Mid-quarter feedback

Thank you, 41% of you!

What is working

Lectures

Homeworks, quizzes (surprisingly!)

What should be improved (ordered list)

Do not have all office hours in the mornings

Ambiguous project goals

- More project help

Less strict grading rubric for projects

Recording quality is uneven, whiteboard on Zoom

More practice problems

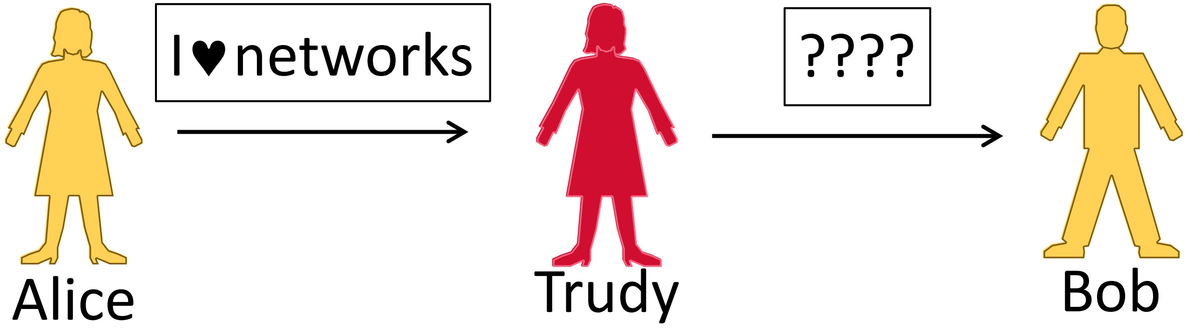
Message Authentication

Goal and Threat Model

Goal: Enable Bob to verify that the message is from Alice and is unchanged ←

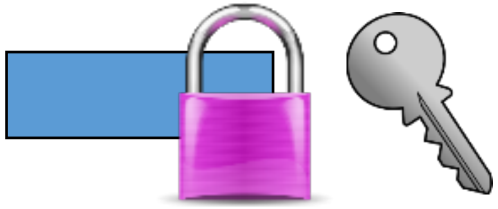
- This is called integrity/authenticity

Threat: Trudy, an active adversary, will tamper with messages



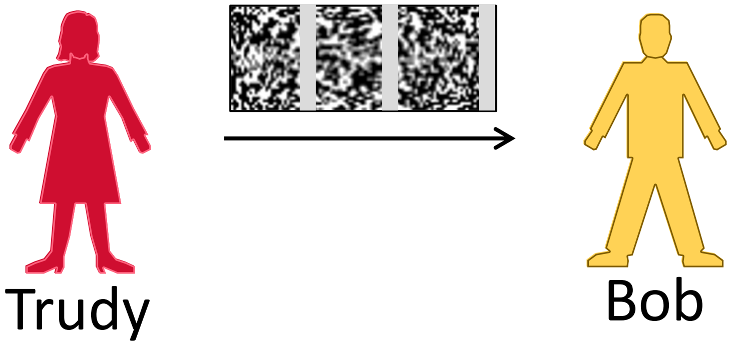
Wait a Minute!

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



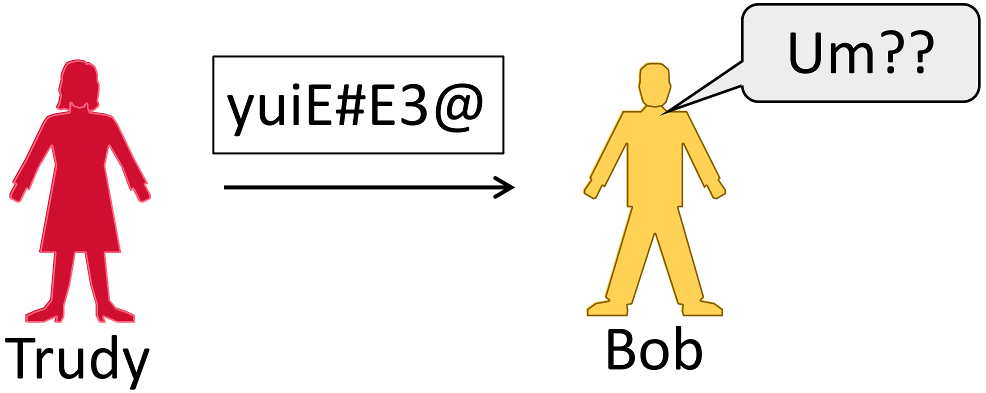
Encryption Issues

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



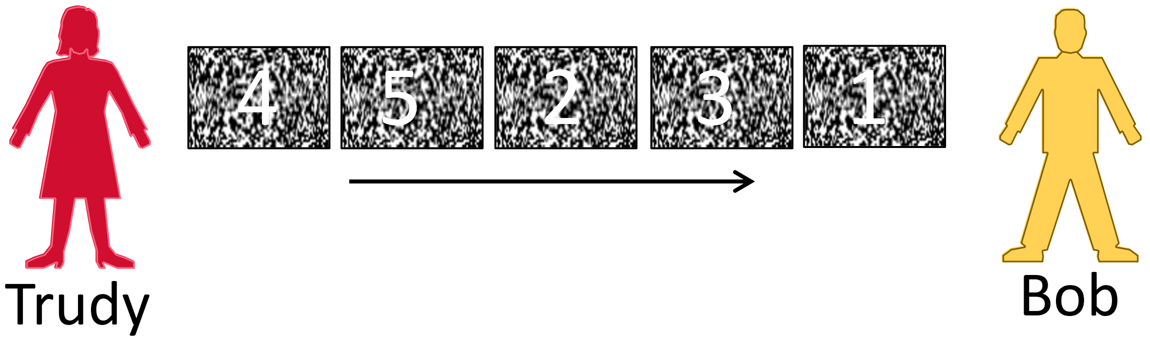
Encryption Issues (2)

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



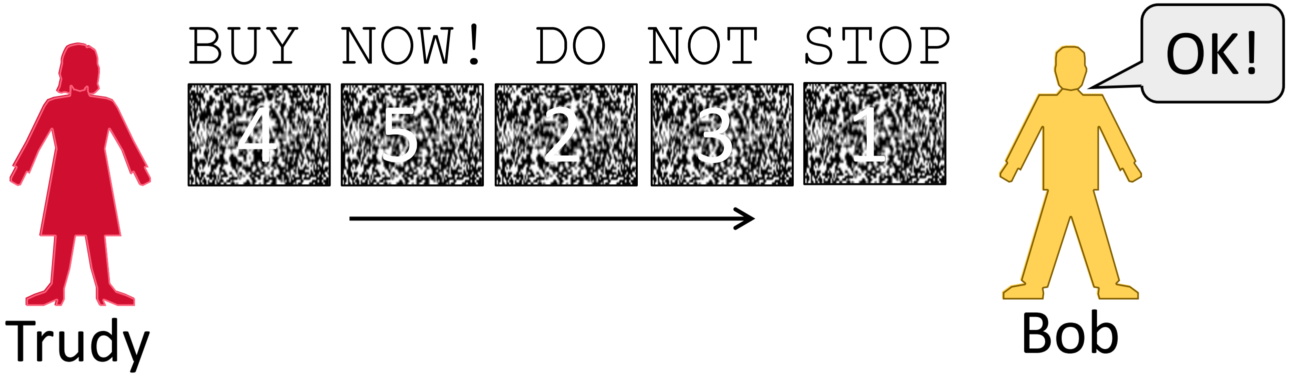
Encryption Issues (3)

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



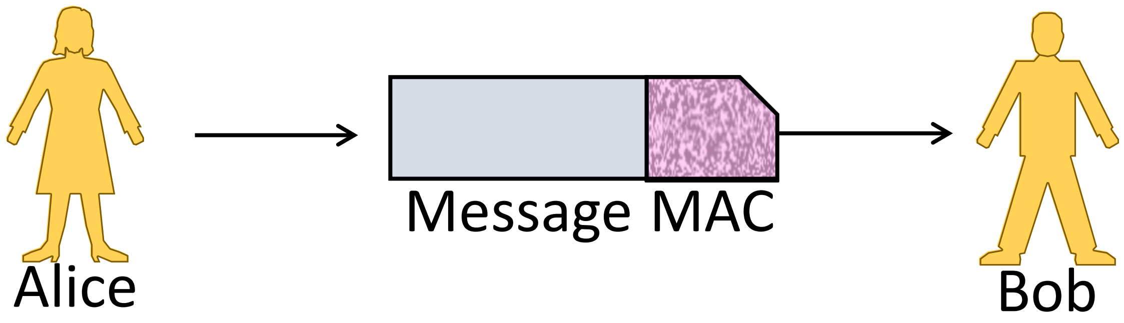
Encryption Issues (4)

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



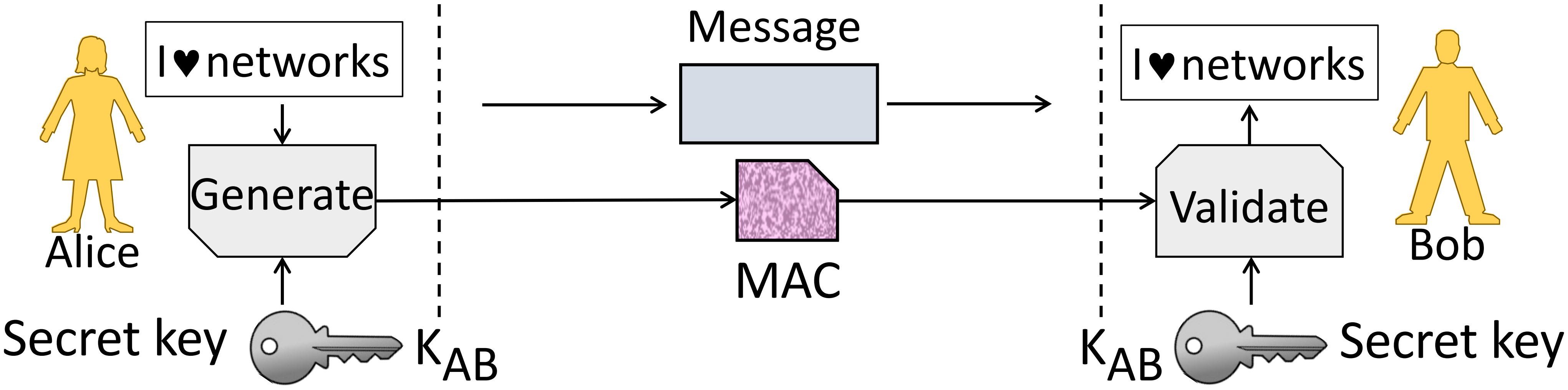
MAC (Message Authentication Code)

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



MAC (2)

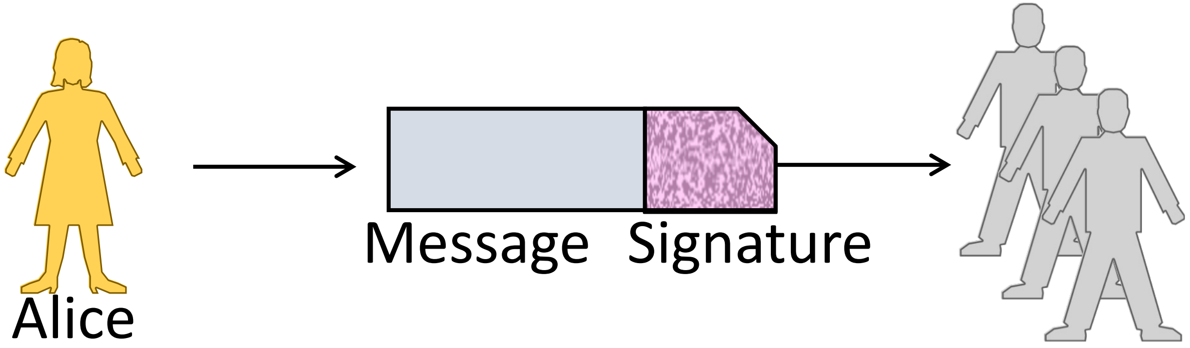
- Sorta symmetric encryption operation – key shared
  - Lets Bob validate unaltered message came from Alice
  - Does NOT let Bob convince Charlie that Alice sent it



Digital Signature

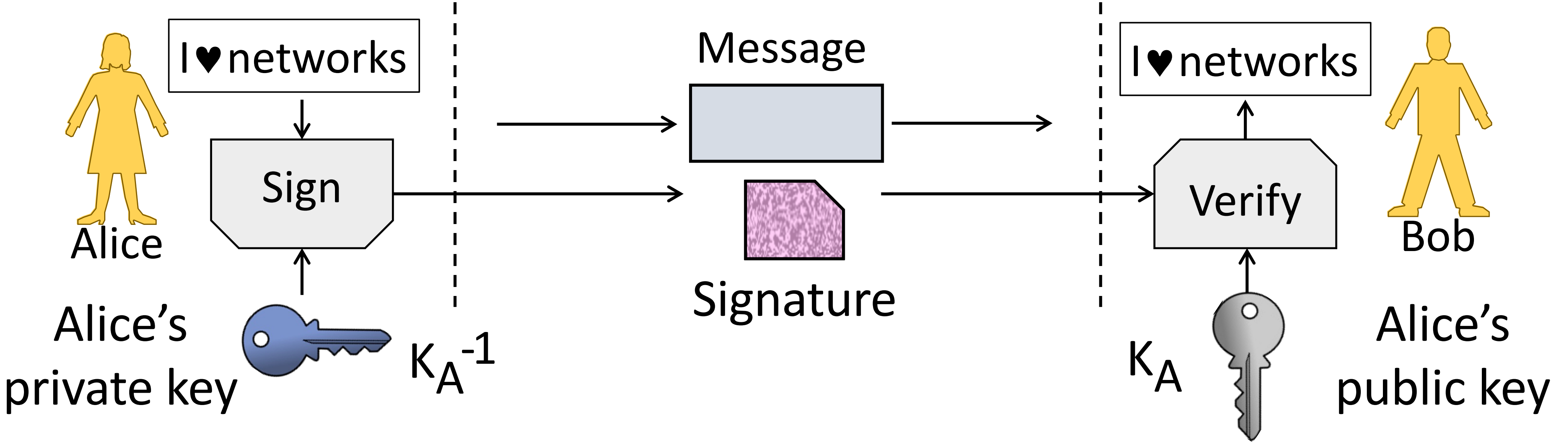
Validates the integrity/authenticity of message

