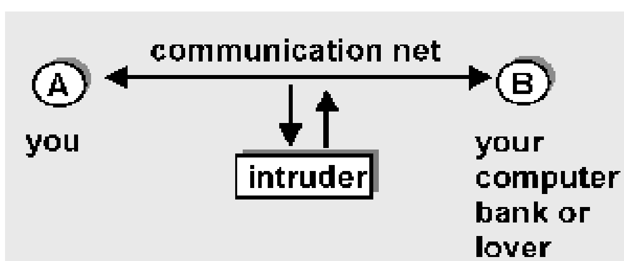
# Security in Distributed Systems

- Introduction
- Cryptography
- Authentication
- Key exchange
- Readings: Tannenbaum, chapter 8

  Ross/Kurose, Ch 7 (available online)



# Network Security




**Intruder may**

- eavesdrop
- remove, modify, and/or insert messages
- read and playback messages

# Issues

## Important issues:

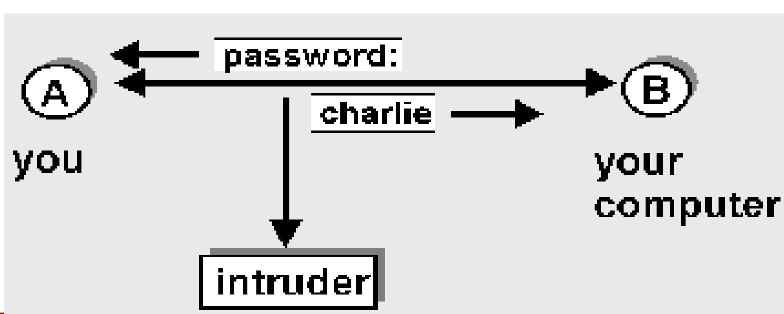
- *cryptography:* secrecy of info being transmitted
- *authentication:* proving who you are and having correspondent prove his/her/its identity



# Security in Computer Networks

## User resources:

- login passwords often transmitted unencrypted in TCP packets between applications (e.g., telnet, ftp)
- passwords provide little protection



# Security Issues

**Network resources:**

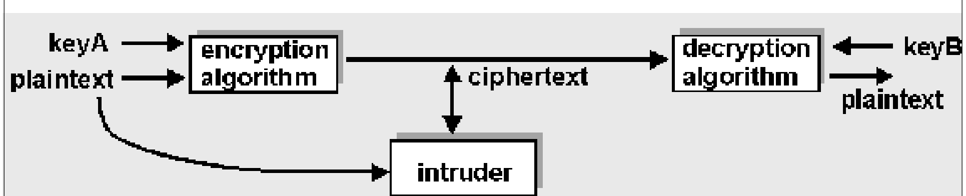
- often completely unprotected from intruder eavesdropping, injection of false messages
- mail spoofs, router updates, ICMP messages, network management messages

**Bottom line:**

- intruder attaching his/her machine (access to OS code, root privileges) onto network can override many system-provided security measures
- users must take a more active role



# Encryption



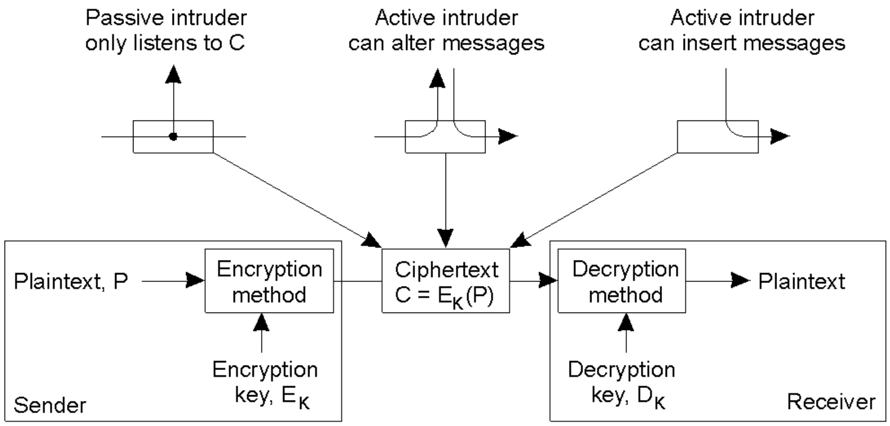

**plaintext:** unencrypted message

**ciphertext:** encrypted form of message

**Intruder may**

- intercept ciphertext transmission
- intercept plaintext/ciphertext pairs
- obtain encryption decryption algorithms

