Information Technology Engineering

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1393

Crypto, Secure Email, SSL, IPSec, Wireless Security, and Operational Security

NETWORK SECURITY

Slides derived from those available on the Web site of the book "Computer Networking", by Kurose and Ross, PEARSON

Chapter 8 Outline

8.1 What is network security?

8.2 Principles of cryptography

8.3 Message integrity and End-Point Authentication

8.4 Securing e-mail

8.5 Securing TCP connections: SSL

8.6 Network layer security: IPsec

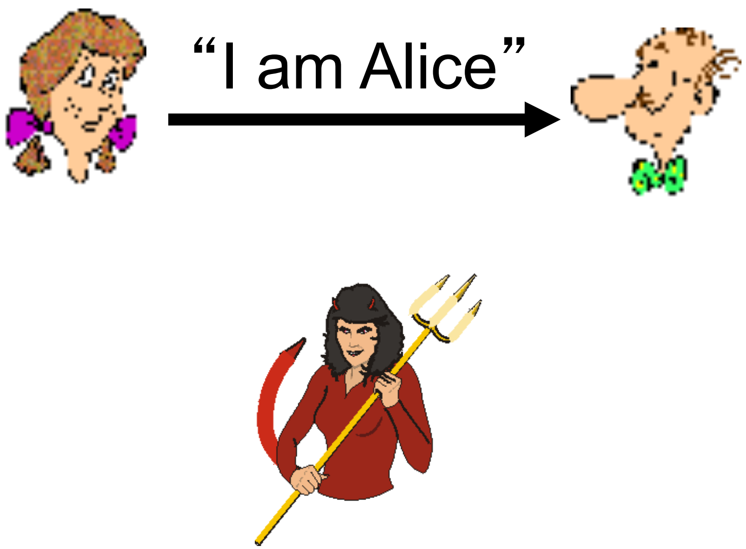
8.7 Securing wireless LANs

8.8 Operational security: firewalls and IDS

Authentication

Goal: Bob wants Alice to "prove" her identity to him

Protocol ap1.0: Alice says "I am Alice"



Failure scenario??

Authentication

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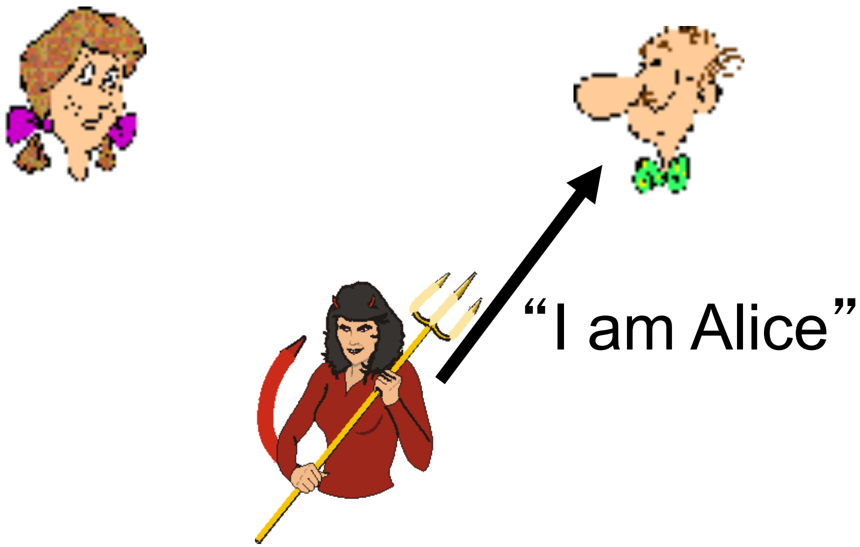


in a network,
Bob can not "see" Alice,
so Trudy simply declares
herself to be Alice

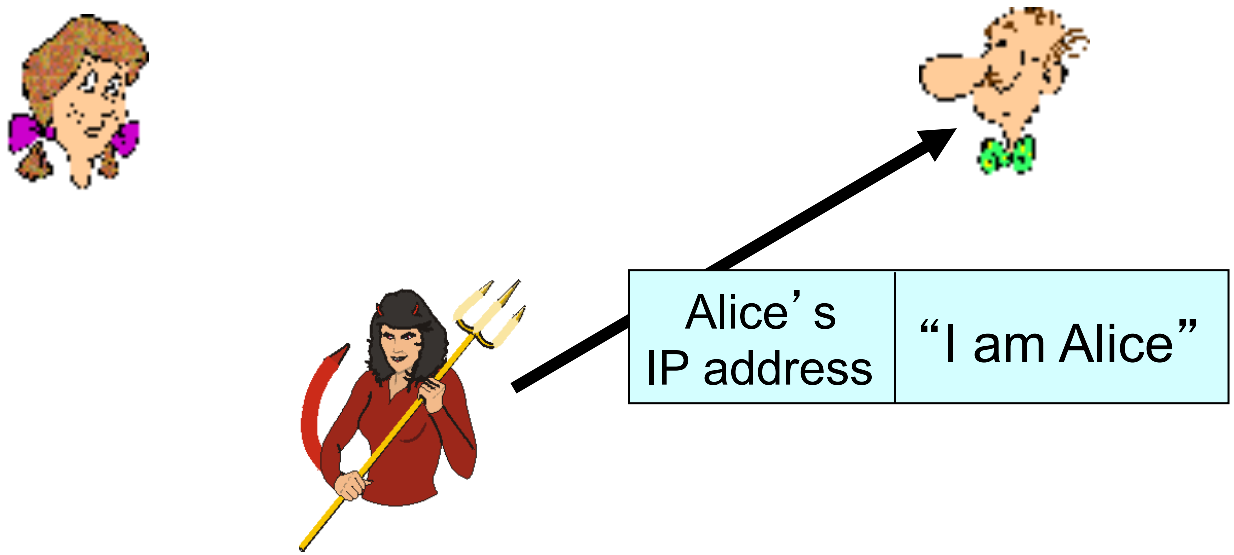
Authentication: another try

Protocol ap2.0: Alice says “I am Alice” in an IP packet containing her source IP address

Failure scenario??

Authentication: another try

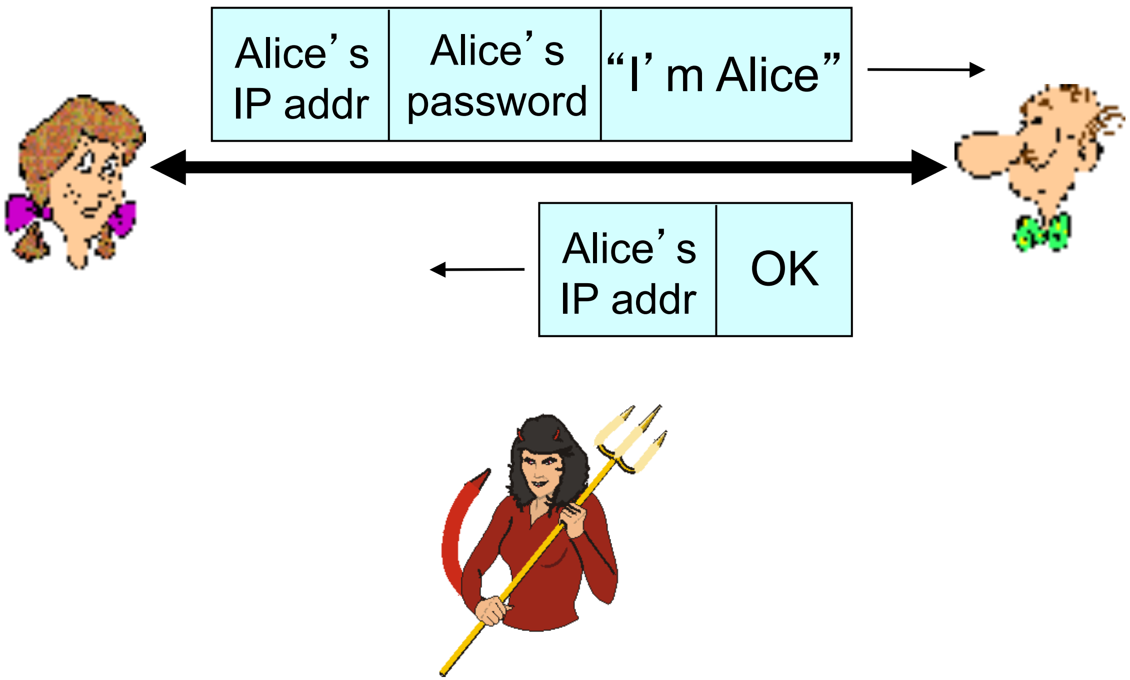
Protocol ap2.0: Alice says “I am Alice” in an IP packet containing her source IP address



Trudy can create a packet “spoofing” Alice’s address

Authentication: another try

Protocol ap3.0: Alice says "I am Alice" and sends her secret password to "prove" it.



Failure scenario??

Authentication: another try

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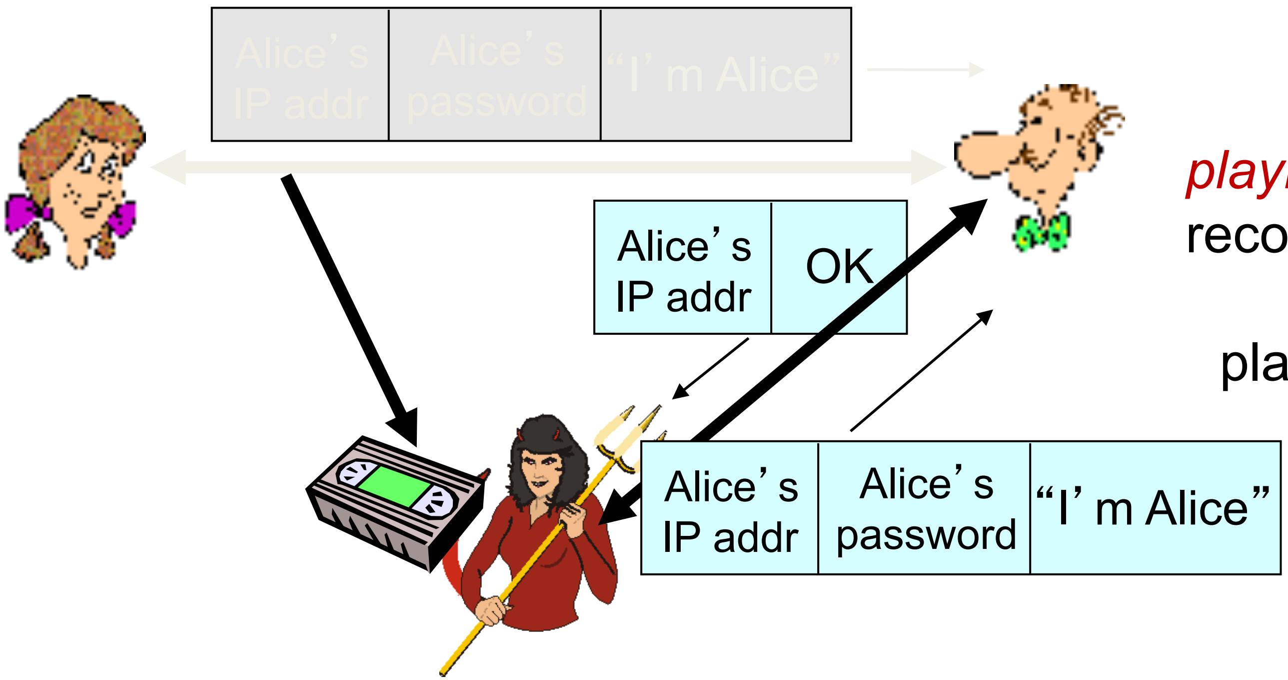
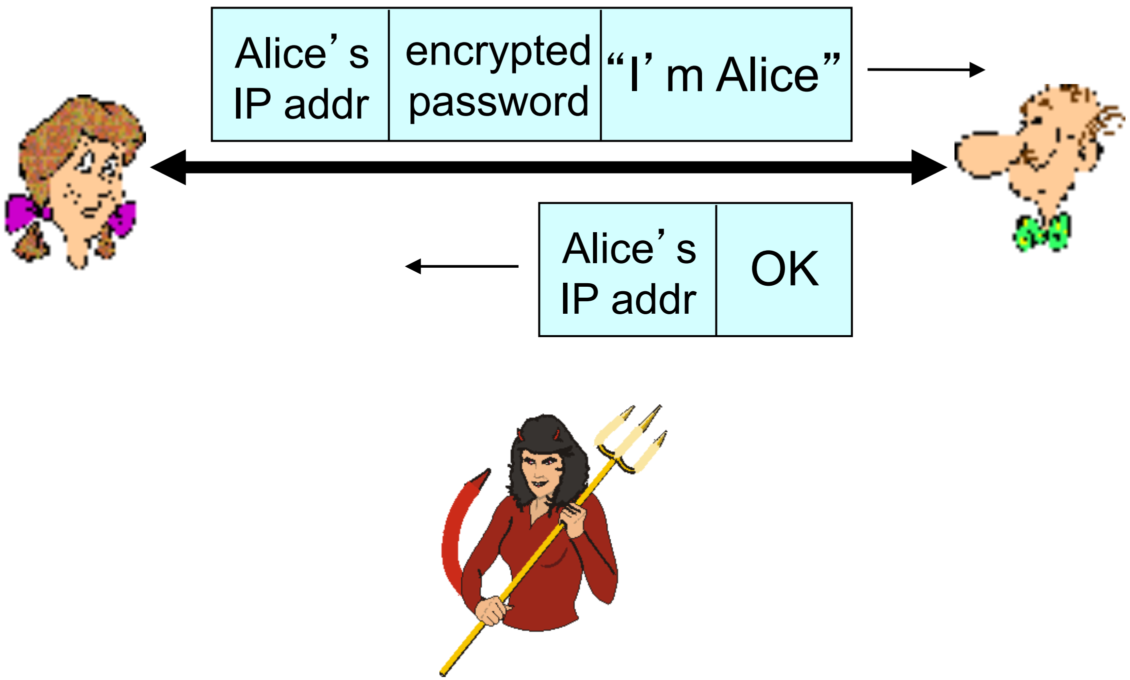


playback attack: Trudy records Alice's packet and later plays it back to Bob

Authentication: yet another try

Protocol ap3.1: Alice says "I am Alice" and sends her *encrypted* secret password to "prove" it.



