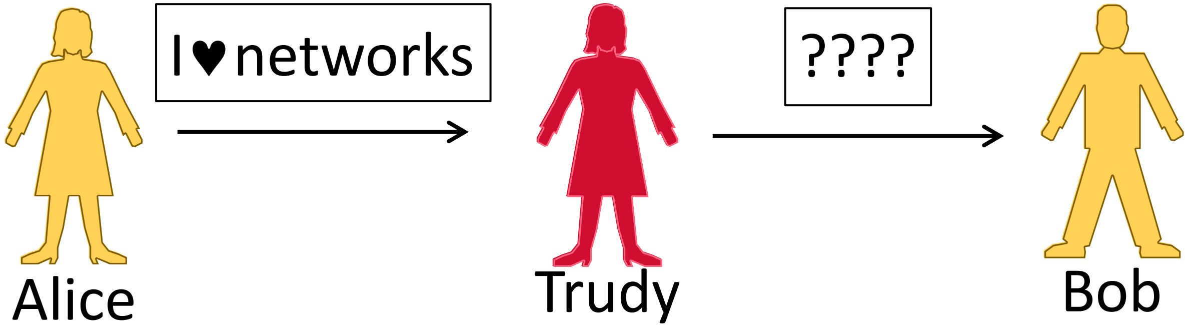
Message Authentication

Goal and Threat Model

- Goal is for Bob to verify the message is from Alice and unchanged
  - This is called integrity/authenticity
- Threat is Trudy will tamper with messages
  - Trudy is an active adversary (interferes)

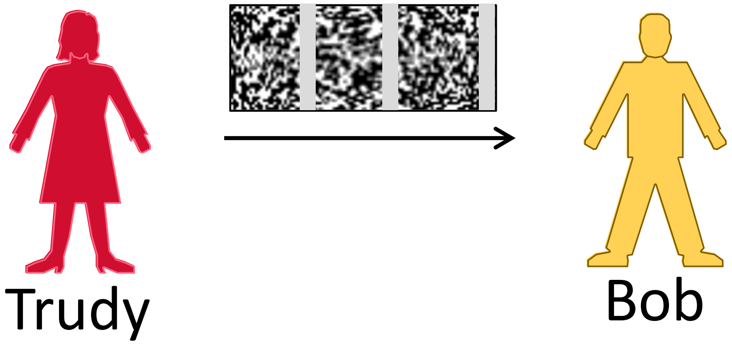


Wait a Minute!

- We’re already encrypting messages to provide confidentiality
- Why isn’t this enough?

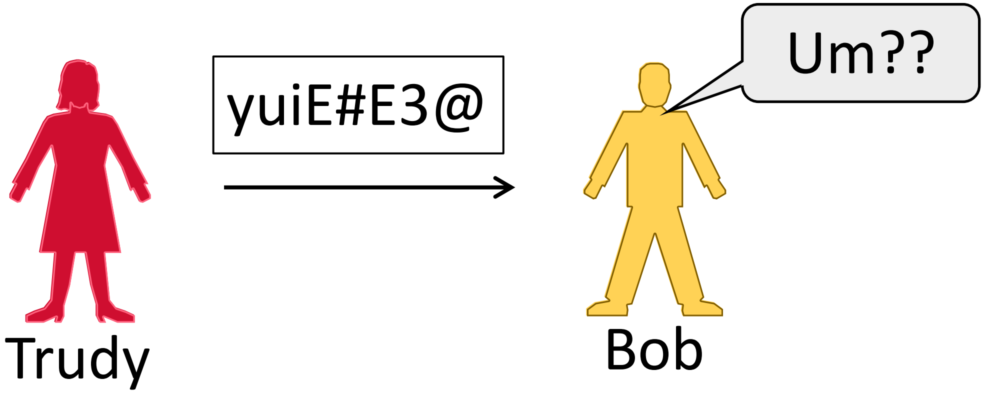
Encryption Issues

- What will happen if Trudy flips some of Alice’s message bits?
  - Bob will decrypt it, and …



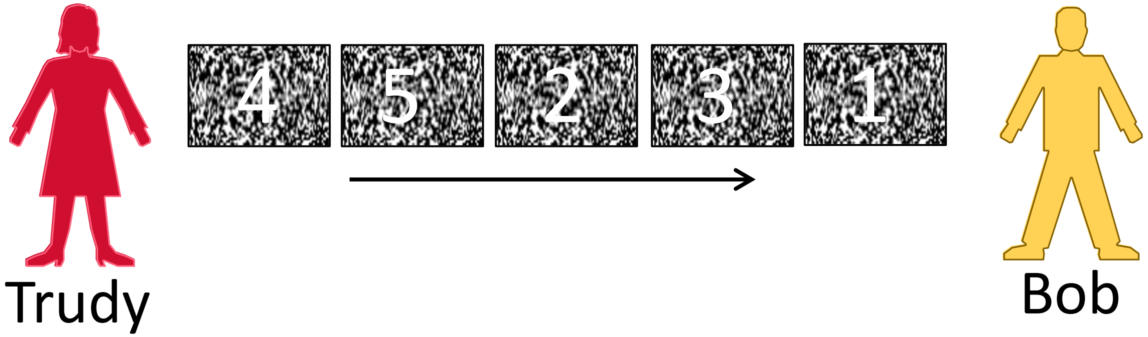
Encryption Issues (2)

- What will happen if Trudy flips some of Alice's message bits?
  - Bob will receive an altered message



