INFS 766/INFT 865
Network and Distributed Systems Security

Lecture 7
Digital Certificates

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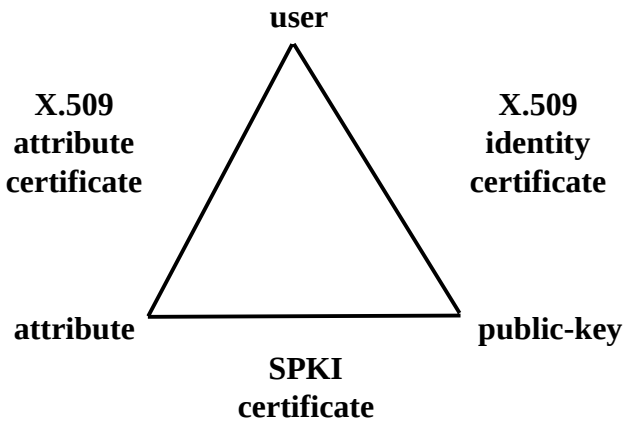
PUBLIC-KEY CERTIFICATES

- 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

2

THE CERTIFICATE TRIANGLE



3

X.509 CERTIFICATE

VERSION
SERIAL NUMBER
SIGNATURE ALGORITHM
ISSUER
VALIDITY
SUBJECT
SUBJECT PUBLIC KEY INFO
SIGNATURE

4

X.509 CERTIFICATE

0
1234567891011121314
RSA+MD5, 512
C=US, S=VA, O=GMU, OU=ISSE
5/1/97-5/1/98
C=US, S=VA, O=GMU, OU=ISSE, CN=Ravi Sandhu
RSA, 1024, xxxxxxxxxxxxxxxxxxxxxxxx
SIGNATURE

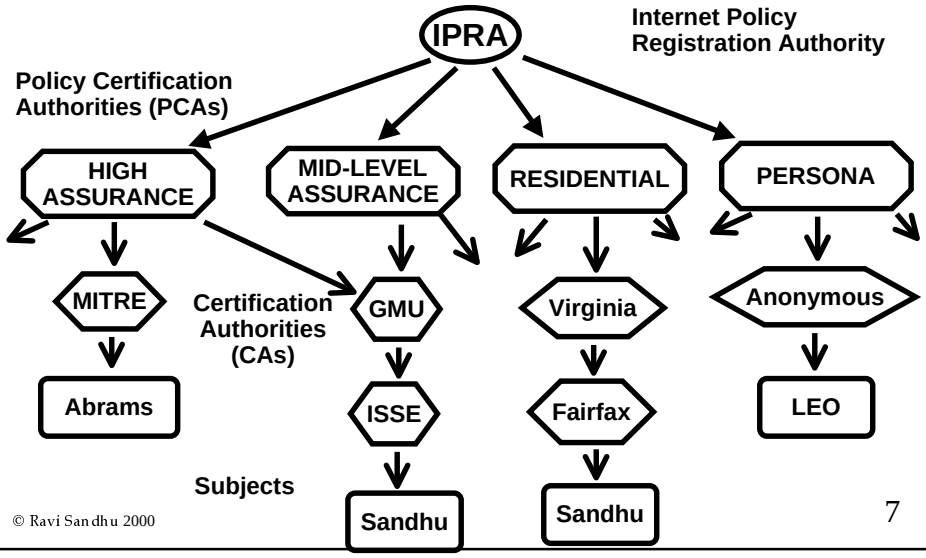
5

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

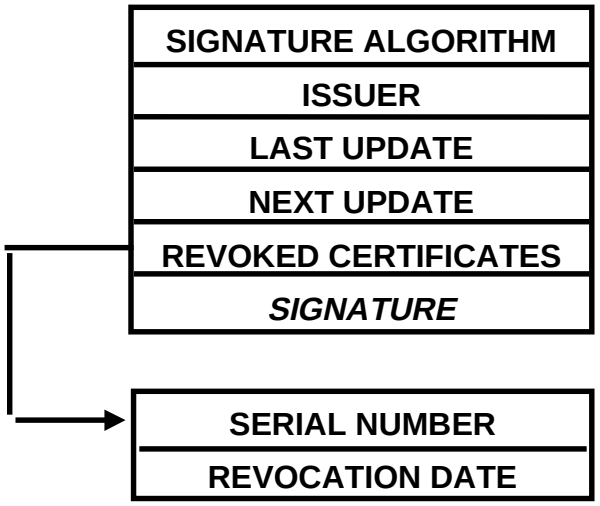
6

PEM CERTIFICATION GRAPH



7

CRL FORMAT



8

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

9

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

10

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**

13

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**

14

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

15

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

16

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

17

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

18

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.**

21

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**

22

CERTIFICATION PATH CONSTRAINTS

- **Basic Constraints**
  - **can or cannot act as CA**
  - **if can act as CA limit on certification path extending from here**
  - **limit=1 means cannot certify other CAs**
- **Name Constraints**
  - **limits names of subjects that this CA can issue certificates for**
  - **to be discussed**
- **Policy Constraints:**
  - **concerned with CA policies**
  - **to be discussed**

CERTIFICATE REVOCATION LISTS

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

CERTIFICATE REVOCATION LISTS

- **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**

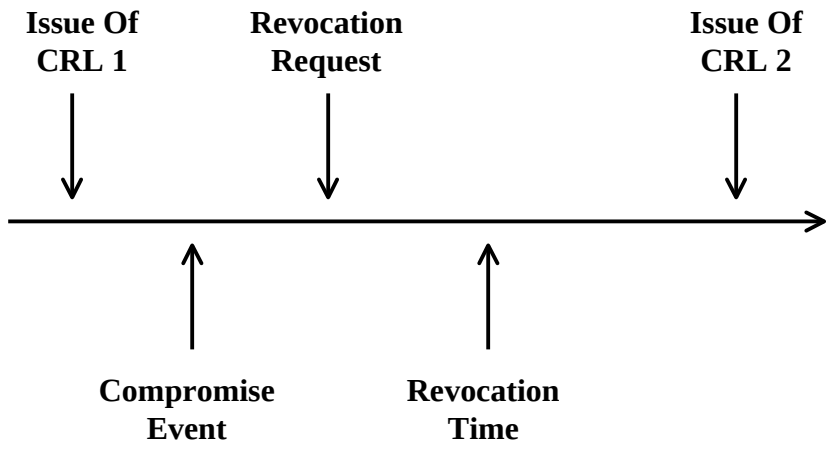
25

CERTIFICATE REVOCATION LISTS

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

26

REVOCATION TIME-LINE



27

OCSP

ON-LINE CERTIFICATE STATUS PROTOCOL

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

28

SHORT-LIVED CERTIFICATES

- **Authorization certificates can be short lived**
  - **minutes, hours, days instead of**
  - **months, years**

29

X.509 CRL EXTENSIONS

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

30

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**

31

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**

32

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

33

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

34

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)

