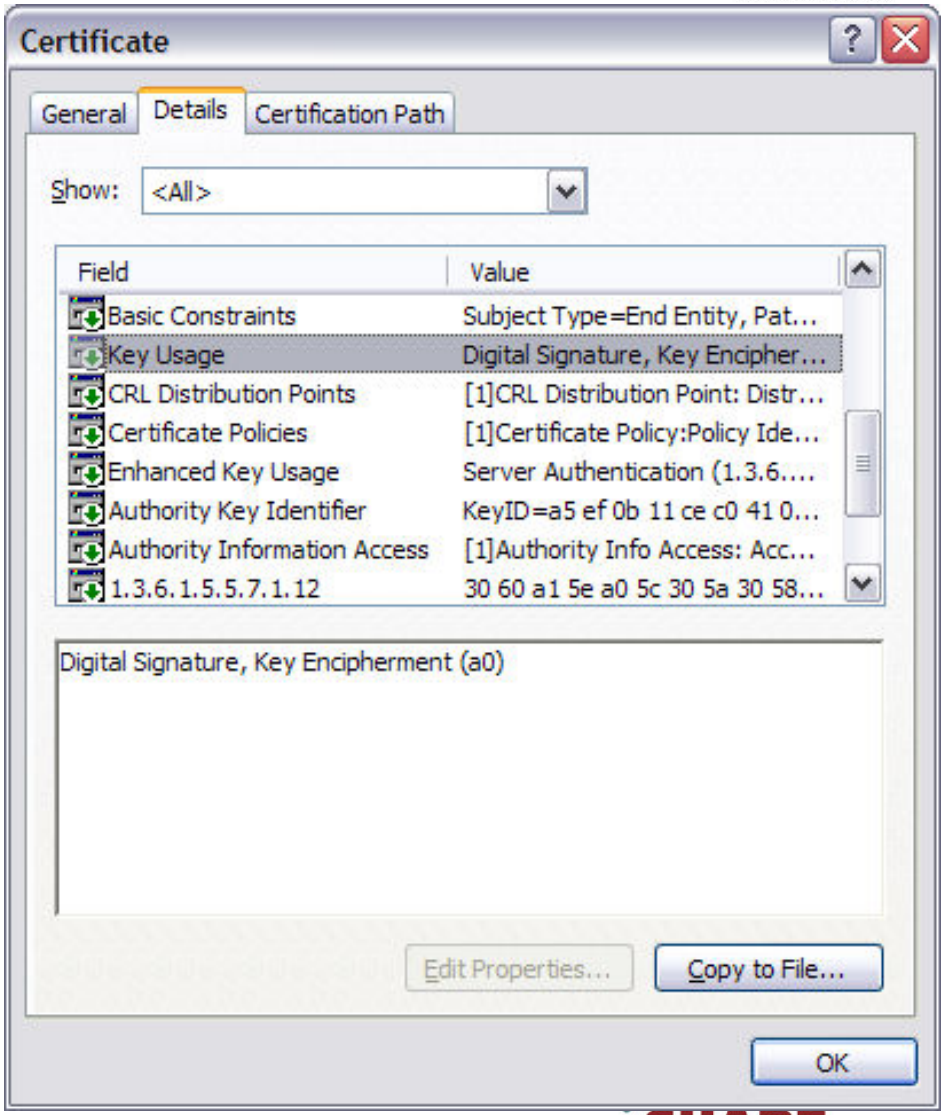
You can NOT change ANY of the certificate information!

Extensions of a X.509 Digital Certificate

- Adds additional definitions to a certificate and its identity information
- 15+ extensions currently defined
- Top 7 extensions of interest:
  - **Authority Key Identifier** – Unique identifier of the signer
  - **Subject Key Identifier** – Unique identifier of the subject
  - **Key Usage** – Defines how the public key can used
    - Digital Signature
    - Key Agreement
    - Certificate Signing
    - Key Encipherment
    - Data Encipherment
    - CRL signing
  - **Subject Alternate Name** – Additional identity information
    - Domain name
    - URI
    - E-mail
    - IP address
  - **Basic Constraints** – Certificate Authority Certificate or not
  - **CRL Distribution** – Locating of Revoked certificate information
  - **Extended Key Usage** – Defines what purposes the public key can be used for
    - Server Auth
    - Client Auth
    - OCSP Signing
    - Code Signing
    - E-mail
    - Timestamping