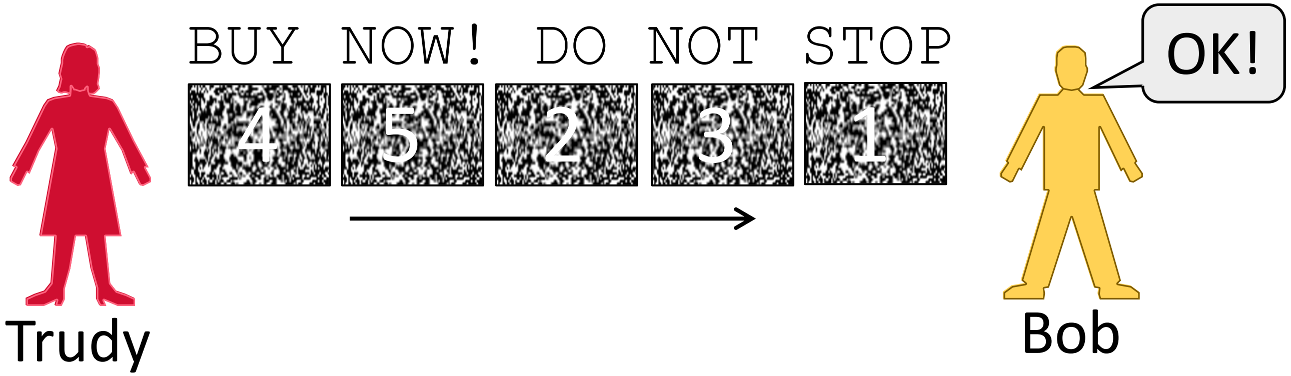
Encryption Issues (3)

- Typically encrypt blocks of data
- What if Trudy reorders message?
  - Bob will decrypt, and …



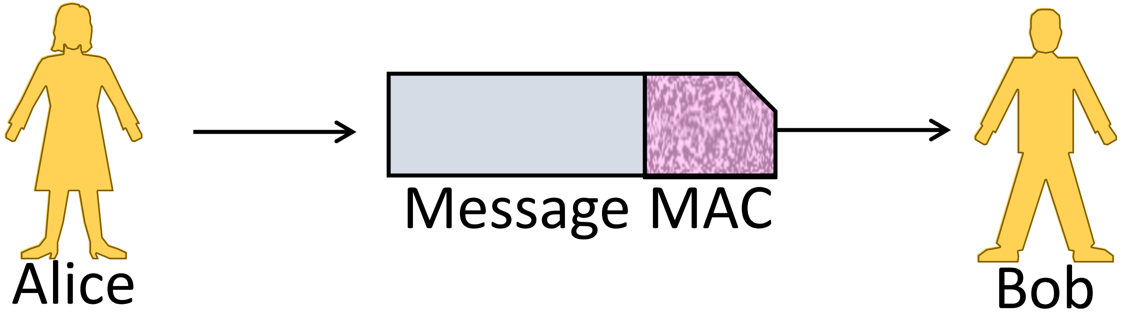
Encryption Issues (4)

- What if Trudy reorders message?
    - Bob will receive altered message



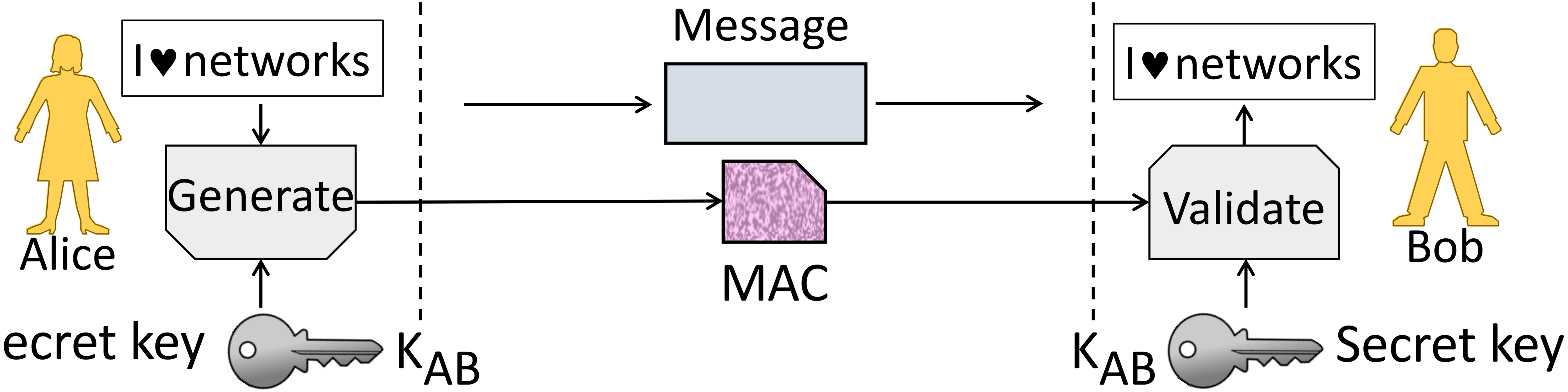
MAC (Message Authentication Code)

- MAC is a small token to validate the integrity/authenticity of a message
  - Conceptually ECCs again
  - Send the MAC along with message
  - Validate MAC, process the message
  - Example: HMAC scheme



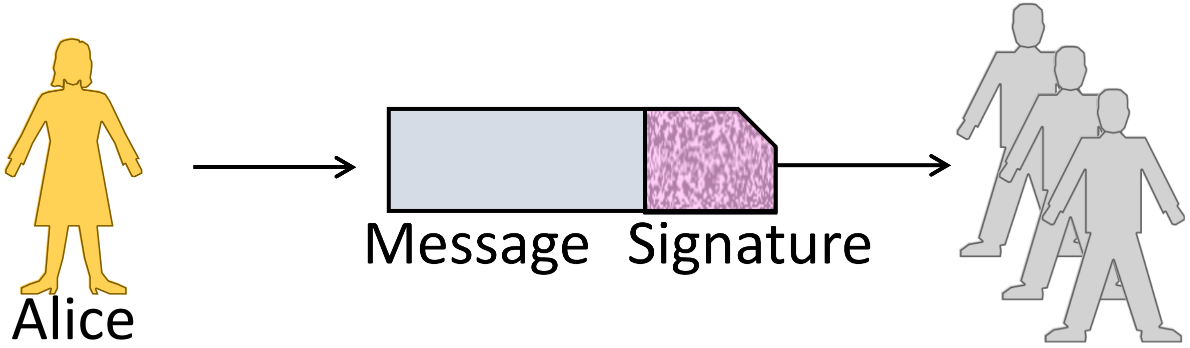
MAC (2)

- Sorta symmetric encryption operation – key shared
  - Lets Bob validate unaltered message came from Alice
  - Doesn’t let Bob convince Charlie that Alice sent the message