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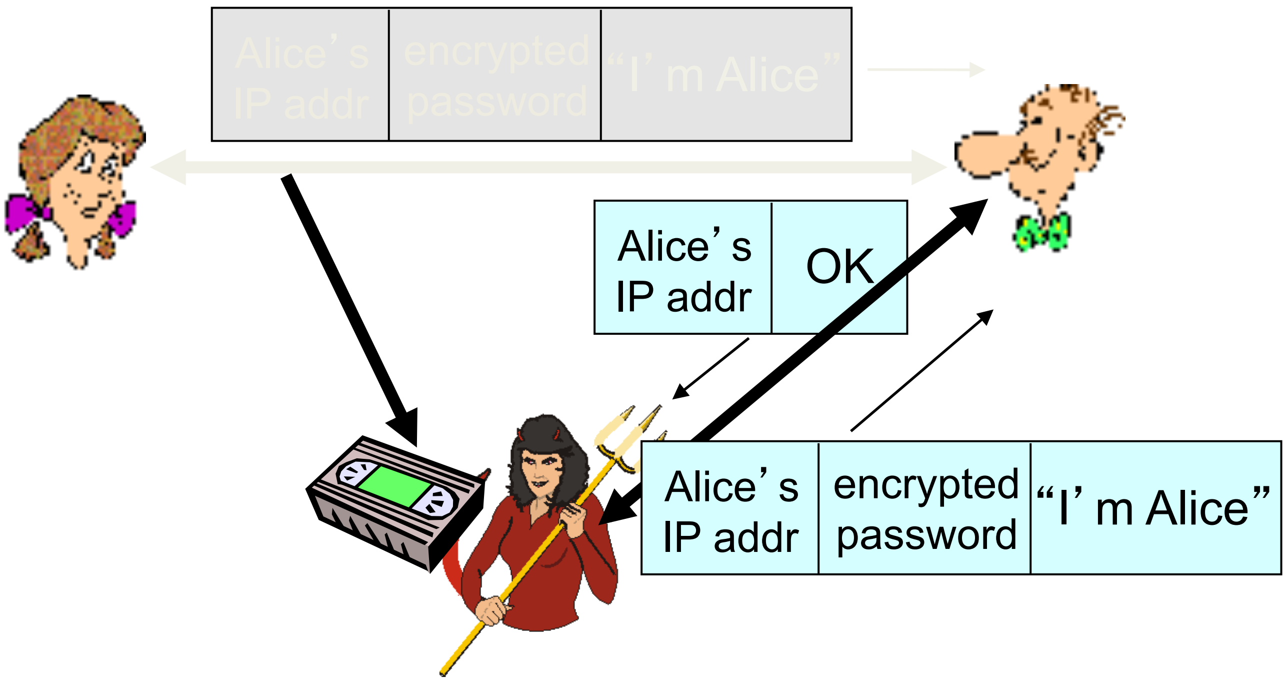
Authentication: yet another try

Protocol ap3.1: Alice says "I am Alice" and sends her *encrypted* secret password to "prove" it.



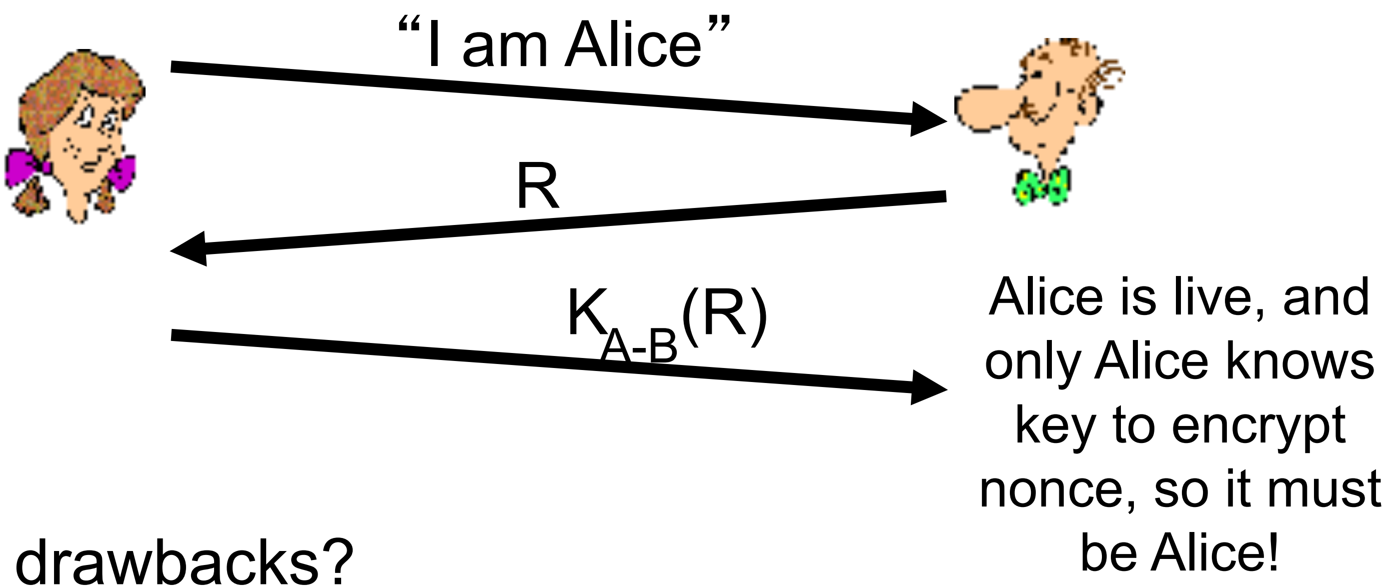
record and playback *still* works!

Authentication: yet another try

Goal: avoid playback attack

nonce: number (R) used only *once-in-a-lifetime*

ap4.0: to prove Alice "live", Bob sends Alice *nonce*, R. Alice must return R, encrypted with shared secret key



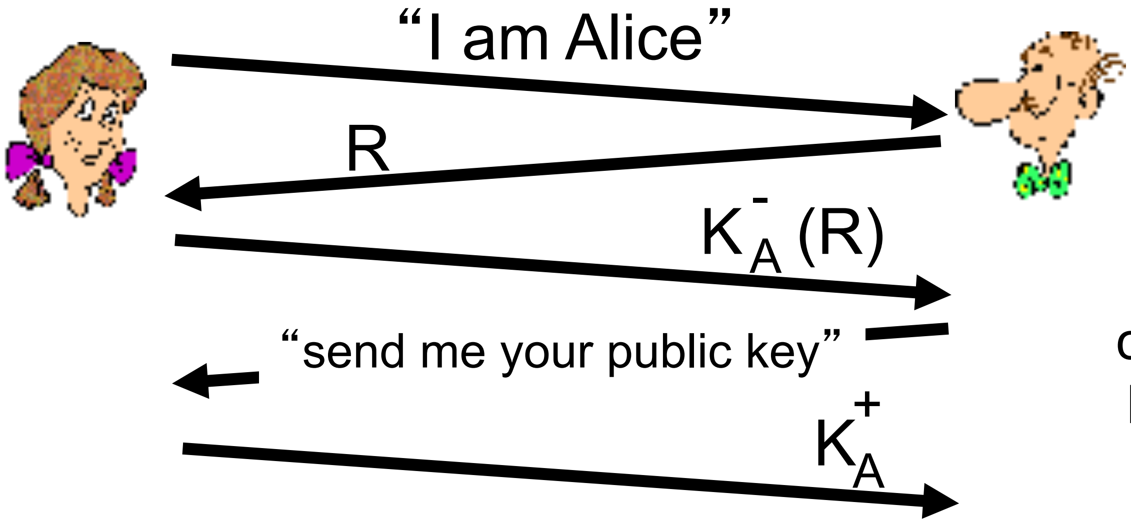
Failures, drawbacks?

Authentication: ap5.0

ap4.0 requires shared symmetric key

- can we authenticate using public key techniques?

ap5.0: use nonce, public key cryptography



Bob computes

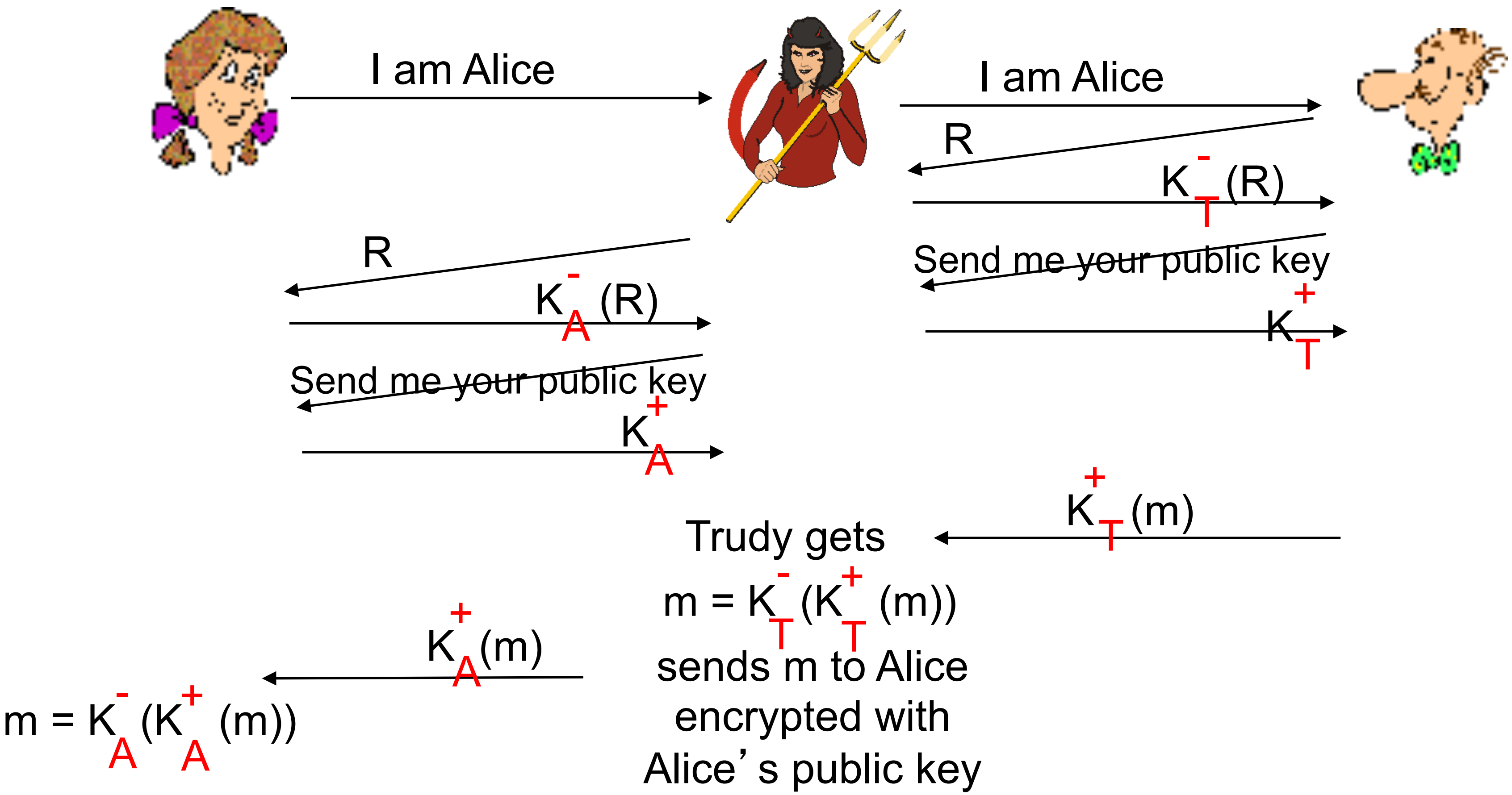
$$K_A^+(K_A^-(R)) = R$$

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

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

ap5.0: security hole

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



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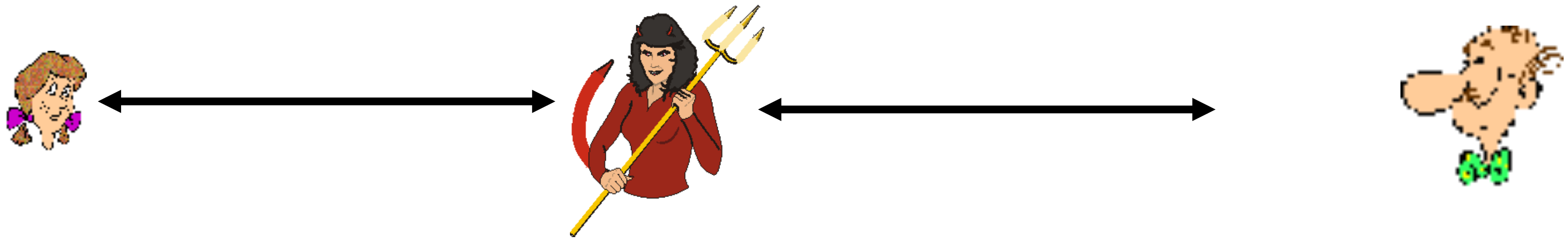


difficult to detect:

