Key Management and Certificates

By the power vested in me I now declare this text and this bit string 'name' and 'key'. What RSA has joined, let no man put asunder

— Bob Blakley

Key Management

Key management is the hardest part of cryptography

Two classes of keys

- Short-term session keys (sometimes called ephemeral keys)
  - Generated automatically and invisibly
  - Used for one message or session and discarded
- Long-term keys
  - Generated explicitly by the user

Long-term keys are used for two purposes

- Authentication (including access control, integrity, and non-repudiation)
- Confidentiality (encryption)
  - Establish session keys
  - Protect stored data

Key Management Problems

Key certification

Distributing keys

- Obtaining someone else’s public key
- Distributing your own public key

Establishing a shared key with another party

- Confidentiality: Is it really known only to the other party?
- Authentication: Is it really shared with the intended party?

Key storage

- Secure storage of keys

Revocation

- Revoking published keys
- Determining whether a published key is still valid

Key Lifetimes and Key Compromise

Authentication keys

- Public keys may have an extremely long lifetime (decades)
- Private keys/conventional keys have shorter lifetimes (a year or two)

Confidentiality keys

- Should have as short a lifetime as possible

If the key is compromised

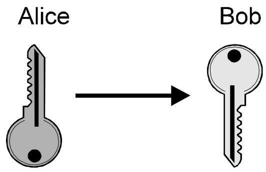
- Revoke the key

Effects of compromise

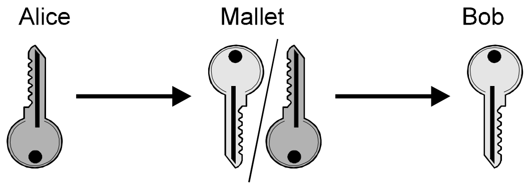
- Authentication: Signed documents are rendered invalid unless timestamped
- Confidentiality: All data encrypted with it is compromised

Key Distribution

Alice retains the private key and sends the public key to Bob



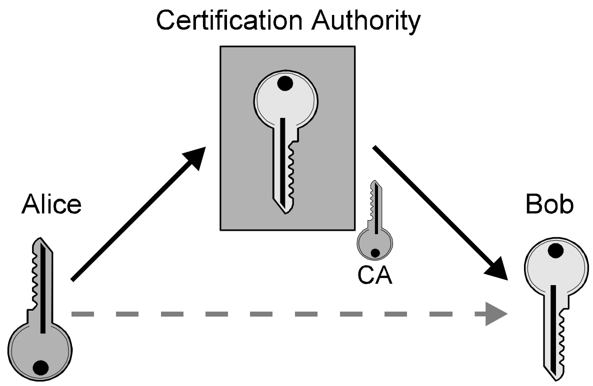
Mallet intercepts the key and substitutes his own key



Mallet can decrypt all traffic and generate fake signed message

Key Distribution (ctd)

A certification authority (CA) solves this problem



CA signs Alice's key to guarantee its authenticity to Bob

- Mallet can't substitute his key since the CA won't sign it

Certification Authorities

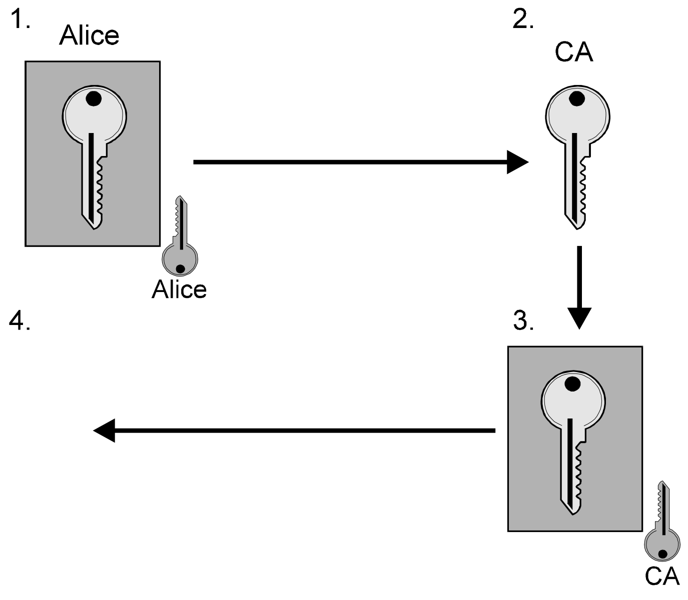
A certification authority (CA) guarantees the connection between a key and an end entity

An end entity is

- A person
- A role ("Director of marketing")
- An organisation
- A pseudonym
- A piece of hardware or software
- An account (bank or credit card)

Some CA's only allow a subset of these types

Obtaining a Certificate



Obtaining a Certificate (ctd)

1. Alice generates a key pair and signs the public key and identification information with the private key
   - Proves that Alice holds the private key corresponding to the public key
   - Protects the public key and ID information while in transit to the CA
2. CA verifies Alices signature on the key and ID information

2a. Optional: CA verifies Alices ID through out-of-band means
   - email/phone callback
   - Business/credit bureau records, in-house records

Obtaining a Certificate (ctd)

3. CA signs the public key and ID with the CA key, creating a certificate
   - CA has certified the binding between the key and ID
4. Alice verifies the key, ID, and CA's signature
   - Ensures the CA didn't alter the key or ID
   - Protects the certificate in transit
5. Alice and/or the CA publish the certificate

Role of a CA

Original intent was to certify that a key really did belong to a given party

Role was later expanded to certify all sorts of other things

- Are they a bona fide business?
- Can you trust their web server?
- Can you trust the code they write?
- Is their account in good standing?
- Are they over 18?

When you have a certificate-shaped hammer, everything looks like a nail

Certificate History

Certificates were originally intended to protect access to the X.500 directory

- All-encompassing, global directory run by monopoly telco's

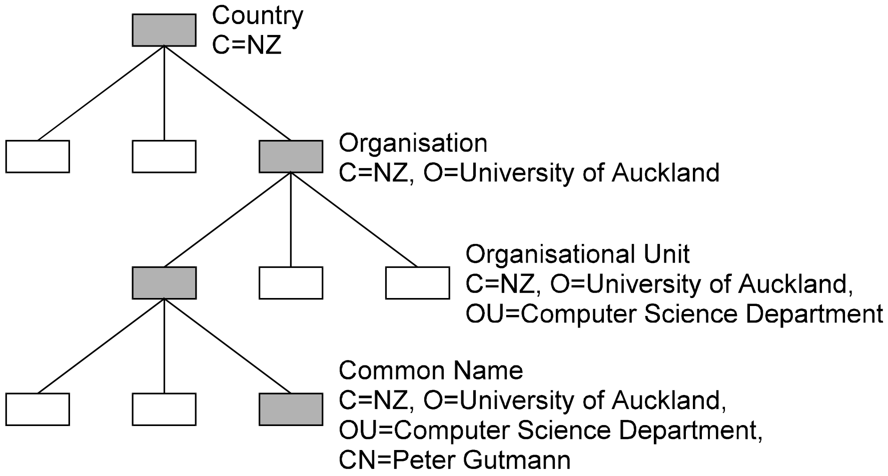
Concerns about misuse of the directory

- Companies don't like making their internal structure public
  - Directory for corporate headhunters
- Privacy concerns
  - Directory of single women
  - Directory of teenage children

X.509 certificates were developed as part of the directory access control mechanisms

X.500 Naming

X.500 introduced the Distinguished Name (DN), a guaranteed unique name for everything on earth



X.500 Naming (ctd)

Typical DN components

- Country C
- State or province SP
- Locality L
- Organisation O
- Organisational unit OU
- Common name CN