- 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

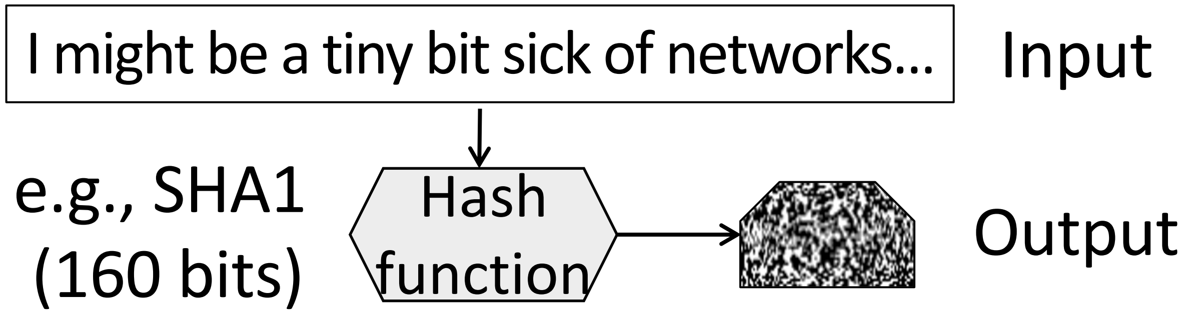


Speeding up Signatures

- 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

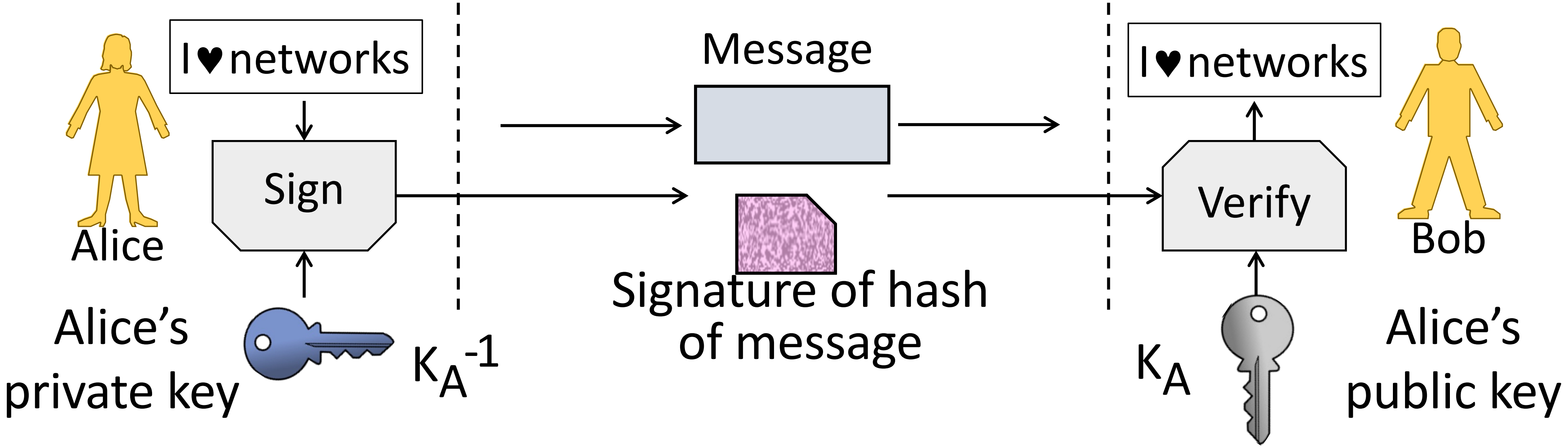
Message Digest or Cryptographic Hash

- 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

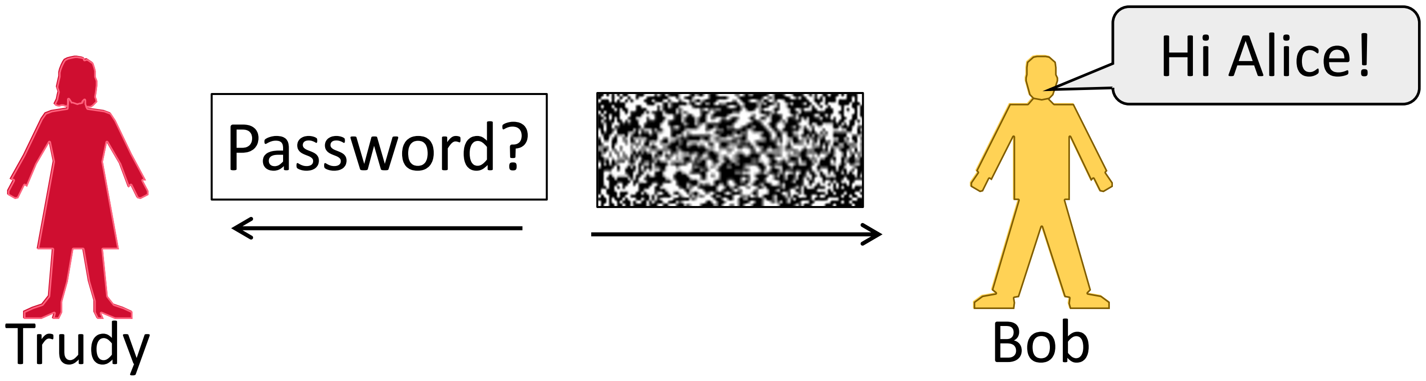


Preventing Replays

- 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

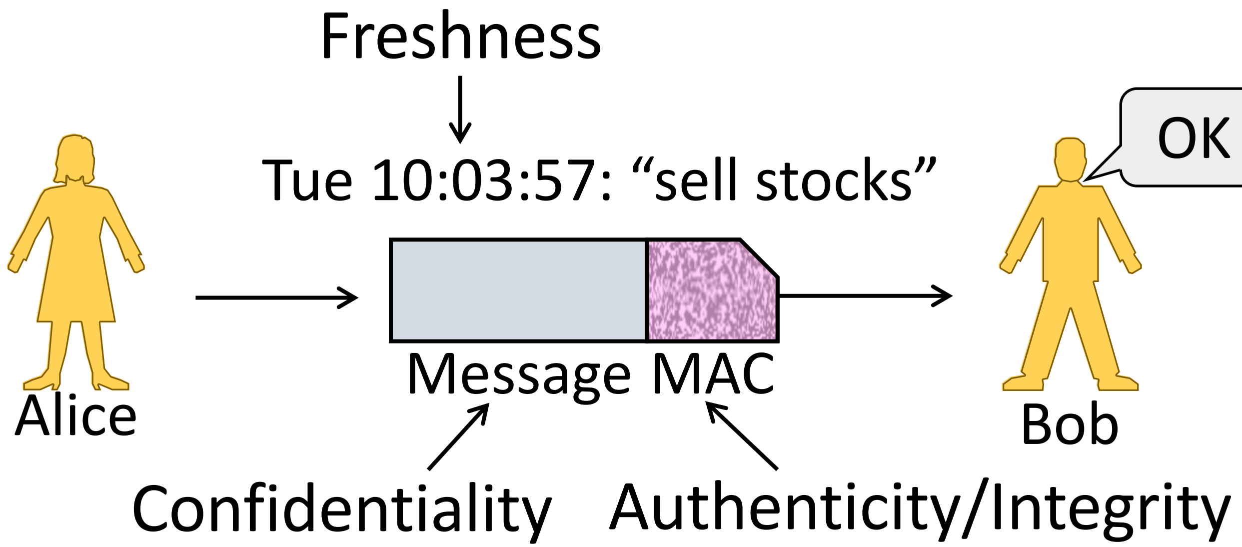
Preventing Replays (2)

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

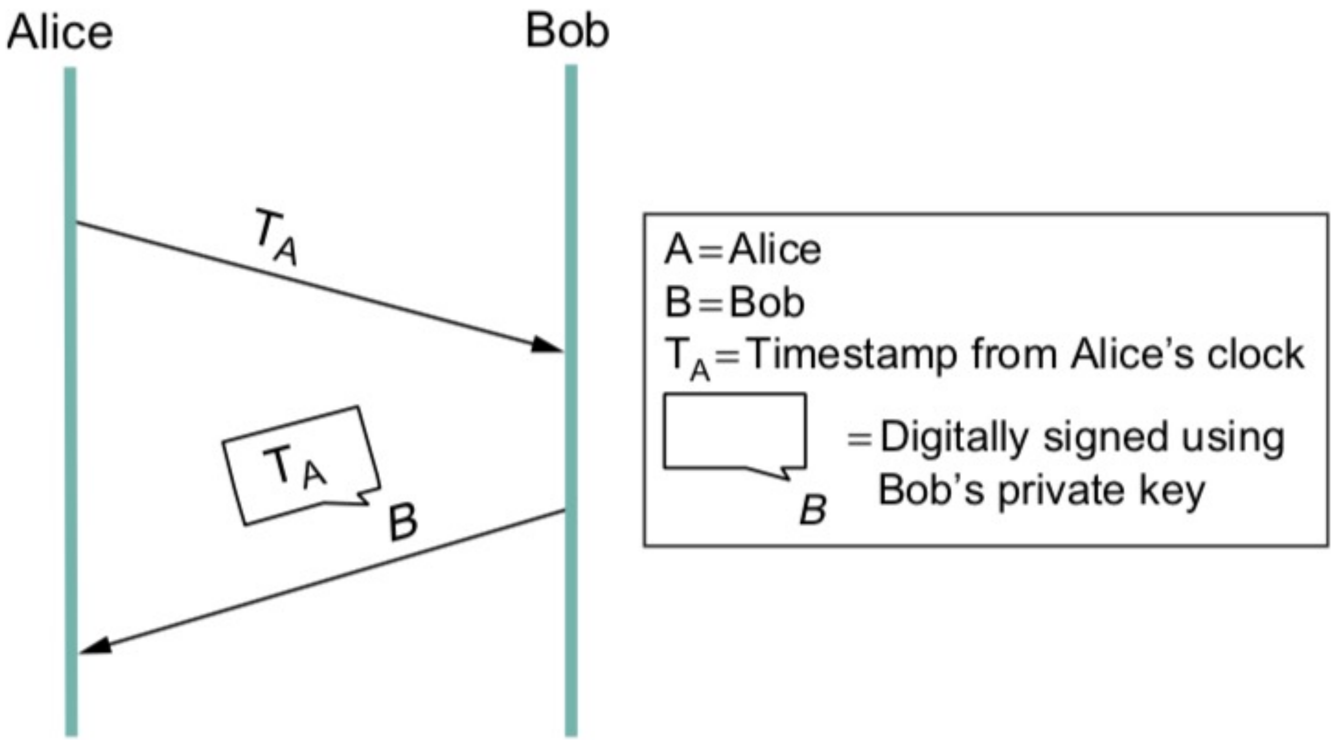


Preventing Replays (3)

- To prevent replays, include a proof of freshness in the messages
  - Use a timestamp, or nonce (number once used)



Using Timestamps



Takeaway

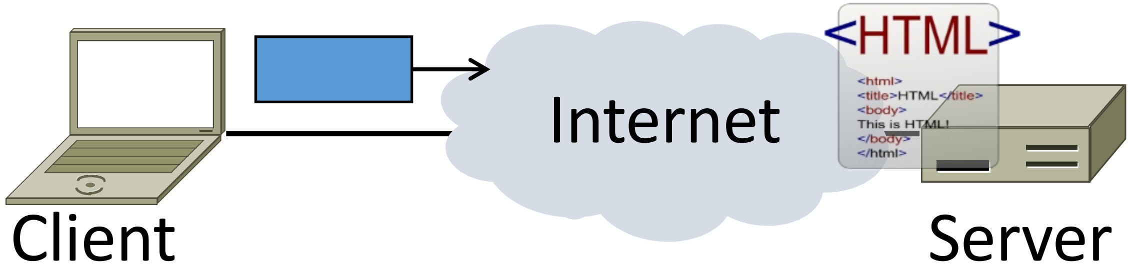
- Cryptographic designs can give us integrity, authenticity and freshness as well as confidentiality.
- Real protocol designs combine the properties in different ways
  - We'll see some examples
  - Note many pitfalls in how to combine, as well as in the primitives themselves

Web Security

What should be the Threat Model for the Web?