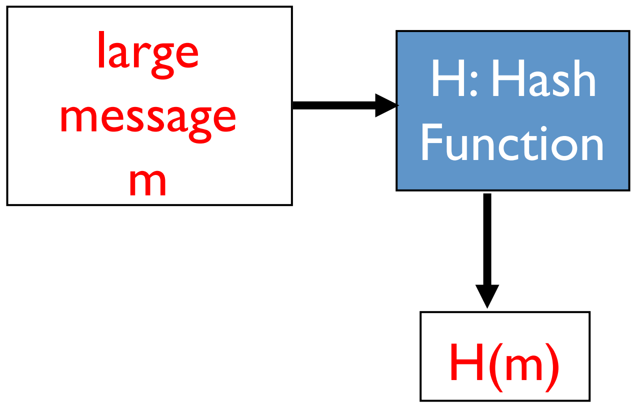
- Bob receives everything that Alice sends, and vice versa. (e.g., so Bob, Alice can meet one week later and recall conversation!)
- problem is that Trudy receives all messages as well!

Message Integrity

- Allows communicating parties to verify that received messages are authentic.
  - Content of message has not been altered
  - Source of message is who/what you think it is
  - Message has not been replayed
  - Sequence of messages is maintained
- Let's first talk about message digests

Message Digests

- Function H( ) that takes as input an arbitrary length message and outputs a fixed-length string: "message signature"
- Note that H( ) is a many-to-1 function
- H( ) is often called a "hash function"



- Desirable properties:
  - Easy to calculate
  - Irreversibility: Can't determine m from H(m)
  - Collision resistance: Computationally difficult to produce m and m' such that H(m) = H(m')
  - Seemingly random output

Internet checksum: poor message digest

Internet checksum has some properties of hash function:

- produces fixed length digest (16-bit sum) of input
- is many-to-one

- But given message with given hash value, it is easy to find another message with same hash value.
- Example: Simplified checksum: add 4-byte chunks at a time:

message	ASCII format
I O U 1	49 4F 55 31
0 0 . 9	30 30 2E 39
9 B O B	39 42 D2 42
	B2 C1 D2 AC

message	ASCII format
I O U 9	49 4F 55 39
0 0 . 1	30 30 2E 31
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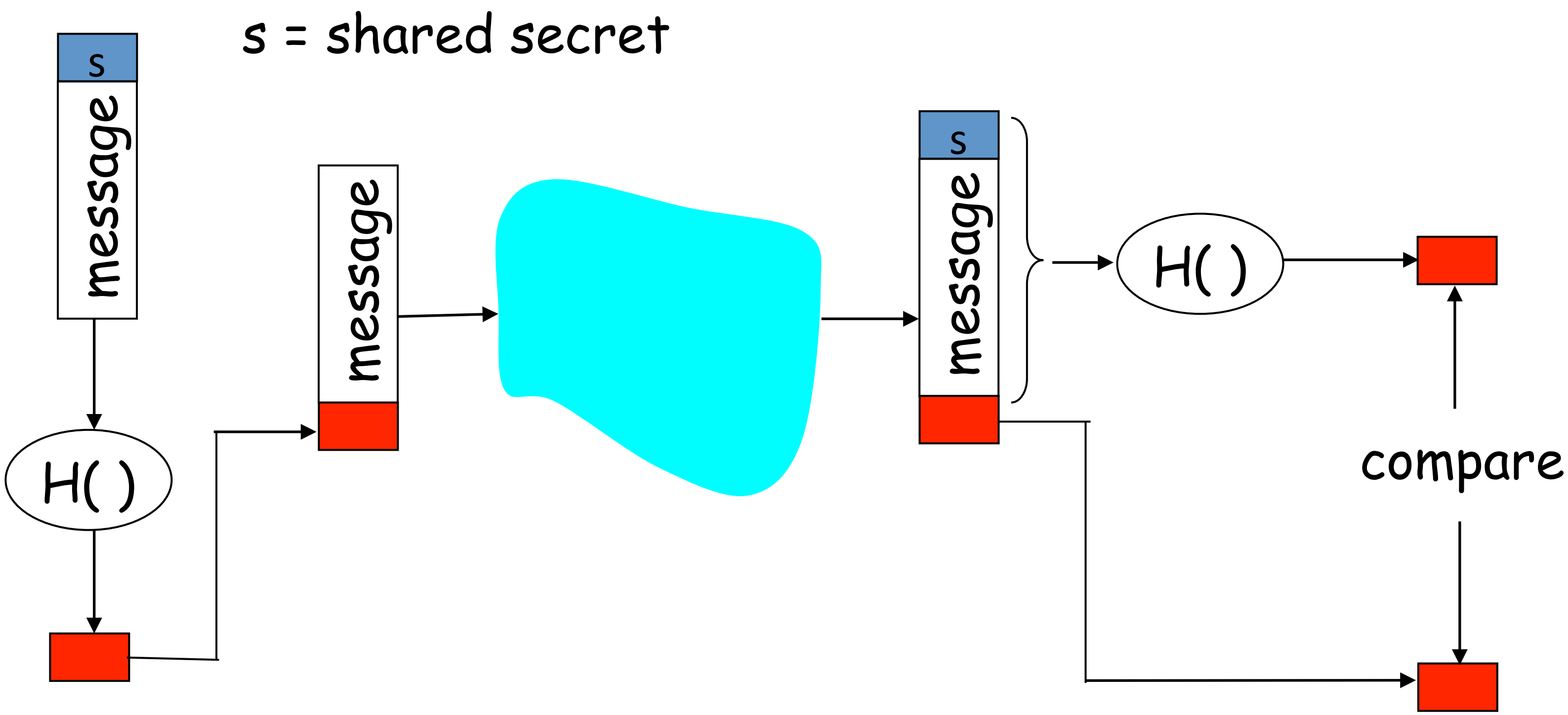
	B2 C1 D2 AC

different messages but identical checksums!

