The X.509 standard, PKI and electronic documents

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X.509 certificates

- standard ITU-T X.509:
  - v1 (1988)
  - v2 (1993) = minor
  - v3 (1996) = v2 + extensions + attribute certificate v1
  - v3 (2001) = v3 + attribute certificates v2
- is part of the standard X.500 for directory services (white pages)
- is a solution to the problem of identifying the owner of a cryptographic key
- definition in ASN.1 (Abstract Syntax Notation 1)

X.509 version 3

- standard completed in June 1996
- groups together in a unique document the modifications required to extend the definition of certificate and CRL
- two types of extensions:
  - public, that is defined by the standard and consequently made public to anybody
  - private, unique for a certain user community

Critical extensions

- an extension can be defined as critical or non critical:
  - in the verification process the certificates that contain an unrecognized critical extension MUST be rejected
  - a non critical extension MAY be ignored if it is unrecognized
- the different (above) processing is entirely the responsibility of the party that performs the verification: the Relying Party (RP)

Public extensions

- X.509v3 defines four extension classes:
  - key and policy information
  - certificate subject and certificate issuer attributes
  - certificate path constraints
  - CRL distribution points
### Key and policy information
- authority key identifier
- subject key identifier
- key usage
- private key usage period
- certificate key policies
- policy mappings

### Key and policy information
- **key usage**
  - identifies the application domain for which the public key can be used
  - can be critical or not critical
  - if it is critical then the certificate can be used only for the scopes for which the corresponding option is defined

### Certificate subject and certificate issuer attributes
- subject alternative name
- issuer alternative name
- subject directory attributes

### Certificate subject and certificate issuer attributes
- **subject alternative name**
  - allows to use different formalisms to identify the owner of the certificate (e.g. e-mail address, IP address, URL)
  - always critical if the field subject-name is empty

### X.509 alternative names
- various possibilities:
  - RFC822Name
  - dNSName
  - iPAddress
  - uniformResourceIdentifier
  - directoryName
  - X400Address
  - ediPartyName
  - registeredID
  - otherName
CRL distribution point
- CRL distribution point
  - identifies the distribution point of the CRL to be used in validating a certificate
  - can be:
    - directory entry
    - e-mail or URL
    - critical or non-critical

PKIX private extensions
- authority information access
  - indicates how to access information and services of the CA that issued the certificate:
    - certStatus
    - certRetrieval
    - cAPolicy
cACerts
    - critical or not critical

Extended key usage
- in addition or in substitution of keyUsage
- possible values:
  - (id-pkix.3.1) serverAuth [DS, KE, KA]
  - (id-pkix.3.2) clientAuth [DS, KA]
  - (id-pkix.3.3) codeSigning [DS]
  - (id-pkix.3.4) emailProtection [DS, NR, KE, KA]
  - (id-pkix.3.8) timeStamping [DS, NR]

CRL X.509
- Certificate Revocation List
- list of revoked certificates
- CRLs are issued periodically and maintained by the certificate issuers
- CRLs are digitally signed:
  - by the CA that issued the certificates
  - by a revocation authority delegated by the (indirect CRL, iCRL)

CRL X.509 version 2
CertificateList ::= SEQUENCE {
  tbsCertList TBSCertList,
  signatureAlgorithm AlgorithmIdentifier,
  signatureValue BIT STRING }
TBSCertList ::= SEQUENCE {
  version Version OPTIONAL,  -- if present, version must be v2
  signature AlgorithmIdentifier,
  issuer Name,
  thisUpdate Time,
  nextUpdate Time OPTIONAL,
  revokedCertificates SEQUENCE {
    userCertificate CertificateSerialNumber,
    revocationDate Time,
    crlEntryExtensions Extensions OPTIONAL
  } OPTIONAL,
  crlExtensions [] Extensions OPTIONAL
}

Extensions of CRLv2
- crlEntryExtensions:
  - reason code
  - hold instruction code
  - invalidity date
  - certificate issuer
- crlExtensions:
  - authority key identifier
  - issuer alternative name
  - CRL number
  - delta CRL indicator
  - issuing distribution point
**Certificate revocation timeline**

<table>
<thead>
<tr>
<th>Event</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key compromise event</td>
<td></td>
</tr>
<tr>
<td>Cert revocation time</td>
<td></td>
</tr>
<tr>
<td>CRL n issued</td>
<td></td>
</tr>
<tr>
<td>Cert revocation request</td>
<td></td>
</tr>
<tr>
<td>CRL n+1 issued</td>
<td></td>
</tr>
</tbody>
</table>

**OCSP**

- RFC-2560: On-line Certificate Status Protocol
- IETF-PKIX standard to verify online if a certificate is valid:
  - good
  - revoked
  - revocationTime
  - revocationReason
  - unknown
- response signed by the server (not by the CA!)
- the OCSP server certificate cannot be verified with OCSP itself!