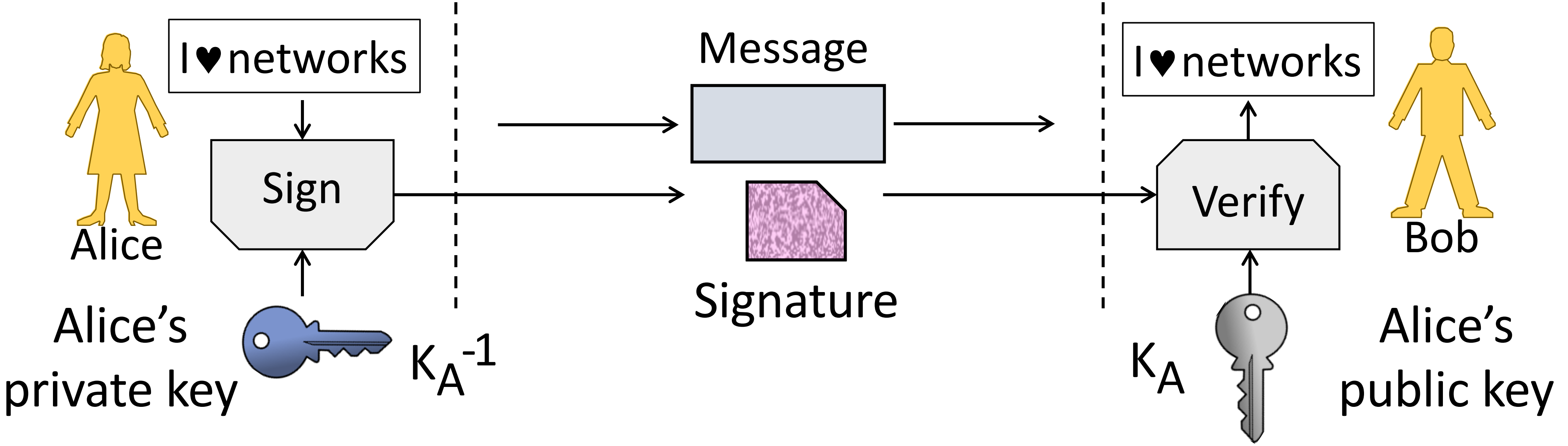
Digital Signature

- Signature validates the integrity/authenticity of message
  - Send it along with the message
  - Lets all parties validate
  - Example: RSA signatures



Digital Signature (2)

- Kind of public key operation – pub/priv key parts
  - Alice signs w/ private key, K_A^{-1}, Bob verifies w/ public key, K_A
  - Does let Bob convince Charlie that Alice sent the message

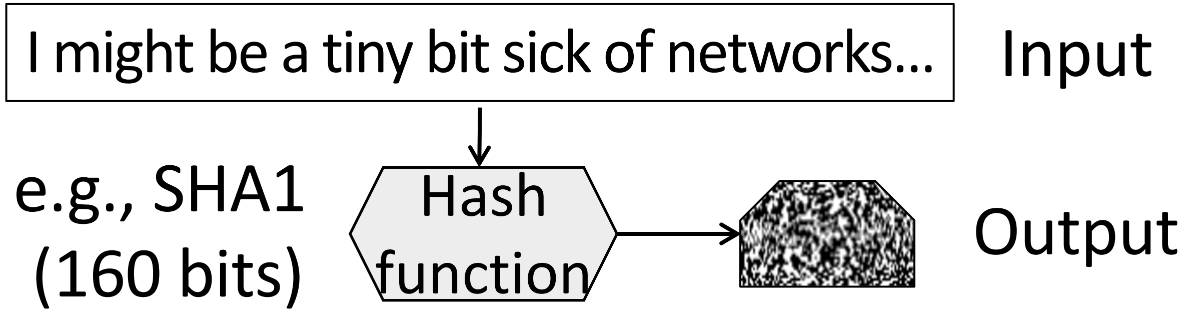


Speeding up Signatures

- Same tension as for confidentiality:
  - Public key has keying advantages
  - But it has slow performance!
- Use a technique to speed it up
  - Message digest stands for message
  - Sign the digest instead of full message

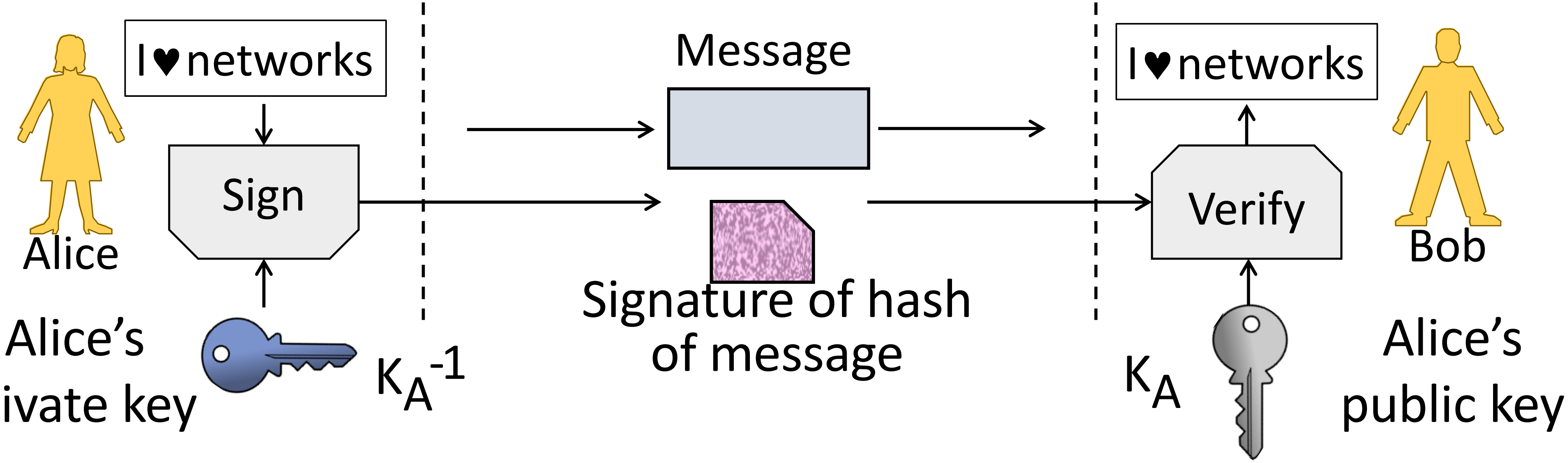
Message Digest or Cryptographic Hash

- Digest/Hash is a secure checksum
  - Deterministically mangles bits to pseudo-random output (like CRC)
  - Can’t find messages with same hash
  - Acts as a fixed-length descriptor of message – very useful!