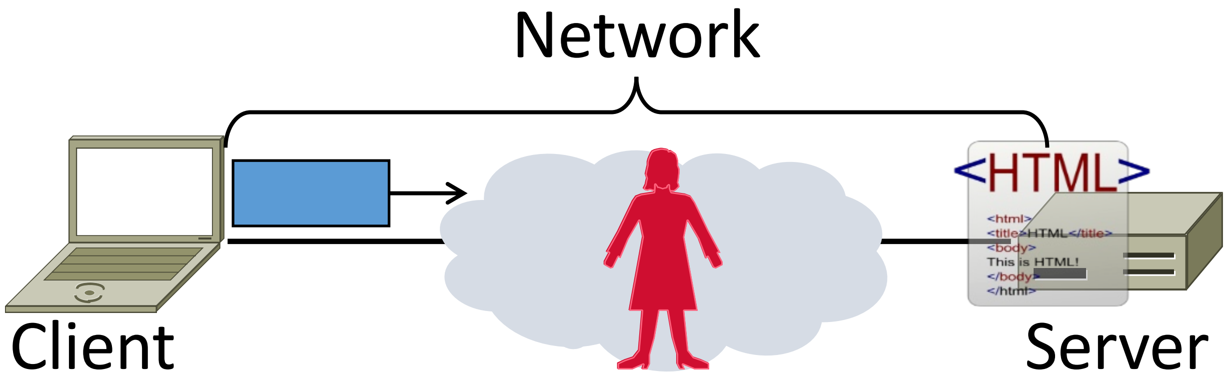
Goal and Threat Model

- 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 …



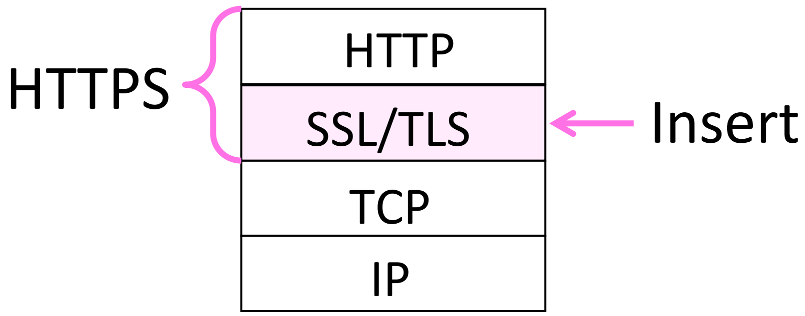
Goal and Threat Model (2)

- 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

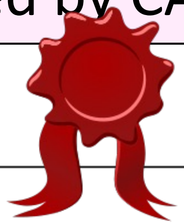
- Must allow clients to securely connect to servers not used before
  - Client must authenticate server
  - Server typically doesn’t identify client
- Uses public key authentication
  - But how does client get server’s key?
  - With certificates »

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

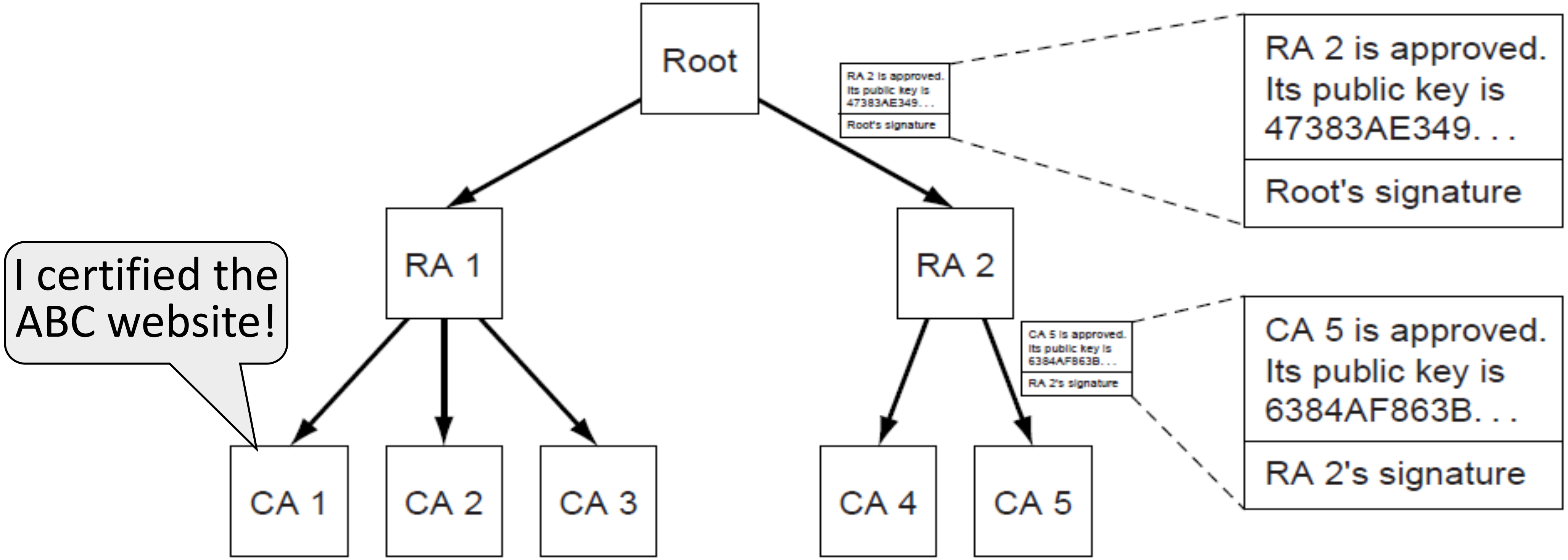
I hereby certify that the public key
  19836A8B03030CF83737E3837837FC3s87092827262643FFA82710382828282A
belongs to
  Robert John Smith
  12345 University Avenue
  Berkeley, CA 94702
  Birthday: July 4, 1958
  Email: bob@superdupernet.com

