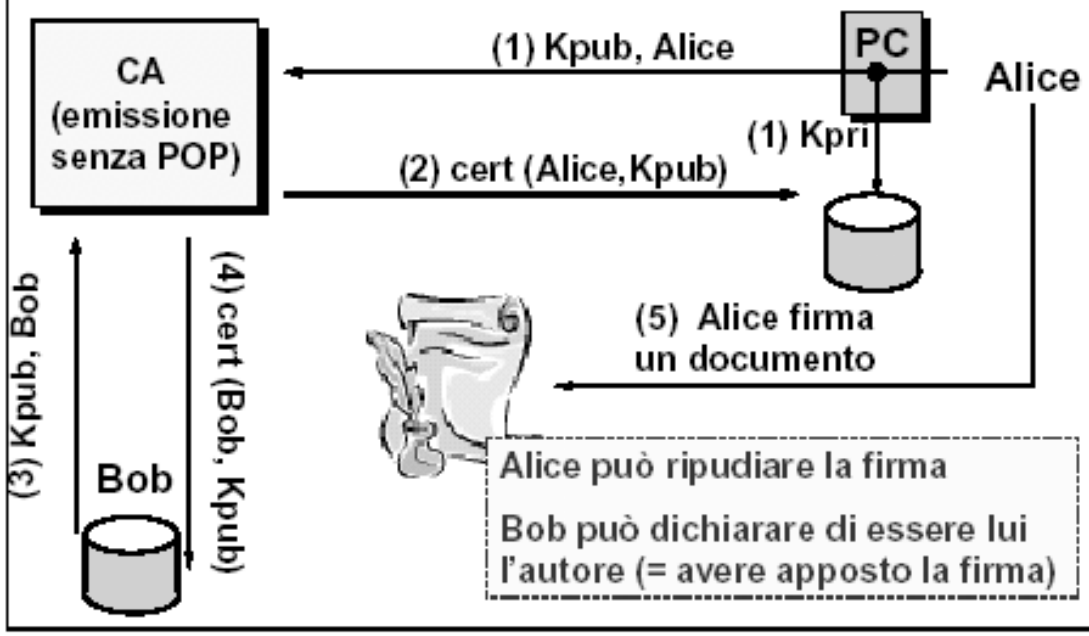
Proof-Of-Possession (POP)

- **POP = la CA ha sufficienti garanzie circa il possesso della chiave privata da parte dell'entità che richiede un certificato (il Subject)**
- **emissione di certificati senza POP può permettere vari attacchi**
  - situazione diversa a seconda dell'uso della chiave (POP fondamentale per garantire il non-ripudio)
  - POP non sempre critico nel caso di cifratura

Assenza di POP-possibili rischi



Contromisure

- **metodo migliore: POP a tempo di firma**
  - il firmatario inserisce un riferimento al certificato (es. un hash) tra le informazioni firmate
  - la firma è funzione quindi anche del certificato
  - attualmente non supportato dai protocolli di sicurezza
- **soluzione alternativa: la CA emette un certificato solo se ha la prova che il richiedente possiede la chiave privata**

Metodi per il POP (I)

- **metodi OOB**
  - chiavi generate da CA/RA e consegnate in token sicuri (es. smart-card, USB crypto-token); fa quindi fede il possesso del token
  - politiche di key-recovery/key-backup (molto rischioso!!!): la CA mantiene una copia di tutte le chiave private – come le protegge efficacemente?

Metodi per il POP (II)

- **metodi on-line**
  - per chiavi di firma e cifratura: possibile usare formati auto-firmati (PKCS-10, SPKAC): la CA verifica la firma ed ottiene il POP
  - per chiavi di cifratura (no firma)
    - utilizzo di protocolli challenge - response che comportino un'operazione di decifratura (=uso della chiave privata)
    - certificato restitituito in forma cifrata (successiva revoca se il certificato non è usato)

Standard Certificate Extensions (1.)

- *version 3 introduces a mechanism whereby certificates can be extended, in a standardized and generic fashion, to include additional information;*
- *certificates are not constrained to only the standard extensions and anyone can register an extension with the appropriate authorities (e.g., ISO);*
- *standard extensions for public key certificates can be separated into the following groups:*
  - *key information;*
  - *policy information;*
  - *user and CA attributes;*
  - *certification path constraints*

Standard Certificate Extensions (2.)

