Network Security

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Network security

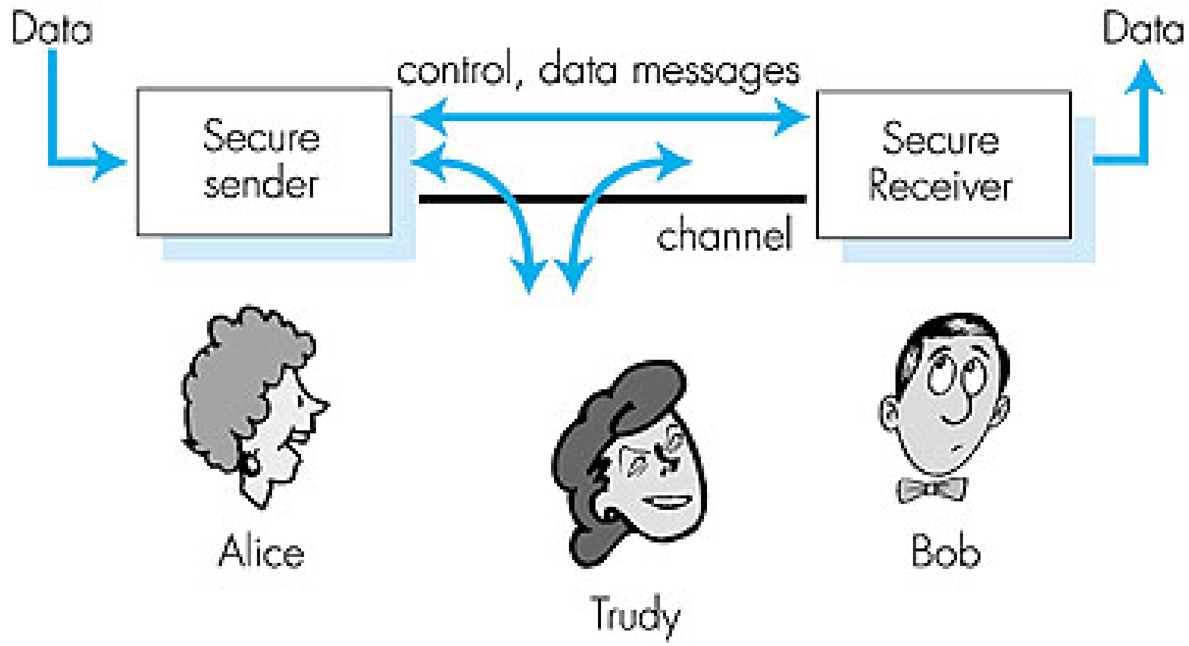
Foundations:

- **what is security?**
- **cryptography**
- **authentication**
- **message integrity**
- **key distribution and certification**

Security in practice:

- **application layer: secure e-mail**
- **transport layer: Internet commerce, SSL, SET**

Friends and enemies: Alice, Bob, Trudy



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

What is network security?

Secrecy: **only sender, intended receiver should "understand" msg contents**

- **sender encrypts msg**
- **receiver decrypts msg**

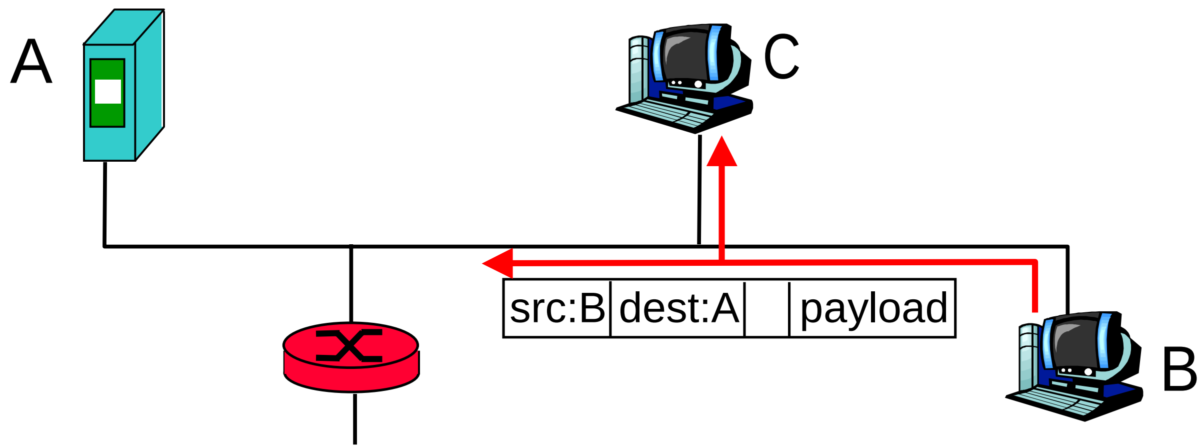
Authentication: **sender, receiver want to confirm identity of each other**

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

Internet security threats

Packet sniffing:

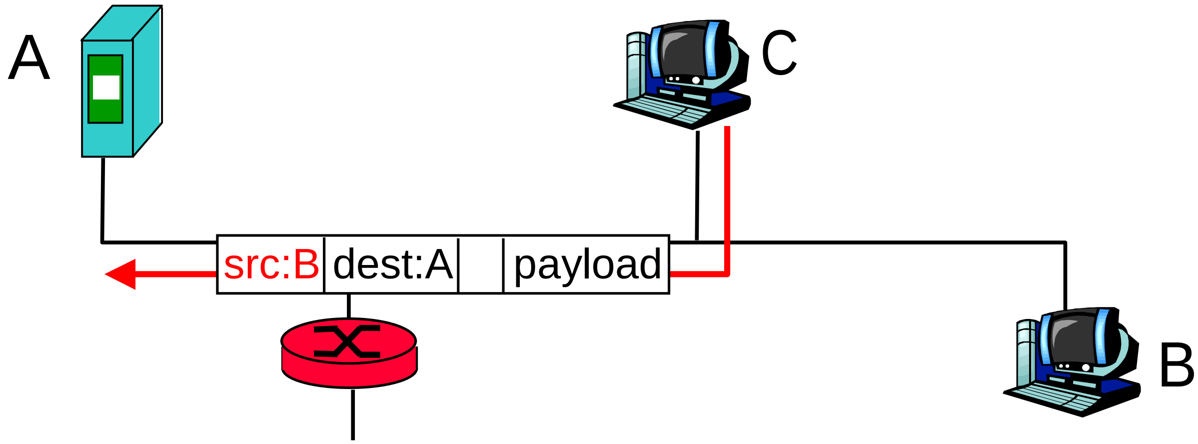
- **broadcast media**
- **promiscuous NIC reads all packets passing by**
- **can read all unencrypted data (e.g. passwords)**
- **e.g.: C sniffs B's packets**



Internet security threats

IP Spoofing:

