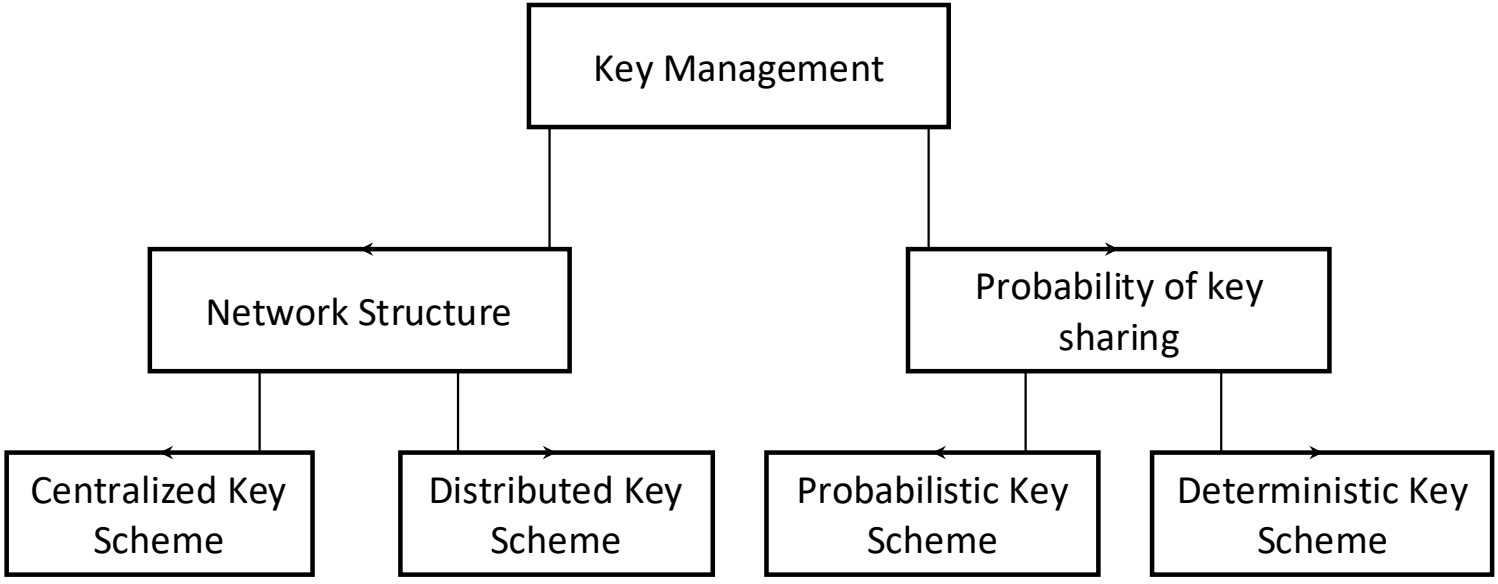
Key Management

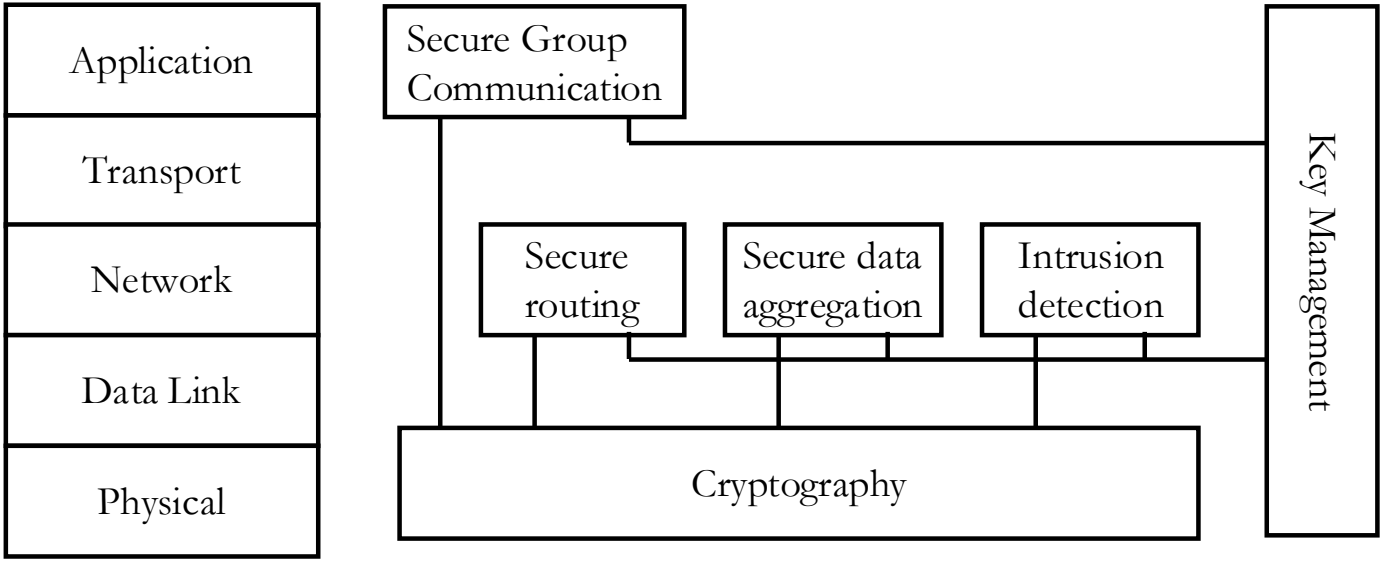
Key Management

- Key management, generation, distribution, revocation of cryptographic keys
  - Key distribution, establish required keys
  - Key revocation, remove keys which are known to be compromised
    - usually a challenging issue
- Scalability is a key concern

Key Management Protocols Classification



Key Management is a Fundamental Issue



Key Management and Distribution

- topics of cryptographic key management / key distribution are complex
  - cryptographic, protocol, & management issues
- symmetric schemes require both parties to share a common secret key
- public key schemes require parties to acquire valid public keys
- have concerns with doing both

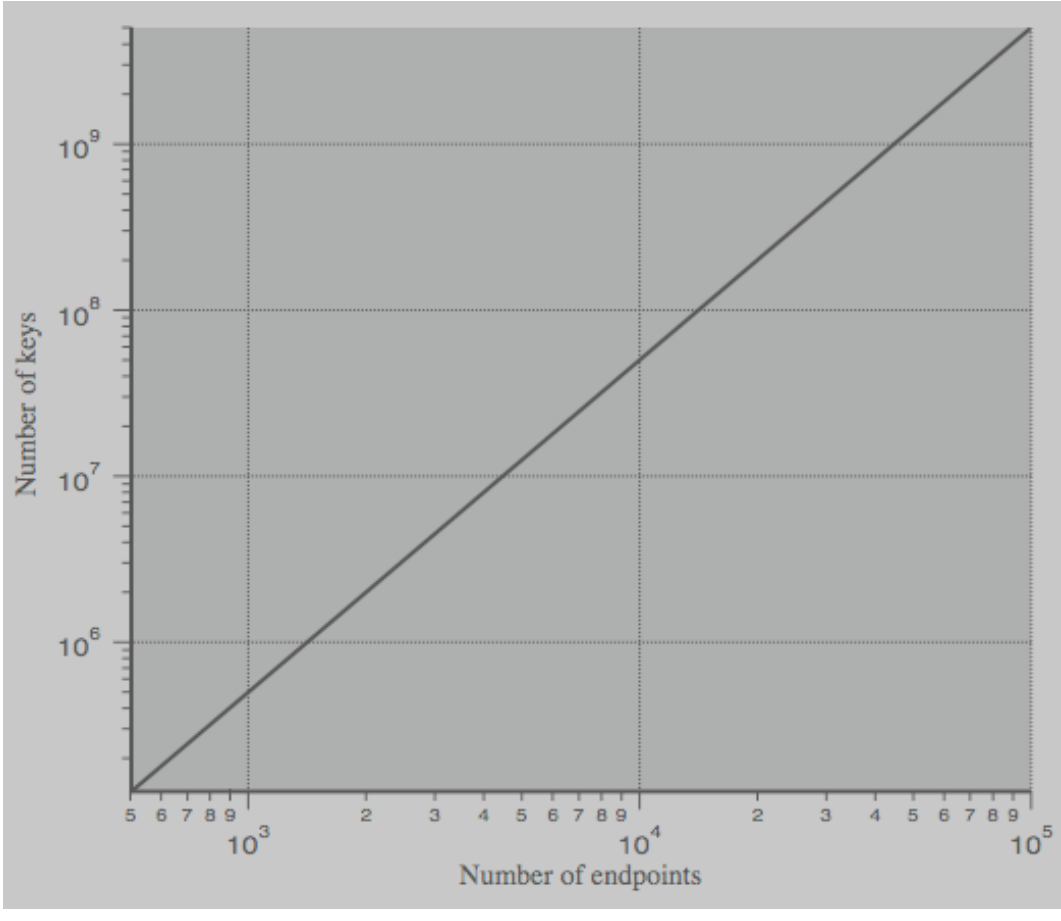
Key Distribution

- symmetric schemes require both parties to share a common secret key
- issue is how to securely distribute this key
- whilst protecting it from others
- frequent key changes can be desirable
- often secure system failure due to a break in the key distribution scheme

Key Distribution

- given parties A and B have various **key distribution** alternatives:
  1. A can select key and physically deliver to B
  2. third party can select & deliver key to A & B
  3. if A & B have communicated previously can use previous key to encrypt a new key
  4. if A & B have secure communications with a third party C, C can relay key between A & B

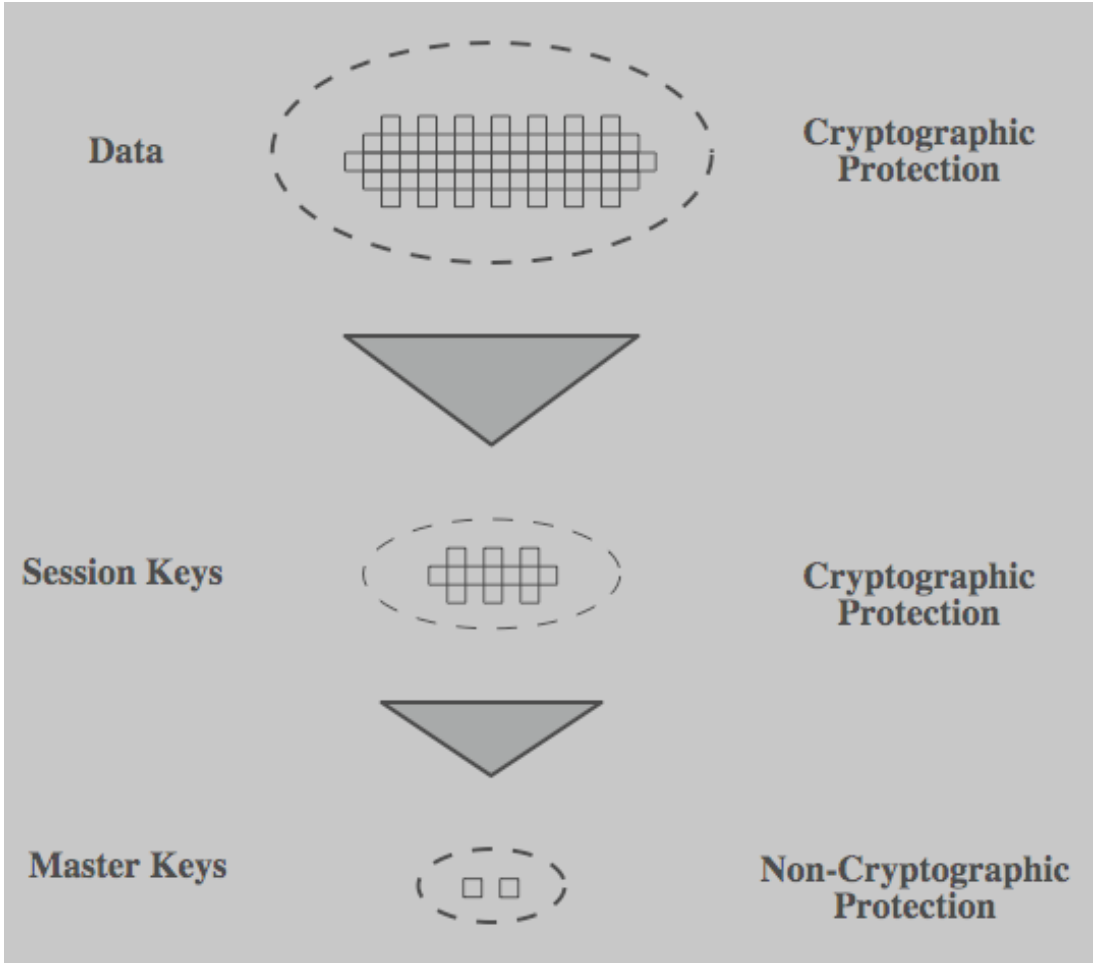
Key Distribution Task



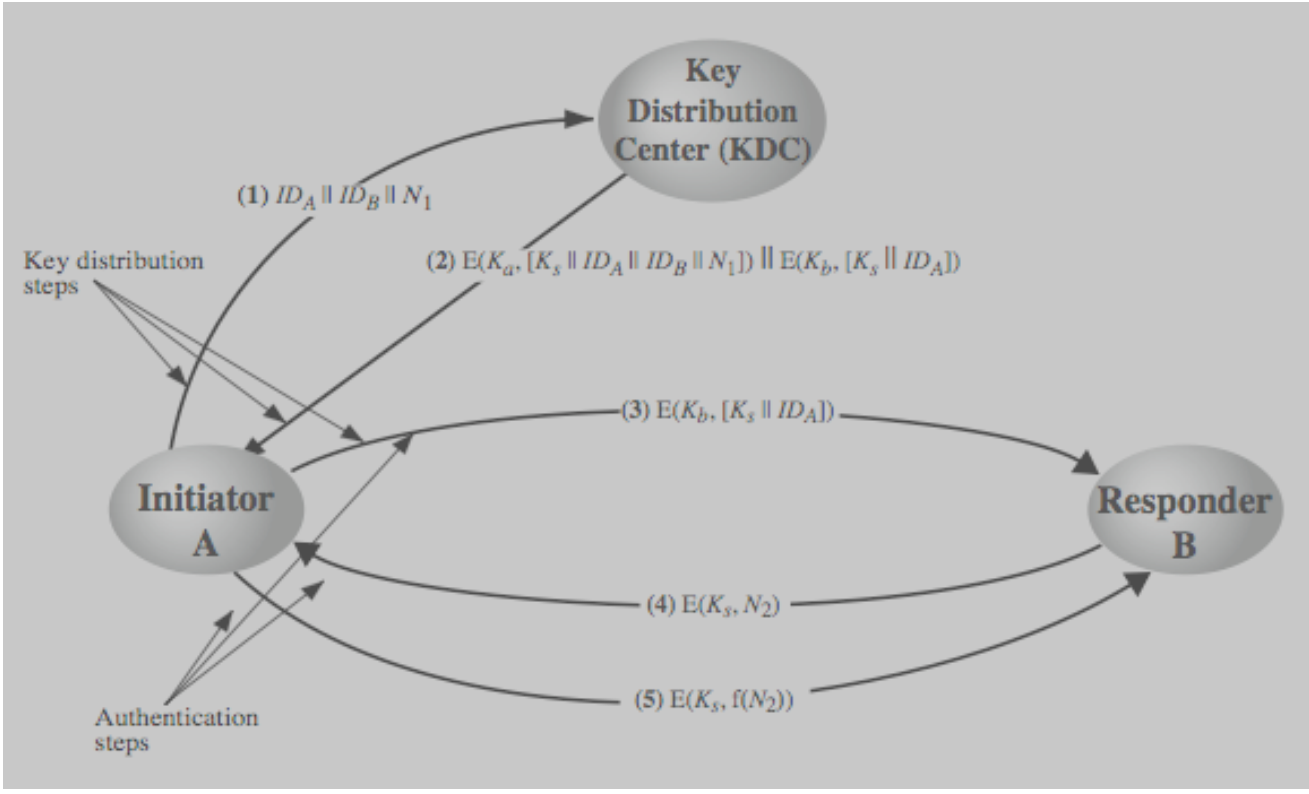
Key Hierarchy

- typically have a hierarchy of keys
- session key
  - temporary key
  - used for encryption of data between users
  - for one logical session then discarded
- master key
  - used to encrypt session keys
  - shared by user & key distribution center

Key Hierarchy



Key Distribution Scenario



Key Distribution Issues

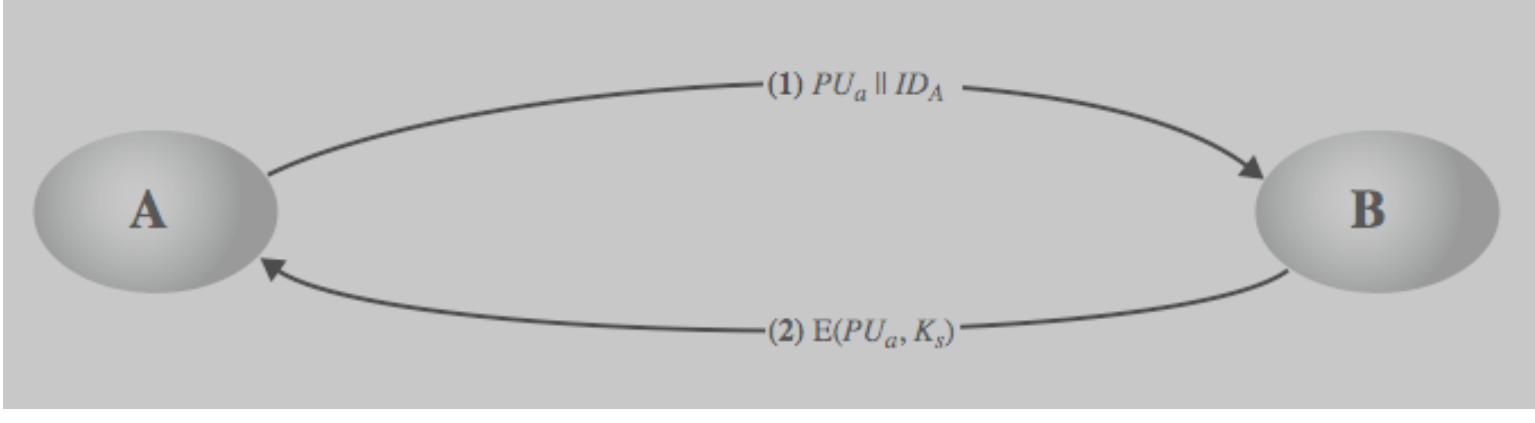
- hierarchies of KDC's required for large networks, but must trust each other
- session key lifetimes should be limited for greater security
- use of automatic key distribution on behalf of users, but must trust system
- use of decentralized key distribution
- controlling key usage

Symmetric Key Distribution Using Public Keys

- public key cryptosystems are inefficient
  - so almost never use for direct data encryption
  - rather use to encrypt secret keys for distribution

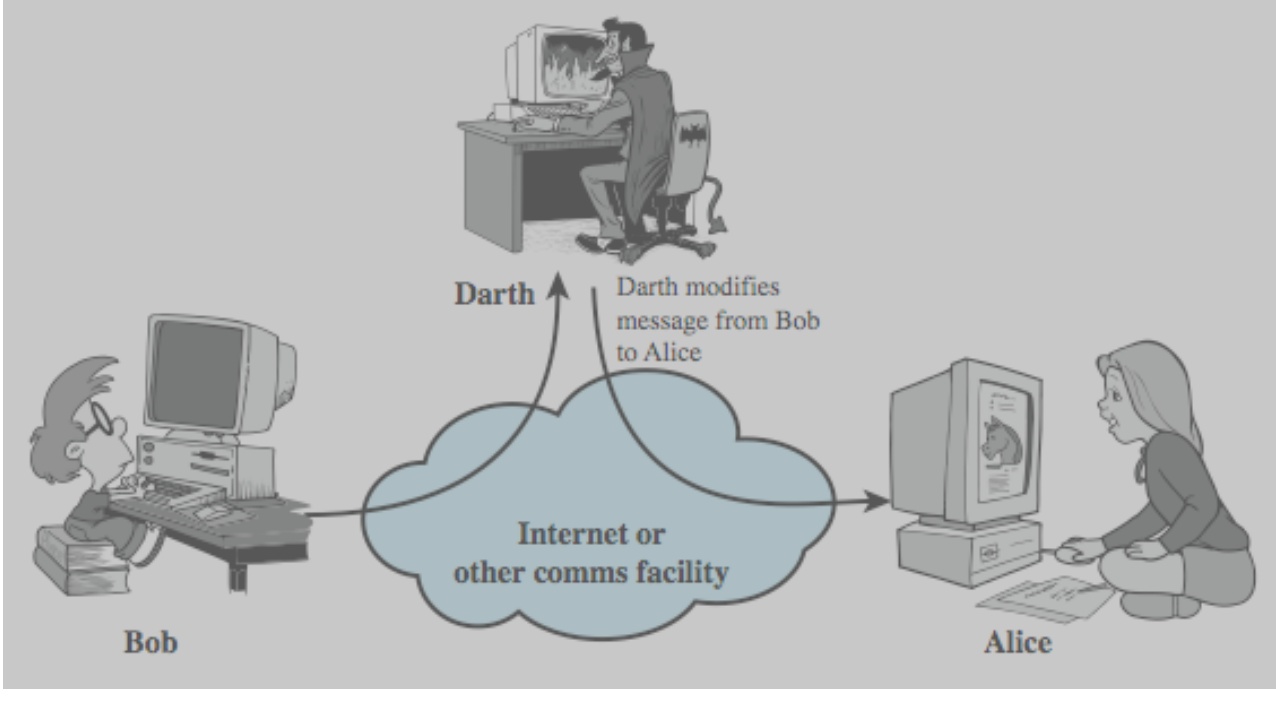
Simple Secret Key Distribution

- Merkle proposed this very simple scheme
  - allows secure communications
  - no keys before/after exist

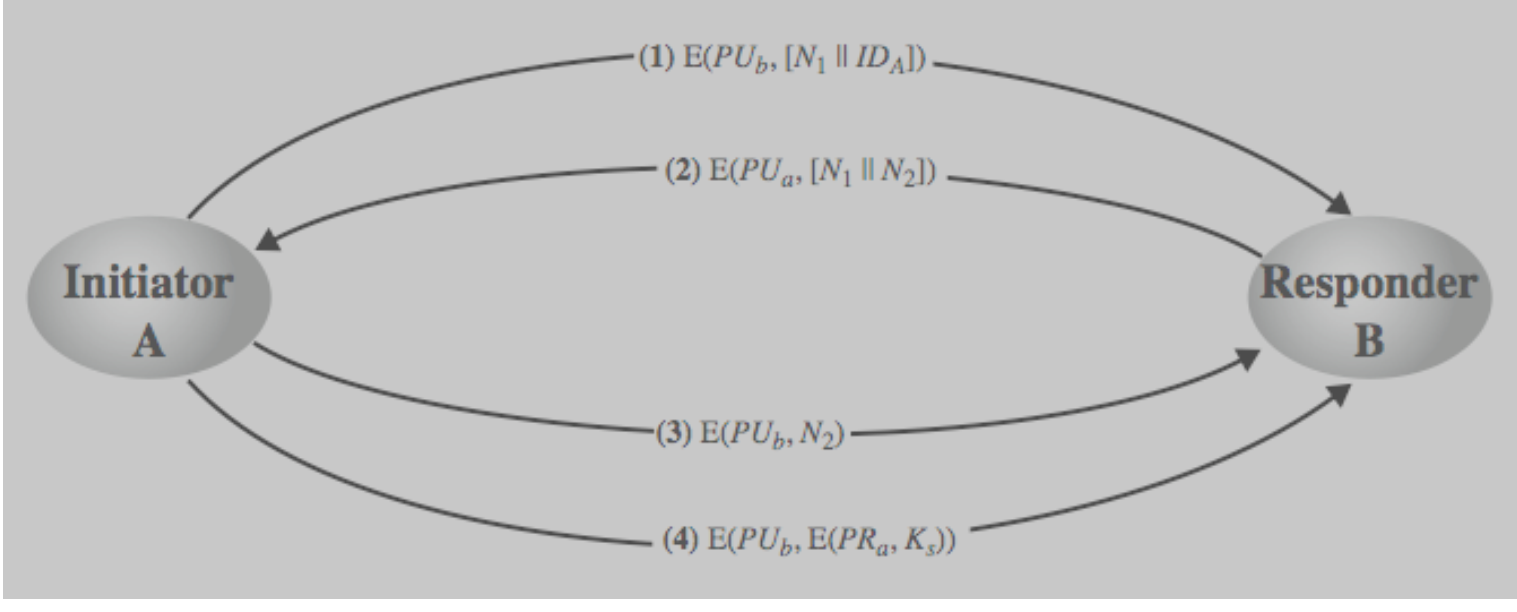


Man-in-the-Middle Attack

- this very simple scheme is vulnerable to an active man-in-the-middle attack



Secret Key Distribution with Confidentiality and Authentication



Hybrid Key Distribution

- retain use of private-key KDC
- shares secret master key with each user
- distributes session key using master key
- public-key used to distribute master keys
  - especially useful with widely distributed users
- rationale
  - performance
  - backward compatibility

Distribution of Public Keys

- can be considered as using one of:
  - public announcement
  - publicly available directory
  - public-key authority
  - public-key certificates

Public Announcement

- users distribute public keys to recipients or broadcast to community at large
  - eg. append PGP keys to email messages or post to news groups or email list
- major weakness is forgery
  - anyone can create a key claiming to be someone else and broadcast it
  - until forgery is discovered can masquerade as claimed user

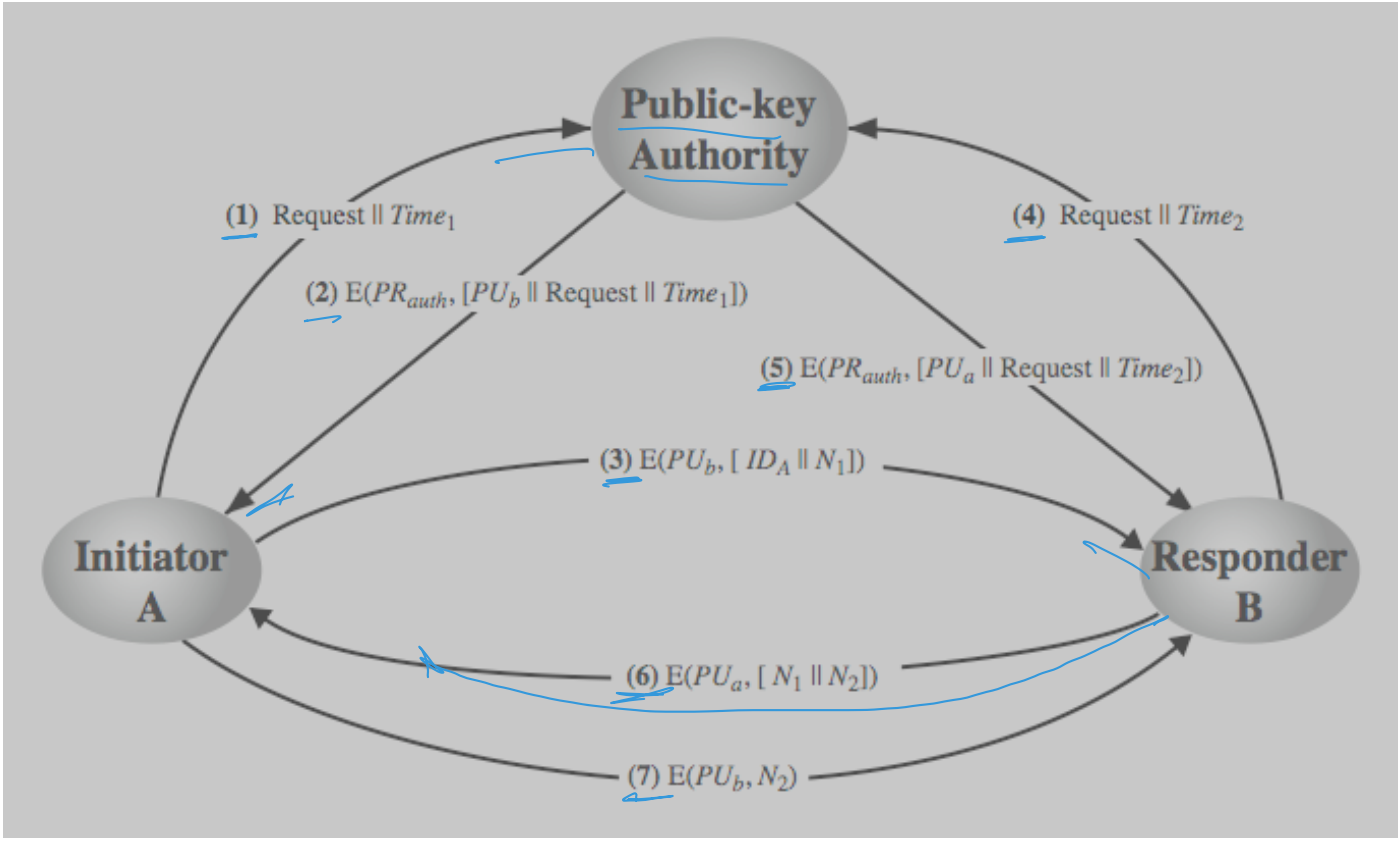
Publicly Available Directory

- can obtain greater security by registering keys with a public directory
- directory must be trusted with properties:
  - contains {name,public-key} entries
  - participants register securely with directory
  - participants can replace key at any time
  - directory is periodically published
  - directory can be accessed electronically
- still vulnerable to tampering or forgery

Public-Key Authority

- improve security by tightening control over distribution of keys from directory
- has properties of directory
- and requires users to know public key for the directory
- then users interact with directory to obtain any desired public key securely
  - does require real-time access to directory when keys are needed
  - may be vulnerable to tampering

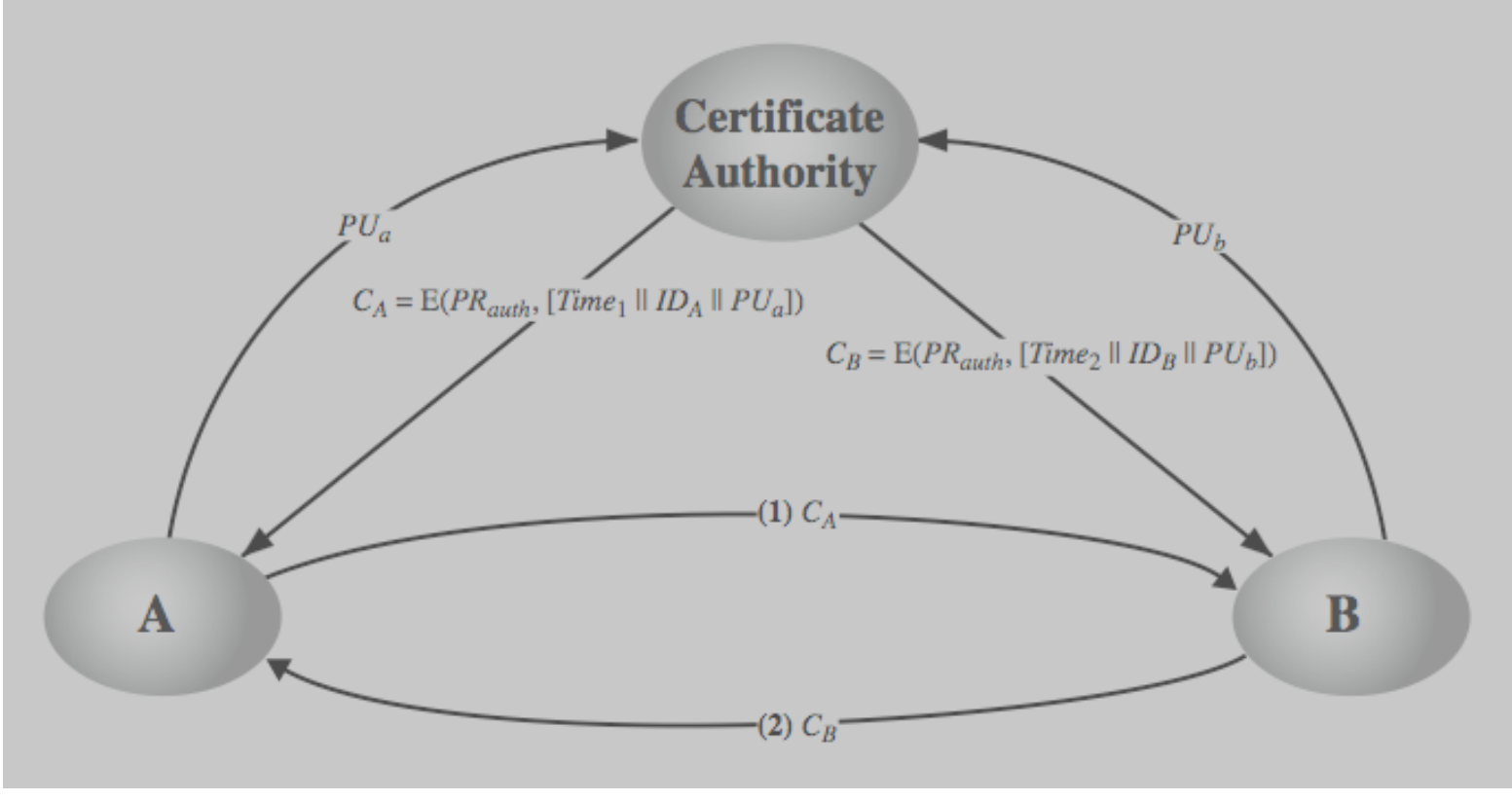
Public-Key Authority



Public-Key Certificates

- certificates allow key exchange without real-time access to public-key authority
- a certificate binds **identity** to **public key**
  - usually with other info such as period of validity, rights of use etc
- with all contents **signed** by a trusted Public-Key or Certificate Authority (CA)
- can be verified by anyone who knows the public-key authorities public-key

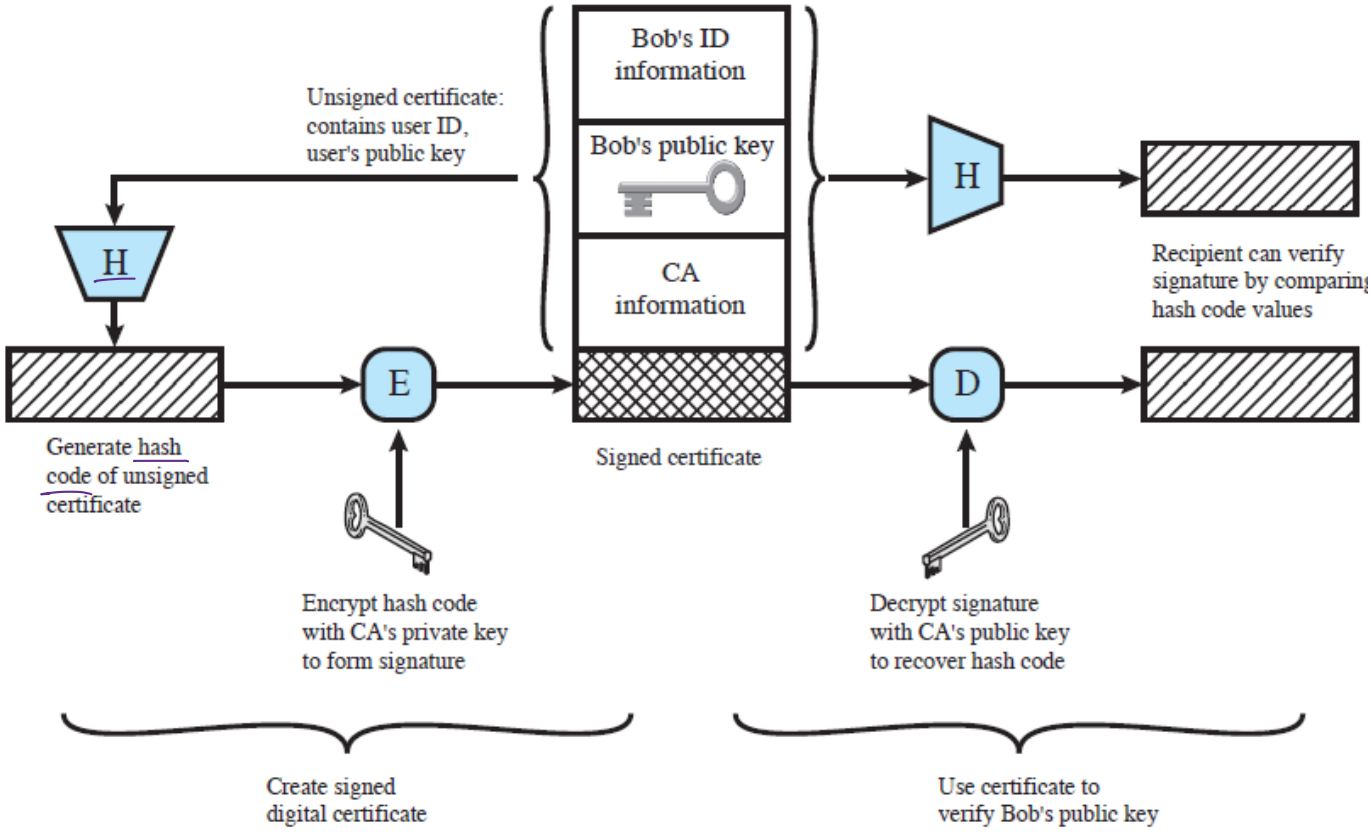
Public-Key Certificates



X.509 Authentication Service

- part of CCITT X.500 directory service standards
  - distributed servers maintaining user info database
- defines framework for authentication services
  - directory may store public-key certificates
  - with public key of user signed by certification authority
- also defines authentication protocols
- uses public-key crypto & digital signatures
  - algorithms not standardised, but RSA recommended
- X.509 certificates are widely used
  - have 3 versions

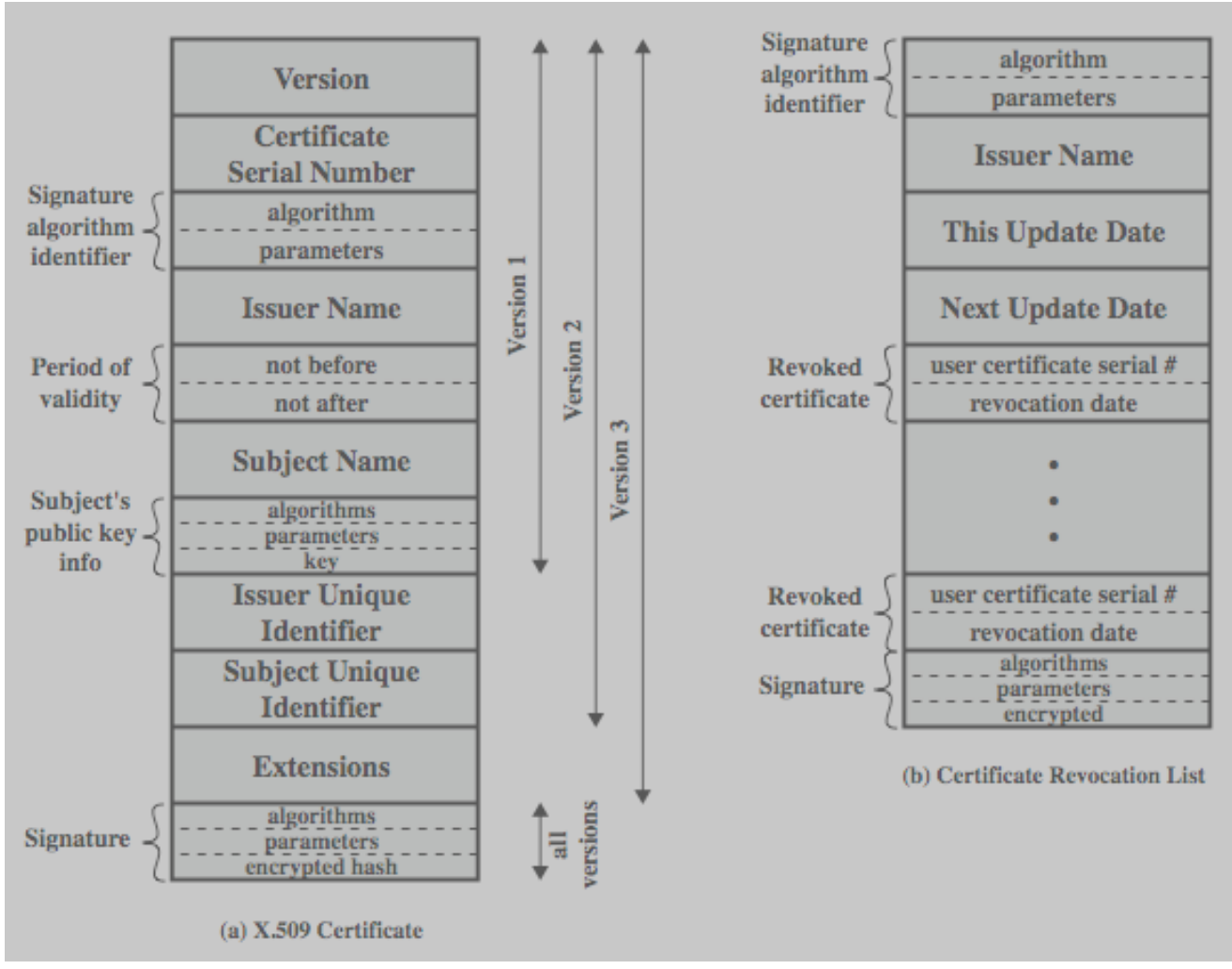
X.509 Certificate Use



X.509 Certificates

- issued by a Certification Authority (CA), containing:
  - version V (1, 2, or 3)
  - serial number SN (unique within CA) identifying certificate
  - signature algorithm identifier AI
  - issuer X.500 name CA)
  - period of validity TA (from - to dates)
  - subject X.500 name A (name of owner)
  - subject public-key info Ap (algorithm, parameters, key)
  - issuer unique identifier (v2+)
  - subject unique identifier (v2+)
  - extension fields (v3)
  - signature (of hash of all fields in certificate)
- notation $CA\langle\langle A\rangle\rangle$ denotes certificate for A signed by CA

X.509 Certificates



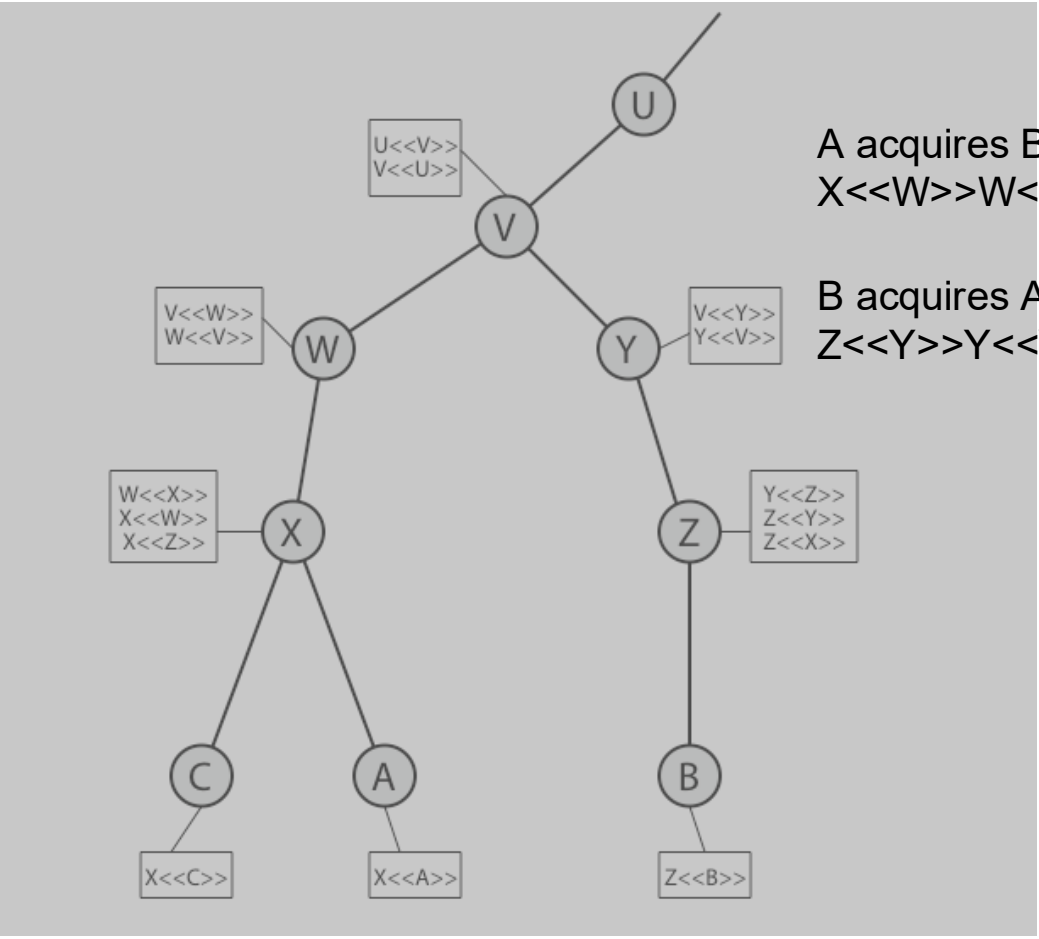
Obtaining a Certificate

- any user with access to CA can get any certificate from it
- only the CA can modify a certificate
- because cannot be forged, certificates can be placed in a public directory

CA Hierarchy

- if both users share a common CA then they are assumed to know its public key
- otherwise CA's must form a hierarchy
- use certificates linking members of hierarchy to validate other CA's
  - each CA has certificates for clients (forward) and parent (backward)
- each client trusts parents certificates
- enable verification of any certificate from one CA by users of all other CAs in hierarchy

CA Hierarchy Use



A acquires B certificate using chain:
X<<W>>W<<V>>V<<Y>>Y<<Z>>Z<<B>>

B acquires A certificate using chain:
Z<<Y>>Y<<V>>V<<W>>W<<X>>X<<A>>

Certificate Revocation

- certificates have a period of validity
- may need to revoke before expiry, eg:
  1. user's private key is compromised
  2. user is no longer certified by this CA
  3. CA's certificate is compromised
- CA’s maintain list of revoked certificates
  - the Certificate Revocation List (CRL)
- users should check certificates with CA’s CRL

X.509 Version 3

- has been recognised that additional information is needed in a certificate
  - email/URL, policy details, usage constraints
- rather than explicitly naming new fields defined a general extension method
- extensions consist of:
  - extension identifier
  - criticality indicator
  - extension value

Certificate Extensions

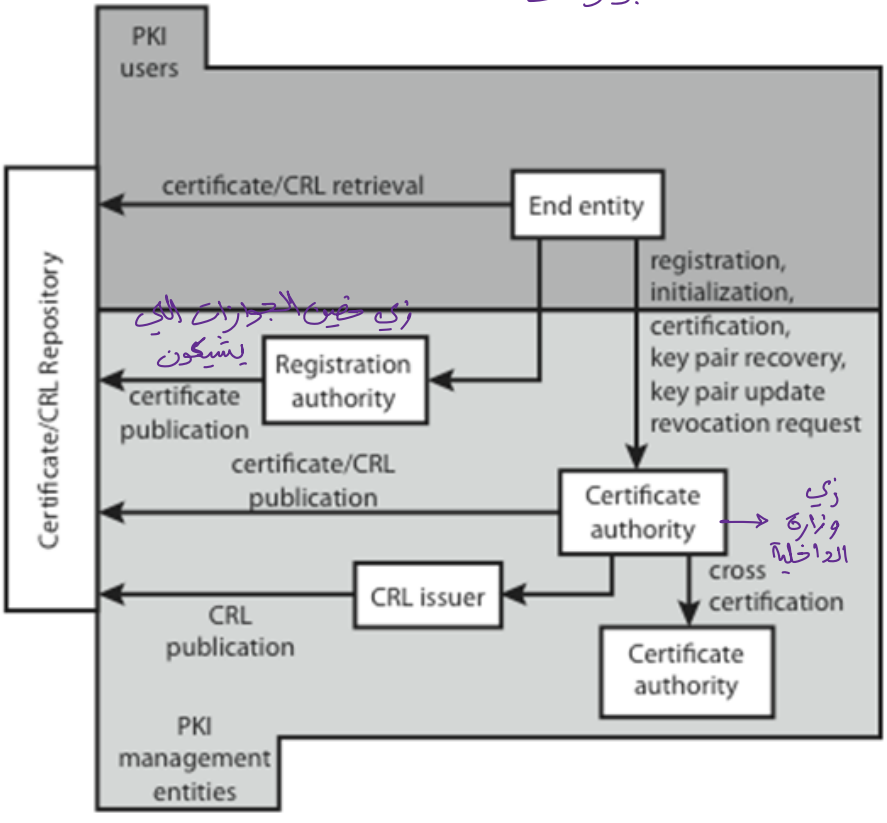
- key and policy information
  - convey info about subject & issuer keys, plus indicators of certificate policy
- certificate subject and issuer attributes
  - support alternative names, in alternative formats for certificate subject and/or issuer
- certificate path constraints
  - allow constraints on use of certificates by other CA's