Hash Function Algorithms

- MD5 hash function widely used (RFC 1321)
  - computes 128-bit message digest in 4-step process.
- SHA-1 is also used.
  - US standard [NIST, FIPS PUB 180-1]
  - 160-bit message digest

Message Authentication Code (MAC)



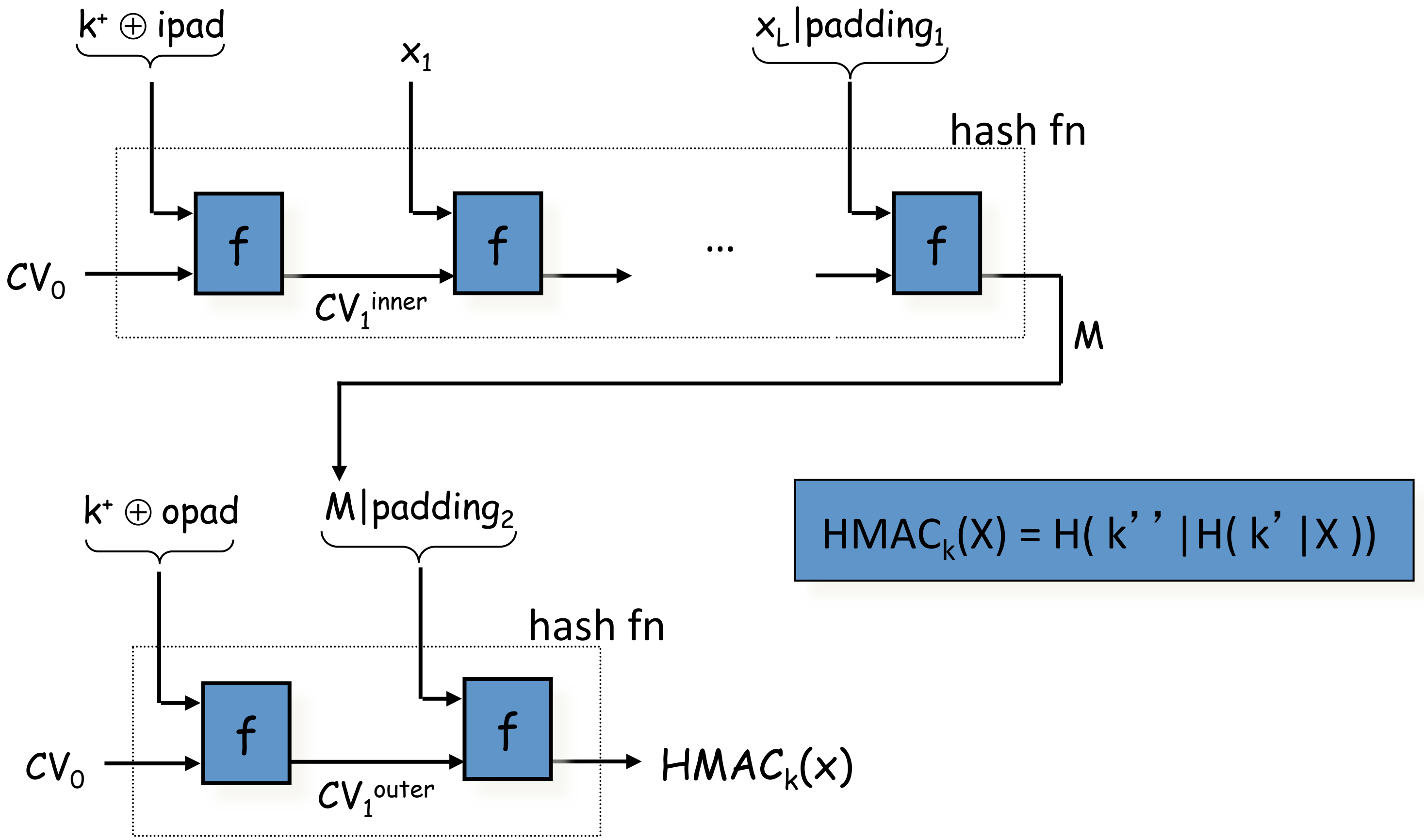
- ***Authenticates sender***
- ***Verifies message integrity***
- No encryption !
- Also called “keyed hash”
- Notation: $MD_m = H(s||m)$; send $m||MD_m$

HMAC

- Popular MAC standard
- Addresses some subtle security flaws

1. Concatenates secret to front of message.
2. Hashes concatenated message
3. Concatenates the secret to front of digest
4. Hashes the combination again.

HMAC


k⁺ ⊕ ipad
x1
xL|padding1
hash fn
CV0
f
CV1inner
f
...
f
M
k⁺ ⊕ opad
M|padding2
hash fn
CV0
f
CV1outer
f
HMACk(x)
HMACk(X) = H(k'' |H(k' |X))

Example: OSPF

- Recall that OSPF is an intra-AS routing protocol
- Each router creates map of entire AS (or area) and runs shortest path algorithm over map.
- Router receives link-state advertisements (LSAs) from all other routers in AS.

Attacks:

- Message insertion
- Message deletion
- Message modification

- How do we know if an OSPF message is authentic?

OSPF Authentication

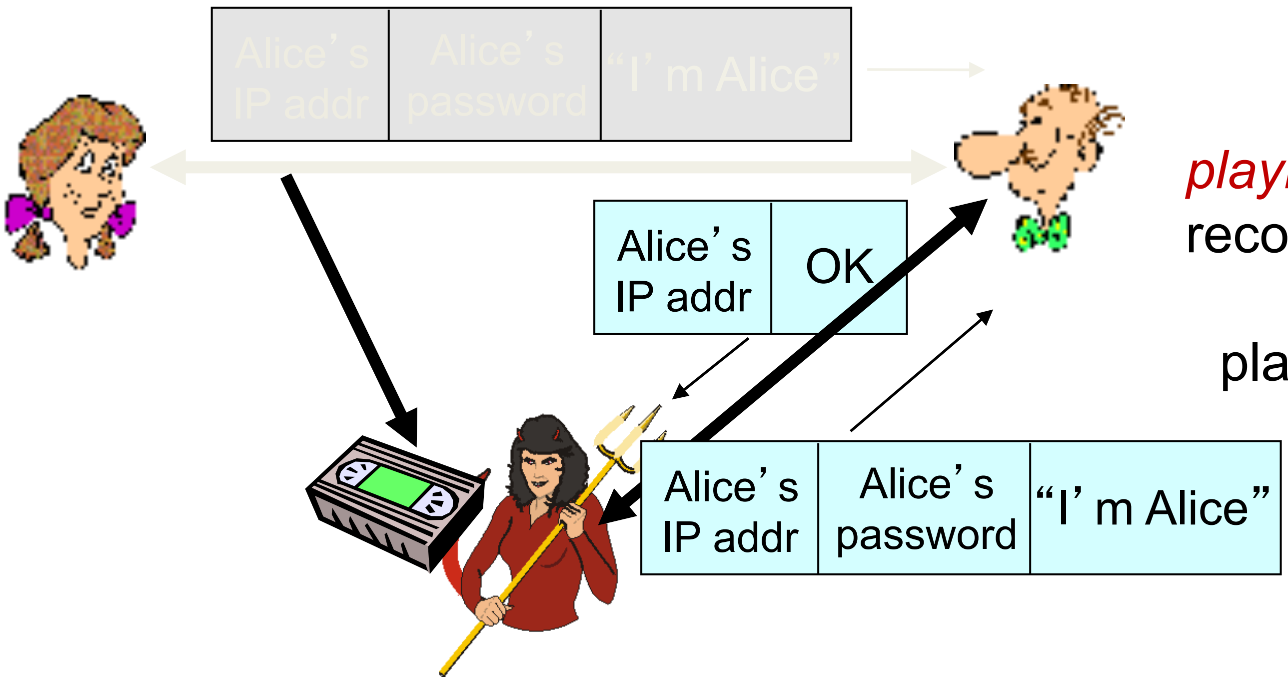
- Within an Autonomous System, routers send OSPF messages to each other.
- OSPF provides authentication choices
  - No authentication
  - Shared password: inserted in clear in 64-bit authentication field in OSPF packet
  - Cryptographic hash
- Cryptographic hash with MD5
  - 64-bit authentication field includes 32-bit sequence number
  - MD5 is run over a concatenation of the OSPF packet and shared secret key
  - MD5 hash then appended to OSPF packet; encapsulated in IP datagram

End-point authentication

- Want to be sure of the originator of the message – *end-point authentication*.
- Assuming Alice and Bob have a shared secret, will MAC provide end-point authentication.
  - We do know that Alice created the message.
  - But did she send it?

Authentication: another try

Protocol ap3.0: Alice says "I am Alice" and sends her secret password to "prove" it.



playback attack: Trudy records Alice's packet and later plays it back to Bob

Digital Signatures

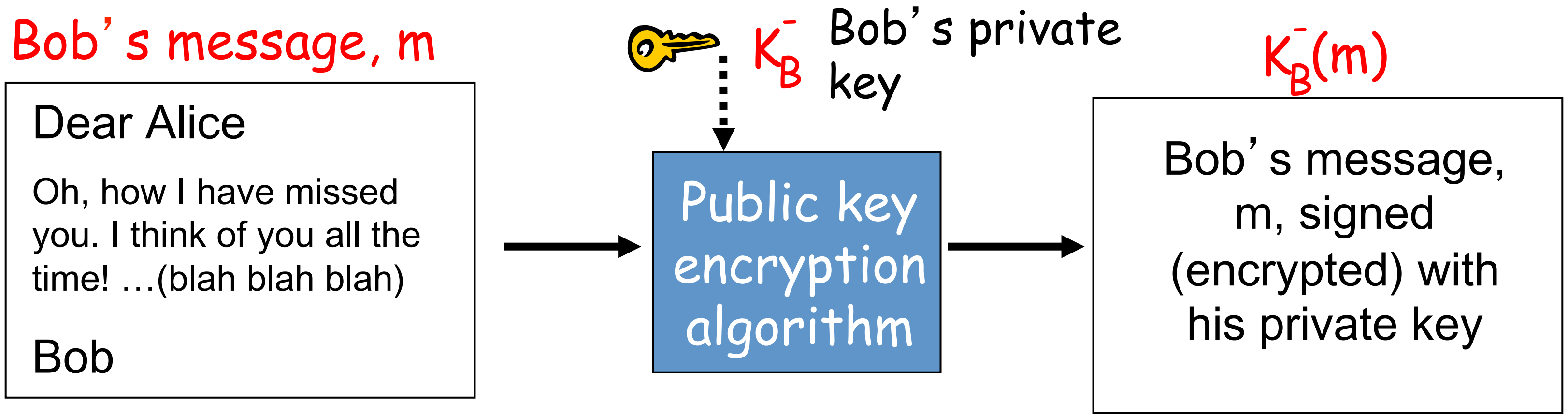
Cryptographic technique analogous to hand-written signatures.

- sender (Bob) digitally signs document, establishing he is document owner/creator.
- Goal is similar to that of a MAC, except now use public-key cryptography
- 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:

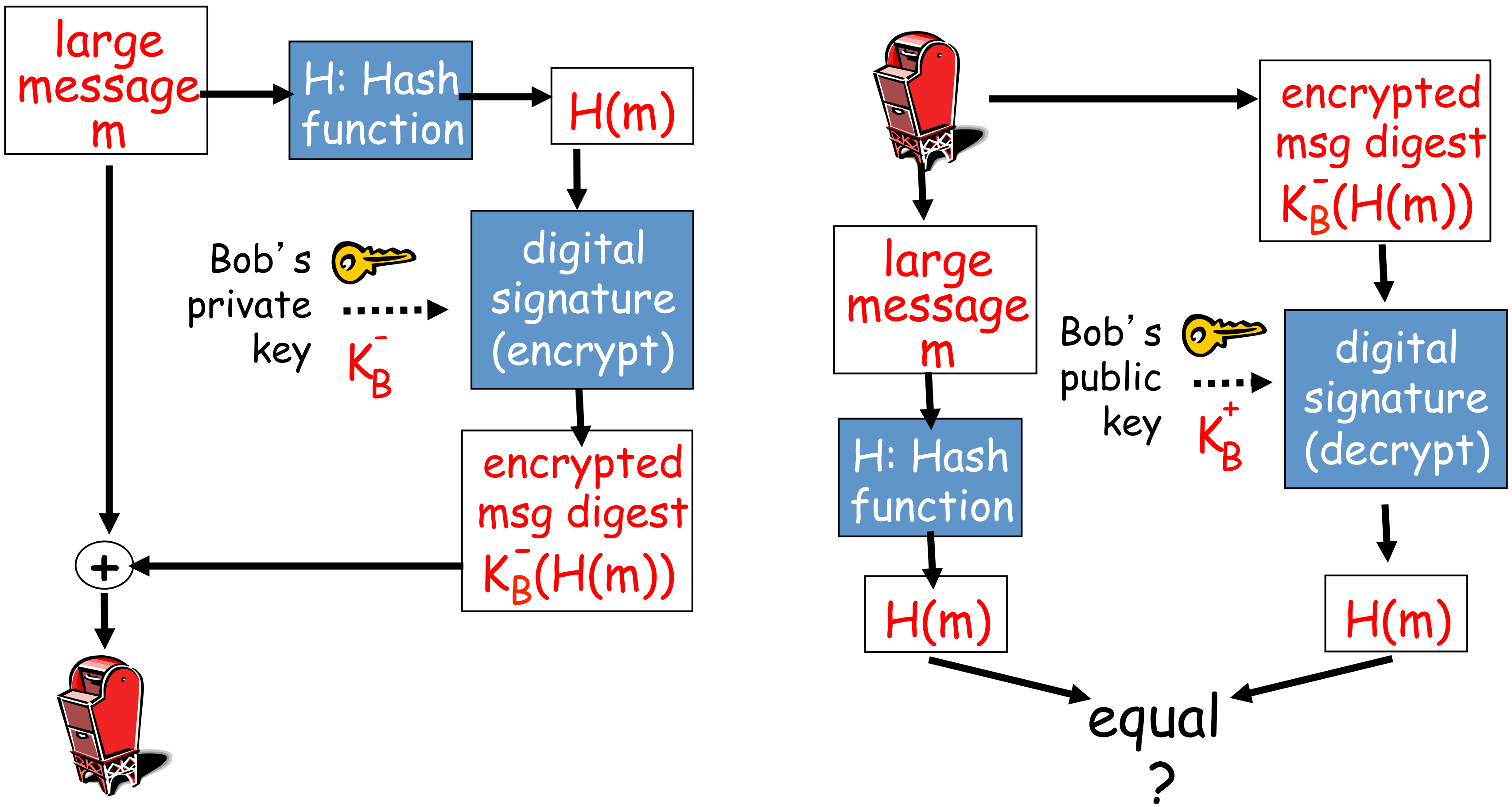
- Bob signs m by encrypting with his private key K_B^-, creating "signed" message, $K_B^-(m)$