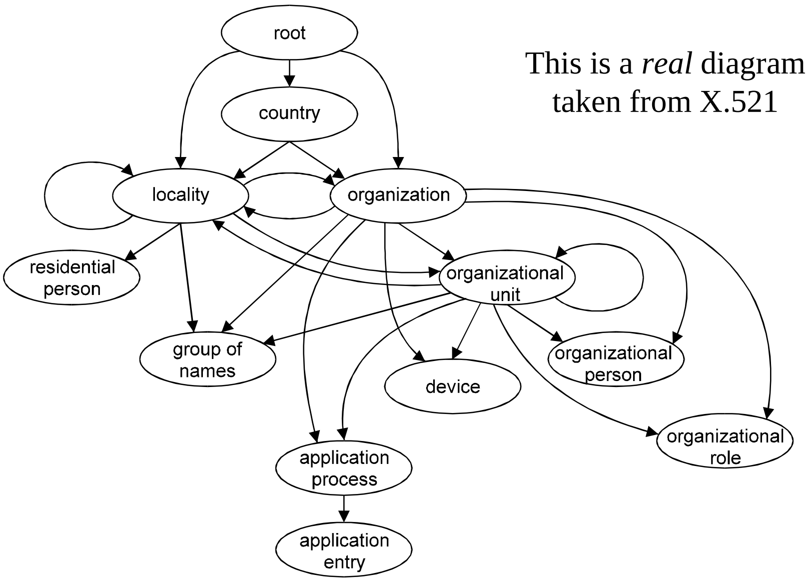
Typical X.500 DN

C=US/L=Area 51/O=Hanger 18/OU=X.500 Standards Designers/CN=John Doe

- When the X.500 revolution comes, your name will be lined up against the wall and shot

Problems with X.500 Names

Noone ever managed to figure out how to make DN's work



This is a *real* diagram taken from X.521

Problems with X.500 Names (ctd)

No clear plan on how to organise the hierarchy

- Attempts were made to define naming schemes, but nothing really worked
- People couldn't even agree on what things like 'localities' were

Hierarchical naming model fits the military and governments, but doesn't work for businesses or individuals

Solving the DN Problem

Two solutions were adopted

1. Users put whatever they felt like into the DN
2. X.509v3 added support for alternative (non-DN) names

General layout for a business-use DN

Country + Organisation + Organisational Unit + Common Name

- C=New Zealand
  O=Dave's Wetaburgers
  OU=Procurement
  CN=Dave Taylor

Solving the DN Problem (ctd)

General layout for a personal-use DN

Country + State or Province + Locality + Common Name

- C=US
  SP=California
  L=San Francisco
  CN=John Doe

There are dozens of other odd things which can be specified

- teletexTerminalIdentifier
- destinationIndicator
- supportedApplicationContext

Luckily these are almost never used

Non-DN Names

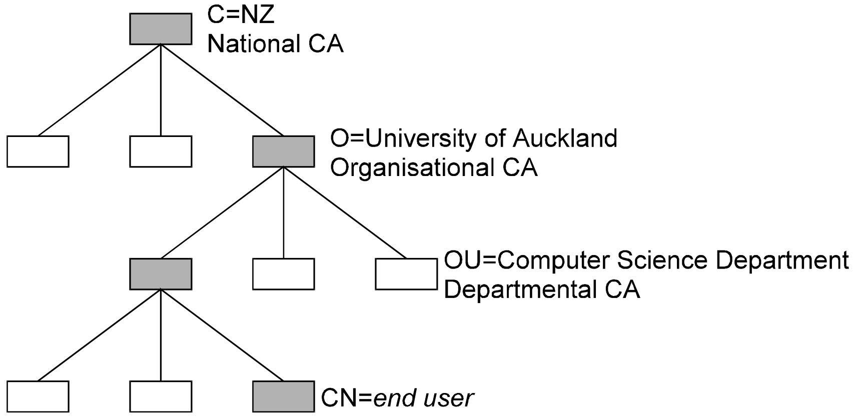
X.509 v3 added support for other name forms

- email addresses
- DNS names
- URL's
- IP addresses
- EDI and X.400 names
- Anything else (type+value pairs)

For historical reasons, email addresses are often stuffed into DN's rather than being specified as actual email addresses

CA Hierarchy in Theory

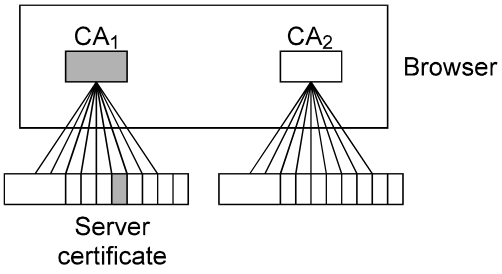
Portions of the X.500 hierarchy have CA's attached to them



Top-level CA is called the root CA, aka "the single point of failure"

CA Hierarchy in Practice

Flat or Clayton's hierarchy



CA certificates are hard-coded into web browsers or email software

- Later software added the ability to add new CA's to the hardcoded initial set

Key Databases/Directories

Today, keys are stored in

- Flat files (one per key)
- Relational databases
- Proprietary databases (Netscape)
- Windows registry (MSIE)

Pragmatic solution uses a conventional RDBMS

- Already exists in virtually all corporates
- Tied into the existing corporate infrastructure
- Amenable to key storage
  - SELECT key WHERE name='John Doe'
  - SELECT key WHERE expiryDate < today + 1 week

In the future keys might be stored in X.500 directories

The X.500 Directory

The directory contains multiple objects in object classes defined by schemas

A schema defines

- Required attributes
- Optional attributes
- The parent class

Object	Attribute	Value
	Attribute	Value
	Attribute	Value

Attributes are type-and-value pairs

- Type = DN, value = John Doe
- Type may have multiple values associated with it
- Collective attributes are attributes shared across multiple entries (eg a company-wide fax number)

The X.500 Directory (ctd)

Each instantiation of an object is a directory entry

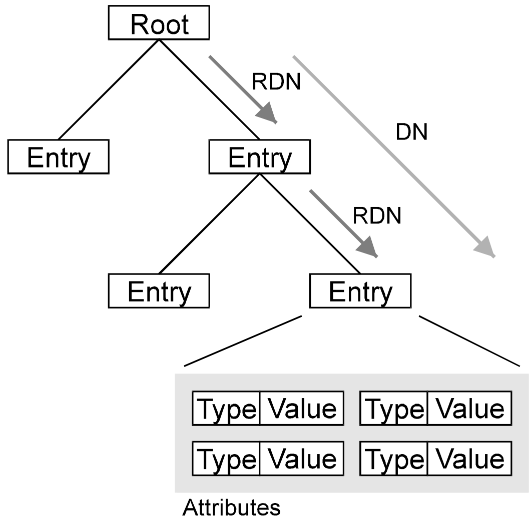
Entries are identified by DN’s

- The DN is comprised of relative distinguished names (RDN’s) which define the path through the directory

Directory entries may have aliases which point to the actual entry

The entry contains one or more attributes which contain the actual data

The X.500 Directory (ctd)



Data is accessed by DN and attribute type

Searching the Directory

Searching is performed by subtree refinement

- Base specifies where the start in the subtree
- Chop specifies how much of the subtree to search
- Filter specifies the object class to filter on

Example

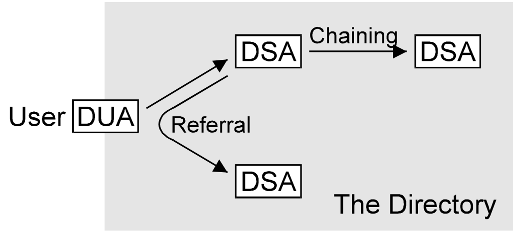
- Base = C=NZ
- Chop = 1 RDN down from the base
- Filter = organisation

Typical application is to populate a tree control for directory browsing

- SELECT name WHERE O=*

Directory Implementation

The directory is implemented using directory service agents (DSA's)



Users access the directory via a directory user agent (DUA)

- Access requests may be satisfied through referrals or chaining

One or more DSA's are incorporated into a management domain

Directory Access

Typical directory accesses:

