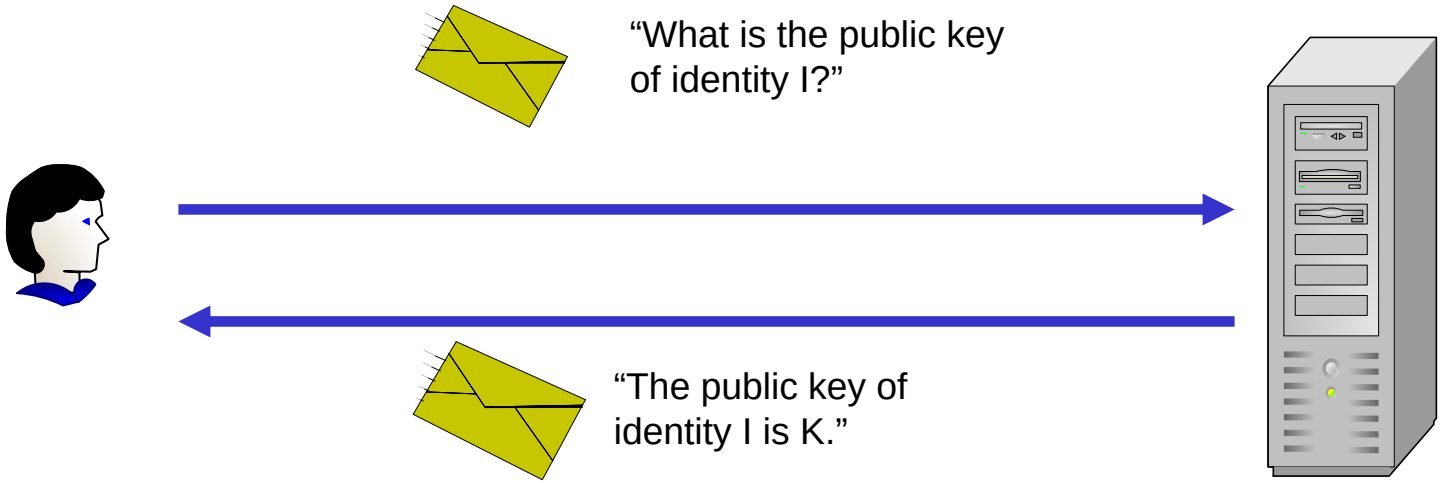
Authentication

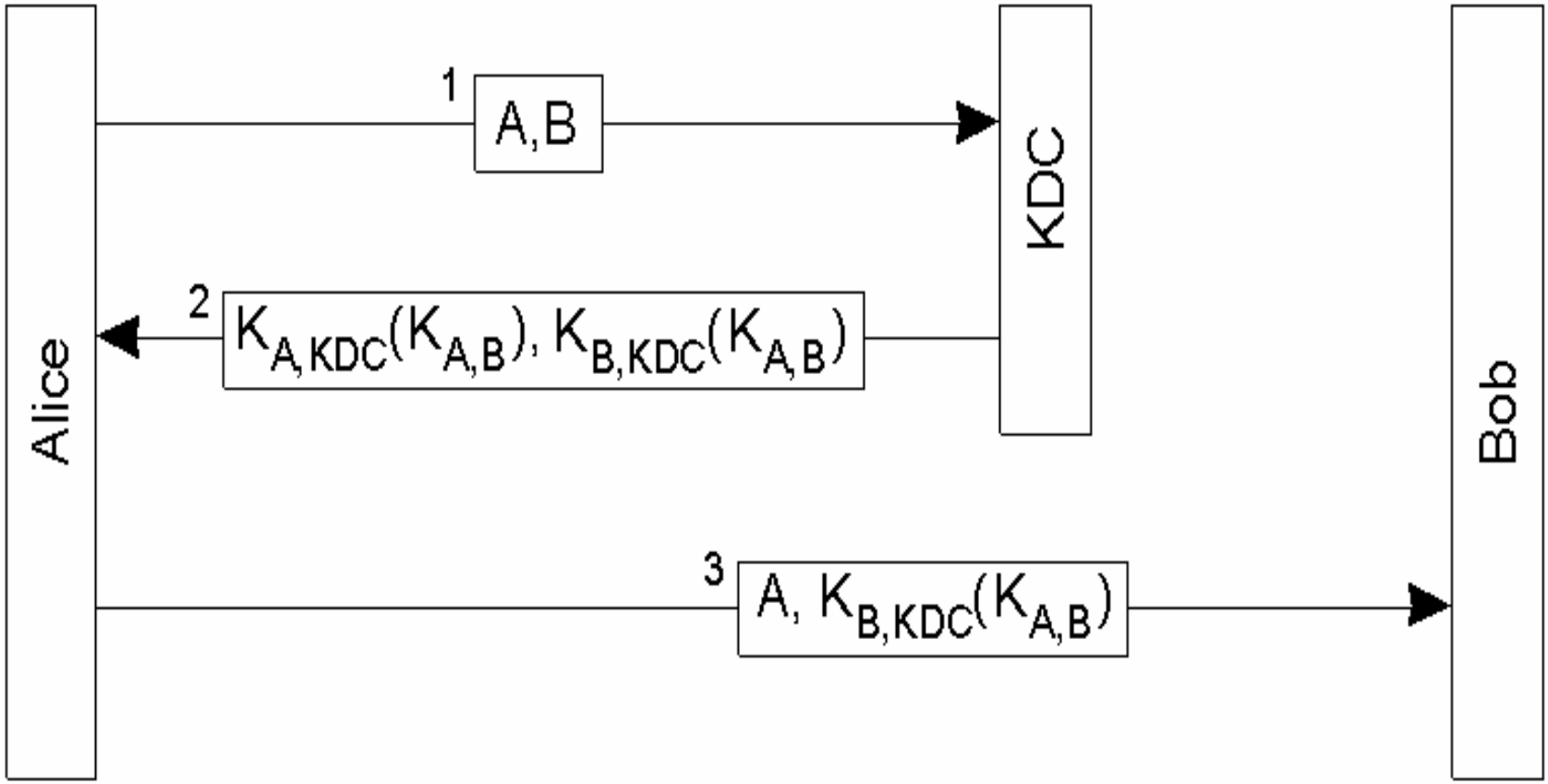
- Digital signature validation proves:
  - message was not altered in transmission
  - came from owner of the private key
- How does a “relying party” know to whom the private key belongs?
  - Key Servers
  - Certificates

Key Server

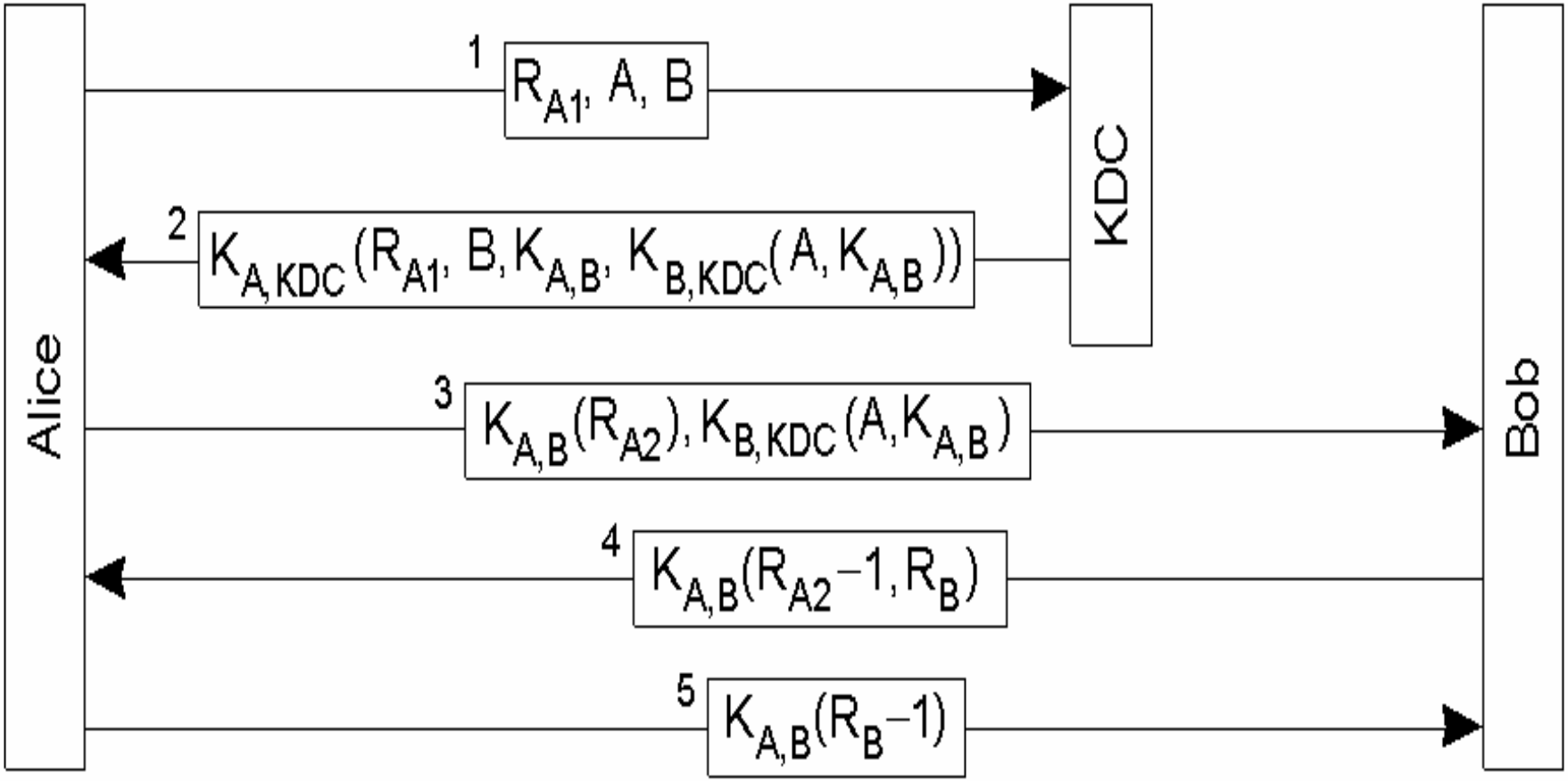


- The key server stores [identity, public key] pairs