- ***authority key identifier****: specifies a unique identifier of the key pair used by the CA to sign the certificate;*
- ***subject key identifier****: serves much the same purpose as the authority key identifier;*
- ***key usage****: specifies the inetnded use(s) of the key. The following list represents the settings for the key usage field: certificate signing (e.g., a CA key pair), CRL signing, digital signature, symmetric key encryption for key transfer, data encryption (other than a symmetric key);*
- ***private key usage period****: specifies the date on which the signing private key expires for a user's digital signature key pair*

Standard Certificate Extensions (3.)

- ***subject alternative name****: specifies one or more unique names for the certificate subject; the permissible name forms are Internet e-mail address, Internet IP address, , web URL*
- *the policy information extensions provide a mechanism for the CA to distribute information regarding the ways a particular certificate should be used and interpreted;*
- ***certificate policies****: specifies the policies under which the certificate was issued to the user and/or the types of uses applicable to the certificate; certificate policies are represented by specially-formatted numbers, known as object identifiers;*

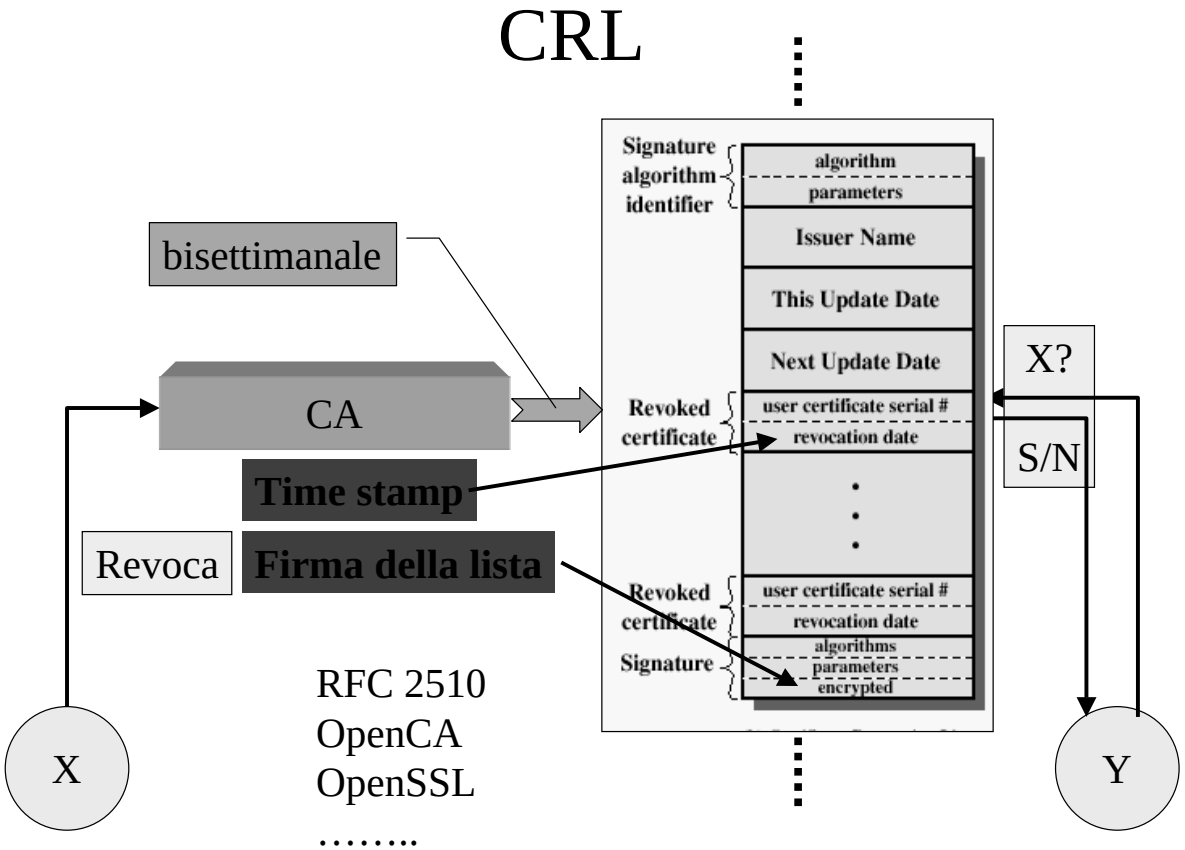
Modelli di Notifica di Revoca

- **pull method**
- **push model**
- **online status checking**

Schemi di Notifica della Revoca:

Schemi off-line:
Certificate Revocation List
Certification / Revocation System
Certificate Revocation Tree
…

Schemi on-line:
On-line Certificate Status Protocol



Estensioni delle CRL

- ***general extensions:*** *CRL number, reason code*

  - key compromise;

  - CA compromise;

  - affiliation change;

  -cessation of operation;

Come ridurre la dimensione delle CRL?

- **partizionamento delle CRL (usando opportunamente il CRLDP):**
  - cert con SN < 1000 hanno CRLDP= crl_1_1000.der
  - cert con 1000 < SN < 2000 hanno CRLDP= crl_1001_2000.der
- **usando deltaCRL**
  - una CRL base (n. N)
  - una o più delta CRL (differenza rispetto a N)

Gestione efficiente delle CRL

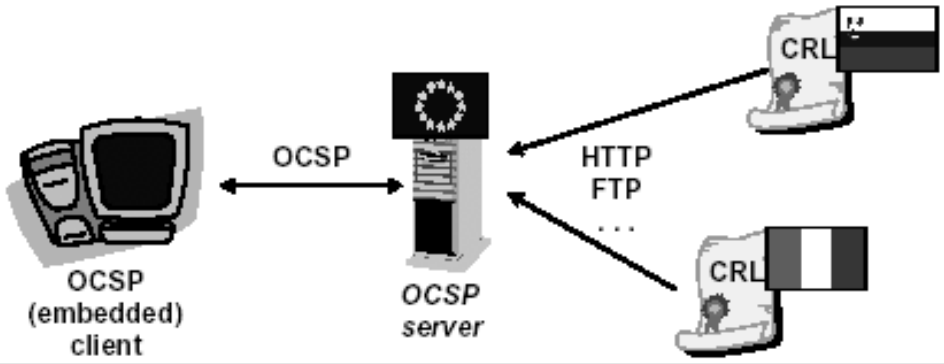
- **problema: le CRL possono diventare molto grosse e quindi onerose da scaricare e da esaminare**
- **varie soluzioni:**
  - eliminare la revoca dopo la prima CRL successiva alla scadenza del certificato
  - pubblicare CRL complete (Base CRL) e poi solo le differenze (Delta CRL)
  - partizionare le CRL in tanti gruppi (es. per ogni mille certificati emessi) usando CRL DP

OCSP

- **RFC-2560: On-line Certificate Status Protocol**
- **standard IETF-PKIX per verificare in linea se un certificato è valido:**
  - good
  - revoked
    - revocationTime
    - revocationReason
  - unknown
- **risposte firmate dal server (non dalla CA!)**
- **certificato del server non verificabile con OCSP!**

Architettura di OCSP

- **possibili risposte pre-calcolate**
  - diminuisce il carico sul server … ma rende possibili attacchi di tipo replay!
- **possibile attingere informazioni non da CRL**



Modelli di OCSP responder

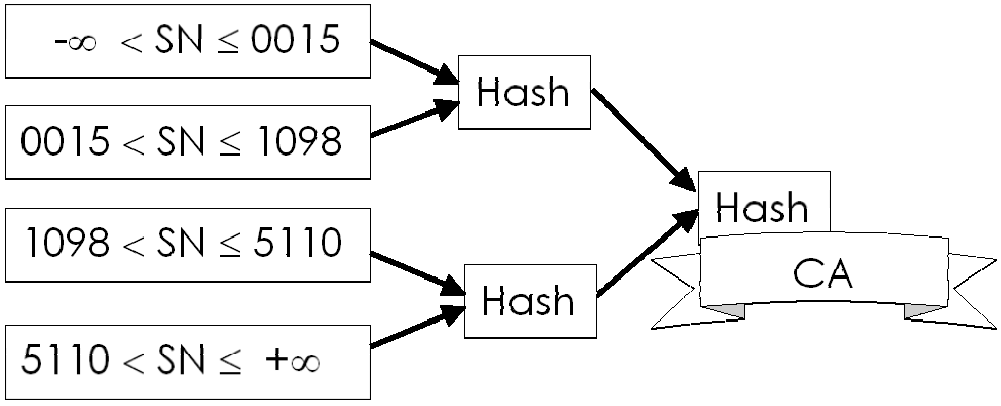
- **Trusted Responder**
  - il server OCSP firma le risposte con una coppia chiave:cert indipendente dalla CA per cui sta rispondendo
  - responder aziendale o TTP pagata dagli utenti
- **Delegated Responder**
  - il server OCSP firma le risposte con una coppia chiave:cert diversa in base alla CA per cui sta rispondendo
  - TTP pagata dalle CA

Certification/ Revocation System

Serial Number	Status
00000001	OK(SN,t,CA)
00000002	OK(SN,t,CA)
…	OK(…,…,…)
13434899	OK(SN,t,CA)
13434900	*REV(SN,CA)*
13434901	OK(SN,t,CA)
…	OK(…,…,…)

Certificates status at time *t*

Certificate Revocation Tree



Performance Evaluation Criteria

- Timeliness
- Involved computational load
- Communication traffic induced on the network

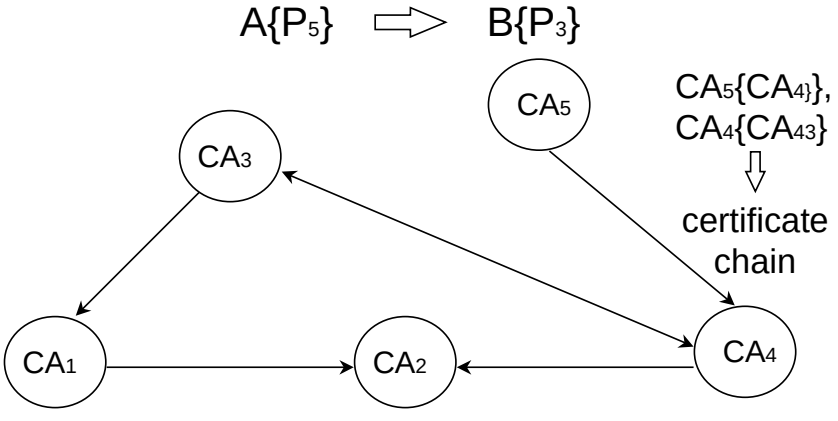
Parametro	Parole chiave	
Prestazioni	Lato Amministratore	Picco di Carico e Picco di Richiesta Carico Medio e Richiesta Media Distribuzione del Carico Ritardo Dimensioni
	Lato Utente	Dimensioni Ritardo Massimo Carico Computazionale Banda
Tempestività		Tempo Massimo tra revoca e distribuzione
Scalabilità	Lato Amministratore	Complessità dello schema
Sicurezza		Autenticità Integrità Confidenzialità Non-Ripudio
Standard		Standard Proprietario Teorico Implementato
Espressività		Granularità dell'informazione di revoca
Gestione dello schema	Lato Amministratore	Automatizzato Archiviazione sicura Complessità
On-line vs. Off-line	Lato Amministratore	Frequenza delle connessioni

Problemi di PKI

- RA sempre disponibile
- CA rapida anche nella gestione della CRL
- Collo di bottiglia (n° max di utenti)
- Ente degno di fiducia
- Interrogazione della CRL
- Vita della chiave di firma

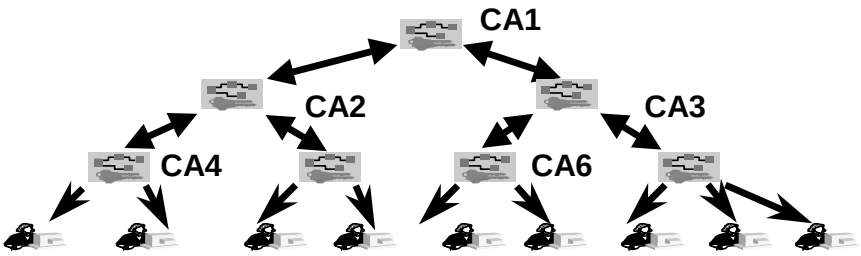
Trust Models

certificate chains and certification paths:



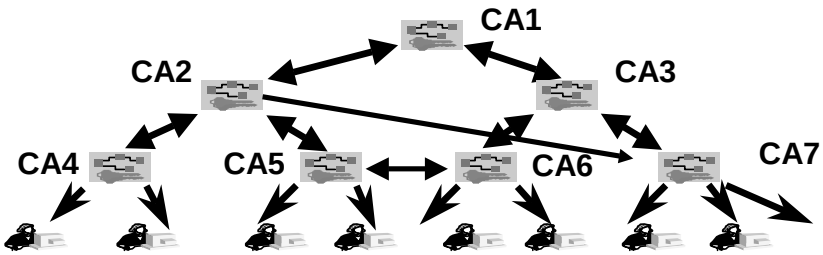
- ***centralized*** trust model;
- ***distributed*** trust model

General Hierarchical Structure



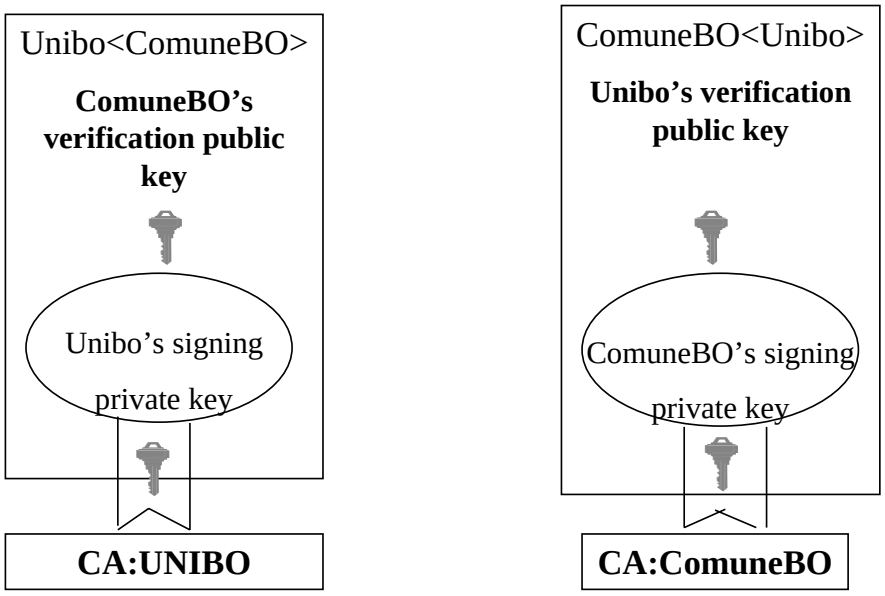
- *it is easy to construct a certification path between any pair of end-entities, regardless of how each end-entity determines which CA it is prepared to accept as root CA;*
- *this model scales reasonably well; provides means for constructing reasonably short certification paths;*
- *complicating factor is trust*

