Transport Security
Part I

Lecture 12, Computer Networks (198:552)

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Why security?

- Malicious people share your network
  - People who want to snoop, corrupt, destroy, pretend, steal, …
- Problem made more severe as Internet becomes more commercialized
- Active and passive attacks

Key aspects of network security

confidentiality: only sender, intended receiver should "understand" message contents

- sender encrypts message
- receiver decrypts message

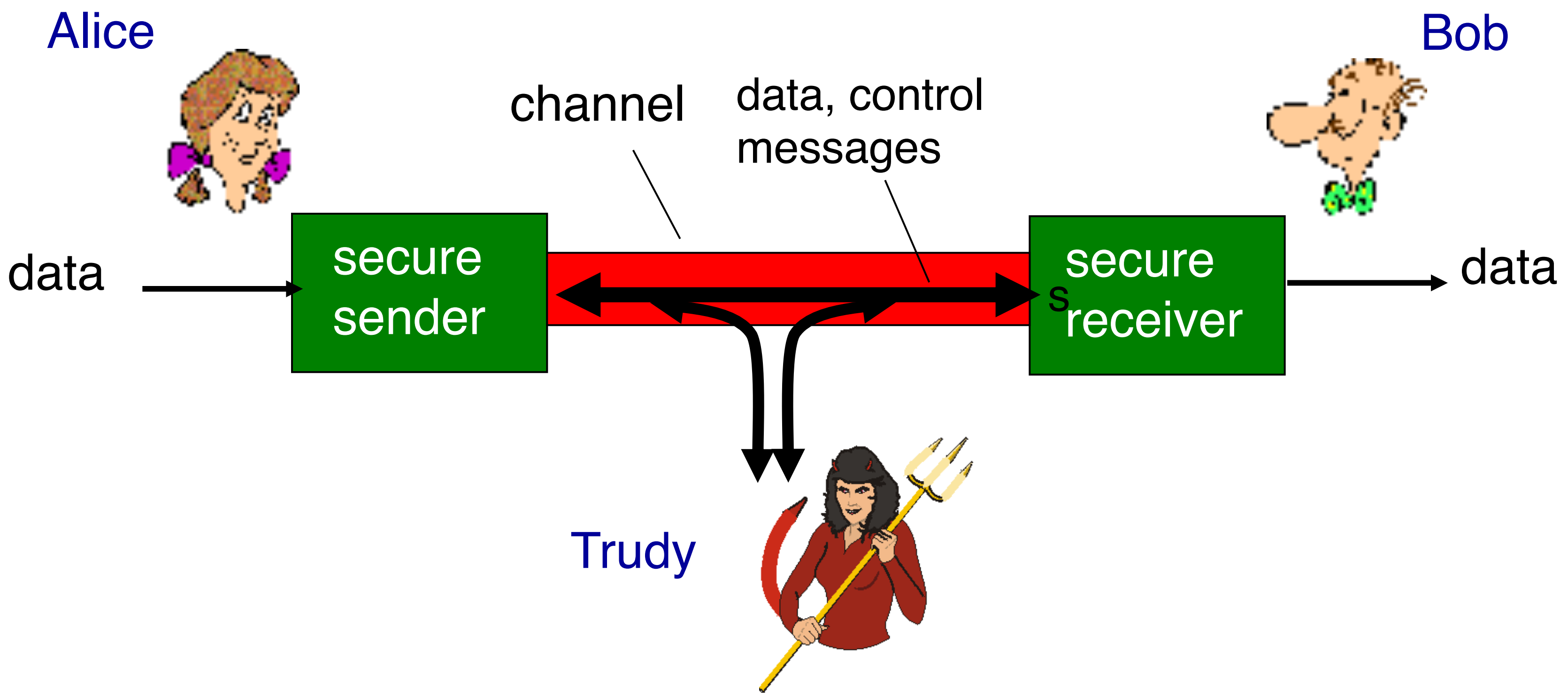
integrity: sender, receiver want to ensure message not altered (in transit, or afterwards) without detection

authentication: sender, receiver want to confirm identity of each other

non-repudiation: Once someone sends a message, or conducts a transaction, she can't later deny the contents of that message

Friends and enemies: Alice, Bob, Trudy

- well-known in network security world
- Bob and Alice want to communicate “securely”
- Trudy (intruder) may intercept, delete, add messages



Who might Bob and Alice be?

