Understanding Digital Certificates on z/OS

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Agenda

- **Symmetric vs. Asymmetric Encryption**
- What are **digital certificates**
- Certificate **types** and **contents**
- Certificate **formats**
- Overview of certificate **utilities** available on z/OS
- **Summary**
Symmetric Encryption

- Defined keys
- Provide data confidentiality
- Algorithm defines strength of the encryption – DES, Triple DES, AES etc

This is a plain text

Original Message

Secret Key

Encryption Algorithm

QWE@56!121!TQM

Encrypted Message

Decryption Algorithm

Secret Key
Hash Algorithm

- One way function
- Arbitrary size input message produced a fixed size message digest
- No keys involved – Result determined only by the algorithm
- Any change to the input results completely unrelated message digest

Examples:
- MD5 = 128 bits (16 bytes)
- SHA-1 = 160 bits (20 bytes)
- SHA-256 = 256 bits (32 bytes)
Asymmetric Encryption

- Public/private key pairs

- 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.

- Public key is intended to be given freely

- Private key needs to be treated very securely and not distributed
Encryption (for confidentiality)

Encrypting a message:

Sender: Msg

Encrypt with Recipient’s Public key

Decrypting a message:

Recipient: Decrypt with Recipient’s Private key

Keys:
- Plain text
- Encrypted text
Signing (for integrity and non repudiation)

**Signing a message:**

Sender:

- **Msg** → **Hash** → Encrypt with **Sender’s Private key** → **Signature**

**Verifying a message:**

Recipient:

- Decrypt With **Sender’s Public key** to recover the hash

Do they match? If yes, the message is unaltered. Assuming the hashing algorithm is strong.
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 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)
    
    - **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 20 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
What's in a Digital Certificate?

Certificate Info
- version
- serial number
- signature algorithm ID
- issuer's name
- validity period
- subject's name
- subject's public key
- extensions

Version 1, 2, 3

This is the hash/encrypt algorithm used in the signature, eg. sha1RSA

The certificate binds a public key to a subject

CA signs the above cert info by encrypting the hash with its **private** key

The private key is NOT in the certificate. It is kept in a key store

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+ currently defined
- Top 6 extensions of interest
  • Authority Key Identifier
  • Subject Key Identifier
  • Key Usage
  • Subject Alternate Name
  • BasicConstraints
  • CRL Distribution Point
Extensions of a x.509 digital Certificate

- **Authority Key Identifier** – Unique identifier of the signer
- **Subject Key Identifier** – Unique identifier of the subject
- **Key Usage** – Defines how the public key can be used
  - Digital Signature
  - Key Encipherment
  - Key Agreement
  - Data Encipherment
  - Certificate Signing
  - CRL signing
- **Subject Alternate Name** – Additional identity information
  - Domain name
  - E-mail
  - URI
  - IP address
- **Basic Constraints** – Certificate Authority Certificate or not
- **CRL Distribution** – Locating of Revoked certificate information
Example of a x.509 digital Certificate

Certificate issued to Server x by CA MyCompany CA to be used for SSL/TLS communication

<table>
<thead>
<tr>
<th>Version</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Number</td>
<td>150</td>
</tr>
<tr>
<td>Signature Algorithm</td>
<td>RSA with SHA1</td>
</tr>
<tr>
<td>Issuer</td>
<td>CN=MyCompany CA,OU=Onsite CA ,O=CA Company,C=US</td>
</tr>
<tr>
<td>Validity</td>
<td></td>
</tr>
<tr>
<td>From</td>
<td>Wednesday, May 31, 2008 10:41:39 AM</td>
</tr>
<tr>
<td>To</td>
<td>Wednesday, May 31, 2009 10:41:39 AM</td>
</tr>
<tr>
<td>Subject</td>
<td>CN=Server x,OU=z/OS,O=IBM,ST=New York,C=US</td>
</tr>
<tr>
<td>Public Key</td>
<td>RSA (1024)</td>
</tr>
<tr>
<td>Extensions</td>
<td></td>
</tr>
<tr>
<td>Key Usage</td>
<td>Digital Signature, Key Encipherment</td>
</tr>
<tr>
<td>Authority Key Identifier</td>
<td>8014 91C1 73B0 73D5 D992 7467 CD1B F151 1434 31B6 2C5A</td>
</tr>
<tr>
<td>Subject Key Identifier</td>
<td>0414 7CA8 9E87 AA37 5D70 0301 7FDA 996C 1238 A20D 4FDE</td>
</tr>
<tr>
<td>Basic Constraints</td>
<td>Certificate issued to a certificate authority= FALSE</td>
</tr>
<tr>
<td>Subject Alternate Name</td>
<td>IP Address=9.1.2.3</td>
</tr>
</tbody>
</table>
Types of digital certificates