General Hierarchical Structure with additional links

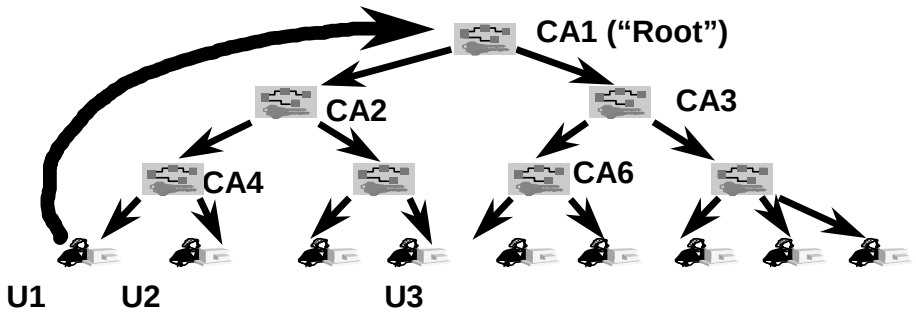


- *added links are called cross-certificates*

Cross-Certificates



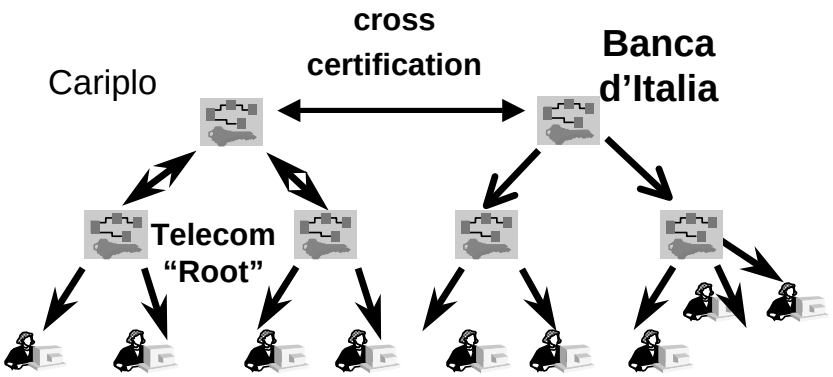
Top-down Hierarchical Structure



Drawbacks:

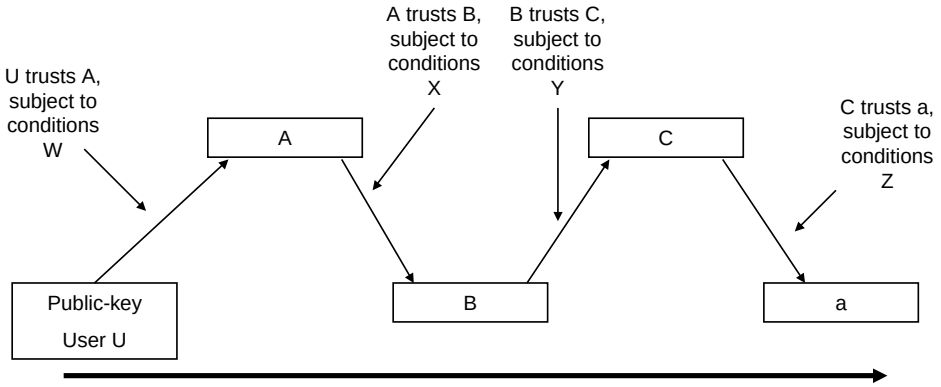
- all trust depends on the root key;
- certificate chains also for two entities on the same CA;
- certificate chains long in deep hierarchies.

Distributed Trust Model



Trust is rooted at the CA close to the end users

Progressive-Constraint Trust Model



X.509 Certificate Policies

- ***certificate policy:*** *a named set of rules that indicates the applicability of a certificate to a particular community and/or class of application with common security requirements;*
- ***policy mapping:*** *only applies to cross-certificates; provides a mechanism for the signing CA to map its policies to the policies of the CA specified in the cross-certificate*
- ***policy constraints:*** *it is used in cross-certificatesthe administrator can specify the set of acceptable policies in a certificate chain extending from a cross-certificate; can specify whether or not all certificates in a chain must meet a specific policy;*
- ….…

Certification Path Discovery

- *the certification path discovery problem is as follows: I need to find a certification path between a particular remote user's public key and any one of the set of root public key that I already know securely*
- *given a CA's name, a service to retrieve certificates for that CA's public keys issued by other Cas, it is possible to find a certification path by working back progressively from the target user's certificate toward a root key, as follows:*
  - ***step 1****: given a certificate issued by CA X, determine the set of Cas that have issued certificates for the public key of X;*
  - ***step 2:*** *if one of the CAs from the Step 1 is a known root authority, the required certification path is found, otherwise proceed to Step3;*
  - ***step 3:*** *for each CA found in Step 1, repeat the Step 1 procedure, treating that CA as CA X*

Certification Path Validation

- *given that a suitable certification path has been found, it is then necessary to validate that path. This involves such actions as:*
  - *verifying the digital signature on each certificate;*
  - *checking that the names in the certificates are consistent with a valid certification path, that is, the subject of every certificate is the issuer of the next certificate;*
  - *checking that the validity periods of all certificates correctly span the time for which validity is being checked;*
  - *checking that each certificate has not been revoked. This may be a complex process;*
  - *checking that the required certificate policies are indicated in the certificates;*