- Real humans ☺
- Web browser/server for electronic transactions (e.g., on-line purchases)
- on-line banking client/server
- DNS servers
- routers exchanging routing table updates

What can bad actors do?

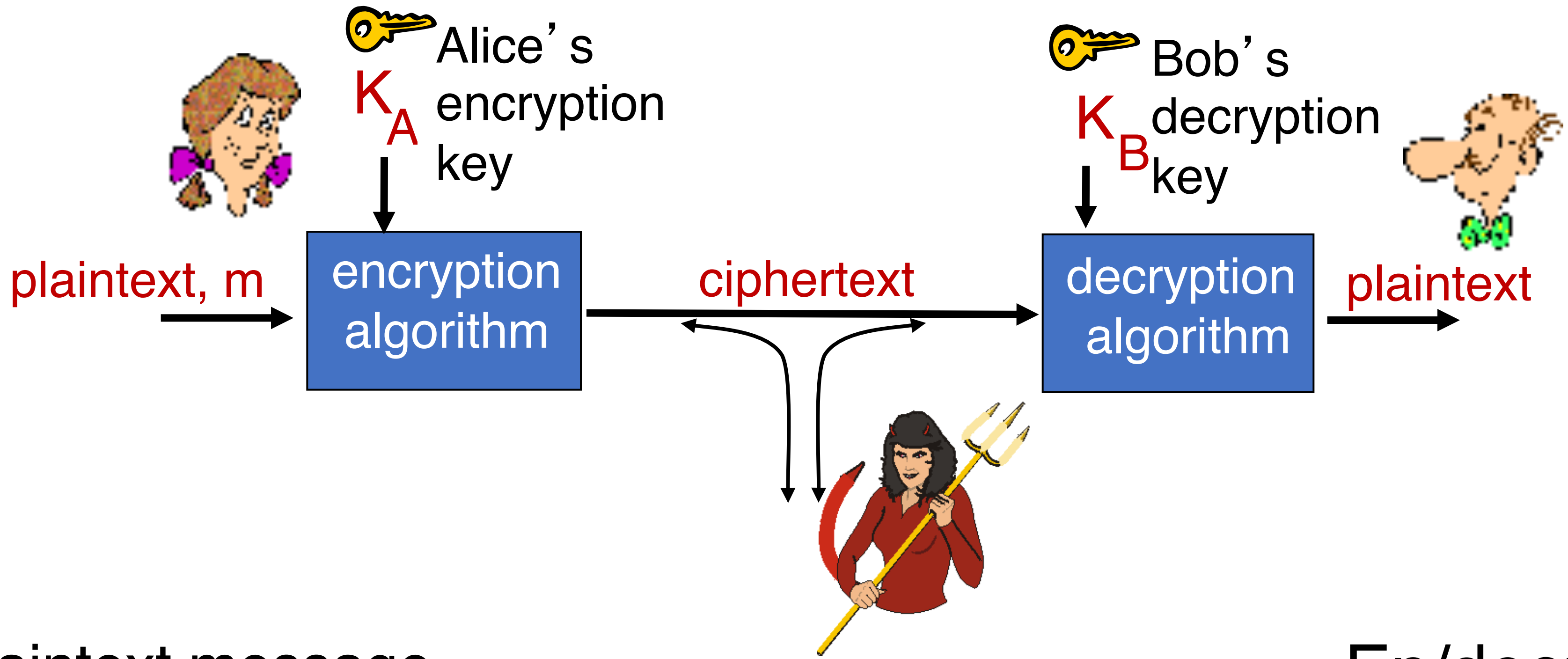
A lot!

- *eavesdrop:* intercept messages
- actively *insert* messages into connection
- *impersonation:* can fake (spoof) source address in packet (or any field in packet)
- *hijacking:* "take over" ongoing connection by removing sender or receiver, inserting itself in place
- *denial of service*: prevent service from being used by others (e.g., by overloading resources)

Confidentiality

Cryptography: preventing adversaries from reading private messages

Cryptography: Terminology



m plaintext message

$c = K_A(m)$, $K_A(m)$ ciphertext, encrypted with key K_A

$m' = K_B(c)$, $K_B(c)$ decrypted plaintext with key K_B

Want: $m = K_B(K_A(m))$

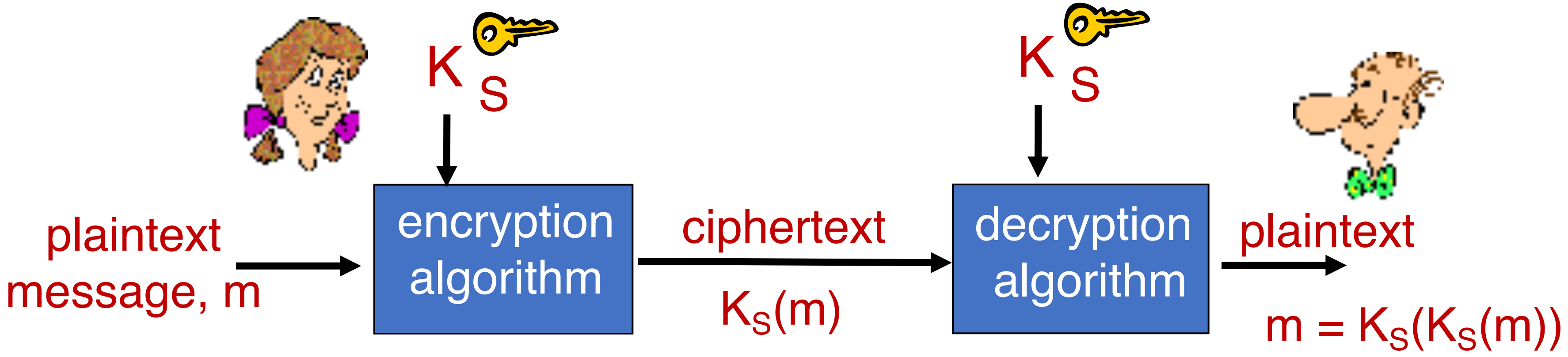
Want: $K_A(m)$ to be uncorrelated with m

En/decryption algorithms are also called ciphers.

Cryptography: Algorithms and Keys

- Cryptography requires both an en-/decryption algorithm and keys
  - Key is a string known only to Alice and Bob, which controls how algorithm works
- Algorithm should be public and known to all
  - Inspires trust that the algorithm works
- Keys
  - Should be long enough to prevent easy breaking of the encryption
  - Should be short enough to keep algorithm efficient
  - Typical key lengths: 56-bit, 128-bit, 256-bit, 512-bit

Symmetric key cryptography



Symmetric keys: Bob and Alice share same (symmetric) key: S

Main techniques of symmetric key cryptography:
Substitution and Permutation

Q: how do Bob and Alice agree on key value?

How to agree on a shared secret key?

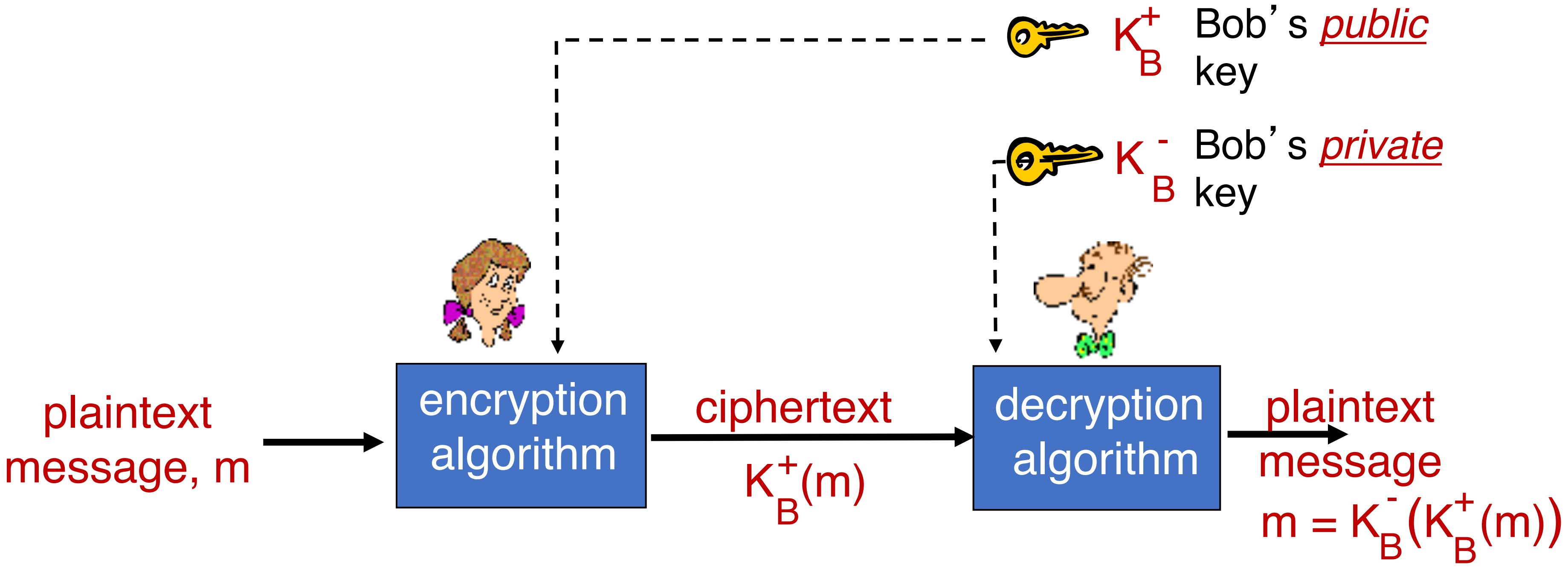
- In reality: two parties may meet in person or communicate “out of band” to exchange shared key
- But communicating parties may never meet in person
  - Example: An online retailer and customer
  - Much more common for a network ☺
- What if the shared secret is stolen?
  - All secret communications can now be decrypted and are visible
  - Including earlier ones that were encrypted using that secret
- How to communicate without necessitating key exchange?

Public key cryptography

Public Key Cryptography

- Sender and receiver do not share secret key
- public encryption key known to all
- private decryption key known only to the receiver

Public key cryptography (eg: RSA)



Diffie Hellman Merkle key exchange

- Alice and Bob agree on a modulus p and base g
- Alice chooses secret a, sends bob $A = g^a \bmod p$
- Bob chooses secret b, sends bob $B = g^b$ mob p
- Alice computes $B^a \bmod p$
- Bob computes $A^b \bmod p$

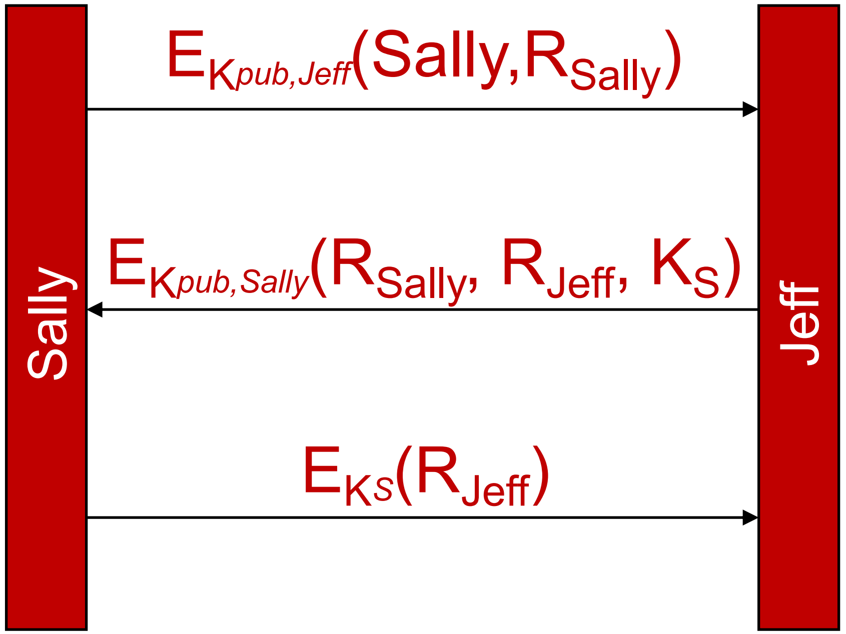
- Is the common key computed by Alice and Bob the same?
- In what sense is D-H-M key exchange secure?

Public vs. Symmetric key crypto

- Public key crypto
- Expensive to encrypt using just modular exponentiation operations
- No need to exchange keys

- Symmetric key crypto
- Encryption and decryption are fast
- But need to solve the key exchange problem

Crypto in practice: session keys



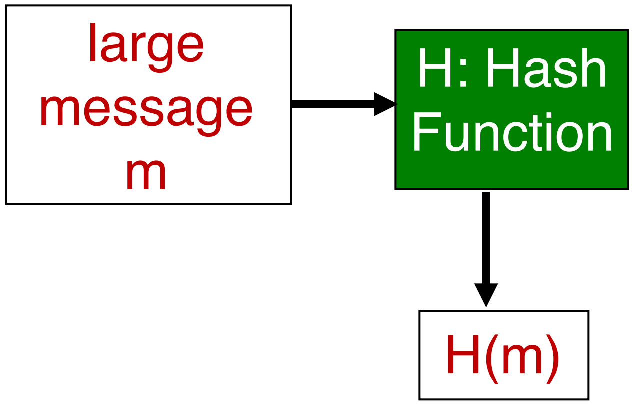
Use public key crypto or key exchange to agree on a symmetric session key

Use symmetric key to protect the rest of the session efficiently

Integrity

Did messages get across without tampering?

Message digests



Can we ensure that a receiver can detect message tampering?

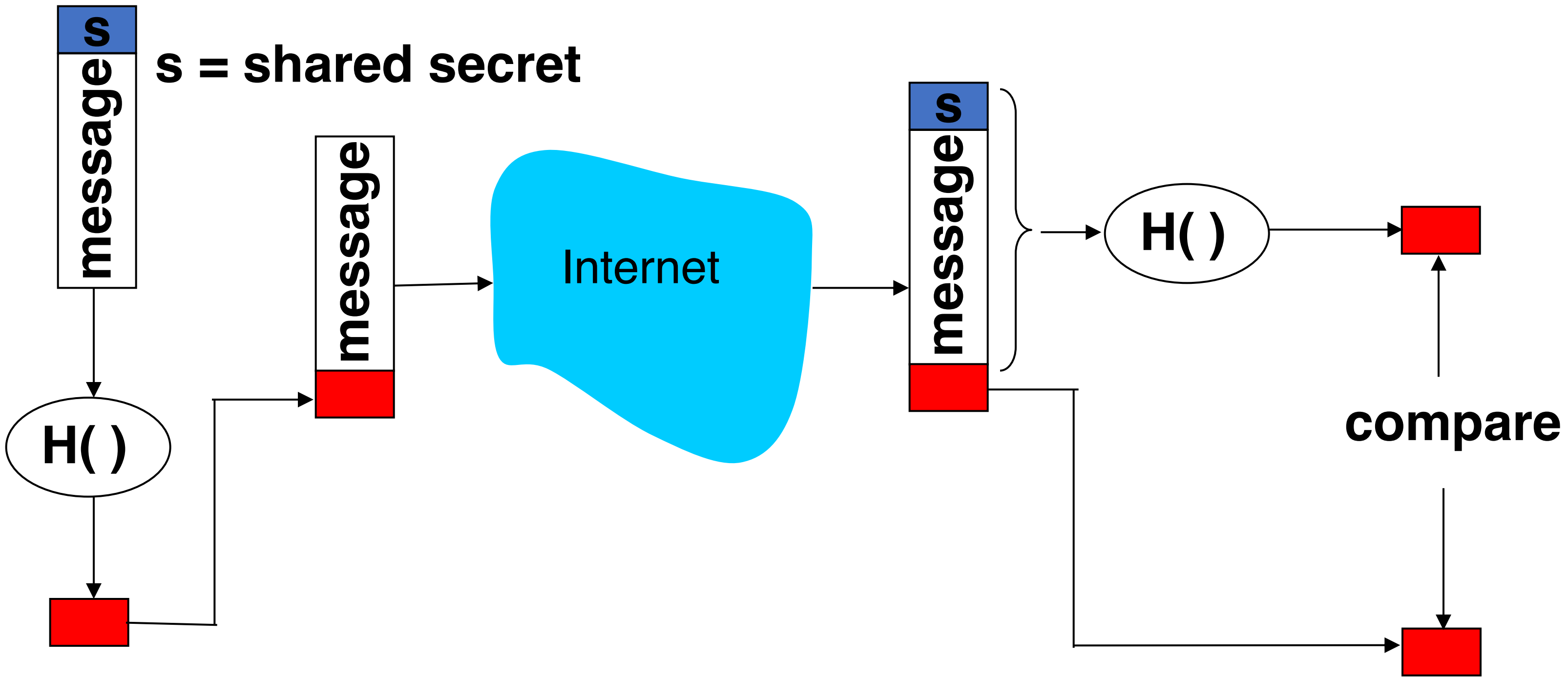
Idea: fixed-length, easy- to-compute digital "fingerprint" of a message

- apply hash function H to *m*, get fixed size message digest, *H(m).*

Cryptographic hash function properties:

- Easy to calculate
- Produces fixed-size msg digest (fingerprint)
- Hard to reverse: given msg digest x,
  - computationally infeasible to find m such that x = H(m)
  - Or another m' such that H(m) = H(m')

Using message digests for integrity



- Verifies message integrity
- Requires a secret shared key
- No encryption

Message digest algorithms

- You’ll see the term “MAC” or Message Authentication Codes
  - I find it confusing (medium access); I will avoid using it.

- MD5 hash function widely used (RFC 1321)
  - computes 128-bit message digest in 4-step process.
  - arbitrary 128-bit string x, appears difficult to construct msg m whose MD5 hash is equal to x

- SHA-1 is also used
  - US standard [NIST, FIPS PUB 180-1]
  - 160-bit message digest

Digital signatures

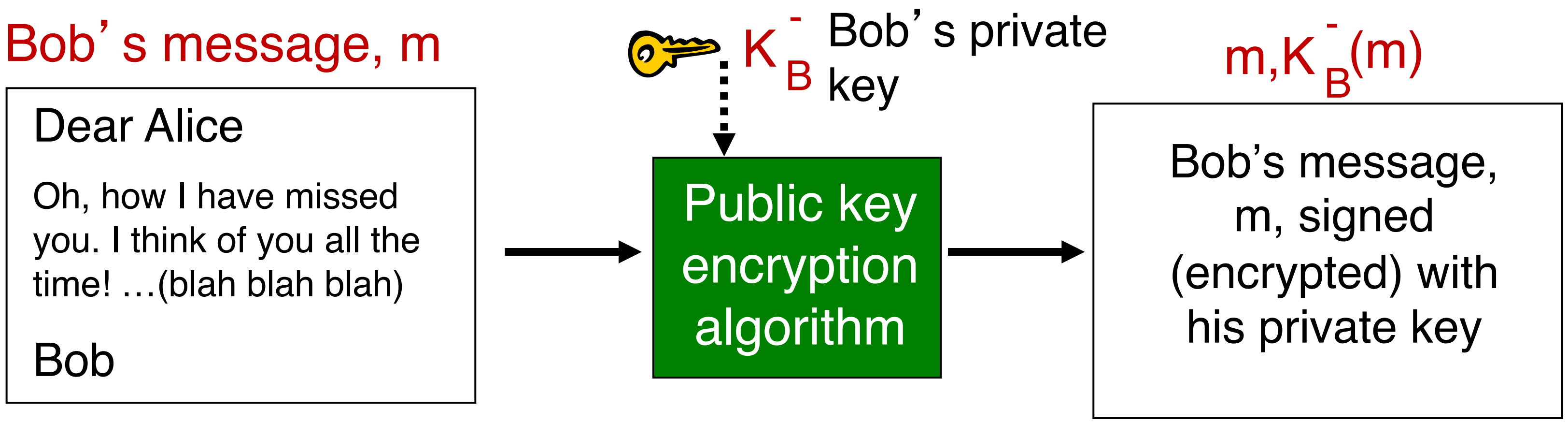
Cryptographic technique analogous to handwritten signatures:

- sender (Bob) digitally signs document, establishing he is document owner/creator.
- verifiable, nonforgeable: recipient (Alice) can prove to someone that Bob, and no one else (including Alice), must have signed document

Digital signatures

simple digital signature for message m:

- Bob signs m by encrypting with his private key K_B^-, creating “signed” message, $K_B^-(m)$

