PUBLIC-KEY CERTIFICATES

- reliable distribution of public-keys
- public-key encryption
  - sender needs public key of receiver
- public-key digital signatures
  - receiver needs public key of sender
- public-key key agreement
  - both need each other’s public keys
THE CERTIFICATE TRIANGLE

user

X.509 attribute certificate

attribute

SPKI certificate

public-key

X.509 identity certificate

X.509 CERTIFICATE

VERSION

SERIAL NUMBER

SIGNATURE ALGORITHM

ISSUER

VALIDITY

SUBJECT

SUBJECT PUBLIC KEY INFO

SIGNATURE
X.509 CERTIFICATE

<table>
<thead>
<tr>
<th>0</th>
<th>1234567891011121314</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RSA+MD5, 512</td>
</tr>
<tr>
<td></td>
<td>C=US, S=VA, O=GMU, OU=ISSE</td>
</tr>
<tr>
<td></td>
<td>5/1/97-5/1/98</td>
</tr>
<tr>
<td></td>
<td>C=US, S=VA, O=GMU, OU=ISSE, CN=Ravi Sandhu</td>
</tr>
<tr>
<td></td>
<td>RSA, 1024, xxxxxxxxxxxxxxxxxxxxxxxxxxxx</td>
</tr>
<tr>
<td></td>
<td>SIGNATURE</td>
</tr>
</tbody>
</table>

CERTIFICATE TRUST

- how to acquire public key of the issuer to verify signature
- whether or not to trust certificates signed by the issuer for this subject
PEM CERTIFICATION GRAPH

Internet Policy Registration Authority

HIGH ASSURANCE

MITRE

Abrams

Certification Authorities (CAs)

Subject

Sandhu

MID-LEVEL ASSURANCE

GMU

Virginia

Sandhu

RESIDENTIAL

ISSE

Fairfax

Sandhu

PERSONA

Anonymous

LEO

Internet Policy Registration Authority

Policy Certification Authorities (PCAs)

PEM CERTIFICATION GRAPH

CRL FORMAT

<table>
<thead>
<tr>
<th>SIGNATURE ALGORITHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISSUER</td>
</tr>
<tr>
<td>LAST UPDATE</td>
</tr>
<tr>
<td>NEXT UPDATE</td>
</tr>
<tr>
<td>REVOKED CERTIFICATES</td>
</tr>
<tr>
<td>SIGNATURE</td>
</tr>
<tr>
<td>SERIAL NUMBER</td>
</tr>
<tr>
<td>REVOCATION DATE</td>
</tr>
</tbody>
</table>

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PGP BOTTOM UP
TRUST MODEL

- How does Alice get Bob's public key
  - directly from Bob through some secure channel (e.g., post, phone, floppy)
  - from Chuck, who is known to both Alice and Bob and introduces Bob to Alice
  - from a trusted certifying authority
- PGP has mechanisms to support these, and related, alternatives

X.509 CERTIFICATES

- X.509v1
  - very basic
- X.509v2
  - adds unique identifiers to prevent against reuse of X.500 names
- X.509v3
  - adds many extensions
  - can be further extended
SEPARATE KEYS FOR SEPARATE PURPOSES

- RSA is the only known public-key cryptosystem in which the same public-private key pair can be used for:
  - digital signatures
  - encryption
- perceived as a major advantage

SIGNATURE KEYS

- private key: must be private for entire life, may never leave smart card
  - needs to be securely destroyed after lifetime
  - no need for backup or archiving (would conflict with above)
  - no need to weaken or escrow due to law
- public key: must be archive possibly for a long time
ENCRYPTION KEY

- private key: backup or archive required for recovery
  - should not be destroyed after lifetime
  - may be weakened/escrowed due to law
- public key:
  - no need to backup RSA or other encryption keys
  - need to backup Diffie-Hellman key agreement keys

X.509 INNOVATIONS

- distinguish various certificates
  - signature, encryption, key-agreement
- identification info in addition to X.500 name
- name other than X.500 name
  - email address
- issuer can state policy and usage
  - good enough for casual email but not good enough for signing checks
- limits on use of signature keys for further certification
X.509v3 EXTENSIONS

- X.509v3 same as X.509v2 but adds extensions
- provides a general extension mechanism
  - extension type: registered just like an algorithm is registered
  - standard extension types: needed for interoperability

X.509v3 EXTENSIONS
CRITICALITY

- non-critical: extension can be ignored by certificate user
  - alternate name can be non-critical
- critical: extension should not be ignored by certificate user
  - limit on use of signatures for further certification
X.509v3 EXTENSIONS
CRITICALITY