# Encryption






# A simple encryption algorithm

## Substitution cipher:

`abcdefghijklmnopqrstuvwxyz`

`poiuytrewqasdfghjklmnbvczx`

- replace each plaintext character in message with matching ciphertext character:

**plaintext:** `Charlotte, my love`

**ciphertext:** `iepksgmmy, dz sgby`

# Encryption Algo (contd)

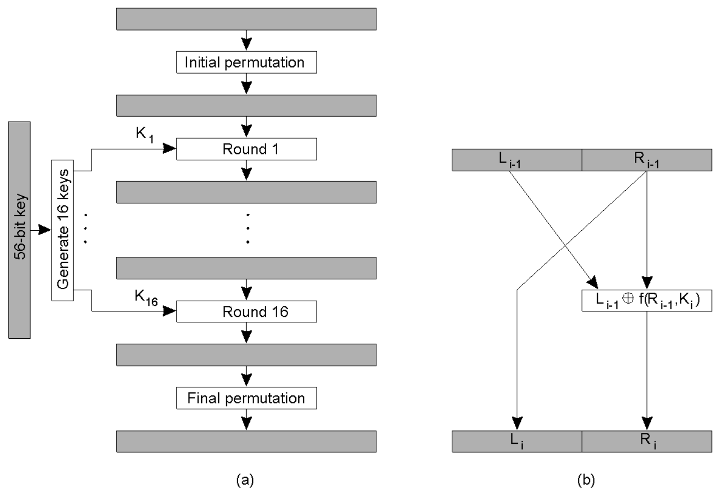
- key is pairing between plaintext characters and ciphertext characters
- **symmetric key:** sender and receiver use same key
- 26! (approx 10^26) different possible keys: unlikely to be broken by random trials
- substitution cipher subject to decryption using observed frequency of letters
  - 'e' most common letter, 'the' most common word



# DES: Data Encryption Standard

- encrypts data in 64-bit chunks
- encryption/decryption algorithm is a published standard
  - everyone knows how to do it
- substitution cipher over 64-bit chunks: 56-bit key determines which of 56! substitution ciphers used
  - substitution: 19 stages of transformations, 16 involving functions of key

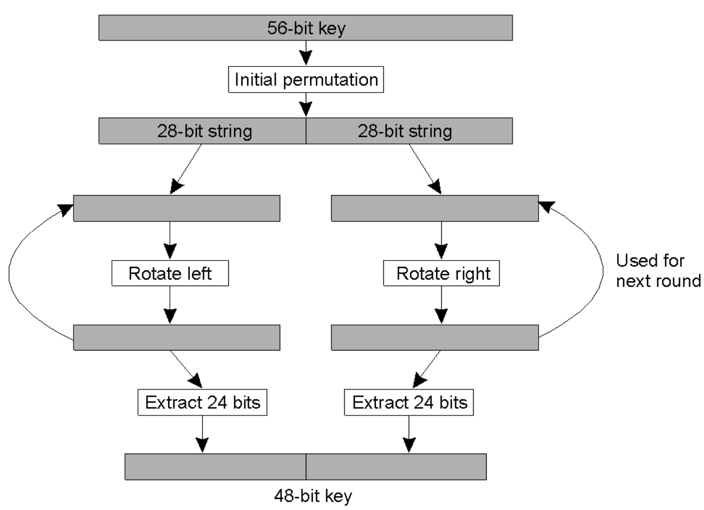
# Symmetric Cryptosystems: DES (1)




a) The principle of DES
b) Outline of one encryption round



# Symmetric Cryptosystems: DES (2)




- Details of per-round key generation in DES.

# Key Distribution Problem

**Problem: how do communicant agree on symmetric key?**

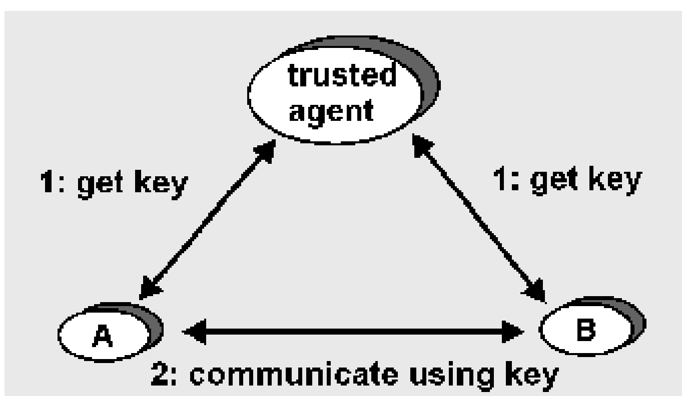
– N communicants implies N keys

**Trusted agent distribution:**

– keys distributed by centralized trusted agent
– any communicant need only know key to communicate with trusted agent
– for communication between i and j, trusted agent will provide a key



