Introduction to Computer Science

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Chapter 4

Networking and the Internet

Chapter 4: Networking and the Internet

Two Major Concepts

* Types of networks
  * The look of the physical network
* Distributed system
  * The software system distributed over the physical network

Network Classifications
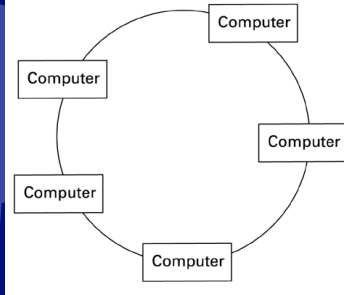
- By the geographical area
  - Local area network (LAN)
  - Wide area network (WAN)
- By the ownership
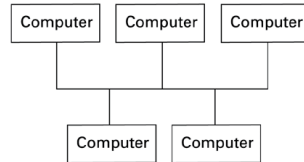 - Closed, or proprietary (private)
  - Open (public)

Network Topologies

- Regular
  - Ring
  - Bus
  - Star
- Irregular

Ring and Bus
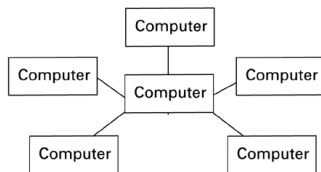
a. Ring

| b. Bus |

Star and Irregular

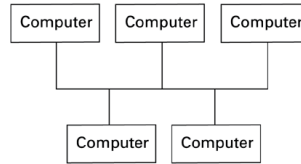c. Star

d. Irregular

4
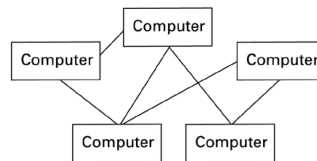
The World is not Perfect

a. Ring
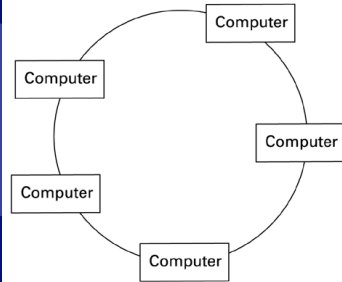
b. Bus

c. Star
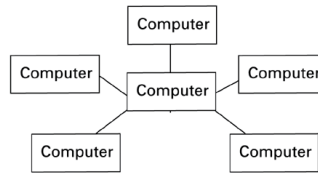
* Computers might fail
* In ring, bus, star networks, would other computers be able to communicate with one of them failing?

Use of Network Topology

* LAN
  * Regular
* WAN
  * Irregular
  * A combination of the regular ones

NTU Campus Network
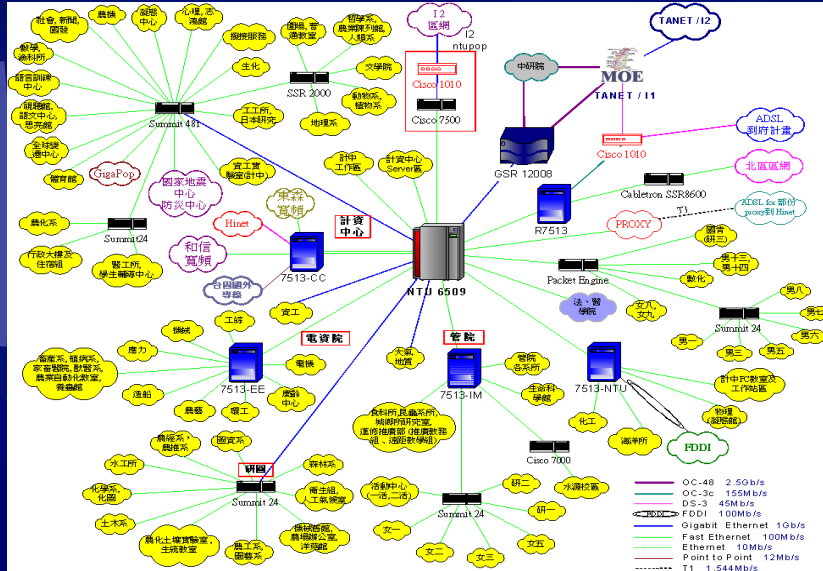
The Internet:
Combination of Domains
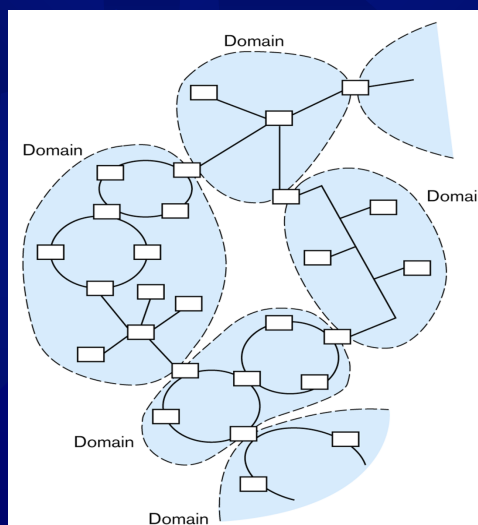
Connecting Networks

- Bridge
  - Connects two compatible networks
  - Connecting homogeneous domains
- Router
  - Connects two incompatible networks
  - Connecting heterogeneous domains
  - Resulting "network" is called an internet

Bridge vs. Router
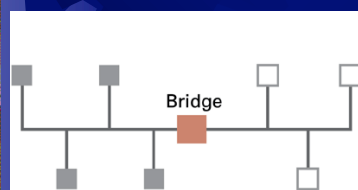
a. A bridge connecting two bus networks to form one large network
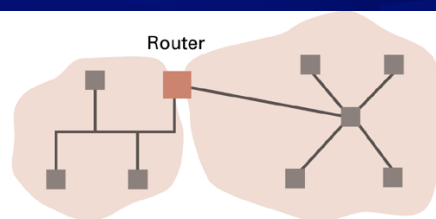
b. A router connecting a bus network to a star network to form an Internet consisting of two networks

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Distributed Systems

* Software consists of parts running on different computers in a network
* A.k.a. network applications
* Example
  * Global information retrieval system such as WWW
  * Company-wide accounting and inventory systems such as online banks
  * World-wide entertainment systems such as the online games

Inter-Process Communication

* Client-server
  * One server, many clients
  * Server must run continuously
  * Server provide information (or services)
  * Client initiates communication
* Peer-to-peer
  * Two processes communicating as equals
  * Each peer provides and request information (or services) to and from other peers
  * Both as the client and server

Client/Server Model

| Client | Requests → ← Service | Server |

Client-Server vs. P2P
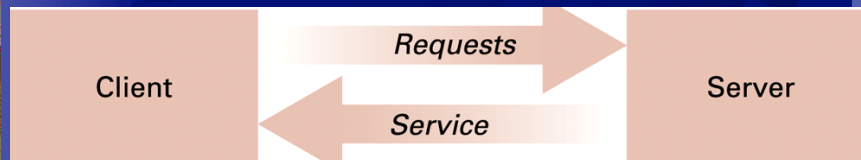
Client   Client

Server
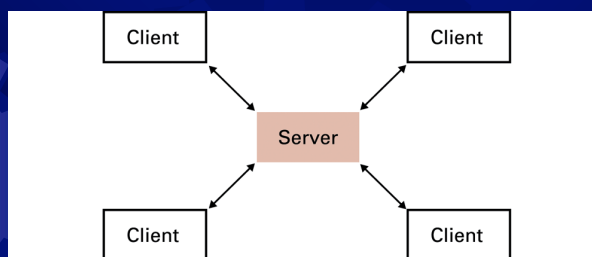
Client   Client

a. Server must be prepared to serve multiple clients at any time.
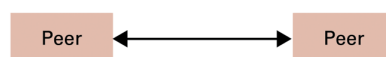
Peer ←→ Peer

b. Peers communicate as equals on a one-to-one basis.

