Digital Signatures & Authentication Protocols

Digital Signatures

- have looked at message authentication
  - but does not address issues of lack of trust
- digital signatures provide the ability to:
  - verify author, date & time of signature
  - authenticate message contents
  - be verified by third parties to resolve disputes

Digital Signature Properties

- must depend on the message signed
- must use information unique to sender
  - to prevent both forgery and denial
- must be relatively easy to produce
- must be relatively easy to recognize & verify
- be computationally infeasible to forge
  - with new message for existing digital signature
  - with fraudulent digital signature for given message
- be practical save digital signature in storage

Direct Digital Signatures

- involve only sender & receiver
- assumed receiver has sender's public-key
- digital signature made by sender signing entire message or hash with private-key
- can encrypt using receivers public-key
- important that sign first then encrypt message & signature
- security depends on sender's private-key

Arbitrated Digital Signatures

- involves use of arbiter A
  - validates any signed message
  - then dated and sent to recipient
- requires suitable level of trust in arbiter
- can be implemented with either private or public-key algorithms
- arbiter may or may not be able to see message

Authentication Protocols

- used to convince parties of each others identity and to exchange session keys
- may be one-way or mutual
- key issues are
  – confidentiality – to protect session keys
  – timeliness – to prevent replay attacks
- published protocols are often found to have flaws and need to be modified

Replay Attacks

- where a valid signed message is copied and later resent
  - simple replay
  - repetition that can be logged
  - repetition that cannot be detected
  - backward replay without modification
- countermeasures include
  - use of sequence numbers (generally impractical)
  - timestamps (needs synchronized clocks)
  - challenge/response (using unique nonce)

Using Symmetric Encryption

- as discussed previously, we can use a two-level hierarchy of keys
- usually with a trusted Key Distribution Center (KDC)
  - each party shares own master key with KDC
  - KDC generates session keys used for connections between parties
  - master keys used to distribute these to them

Needham-Schroeder Protocol

- original third-party key distribution protocol
- for session between A B mediated by KDC
- protocol overview is:

1. A->KDC: $ID_A \| ID_B \| N_1$

2. KDC -> A: $E_{Ka}[Ks \| ID_B \| N_1 \| E_{Kb}[Ks\|ID_A]]$

3. A -> B: $E_{Kb}[Ks\|ID_A]$

4. B -> A: $E_{Ks}[N_2]$

5. A -> B: $E_{Ks}[f(N_2)]$

Needham-Schroeder Protocol

- used to securely distribute a new session key for communications between A & B
- but is vulnerable to a replay attack if an old session key has been compromised
  - then message 3 can be resent convincing B that is communicating with A
- modifications to address this require:
  - timestamps (Denning 81)
  - using an extra nonce (Neuman 93)

Using Public-Key Encryption

- have a range of approaches based on the use of public-key encryption
- need to ensure have correct public keys for other parties
- using a central Authentication Server (AS)
- various protocols exist using timestamps or nonces

Denning AS Protocol

- Denning 81 presented the following:
  1. A -> AS: ID_A || ID_B
  2. AS -> A: $E_{PRas}[ID_A||PU_a||T]$ || $E_{PRas}[ID_B||PU_b||T]$
  3. A -> B: $E_{PRas}[ID_A||PU_a||T]$ || $E_{PRas}[ID_B||PU_b||T]$ || $E_{PUb}[E_{PRas}[K_s||T]]$
- note session key is chosen by A, hence AS need not be trusted to protect it
- timestamps prevent replay but require synchronized clocks

One-Way Authentication

- required when sender & receiver are not in communications at same time (e.g., email)
- have header in clear so can be delivered by email system
- may want contents of body protected & sender authenticated

Using Symmetric Encryption

- can refine use of KDC but can’t have final exchange of nonces:
  1. A->KDC: ID_A || ID_B || N_1
  2. KDC -> A: E_{Ka}[Ks || ID_B || N_1 || E_{Kb}[Ks||ID_A]]
  3. A -> B: E_{Kb}[Ks||ID_A] || E_{Ks}[M]
- does not protect against replays
  - could rely on timestamp in message, though email delays make this problematic

Public-Key Approaches

- have seen some public-key approaches
- if confidentiality is major concern, can use:

  A->B: $E_{PUb}[Ks] || E_{Ks}[M]$

  – has encrypted session key, encrypted message
- if authentication needed, use a digital signature with a digital certificate:

