Information Security

Outline and Reading

- Digital signatures
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- One-way hash functions
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Digital Signature

- A digital signature is a string S associated with a message M and the author A of M that has the following properties
  - Integrity: S establishes that M has not been altered
  - Nonrepudiation: S unequivocally identifies the author A of M and proves that A did indeed sign M
- A digital signature scheme provides algorithms for
  - Signing a message by the author
  - Verifying the signature of a message by the reader
- A recently passed law in the US gives digital signatures the same validity of handwritten signatures
- A public-key cryptosystem yields a digital signature scheme provided $encrypt(K_E, decrypt(K_D, M)) = M$
  - Signature: Alice (author) computes $S = decrypt(K_D, M)$ using her private key K_D and sends the pair (M,S) to Bob
  - Verification: Bob (reader) computes $M' = encrypt(K_E, S)$ using Alice's public key K_E and checks that $M' = M$

RSA Digital Signature

- Setup:
  - $n = pq$, with p and q primes
  - e relatively prime to $\phi(n) = (p-1)(q-1)$
  - d inverse of e in $Z_{\phi(n)}$
- Keys:
  - Public key: $K_E = (n, e)$
  - Private key: $K_D = d$
- Signature:
  - Message M in Z_n
  - Signature $S = M^d \bmod n$
- Verification:
  - Check that $M = S^e \bmod n$

- Setup:
  - $p = 5,\ q = 11$
    $n = 5 \cdot 11 = 55$
  - $\phi(n) = 4 \cdot 10 = 40$
    $e = 3$
  - $d = 27\ (3 \cdot 27 = 81 = 2 \cdot 40 + 1)$
- Keys:
  - Public key: $K_E = (55, 3)$
  - Private key: $K_D = 27$
- Signature:
  - $M = 51$
  - $S = 51^{27} \bmod 55 = 6$
- Verification:
  - $S = 6^3 \bmod 55 = 216 \bmod 55 = 51$

One-Way Hash Function

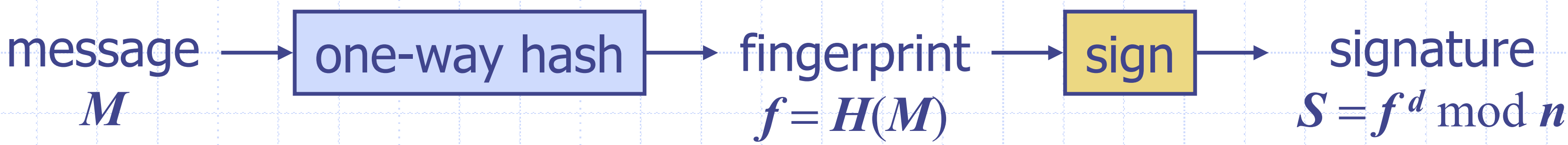
- A one-way hash function is a function H with the following properties
  - M maps a string M of arbitrary length into an integer $f = H(M)$ with a fixed number of bits, called the fingerprint or digest of M
  - H can be computed efficiently
  - Given an integer f, it is computationally infeasible to find a string M such that that $H(M) = d$
  - Given a string M , it is computationally infeasible to find another string M' such that $H(M) = H(M')$ (collision resistance)
  - It is computationally infeasible to find two strings M and M' such that $H(M) = H(M')$ (strong collision resistance)
- Two widely used one-way hash functions are
  - MD5 (Message Digest 5, 1992), which uses a 128-bit (16 bytes) fingerprint
  - SHA-1 (Secure Hash Algorithm 1, 1995), which uses a 160-bit (20 bytes) fingerprint

Coin Flipping Over the Net

- Alice and Bob want to flip a random coin by communicating over the internet
- The following protocol, based on a one-way hash function H, ensures the fairness of the outcome
  - Alice picks a random integer x, computes the fingerprint $f = H(x)$ and sends f to Bob
  - Bob sends to Alice his guess of whether x is odd or even
  - Alice announces the result of the coin flip: heads if Bob has guessed correctly and tails otherwise
  - Alice sends to Bob integer x as a proof of the outcome of the flip
  - Bob verifies that $f = H(x)$
- Because of the strong-collision resistance property, it is computationally infeasible for Alice to cheat

Digitally Signed Fingerprints

- In the RSA digital signature scheme with modulus n, the message to be signed must be an integer in Z_n, i.e., the message should have at most $b = \log n$ bits
- To overcome the above restriction on the message length, we can use the fingerprint $f = H(M)$ of the message instead of the message itself, where H is a one-way hash function
  - Alice computes first $f = H(M)$ and then the signature S of f
  - Bob first computes $f = H(M)$ and then verifies S
- Since the one-way hash function H has the collision-resistance property, it is computationally infeasible to modify the message M while preserving the signature of the fingerprint $f = H(M)$

