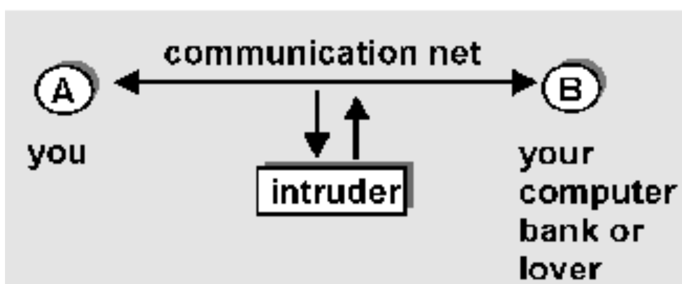
Security in Distributed Systems

- Introduction
- Cryptography
- Authentication
- Key exchange
- Readings: Tannenbaum, chapter 9
  Ross/Kurose, Ch 7

Network Security



Intruder may

- eavesdrop
- remove, modify, and/or insert messages
- read and playback messages
- Security threats
  - Interception, Interruption, Modification, Fabrication

Issues

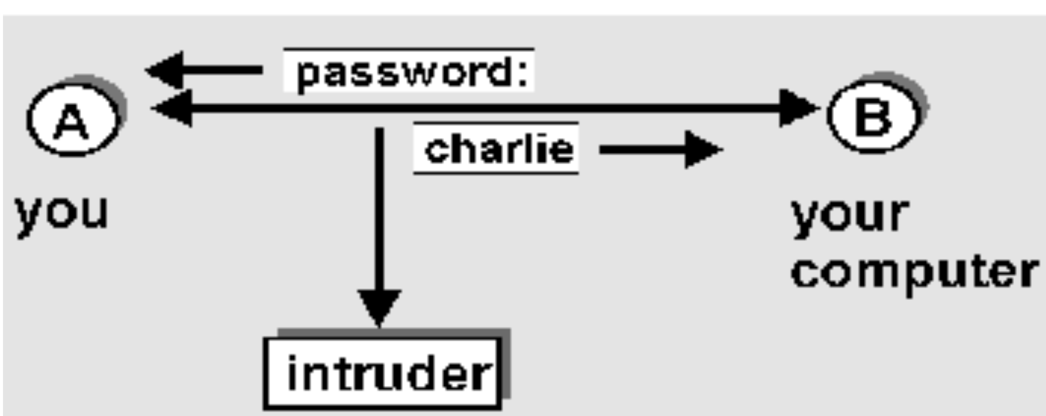
Important issues:

- *Encryption/ cryptography:* secrecy of info being transmitted
- *authentication:* proving who you are and having correspondent prove his/her/its identity
- *Authorization:* verify you have rights to perform requested action
- *Auditing:* log actions and do post-facto analysis (forensics)

Security in Computer Networks

User resources:

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



Security Issues

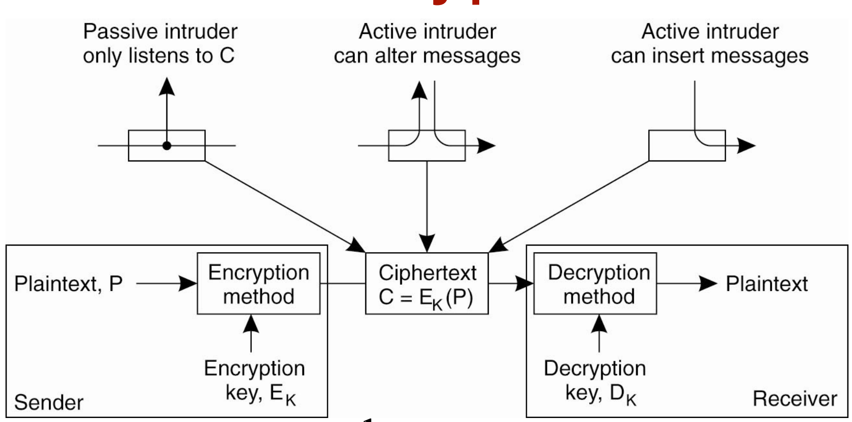
Network resources:

- 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

A simple encryption algorithm

Substitution cipher:

```
abcdefghijklmnopqrstuvwxyz

poiuytrewqasdfghjklmnbvczx
```

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

plaintext: `Charlotte, my dear`

ciphertext: `iepksgmmy, dz uypk`

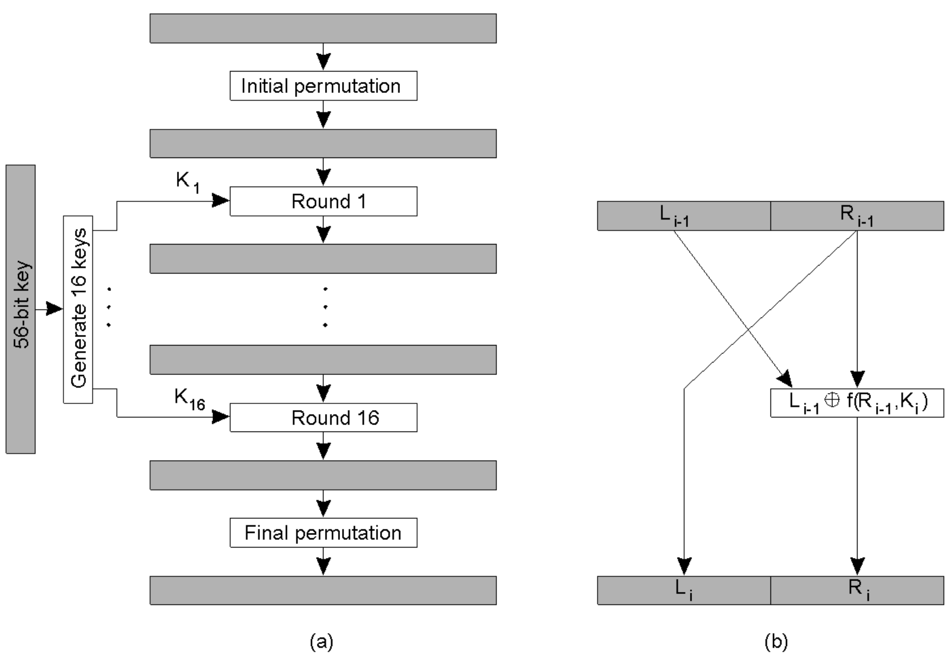
Encryption Algo (contd)

- 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

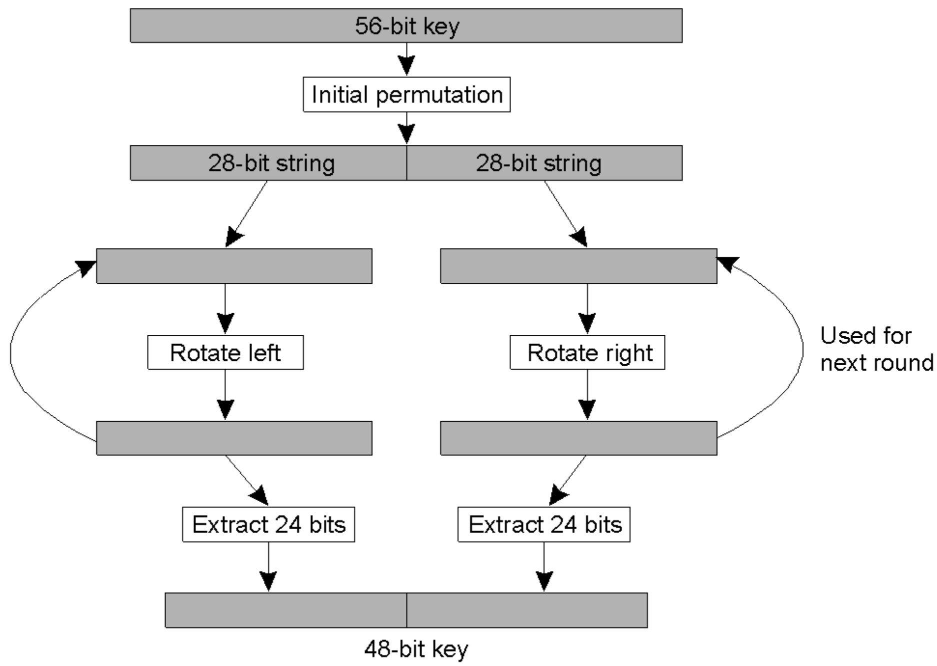
- encrypts data in 64-bit chunks
- encryption/decryption algorithm is a published standard
  - everyone knows how to do it
- substitution cipher over 64-bit chunks: 56-bit key determines which of 56! substitution ciphers used
  - substitution: 19 stages of transformations, 16 involving functions of key
- Replacements: DES3 and now AES