Speeding up Signatures (2)

- Conceptually similar except sign the hash of message
  - Hash is fast to compute, so it speeds up overall operation
  - Hash stands for msg as can’t find another w/ same hash

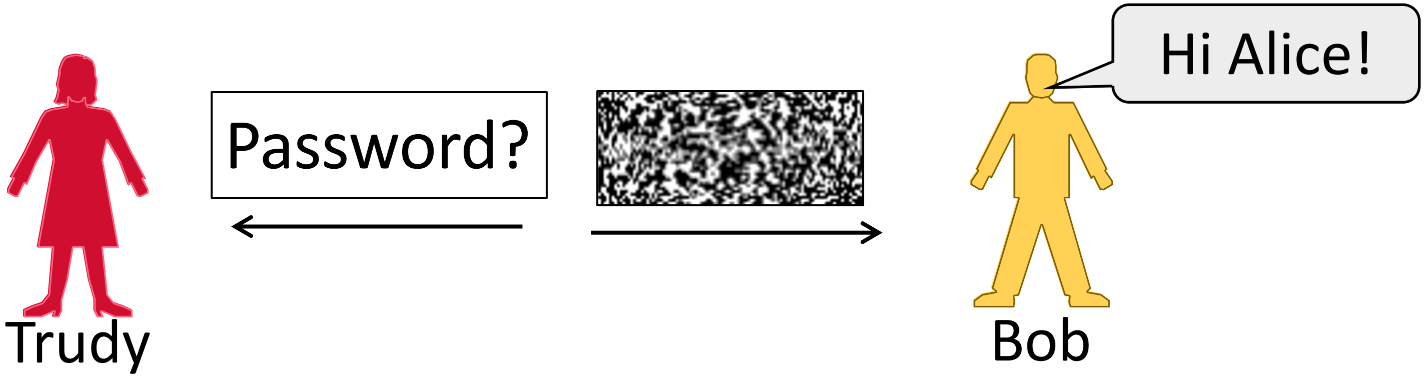


Preventing Replays

- We normally want more than confidentiality, integrity, and authenticity for secure messages!
  - Want to be sure message is fresh
- Need to distinguish message from replays
  - Repeat of older message
  - Acting on it again may cause trouble

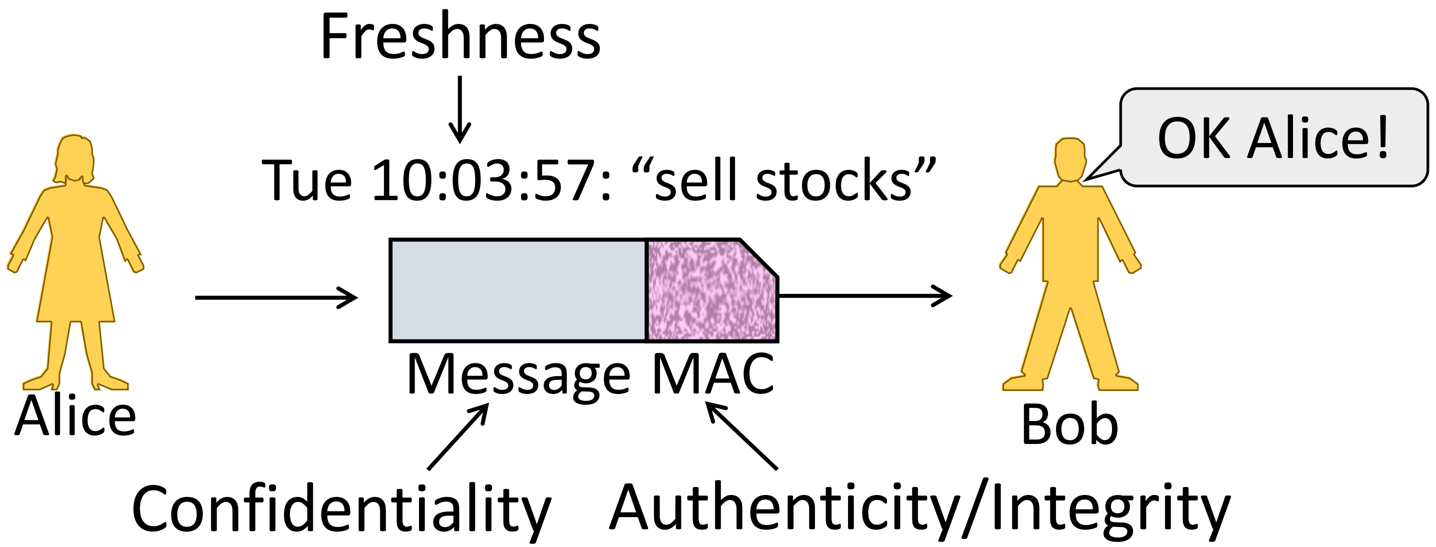
Preventing Replays (2)

- Replay attack:
  - Trudy records Alice's messages to Bob
  - Trudy later replays them (unread) to Bob
    - She pretends to be Alice