Example of a x.509 Digital Certificate





Digital Certificates and Certificate stores

- Certificate must be placed in a **certificate store** before it can be used by an application, like Communication Server's AT-TLS or HTTP server, for secure communication

- On z/OS, many components call System SSL APIs, which in turn call RACF **R_datalib** callable service to access the certificate store
  - Application → System SSL → R_DataLib

- Different names:
  - Certificate store = key ring = key file = key database

Types of Digital Certificates

- **Self signed**
  - Self-issued
  - Issuer and subject names identical
  - Signed by itself using associated private key
  - No trusted party involved; trusting subject

- **Signed Certificate**
  - **Signed/issued by a trusted Certificate Authority** Certificate using its private key.
  - By signing the certificate, the **CA certifies the validity of the information**. Can be a well-known commercial organization or local/internal organization.
  - **Signed certificate** can be a end-entity certificate or a Certificate Authority certificate.

Types of Digital Certificates - Usage

- **Secure Socket Layer (SSL) Certificate**
  - Install on a server that needs to be authenticated, to ensure secure transactions between server and client
- **Code Signing Certificate**
  - Sign software to assure to the user that it comes from the publisher it claims
- **Personal Certificate**
  - Identify an individual, enable secure email – to prove that the email really comes from the sender and /or encrypt the email so that only the receiver can read it
- **More (name it whatever you want)…**
  - Wireless certificate, smart card certificate, EV Certificate…
- **Certificate Authority (CA) certificate**
  - Used to sign other certificates
  - Root CA: the top
  - Intermediate CA: signed by root CA or other intermediate CA

Digital Certificate Formats

- X.509 Digital Certificate can exist in many different forms
  - Single certificate
  - **PKCS Package -** (Public-Key Cryptographic Standards)
    – Developed by RSA
    - **PKCS #7** certificate package
      - Contains 1 or more certificates
    - **PKCS #12** certificate package
      - A password encrypted package containing 1 or more certificates and the private key associated with the end-entity certificate.
      - Only package type that contains a private key
- Can be in binary or Base64 encoded format
  - Base64 is used to convert binary data to displayable text for easy cut and paste

Certificate Revocation

- Normally the lifetime of certificate is the defined **validity period**
- Revocation provides a means for a certificate to become **invalid prior to its validity end date**
- **Reasons for revocation:**
  - Private key associated with the certificate has been **compromised**
  - Certificates are being used for purpose other than what they are defined
- **CRL** – Certificate Revocation List:
  - List of certificates that should no longer be trusted
  - CRL Distribution Point extension in the X.509 certificate gives information about where to locate revocation information for the certificate.
- **OCSP** – Online Certificate Status Protocol:
  - Provides a query function for the revocation status of a certificate

Certificate Chain Validation

Is the root CA in my key ring ?

Finish

Self signed:
Issuer=Subject

Root CA
Issuer – CN=Root CA,OU=Signers,O=IBM,C=US
Subject -CN=Root CA,OU=Signers,O=IBM,C=US
…
Signature

Intermediate CA
Issuer - CN=Root CA,OU=Signers,O=IBM,C=US
Subject – CN=Intermediate CA,OU=Signers,O=IBM,C=US
…
Signature

End Entity
Issuer – CN=Intermediate CA,OU=Signers,O=IBM,C=US
Subject -CN=Server Certificate,OU=z/OS,O=IBM,C=US
…
Signature