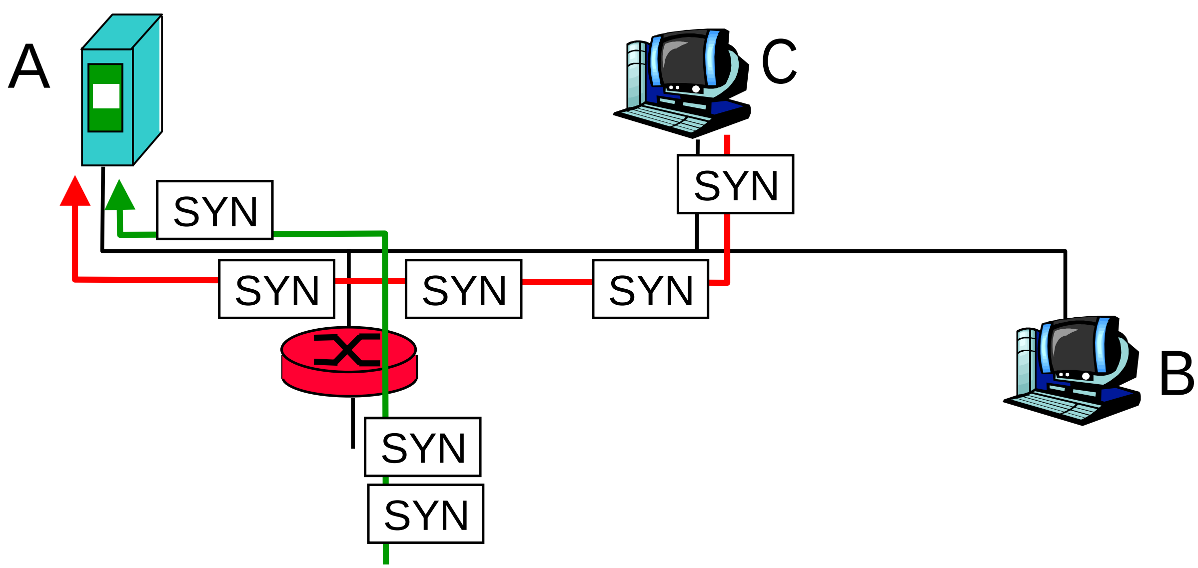
- can generate “raw” IP packets directly from application, putting any value into IP source address field
- receiver can’t tell if source is spoofed
- e.g.: C pretends to be B



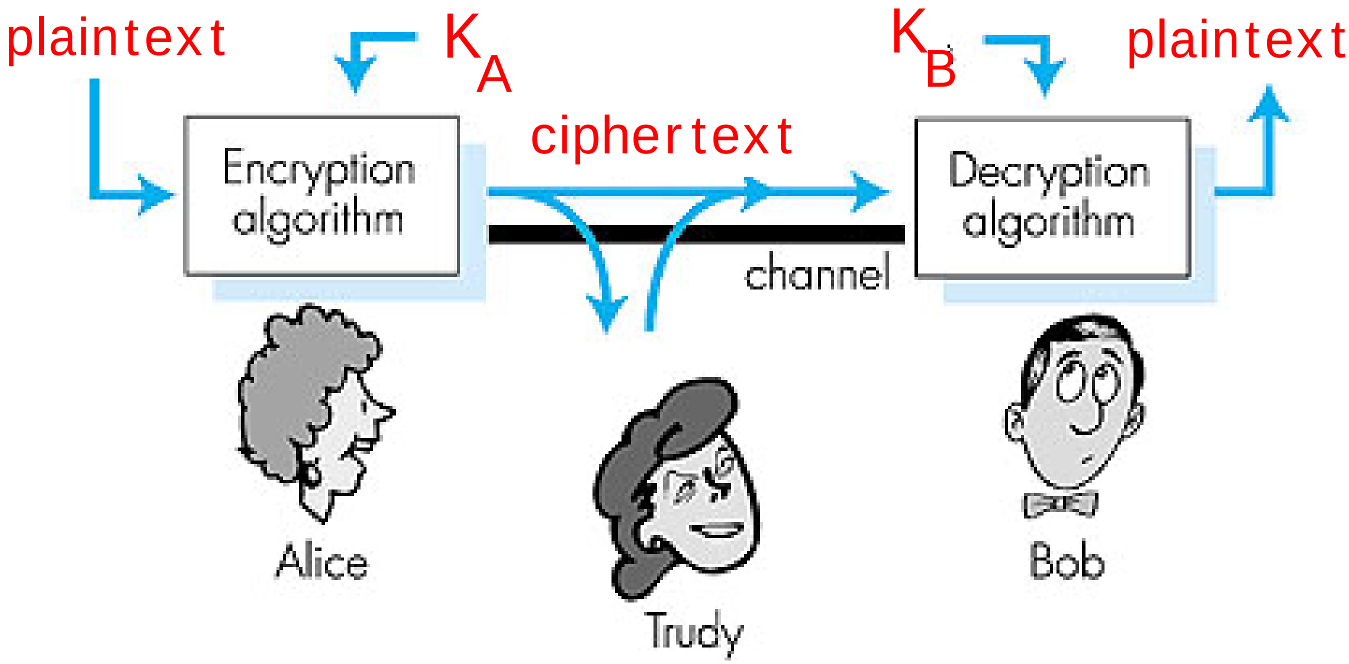
Internet security threats

Denial of service (DOS):

- **flood of maliciously generated packets "swamp" receiver**
- **Distributed DOS (DDOS): multiple coordinated sources swamp receiver**
- **e.g., C and remote host SYN-attack A**



The language of cryptography



symmetric key crypto: sender, receiver keys identical

public-key crypto: encrypt key *public*, decrypt key *secret*

Symmetric key cryptography

substitution cipher: substituting one thing for another

– **monoalphabetic cipher: substitute one letter for another**

```
plaintext:   abcdefghijklmnopqrstuvwxyz

ciphertext:  mnbvcxzasdfghjklpoiuytrewq
```

E.g.:

```
Plaintext: bob. i love you. alice
ciphertext: nkn. s gktc wky. mgsbc
```

Q: How hard to break this simple cipher?:

- brute force (how hard?)
- other?