Signed by CA



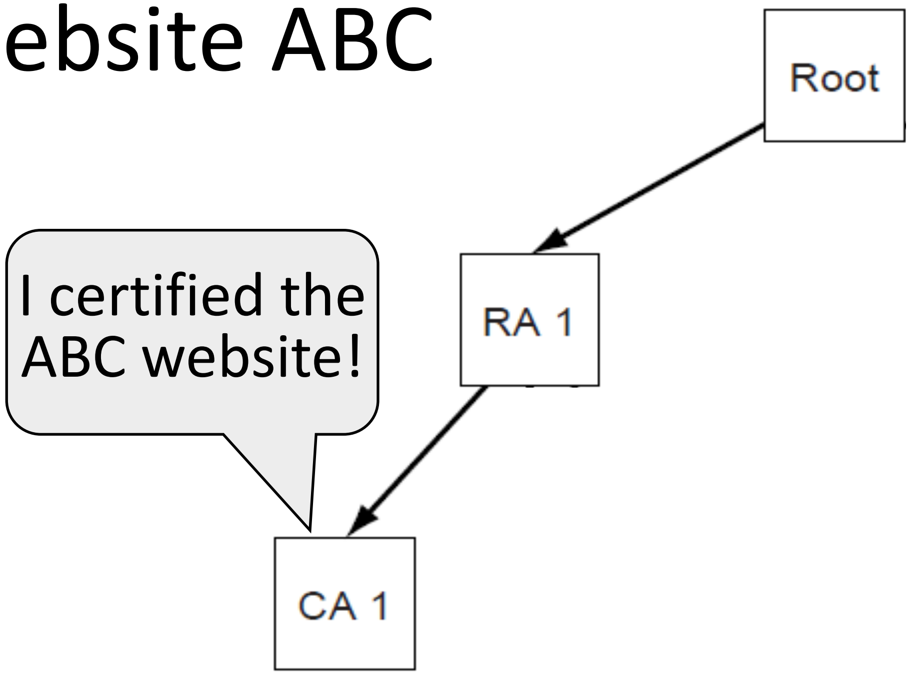
PKI (Public Key Infrastructure)

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



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)

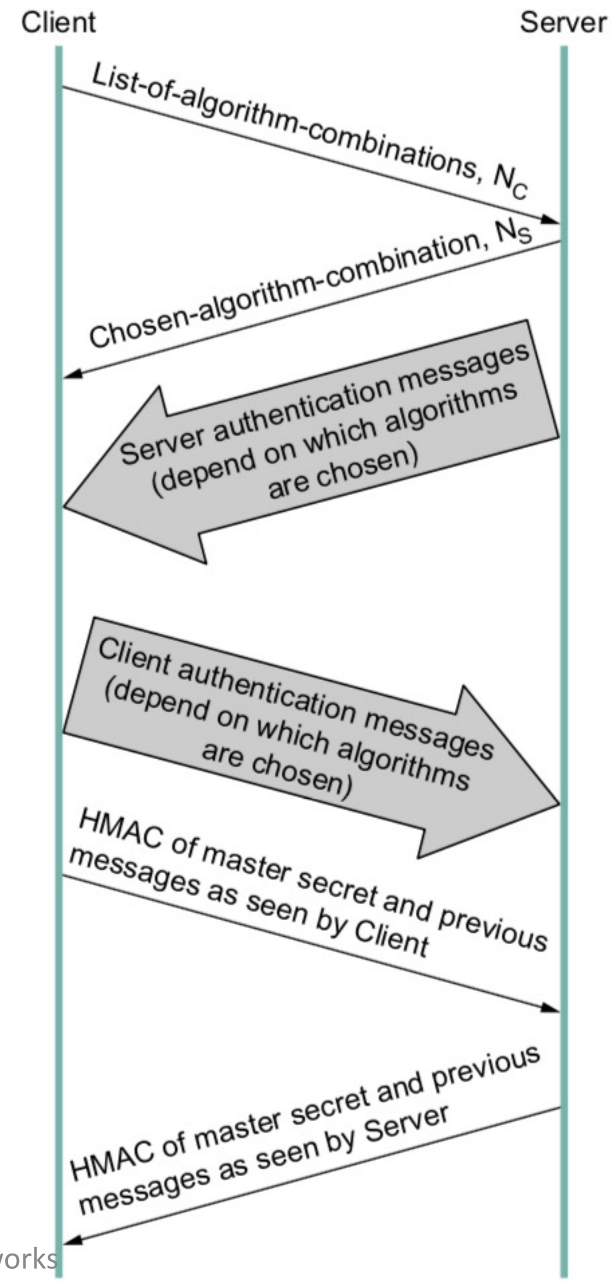
- Browser/OS has public keys of the trusted roots of PKI
  - >100 root certificates!
  - Inspect your web browser

Certificate for wikipedia.org
issued by DigiCert

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



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

A: 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