Start

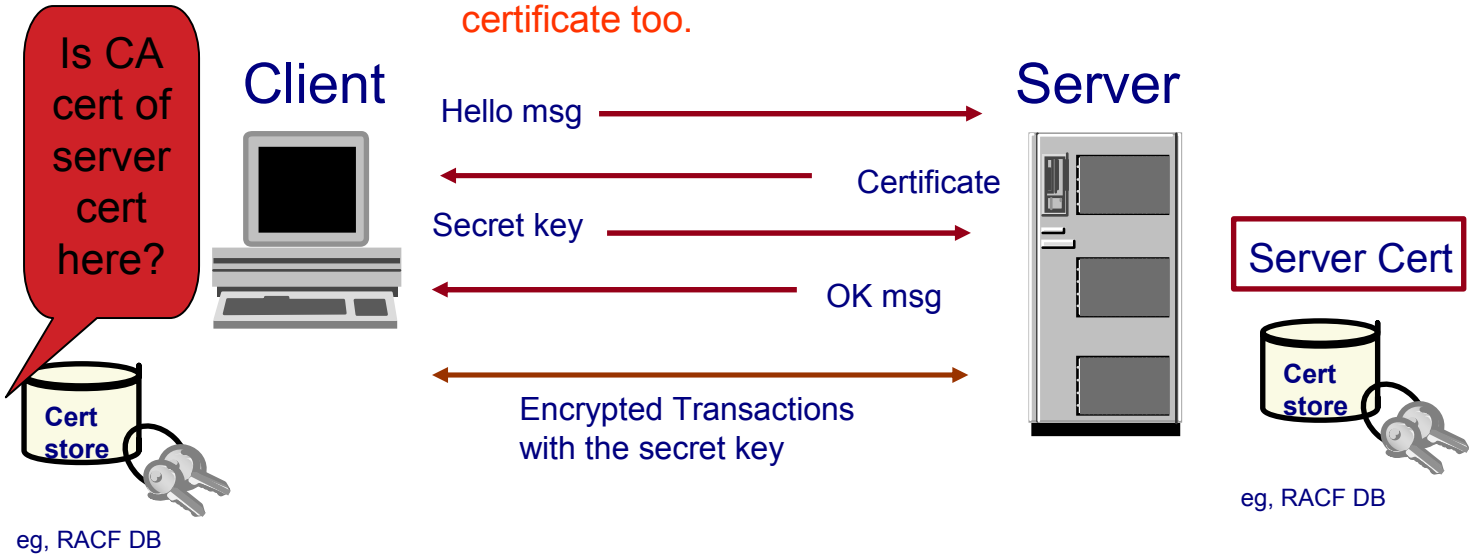
Certificate Validation

- **Signature chain validation:**
  - End Entity certificate signature is validated by signer's public key
  - Any intermediate CA certificates signatures are validated against their signer's public key
  - Root CA certificate is validated against it's own public key
  - Root CA certificate must be trusted
- **Validity period** – Check if the certificate has expired
- **Status** – Check if the certificate has been revoked:
  - **CRL** - Check if it is on a Certificate Revocation List
  - **OCSP** - Check with the CA which issued this certificate through the Online Certificate Status Protocol

Certificates in SSL handshake

1. Client sends a 'hello' msg to server
2. Server sends its certificate to client
3. Client validates the server's certificate
4. Client encrypts a secret key material with server's public key and sends it to server
5. Server decrypts the secret key material with its private key
6. Server encrypts a 'handshake OK' msg with the secret key and sends it to client
7. Client trusts server, business can be conducted

* Note the above steps illustrate server authentication. For client authentication, server needs to validate client's certificate too.



Certificate Life Cycle Planning

- Initially getting a certificate for secure traffic is **only the beginning**
- Must plan for the **certificate life cycle**
- Certificate expiration causes **system outage**
- Things to consider:
  - **How many** certificates are actively used in the system?
  - Certs **locally created** VS Certs by **external provider**
  - Renew using **existing public/private keys** or **require new keys**

- How to **keep track of the expiration dates** of all the certificates in the system?
  Spreadsheets?
  Utilities?
  Automation for renew?
  Use certificate management vendor products?

RACDCERT Overview

- **RACDCERT** is the primary administrative tool for managing digital certificates using RACF.
- **TSO command** shipped as part of **RACF**
- Command line interface with ISPF panels
- Certificates and Rings are protected by RACF profiles
- Learn more:
  - RACF Command Language Reference

```
                RACF - Digital Certificate Key Ring Services
OPTION ===> _

   For user: ________

Enter one of the following at the OPTION line:

    1   Create a new key ring
    2   Delete an existing key ring
    3   List existing key ring(s)
    4   Connect a digital certificate to a key ring
    5   Remove a digital certificate from a key ring
```

RACDCERT ID(FTPServer) GENCERT SUBJECTSDN(CN('Server Certificate')OU('Production')O('IBM')L('Poughkeepsie') SP('New York')C('US')) SIZE(1024) WITHLABEL('Server Certificate') ALTNAME(DOMAIN('mycompany.com'))