Symmetric key crypto: DES

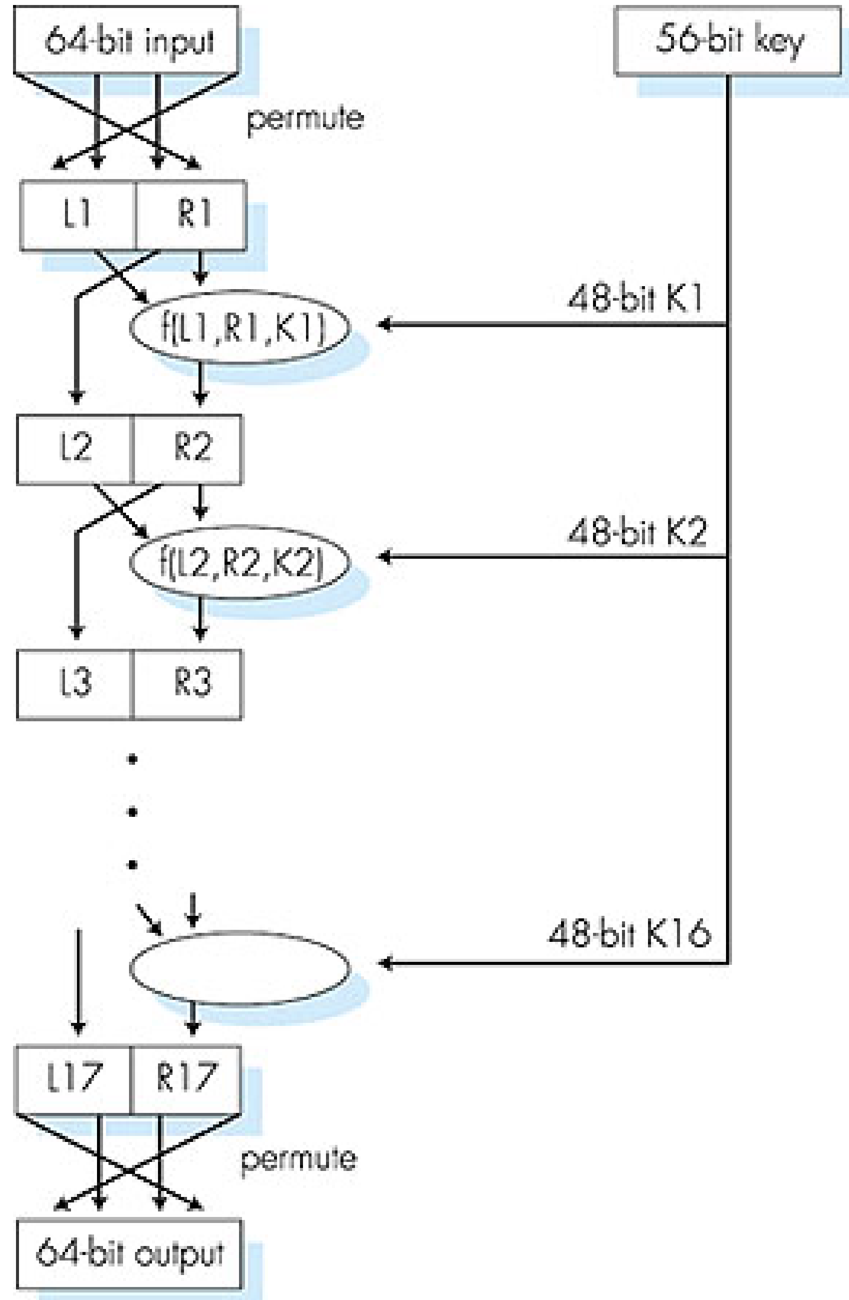
DES: Data Encryption Standard

- **US encryption standard [NIST 1993]**
- **56-bit symmetric key, 64 bit plaintext input**
- **How secure is DES?**
  - **DES Challenge: 56-bit-key-encrypted phrase ("Strong cryptography makes the world a safer place") decrypted (brute force) in 4 months**
  - **no known "backdoor" decryption approach**
- **making DES more secure**
  - **use three keys sequentially (3-DES) on each datum**
  - **use cipher-block chaining**

Symmetric key crypto: DES

DES operation

- initial permutation
- 16 identical "rounds" of function application, each using different 48 bits of key
- final permutation



Public Key Cryptography

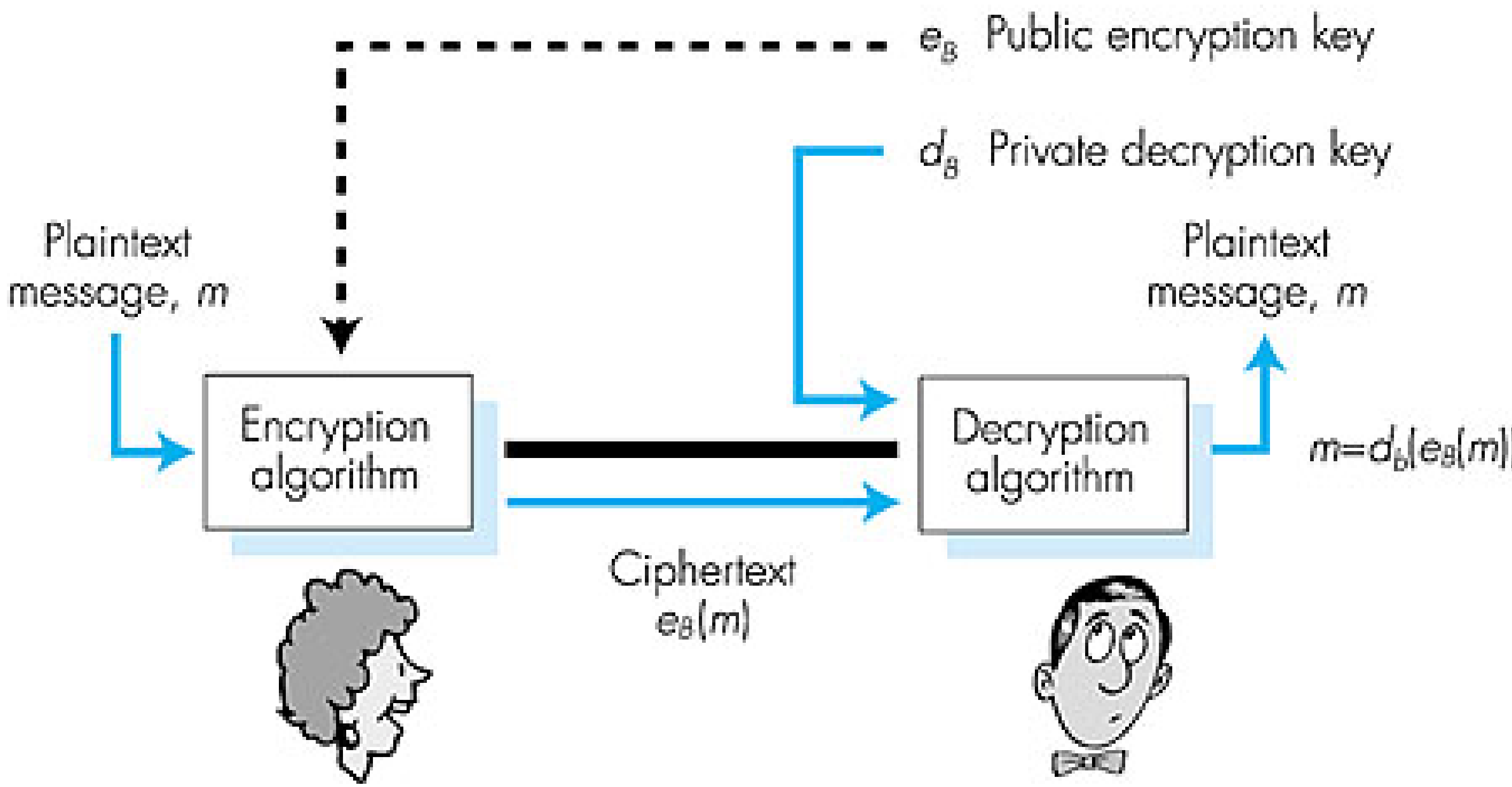
***symmetric* key crypto**

- **requires sender, receiver know shared secret key**
- **Q: how to agree on key in first place (particularly if never “met”)?**

***public* key cryptography**

- **radically different approach [Diffie-Hellman76, RSA78]**
- **sender, receiver do *not* share secret key**
- **encryption key *public* (known to *all*)**
- **decryption key private (known only to receiver)**

Public key cryptography



Public key encryption algorithms

Two inter-related requirements:

① **need $d_B(\cdot)$ and $e_B(\cdot)$ such that**

$$d_B(e_B(m)) = m$$

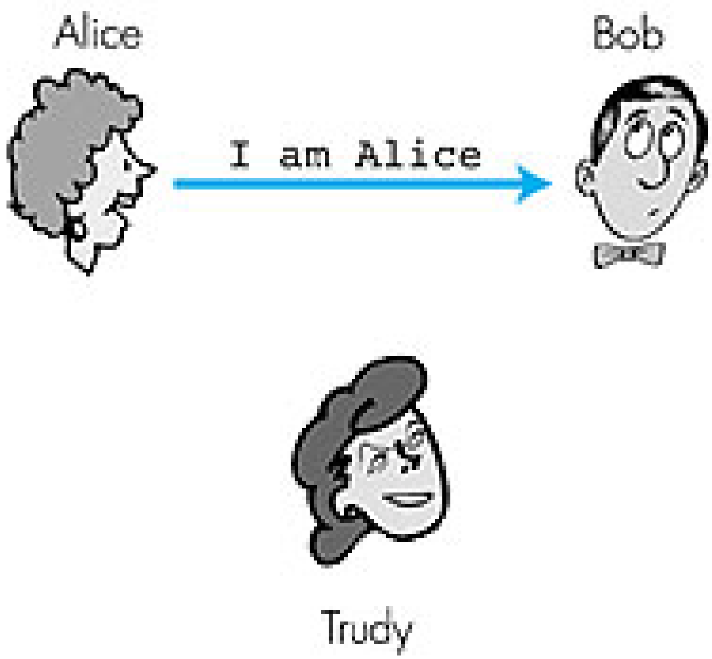
② **need public and private keys for $d_B(\cdot)$ and $e_B(\cdot)$**