Public Key Infrastructure (PKI)

- PKI is an Infrastructure to support and manage Public Key-based Digital Certificates
  - X.509 PKI
  - X.509 Digital Certificates
- Standards defined by IETF, PKIX WG: http://www.ietf.org/

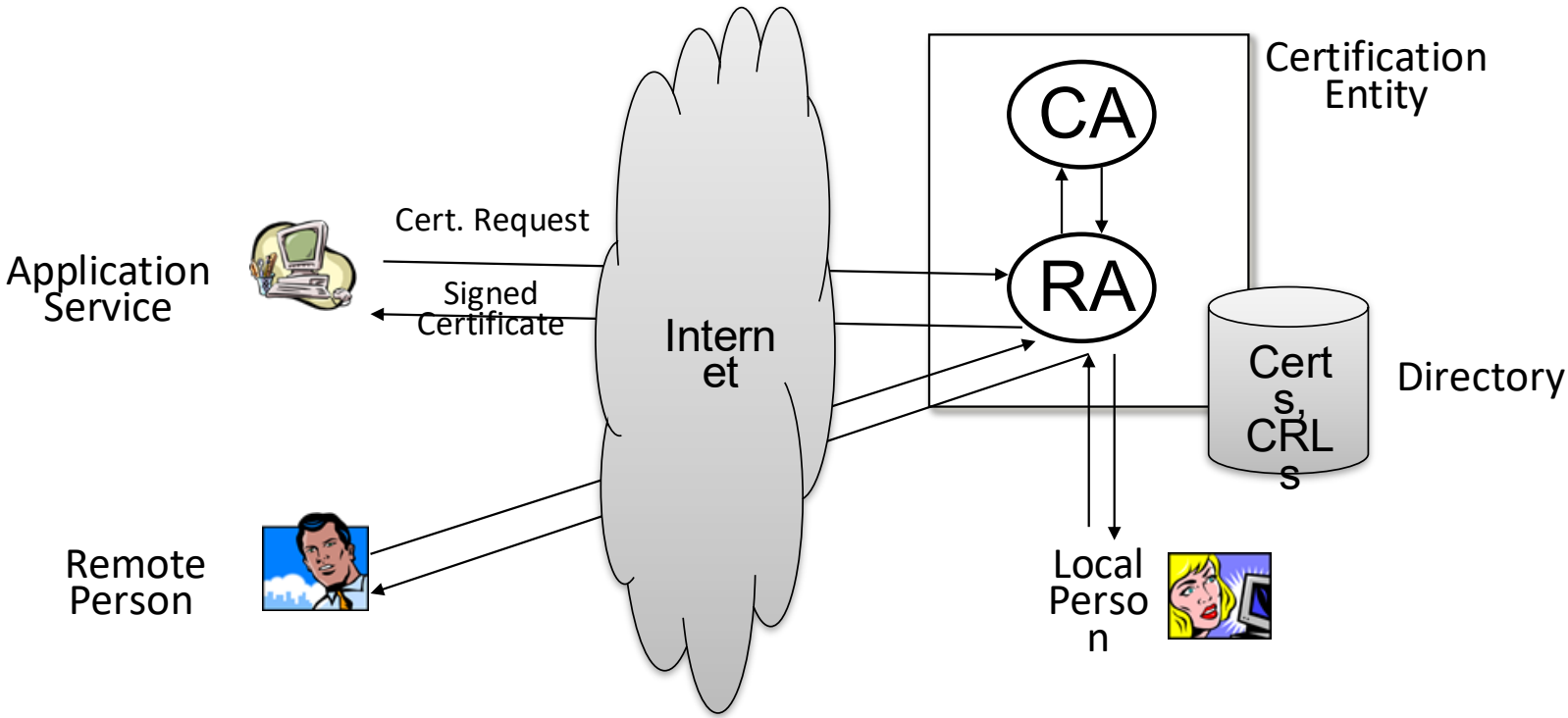
Public Key Infrastructure

مثال الجوازات



- Provider side
  - Certificate Authority (CA)
  - Registration Authority (RA)
  - Certificate Distribution System
- Consumer side
  - PKI enabled applications

X.509 PKI Simple Model



X.509 PKI Certificate Authority (CA)

- Basic Tasks
  - Key Generation
  - Digital Certificate Generation
  - Certificate Issuance and Distribution
  - Revocation
  - Key Backup and Recovery System
  - Cross-Certification

X.509 PKI Registration Authority (RA)

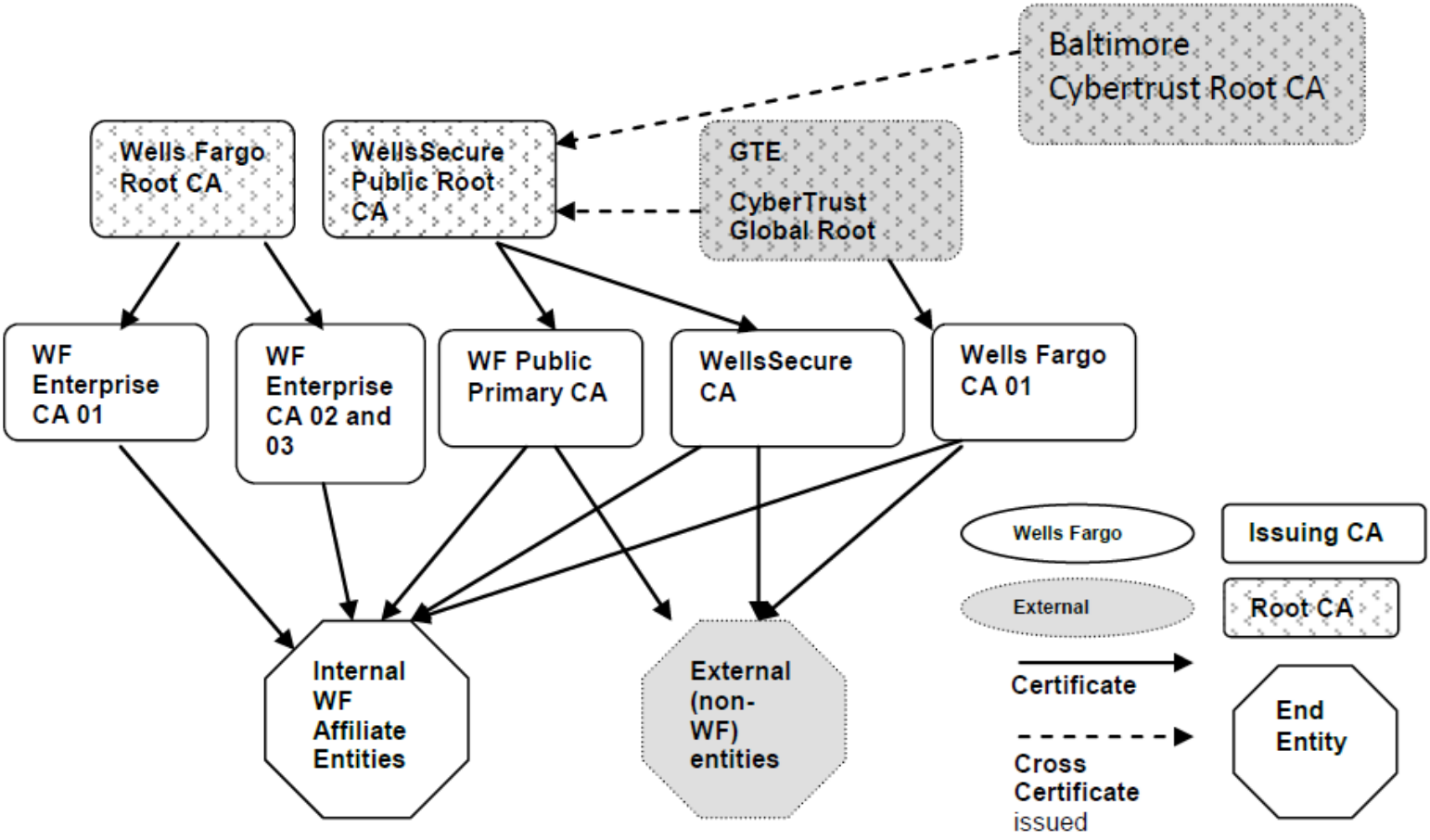
- Basic Tasks:
  - Registration of Certificate Information
  - Face-to-Face Registration
  - Remote Registration
  - Automatic Registration
  - Revocation

X.509 PKI Certificate Distribution System

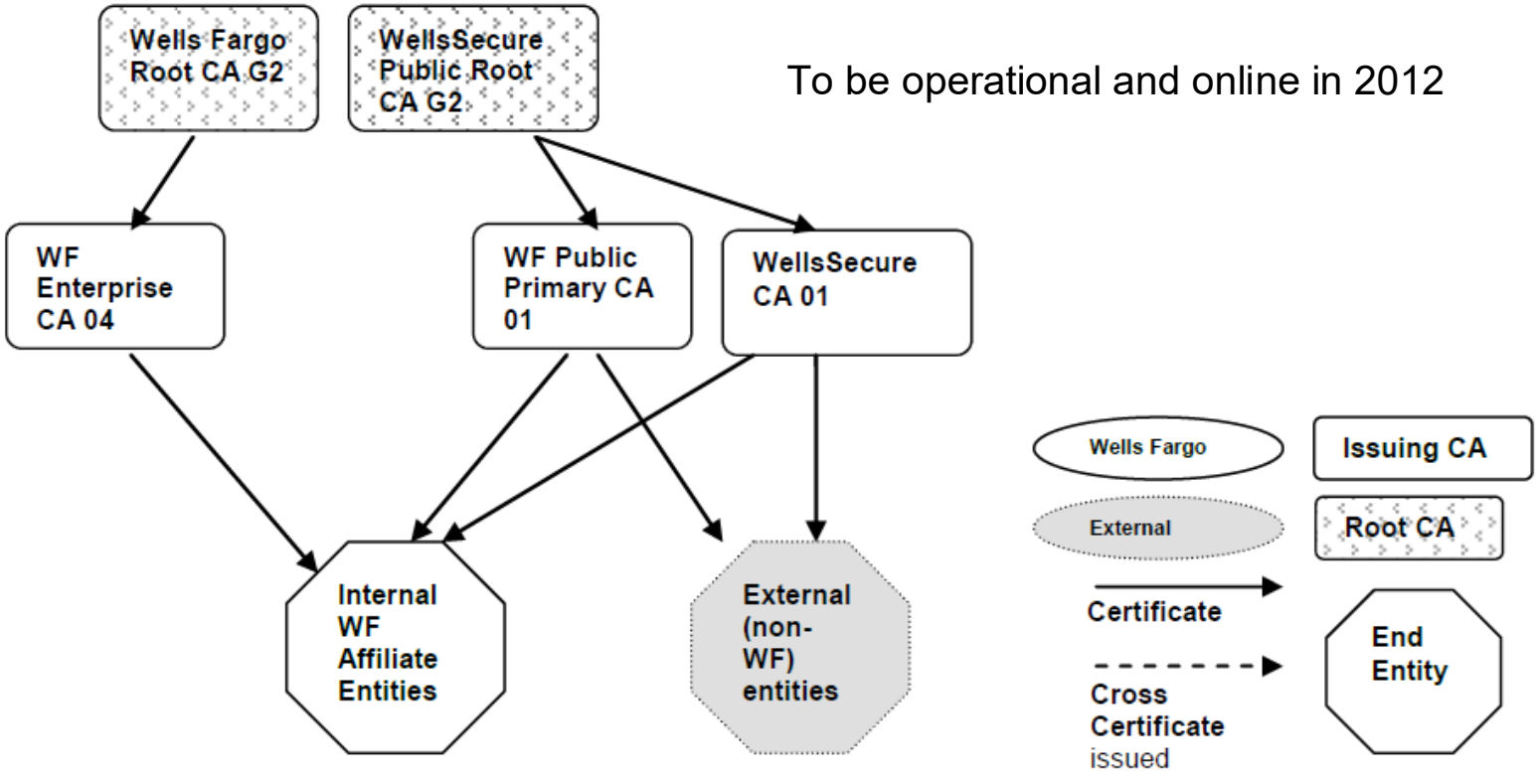
- Provide Repository for:
  - Digital Certificates
  - Certificate Revocation Lists (CRLs)

- Typically:
  - Special Purposes Databases
  - LDAP directories

Case Study 1: WellsSecure PKI SHA-1 Hierarchy



Case Study 2: WellsSecure PKI SHA-2 Hierarchy



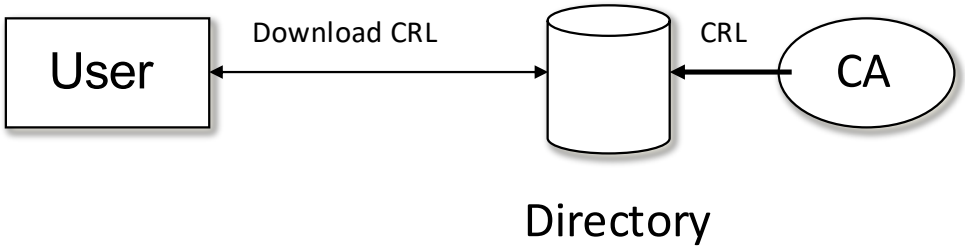
Certificate Revocation List (CRL)

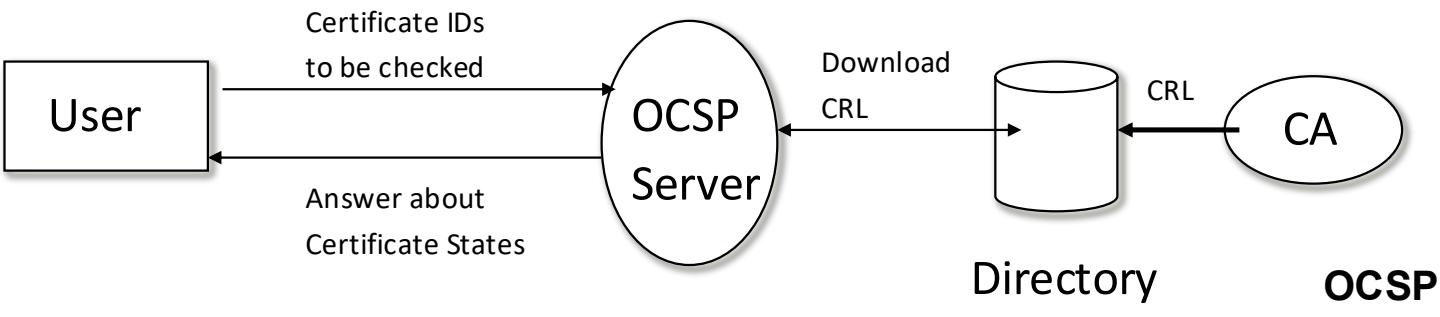
- CRLs are published by CAs at well defined interval of time
- It is a responsibility of “Users” of certificates to “download” a CRL and verify if a certificate has been revoked
- User application must deal with the revocation processes
- Revoked Certificates remain in CRL until they expire

Online Certificate Status Protocol (OCSP)

- An alternative to CRLs
  - IETF/PKIX standard for a real-time check if a certificate has been revoked/suspended
- Requires a high availability OCSP Server

CRL vs OCSP Server





Case Study 3: Verify Certificates

	Windows® 2000	Windows XP / Windows Server 2003	Windows Vista	Windows 7 / Windows Server 2008	Mac® OS X
Internet Explorer®	CRL	CRL	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available	N/A
Firefox®	OCSP	OCSP	OCSP	OCSP	OCSP
Safari®	N/A	CRL	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available
Chrome	N/A	CRL	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available
Opera®	OCSP and CRL	OCSP and CRL	OCSP and CRL	OCSP and CRL	OCSP and CRL
Verifying Code Signing Certificates	CRL	CRL	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available	OCSP first; will use CRL if OCSP is not available

Standard format

X.509 PKI-enabled Applications

- Functionality Required:
  - Cryptographic functionality
  - Secure storage of Personal Information
  - Digital Certificate Handling
  - Directory Access
  - Communication Facilities

Summary

- have considered:
  - symmetric key distribution using symmetric encryption
  - symmetric key distribution using public-key encryption
  - distribution of public keys
    - announcement, directory, authrority, CA
  - X.509 authentication and certificates
  - public key infrastructure (PKIX)