PV181 Laboratory of security and applied cryptography

Digital certificates

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Digital certificate

- used to prove ownership of the public key
- binds public key to identity (identity, email,…)
- **Public key** is **signed** by trusted third party
  - Certification Authority (CA) or other party
- two models: centralized and decentralized

Certificates history

- Introduced in 1978 – Kohnfelder's bachelor thesis
- X.509 – standard
  - v.1 (1988) – not extendable
  - v.2 – similar to v.1
  - **v.3** (1997) optional extension
  - Other extend X.509

Others

- PGP, SPKI, etc.

Trust models

- Public key infrastructure (PKI)
  - centralized – hierarchy of CA’s
  - cert signed by party
  - used in web browsers
  - standard X.509
- Web of trust
  - decentralized model
  - signed by many parties
  - used in PGP, GPG
  - standard OpenPGP

PGP

- 1991 - Paul Zimmerman
- tool to en/decryption, sign data (files, emails,…)
- Algs: hash, asymmetric, symmetric, compression
- Confidentiality, authentization, integrity
- standardized as OpenPGP - RFC 4880
- PGP – commercial
  – free alternative GPG

OpenPGP encryption

- Authentication & integrity & non-repudiation
  – hash of plaintext **signed** by Alice’s private key
- Confidentiality
  1. Alice generates randomly symmetric key
  2. Symmetric key is encrypted with Bob’s public key

- Alice sends:
  – encrypted signed data
  – encrypted session key

PGP certificates

- Two formats:
  - PGP cert
  - X.509
- PGP cert:
  - PGP version number
  - Public key (+algorithm)
  - Identity information
  - Digital signature -
  - Validity period
  - Preffered symmetric encryption

PGP signing and trust

- Key distribution: server or sent with data

- signing: PGP party – verification of binding
  - KEY-ID, KEYNAME, FINGERPRINT + identity

- Trust:
  - user – set of certs signed by different entities
  - 4 levels – unknown, non, marginal, full
  - signed by myself or fully or 3 marginally keys

Public key Infrastructure (PKI)

- set of roles and procedures:
  - issue, maintain, administer, revoke, suspend, reinstate, and renew digital certificates
  - create and manage a public key repository

PKI:

- CA – stores, issues, signs certs
- RA – verifies identity
- Central directory– cert requests issued and revoked,
- Management system
- Cert policy