- **Self signed**
  - Self-issued
  - Issuer and subject names identical
  - Signed by itself using associated private key

- **Signed Certificates**
  - 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.
Certificate Formats

- X.509 certificates 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 encoding

- Converting binary data to displayable text for easy cut and paste.

-----BEGIN CERTIFICATE-----
MIICPTCCaagAwIBAgIIR49S4QANLueDQYJKoZIhvcNAQEFBQAwNzELMAkGA1UE
BhMCVVMxDTALBgNVBAoTBFRlc3RMTE2MTMwNjQxWhcNMDkwMTE2MTMwNjQxWjA3MQsw
CQYDVQQGEwJVUzENMAsGA1UEChMEVGVzdDEZMBcGA1UEAwwQVGVzdF9zZWxmX3NpZ25l
ZDCBnzANBgkqhkjG9w0BAQEFAAOBjQAwgYkCgYEA9tKOv5gLaceozMfMeVd891fCjBVoR+
dpzhwKR2B/QcQYBGLfqs4YM/wGSh6YrmVygO0VxociySbcxRuBayw3pE4/3J2myINmLp
bFIcPCnqk/qvFK+1N+nrEnBK9yls7NmxDIuQ0FsX/o/Dpoxwzxf+JbWdWqR
NyLiTGMCAwEAAaNSMFAswHQYDVR0OBBYEFAwDFljOUCRa62BV3jVyHewuOWEMB8G
A1UdIwQYMBaAFAwDFljOUCRa62BV3jVyHewuOWEMA4GA1UdDwEB/wQEAwIE8DAN
BgkqhkiG9w0BAQUFAAObGACQ5sW1f3EdE0k9zc8wKNTlsczWkQBrVy4Rdr17ERqN
D2Q7kBo4dJoXiNwN18p6WPFwY80MNwhP40oJSVePnzElh4Wzi2wzlzI8rINSW7px3
w16lz+8jEI84q/N0q0toPTAtEb6fIzwjkLttt3oF+IjunvE5O0sXRJbbTMD/EG
jw==
-----END 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

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

Is the root CA in my key ring?
Using Certificates for SSL handshakes

Client

- Client validates the server’s certificate
- [Client sends its certificate
  Signs a certificate verify message using its private key]
- Clients encrypts key generation information using the server’s public key

Server

- Server sends its certificate
  [optionally requests the client to send its certificate]
- [Server validates the client’s certificate. Using the passed client’s public key verifies the signed certificate message]
- Using its private key, decrypts the key generation info from the client

Encrypted data flow
Using certificates to secure communication through the SSL/TLS protocol

- For example, Wilma wants to establish a secure FTP TLS connection between her workstation and FTP Server. The FTP Server is using a RACF key ring and Wilma has a key database file.

- The server certificate has been signed by CA1

- Wilma’s certificate has been signed by CA2.

**Wilma’s Key Database File**
- Wilma’s Identity Certificate
- CA2 Certificate
- CA1 Certificate

**FTP Server Key Ring**
- FTP Server Identity Certificate
- CA1 Certificate
- CA2 Certificate
Defining a Certificate

- How will the certificate be used?
- What certificate store is to be used?
- Who will be the certificate authority?
- What is the identity’s subject name?
- What is the size of the public/private keys?
- Whether additional identity information is to be added to the certificate?
- What label or nickname will the certificate be known by?
Defining a Certificate Request to be signed by a CA

- A **certificate signing request** (CSR or **PKCS #10**) is a message sent from the certificate requestor to a certificate authority to obtain a signed digital certificate.

