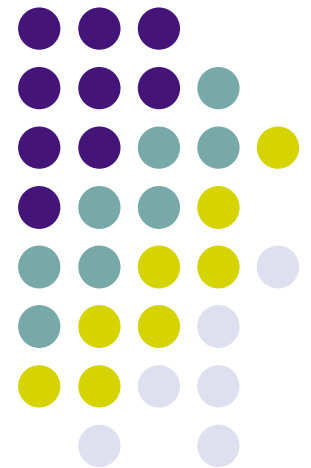
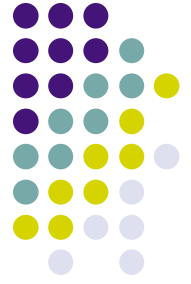


Public Key Infrastructures

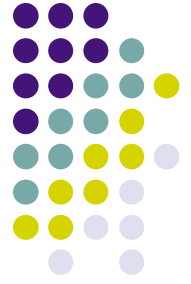
Using PKC to solve network
security problems





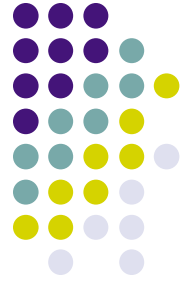
Distributing public keys

- P keys allow parties to share secrets over unprotected channels
 - Extremely useful in an open network:
 - Parties are not under a single manager
 - Symmetric keys cannot be shared beforehand
- How to distribute public keys?
 - Not a problem of secrecy (symmetric key)
 - A problem of legitimacy (identity binding)



Certification

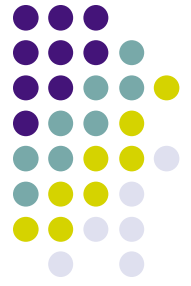
- Public keys must be certified, i.e., an **authenticated** statement like “Public key PA belongs to user A” must be made by a **trusted** party.
- A **Public Key Infrastructure** defines:
 - The set of trusted parties **or** a mechanism to infer trust
 - An authentication/certification algorithm



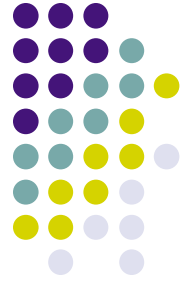
Monopoly Model

- A central Certification Authority (CA) is:
 - universally trusted
 - its public key is known to all
- The central CA signs all public key certificates, or delegates its powers:
 - to lower level CAs: Certificate chaining
 - to registration authorities (RAs): single cert.
- This is a “flat” trust model.

Olygarchy

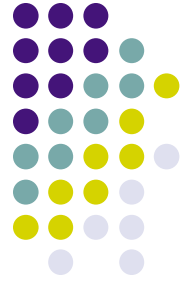


- The X.509 PKI is olygarchic.
- A number of root CAs is known in advance
- User discretion is an afterthought; multiple points of failure
- Certificate chaining is supported
- Web browsers support olygarchic PKIs.



Certificate Revocation

- As the trusted parties multiply, so does the possibility of having to revoke trust
 - Private key of user compromised:
 - Revocation of user certificate
 - Publication of revoked certificates:
 - Certificate revocation lists, or CRLs.
 - Private key of trusted party compromised:
 - Update of CA's public key
 - Re-certification of existing certificates?
 - Timestamping?



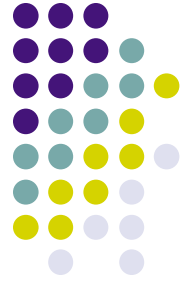
Anarchy model

- PGP: Each user is fully responsible for deciding its trust anchors (roots).
 - Practical for individual communication
 - Put your public key in your e-mail signature or website
 - Call user to verify PK fingerprint
 - Impractical for automated trust inference
 - How to decide that a certificate chain is trustworthy?



PGP: Details

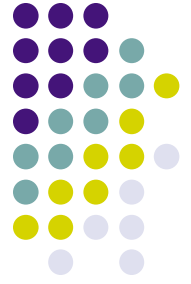
- **PGP Identity** - Name and e-mail address associated with a key.
- **PGP Public key ring** - a local file/database of keys. Should have all keys that the user plans to correspond with, and any keys that have signed the user's public key.
- **PGP key server** - a networked repository for storing, retrieving, and searching for public keys. Key servers can use a few standardized protocols, among them LDAP, HTTP, and SMTP as public interfaces. A PGP key server is basically a centralized networked PGP public key ring.
- **Public key fingerprint** - A uniquely identifying string of numbers and characters used to identify public keys. This is the primary means for checking the authenticity of a key.



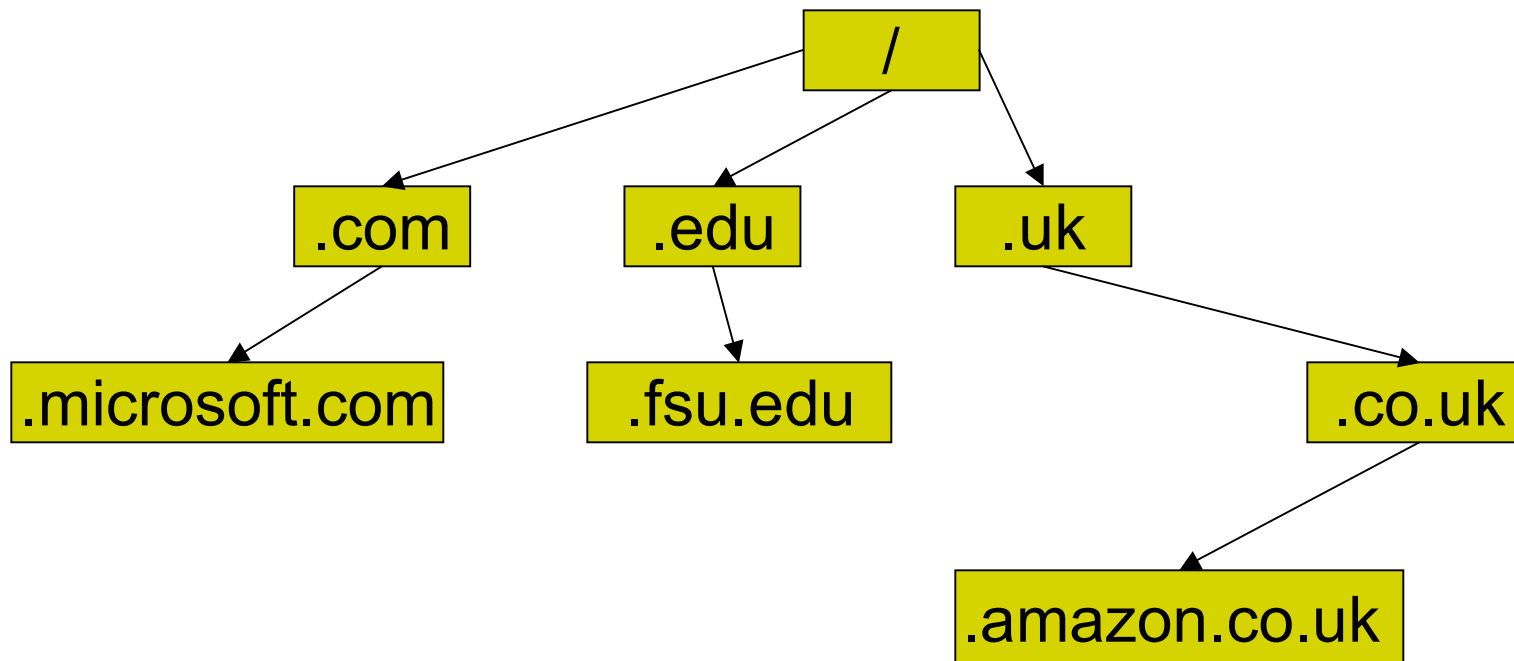
Constrained Naming PKIs

- Assumptions:
 - X.509 and other oligarchic PKIs cannot handle a very complex world without becoming very complex themselves
 - Many certification needs are inherently local
 - Local certification and local naming uniqueness can be maintained with minimal effort
 - Global naming conventions exist (e.g.: DNS)
 - If public keys need global certification, then rely on relationships to infer trust

Top-Down Constrained Naming



- Similar to oligarchic/monopoly model model, but delegation takes place with domain name constraints:

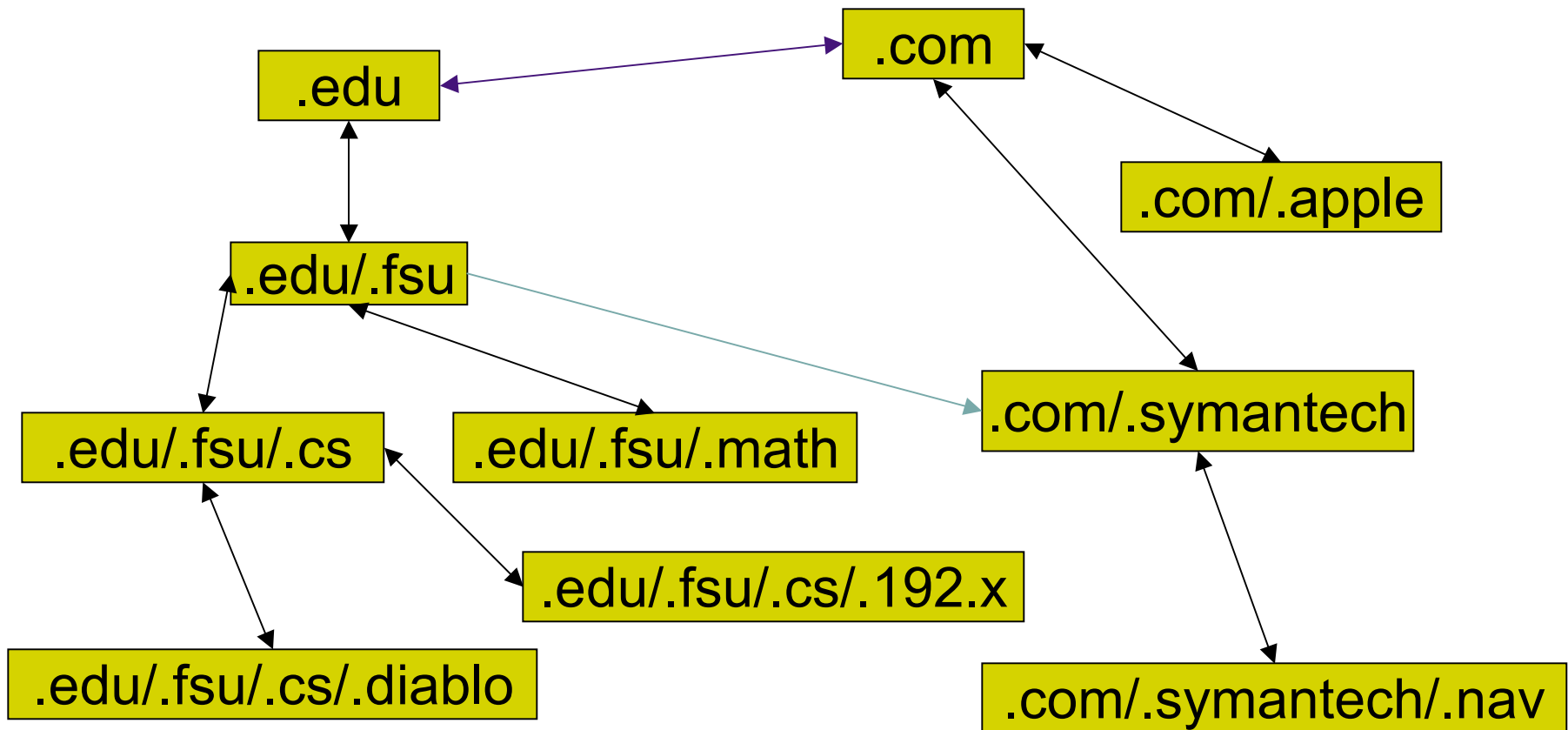
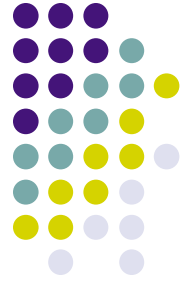


Bottom-Up Constrained Naming

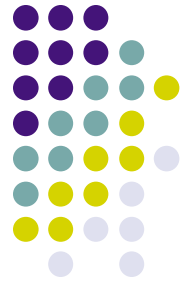


- Each organization creates an independent PKI and then link to others:
 - Top-down links: Parent certifies child
 - Bottom-up links: Child attests parent
 - Cross-links: A node certifies another node
- To certify a node N:
 1. Start from your trust anchor: if it is also an ancestor to N, just verify the delegation chain
 2. If (1) fails, query your trust anchor for a cross-link to an ancestor of N
 3. Else repeat using the parent of your trust anchor.

Example



Advantages of constrained naming PKIs

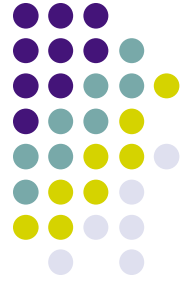


- Simple and flexible
- Locally deployable
- Compartmentalized trust
- Easy to replace keys at local levels
 - Lightweight and fast revocation
- Non-monopolistic, open architecture
- PKIX/X.509 (oligarchic) has recognized the advantages of constrained naming, and support it through the NameConstraints field.



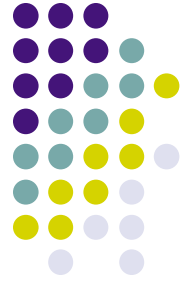
Relative names

- Aliases, shorthand forms or non-global names that are locally understood:
 - Parent may refer to each child simply the part of the child's name that extends of its own name
 - Child refers to parent simply as "parent"
 - Think of how file systems work
- Cross links can use global names (absolute paths) or relative names
- SPKI certificates support relative names



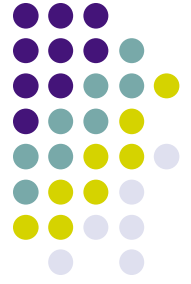
Certificate revocation

- CRLs:
 - Signed, time-stamped list of all revoked certificates
 - Cost to generate and verify a CRL is proportional to the number of all revoked certificates
- Δ CRLs:
 - Publish only changes from a latest full CRL
- OLRs (On-line Revocation Server)
- Affirmation of valid certificates



Other issues

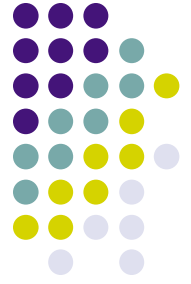
- Directories
 - A standardized mechanism for querying names is required for some PKIs (e.g. constrained names)
 - E.g.: DNS directory service
- Should a certification record be stored with the issuer or subject of the certification?
- Certificate chaining:
 - To certify Alice -- start with Alice's name and go up (forward building) or with our trust anchor and down (reverse building)?



X.509

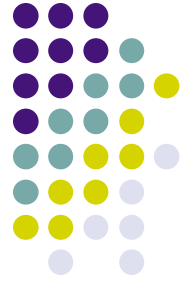
- The IETF chose to use X.500 naming standards for certificates
 - C=US, O=Sun, OU=Java, CN=java.sun.com
- Browsers know websites by DNS names, not X.500 names
 - Initial browser implementations did not check CN.
 - Today, DNS names are included either in CN or in SubjectAltName field
- Rationale: DNS does not support certificate lookup

X509 + PKIX Certificates



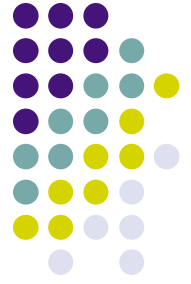
- Version
- SerialNumber
- Signature
- Issuer
- Validity
- Subject
- SubjectPublicKeyInfo
- IssuerUniqueIdentifier
- SubjectUniqueIdentifier
- AlgorithmIdentifier
- Encrypted
- Extensions
 - AuthorityKeyIdentifier
 - SubjectKeyIdentifier
 - KeyUsage
 - CertificatePolicies
 - PolicyMappings
 - NameConstraints
 - ...

X.509



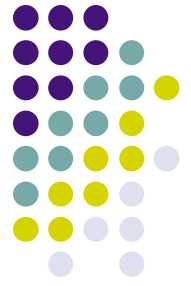
- PKIX Working Group (established 1995)
- Goal: develop Internet standards needed to support an X.509-based PKI:
 - RFC 2459, profiled X.509 version 3 certificates and version 2 CRLs for use in the Internet.
 - Profiles for the use of Attribute Certificates (RFC XXXX [pending])
 - LDAP v2 for certificate and CRL storage (RFC 2587)
 - X.509 Public Key Infrastructure Qualified Certificates Profile (RFC 3039)
 - Internet X.509 Public Key Infrastructure Certificate Policy and certification Practices Framework (RFC 2527 - Informational)

X.509



- Certificate Management Protocol (CMP: RFC 2510)
- Online Certificate Status Protocol (OCSP: RFC 2560)
- Certificate Management Request Format (CRMF: RFC 2511)
- Time-Stamp Protocol (RFC 3161)
- Certificate Management Messages over CMS (RFC 2797)
- Internet X.509 Public Key Infrastructure Time Stamp Protocols (RFC 3161)
- Use of FTP and HTTP for transport of PKI operations (RFC 2585)

Using capabilities for access control



- ACLs store permissions (read, write, execute, append, etc.) on the object
 - Easy to decide who has access to an object
 - Hard to revoke subjects
- Capabilities-based systems store capabilities on the subject
 - Hard to decide who has access to an object
 - Easy to revoke or add capabilities to a subject
- Role-based access control