# Key Distribution



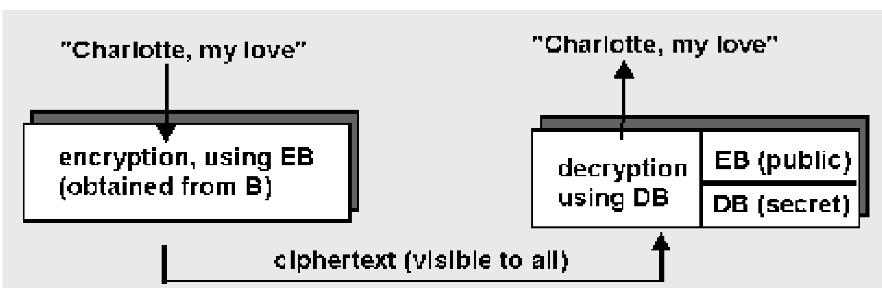

We will cover in more detail shortly

## Public Key Cryptography

- separate encryption/decryption keys
  - receiver makes *known* (!) its encryption key
  - receiver keeps its decryption key secret
- to send to receiver B, encrypt message M using B's publicly available key, EB
  - send EB(M)
- to decrypt, B applies its private decrypt key DB to receiver message:
  - computing DB( EB(M) ) gives M



## Public Key Cryptography




- knowing encryption key does not help with decryption; decryption is a non-trivial inverse of encryption
- only receiver can decrypt message

**Question:** good encryption/decryption algorithms

# RSA: public key encryption/decryption

**RSA:** a public key algorithm for encrypting/decrypting

Entity wanting to receive encrypted messages:

- choose two prime numbers, $p, q$ greater than 10^100
- compute $n=pq$ and $z = (p-1)(q-1)$
- choose number $d$ which has no common factors with $z$
- compute $e$ such that $ed = 1$ mod $z$, i.e.,

  *integer-remainder( (ed) / ((p-1)(q-1)) ) = 1*, i.e.,

  $ed = k(p-1)(q-1) +1$
- three numbers:
  - $e, n$ made public
  - $d$ kept secret



# RSA (continued)

**to encrypt:**

- divide message into blocks, $\{b\_i\}$ of size $j$: $2^j < n$
- encrypt: *encrypt(b_i) = b_I^e mod n*

**to decrypt:**

- *b_i = encrypt(b_i)^d*

**to break RSA:**

- need to know $p, q$, given $pq=n$, $n$ known
- factoring 200 digit $n$ into primes takes 4 billion years using known methods

# RSA example

- choose $p=3$, $q=11$, gives $n=33$, $(p-1)(q-1)=z=20$
- choose $d = 7$ since 7 and 20 have no common factors
- compute $e = 3$, so that $ed = k(p-1)(q-1)+1$ (note: $k=1$ here)



# Further notes on RSA

why does RSA work?

- crucial number theory result: if $p$, $q$ prime then
  $b_i^{(p-1)(q-1)} \bmod pq = 1$
- using mod $pq$ arithmetic:

$(b^e)^d = b^{ed}$

$= b^{k(p-1)(q-1)+1}$ for some $k$

$= b\, b^{(p-1)(q-1)}\, b^{(p-1)(q-1)} \ldots b^{(p-1)(q-1)}$

$= b\ 1\ 1 \ldots 1$

$= b$

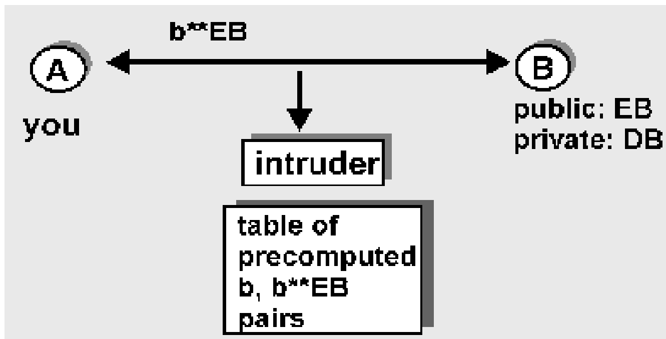
**Note:** we can also encrypt with $d$ and encrypt with $e$.

- this will be useful shortly

# How to break RSA?

Brute force: get B's public key

- for each possible *b_i* in plaintext, compute *b_i^e*
- for each observed *b_i^e*, we then know *b_i*
- moral: choose size of *b_i* "big enough"






# Breaking RSA

man-in-the-middle: intercept keys, spoof identity: