Public Key Infrastructure
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Motivation:

1. Numerous people buy/sell over the internet – hard to manage security of all possible pairs of connections with secret keys

2. US government subject to the Government Paperwork Elimination Act requiring electronic transactions with the public (from 2003)

3. Agencies are required to use electronic authentication technology to verify identity of the sender and the integrity of electronic content

4. This is especially important when doing classified work or working with contractors who do classified work

5. The Health Insurance Portability and Accountability Act of 1996 mandates security and privacy standards to protect health information that is exchanged electronically.
Public Key Infrastructure

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1. binds public keys to entities
2. enables other entities to verify public key bindings
3. provides services for management of keys in a distributed system
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Integrates:
1. Digital certificates
2. Public key cryptography
3. Certification authorities
for an enterprise-wide network security architecture
Public Key Infrastructure

Components:

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   - confirms the identity of transmitting parties
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   - provides data that allows users to confirm the status of digital certificates for individuals and businesses that receive digitally signed messages
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5. Certificates
   - includes public key, information about the identity of the party holding the corresponding private key, the operational period for the certificate, and the CA's own digital signature
   - may contain other information about the signing party or information about the recommended uses for the public key
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X.509 certificate standard:

- version
- serial number
- algorithm ID
- issuer
- validity – not before, not after
- subject
- subject key key info – algorithm and public key
- extensions
  - basic constraints – includes public
  - key usage – crypto operations that key can be used for
    Ex: signing but not encryption
  - extended key usage – indicates allowed usage per application
    Ex: may be used on the server end of a TLS connection
    may be used to protect email
- certificate signature algorithm
- certificate signature
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   - issues certificates (creates and signs them)
   - maintains certificate status information and issues CRLs
   - publishes its current (e.g., unexpired) certificates and CRLs, so users can obtain the information they need to implement security services
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8. CA *must* provide adequate protection for its own private key
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Repositories:

1. Directory service for distribution of certificates and certificate status
   - provides means of storing and distributing certificates
   - manages updates to certificates
   - typically implementations of the X.500 standard
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5. Directory servers need to be *interoperable* to be able to retrieve CRLs and certificates from remote sites for signature verification
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Archives:
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6. This permits the verification of signatures on old documents (such as wills) at a later date.
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Trust Models:

**Monopoly model:** One organization is trusted by all others to issue certificates. All software contains public key of that CA

**Monopoly + Registration Authorities:** Use other organizations to check identities and vouch for public keys

**Delegated CAs:** Trust anchor issues certificates to other CAs. Users can get a certificate from one of the other CAs.

**Oligarchy (Browsers):** Many trust anchors, certificate from one is sufficient

**Anarchy (PGP):** Each user responsible for configuring TAs.
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Monopoly:
There is no one universally trusted organization
Infeasible to change the key in all software if it is compromised
CA could charge whatever it wants to issue certificates

Monopoly + RAs:
More convenient than above – many places to get certified

Delegated CAs:
Recipient may see a chain of certificates vs. one for Mon+RAs

Oligarchy (e.g. browsers):
Worse than monopoly since *any* of trust anchors could be comp.
Trust anchors may be trusted by vendor but not user!
It is easy to trick a naive user into accepting a bogus trust anchor
Users do not understand what's up: ex: use of public terminal
Unlikely a user will check trust anchor list to see if it's tampered

Anarchy (PGP):
Trust of a single certificate varies so create a trust score from several
then make a decision
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Name Constraints:
Assume CA trusted to issue certs for only some users or domains

Top-Down with Name Constraints:
Tree of CAs, each can only issue certs in their domain.

Bottom-Up with Name Constraints:
Each org creates its own PKI and links to the WWW of PKIs
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Top-Down with Name Constraints:

Like Monopoly with delegated CAs where delegates are restricted to parts of the name hierarchy
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Bottom-Up with Name Constraints:

1. Easy to determine whether path exists
2. Hierarchy corresponding to the name of the principal is intuitive
3. PKI can be deployed in any org, no need to pay someone to do it. Can have a PKI in your org even if lots of other orgs do not.
4. Damage due to compromised CA is limited to that org. No one can impersonate you from a compromised CA outside of your org.
5. Configuration is easy: all CAs can be reached beginning with your key pair - new employee gets a key just like a badge.
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Relative Names:
Certificates carry relative names, not absolute names
e.g. Use cs instead of cs.uc.edu

If an entire subtree of names has to be moved, no certificates need to be reissued

Do not use name A/B/C/D but only D on certificates from A/B/C - then if that moves to H/Y, say, only certificates between H/Y and ancestors need be reissued.
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Name Constraints in Certificates:
Field in certificate stating names

Allows issuer to specify names that subject is trusted to certify
Can also disallow names.
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Policies in Certificates:

Statement of how carefully the identity of requester is checked. If not obeyed, no certificate is issued. Can deny certificates to users not at high level of security.
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Expiration and Revocation:

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Hence, security is down the tubes.
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Certificate Revocation Lists (CRL):
- CA periodically issues a timestamped, signed list of revoked certs
- Delta CRL – just the changes since a particular time/day

On-Line Revocation Server (OLRS):
- System that can be queried over the net
- Can this service be trusted?
- Not security-sensitive -
- Contains no vulnerable database of secrets
- Worst thing it can do is to claim an invalid cert is still valid
  - damage from this is limited