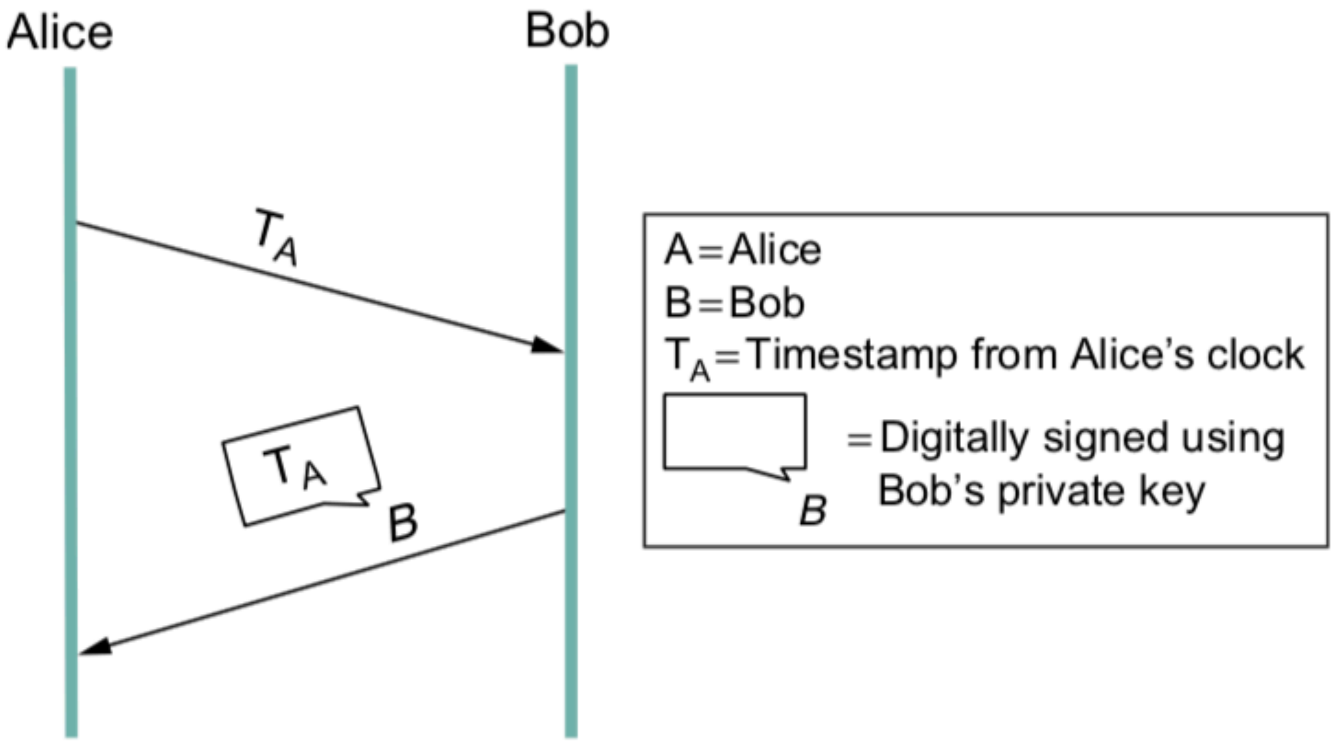


Preventing Replays (3)

- To prevent replays, include a proof of freshness in the messages
  - Use a timestamp, or nonce



Using Timestamps


Alice
Bob
T_A
T_A
B
A = Alice
B = Bob
T_A = Timestamp from Alice's clock
B
= Digitally signed using Bob's private key

Takeaway

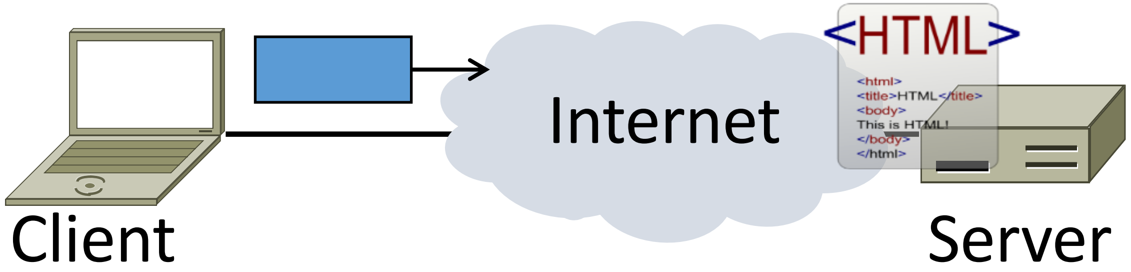
- Cryptographic designs can give us integrity, authenticity and freshness as well as confidentiality.
- Real protocol designs combine the properties in different ways
  - We’ll see some examples
  - Note many pitfalls in how to combine, as well as in the primitives themselves

Web Security

What should be the Threat Model for the Web?

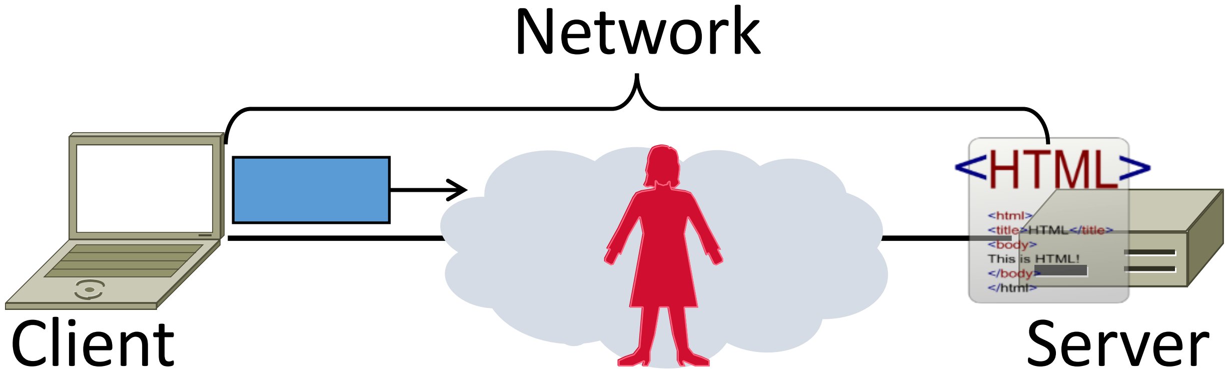
Goal and Threat Model

- Much can go wrong on the web!
  - Clients encounter malicious content
  - Web servers are target of break-ins
  - Fake content/servers trick users
  - Data sent over network is stolen …