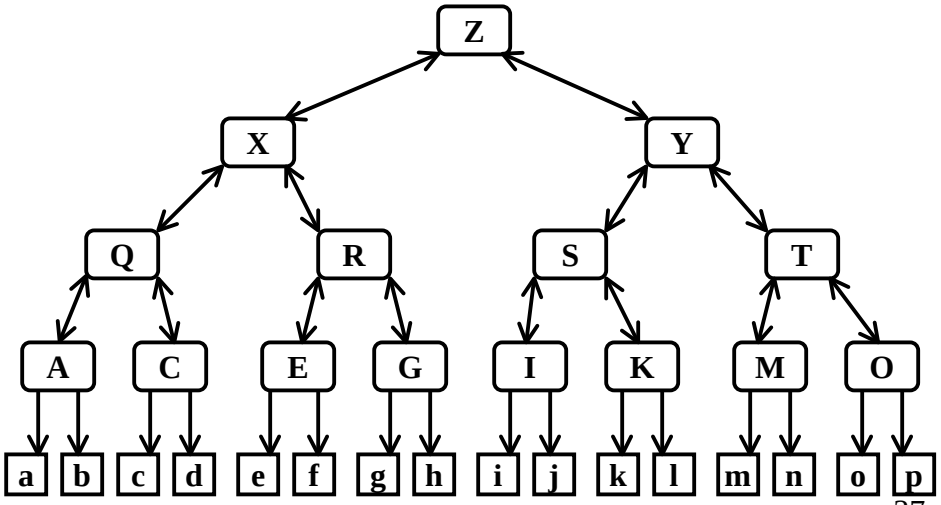
35

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

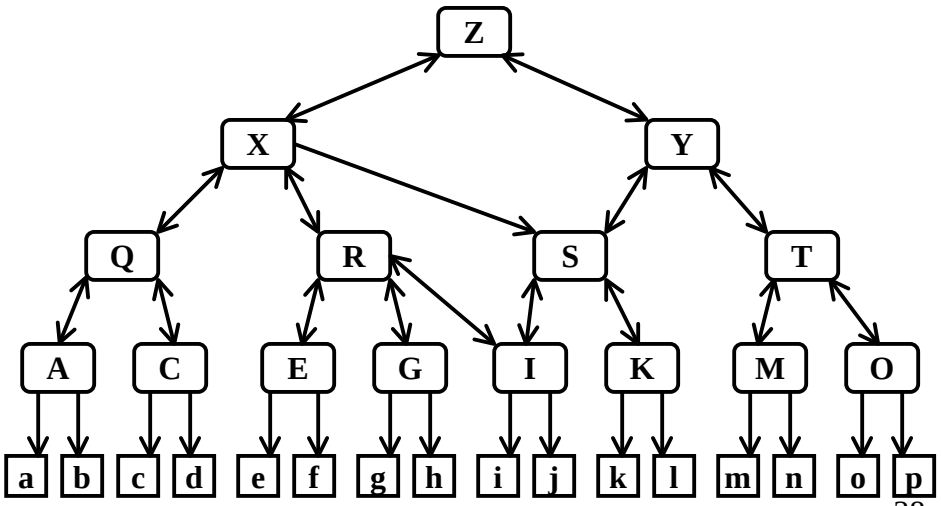
36

GENERAL HIERARCHICAL STRUCTURE



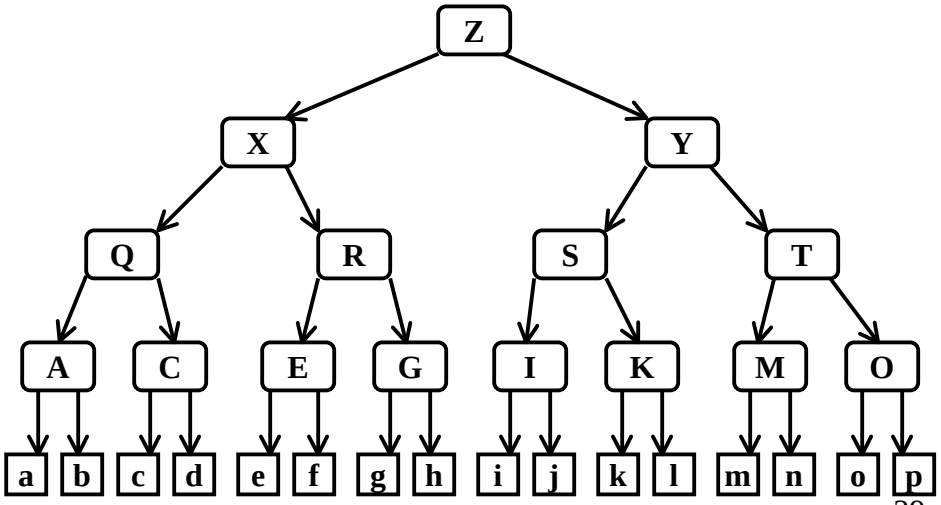
37

GENERAL HIERARCHICAL STRUCTURE WITH ADDED LINKS



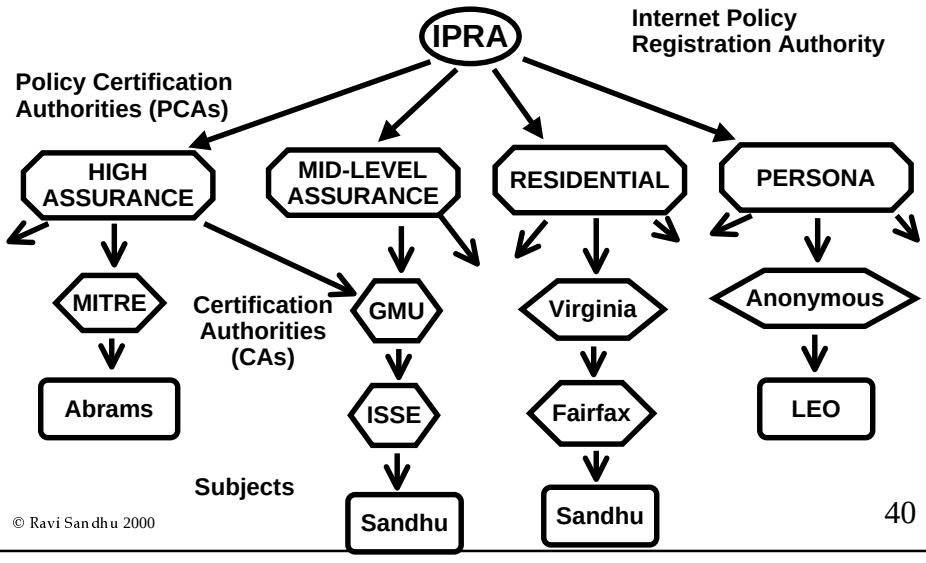
38

TOP-DOWN HIERARCHICAL STRUCTURE



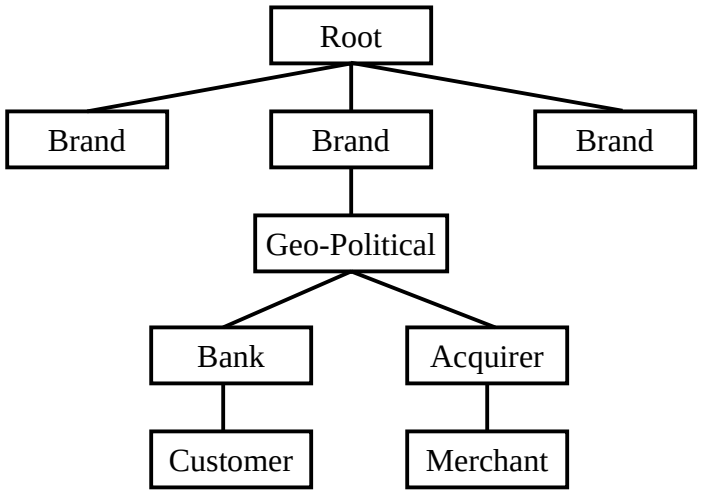
39

PEM CERTIFICATION GRAPH



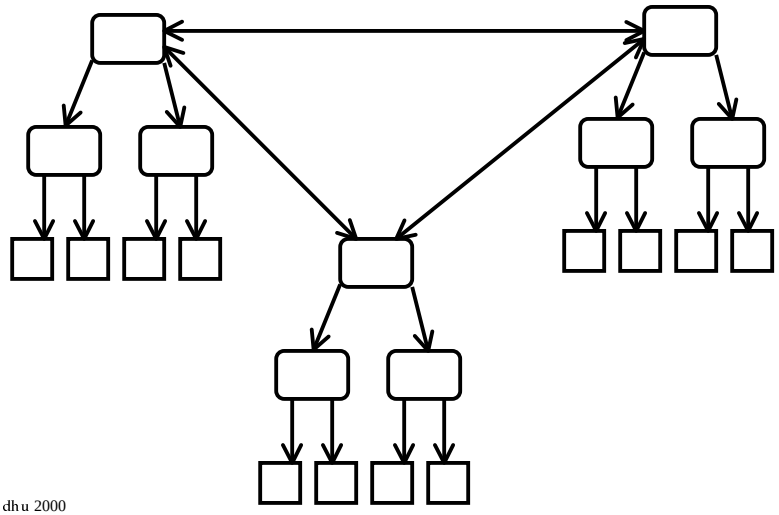
40

SET CA HIERARCHY



41

FOREST OF HIERARCHIES



42