RSA: Rivest, Shamir, Adelson algorithm

Authentication

<u>Goal:</u> Bob wants Alice to "prove" her identity to him

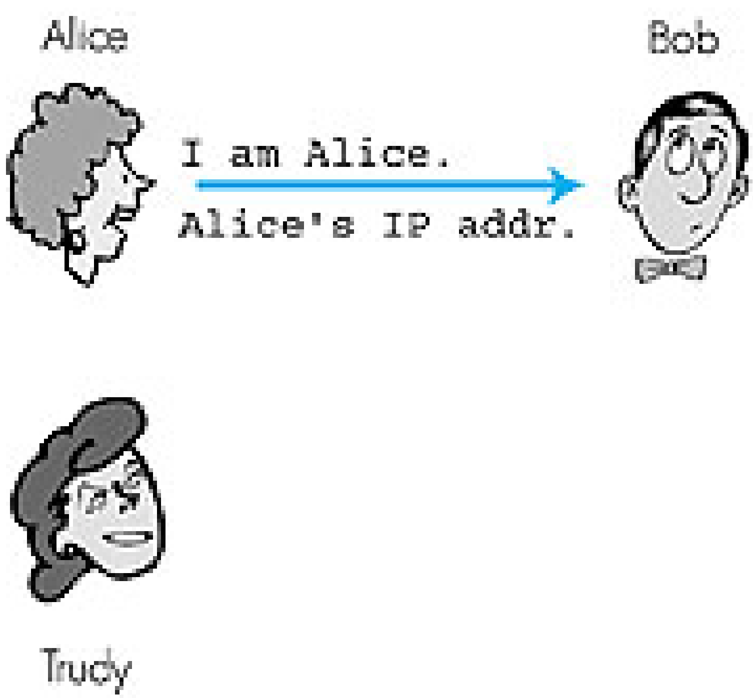
<u>Protocol ap1.0:</u> Alice says "I am Alice"



Failure scenario??

Authentication: another try

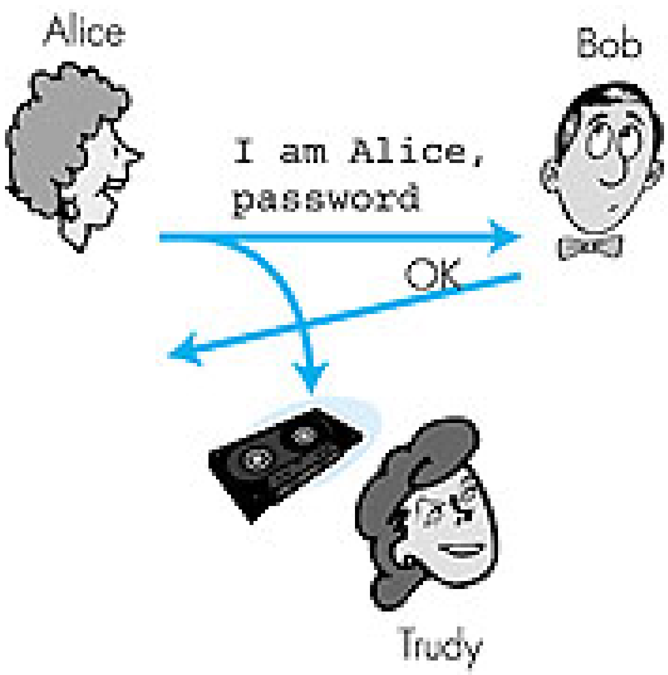
Protocol ap2.0: Alice says "I am Alice" and sends her IP address along to "prove" it.



Failure scenario??

Authentication: another try

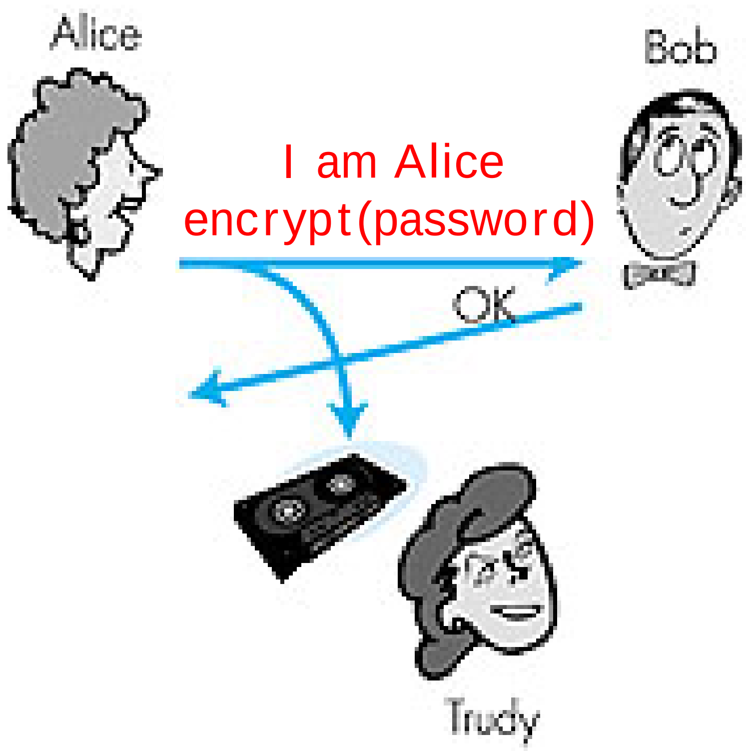
Protocol ap3.0: Alice says "I am Alice" and sends her secret password to "prove" it.



Failure scenario?

Authentication: yet another try

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



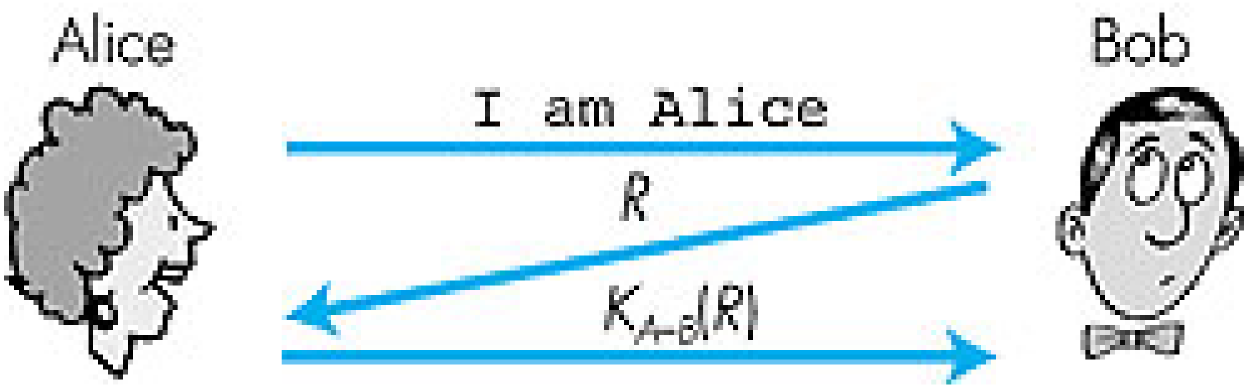
Failure scenario?