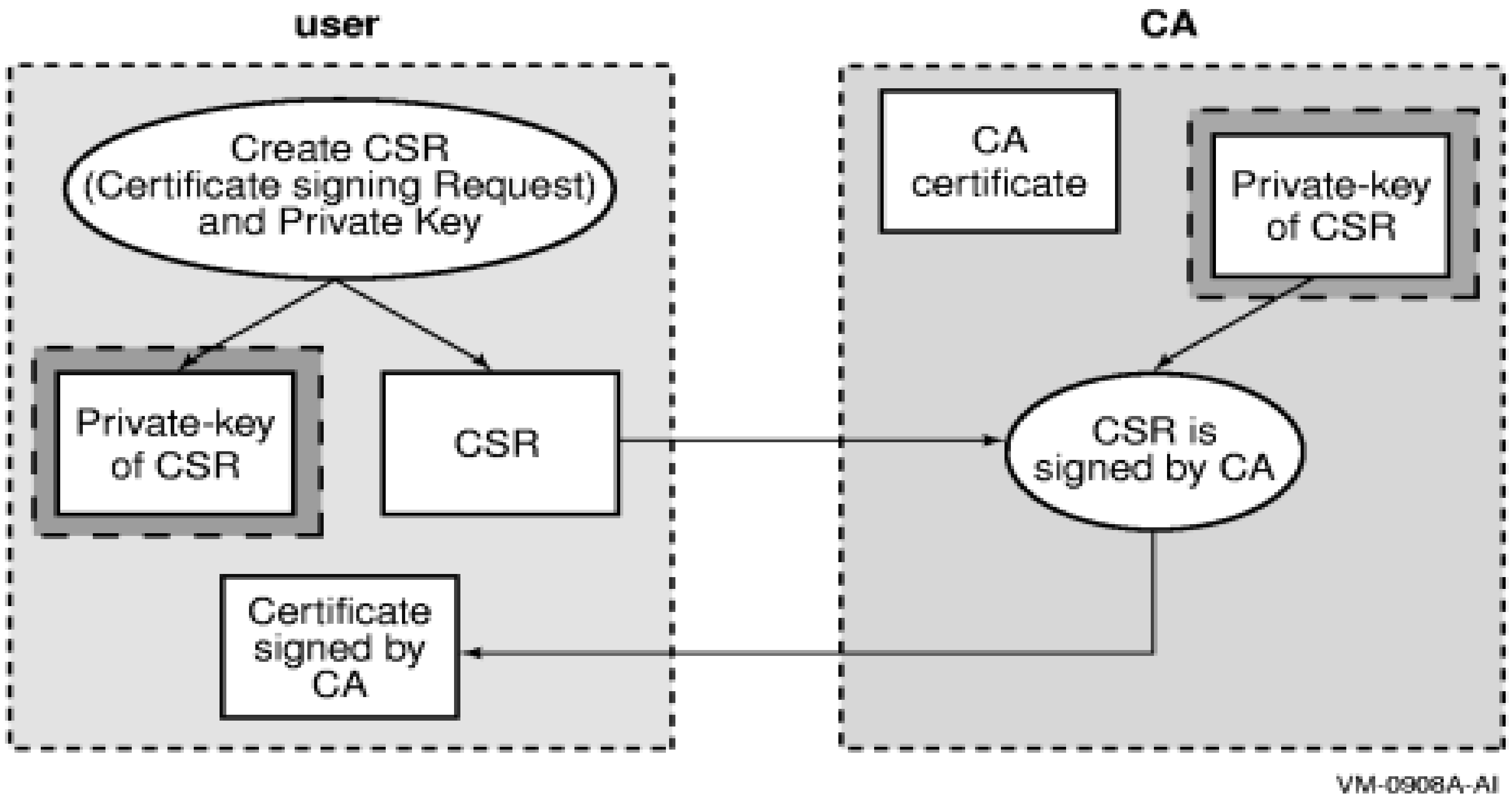
X.509 PKI certificate

- Certification Authority – trusted third party
- Certificate revocation lists (CRL) – certificates no longer be trusted (compromised key, CA,…)
- RFC5280 – defines format and semantics of certs and CRLs
- X.509 versions 1,2,3

X.509 PKI certificate content

Serial Number: unique ID of cert
Subject: ID of entity
Signature algorithm:
Signature:
Issuer: verifier of info and issued cert
Valid–From: date cert is first valid from
Valid–To: expiry date
Key-Usage: purpose of PK (signature, cert signing, …)
Public Key:
Thumbprint algorithm: to compute hash of PK cert
Thumbprint (fingerprint): hash of abbreviated PK cert

