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

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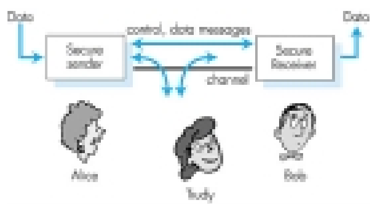
Friends and enemies: Alice, Bob, Trudy



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

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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

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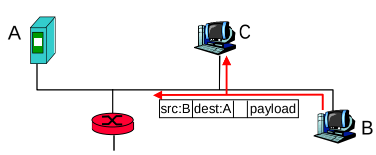
Internet security threats

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



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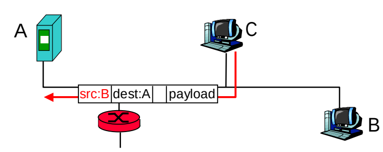
Internet security threats

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



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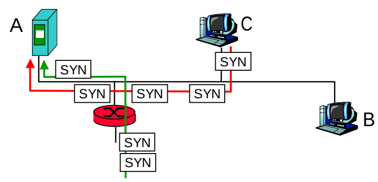
Internet security threats

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



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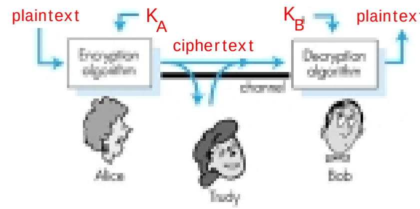
The language of cryptography



symmetric key crypto: sender, receiver keys identical

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

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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?

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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

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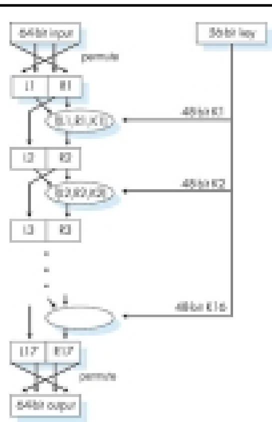
Symmetric key crypto: DES

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)**

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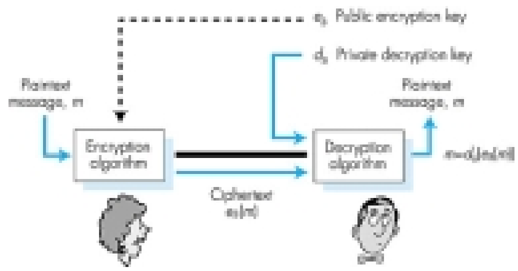
Public key cryptography



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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 $d_B(\,)$ and $e_B(\,)$

RSA: Rivest, Shamir, Adelson algorithm

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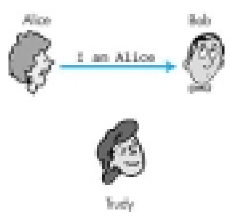
Authentication

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

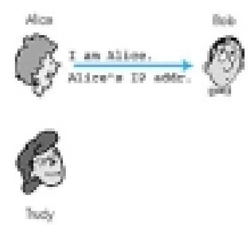
Protocol ap1.0: Alice says "I am Alice"



Failure scenario??

Authentication: another try

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



Failure scenario??

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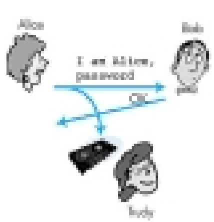
Authentication: another try

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



Failure scenario?

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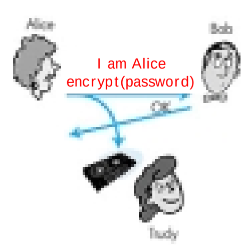
Authentication: yet another try

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



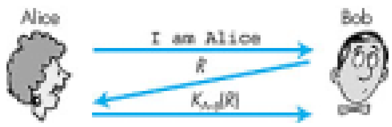
Failure scenario?

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?

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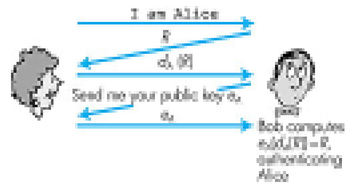
Authentication: ap5.0

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



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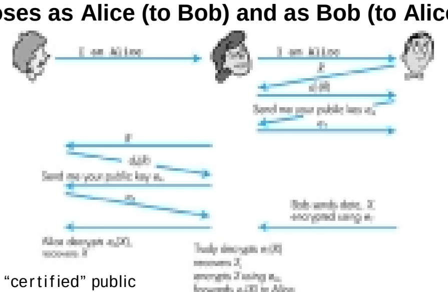
ap5.0: security hole

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



Need "certified" public keys (more later …)

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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.**

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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*.**

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Message Digests

Computationally expensive to public-key-encrypt long messages

Goal: 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').**

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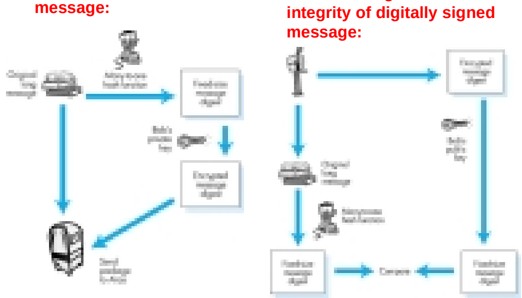
Digital signature = Signed message digest

Bob sends digitally signed message:

Alice verifies signature and integrity of digitally signed message:



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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

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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)

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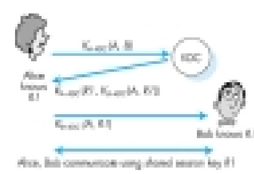
Key Distribution Center (KDC)

- 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.

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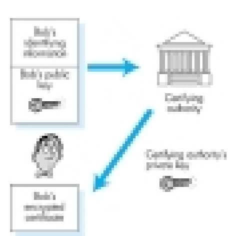
Certification Authorities

- 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

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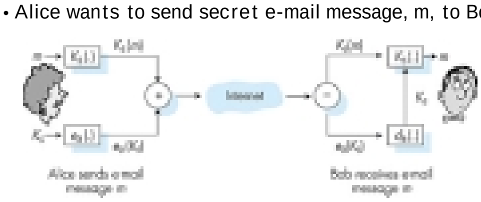
Secure e-mail

- 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.

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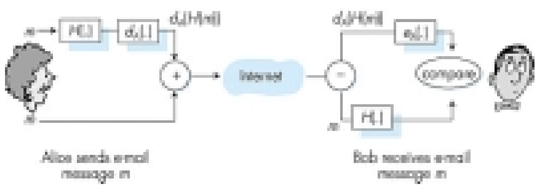
Secure e-mail (continued)

- Alice wants to provide sender authentication message integrity.



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

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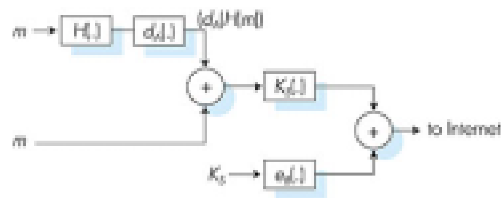
Secure e-mail (continued)

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



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

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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---
```

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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.**

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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.**

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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.**

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