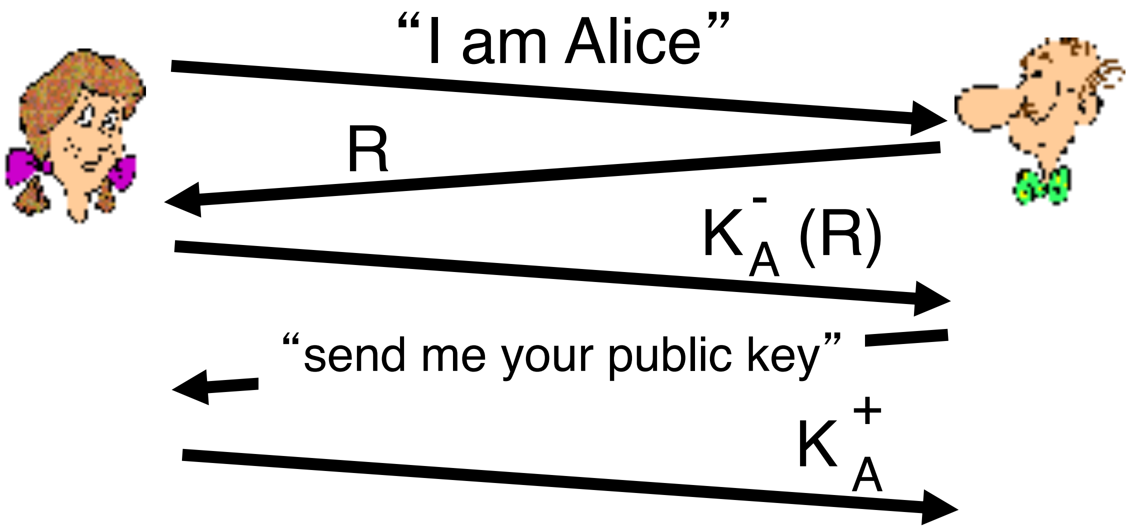


Authentication

How do I know you are who you say you are?

