



Computer Security

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COMP4631



Lecture 11: Public-Key Infrastructure

Main Topics of this Lecture

1. Digital certificate
2. Certificate authority (CA)
3. Public key infrastructure (PKI)



Part I: Digital Certificates



What is a Digital Certificate?

Definition: A digital certificate is an electronic document issued and digitally signed by a “certification authority” that authenticates the identity of its holder.

- It can protect data exchanged online if a public-key is included.
- They cannot be forged.

Real world example: [passport](#)



Types of Digital Certificate?

- Server certificates, and
- personal certificates (e.g., containing a public key), also called client certificates.

Question: Any standard on the format of digital certificates?



The X.509v3 Certificate

Signature algorithm identifier: The algorithm used to sign the certificate, together with any associated parameters. This information is repeated in the Signature field at the end of the certificate.

Issuer and subject name: X.500 Distinguished Name (DN)

- Comprised of multiple Relative DNs (RDNs)
- C = country, ST = state, L = locale, O = organiz.
- OU = organization unit, CN = common name

Subject's public key information: Public key of the subject, plus the identifier of the algorithm for which this key is to be used, together with any associated parameters.



The X.509v3 Certificate

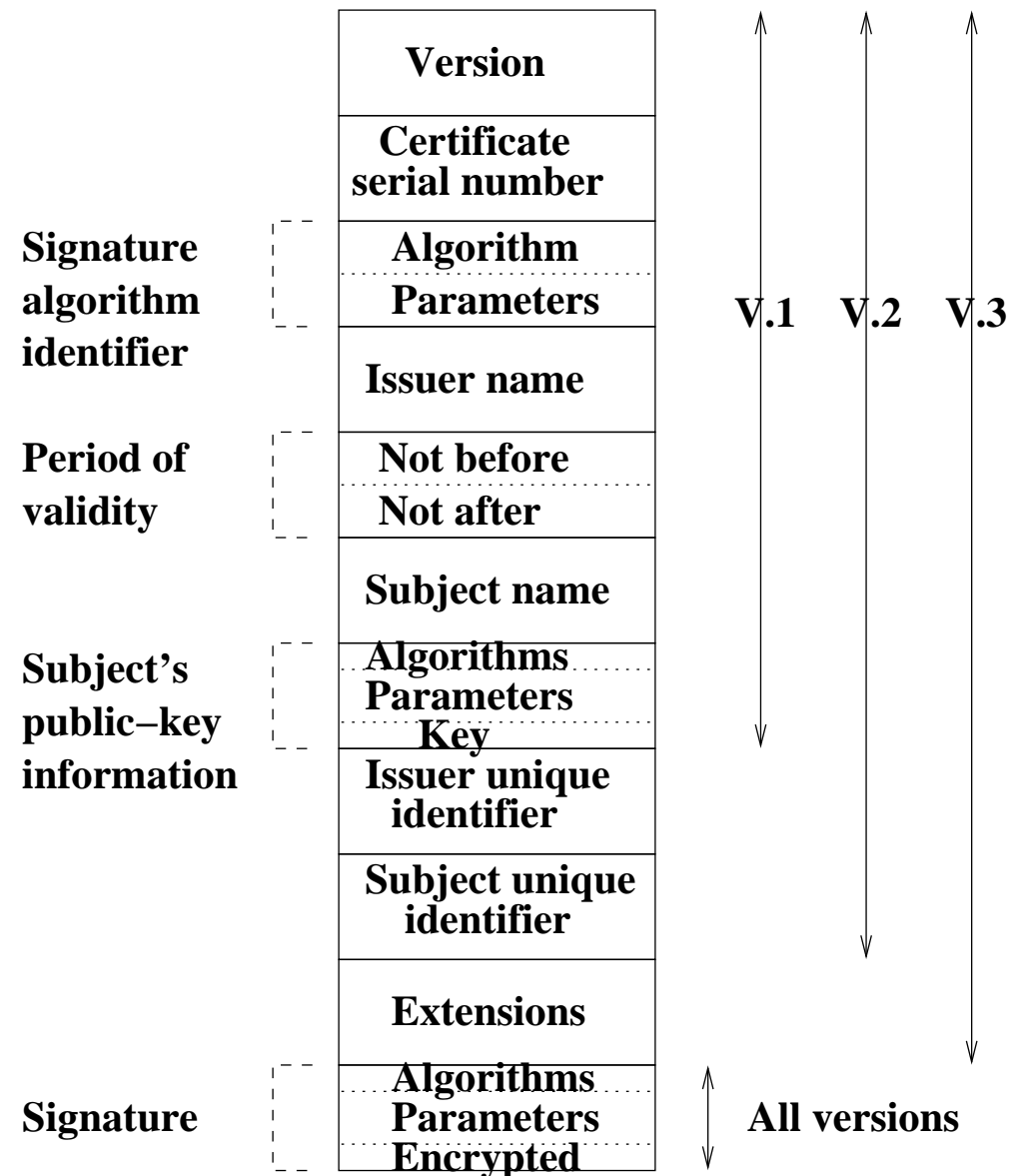
Issuer unique identifier: An optional bit string field used to identify uniquely the issuing CA in the event the X.500 name has been used for different entities.

Subject unique identifier: An optional bit string field used to identify uniquely the subject in the event the X.500 name has been used for different entities.

Extensions: A key usage extension defines for which applications and under which policies a certificated public key can be used.

Examples: Digital signature, nonrepudiation, key encryption, data encryption, key agreement, CA signature verification on certificates, CA signature verification on **CRL**.

Remark: **CRL:** Certificate Revocation List (to be introduced later).



Sample X.509 Certificates

Version: 3 (0x2)

Serial Number: 1 (0x1)

Signature Algorithm: md5WithRSAEncryption

Issuer: C=ZA, ST=Western Cape, L=Cape Town, O=Thawte Consulting cc,
OU=Certification Services Division,
CN=Thawte Server CA/emailAddress=server-certs@thawte.com

Validity

Not Before: Aug 1 00:00:00 1996 GMT

Not After : Dec 31 23:59:59 2020 GMT

Subject: C=ZA, ST=Western Cape, L=Cape Town, O=Thawte Consulting cc,
OU=Certification Services Division,
CN=Thawte Server CA/emailAddress=server-certs@thawte.com

Subject Public Key Info:



Public Key Algorithm: rsaEncryption

RSA Public Key: (1024 bit)

Modulus (1024 bit):

00:d3:a4:50:6e:c8:ff:56:6b:e6:cf:5d:b6:ea:0c:
68:75:47:a2:aa:c2:da:84:25:fc:a8:f4:47:51:da:
85:b5:20:74:94:86:1e:0f:75:c9:e9:08:61:f5:06:
6d:30:6e:15:19:02:e9:52:c0:62:db:4d:99:9e:e2:
6a:0c:44:38:cd:fe:be:e3:64:09:70:c5:fe:b1:6b:
29:b6:2f:49:c8:3b:d4:27:04:25:10:97:2f:e7:90:
6d:c0:28:42:99:d7:4c:43:de:c3:f5:21:6d:54:9f:
5d:c3:58:e1:c0:e4:d9:5b:b0:b8:dc:b4:7b:df:36:
3a:c2:b5:66:22:12:d6:87:0d

Exponent: 65537 (0x10001)

X509v3 extensions:

X509v3 Basic Constraints: critical

CA:TRUE

Signature Algorithm: md5WithRSAEncryption

```
07:fa:4c:69:5c:fb:95:cc:46:ee:85:83:4d:21:30:8e:ca:d9:
a8:6f:49:1a:e6:da:51:e3:60:70:6c:84:61:11:a1:1a:c8:48:
3e:59:43:7d:4f:95:3d:a1:8b:b7:0b:62:98:7a:75:8a:dd:88:
4e:4e:9e:40:db:a8:cc:32:74:b9:6f:0d:c6:e3:b3:44:0b:d9:
8a:6f:9a:29:9b:99:18:28:3b:d1:e3:40:28:9a:5a:3c:d5:b5:
e7:20:1b:8b:ca:a4:ab:8d:e9:51:d9:e2:4c:2c:59:a9:da:b9:
b2:75:1b:f6:42:f2:ef:c7:f2:18:f9:89:bc:a3:ff:8a:23:2e:
70:47
```

This is an example of a self-signed certificate. There's no way to verify this certificate except by checking it against itself; instead, these top-level certificates are manually stored by web browsers. Thawte is one of the root certificate authorities recognized by both Microsoft and Netscape. This certificate comes with the web browser and is trusted by default.



Demonstration of Digital Certificates

- Go to: www.cs.ust.hkfaculty.php
- Click on some faculty's digital certificate and open the file.



Signature algorithm identifier	Algorithm Parameters
	Issuer name
	This update date
	Next update date
Revoked certificate	User certificate serial# Revocation date
	. . .
	User certificate serial# Revocation date
Signature	Algorithms Parameters Encrypted

Certificate Revocation List



Part II: Certificate Authority



Certificate Authority

(1) It is a trusted third-party.

It is responsible for verifying the identities of cryptographic key holders.

(2) It issues digital certificates.

Asserts that a public key is part of a key-pair held by an individual, organization, or other entity.

(3) It publishes policy detailed in a Certification Practices Statement (CPS).



Part III: Public Key Infrastructure



Definition of PKI

Definition: Standards and services that facilitate the use of public-key cryptography and X.509 version 3 certificates in a networked environment are collectively called Public-key Infrastructure (PKI).

Remark: There are slightly different definitions. This is similar to **education infrastructure**.



Elements of Public Key Infrastructure

- Certificate Authority (CA): e.g., OpenSSL, Netscape, Verisign, Entrust, RSA Keon
- Public/Private Key Pairs - key management
- X.509 Identity Certificates - certificate management
- LDAP servers (LDAP: Lightweight Directory Access Protocol)
- Certification Practice Statement (issued by a Certification Authority (CA) to specify the practices and standards that the Certification Authority (CA) employs in issuing certificates.)

Example: HKUST PKI: <http://www.ust.hk/itsc/pki/general/index.html>



Issues

- **Scalability:** How many certificates can one CA manage?
- **Administration:** How to revoke already issued certificates?
- **Trust:**
Why should I trust your CA?

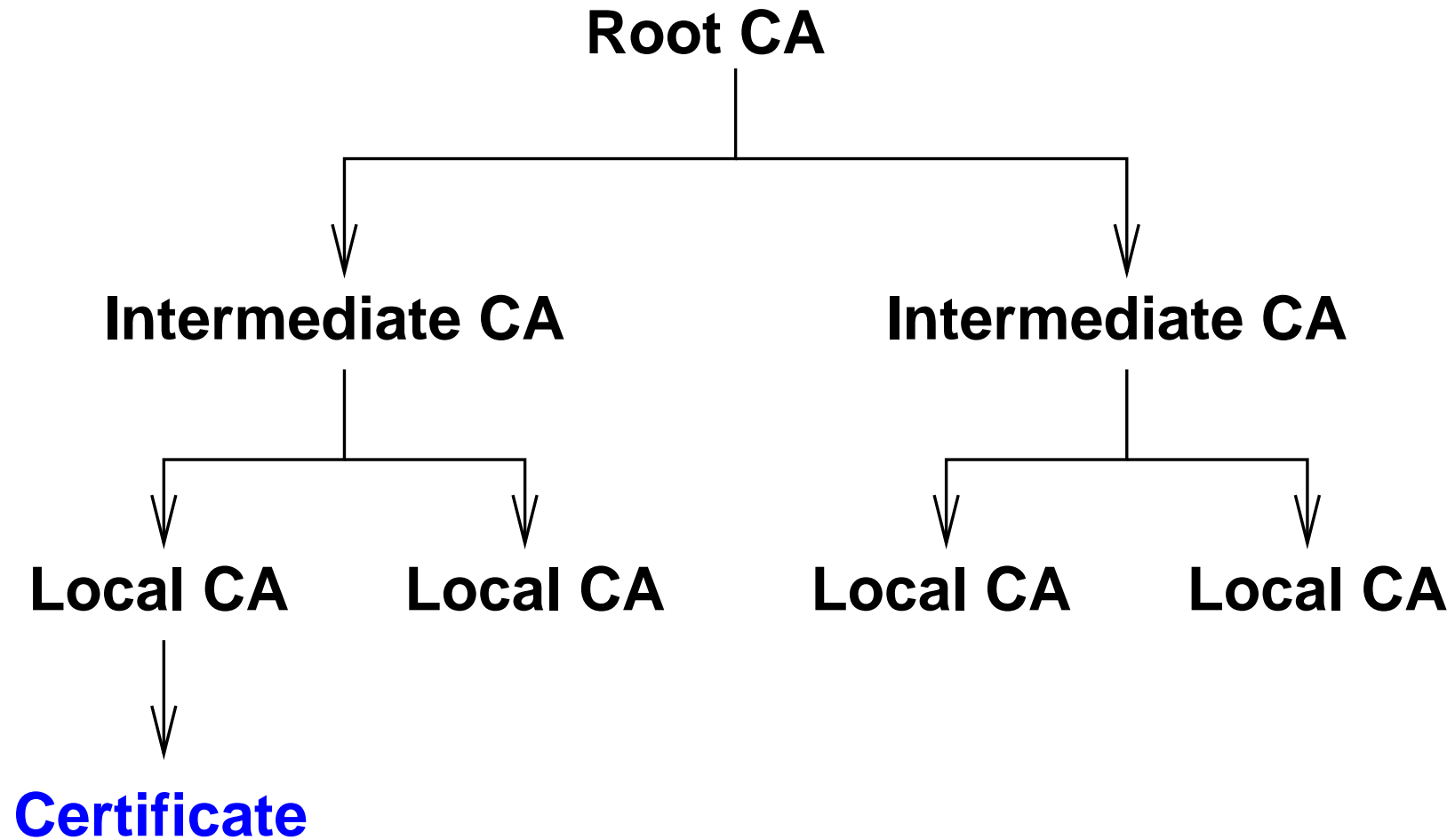


Issues: PKI Scalability

- A large PKI requires distributed CAs
 - Local, Regional, National CAs
 - International CAs
- Certificate Hierarchy
 - Intermediate CA certificates are signed by the CA one-step up.
 - End-user certificates are part of a certificate chain.



Certificate Hierarchy





Verifying Certificate Chains

- Entity accepting certificates must be able to verify CA in the chain.
 - Should the entire chain be present during a handshake?
- Must distinguish types of certificates.
 - Otherwise, end-users could sign bogus certificates.
 - X.509v3 extensions indicate use of certificate.



Methods of Publishing Digital Certificates

Without a 3rd party: Own web page, via FTP file

With a 3rd party: Dedicated key server, directory



Why Digital Certificates on Server?

- Encrypt data for someone without prior contact.
- You do not have to store all keys yourself.
- Easier distribution of new keys and updates.



Directory as Key Server

- As a publishing medium for public keys and certificates.
- Users can put their public key certificate there.
- CAs may put their certificates there.
- The directory documents revocation of keys and/or certificates in the CRL.
- It documents status of a certificate at specific time.