- **Contains identifying information and public key** for the requestor.

- 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.

- CSR may be accompanied by **other credentials or proofs of identity** required by the certificate authority, and the certificate authority may contact the requestor for further information.

- 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.
Certificate Stores on z/OS

- gskkyman manages certificates stored in a key database file
- RACDCERT manages certificates stored in a RACF key ring.
Certificate utilities on z/OS

- Provide basic certificate functions:
  - **Create/delete** certificate store
    (HFS key database file / SAF key ring)
  - **Create certificate requests** (to be signed by trusted Certificate Authority)
  - **Import / Export** certificates (with and without private keys)
  - **Create** self-signed and signed certificates
- Do not have all the functions of a full featured Certificate Authority
gskkyman

- **gskkyman** is a UNIX based utility shipped as part of the **System SSL** product in the z/OS Cryptographic Services Element
- **Menu** interface
  - Certificates and keys are stored in a **key database file** in the HFS
  - Protected by the file system’s **permission bits** and **password**
- Learn more:
  - Cryptographic Services System Secure Sockets Layer Programming (SC24-5901)

**Database Menu**

1 - Create new key database
2 - Open key database
3 - Change database password
4 - Change database record length
5 - Delete database
6 - Create key parameter file
7 – Display certificate file (Binary or Base64 ASN.1 DER)
0 - Exit Program

**Key Management Menu**

- Database: /tmp/my.kdb
  1 - Manage keys and certificates
  2 - Manage certificates
  3 - Manage certificate requests
  4 - Create new certificate request
  5 - Receive requested certificate or a renewal certificate
  6 - Create a self-signed certificate
  7 - Import a certificate
  8 - Import a certificate and a private key
  9 - Show the default key
  10 - Store database password
  11 - Show database record length
0 - Exit program
**RACDCERT**

- **RACDCERT** is a **TSO command** shipped as part of **RACF**
- Command line interface with ISPF panels
- RACF certificates and rings are protected by RACF profiles
- Learn more:

RACF Command Language Reference (SC22-7687)

**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')**
Certificate Authority on z/OS: PKI Services

- A complete PKI solution to manage the whole certificate life cycle:
  - Request, create, renew, revoke certificates
  - Provide certificate status: CRLs & OCSP
- Closely tied to RACF:
  - The CA cert must be installed in RACF’s key ring
  - Authority checking goes through RACF’s callable service
  - Most of the auditing work done through RACF
- CA cert private key can be stored in ICSF
- Generation and administration of certificates via customizable web pages
- Keys can be generated by requestor, or generated by PKI (Key escrow)
- Smart card support
Steps to request a CA signed Certificate

- Steps:
  - Create a key database file or SAF key ring
  - Receive CA certificate, if not already in database
  - Create a new certificate request and send to CA
  - Receive signed certificate
  - Indicate to the application that this certificate is to be used
    - Mark it as ‘default’
    - Name it with a specific required label
If you use gskkyman...
Create a key database

Database Menu

1 - Create new key database
2 - Open key database
3 - Change database password
4 - Change database record length
5 - Delete database
6 - Create key parameter file
7 – Display certificate file (Binary or Base64 ASN.1 DER)

0 - Exit Program

Enter your option number: 1
Enter key database name (press ENTER to return to menu: /tmp/my.kdb
Enter database password (press ENTER to return to menu: password
Re-enter database password: password
Enter password expiration in days (press ENTER for no expiration): <enter>
Enter database record length (press ENTER to use 2500): <enter>

This will add a number of well-known trusted CA certificates to the key database.
Importing a signing Certificate Authority Certificate

Key Management Menu

Database: /tmp/my.kdb

1 - Manage keys and certificates
2 - Manage certificates
3 - Manage certificate requests
4 - Create new certificate request
5 - Receive requested certificate or a renewal certificate
6 - Create a self-signed certificate
7 - Import a certificate
8 - Import a certificate and a private key
9 - Show the default key
10 - Store database password
11 - Show database record length

0 - Exit program

Enter option number (press ENTER to return to previous menu): 7
Importing a signing Certificate Authority Certificate Continued

Enter import file name (press ENTER to return to menu): cacert.b64
Enter label (press ENTER to return to menu): CA Certificate