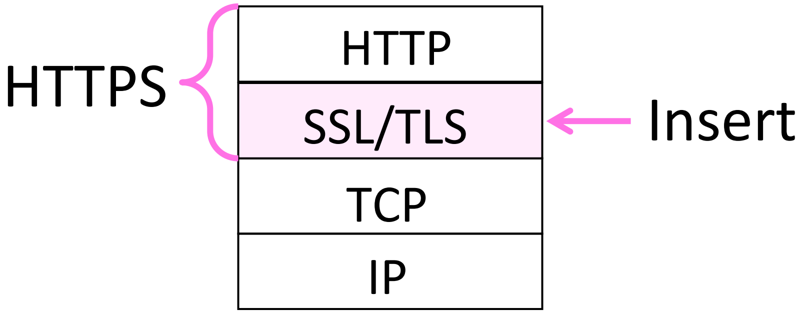
Goal and Threat Model (2)

- Goal of HTTPS is to secure HTTP
- We focus on network threats:
  1. Eavesdropping client/server traffic
  2. Tampering with client/server traffic
  3. Impersonating web servers



HTTPS Context

- HTTPS (HTTP Secure) is an add-on
  - Means HTTP over SSL/TLS
  - SSL (Secure Sockets Layer) precedes TLS (Transport Layer Security)



HTTPS Context (2)

- SSL came out of Netscape
  - SSL2 (flawed) made public in ‘95
  - SSL3 fixed flaws in ‘96
- TLS is the open standard
  - TLS 1.0 in ‘99, 1.1 in ‘06, 1.2 in ‘08
- Motivated by secure web commerce
  - Slow adoption, now widespread use
  - Can be used by any app, not just HTTP

SSL/TLS Operation

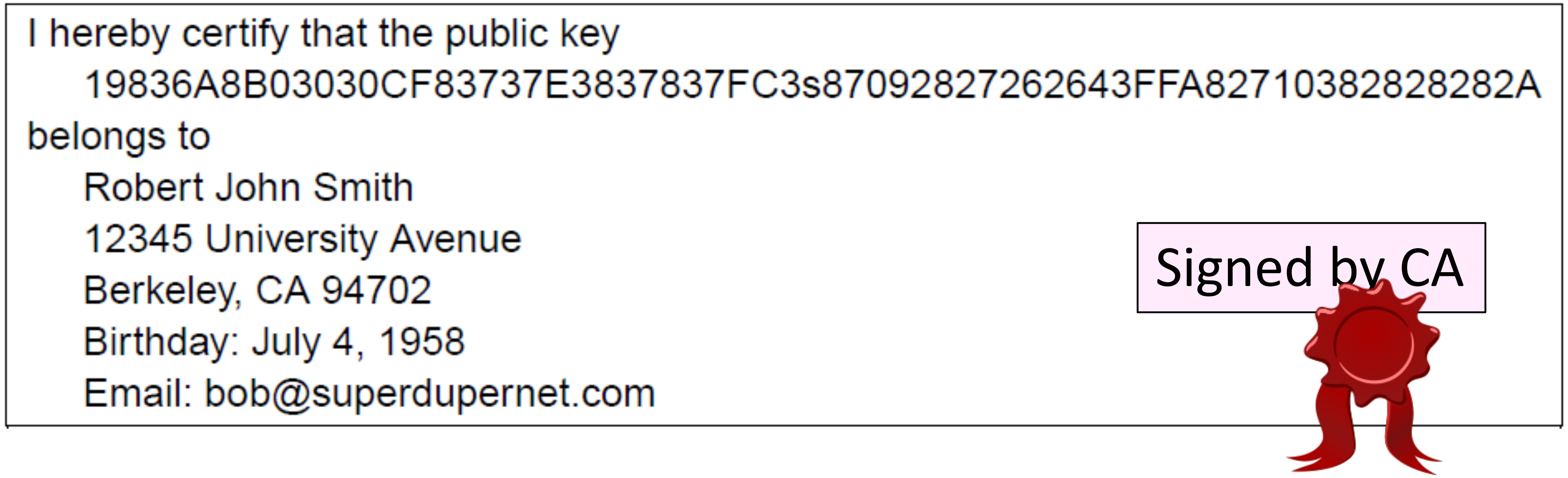
- Protocol provides:
  1. Verification of identity of server (and optionally client)
  2. Message exchange between the two with confidentiality, integrity, authenticity and freshness
- Consists of authentication phase (that sets up encryption) followed by data transfer phase

SSL/TLS Authentication

- Must allow clients to securely connect to servers not used before
  - Client must authenticate server
  - Server typically doesn’t identify client
- Uses public key authentication
  - But how does client get server’s key?
  - With certificates »

Certificates

- A certificate binds pubkey to identity, e.g., domain
  - Distributes public keys when signed by a party you trust
  - Commonly in a format called X.509

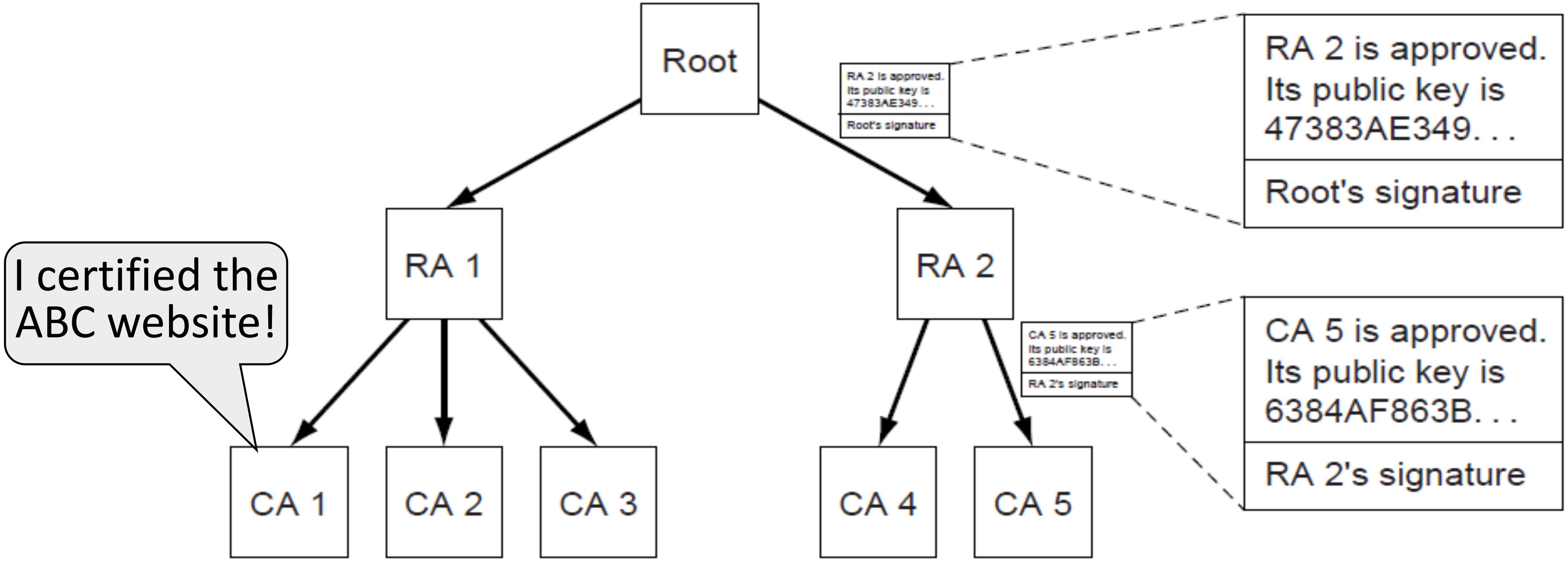


I hereby certify that the public key
    19836A8B03030CF83737E3837837FC3s87092827262643FFA82710382828282A
belongs to
    Robert John Smith
    12345 University Avenue
    Berkeley, CA 94702
    Birthday: July 4, 1958
    Email: bob@superdupernet.com

Signed by CA

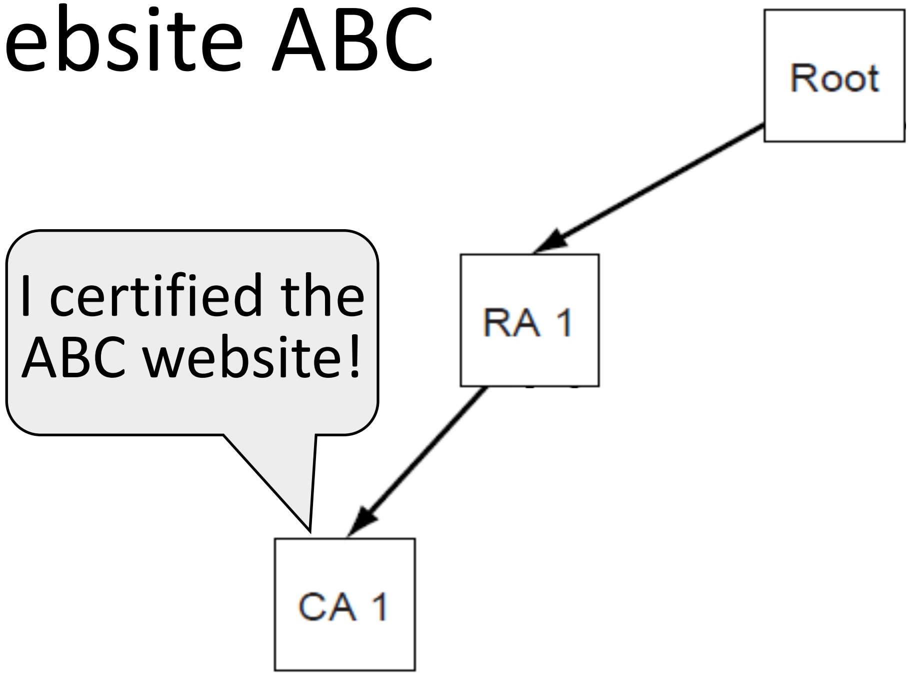
PKI (Public Key Infrastructure)

- Adds hierarchy to certificates to let parties issue
    - Issuing parties are called CAs (Certificate Authorities)


Root
RA 1
RA 2
CA 1
CA 2
CA 3
CA 4
CA 5
I certified the ABC website!
RA 2 is approved. Its public key is 47383AE349. . .
Root's signature
RA 2 is approved. Its public key is 47383AE349. . .
Root's signature
CA 5 is approved. Its public key is 6384AF863B. . .
RA 2's signature
CA 5 is approved. Its public key is 6384AF863B. . .
RA 2's signature

PKI (2)

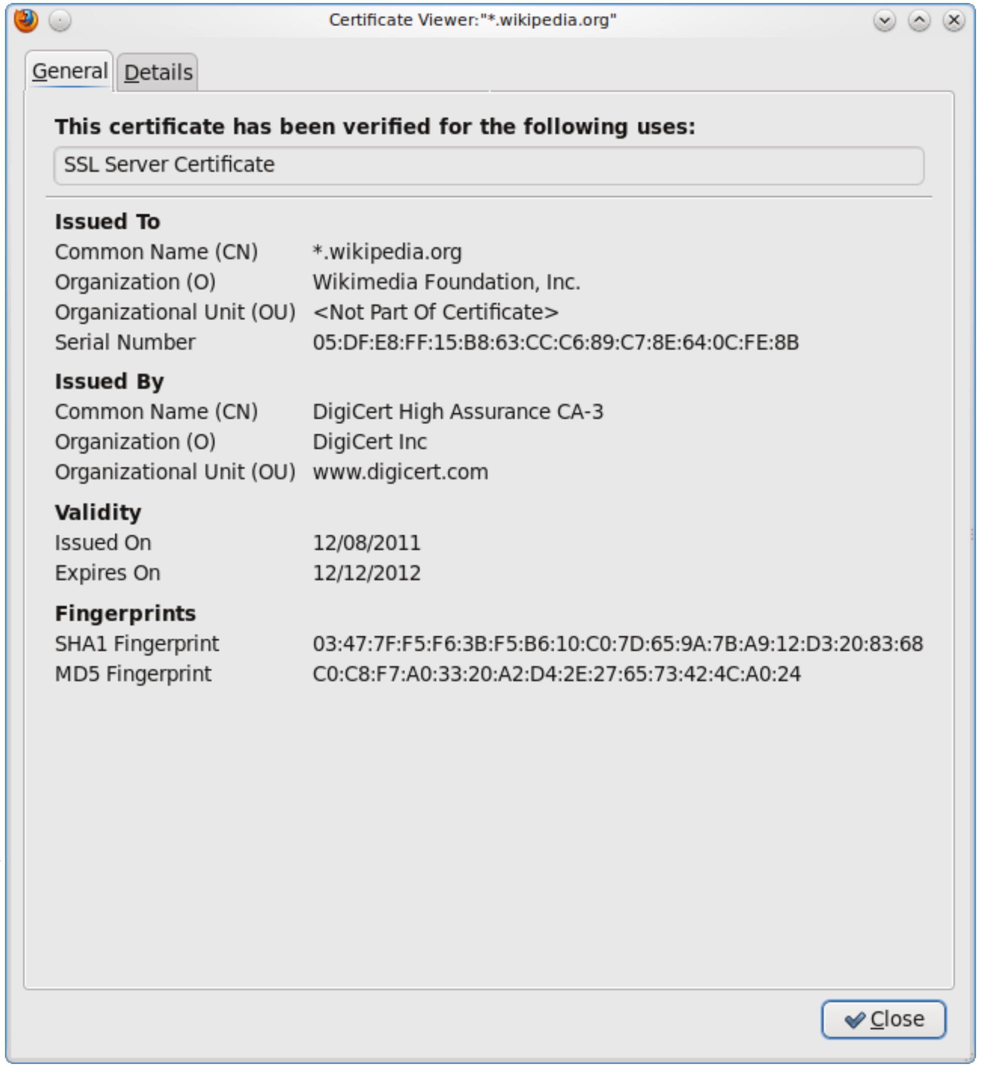
- Need public key of PKI root and trust in servers on path to verify a public key of website ABC
  - Browser has Root’s public key
  - {RA1’s key is X} signed Root
  - {CA1’s key is Y} signed RA1
  - {ABC’s key is Z} signed CA1