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

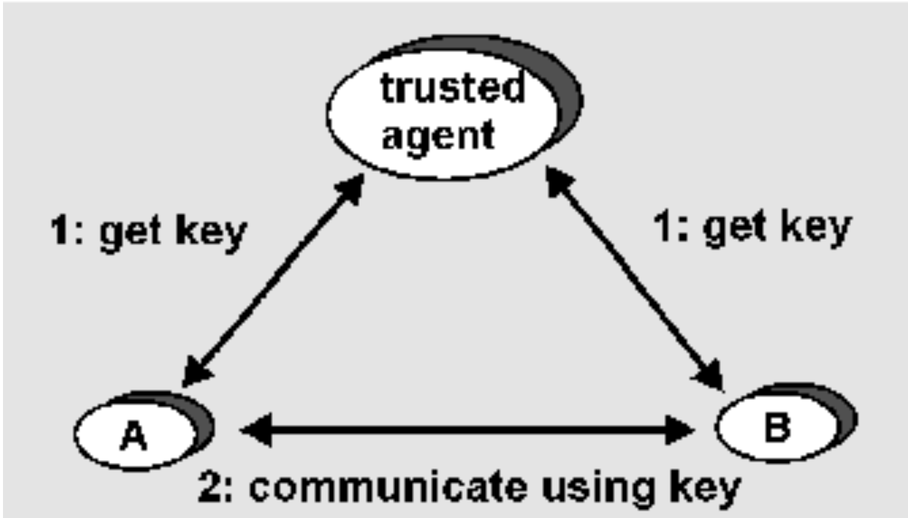
Problem: how do communicant agree on symmetric key?

- 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

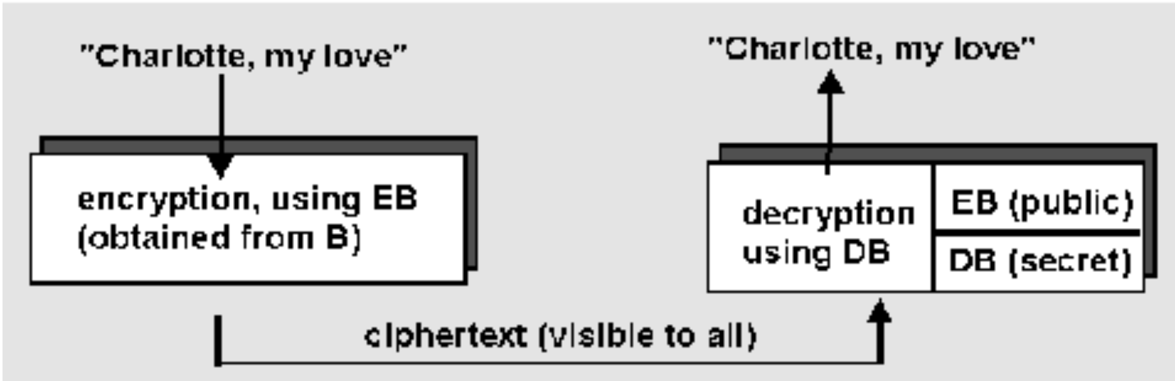


We will cover in more detail shortly

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 $ed = 1 \bmod z$, 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
  $b\_i\text{^}((p-1)(q-1)) \bmod pq = 1$
- using mod pq arithmetic:

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

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

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

$= b\ 1\ 1\ \ldots\ 1$

$= b$

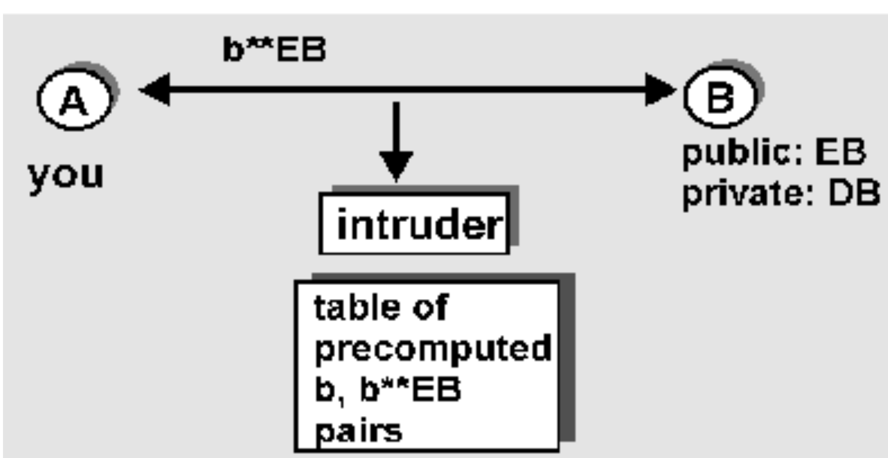
Note: we can also encrypt with d and encrypt with e.

- 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: