Digital Certificates, Certification Authorities, and Public Key Infrastructure

Sections 14.3-14.5

Basic Problem

- What does a public-key signature verification tell you?
  Verification parameters include public key, and successful verification says "*Only someone holding the corresponding private key could have made this signature*."
- What do you ***want*** a signature verification to tell you?
  Probably something like "*Joe Smith signed this*."
- Problem: What assurance do you have that the public key really belongs to Joe Smith?

What is a Digital Certificate?

- Associates an identity/properties with a public key
  - Identity can be person's name, website, e-mail, ...
  - Properties can be valid key uses, age of individual, access rights granted, …
- Signed by someone you trust
  - Signature is trusted party vouching for ID/key pair
  - Role is similar to a notary public
- Some typical properties of certificates:
  - Good for a set time (validity period)
    - Must get a new certificate after expiration
  - Certificates may be revoked

More on Certificates

- Common types of certificates:
  - X.509 standard (version 3)
  - PGP certificates
- Who signs certificates? Several possibilities:
  - Independent "Certification Authority" organization
    - Disinterested third party – company or government
    - Examples: Verisign, Deutsche Telekom, Entrust, AOL, …
  - Internal (organizational) certification authority
    - Organization controls certificates for employees or clients
  - Could be just an individual you trust
    - This is how PGP certificates are typically certified

X.509 Certificates

- Most prevalent type of digital certificate
- Related to X.500 directory services
- An integral part of the Web
  - All major web browsers and servers support X.509
  - CA "industry" (Verisign, etc.) built around X.509
- Also part of secure e-mail specifications
  - S/MIME
- Currently "version 3" of X.509
  - Includes a flexible "extension field" capability

X.500 Names

(Also called "Distinguished Names")

- Hierarchical naming
- Parts of names are attribute/value pairs
- Example attributes:
  - C=country
  - ST=state
  - L=locality
  - O=organization
  - OU=organizational unit
  - CN=common name

Important “Additional Information”

- How does a CA state how they do business?
  - A Certification Practices Statement (CPS) is a human-readable statement of practices used by CA
    - Based on this, a person/vendor may decide whether to trust or not trust the CA
    - Problem: What if CPS becomes a dead link? Trust the CA?
- Where to obtain the Certification Revocation List (CRL)
  - Called a CRL Distribution Point (CDP)
  - Certificates may be revoked due to
    - Private key compromised
    - Incorrectly issued certificate
    - CA compromised
    - Properties change
  - CRL contains ***unexpired*** revoked certificates
    - Current (2018) size of Symantec CRL: 1,211,730 bytes (34,610 entries)
  - Newer technology: OCSP (Online Certificate Status Protocol)

Example: Amazon Certificate

(Extension fields removed)

```
Data:
     Version: 3 (0x2)
     Serial Number:
     79:df:6e:64:52:f0:6a:12:05:ac:c8:80:7b:0a:d5:8e
Signature Algorithm: sha256WithRSAEncryption
     Issuer: C=US, O=Symantec Corporation, OU=Symantec Trust Network, CN=Symantec
Class 3 Secure Server CA - G4
     Validity
     Not Before: Oct  6 00:00:00 2017 GMT
     Not After : Sep 21 23:59:59 2018 GMT
     Subject: C=US, ST=Washington, L=Seattle, O=Amazon.com, Inc., CN=www.amazon.com
     Subject Public Key Info:
     Public Key Algorithm: rsaEncryption
          Public-Key: (2048 bit)
          Modulus:
               00:de:59:92:15:5c:f4:ae:8e:c4:ee:8e:ff:b3:97:
               ...    [ Deleted ]      ...
          Exponent: 65537 (0x10001)
...
Signature Algorithm: sha256WithRSAEncryption
     1f:01:57:8d:2f:fe:26:bb:5d:43:59:5a:86:42:47:47:2f:5e:
```

Example: Amazon Certificate, Part 2

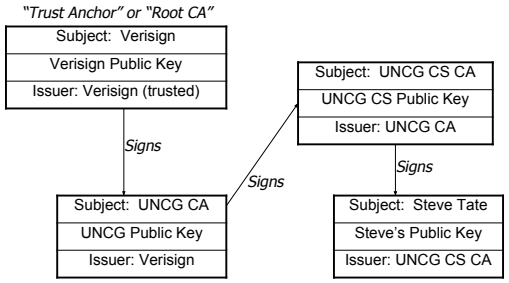
Extension fields

```
X509v3 extensions:
     X509v3 Subject Alternative Name:
     DNS:amazon.com, DNS:amzn.com, DNS:buybox.amazon.com, [ ... ]
     X509v3 Basic Constraints:
     CA:FALSE
     X509v3 Key Usage: critical
     Digital Signature, Key Encipherment
     X509v3 Extended Key Usage:
     TLS Web Server Authentication, TLS Web Client Authentication
     X509v3 Certificate Policies:
     Policy: 2.23.140.1.2.2
          CPS: https://d.symcb.com/cps
          User Notice:
          Explicit Text: https://d.symcb.com/rpa
     X509v3 Authority Key Identifier:
         keyid:5F:60:CF:61:90:55:DF:84:43:14:8A:60:2A:B2:F5:7A:F4:43:18:EF

     X509v3 CRL Distribution Points:
          Full Name:
          URI:http://ss.symcb.com/ss.crl

     Authority Information Access:
     OCSP - URI:http://ss.symcd.com
     CA Issuers - URI:http://ss.symcb.com/ss.crt
```

Certificate Chains
(Hypothetical)



Public Key Infrastructure (PKI)

- A PKI is "a collection of technologies and policies for creating and using digital certificates." [Garfinkel and Spafford]
- Many people originally envisioned an official digital ID system
  - In reality: Very little personal ID done with certificates – mostly used for server identification
  - Could change if security tokens or smart cards become more prevalent! Maybe smartphones?

Another Trust Model: PGP "Web of Trust"

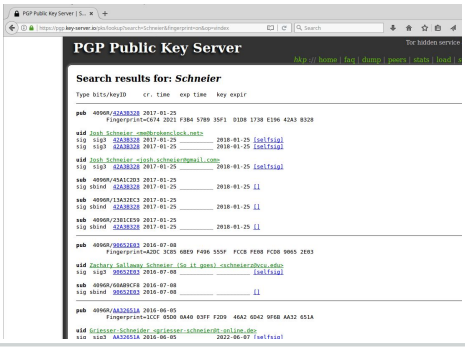
- PGP is "Pretty Good Privacy"
  - Originally for e-mail encryption/signing
    - Now regularly used for software verification
  - Originally written by Phil Zimmerman
  - Now several free and commercial versions
  - GPG ("Gnu Privacy Guard") is a Free-Software alternative (they use only free algorithms)
- Trust model is less hierarchical than X.509
- I can sign keys and distribute them
  - Anyone who trusts me can use me as a CA!
  - Difference between "trusted" and "valid" keys

PGP/GPG Keyservers

- Problem: How do you get public keys?
  - Note: In PGP public keys are always certificates
- Solution: Keyservers – databases of keys
  - You can submit your own keys
  - You can look up keys by name or e-mail address
  - Support integrated into many e-mail programs
- Keyservers can be accessed in many ways
  - LDAP
  - HTTP
  - E-mail

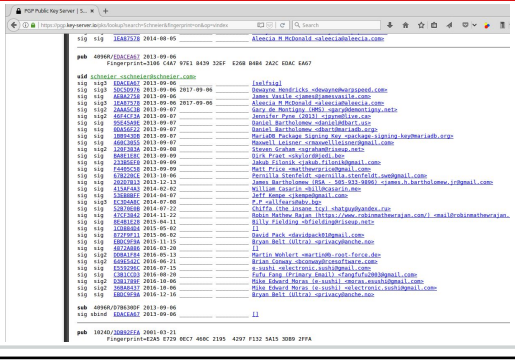
Keyserver example – WWW interface

Sending an encrypted email – Step 1: Look up the key



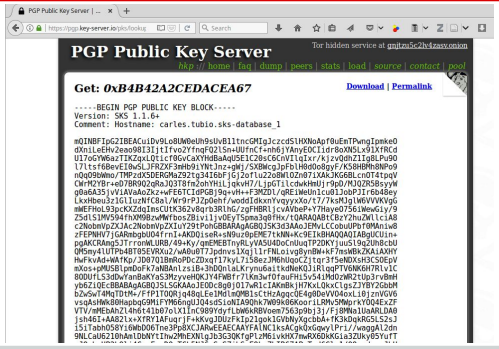
Keyserver example – WWW interface

Sending an encrypted email – Step 2: Find the right one - who vouches for it?



Keyserver example – WWW interface

Sending an encrypted email – Step 3: Download key (to import into PGP)



Some problems with certificates

- Private keys are not people
- Distinguished names are not people
- There are too many Robert Smiths
- X.509 v3 doesn't allow selective disclosure
- Ubiquitous certificates could lead to privacy issues
- How do you loan a key?
- Signatures are "brittle"

- But overall: Not perfect, but solves some important problems