RACDCERT ID(FTPServer) ADD('user1.svrcert') WITHLABEL('Server Certificate')

RACDCERT ID(userid) EXPORT (LABEL('label-name')) DSN(output-data-set-name) FORMAT(CERTDER | CERTB64 | PKCS7DER | PKCS7B64 | PKCS12DER | PKCS12B64) PASSWORD('pkcs12-password')

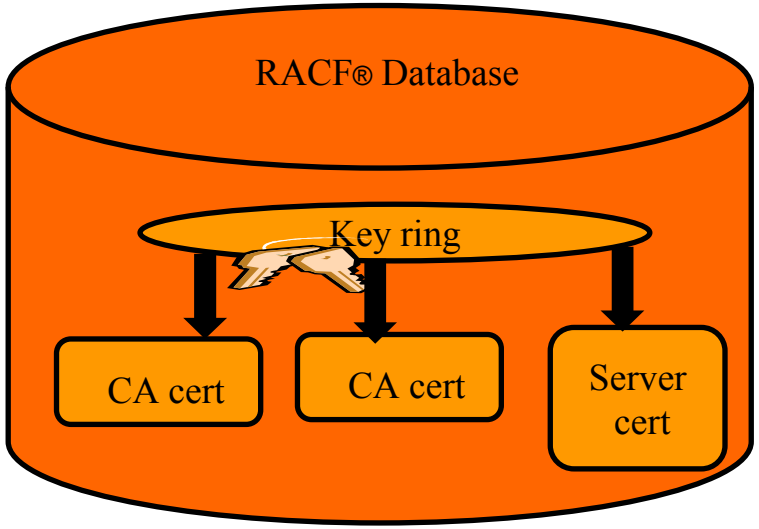
```
             RACF - Digital Certificate Services
OPTION ===>
                _
  Select one of the following:

       1. Generate a certificate and a public/private key pair.

       2. Create a certificate request.

       3. Write a certificate to a data set.

       4. Add, Alter, Delete, or List certificates or
          check whether a digital certificate has been added to
          the RACF database and associated with a user ID.

       5. Renew, Rekey, or Rollover a certificate.
```

RACDCERT Commands

- **Certificate Generation:**
  - RACDCERT **GENCERT** – Generate key pair and certificate
  - RACDCERT **GENREQ** – Generate a certificate request
- **Certificate Installation:**
  - RACDCERT **ADD** – Install a certificate and public/private key
- **Certificate Administration:**
  - RACDCERT **LIST** – Display certificate information from an installed certificate
  - RACDCERT **ALTER** – Change certificate installation information
  - RACDCERT **DELETE** – Delete certificate and key pair
  - RACDCERT **CHECKCERT** – Display certificate information from a dataset
  - RACDCERT **EXPORT** – Export a certificate or a certificate and private key
  - RACDCERT **REKEY** – Renew certificate with new key pair
  - RACDCERT **ROLLOVER** – Finalize the REKEY process

RACDCERT Commands

- **Certificate Ring Administration:**
  - RACDCERT **ADDRING** – Create a key ring
  - RACDCERT **CONNECT** – Place a certificate in a key ring
  - RACDCERT **REMOVE** – Remove a certificate from a key ring
  - RACDCERT **LISTRING** – Display key ring information
  - RACDCERT **DELRING** – Delete a key ring



RACF Key Rings and certificates

- A key ring is a collection of certificates that **identify a networking trust relationship**.

- A certificate must be placed in a key ring before it can be used by middleware applications

- Key Ring Syntax for applications: **<user-id>/<ring-name>**

  Types of Certificates in RACF:
  - **User** – Directly Associated with one z/OS user ID (end entity)
  - **CERTAUTH** – Trusted CA certificate used to verify the peer entity's certificate.
  - **SITE** – Certificates associated with an off-platform server or other network identity. SITE certificates bypass the normal certificate chain validation. Private keys can be shared.

- **Key Rings contain Certificate Usage –** The usage assigned to a certificate when it is connected to a key ring indicates its intended purpose.
  - **PERSONAL –** Used to identify a local user or server application. Personal usage must be used to get access to the private key.
  - **CERTAUTH –** Used to verify the peer entity's certificate. Used to identify the local server's CA certificate.
  - **SITE** – Certificate associated with an off-platform server or other network identity. SITE certificates bypass the normal certificate chain validation.