**Architecture of OCSP**

- possible pre-computed responses
  - decreases the computational load on the server ... but makes possible replay attacks!
  - possible to obtain information not from CRL

**Models of OCSP responder**

- Trusted Responder
  - the OCSP server signs the responses with a pair key:cert independent of the CA for which it is responding
  - company responder or TTP paid by the users
- Delegated Responder
  - the OCSP server signs the responses with a pair key:cert which is (can be) different based on the CA for which it is responding
  - TTP paid by the CA

**Time-stamping**

- proof of creation of data before a certain point in time
- TSA (Time-Stamping Authority)
- RFC-3161:
  - request protocol (TSP, Time-Stamp Protocol)
  - format of the proof (TST, Time-Stamp Token)

**PSE (Personal Security Environment)**

- each user should protect:
  - his own private key (secret!)
  - the certificates of the trusted root CAs (authentic!)
- software PSE:
  - (encrypted) file of the private key
- hardware PSE:
  - passive = protected keys (same as sw PSE)
  - active = protected keys + crypto operations
- mobility is possible in both cases (but with problems)
Cryptographic smart-card
- chip cards with memory and/or autonomous cryptographic capacity
- simple: DES
- complex: RSA
  - length of the key?
  - generation of the private key on board?
- few memory (EEPROM): 4 - 32 Kbyte

<table>
<thead>
<tr>
<th>ROM</th>
<th>μcontroller</th>
<th>cryptographic coprocessor</th>
<th>RAM</th>
<th>E2PROM</th>
</tr>
</thead>
</table>

HSM (HW Security Module)
- cryptographic accelerator for servers
  - secure storage of private key
  - autonomous encryption capabilities (RSA, sometimes symmetric algorithms too)
- form factor: PCI board or external device (USB, IP, SCSI, ...)

Secure data formats
- PKCS-7 = secure envelope
  - signed and/or encrypted
- PKCS-10 = certificate request
  - used in the communication among the client and CA / RA
- PKCS-12 = software PSE (Personal Security Environment)
  - transport of keys and certificates
- are not application formats:
  - S/MIME? IDUP-GSS-API? XML-DSIG?
  - legal electronic documents?

PKCS-7 and CMS formats
- cryptographic message syntax
- PKCS-7 is the RSA standard for secure envelope (v1.5 is also RFC-2315)
- CMS is the evolution of PKCS-7 inside IETF, numbered as RFC-2630
- allows signing and/or encryption of data, with symmetric or asymmetric algorithms
- allows to put more signatures on the same object (hierarchical or parallel)
- can include the certificates used for the signature
- is a recursive format

PKCS-7: structure

<table>
<thead>
<tr>
<th>contentType</th>
<th>...</th>
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<th>content</th>
<th>...</th>
<th>content</th>
<th>...</th>
</tr>
</thead>
</table>

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PKCS-7: contentType
- data
  encoding of a generic sequence of bytes
- signedData
  data + parallel digital signatures (1..N)
- envelopedData
  data encrypted symm. + key encrypted with RSA
- signedAndEnvelopedData
  RSA encryption of (data + digital signatures)
- digestData
  data + digest
- encryptedData
  data encrypted with a symmetric algorithm

PKCS-7: signedData
- signedData
  content
  version
digestAlgorithm
contentInfo
certificates
cRLs
signerInfo
encryptedDigest

PKCS-7: envelopedData
- envelopedData
  content
  version
encryptedContentInfo
recipientInfo
...recipientInfo

PKCS-10
- data to `be certified
  DN
  public key
  attributes
  computation of signature
  signature
PKCS#10
private key of the entity to be certified

PKCS-12 format (security bag)
- transport of (personal) cryptographic material among applications / different systems
- transports a private key and one or more certificates
- transports the digital identity of a user
- used by Netscape, Microsoft, Lotus, ...
- criticized from the technical point of view (especially in the MS implementation) but widely used

Formats of signed documents
- signed data
  document
  signature
  enveloping signature (es. PKCS-7)
- document data
  document
  signature
  enveloped signature (es. PDF)
- document
  signature
  detached signature (es. PKCS-7)
Multiple signatures (parallel / independent)

Multiple signatures (sequential / hierarchical)