PKI (3)

- Browser/OS has public keys of the trusted roots of PKI
    - >100 root certificates!
    - Inspect your web browser

Certificate for wikipedia.org issued by DigiCert



This certificate has been verified for the following uses:

SSL Server Certificate

Issued To

Common Name (CN)	*.wikipedia.org
Organization (O)	Wikimedia Foundation, Inc.
Organizational Unit (OU)	<Not Part Of Certificate>
Serial Number	05:DF:E8:FF:15:B8:63:CC:C6:89:C7:8E:64:0C:FE:8B

Issued By

Common Name (CN)	DigiCert High Assurance CA-3
Organization (O)	DigiCert Inc
Organizational Unit (OU)	www.digicert.com

Validity

Issued On	12/08/2011
Expires On	12/12/2012

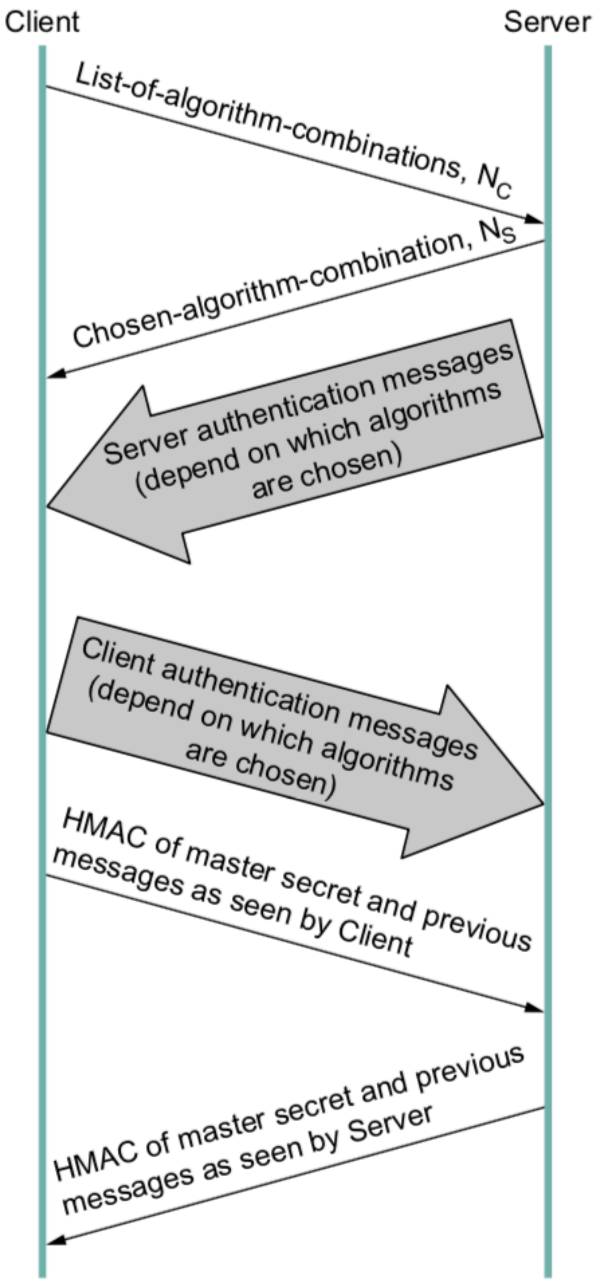
Fingerprints

SHA1 Fingerprint	03:47:7F:F5:F6:3B:F5:B6:10:C0:7D:65:9A:7B:A9:12:D3:20:83:68
MD5 Fingerprint	C0:C8:F7:A0:33:20:A2:D4:2E:27:65:73:42:4C:A0:24

PKI (4)

- Real-world complication:
  - Public keys may be compromised
  - Certificates must then be revoked
- PKI includes a CRL (Certificate Revocation List)
  - Browsers use to weed out bad keys

TLS handshake



Client

Server

List-of-algorithm-combinations, N_C

Chosen-algorithm-combination, N_S

Server authentication messages (depend on which algorithms are chosen)

Client authentication messages (depend on which algorithms are chosen)

HMAC of master secret and previous messages as seen by Client

HMAC of master secret and previous messages as seen by Server

What can attacker (in the network) still learn from an HTTPS connection?

- “Metadata”

Takeaways

- SSL/TLS is a secure transport
  - For HTTPS and more, with the usual confidentiality, integrity / authenticity
  - Very widely used today
- Client authenticates web server
  - Done with a PKI and certificates
  - Major area of complexity and risk
- “Metadata” leaks
  - Use other tools (Tor or VPN) if you want to hide that