Certificate imported.
Creating a new certificate request

Key Management Menu

Database: /tmp/my.kdb

1 - Manage keys and certificates
2 - Manage certificates
3 - Manage certificate requests
4 - Create new certificate request
5 - Receive requested certificate or a renewal certificate
6 - Create a self-signed certificate
7 - Import a certificate
8 - Import a certificate and a private key
9 - Show the default key
10 - Store database password
11 - Show database record length

0 - Exit program

Enter option number (press ENTER to return to previous menu): 4
Certificate Type

1 - Certificate with 1024-bit RSA key
2 - Certificate with 2048-bit RSA key
3 - Certificate with 4096-bit RSA key
4 - Certificate with 1024-bit DSA key

Enter certificate type (press ENTER to return to menu): 1
Enter request file name (press ENTER to return to menu): certreq.arm
Enter label (press ENTER to return to menu): Server Certificate
Enter subject name for certificate
  Common name (required): Server Certificate
  Organizational unit (optional): Production
  Organization (required): IBM
  City/Locality (optional): Endicott
  State/Province (optional): New York
  Country/Region (2 characters - required): US

Enter 1 to specify subject alternate names or 0 to continue: 1
Content of the certificate request

Contents of certreq.arm file:

-----BEGIN NEW CERTIFICATE REQUEST-----
MIIB3jCCAUcCAQAwczELMAkGA1UEBhMCVVMxETAPBgNVBAgTCE5ldyBZb3JrMREw
DwYDVQQHEwhFbmRpY290dDEMMAoGA1UEChMDSUJNMRMwEQYDVQQLEwpQcm9kdWN0
aW9uMRswGQYDVQQDEExJTZXJ2ZXIgQ2Vydg1maWNhdGwz8wDQYJKoZIhvcNAQcEB
BQADgY0AMIGJaoGBAMTiaO7czZdi8IU+eCL23xtrqhXBqnksHBwedW8zeCjnqxq1l
ump9GY4Jw9Wyqq9a2J85bWJD06TaHhFALru5pgO1+jMOQTbB+wZoS0lbIrwoW161
pLx1cqJOn53mBmv6ruP/d055jjgKTczYh0a2JdhmfpAvf+C6tUkn7qMW1RzNAgMB
AAAgKzApBgkqhkiG9w0BCQ4xHDAaMBgGA1UDEQQRMA+CDW15Y29tcGFueS5jb20w
DQYJKoZIhvcNAQEFBQADgYEAAx4CvL14Cq+YVdjUHGnVr28ySnPz8E1uMT/k9Y6qM
EE+3Hiy2aD2mUREyeljehF5VNSbHwG5VCrFVVOtuVomeJgY8bYmLE45Z4oJoyqFG
HdQVUQO5E+W3UvKYv698KQTp1668BV51F3xlBwNx6K1PL40i0fq8gFMfB8nP0KM
LOs=
-----END NEW CERTIFICATE REQUEST-----
Receiving a signed certificate request

Key Management Menu

Database: /tmp/my.kdb

1 - Manage keys and certificates
2 - Manage certificates
3 - Manage certificate requests
4 - Create new certificate request
5 - Receive requested certificate or a renewal certificate
6 - Create a self-signed certificate
7 - Import a certificate
8 - Import a certificate and a private key
9 - Show the default key
10 - Store database password
11 - Show database record length
0 - Exit program

Enter option number (press ENTER to return to previous menu): 5
Enter certificate file name (press ENTER to return to menu): svrcert.arm

File contains cert returned from CA
Marking a certificate as the default

Key and Certificate Menu

Label: Server Certificate

1 - Show certificate information
2 - Show key information
3 - Set key as default
4 - Set certificate trust status
5 - Copy certificate and key to another database
6 - Export certificate to a file
7 - Export certificate and key to a file
8 - Delete certificate and key
9 - Change label
10 - Create a signed certificate and key
11 - Create a certificate renewal request

0 - Exit program

Enter option number (press ENTER to return to previous menu): 3
If you use RACDCERT…
(ISPF Panel or Command)
RACDCERT Panel on Key Ring