- The key request can be in plaintext
- The key server reply is encrypted using the private key of the key server
- The public key of key server is known to the relying party
- The key server can be a point of attack or performance bottleneck
- The key server must be trustworthy
- Observations:
    - the relying party only cares about the reply
    - the reply can be precomputed and distributed

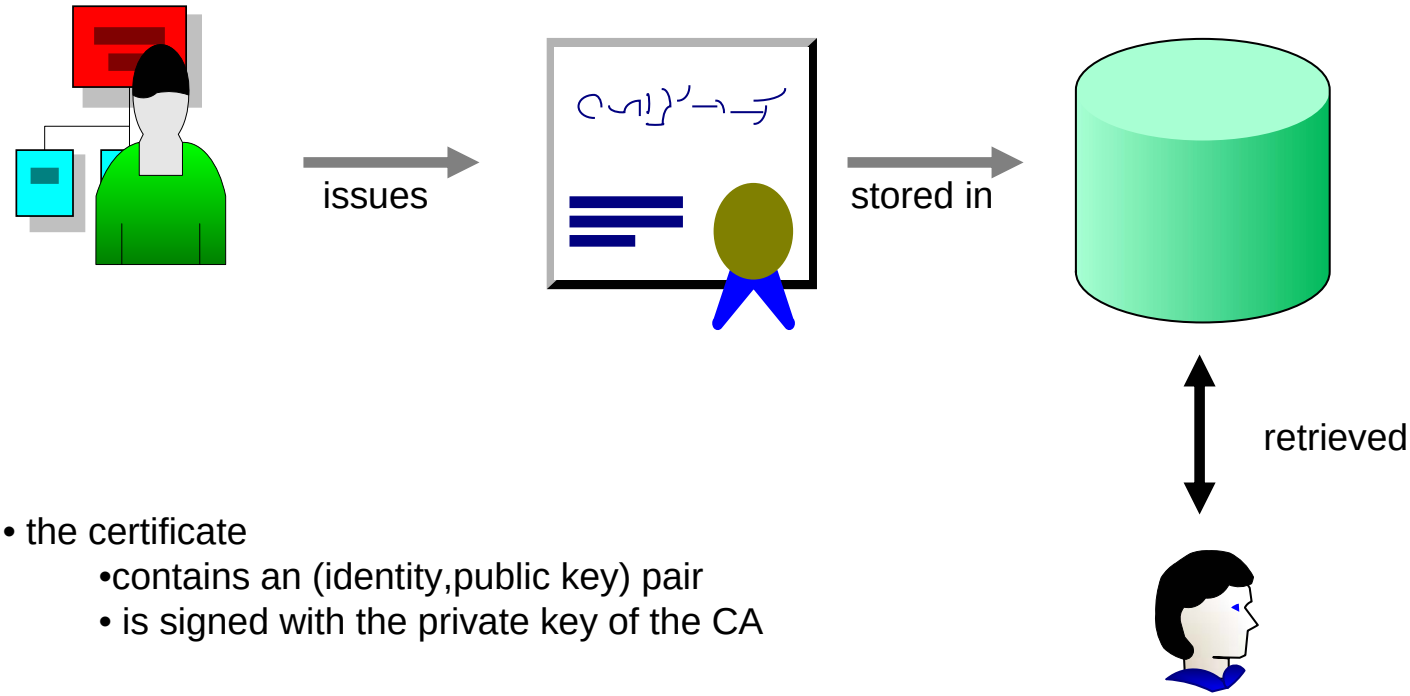
Authentication using a Key Server



Needham-Schroeder Protocol

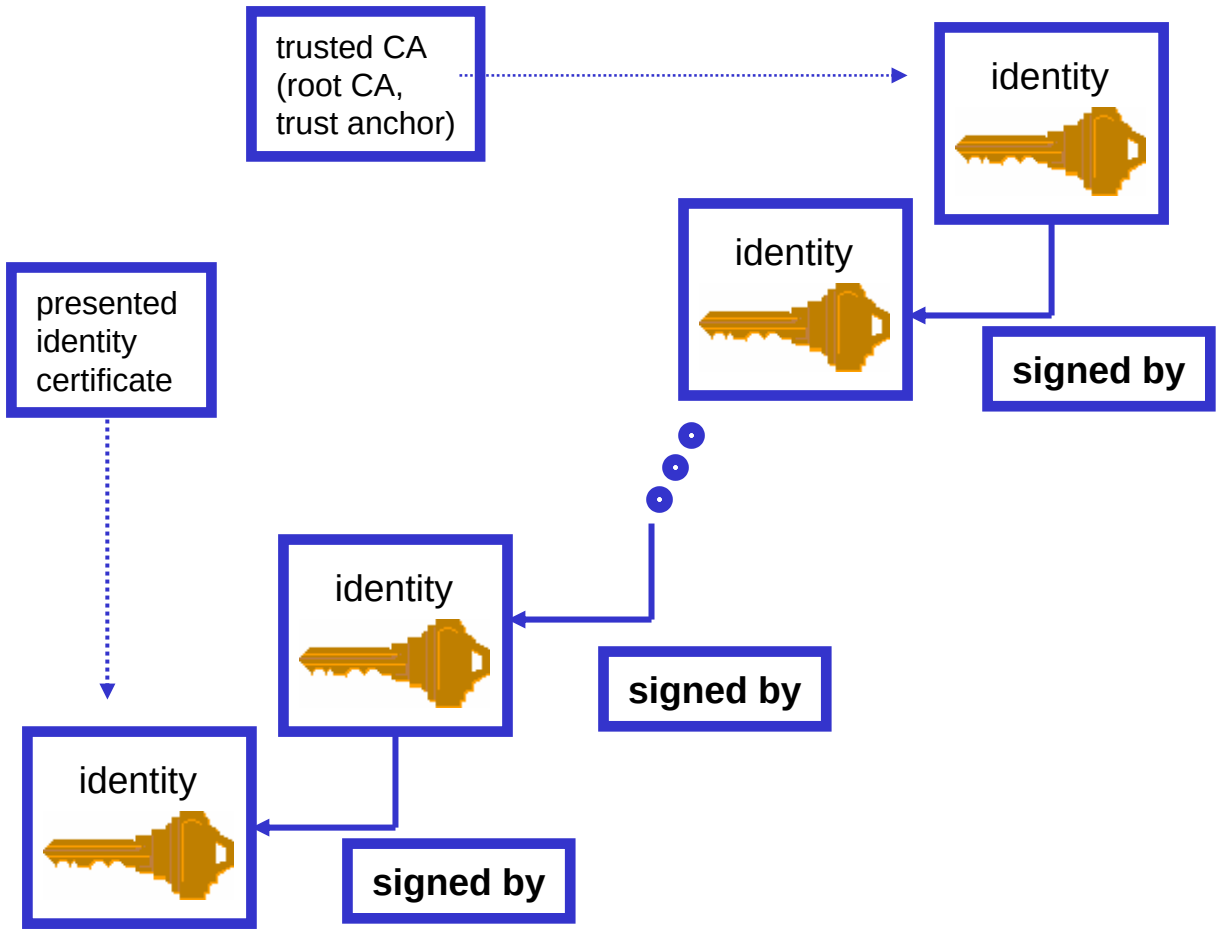


Certificates

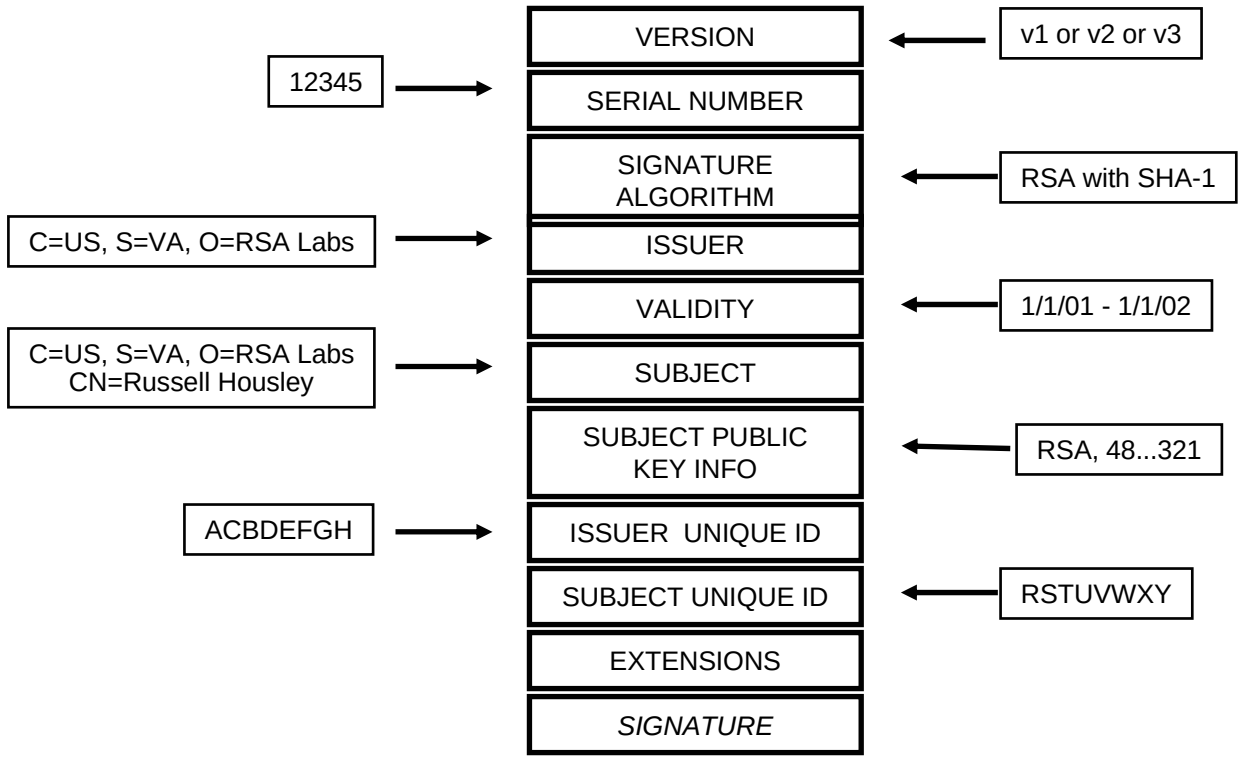


- the certificate
  - •contains an (identity,public key) pair
  - • is signed with the private key of the CA
- the repository
  - •need not be trusted
  - •is read-only
  - •may be duplicated for performance
- the certificate can be “pushed” to the relying party

Chain of Trust



X.509 Certificate Format



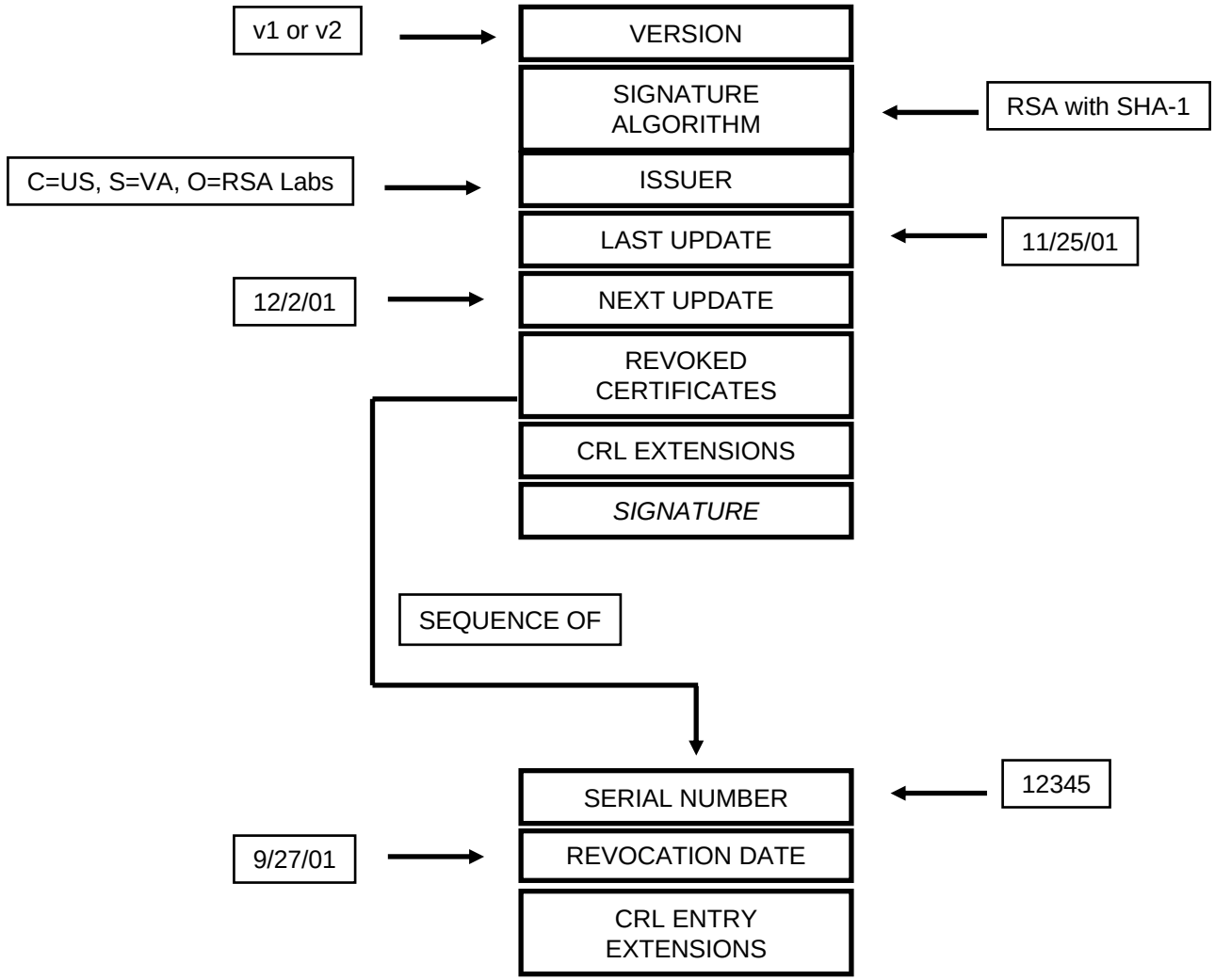
Example Certificate

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number: 1097588 (0x10bf74)
        Signature Algorithm: md5WithRSAEncryption
        Issuer: C=US, ST=Massachusetts, O=Massachusetts Institute of Technology, OU=Client CA v1
        Validity
            Not Before: Jul 31 14:07:49 2000 GMT
            Not After : Jul 31 14:07:49 2001 GMT
        Subject: C=US, ST=Massachusetts, O=Massachusetts Institute of Technology, OU=Client CA v1, CN=Jeffrey I Schiller/Email=jis@MIT.EDU
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
            RSA Public Key: (1024 bit)
                Modulus (1024 bit):
                    00:cf:01:0a:e5:f1:3c:60:c1:f2:c1:ca:99:96:1d:
                    7d:39:97:8c:72:cf:e8:7c:51:a1:84:a4:5b:b8:b3:
                    3a:dc:dd:c5:99:76:cb:5d:b1:24:86:67:46:52:45:
                    69:09:fb:01:b0:dd:41:02:de:27:c2:b7:cd:b1:cd:
                    47:9a:ae:55:bb:83:cd:bd:c1:aa:2b:23:3d:85:06:
                    e0:4a:6c:a8:af:b4:cb:64:ea:c9:33:f7:ef:a9:8f:
                    d9:7a:20:68:a1:09:c4:4e:62:20:00:d1:fd:a5:7c:
                    14:90:48:79:a9:7d:ef:f5:46:b6:fb:4e:c5:fc:94:
                    8f:11:bf:1a:ef:7b:2d:06:ef
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Key Usage:
                ....
            1.2.840.113554.1.3.1:
                0....]/e.ii;....m.....j....Nr....$wF..t...QZ...
    Signature Algorithm: md5WithRSAEncryption
        30:4c:3b:a5:d8:11:e1:04:61:d2:39:ff:e1:74:c3:06:2f:3b:
        52:59:9c:75:05:2e:31:cc:c3:99:5c:02:e5:67:bf:06:99:7f:
        c8:2a:5b:dd:bd:67:a5:a7:98:74:14:44:a7:db:76:19:9c:80:
        0a:58:1d:53:35:d0:75:82:9d:2a:e7:12:53:3f:8b:60:cc:a3:
        c9:5b:dd:34:b6:a4:33:a9:a5:93:64:3e:50:0d:e4:ae:a8:5d:
        c9:8d:f9:96:68:22:cd:66:3d:eb:66:11:68:04:f6:3d:64:05:
        62:64:01:41:af:23:f9:d2:a3:5b:be:e3:33:45:71:08:05:e2:
        2a:6e
```

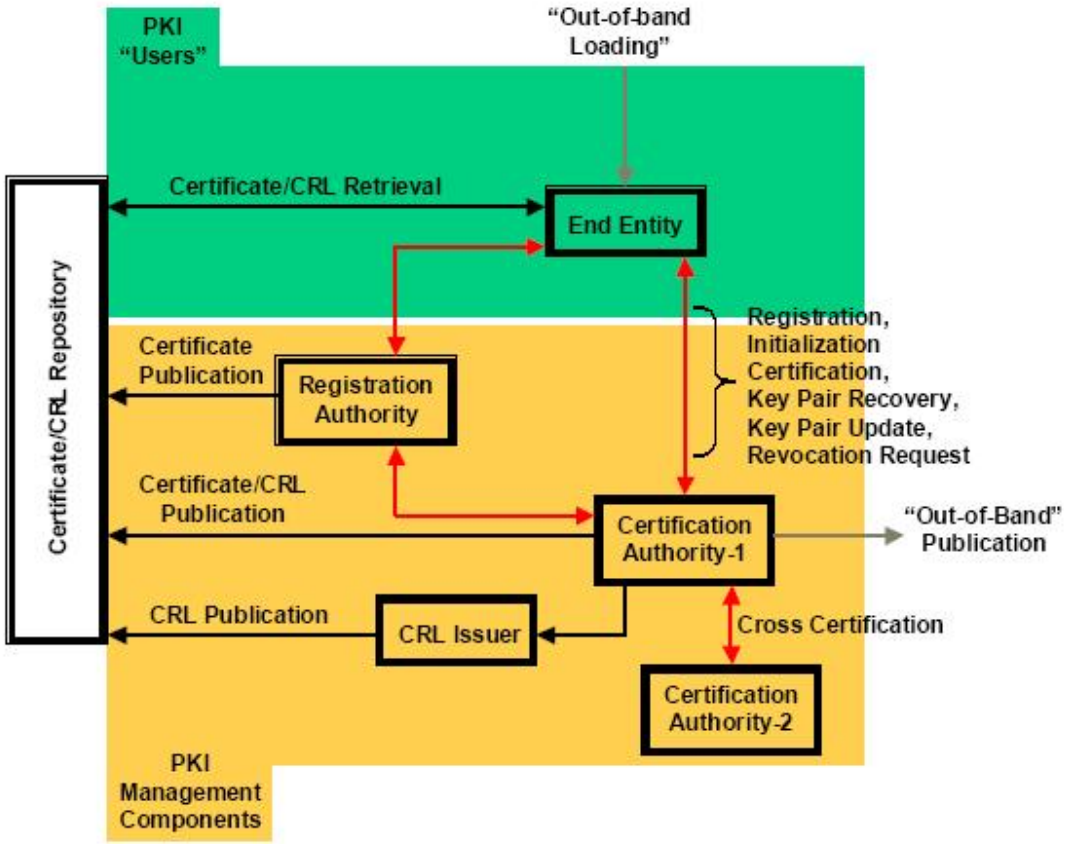
Revocation

- Is a certificate still valid?