Digital signature = signed message digest

Bob sends digitally signed message:

Alice verifies signature and integrity of digitally signed message:



Digital Signatures (more)

- Suppose Alice receives msg m, digital signature $K_B^-(m)$
- Alice verifies m signed by Bob by applying Bob's public key K_B^+ to $K_B^-(m)$ then checks $K_B^+(K_B^-(m)) = m$.
- If $K_B^+(K_B^-(m)) = m$, whoever signed m must have used Bob's private key.

Alice thus verifies that:

- ➽ Bob signed m.
- ➽ No one else signed m.
- ➽ Bob signed m and not m'.

Non-repudiation:

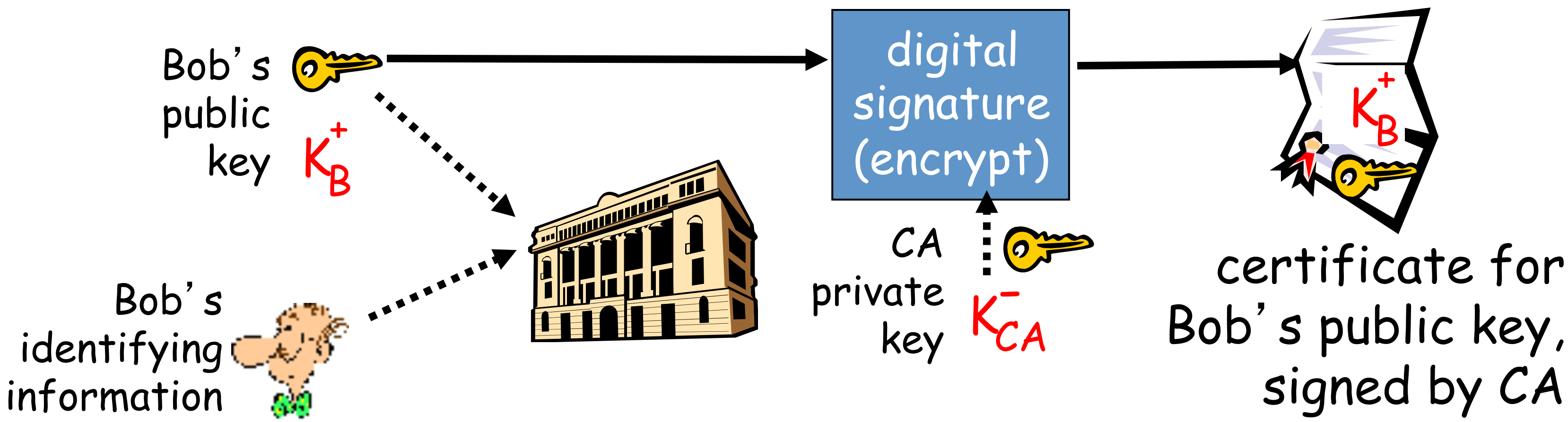
- ✓ Alice can take m, and signature $K_B^-(m)$ to court and prove that Bob signed m.

Public-key certification

- Motivation: Trudy plays pizza prank on Bob
  - Trudy creates e-mail order:
    Dear Pizza Store, Please deliver to me four pepperoni pizzas. Thank you, Bob
  - Trudy signs order with her private key
  - Trudy sends order to Pizza Store
  - Trudy sends to Pizza Store her public key, but says it's Bob's public key.
  - Pizza Store verifies signature; then delivers four pizzas to Bob.
  - Bob doesn't even like Pepperoni

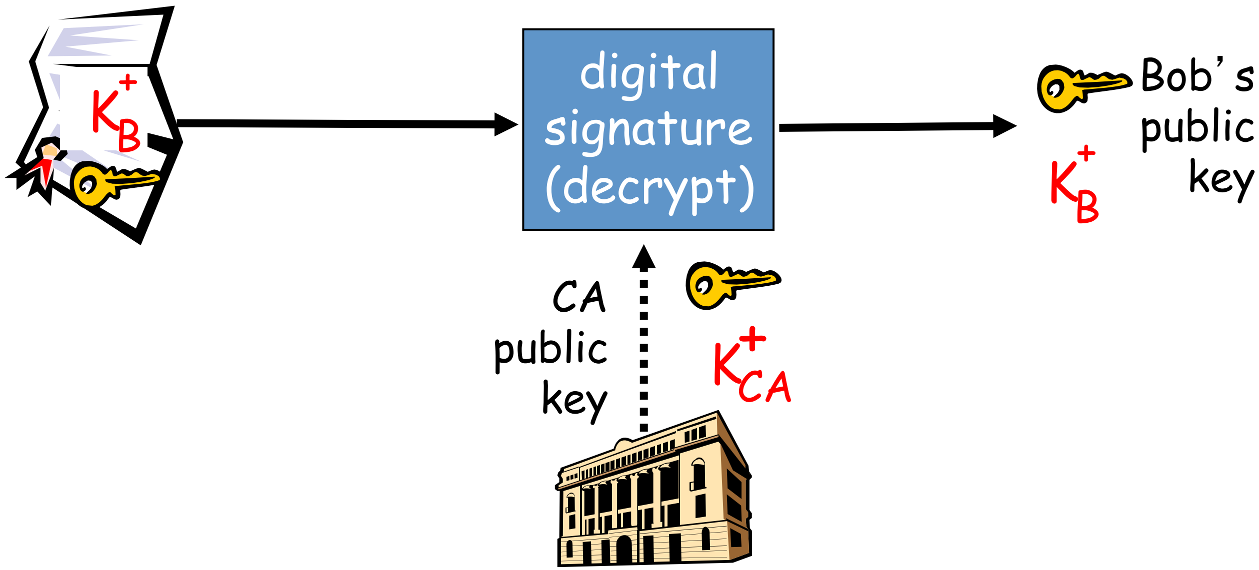
Certification Authorities

- 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 (Bob or elsewhere).
  - apply CA's public key to Bob's certificate, get Bob's public key



Certificates: summary

- Primary standard X.509 (RFC 2459)
- Certificate contains:
  - Issuer name
  - Entity name, address, domain name, etc.
  - Entity's public key
  - Digital signature (signed with issuer's private key)
- Public-Key Infrastructure (PKI)
  - Certificates and certification authorities
  - Often considered "heavy"