Setup a certificate for SSL handshake requiring server authentication

Client Key Ring (Client_A)

CA Certificate

Server Key Ring (Server_A)

CA Certificate
Intermediate CA Certificate
Server Certificate

1. Create a **key ring** (aka key file, certificate store) for server and client

RACDCERT ID(SERVER) ADDRING('Server_A')
RACDCERT ID(CLIENT) ADDRING('Client_A')

Setup a certificate for SSL handshake

2. Generate a **certificate signing request**

- a **certificate signing request** (also **CSR** or **certification request**) is a message sent from the certificate requestor to a certificate authority to obtain a signed digital certificate
- Contains info about the requestor
  - Identifying information, like **subject name**
  - **Public key** (may be generated before the request or generated at the same time as the request)
  - Other credentials or **proofs of identity** required by the certificate authority
  - Corresponding **private key is not included** in the CSR, but is used to digitally sign the request to ensure the request is actually coming from the requestor

```
RACDCERT ID(SERVER) GENCERT SUBJECTSDN(CN('Server
    Certificate')OU('Production')O('IBM')L('Endicott')SP('New York')C('US'))
    SIZE(1024) WITHLABEL('Server Certificate')
    ALTNAME(DOMAIN('mycompany.com'))

RACDCERT ID(SERVER) GENREQ(LABEL('Server Certificate'))
    DSN('SUAPC8.HIGHRISK.CERTREQ')
```

Setup a certificate for SSL handshake

3. Provide certificate request to Certificate Authority for signing.

```
-----BEGIN NEW CERTIFICATE REQUEST-----
MIIB/TCCAWYCAQAwczELMAkGA1UEBhMCVVMxETAPBgNVBAgTCE5ldyBZb3JrMREw
DwYDVQQHEwhFbmRpY290dDEMMAoGA1UEChMDSUJNMRMwEQYDVQQLEwpQcm9kdWN0
aW9uMRswGQYDVQQDExJTZXJ2ZXIgQ2VydGlmaWNhdGUwgZ8wDQYJKoZIhvcNAQEB
BQADgY0AMIGJAoGBAMiMS+wcxWogUANwFSZo4UFTkT4vjJrdd1ntJ5f0DTTTYkPV
0rnztynih3xyCpem54k57iTyVJTCWdHmOhiNuCB7CZySoLZG0EAIM3Zl+1s4f93A
KAnzP71JhP4sFCbNvRA96dPfRlx6/dRbAmi4IxNmBlLJBMqusebsYTA8+vWzAgMB
AAGgSjBIBgkqhkiG9w0BCQ4xOzA5MBgGA1UdEQQRMA+CDW15Y29tcGFueS5jb20w
HQYDVR0OBBYEFIATTW6P6lpujfpaR4NrdtWcizOuMA0GCSqGSIb3DQEBBQUAA4GB
AJv6GSrF7Ah51Gg2GnNj7OnizIyNGw2tKVhcOPINzFOBjK8JwE7y9l3/YJ+px/Yc
ESGB3azSb12deC3XsYHv2qBffMG6j3YJeGhagiAwLBhzIpVtgO4LDqd4J9ibQ/GT
+1WWV+/Lm97WjAAbtfZnNS3lO4XeAHN/RoZ6T9yqxgal
-----END NEW CERTIFICATE REQUEST-----
```