  A->B: $M || E_{PRa}[H(M)] || E_{PRas}[T||ID_A||PU_a]$

  – with message, signature, certificate

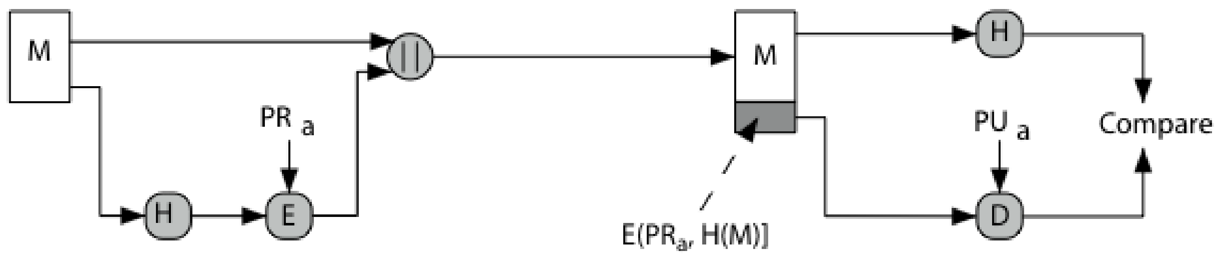
Digital Signature Standard (DSS)

- US Govt approved signature scheme
- designed by NIST & NSA in early 90's
- published as FIPS-186 in 1991
- revised in 1993, 1996 & then 2000
- uses the SHA hash algorithm
- DSS is the standard, DSA is the algorithm
- FIPS 186-2 (2000) includes alternative RSA & elliptic curve signature variants

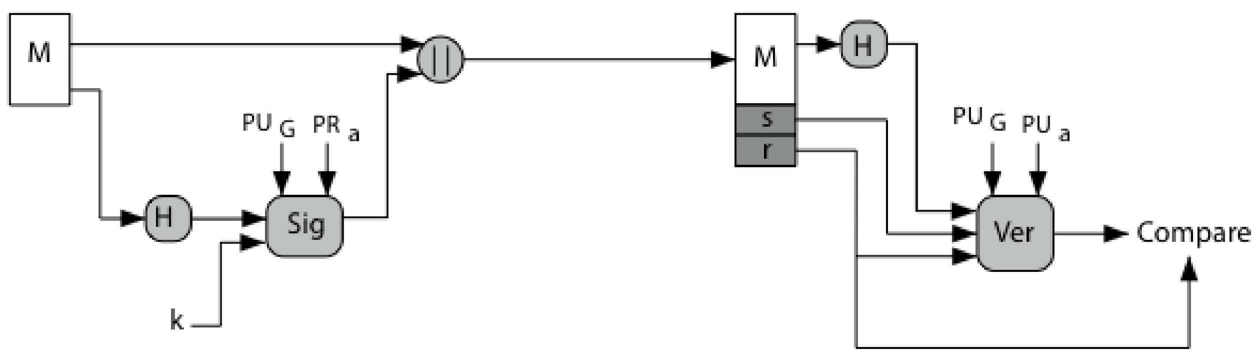
Digital Signature Algorithm (DSA)

- creates a 320 bit signature
- with 512-1024 bit security
- smaller and faster than RSA
- a digital signature scheme only
- security depends on difficulty of computing discrete logarithms
- variant of ElGamal & Schnorr schemes

Digital Signature Algorithm (DSA)



(a) RSA Approach



(b) DSS Approach

DSA Key Generation

- have shared global public key values (p,q,g):
  - choose q, a 160 bit
  - choose a large prime $p = 2^L$
    - where L= 512 to 1024 bits and is a multiple of 64
    - and q is a prime factor of $(p-1)$
  - choose $g = h^{(p-1)/q}$
    - where $h<p-1$, $h^{(p-1)/q} \pmod{p} > 1$
- users choose private & compute public key:
  - choose $x<q$
  - compute $y = g^x \pmod{p}$

DSA Signature Creation

- to **sign** a message M the sender:
  - generates a random signature key k, $k<q$
  - k must be random, be destroyed after use, and never be reused
- then compute signature pair:

  $r = (g^k \pmod p) \pmod q$

  $s = (k^{-1}.H(M) + x.r) \pmod q$
- sends signature (r,s) with message M

DSA Signature Verification

- having received M & signature `(r,s)`
- to **verify** a signature, recipient computes:

$$w = s^{-1} \pmod q$$

$$u1 = (H(M).w) \pmod q$$

$$u2 = (r.w) \pmod q$$

$$v = (g^{u1}.y^{u2} \pmod p) \pmod q$$

- if `v=r` then signature is verified
- see book web site for details of proof why

Summary

- have discussed:
  - digital signatures
  - authentication protocols (mutual & one-way)
  - digital signature algorithm and standard