Authentication: yet another try

Goal: avoid playback attack

Nonce: number (R) used onlyonce in a lifetime

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



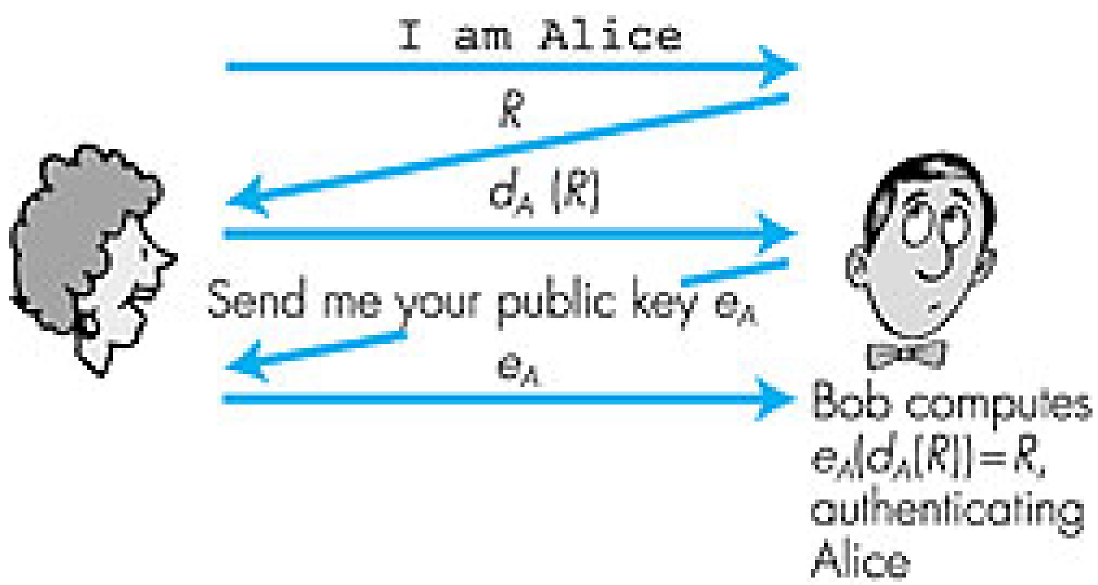
Failures, drawbacks?

Authentication: ap5.0

ap4.0 requires shared symmetric key

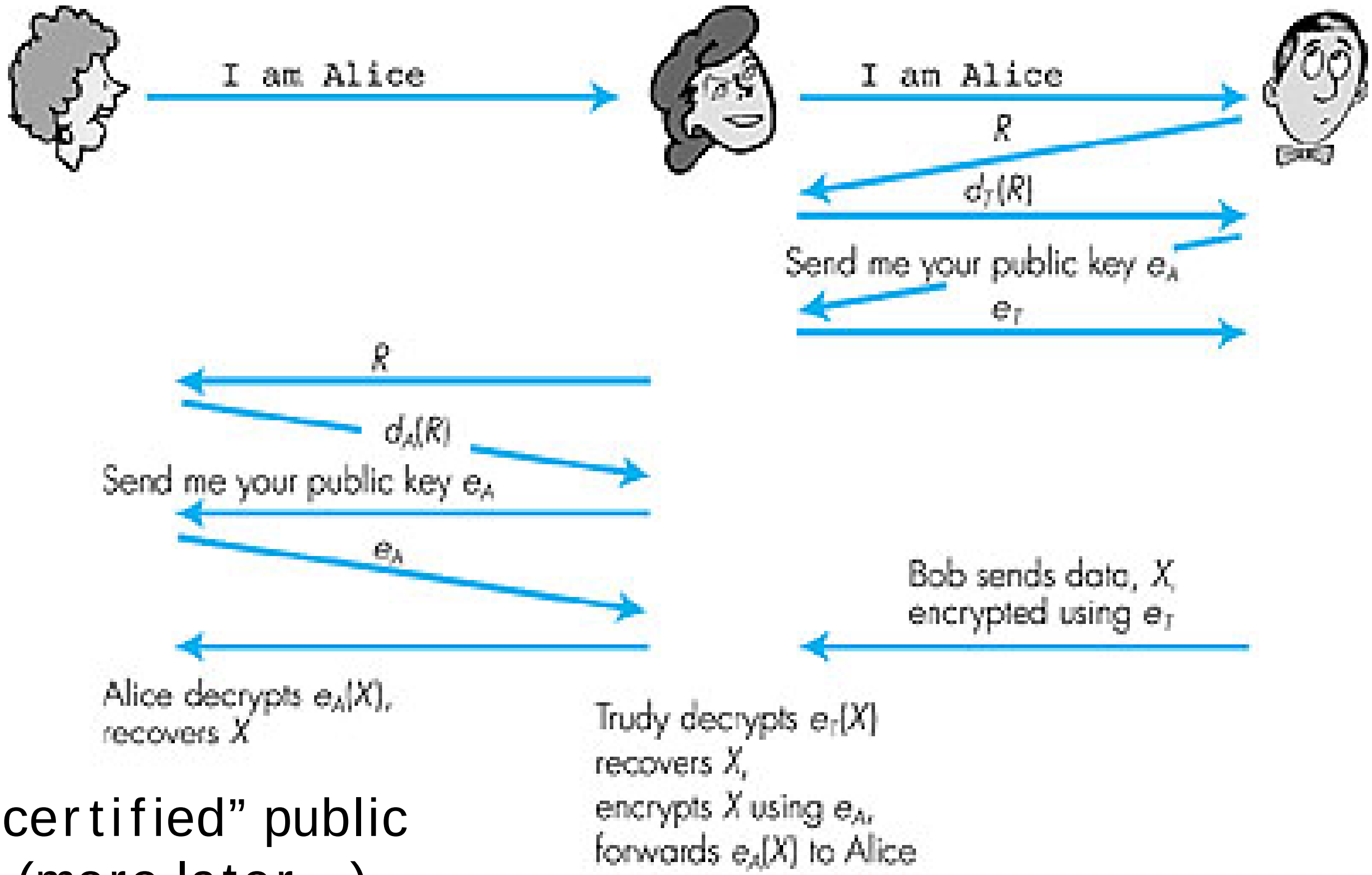
- **problem: how do Bob, Alice agree on key**
- **can we authenticate using public key techniques?**

ap5.0: use nonce, public key cryptography



ap5.0: security hole

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



Need "certified" public keys (more later …)

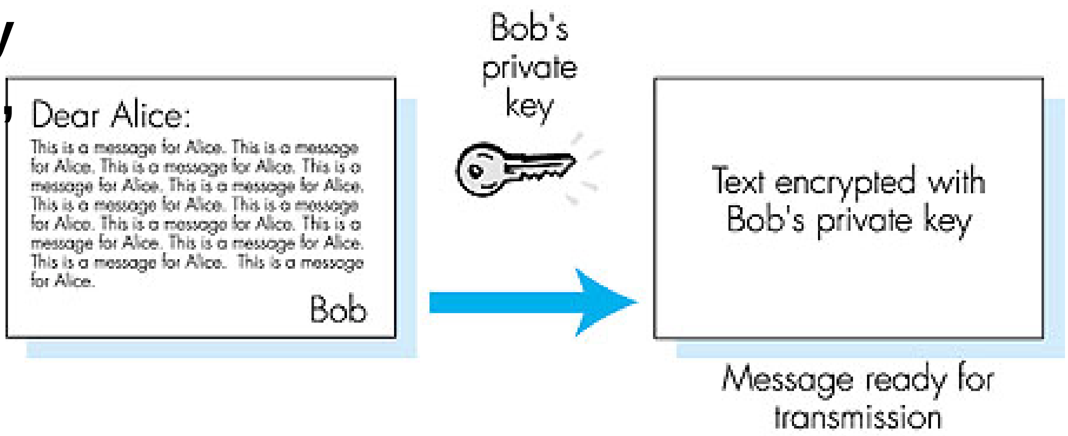
Digital Signatures

Cryptographic technique analogous to hand-written signatures.

- **Sender (Bob) digitally signs document, establishing he is document owner/creator.**
- **Verifiable, nonforgeable: recipient (Alice) can verify that Bob, and no one else, signed document.**

Simple digital signature for message m:

- **Bob encrypts m with his private key d_B, creating signed message, $d_B(m)$.**
- **Bob sends m and $d_B(m)$ to Alice.**



Digital Signatures (more)

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

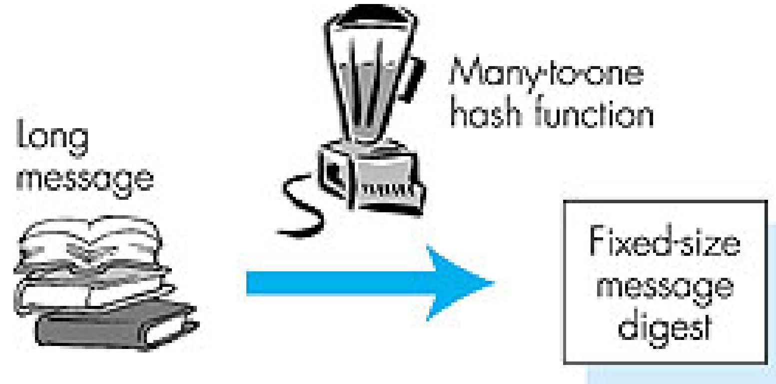
Alice thus verifies that:

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

Non-repudiation:

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

Message Digests



Computationally expensive to public-key-encrypt long messages

<u>Goal:</u> fixed-length,easy to compute digital signature, "fingerprint"

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

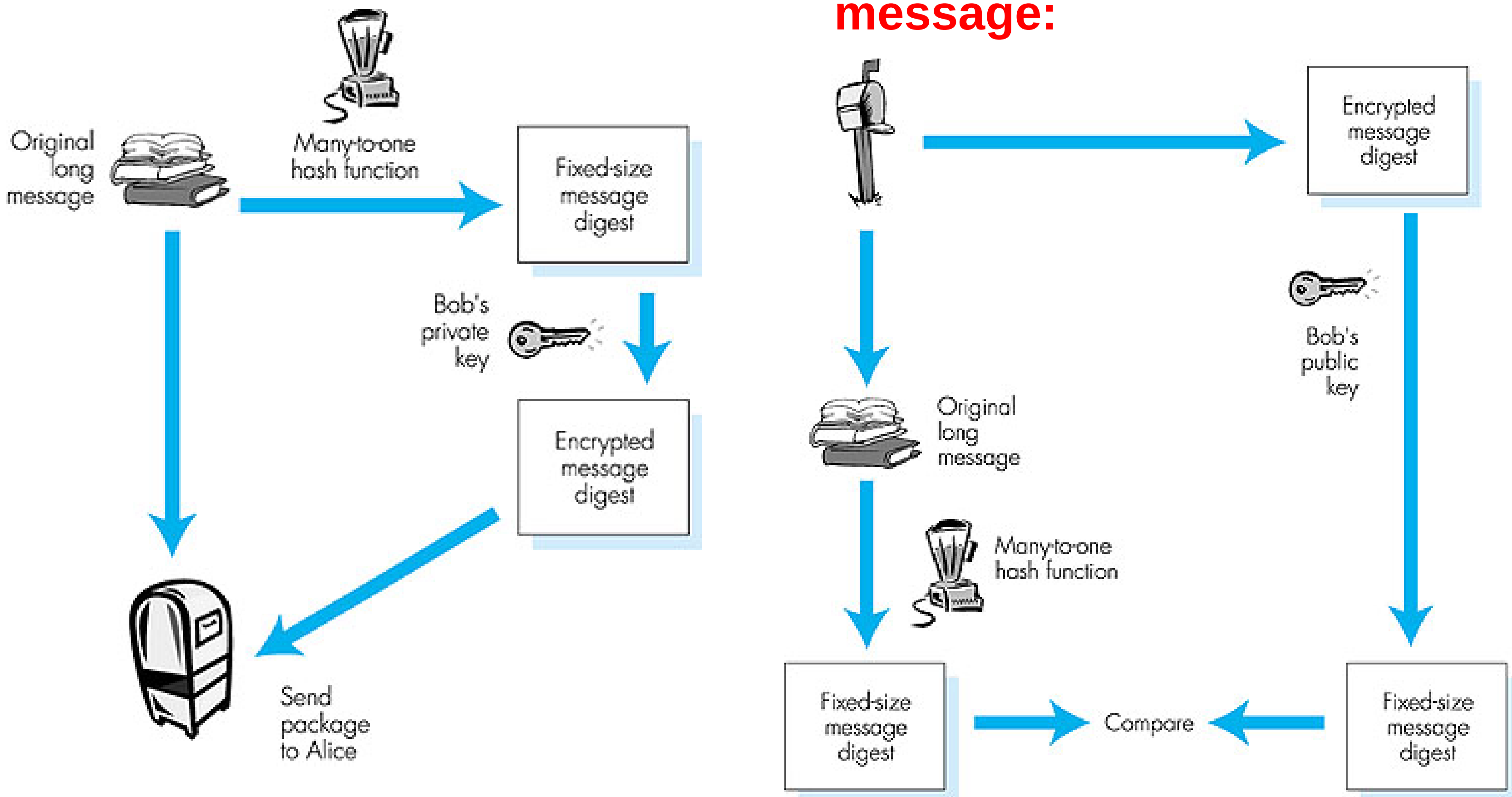
Hash function properties:

- Many-to-1
- Produces fixed-size msg digest (fingerprint)
- Given message digest x, computationally infeasible to find m such that x = H(m)
- computationally infeasible to find any two messages m and m' such that H(m) = H(m').