  - Private key compromise
  - CA compromise
  - Affiliation changed
  - Superseded
  - CA ceased operation
  - …
- Certificate Revocation List (CRL) provides a list of the unexpired certificates that should no longer be used

CRL Format


v1 or v2
VERSION
SIGNATURE ALGORITHM
RSA with SHA-1
C=US, S=VA, O=RSA Labs
ISSUER
LAST UPDATE
11/25/01
12/2/01
NEXT UPDATE
REVOKED CERTIFICATES
CRL EXTENSIONS
SIGNATURE
SEQUENCE OF
SERIAL NUMBER
12345
9/27/01
REVOCATION DATE
CRL ENTRY EXTENSIONS

PKIX Architecture



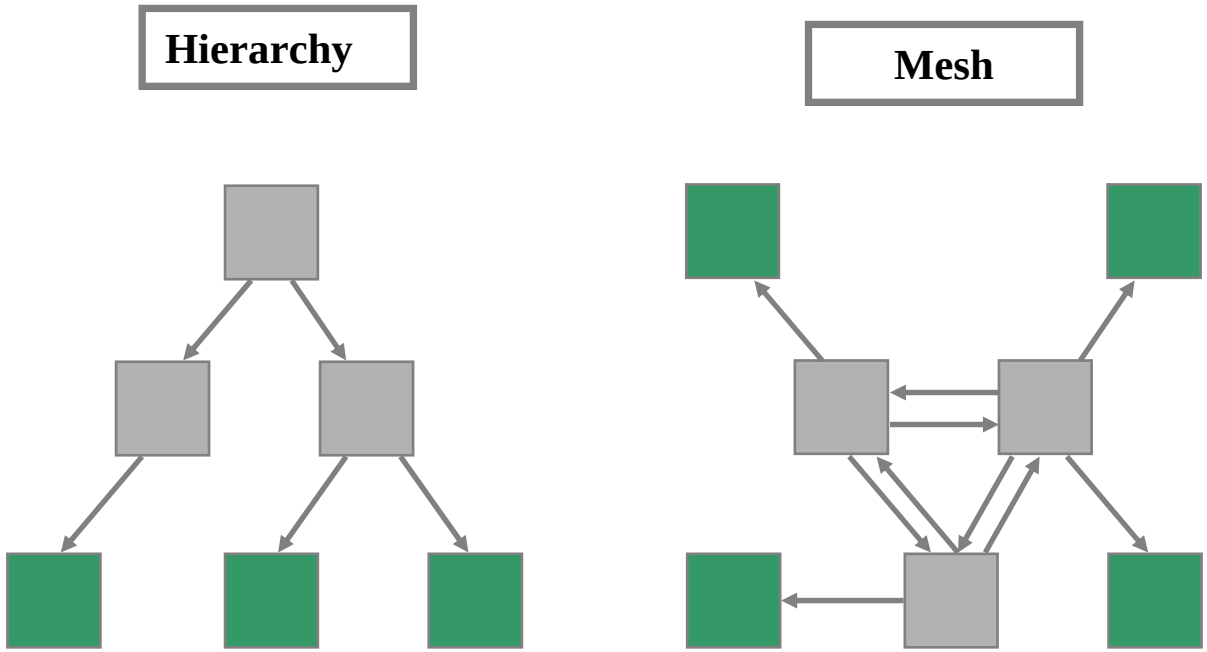
PKIX Elements

COMPONENT	PRIMARY ROLE
• End Entity	End Entity is a generic term used to denote end-users, devices (e.g., servers, routers), or any other entity that can be identified in the subject field of a public key certificate. End entities typically consume and/or support PKI-related services.
• Certification Authority (CA)	The CA is the issuer of certificates and (usually) CRLs. It may also support a variety of administrative functions, although these are often delegated to one or more Registration Authorities.
• Registration Authority (RA)	The RA is an optional component that can assume a number of administrative functions from the CA. The RA is often associated with the End Entity registration process, but can assist in a number of other areas as well.
• Repository	A repository is a generic term used to denote any method for storing certificates and CRLs so that they can be retrieved by End Entities.
• CRL Issuer	The CRL Issuer is an optional component that a CA can delegate to publish CRLs.

Role of the CA

- Verifies certificate request information
- Generates and digitally signs the certificate
- Revokes certificate if information changes
- Revokes certificate if private key is disclosed
- Support certificate hierarchies
- Optional services
  - Key generation
  - Issue hardware token

CA Topologies



Cross Certification