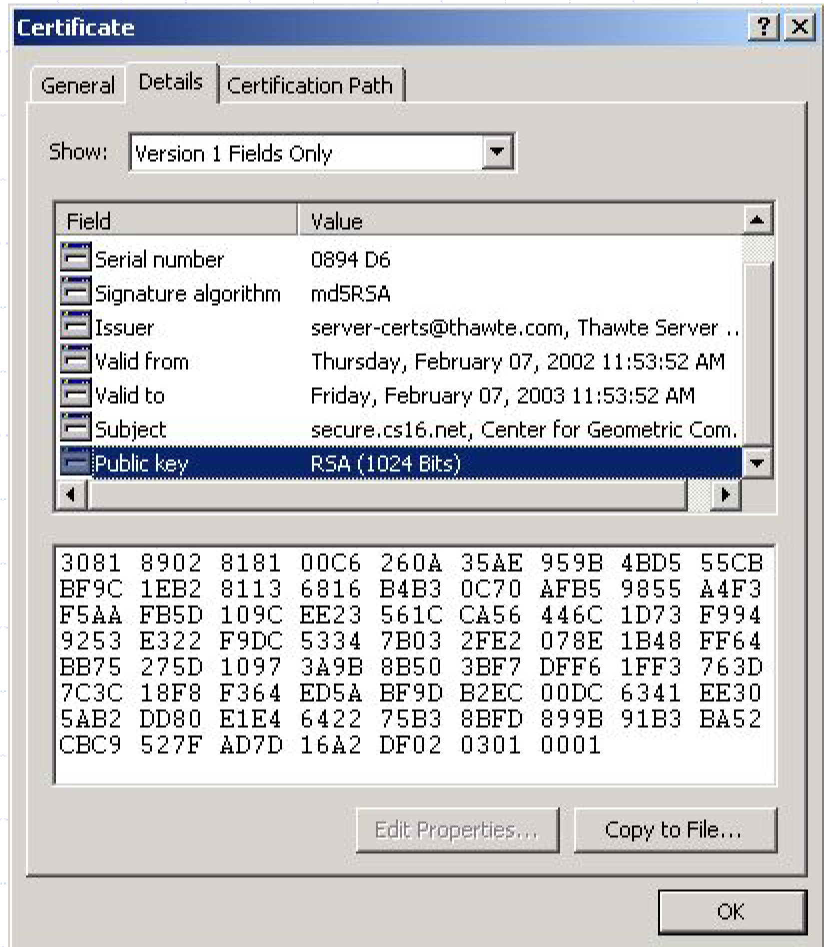


Certificates

- Public-key cryptography is based on the knowledge by each participant of the public key of the other participants
- It is complicated to securely distribute the public keys of all the participants
- A certificate is a message of the type (name, public key) signed by a third-party
- Public-key infrastructure (PKI)
  - An entity trusted by all the participants, called certification authority (CA), issues to each participant a certificate $(\boldsymbol{Name}, \boldsymbol{K_E})$ that authoritatively binds the participants to their public keys
  - Only the CA's public key needs to be distributed securely
  - Before sending an encrypted message to Bob or verifying a message digitally signed by Bob, Alice determines Bob's public key $\boldsymbol{K_E}$ by using Bob's certificate (Bob, $\boldsymbol{K_E}$)

Web Server Certificates

- A Web server certificate is used to authenticate the public key of a Web server
- Fields of a Web server certificate
  - Serial number
  - Hash and signature schemes (e.g., MD5 and RSA)
  - Issuer (certification authority)
  - Period of validity (from, to)
  - Subject (URL and organization)
  - Public key
- The SSL (secure socket layer) protocol uses Web server certificates to provide encryption and authentication in a secure Web connection (https)



Certificate Revocation

- In certain circumstances, a certificate may have to be revoked before its expiration date
  - The private key of the subject has been compromised
  - The certificate was incorrectly issued by the CA
- Certificate Revocation List (CRL)
  - Time-stamped list of all the unexpired certificates that have been revoked by the CA
  - Periodically published and signed by the CA
- When presented with a certificate, one should
  - Verify the CA's signature on the certificate
  - Check that the certificate has non been revoked by searching in the latest available CRL
- By default, Web browsers do not check the revocation status of a Web server certificate, which poses a security risk