CS 725/825 & IT 725
Lecture 11
Network Security

October 2, 2024

Encryption Methods

- Cæsar (substitution) cipher
  - ... frequency analysis
- “Unbreakable” cipher: One Time Pad
- DES - Data Encryption Standard
  - 1977, symmetric key, 56-bit key, 64-bit data blocks
- AES - Advanced Encryption Standard
  - 1998, symmetric key, 128,192, and 256-bit keys, 128-bit data blocks

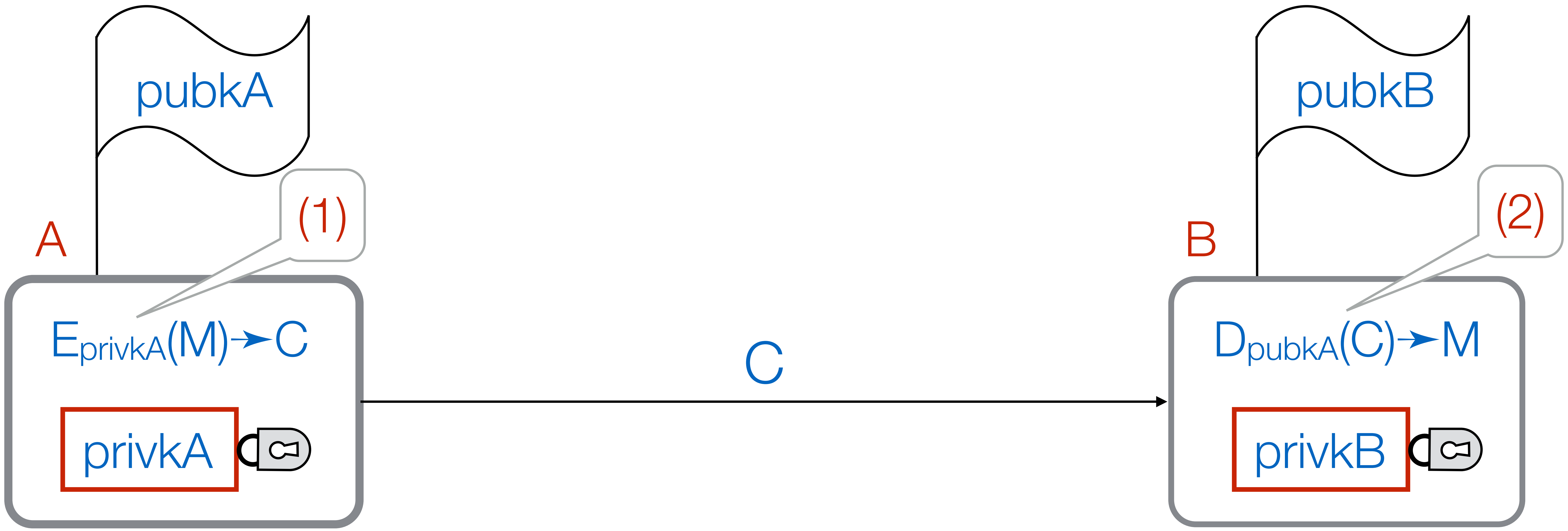
Encryption Methods

- (Diffie-Hellman key exchange)
  - a method allows two parties that have no prior knowledge of each other to jointly establish a shared secret key over an insecure communications channel.
- RSA - Rivest, Shamir, and Adleman
  - 1978, public/private key algorithm, 1,024 to 4,096- bit keys (typically)
- Elliptic-curve cryptography (ECC)
  - 2005, allows shorter keys while providing equivalent security

Authentication

- Basic idea:
  - use “flipped” public/private key cryptography
  - only possessor of private key could have encrypted something that decrypts using its public key
- Problem: Replay Attack
  - solution: use of a nonce
- Still unaddressed: We need a trusted way to obtain someone’s public key

Authentication - Basics



(1) A “encrypts” the message: $E_{privkA}(M) \rightarrow C$ and sends it to B

(2) B “decrypts” the message: $D_{pubkA}(C) \rightarrow M$

(3) if M “looks OK”*, its sender is authenticated

* the assumption is that recipient can tell the difference between a valid message and a random string of bits that would be the result of decryption with a wrong key