Authentication using public key crypto

Idea: Use nonce and public key cryptography



Bob computes

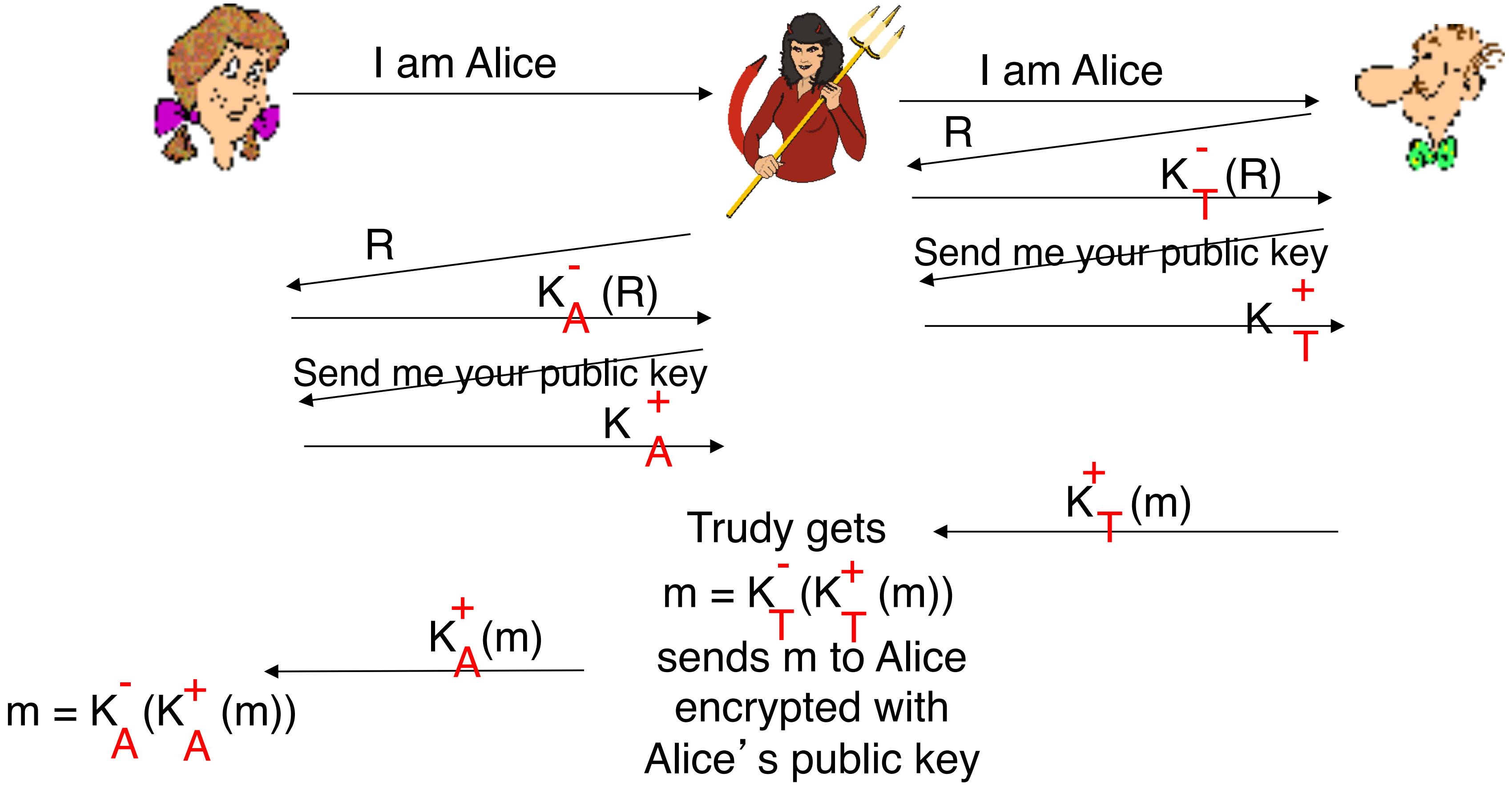
$$K_A^+(K_A^-(R)) = R$$

and knows only Alice could have the private key, that encrypted R such that

$$K_A^+(K_A^-(R)) = R$$

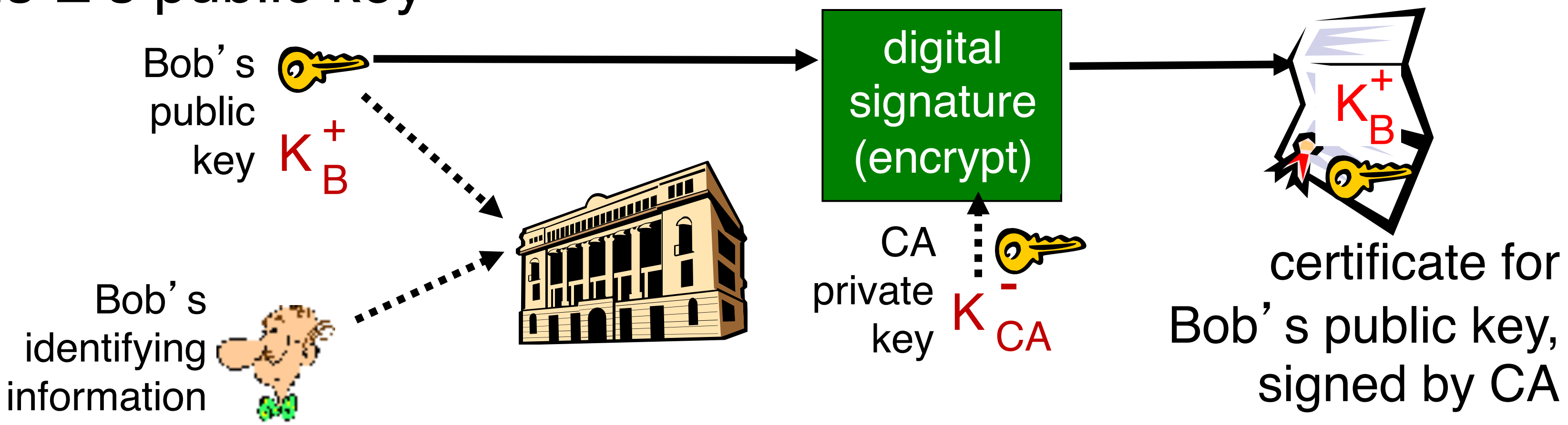
Security hole -- if you ask for public keys!

man (or woman) in the middle attack: Trudy poses as Alice (to Bob) and as Bob (to Alice)



Certification authorities

- *certification authority (CA):* binds public key to particular entity, E.
- E (person, router) registers its public key with CA.
  - E provides "proof of identity" to CA.
  - CA creates certificate binding E to its public key.
  - certificate containing E's public key digitally signed by CA – CA says "this is E's public key"



Certification authorities

- When Alice wants Bob's public key:
  - gets Bob's certificate (from Bob or elsewhere).
  - apply CA's public key to Bob's certificate, get Bob's public key