Setup a certificate for SSL handshake

4. If the request is successful, the **certificate authority will send back an identity certificate** that has been digitally signed with the private key of the certificate authority.

```
-----BEGIN CERTIFICATE-----
MIICkTCCAfqgAwIBAgIIUQfG7AAG4hMwDQYJKoZIhvcNAQEFBQAwNTELMAkGA1UE
BhMCVVMxDTALBgNVBAoTBHRlc3QxFzAVBgNVBAMTDkNBIENlcnRpZmljYXRlMB4X
DTEzMDEyOTEyNTYxMloXDTEzMDUwOTEyNTYxMlowczELMAkGA1UEBhMCVVMxETAP
BgNVBAgTCE5ldyBZb3JrMREwDwYDVQQHEwhFbmRpY290dDEMMAoGA1UEChMDSUJN
MRMwEQYDVQQLEwpQcm9kdWN0aW9uMRswGQYDVQQDExJTZXJ2ZXIgQ2VydGlmaWNh
dGUwgZ8wDQYJKoZIhvcNAQEBBQADgY0AMIGJAoGBAMiMS+wcxWogUANwFSZo4UFT
kT4vjJrdd1ntJ5f0DTTTYkPV0rnztynih3xyCpem54k57iTyVJTCWdHmOhiNuCB7
CZySoLZG0EAIM3Zl+1s4f93AKAnzP71JhP4sFCbNvRA96dPfRlx6/dRbAmi4IxNm
BlLJBMqusebsYTA8+vWzAgMBAAGjbDBqMBgGA1UdEQQRMA+CDW15Y29tcGFueS5j
b20wHQYDVR0OBBYEFIATTW6P6lpujfpaR4NrdtWcizOuMA4GA1UdDwEB/wQEAwIE
8DAfBgNVHSMEGDAWgBSwO8SNzbU2ow8CA/zB9y4pQ7y8tzANBgkqhkiG9w0BAQUF
AAOBgQAo/GQbaI7D1xEK92KAKmWRCzYjGni2ttrnpUBQS4QP+mPpolqMcvHVfNeD
stzLWNG4jSxQMwH1FK9C3vF2Y1G7/kpt1JGI1ebW4I1u+9GlYrVBk9X0j6kGuHrd
LT24VxJUK+n8td5qpA/Smf08clT8XAYJpi3CeVy1mrfUSpQUdg==
-----END CERTIFICATE-----
```

Setup a certificate for SSL handshake

5. Add the **certificates (CA, Intermediate CA and Server) t**o the RACF **database**

RACDCERT CERTAUTH ADD('suapc8.highrisk.cacert')
TRUST WITHLABEL('CA Certificate')

RACDCERT CERTAUTH ADD('suapc8.highrisk.cacert2')
TRUST WITHLABEL('Intermediate CA Certificate')

RACDCERT ID(SERVER) ADD('suapc8.highrisk.signed')
WITHLABEL('Server Certificate')

Setup a certificate for SSL handshake

6. Connect certificates to the **key rings**

RACDCERT ID(SERVER) CONNECT (CERTAUTH LABEL('CA Certificate') RING(Server_A) USAGE(CERTAUTH))

RACDCERT ID(SERVER) CONNECT(CERTAUTH LABEL('Intermediate CA Certificate') RING (Server_A) USAGE(CERTAUTH))

RACDCERT ID(SERVER) CONNECT(ID(SERVER) LABEL('Server Certificate') RING(Server_A) USAGE(PERSONAL) DEFAULT)

Server Authentication requires the CA Certificate to be connected to the client's key ring