Message Integrity

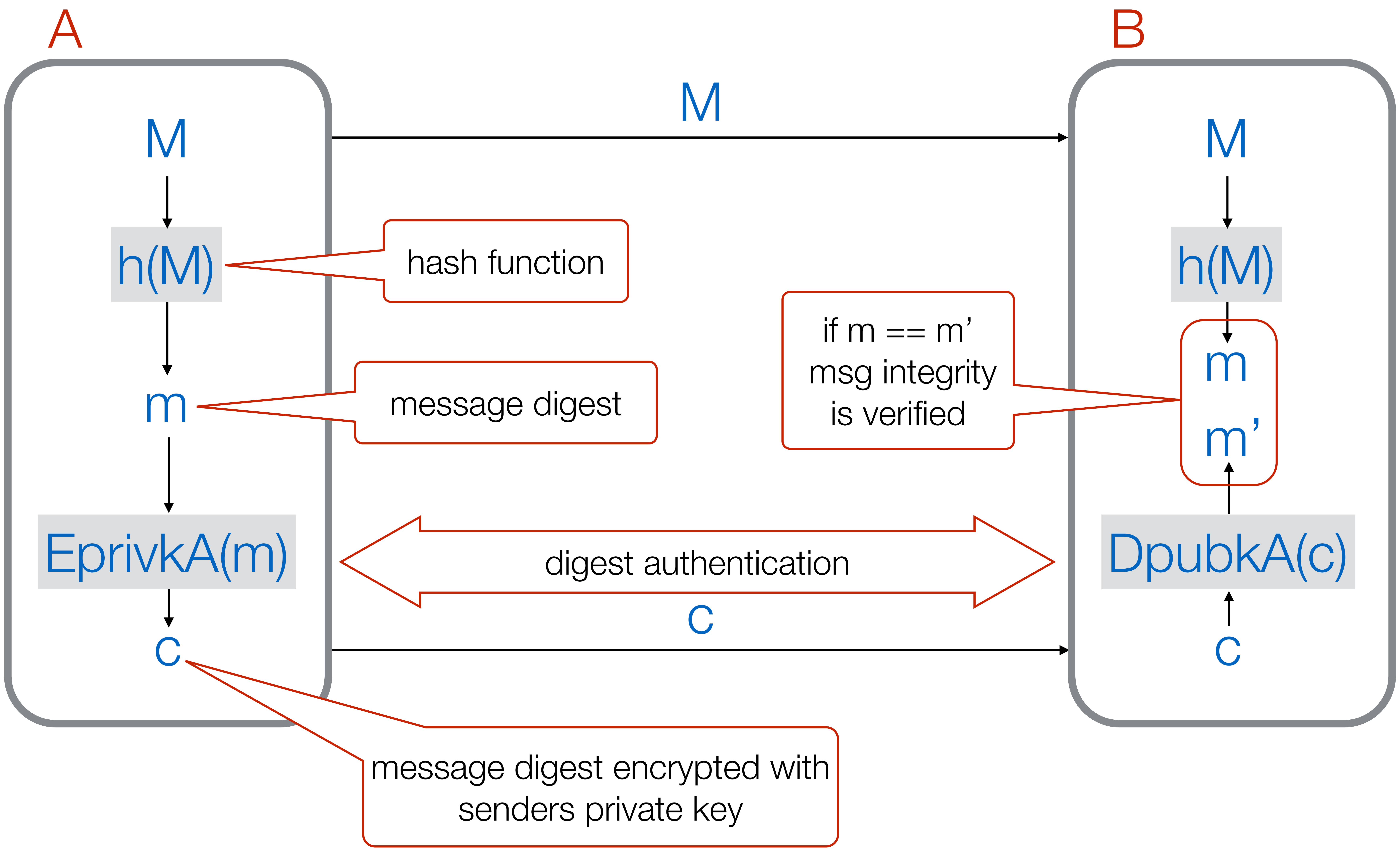
- Basic idea:
  - use public/private key cryptography
  - send encrypted (using sender's private key) hash of a message
  - if hash of the received message agrees with decrypted received hash, it is assumed that the message was not altered in transit
- Problems:
  - need a cryptographic hash function
  - need a secure method for public key distribution

Cryptographic hash function

$H(M) \rightarrow m$

- Even the smallest change in message M results in a significant "unpredictable" change of the hash value m
- It is infeasible to find two distinct messages, M_1 and M_2, with the same hash value m ($H(M_1) = H(M_2)$)
- It is infeasible to modify a message M to get M' in a way that the hash value remains the same ($H(M) = H(M')$)
- … must be easy to compute
  - M is arbitrarily large, m is small and fixed-size (100's of bits)

Message Integrity



Cryptographic hash functions

- MD5 - Message Digest Algorithm
  - 1992, R. Rivest, digest size 128 bits
- SHA-1 - Secure Hash Algorithm
  - 1995, NSA, digest size 160 bits
- SHA-2
  - 2001 NSA designed, variants SHA-256 and SHA-512
- SHA-3
  - 2012 public competition winner, 2015 NIST-designated hashing standard (SHAKE variant allows arbitrary output length)

Certificates

- Solving the public key distribution problem
- Shared trust (having somebody's public key) helps:
  - When both A and B trust C
    $\Rightarrow$ A can establish trust with B (and vice versa)
- Where to start?
  - who to trust
  - how is the initial trust established
- Solution: Certificate Authority (CA)

Certificates

- Goal: A wants to prove its identity to B
- Given: A and B trust CA (both have CA's public key)
- Broad approach: Public key certificate
  - A's public key encrypted with CA's private key (ensures integrity of the key)
  - … plus additional information
- Use: A presents its certificate when initiating communication with B

Certificates - Questions

- Man in the Middle Attack: How does B know that it is A's certificate and not an impostor's one?
  - Include A's identification (hostname, human-readable info)
- Replay Attack: Attacker overhears/requests A certificate and presents it when pretending to be A
  - Use nonce encrypted with A's private key during communication
- Compromised certificate: Either A's or CA's private keys are compromised
  - Limited validity and certificate revocation

Certificates - Issuance

- A gets a certificate from a CA
  - A generates public/private key pair
  - A generates a Certificate Signing Request (CSR)
  - CA (hopefully) makes sure that it interacts with A and not an impostor
  - CA encrypts the certificate (public key + A's identification + ...) with its own private key
  - certificate is delivered to A (can be done securely since A has CA's public key)

Certificates - Use

- B authenticates A
  - B requests a certificate from A together with a nonce
  - A sends back the certificate together with the nonce encrypted with A's private key
  - B decrypts the certificate with CA's public key and verifies that it was issued to A
  - B decrypts the nonce using A's public key and verifies that the value matches the value sent