Digital signature = Signed message digest

Bob sends digitally signed message:

Alice verifies signature and integrity of digitally signed message:



Hash Function Algorithms

- **Internet checksum would make a poor message digest.**
  – **Too easy to find two messages with same checksum.**
- **MD5 hash function widely used.**
  – **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**
  – **160-bit message digest**

Trusted Intermediaries

Problem:

- **How do two entities establish shared secret key over network?**

Solution:

- **trusted key distribution center (KDC) acting as intermediary between entities**

Problem:

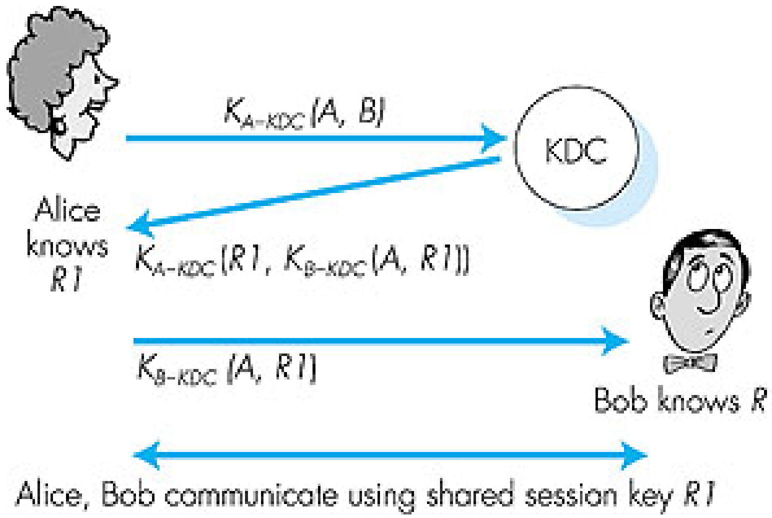
- **When Alice obtains Bob's public key (from web site, e-mail, diskette), how does she know it is Bob's public key, not Trudy's?**

Solution:

- **trusted certification authority (CA)**

Key Distribution Center (KDC)

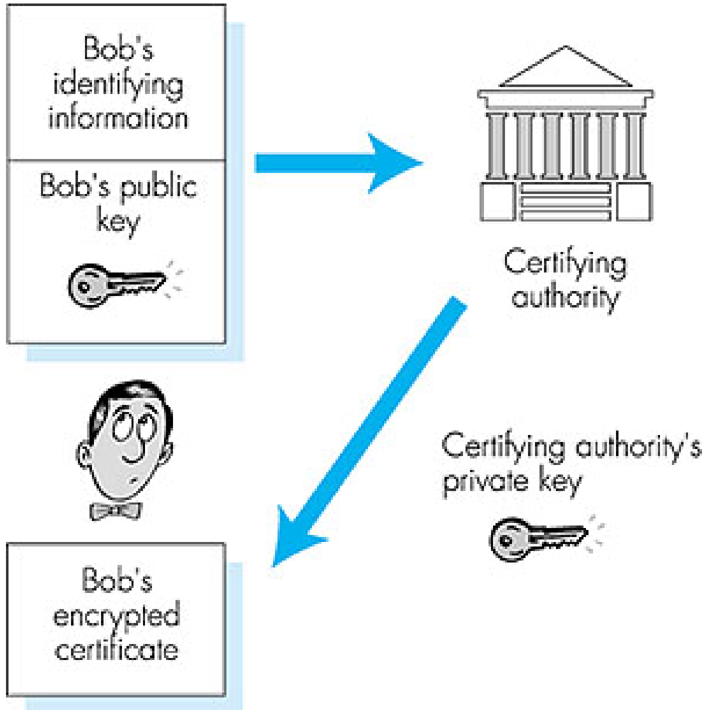
- **Alice,Bob need shared symmetric key.**
- **KDC: server shares different secret key with each registered user.**
- **Alice, Bob know own symmetric keys, $K_{A\text{-}KDC}$ $K_{B\text{-}KDC}$, for communicating with KDC.**



- **Alice communicates with KDC, gets session key R1, and $K_{B\text{-}KDC}$(A,R1)**
- **Alice sends Bob $K_{B\text{-}KDC}$(A,R1), Bob extracts R1**
- **Alice, Bob now share the symmetric key R1.**

Certification Authorities

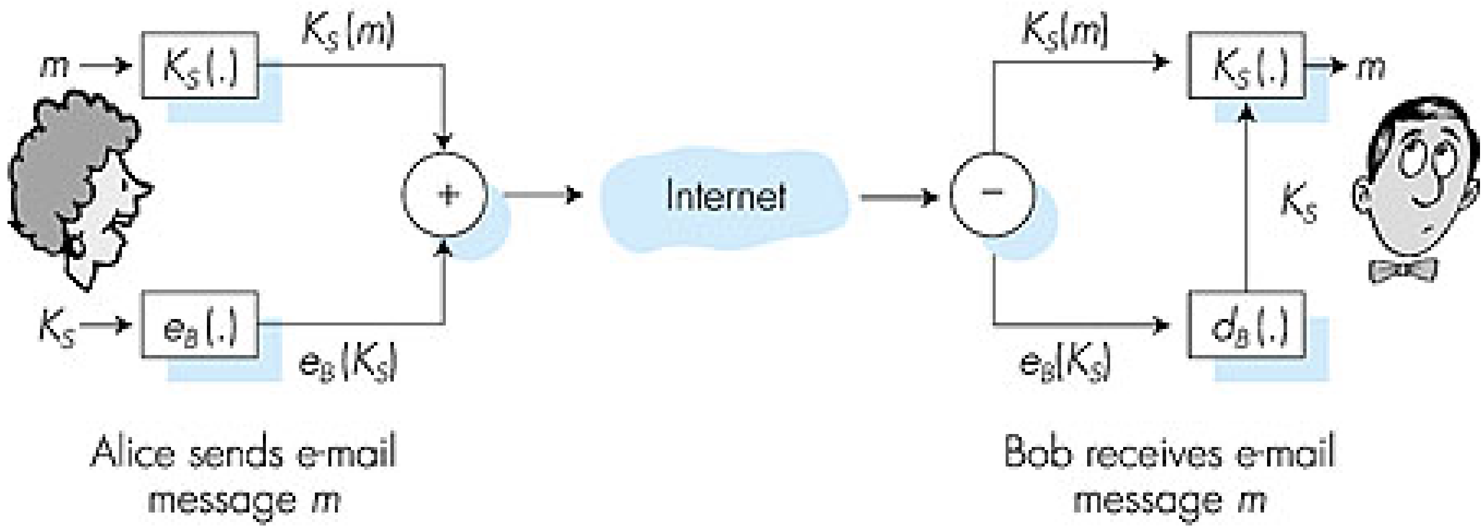
- **Certification authority (CA) binds public key to particular entity.**
- **Entity (person, router, etc.) can register its public key with CA.**
  - **Entity provides "proof of identity" to CA.**
  - **CA creates certificate binding entity to public key.**
  - **Certificate digitally signed by CA.**