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 Panel on Certificate

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.
Create a key ring

RACDCERT ID(FTPserver) ADDRING(MyRACFKeyRing)

Importing a signing Certificate Authority Certificate

RACDCERT CERTAUTH ADD(‘user1.cacert’) TRUST WITHLABEL(‘CA Certificate’)

RACDCERT ID(FTPServer) CONNECT (CERTAUTH LABEL(‘CA Certificate’) RING(MyRACFKeyRing) USAGE(CERTAUTH))
Creating a new certificate request

RACDCERT ID(FTPServer) 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(FTPServer) GENREQ(LABEL('Server Certificate'))
DSN('user1.certreq')

Dataset to contain certificate request
Receiving a signed certificate request

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

RACDCERT ID(FTPServer) CONNECT(ID(SUIMGTF) LABEL(‘Server Certificate’) RING(MyRACFKeyRing) USAGE(PERSONAL) DEFAULT)

Dataset contains cert returned from CA
Listing a RACF Key Ring

RACDCERT ID(FTPServer) LISTING(MyRACFKeyRing)

Ring:

>MyRACFKeyRing<

<table>
<thead>
<tr>
<th>Certificate Label Name</th>
<th>Cert Owner</th>
<th>USAGE</th>
<th>DEFAULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA Certificate</td>
<td>CERTAUTH</td>
<td>CERTAUTH</td>
<td>NO</td>
</tr>
<tr>
<td>Server Certificate</td>
<td>ID(FTPServer)</td>
<td>PERSONAL</td>
<td>YES</td>
</tr>
</tbody>
</table>

Note: RACF key rings allow for a certificate’s private key to be stored into ICSF’s (Integrated Cryptographic Service Facility) PKDS (Public Key Dataset) for added security.
Exporting Certificates through gskkyman

Key and Certificate Menu

Label: Server Certificate

1 - Show certificate information
2 - Show key information
3 - Set key as default
4 - Set certificate trust status
5 - Copy certificate and key to another database
6 - Export certificate to a file
7 - Export certificate and key to a file
8 - Delete certificate and key
9 - Change label
10 - Create a signed certificate and key
11 - Create a certificate renewal request

0 - Exit program

Enter option number (press ENTER to return to previous menu):
Exporting Certificates through gskkyman

Option 6 – Public Certificate Information

Export File Format

1 - Binary ASN.1 DER
2 - Base64 ASN.1 DER
3 - Binary PKCS #7
4 - Base64 PKCS #7

Option 7 – Public Certificate Information and Private Key

Export File Format

1 - Binary PKCS #12 Version 1 (Few very old applications still use V1)
2 - Base64 PKCS #12 Version 1
3 - Binary PKCS #12 Version 3
4 - Base64 PKCS #12 Version 3
Exporting Certificates through RACDCERT

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

- Example - Export Server Certificate with its private key
  - RACDCERT ID(FTPServer) EXPORT
    LABEL('Server Certificate') DSN('USER1.SERVER.CERT')
    FORMAT(PKCS12DER) PASSWORD('passwd')
Summary

- Digital certificates provide **electronic identity** and **public key** information to be utilized through public key protocols (ie. SSL/TLS)
- Utilizing **trusted CAs** is key to ensure validity of the digital certificate
- **Protect the private key!!!**
- **Larger** the public/private **key pair size**, **greater security**, but **more computation intense**
Summary

- **Certificate** source **usage** is application defined.

- When **transferring** certificates, use a **format** acceptable to the receiving side.

- When **transferring** certificates, be sensitive to **binary** and **text modes** to ensure proper transfer.
References

- IBM Education Assistant web site:
  http://publib.boulder.ibm.com/infocenter/ieduasst/stgv1r0/index.jsp
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  http://www.ibm.com/servers/eserver/zseries/zos/pki
- IBM Redbooks
  z/OS V1 R8 RACF Implementation (SG24-7248)
- Security Server Manuals:
  RACF Command Language Reference (SC22-7687)
  RACF Security Administrator's Guide (SC28-1915)
- Cryptographic Server Manual
  Cryptographic Services System Secure Sockets Layer Programming (SC24-5901)
- 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?

See you later in 9553 / 9554
(PKI Services overview and lab)