Certificate issuing



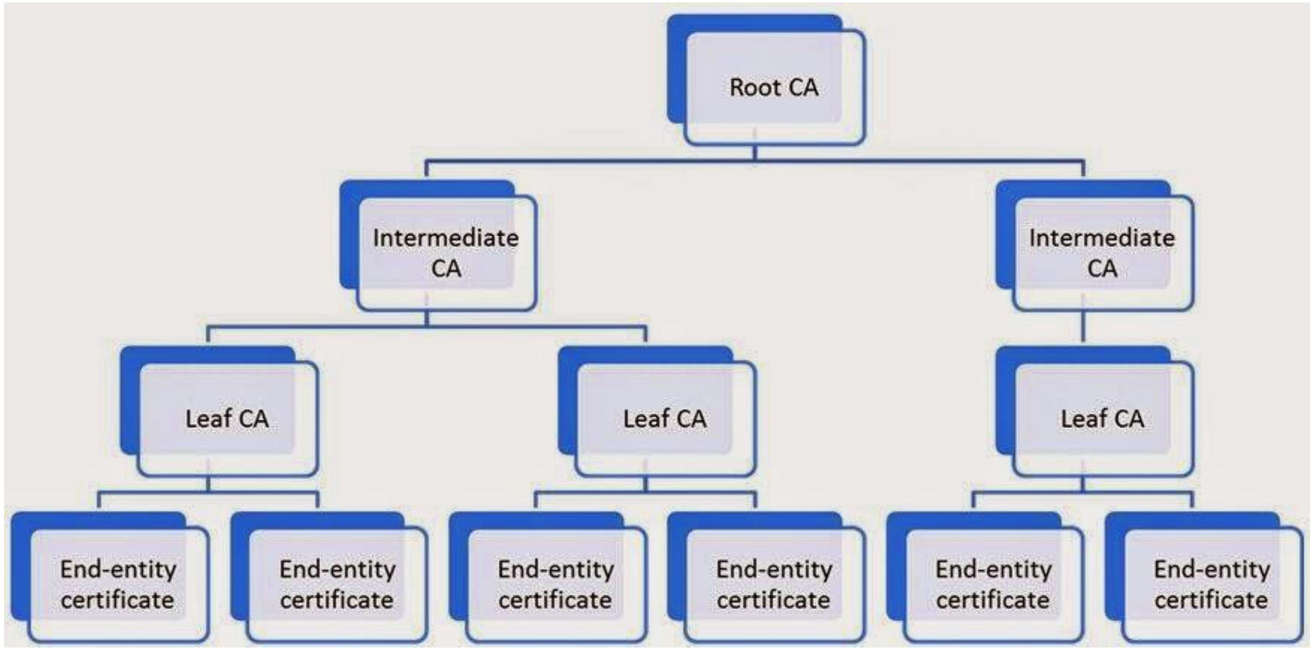
Certificate verification

Checking single cert:

- current **date** against validity period
- current validity of CA public key
- signature of CA on cert
- check whether certificate is revoked
  - CRL or OCSP
- policies

Certificates hierarchy

- **root CA (trust anchor)** - self-signed certificate
- Intermediate CA's
- **End entity** – user certificate

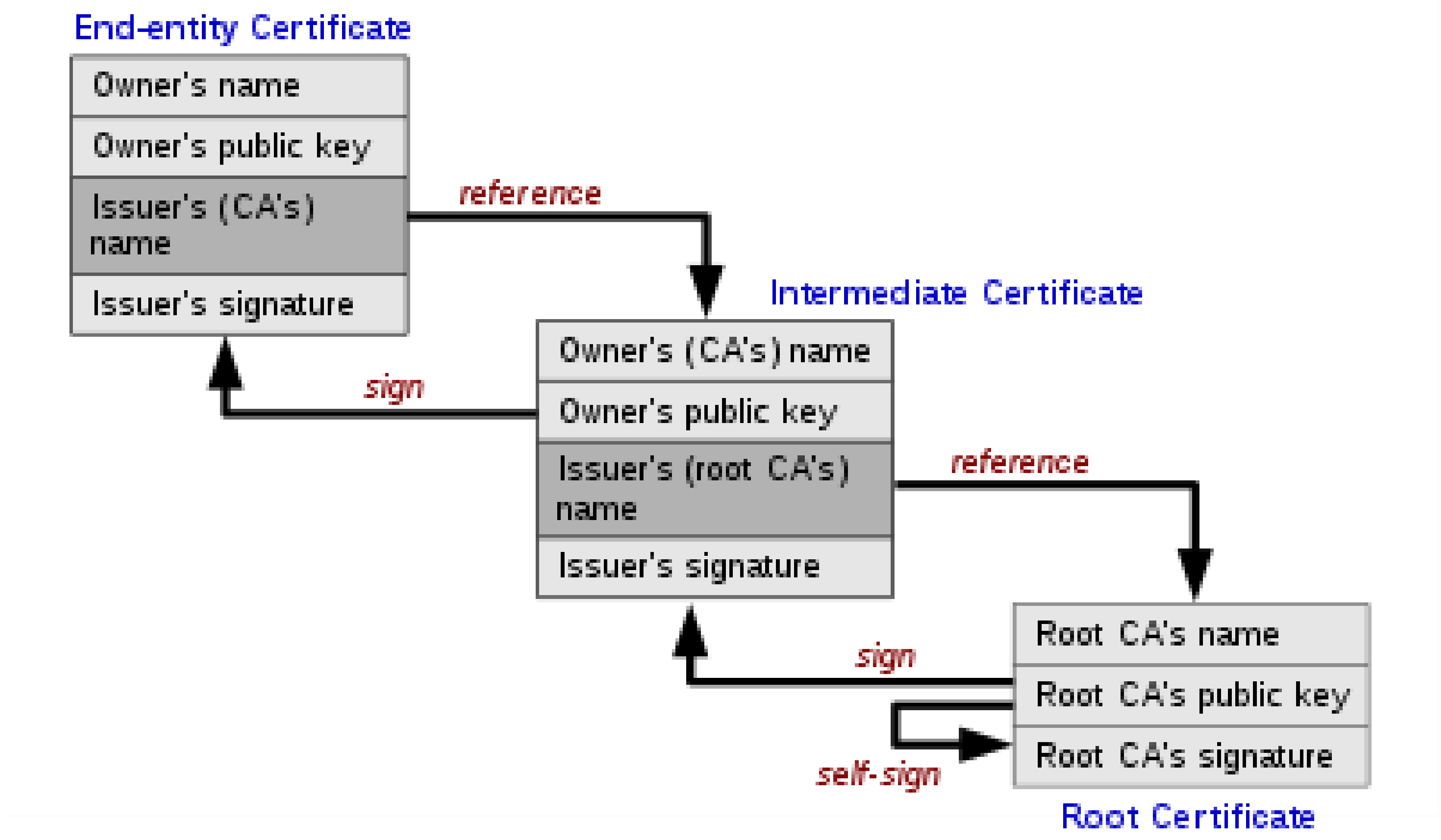


Chain of trust

- Trust transfer – to lower CA's
- Root cert, intermediate certs, end-user cert.
- Chain:
  - end-user cert – signed by CA1
  - CA1 cert – signed by CA2…
  - root CA cert – signed by itself

Server – sends all certs up to root cert to browser

Chain of trust



Certificate path validation

Input: cert path, trust anchor

Path validation:

1. Check all certs if still valid
2. Check revocation status of certs
3. Check issuer = of previous cert subject
4. Check policy constraints
5. …

Revocation

- Reasons for revocation
  - **key compromise** (most common), CA compromise, affiliation change,…
- Two states:
  - revoked – irreversibly for compromised private key
  - hold – unsure user about key compromising, can be reinstalled
- Checked using:
  - CRL – list of revoked certs
  - Online Certificate Status Protocol – on demand

CRL

Issued by CA:

- Certificate Revocation List (CRL):
  - list of revoked certificates of end-users
- Authority Revocation list
  - List of revoked cert of CA’s

1. Issuer name
2. Date list created
3. Date next CRL scheduled
4. Entries = serial number + revocation date of cert

CRL distribution problem

- **Fixed** validity of CRLs
  - massive load when CRL expires

  (e.g10M clients download a 1MB CRL issued once a minute = ~150GB/s traffic)

Solutions:

delta CRL – updates only – newly revoked certs

Online Certificate Status Protocol (OCSP)

- status of cert -OK / revoked / unknown

Time aspect

What if private key is compromised?

How to prove signature was created using secure private key?

- Time - **critical** parameter!!!!
- Time stamping authority – sign time stamp
- Time stamp – Sig(H(H(data) | time)
  – is stored by requester with data
- Standards - RFC 3161, X9.95, ISO 18014