- **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**

Secure e-mail

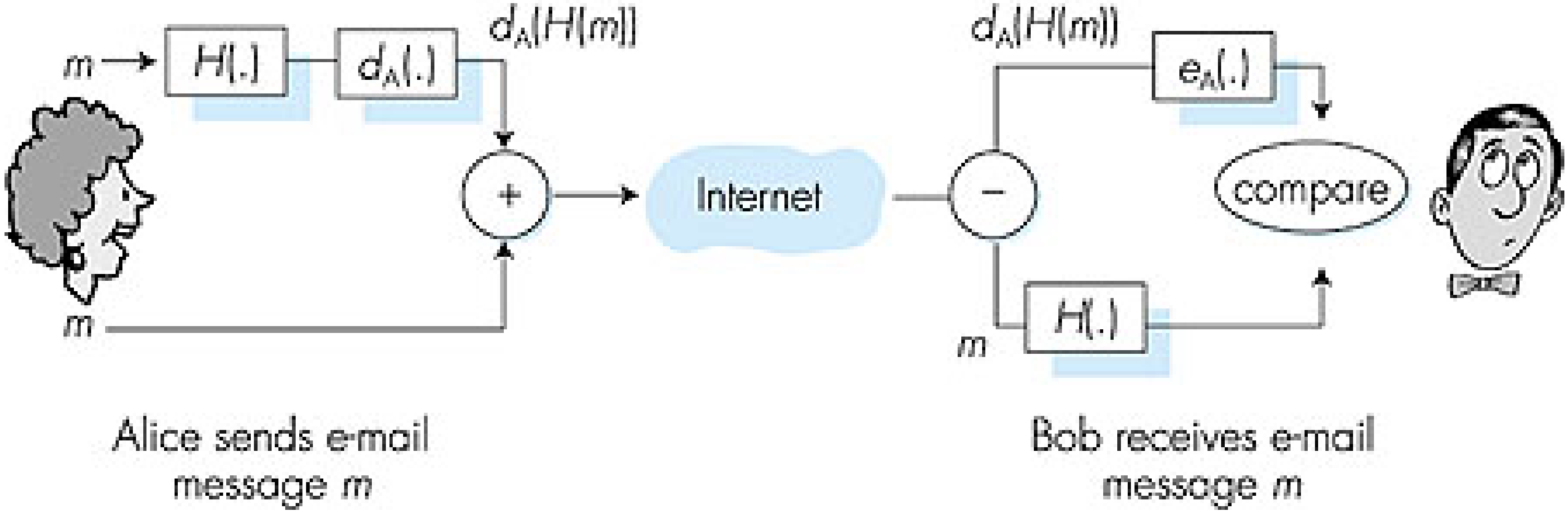
- Alice wants to send secret e-mail message, m, to Bob.



- generates random symmetric private key, K_S.
- encrypts message with K_S
- also encrypts K_S with Bob's public key.
- sends both $K_S(m)$ and $e_B(K_S)$ to Bob.

Secure e-mail (continued)

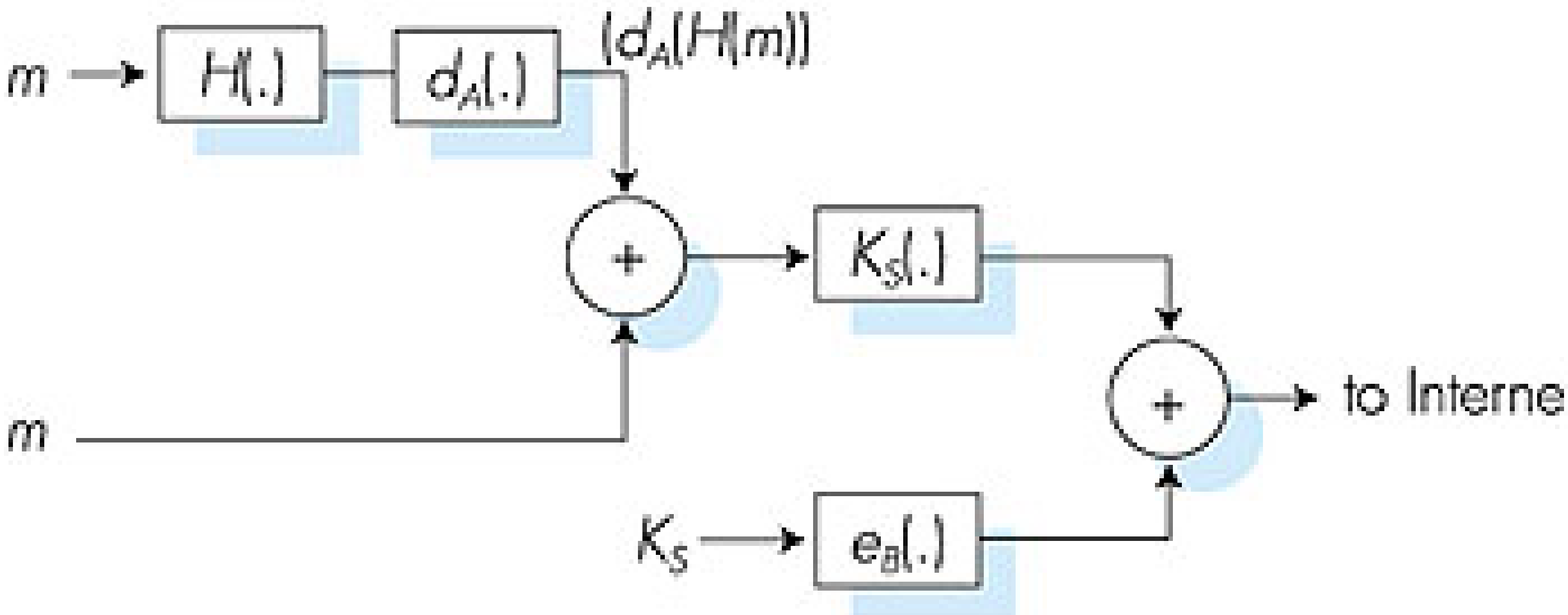
• Alice wants to provide sender authentication message integrity.



- Alice digitally signs message.
- sends both message (in the clear) and digital signature.

Secure e-mail (continued)

- Alice wants to provide secrecy, sender authentication, message integrity.



Note: Alice uses both her private key, Bob's public key.

Pretty good privacy (PGP)

- **Internet e-mail encryption scheme, a de-facto standard.**
- **Uses symmetric key cryptography, public key cryptography, hash function, and digital signature as described.**
- **Provides secrecy, sender authentication, integrity.**
- **Inventor, Phil Zimmerman, was target of 3-year federal investigation.**

A PGP signed message:

```
---BEGIN PGP SIGNED MESSAGE---
Hash: SHA1

Bob:My husband is out of town
   tonight.Passionately yours,
   Alice

---BEGIN PGP SIGNATURE---
Version: PGP 5.0
Charset: noconv
yhHJRHhGJGhgg/12EpJ+lo8gE4vB3mqJ
   hFEvZP9t6n7G6m5Gw2
---END PGP SIGNATURE---
```

Secure sockets layer (SSL)

- **PGP provides security for a specific network app.**
- **SSL works at transport layer. Provides security to any TCP-based app using SSL services.**
- **SSL: used between WWW browsers, servers for I-commerce (shttp).**
- **SSL security services:**
  - **server authentication**
  - **data encryption**
  - **client authentication (optional)**
- **Server authentication:**
  - **SSL-enabled browser includes public keys for trusted CAs.**
  - **Browser requests server certificate, issued by trusted CA.**
  - **Browser uses CA's public key to extract server's public key from certificate.**
- **Visit your browser's security menu to see its trusted CAs.**

SSL (continued)

Encrypted SSL session:

- **Browser generates symmetric session key, encrypts it with server's public key, sends encrypted key to server.**
- **Using its private key, server decrypts session key.**
- **Browser, server agree that future msgs will be encrypted.**
- **All data sent into TCP socket (by client or server) i encrypted with session key.**

- **SSL: basis of IETF Transport Layer Security (TLS).**
- **SSL can be used for non-Web applications, e.g., IMAP.**
- **Client authentication can be done with client certificates.**

Secure electronic transactions (SET)

- designed for payment-card transactions over Internet.
- provides security services among 3 players:
  - customer
  - merchant
  - merchant's bank

  All must have certificates.
- SET specifies legal meanings of certificates.
  - apportionment of liabilities for transactions
- Customer's card number passed to merchant's bank without merchant ever seeing number in plain text.
  - Prevents merchants from stealing, leaking payment card numbers.
- Three software components:
  - Browser wallet
  - Merchant server
  - Acquirer gateway
- See text for description of SET transaction.