- criticality is flagged by certificate issuer
  - certificate user may consider non-critical extensions more important than critical ones
  - certificate user may refuse to use certificate if some extensions are missing
- critical extensions should be few and should be standard

X.509v3 NAMES

- internet email address
- internet domain name
- web uri (url's are subset of uri)
- IP address
- X.400 email address
- X.500 directory name
- registered identifier
- other name
**X.509v3 STANDARD EXTENSIONS**

- Key and policy information
- Subject and issuer attributes
- Certification path constraints
- Extensions related to CRLs
  - will be discussed with CRLs

---

**KEY AND POLICY INFORMATION**

- **key usage**
  - critical: intended only for that purpose, limits liability of CA
  - non-critical: advisory to help find the correct key, no liability implication
- **private-key usage period**
  - certificate valid for 2 years for verifying signature
  - key valid only for one year for signing
- **certificate policies**
  - for CAs
SUBJECT AND ISSUER ATTRIBUTES

- Subject alternative names
- Issuer alternative names
- Subject directory attributes
  - whatever you like
  - position, phone, address etc.

CERTIFICATION PATH CONSTRAINTS

- Basic Constraints
  - can or cannot act as CA
  - if can act as CA limit on certification path
    - limit=1 means cannot certify other CAs

- Name Constraints
  - limits names of subjects that this CA can issue certificates for

- Policy Constraints
  - concerned with CA policies
CERTIFICATE REVOCATION LISTS

- CRLs issued periodically as per CA policy
  - off-cycle CRLs may also be needed
  - blank CRLs can be issued

- CRL distribution
  - pull method
  - push method

- DMS example
  - pull method with push for compromised key list (CKL) which is broadcast via secure email, single CKL for entire system
CERTIFICATE REVOCATION LISTS

- immediate or real-time revocation
  - needs query to CA on every certificate use
  - maybe ok for small closed communities

REVOCATION TIME-LINE

- Issue Of CRL 1
- Revocation Request
- Issue Of CRL 2
- Compromise Event
- Revocation Time
OCSP
ON-LINE CERTIFICATE STATUS PROTOCOL

- consult authoritative server
- the server in turn can look up CRLs

SHORT-LIVED CERTIFICATES

- Authorization certificates can be short lived
  - minutes, hours, days instead of
  - months, years
X.509 CRL EXTENSIONS

- General Extensions
- CRL distribution points
- Delta-CRLs
- Indirect-CRLs
- Certificate Suspension

GENERAL EXTENSIONS

- Reason Code
  - Key Compromise
  - CA Compromise
  - Affiliation changed
  - Superseded
  - Cessation of operation
  - Remove from CRL: defer till Delta-CRL
  - Certificate hold: defer

- Invalidity Date
CRL DISTRIBUTION POINTS

❖ CRLs can get very big
   ➢ version 1 CRL (1988, 1993)
     • each CA has two CRLs: one for end users, one for CAs
     • end user CRL can still be very big
   ➢ version 2 CRL
     • can partition certificates, each partition associated with one CRL
     • distribution point
     • also can have different distribution points for different revocation reasons

CRL DISTRIBUTION POINTS

❖ certificate extension field, says where to look
❖ CRL extension field
   ➢ distribution point for this CRL and limits on scope and reason of revocation
   ➢ protects against substitution of a CRL from one distribution point to another
DELTA-CRLs

- Delta CRL indicator
  - only carries changes from previous CRL
- Remove from CRL reason code causes purge from base CRL (stored at certificate user)
- removal due to expiry of validity period or restoration of suspension

INDIRECT-CRL

- CRL can be issued by different CA than issuer of certificate
  - allows all compromise revocations to be one list
  - allows all CA revocations to be on one list (simplify certificate chasing)
CERTIFICATE SUSPENSION

- Certificate hold reason code in CRL
- Supporting CRL entry extension
  - Instruction code: instructions on what to do with held certificate
    - call CA, repossess token

GENERAL HIERARCHICAL STRUCTURE
PEM CERTIFICATION GRAPH

Policy Certification Authorities (PCAs)

HIGH ASSURANCE
- MITRE
  - Abrams

MID-LEVEL ASSURANCE
- Certification Authorities (CAs)
  - GMU
    - ISSE
      - Subjects
        - Sandhu

RESIDENTIAL
- Virginia
  - Fairfax
  - Anonymous
    - LEO

PERSONA

Internet Policy Registration Authority

SET CA HIERARCHY

Root
- Brand
- Brand
- Brand
  - Geo-Political
    - Bank
    - Acquirer
      - Customer
      - Merchant

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FOREST OF HIERARCHIES