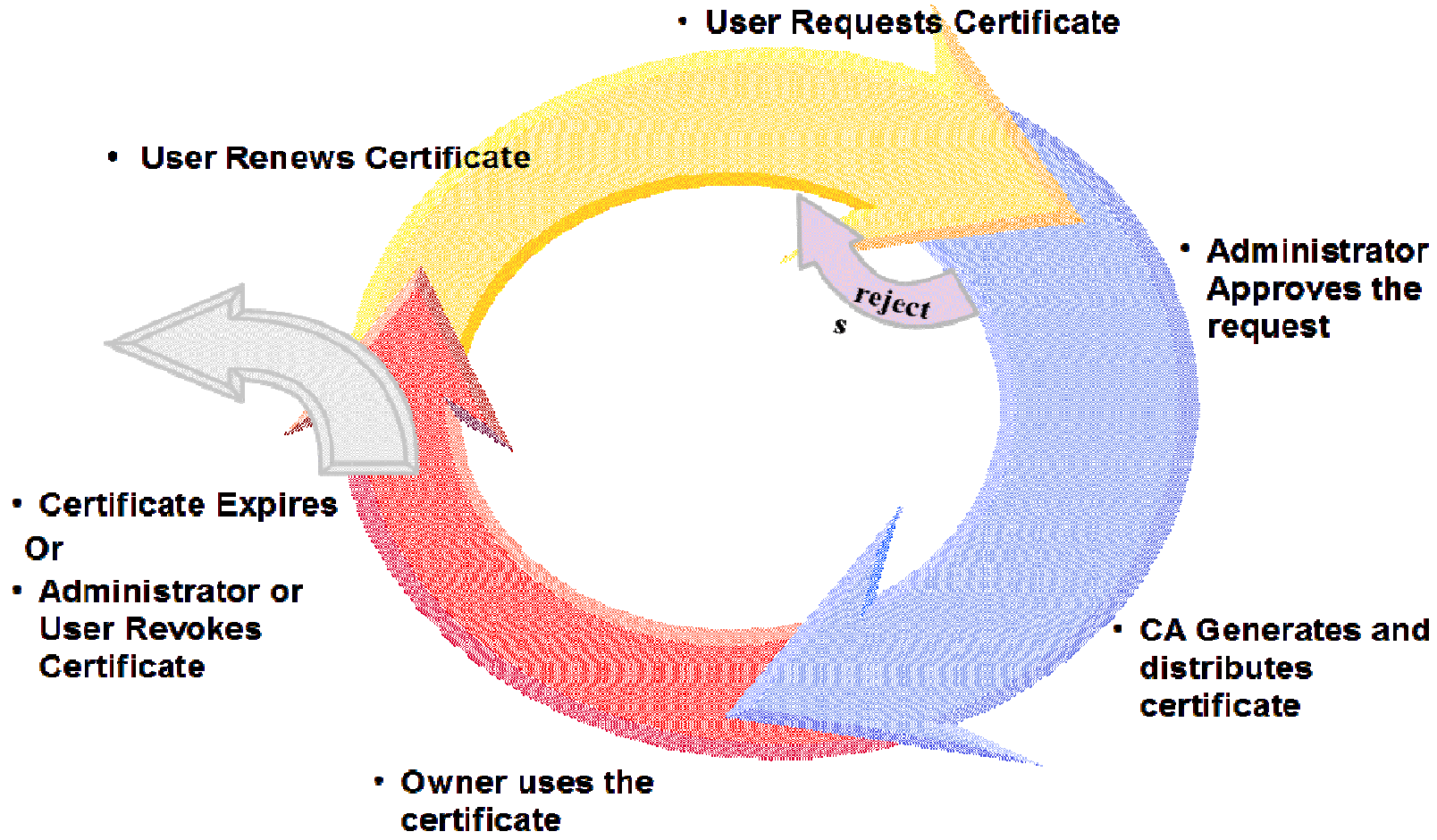
RACDCERT ID(CLIENT) CONNECT (CERTAUTH LABEL('CA Certificate') RING(Client_A) USAGE(CERTAUTH))

Setup a certificate for SSL handshake

7. **Permit the client and server application** access to their key ring, the certificates

```
RDEFINE FACILITY IRR.DIGTCERT.LISTRING UACC(NONE)

PERMIT IRR.DIGTCERT.LISTRING CLASS(FACILITY) ID(SERVER)
    ACCESS(READ)

PERMIT IRR.DIGTCERT.LISTRING CLASS (FACILITY) ID(CLIENT)
    ACCESS(READ)
```

Certificate Authority and User Interaction



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Certificate Authority on z/OS: PKI Services

- **PKI Services** provides full certificate life cycle management
  - **Request**, **create**, **renew**, **revoke** certificates
  - Provides certificate status:
    - **Certificate Revocation List (CRL)**
    - **Online Certificate Status Protocol (OCSP)**
  - Generation and administration of certificates via customizable web pages
  - **Automatic notifications** or renewal of expiring certificates

Review

- **Cryptography**
- What are **Digital Certificates**
- Certificate **Types** and **Contents**
- Certificate **Formats**
- Certificate **Validation**
- Certificates and **SSL**
- Certificate **Life Cycle**
- **RACDCERT** command
- Using **RACDCERT** for **SSL** certificates
- **z/OS PKI Services**

References

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- **RACF web site:**
  http://www.ibm.com/servers/eserver/zseries/zos/racf
- **PKI Services web site:**
  http://www.ibm.com/servers/eserver/zseries/zos/pki
- **IBM Redbooks**
  z/OS V1 R8 RACF Implementation
- **Security Server Manuals:**
  RACF Command Language Reference
  RACF Security Administrator's Guide
- **Cryptographic Server Manual**
  Cryptographic Services System Secure Sockets Layer Programming
- **RFCs**
  RFC2459 - Internet X.509 Public Key Infrastructure Certificate and CRL Profile
  RFC5280 - Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile

Questions?

Alyson Comer
Session
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