- Read attribute or attributes from an entry
- Compare supplied value with an attribute of an entry
- List DN's of subordinate entries
- Search entries using a filter
  - Filter contains one or more matching rules to apply to attributes
  - Search returns attribute or attributes which pass the filter
- Add a new leaf entry
- Remove a leaf entry
- Modify an entry by adding or removing attributes
- Move an entry by modifying its DN

LDAP

X.500 Directory Access Protocol (DAP) adapted for Internet use

- Originally Lightweight Directory Access Protocol, now closer to HDAP

Provides access to LDAP servers (and hence DSA's) over a TCP/IP connection

- `bind` and `unbind` to connect/disconnect
- `read` to retrieve data
- `add`, `modify`, `delete` to update entries
- `search`, `compare` to locate information

LDAP (ctd)

LDAP provides a complex heirarchical directory containing information categories with sub-categories containing nested object classes containing entries with one or more (usually more) attributes containing actual values

Simplicity made complex

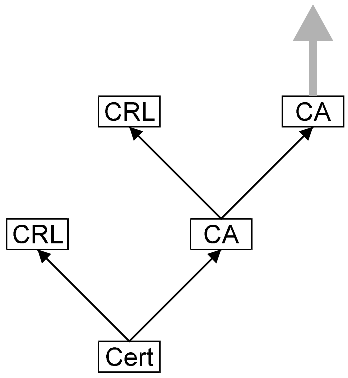
"It will scale up into the billions. We have a pilot with 200 users running already"

Most practical way to use it is as a simple database

SELECT key WHERE name='John Doe'

Certificate Verification using the Directory

Checking works in reverse order to normal lookup



Check certificate
Check certificates CRL
repeat
  Check CA's certificate
  Check CA's CRL
until root reached

Alternative Verification Schemes

Checking as per the X.509 design isn't really practical

- Extremely high overhead for each cert access/use
- Lack of a directory makes locating a cert difficult

Best solution may be some form of DNS-style verification system

- Lightweight at the user end
- User is told either "Yes" or "No"
  - Follows the credit card authorisation model: Reject, card stolen, card expired, amount exceeded, ..., accept
- Revocation is easy
- Information is held at easy-to-maintain centralised sites

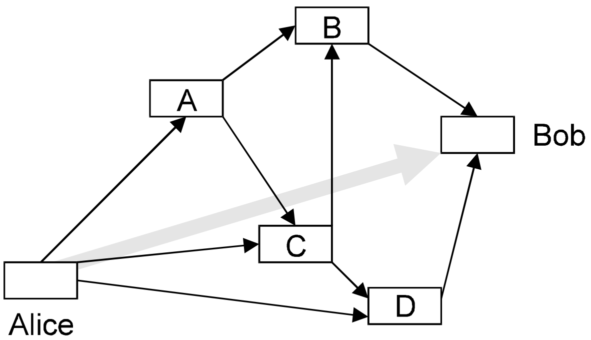
Alternative Verification Schemes (ctd)

Problems with centralised verification

- Requires trusted verification servers
- Users need to register certificates of interest or the problem becomes too large
- Servers become a high-value target

Alternative Trust Hierarchies

PGP web of trust



Bob knows B and D who know A and C who know Alice
$\Rightarrow$ Bob knows the key came from Alice

Web of trust more closely reflects real-life trust models

Certificate Revocation

Revocation is managed with a certificate revocation list (CRL), a form of anti-certificate which cancels a certificate

- Equivalent to 1970's-era credit card blacklist booklets
- Relying parties are expected to check CRL's before using a certificate
  - "This certificate is valid unless you here somewhere that it isn't"

CRL's don't really work

- Difficult to implement and use
- Uncertain performance
- Vulnerable to simple denial-of-service attacks (attacker can prevent revocation by blocking CRL's)

Certificate Revocation (ctd)

Many applications require prompt revocation

- CA's (and X.509) don't really support this
- CA's are inherently an offline operation

Online protocols have been proposed to fix CRL's

- Online Certificate Status Protocol, OCSP
  - Inquires of the issuing CA whether a given certificate is still valid
  - Acts as a simple responder for querying CRL's
  - Still requires the use of a CA to check validity

Certificate Revocation (ctd)

Alternative revocation techniques

- Self-signed revocation (suicide note)
- Certificate of health/warrant of fitness for certificates (anti-CRL)

The general problem may be fixable with quick-turnaround online revocation authorities

- Anyone who can figure out how to make revocation work, please see me afterwards

Key Backup/Archival

Need to very carefully balance security vs backup requirements

- Every extra copy of your key is one more failure point
- Communications and signature keys never need to be recovered — generating a new key only takes a minute or so
- Long-term data storage keys should be backed up

Never give the entire key to someone else

- By extension, never use a key given to you by someone else (eg generated for you by a third party)

Key Backup/Archival (ctd)

Use a threshold scheme to handle key backup

- Break the key into *n* shares
- Any *m* of *n* shares can recover the original
- Store each share in a safe, different location (locked in the company safe, with a solicitor, etc)
- Shares can be reconstructed under certain conditions (eg death of owner)

Defeating this setup requires subverting multiple shareholders

Never give the entire key to someone else

Never give the key shares to an outside third party

Certificate Structure

Version (X.509 v3)
Serial number Issuer name (DN)
Validity (start and end time)
Subject Name (DN) Subject public key
Extensions (added in v3) Extra identification information, usage constraints, policies, etc

Usually either the subject name or issuer and serial number identify the certificate

Certificate Structure (ctd)

Typical certificate

- Serial Number = 177545
- Issuer Name = Verisign
- ValidFrom = 12/09/98
- ValidTo = 12/09/99
- Subject Name = John Doe
- Public Key = RSA public key

Certificate Extensions

Extensions consist of a type-and-value pair, with optional critical flag

Critical flag is used to protect CA's against assumptions made by software which doesn't implement support for a particular extension

- If flag is set, extension must be processed (if recognised) or the certificate rejected
- If flag is clear, extension may be ignored

Ideally, implementations should process and act on all components of all fields of an extension in a manner which is compliant with the semantic intent of the extension

Certificate Extensions (ctd)

Actual definitions of critical flag usage are extremely vague

- X.509: Noncritical extension “is an advisory field and does not imply that usage of the key is restricted to the purpose indicated”
- PKIX: “CA’s are required to support constraint extensions”, but “support” is never defined
- S/MIME: Implementations should “correctly handle” certain extensions
- MailTrusT: “non-critical extensions are informational only and may be ignored”
- Verisign: “all persons shall process the extension... or else ignore the extension”

Certificate Extensions (ctd)

Extensions come in two types

Usage/informational extensions

- Provide extra information on the certificate and its owner

Constraint extensions

- Constrain the user of the certificate
- Act as a Miranda warning (“You have the right to remain silent, you have the right to an attorney, ...”) to anyone using the certificate

Certificate Usage Extensions

Key Usage

- Defines the purpose of the key in the certificate

digitalSignature

- Short-term authentication signature (performed automatically and frequently)

nonRepudiation

- Binding long-term signature (performed consciously)
- Another school of thought holds that nonRepudiation acts as an additional service on top of digitalSignature

Certificate Usage Extensions (ctd)

keyEncipherment

- Exchange of encrypted session keys (RSA)

keyAgreement

- Key agreement (DH)

keyCertSign/cRLSign

- Signature bits used by CA’s

Certificate Usage Extensions (ctd)

Extended Key Usage

Extended forms of the basic key usage fields

- serverAuthentication
- clientAuthentication
- codeSigning
- emailProtection
- timeStamping

Netscape cert-type

An older Netscape-specific extension which performed the same role as keyUsage, extKeyUsage, and basicConstraints

Certificate Usage Extensions (ctd)

Private Key Usage Period

Defines start and end time in which the private key for a certificate is valid

- Signatures may be valid for 10-20 years, but the private key should only be used for a year or two

Alternative Names

Everything which doesn’t fit in a DN

- rfc822Name
  - email address, `dave@wetaburgers.com`
- dNSName
  - DNS name for a machine, `ftp.wetaburgers.com`

Certificate Usage Extensions (ctd)

- uniformResourceIdentifier
  - URL, `http://www.wetaburgers.com`
- iPAddress
  - 202.197.22.1 (encoded as CAC51601)
- x400Address, ediPartyName
  - X.400 and EDI information
- directoryName
  - Another DN, but containing stuff you wouldn't expect to find in the main certificate DN
  - Actually the alternative name is a form called the GeneralName, of which a DN is a little-used subset
- otherName
  - Type-and-value pairs (type=MPEG, value=MPEG-of-cat)

Certificate Usage Extensions (ctd)

Certificate Policies

Information on the CA policy under which the certificate is issued

- Policy identifier
- Policy qualifier(s)
- Explicit text ("This certificate isn't worth the paper it's not printed on")

Certificate Usage Extensions (ctd)

X.509 delegates most issues of certificate semantics or trust to the CA's policy

- Many policies serve mainly to protect the CA from liability
  - "Verisign disclaims any warranties... Verisign makes no representation that any CA or user to which it has issued a digital ID is in fact the person or organisation it claims to be... Verisign makes no assurances of the accuracy, authenticity, integrity, or reliability of information"
- Effectively these certificates have null semantics
- If CA's didn't do this, their potential liability would be enormous

Certificate Usage Extensions (ctd)

Policy Mappings

- Maps one CA's policy to another CA
- Allows verification of certificates issued under other CA policies
  - "For verification purposes we consider our CA policy to be equivalent to the policy of CA *x*"

Certificate Constraint Extensions

Basic Constraints

Whether the certificate is a CA certificate or not

- Prevents users from acting as CA's and issuing their own certificates

Name Constraints

Constrain the DN subtree under which a CA can issue certificates

- Constraint of C=NZ, O=University of Auckland would enable a CA to issue certificates only for the University of Auckland
- Main use is to balkanize the namespace so a CA can buy or license the right to issue certificates in a particular area
- Constraints can also be applied to email addresses, DNS names, and URL's

Certificate Constraint Extensions (ctd)

Policy Constraints

Can be used to disable certificate policy mappings

- Policy = "For verification purposes we consider our CA policy to be equivalent to the policy of CA *x*"
- Policy constraint = "No it isn't"

Certificate Profiles

X.509 is extremely vague and nonspecific in many areas

- To make it usable, standards bodies created certificate profiles which nailed down many portions of X.509

PKIX

Internet PKI profile

- Requires certain extensions (basicConstraints, keyUsage) to be critical
  - Doesn't require basicConstraints in end entity certificates, interpretation of CA status is left to chance
- Uses digitalSignature for general signing, nonRepudiation specifically for signatures with nonRepudiation
- Defines Internet-related altName forms like email address, DNS name, URL

Certificate Profiles (ctd)

FPKI

(US) Federal PKI profile

- Requires certain extensions (basicConstraints, keyUsage, certificatePolicies, nameConstraints) to be critical
- Uses digitalSignature purely for ephemeral authentication, nonRepudiation for long-term signatures
- Defines (in great detail) valid combinations of key usage bits and extensions for various certificate types

MISSI

US DoD profile

- Similar to FPKI but with some DoD-specific requirements (you'll never run into this one)

Certificate Profiles (ctd)

ISO 15782

Banking — Certificate Management Part 1: Public Key Certificates

- Uses digitalSignature for entity authentication and nonRepudiation strictly for nonrepudiation (leaving digital signatures for data authentication without nonrepudiation hanging)
- Can't have more than one flag set

Canada

- digitalSignature or nonRepudiation must be present in all signature certs
- keyEncipherment or dataEncipherment must be present in confidentiality certs

Certificate Profiles (ctd)

SEIS

Secured Electronic Information in Society

- Leaves extension criticality up to certificate policies
- Uses digitalSignature for ephemeral authentication and some other signature types, nonRepudiation specifically for signatures with nonRepudiation
  - nonRepudiation can't be combined with other flags
  - Requires three separate keys for digital signature, encryption, and nonrepudiation
- Disallows certain fields (policy and name constraints)

Certificate Profiles (ctd)

TeleTrusT/MailTrusT

German MailTrusT profile for TeleTrusT (it really is capitalised that way)

- Requires keyUsage to be critical in some circumstances
- Uses digitalSignature for general signatures, nonRepudiation specifically for signatures with nonRepudiation

Certificate Profiles (ctd)

Australian Profile

Profile for the Australian PKAF

- Requires certain extensions (basicConstraints, keyUsage) to be critical
- Defines key usage bits (including digitalSignature and nonRepudiation) in terms of which bits may be set for each algorithm type
- Defines (in great detail) valid combinations of key usage bits and extensions for various certificate types

German Profile

Profile to implement the German digital signature law

- Requires that private key be held only by the end user

Certificate Profiles (ctd)

SIRCA Profile

(US) Securities Industry Association

- Requires all extensions to be non-critical
- Requires certificates to be issued under the SIA DN subtree

Microsoft Profile (de facto profile)

- Rejects certificates with critical extensions
- Always seems to set nonRepudiation flag when digitalSignature flag set
- Ignores keyUsage bit
- Treats all certificate policies as the hardcoded Verisign policy

Setting up a CA

Noone makes money running a CA

- You make money by selling CA services and products

Typical cost to set up a proper CA from scratch: $1M

Writing the policy/certificate practice statement (CPS) requires significant effort

Getting the top-level certificate (root certificate) installed and trusted by users can be challenging

- Root certificate is usually self-signed

Bootstrapping a CA

Get your root certificate signed by a known CA

- Your CA's certificate is certified by the existing CA
- Generally requires becoming a licensee of the existing CA
- Your CA is automatically accepted by existing software

Get users to install your CA certificate in their applications

- Difficult for users to do
- Specific to applications and OS's
- Not transparent to users
- No trust mechanism for the new certificate

Bootstrapping a CA (ctd)

Publish your CA certificate(s) by traditional means

- Global Trust Register, `http://www.cl.cam.ac.uk/Research/Security/Trust-Register/`
- Book containing register of fingerprints of the world's most important public keys
- Implements a top-level CA using paper and ink

Install custom software containing the certificate on user PC's

- Even less transparent than manually installing CA certificates
- No trust mechanism for the new certificate

CA Policies

Serves two functions

- Provides a CA-specific mini-profile of X.509
- Defines the CA terms and conditions/indemnifies the CA

CA policy may define

- Obligations of the CA
  - Checking certificate user validity
  - Publishing certificates/revocations
- Obligations of the user
  - Provide valid, accurate information
  - Protect private key
  - Notify CA on private key compromise

CA Policies (ctd)

- List of applications for which issued certs may be used/may not be used
- CA liability
  - Warranties and disclaimers
- Financial responsibility
  - Indemnification of the CA by certificate users
- Certificate publication details
  - Access mechanism
  - Frequency of updates
  - Archiving
- Compliance auditing
  - Frequency and type of audit
  - Scope of audit

CA Policies (ctd)

- Security auditing
  - Which events are logged
  - Period for which logs are kept
  - How logs are protected
- Confidentiality policy
  - What is/isn’t considered confidential
  - Who has access
  - What will be disclosed to law enforcement/courts

CA Policies (ctd)

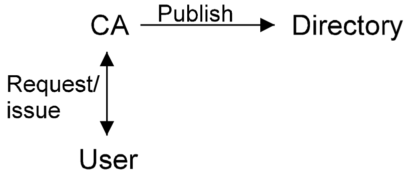
- Certificate issuing
  - Type of identification/authentication required for issuance
  - Type of name(s) issued
  - Resolution of name disputes
  - Handling of revocation requests
    - Circumstances under which a certificate is revoked, who can request a revocation, type of identification/authentication required for revocation, how revocation notices are distributed
- Key changeover
  - How keys are rolled over when existing ones expire
- Disaster recovery

CA Policies (ctd)

- CA security
  - Physical security
    - Site location, access control, fire/flood protection, data backup
  - Personnel security
    - Background checks, training
  - Computer security
    - OS type used, access control mechanisms, network security controls
  - CA key protection
    - Generation, key sizes, protection (hardware or software, which protection standards are employed, key backup/archival, access/control over the key handling software/hardware)
- Certificate profiles
  - Profile amendment procedures
  - Publication

CA's and Scaling

The standard certification model involves direct user interaction with a CA

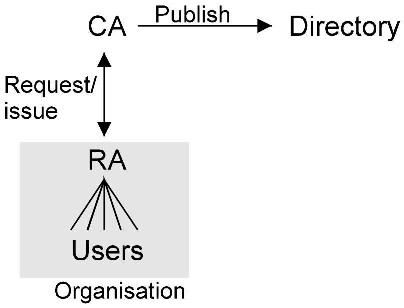


This doesn't scale well

- CA has to verify details for each user
- Processing many users come from a similar background (eg a single organisation) results in unnecessary repeated work

RA's

Registration authorities offload user processing and checking from the CA



RA acts as a trusted intermediary

- RA has a trusted relationship with CA
- RA has access to user details

Timestamping

Certifies that a document existed at a certain time

Used for added security on existing signatures

- Timestamped countersignature proves that the original signature was valid at a given time
- Even if the original signatures key is later compromised, the timestamp can be used to verify that the signature was created before the compromise

Requires a data format which can handle multiple signatures

- Only PGP keys and S/MIME signed data provide this capability

Problems with X.509

Most of the required infrastructure doesn’t exist

- Users use an undefined certification request protocol to obtain a certificate which is published in an unclear location in a nonexistant directory with no real means to revoke it
- Various workarounds are used to hide the problems
  - Details of certificate requests are kludged together via web pages
  - Complete certificate chains are included in messages wherever they’re needed
  - Revocation is either handled in an ad hoc manner or ignored entirely

Standards groups are working on protocols to fix this

- Progress is extremely slow

Problems with X.509 (ctd)

Certificates are based on owner identities, not keys

- Owner identities don’t work very well as certificate ID’s
  - Real people change affiliations, email addresses, even names
  - An owner will typically have multiple certificates, all with the same ID
- Owner identity is rarely of security interest (authorisation/capabilities are what count)
- Revoking a key requires revoking the identity of the owner
- Renewal/replacement of identity certificates is nontrivial

Problems with X.509 (ctd)

Authentication and confidentiality certificates are treated the same way for certification purposes

- X.509v1 and v2 couldn’t even distinguish between the two

Users should have certified authentication keys and use these to certify their own confidentiality keys

- No real need to have a CA to certify confidentiality keys
- New confidentiality keys can be created at any time
- Doesn’t require the cooperating of a CA to replace keys

Aggregation of attributes shortens the overall certificate lifetime

Problems with X.509 (ctd)

Certificates rapidly become a dossier as more attributes are added

```
SEQUENCE {
 OBJECT IDENTIFIER signedData (1 2 840 113549 1 7 2)
 [0] {
  SEQUENCE {
   INTEGER 1
   SET {
    SEQUENCE {
     OBJECT IDENTIFIER sha1 (1 3 14 3 2 26)
     NULL
     }
    }
   SEQUENCE {
    OBJECT IDENTIFIER data (1 2 840 113549 1 7 1)
    }
   [0] {
    SEQUENCE {
     SEQUENCE {
      [0] {
       INTEGER 2
       }
      INTEGER 145
      SEQUENCE {
       OBJECT IDENTIFIER md5withRSAEncryption (1 2 840 113549 1 1 4)
       NULL
       }
```

```
SEQUENCE {
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER countryName (2 5 4 6)
   PrintableString 'CH'
   }
  }SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationName (2 5 4 10)
   PrintableString 'Swisskey AG'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
   PrintableString 'Public CA Services'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER localityName (2 5 4 7)
   PrintableString 'Zuerich'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER commonName (2 5 4 3)
   PrintableString 'Swisskey ID CA 1024'
   }
  }
 }
```

continues

Problems with X.509 (ctd)

```
SEQUENCE {
 UTCTime '980929093816Z'
 UTCTime '000929093800Z'
 }
SEQUENCE {
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationName (2 5 4 10)
   PrintableString 'Swisskey AG'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
   PrintableString '00851000005020000012'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
   PrintableString 'Product Management'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER postalCode (2 5 4 17)
   PrintableString '8008'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER localityName (2 5 4 7)
   PrintableString 'Zuerich'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER countryName (2 5 4 6)
   PrintableString 'CH'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER commonName (2 5 4 3)
   PrintableString 'Juerg Spoerndli'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER emailAddress (1 2 840 113549 1 9 1)
   IA5String 'jspoerndli@swisskey.ch'
   }
  }
 }
SEQUENCE {
 SEQUENCE {
  OBJECT IDENTIFIER rsaEncryption (1 2 840 113549 1 1 1)
  NULL
  }
 BIT STRING 0 unused bits
  30 81 89 02 81 81 00 EE 7B BA 00 A0 1A C2 05 8B
  8F 52 26 E9 01 C4 A3 7A C9 6E C5 4C 2B FD 3A 2A
  44 48 72 29 7E E3 57 03 2A C9 F3 BB 1D C2 12 2D
  E7 7E 8D B3 3C 58 AD D6 8A 29 4D D1 9F 0F 1E 45
  F3 1E 67 39 9D 83 0B 1A 0D 1F 82 35 B0 D7 2A 6E
  35 6B 76 C2 05 9B 67 E4 3F 8B 6A 8F A6 04 85 F7
  56 EB 51 D9 69 D6 C9 23 AF 5E 0A AE D3 90 7F 60
  16 81 CF 1F 20 B6 A5 A5 5E F0 9F 6D B0 40 F9 8D
      [ Another 12 bytes skipped ]
 }
```

continues

Problems with X.509 (ctd)

```
[3] {
 SEQUENCE {
  SEQUENCE {
   OBJECT IDENTIFIER netscape-cert-type (2 16 840 1 113730 1 1)
   OCTET STRING, encapsulates {
     BIT STRING 5 unused bits
      '101'B
     }
   }
  SEQUENCE {
   OBJECT IDENTIFIER netscape-comment (2 16 840 1 113730 1 13)
   OCTET STRING
    16 81 C6 54 68 69 73 20 63 65 72 74 69 66 69 63
    61 74 65 20 68 61 73 20 62 65 65 6E 20 69 73 73
    75 65 64 20 62 79 20 53 77 69 73 73 6B 65 79 20
    41 47 20 67 6F 76 65 72 6E 65 64 20 62 79 20 69
    74 73 20 43 65 72 74 69 66 69 63 61 74 65 20 50
    72 61 63 74 69 63 65 20 53 74 61 74 65 6D 65 6E
    74 20 28 43 50 53 29 2E 20 43 50 53 20 61 6E 64
    20 66 75 72 74 68 65 72 20 69 6E 66 6F 72 6D 61
        [ Another 73 bytes skipped ]
   }
  SEQUENCE {
   OBJECT IDENTIFIER keyUsage (2 5 29 15)
   OCTET STRING, encapsulates {
     BIT STRING 5 unused bits
      '101'B
     }
   }
      SEQUENCE {
       OBJECT IDENTIFIER privateKeyUsagePeriod (2 5 29 16)
       OCTET STRING, encapsulates {
         SEQUENCE {
          [0] '19980929093816Z'
          [1] '20000929093800Z'
          }
         }
        }
      }
    }
   }
 SEQUENCE {
  OBJECT IDENTIFIER md5withRSAEncryption (1 2 840 113549 1 1 4)
  NULL
  }
 BIT STRING 0 unused bits
  2A 2A 40 C4 03 48 0B B9 7D 7F B6 85 FD CF A8 D7
  CF 96 D8 55 5D C0 87 4D BE E6 C1 0F 7A 0B 0F 17
  DF 7A 10 49 81 EB A1 6B 8C 16 93 FB 38 37 79 A0
  B6 1F B3 EA F0 AA D5 CA 0A 52 DA D3 19 3A 55 B6
  F6 7F 77 4E 30 15 D4 5C 8C 73 44 62 FF 15 9C 44
  C3 38 F0 D1 58 85 D0 C6 88 55 7C FF D0 67 14 4C
  DE D2 7F F8 00 A8 BC 6E A7 35 BD 51 DD CB 7D F2
  C8 E7 34 61 00 C2 25 51 F0 ED 0B B0 38 93 FC 30
 }
SEQUENCE {
 SEQUENCE {
  [0] {
   INTEGER 2
   }
  INTEGER 5
  SEQUENCE {
   OBJECT IDENTIFIER md5withRSAEncryption (1 2 840 113549 1 1 4)
   NULL
   }
```

continues

Problems with X.509 (ctd)

```
SEQUENCE {
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER countryName (2 5 4 6)
   PrintableString 'CH'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationName (2 5 4 10)
   PrintableString 'Swisskey AG'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
   PrintableString 'Public CA Services'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER localityName (2 5 4 7)
   PrintableString 'Zuerich'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER commonName (2 5 4 3)
   PrintableString 'Swisskey Root CA'
   }
  }
 }
SEQUENCE {
 UTCTime '980706134849Z'
 UTCTime '051231235900Z'
 }
```

```
SEQUENCE {
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER countryName (2 5 4 6)
   PrintableString 'CH'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationName (2 5 4 10)
   PrintableString 'Swisskey AG'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
   PrintableString 'Public CA Services'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER localityName (2 5 4 7)
   PrintableString 'Zuerich'
   }
  }
 SET {
  SEQUENCE {
   OBJECT IDENTIFIER commonName (2 5 4 3)
   PrintableString 'Swisskey ID CA 1024'
   }
  }
 }
SEQUENCE {
 SEQUENCE {
  OBJECT IDENTIFIER rsaEncryption (1 2 840 113549 1 1 1)
  NULL
  }
```

continues

Problems with X.509 (ctd)

```
 BIT STRING 0 unused bits
  30 81 89 02 81 81 00 AB E9 1F E9 AD FF 53 9F 71
  70 35 6D F8 F8 4C 76 B4 F7 43 E8 19 80 DD A9 0A
  D6 4E 60 C2 FD 48 7B 43 F6 6E BE 53 D0 0E 62 F0
  35 27 6F 2E 55 22 F2 82 40 2E 21 5B 5D 7E 18 16
  CA 87 31 2E 12 71 4C 5F 92 8A AB 36 61 9C 91 38
  BC BD 95 88 BF 7E 0C 4A D7 A0 12 F9 FA FF 0F 84
  F8 57 6E DE AE B4 03 FC 77 CF 7C E5 B3 33 79 61
  31 4E CE 70 03 E7 73 D8 E8 1B D3 EB 15 FF 69 B3
      [ Another 12 bytes skipped ]
 }
[3] {
 SEQUENCE {
  SEQUENCE {
   OBJECT IDENTIFIER basicConstraints (2 5 29 19)
   BOOLEAN TRUE
   OCTET STRING, encapsulates {
     SEQUENCE {
      BOOLEAN TRUE
      INTEGER 0
      }
     }
   }
  SEQUENCE {
   OBJECT IDENTIFIER keyUsage (2 5 29 15)
   BOOLEAN TRUE
   OCTET STRING, encapsulates {
     BIT STRING 1 unused bits
      '1100000'B
     }
   }
  }
 }
}
```

```
 SEQUENCE {
  OBJECT IDENTIFIER md5withRSAEncryption (1 2 840 113549 1 1 4)
  NULL
  }
 BIT STRING 0 unused bits
  0E 0F 67 22 AA D2 8A 7B BF 3D 47 AB 1F 5E 8C F3
  2C 32 3E AB D3 48 60 A1 BA 49 FD 81 28 6A 26 69
  83 97 29 1F E8 80 14 96 30 2B C3 18 97 3B 6C F3
  F0 A2 D6 E0 30 EF F6 2C 38 1F C0 37 7E 9E 45 FD
  62 38 67 07 27 BE 81 07 E9 12 60 E8 BE 6B ED 14
  8E 61 17 52 99 C2 FE 33 B7 21 CA 5E FE 6D B4 1E
  B9 8C 54 36 42 55 1E 73 D9 81 DE 5D 25 AD 72 39
  15 AF 68 E9 44 45 55 7F 2E 2E F9 6F EF 44 B0 E0
 }
SEQUENCE {
 SEQUENCE {
  [0] {
   INTEGER 2
   }
  INTEGER 1
  SEQUENCE {
   OBJECT IDENTIFIER md5withRSAEncryption (1 2 840 113549 1 1 4)
   NULL
   }
  SEQUENCE {
   SET {
    SEQUENCE {
     OBJECT IDENTIFIER countryName (2 5 4 6)
     PrintableString 'CH'
     }
    }
   SET {
    SEQUENCE {
     OBJECT IDENTIFIER organizationName (2 5 4 10)
     PrintableString 'Swisskey AG'
     }
    }
```

continues

Problems with X.509 (ctd)

```
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
      PrintableString 'Public CA Services'
      }
     }
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER localityName (2 5 4 7)
      PrintableString 'Zuerich'
      }
     }
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER commonName (2 5 4 3)
      PrintableString 'Swisskey Root CA'
      }
     }
    }
   SEQUENCE {
    UTCTime '980706120207Z'
    UTCTime '051231235900Z'
    }
   SEQUENCE {
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER countryName (2 5 4 6)
      PrintableString 'CH'
      }
     }
```

```
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER organizationName (2 5 4 10)
      PrintableString 'Swisskey AG'
      }
     }
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
      PrintableString 'Public CA Services'
      }
     }
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER localityName (2 5 4 7)
      PrintableString 'Zuerich'
      }
     }
    SET {
     SEQUENCE {
      OBJECT IDENTIFIER commonName (2 5 4 3)
      PrintableString 'Swisskey Root CA'
      }
     }
    }
   SEQUENCE {
    SEQUENCE {
     OBJECT IDENTIFIER rsaEncryption (1 2 840 113549 1 1 1)
     NULL
     }
```

continues

Problems with X.509 (ctd)

```
    BIT STRING 0 unused bits
     30 81 89 02 81 81 00 AC AB 60 E0 C5 69 FD 07 4E
     97 9B AF 4A 1C 30 D7 68 26 D1 2C 3D 44 F0 D6 AB
     16 34 6F 00 D8 7F D6 3F B9 35 D6 83 28 77 A3 3E
     24 5D A4 D1 C2 FA 04 B3 DB 4D 38 91 23 70 6C 2B
     2D 48 69 D5 15 6F 4A 9F 91 BC E4 83 2F 35 A2 29
     DB 55 66 F8 90 C6 0E 0C 32 75 95 24 E0 8D B7 8E
     AB 13 70 61 1E 01 91 7D 9D 44 37 42 41 C9 C2 01
     DD 26 D8 B9 2C 29 57 A1 54 17 1E AC 1A DE 8C 6C
         [ Another 12 bytes skipped ]
    }
   [3] {
    SEQUENCE {
     SEQUENCE {
      OBJECT IDENTIFIER basicConstraints (2 5 29 19)
      BOOLEAN TRUE
      OCTET STRING, encapsulates {
        SEQUENCE {
         BOOLEAN TRUE
         INTEGER 3
         }
        }
      }
     SEQUENCE {
      OBJECT IDENTIFIER keyUsage (2 5 29 15)
      BOOLEAN TRUE
      OCTET STRING, encapsulates {
        BIT STRING 1 unused bits
         '1100000'B
        }
      }
     }
    }
   }
```

```
   SEQUENCE {
    OBJECT IDENTIFIER md5withRSAEncryption (1 2 840 113549 1 1 4)
    NULL
    }
   BIT STRING 0 unused bits
    72 A7 93 A3 CD D7 3A DB 79 50 DB 98 03 52 B0 CD
    AF 0C D2 A6 89 38 52 6C 5C E9 7C B3 37 3C 9E 94
    C4 74 57 D4 BB 78 05 5B B6 B9 31 04 FC 60 33 51
    5F CF 2C 44 55 85 EC 1F 0B CB 89 E7 F0 93 D4 CD
    85 D3 FF B6 B5 99 D3 7C 35 06 11 7B 0E 9F E6 BE
    99 B3 49 D0 5A 85 FA 7C BA 54 9B B9 AF F7 4B E3
    FF DC 83 4A 04 F8 F9 A5 1D EC 37 AE C6 23 4C 9D
    B2 01 1F D4 26 EA E4 4A 7E BE BE 1E 11 1E 27 D1
   }
  }
 SET {
  SEQUENCE {
   INTEGER 1
   SEQUENCE {
    SEQUENCE {
     SET {
      SEQUENCE {
       OBJECT IDENTIFIER countryName (2 5 4 6)
       PrintableString 'CH'
       }
      }
     SET {
      SEQUENCE {
       OBJECT IDENTIFIER organizationName (2 5 4 10)
       PrintableString 'Swisskey AG'
       }
      }
     SET {
      SEQUENCE {
       OBJECT IDENTIFIER organizationalUnitName (2 5 4 11)
       PrintableString 'Public CA Services'
       }
      }
```

continues

Problems with X.509 (ctd)

```
      SET {
       SEQUENCE {
        OBJECT IDENTIFIER localityName (2 5 4 7)
        PrintableString 'Zuerich'
        }
       }
      SET {
       SEQUENCE {
        OBJECT IDENTIFIER commonName (2 5 4 3)
        PrintableString 'Swisskey ID CA 1024'
        }
       }
      }
     INTEGER 145
     }
    SEQUENCE {
     OBJECT IDENTIFIER sha1 (1 3 14 3 2 26)
     NULL
     }
    [0] {
     SEQUENCE {
      OBJECT IDENTIFIER contentType (1 2 840 113549 1 9 3)
      SET {
       OBJECT IDENTIFIER data (1 2 840 113549 1 7 1)
       }
      }
     SEQUENCE {
      OBJECT IDENTIFIER signingTime (1 2 840 113549 1 9 5)
      SET {
       UTCTime '981113072133Z'
       }
      }
SEQUENCE {
 OBJECT IDENTIFIER messageDigest (1 2 840 113549 1 9 4)
 SET {
  OCTET STRING
   2F 7E 95 9F 34 AC 85 B8 1C 53 9E 5C F8 60 BE 3A
   AA D0 30 B5
  }
 }
SEQUENCE {
 OBJECT IDENTIFIER sMIMECapabilities (1 2 840 113549 1 9 15)
 SET {
  SEQUENCE {
   SEQUENCE {
    OBJECT IDENTIFIER des-EDE3-CBC (1 2 840 113549 3 7)
    }
   SEQUENCE {
    OBJECT IDENTIFIER rc2CBC (1 2 840 113549 3 2)
    INTEGER 128
    }
   SEQUENCE {
    OBJECT IDENTIFIER desCBC (1 3 14 3 2 7)
    }
   SEQUENCE {
    OBJECT IDENTIFIER rc2CBC (1 2 840 113549 3 2)
    INTEGER 64
    }
   SEQUENCE {
    OBJECT IDENTIFIER rc2CBC (1 2 840 113549 3 2)
    INTEGER 40
    }
   }
  }
 }
}
```

continues

Problems with X.509 (ctd)

```
    SEQUENCE {
     OBJECT IDENTIFIER rsaEncryption (1 2 840 113549 1 1 1)
     NULL
     }
    OCTET STRING
     9F EC C4 B4 B2 5A FE 87 EA 28 22 C2 6A 1F E3 2F
     16 8D 01 EA 2F 35 0E 13 D1 3E BE 1D 92 48 EF F0
     8E BB BC 98 3B 11 44 88 A8 20 AE AB 65 2D 98 E1
     3E 62 E1 47 5F FE 18 39 AF 97 29 7E D1 68 03 F1
     03 78 44 DB A1 BB 9F 3B C9 89 D5 0D 00 B3 0B FA
     98 F8 2E 58 4C E4 4F 73 02 D6 17 41 84 B6 50 A2
     94 F8 E2 6F C3 78 AF 4D 71 CF E7 FF 25 97 B9 00
     CC A5 BE A8 8C 3D 52 43 C9 BB 41 A9 87 5F 85 6F
    }
   }
  }
 }
}
```

All this from a standard S/MIME signature!

Problems with X.509 (ctd)

Hierarchical certification model doesn't fit typical business practices

- Businesses generally rely on bilateral trading arrangements or existing trust relationships
- Third-party certification is an unnecessary inconvenience when an existing relationship is present

X.509 PKI model entails building a parallel trust infrastructure alongside the existing, well-established one

- In the real world, trust and revocation is handled by closing the account, not with PKI's, CRL's, certificate status checks, and other paraphernalia

PGP Certificates

Certificates are key-based, not identity-based

- Keys can have one or more free-form names attached
- Key and name(s) are bound through (independent) signatures

Certification model can be hierarchical or based on existing trust relationships

- Parties with existing relationships can use self-signed certificates
  - Self-signed end entity certificates are a logical paradox in X.509v3

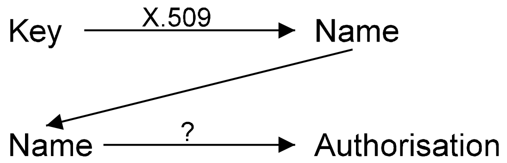
Authentication keys are used to certify confidentiality keys

- Confidentiality keys can be changed at any time, even on a per-message basis

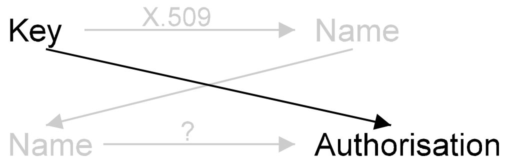
SPKI

Simple Public Key Infrastructure

Identity certificates bind a key to a name, but require a parallel infrastructure to make use of the result



SPKI certificates bind a key to an authorisation or capability



SPKI (ctd)

Certificates may be distributed by direct communications or via a directory

Each certificate contains the minimum information for the job (cf X.509 dossier certificates)

If names are used, they only have to be locally unique

- Global uniqueness is guaranteed by the use of the key as an identifier
- Certificates may be anonymous (eg for balloting)

Authorisation may require *m* of *n* consensus among signers (eg any 2 of 3 company directors may sign)

SPKI Certificate Uses

Typical SPKI uses

- Signing/purchasing authority
- Letter of introduction
- Security clearance
- Software licensing
- Voter registration
- Drug prescription
- Phone/fare card
- Baggage claim check
- Reputation certificate (eg Better Business Bureau rating)
- Access control (eg grant of administrator privileges under certain conditions)

Certificate Structure

SPKI certificates use collections of assertions expressed as LISP-like S-expressions of the form (*type value(s)*)

(name fred) ⇒ Owner name = fred

(name *CA_root CA1 CA2 ... CAn leaf_cert*) ⇒ X.500 DN

(name (hash sha1 |TLCgPLFlGTzyUbcaYLW8kGTEnUk=|) fred) ⇒ Globally unique name with key ID and locally unique name

(ftp (host ftp.warez.org)) ⇒ Keyholder is allowed FTP access to an entire site

(ftp (host ftp.warez.org) (dir /pub/warez)) ⇒ Keyholder is allowed FTP access to only one directory on the site

Certificate Structure (ctd)

```
( cert
    ( issuer ( hash sha1 |TLCgPLFlGTzyUbcaYLW8kGTEnUk=|
      ) )
    ( subject ( hash sha1 |Ve1L/7MqiJcj+LSa/l10fl3tuTQ=l| ) )
    ...
    ( not-before “1998-03-01_12:42:17” )
    ( not-after “2012-01-01_00:00:00” )
  ) ⇒ X.509 certificate
```

Internally, SPKI certificates are represented as 5-tuples <Issuer, Subject, Delegation, Authority, Validity>

- Delegation = Subject has permission to delegate authority
- Authority = Authority granted to certificate subject
- Validity = Validity period and/or online validation test information

Trust Evaluation

5-tuples can be automatically processed using a general-purpose tuple reduction mechanism

<I1, S1, D1, A1, V1> + <I2, S2, D2, A2, V2>
⇒ <I1, S2, D2, intersection(A1, A2), intersection(V1, V2)
if S1 = I2 and D1 = true

Eventually some chains of authorisation statements will reduce to <Trusted Issuer, *x*, D, A, V>

- All others are discarded
- Trust management decisions can be justified/explained/verified
  - “How was this decision reached?”
  - “What happens if I change this bit?”
- X.509 has nothing even remotely like this

Digital Signature Legislation

A signature establishes validity and authentication of a document to allow the reader to act on it as a statement of the signers intent

Signatures represent a physical manifestation of consent

A digital signature must provide a similar degree of security

Digital Signature Legislation (ctd)

Typical signature functions are

- Identification
- Prove involvement in the act of signing
- Associate the signer with a document
- Provide proof of the signers involvement with the content of the signed document
- Provide endorsement of authorship
- Provide endorsement of the contents of a document authored by someone else
- Prove a person was at a given place at a given time
- Meet a statutory requirement that a document be signed to make it valid

General Requirements for Digital Signatures

The signing key must be controlled entirely by the signer for non-repudiation to function

The act of signing must be conscious

- "Grandma clicks the wrong button and loses her house"
- "You are about to enter into a legally binding agreement which stipulates that ..."

May require a traditional written document to back up the use of electronic signatures

- "With the key identified by ... I agree to ... under the terms ..."

Cross-jurisdictional signatures are a problem

Utah Digital Signature Act

First digital signature act, passed in 1995

The Law of X.509

- Requires public-key encryption based signatures, licensed CA's, CRL's, etc etc.

Duly authorised digital signatures may be used to meet statutory requirements for written signatures

Liability of CA's is limited, signers and relying parties assume the risk

Signature carries evidentiary weight of notarised document

- If your key is compromised, you're in serious trouble
- If you hand over your key to a third party, you're in serious trouble

California Digital Signature Law

Very broad, allows any agreed-upon mark to be used as a digital signature

- Western culture has no real analog for this
- Asia has chop-marks, a general-purpose mark used to authenticate and authorise

One-sentence digital signature law:

“You can’t refuse a signature just because it’s digital”

- Many later laws followed this model

Massachusetts Electronic Records and Signatures Bill

“A signature may not be denied legal effect, validity, or enforceability because it is in the form of an electronic signature. If a rule of law requires a signature [...] an electronic signature satisfies that rule of law”

“A contract between business entities shall not be unenforceable, nor inadmissible in evidence, on the sole ground that the contract is evidenced by an electronic record or that it has been signed by an electronic signature”

The Massachusetts law doesn’t legislate forms of signatures or the use of CA’s, or allocate liability

- “Attorneys Full Employment Act of 1997”

German Digital Signature Law

Like the Utah act, based on public-key technology

Requirements

- Licensed CA's which meet certain requirements
  - CA's must provide a phone hotline for revocation
- Identification is based on the German ID card
  - This type of identification isn't possible in most countries
  - Allows pseudonyms in certificates
- Key and storage media must be controlled only by the key owner
- Provisions for timestamping and countersigning

Signatures from other EU countries are recognised provided an equivalent level of security is employed

German Digital Signature Law (ctd)

Details are set out in the implementation guidelines

- Extremely detailed (over 300 pages)
- Specifies things like
  - Hash and signature algorithms
  - Random number generation for keys
  - Personnel security
  - Directory and timestamping services
- Criticised as being too detailed and complex to follow

Italian Digital Signature Law

Similar to the German law, but all requirements are listed in one place

- Minimum key size is 1024 bits

Everything has to be certified to various ITSEC levels

- Key generation devices must be certified to ITSEC E3 with a HIGH level of robustness
  - In practice, this forces everyone to use smart cards for key management
- The OS must be ITSEC F-C2/E2 or TCSEC C2
- Access to the system must be controlled, users identified, usage logged
- CA's must be ISO 9000 certified
- This severely limits the technology which can be used

Italian Digital Signature Law (ctd)

Signature mechanism must present the data to be signed in a clear and unambiguous manner, and ask for confirmation of signature generation

- Allows for automated signature generation provided that this is "clearly connected to the will of the subscriber"

Certificates must contain users name, date of birth, and company name

- Allows pseudonyms, but this must be indicated in the cert and CA must record real identity

Italian Digital Signature Law (ctd)

CA must

- Verify that the key hasn’t been certified by another CA
- Verify that the users possesses the private key
- Publish certificates in LDAP directories
- Publish details on themselves (company name, address, contact details, terms and conditions, substitute CA)

Except for the fixation with (very expensive and complicated) security certification, this is a rather nice law which addresses most digital signature issues

Singapore Electronic Transactions Act

Follows the one-sentence signature law model

- Where the law requires a paper signature, an electronic one will do

Offer of acceptance of contracts may be expressed electronically

Signature apparatus must be under sole control of signer

Certificate requirements

- Cannot publish a certificate known to be false
- Certificates must specify a reliance limit

Compliant CA’s are not liable for certificate problems

ETSI Digital Signature Draft

ETSI TR 101 specifies technical requirements for signatures

- Role of signer (eg Financial director) is more important than the name
- Signature must be dated to allow later dispute resolution

References various standards efforts (eg PKIX) for further study

Privilege attribute certificates (PAC's)

- Defined by ECMA, special short-lived (1 day max) certificates
- Vouch for a certain property of the user

UNCITRAL Model Law on Electronic Commerce

UN Comission on International Trade (UNCITRAL) model e-commerce law

- Many acts and laws legislate a particular technology to provide reliance for digital signatures
- The model law provides a general framework for electronic signatures without defining their exact form

Later revisions may nail down precise forms for electronic signatures

UN Draft Articles on Electronic Signatures

Follows the one-sentence signature law model

- Includes a rationale for each point

Defines two levels of signature

- “Electronic signature” = data attached to a message to indicate a signers approval of the message
- “Enhanced electronic signature” = electronic signature with extra constraints
  - Unique to the signature holder
  - Verifiable through a standard procedure
  - Under the sole control of the signer

Extremely broad and technology-independent

Specifies (rather vague) reliance and obligation details

EU Directive on Electronic Signatures

Defines an electronic signature as linking signer and data, created by a means solely controlled by the signer (not necessarily a cryptographic signature)

Precedes the directive itself with the intended aims of the directive

Makes accreditation and licensing voluntary and non-discriminatory

- No-one can be prevented from being a CA
- Intent is to encourage best practices while letting the market decide

EU Directive on Electronic Signatures (ctd)

Electronic signature products must be made freely available within the EU

Electronic signatures can't be denied recognition just because they're electronic

Absolves CA's of certain types of liability

- Provides for reliance limits in certificates

Recognises certificates from non-EU states issued under equivalent terms

Allows for pseudonyms in certificates

EU Directive on Electronic Signatures (ctd)

Recognises that a regulatory framework isn't needed for signatures used in closed systems

- Trust is handled via existing commercial relationships
- Parties may agree among themselves on terms and conditions for electronic signatures
- Keys may be identified by a key fingerprint on a business card or in a letterhead