Web

BitTorrent

Other Examples

- **Propagation of knowledge**
  - Teachers giving lectures
    - Client-server? peer-to-peer?
  - Students having discussions
    - Client-server? peer-to-peer?
- **$$ loans**
  - Borrowing from the banks
    - Client-server? peer-to-peer?
  - Taking a company public
    - Client-server? peer-to-peer?

Quiz Time!

Network Application Programming Toolkits

* IP Sockets from open source Unix
* Enterprise Java Beans from Sun Microsystems
* .NET framework from Microsoft

Chapter 4: Networking and the Internet

* 4.1 Network Fundamentals
* 4.2 The Internet
* 4.3 The World Wide Web
* 4.4 Network Protocols
* 4.5 Security

The Internet

* The Internet
  * One interconnected network spanning the world
  * Started by DARPA in 1973
  * Today involves millions of machines

The Internet, Circa 1969

THE INTERNET: 01.01.00

[Data courtesy CAIDA]
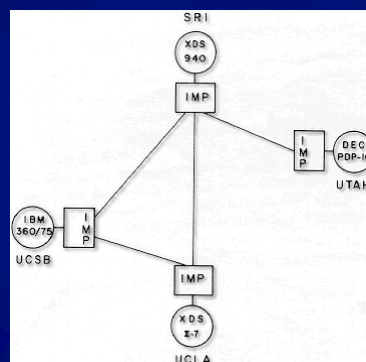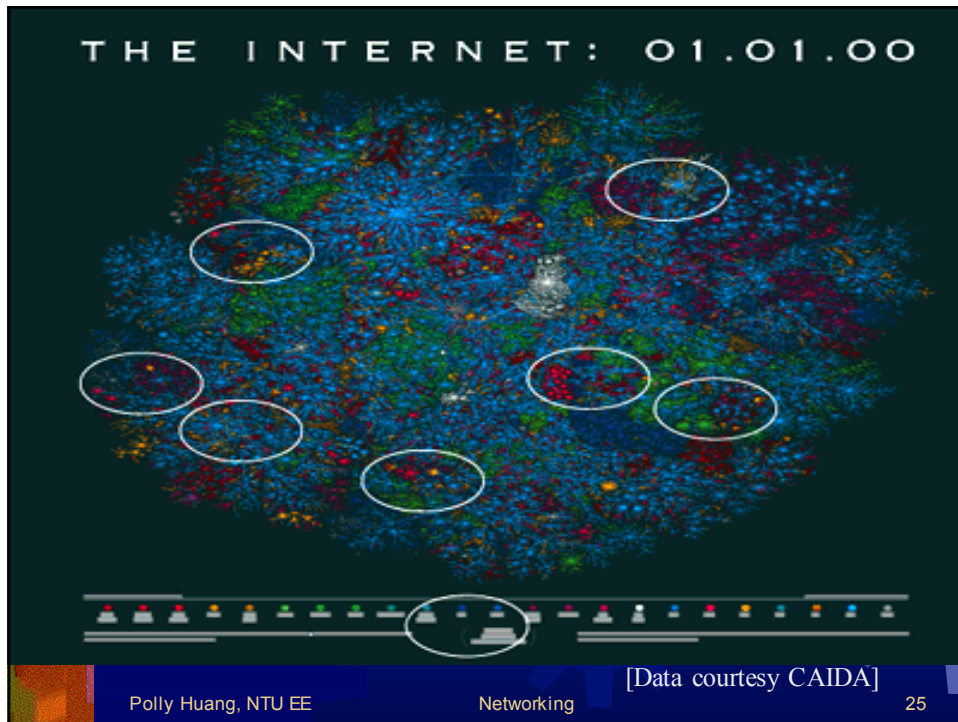
Internet Architecture

* Domain
  * A network or a portion of internet controlled by one organization
* Gateway
  * Router connecting a domain to the cloud
  * Cloud meaning the rest of the internet
* Domains must be registered by their owners
  * Internet Corporation for Assigned Names & Numbers (ICANN) serves as registrar

Connecting to the Internet

Domain

The Internet cloud

Router

Regional network of gateways
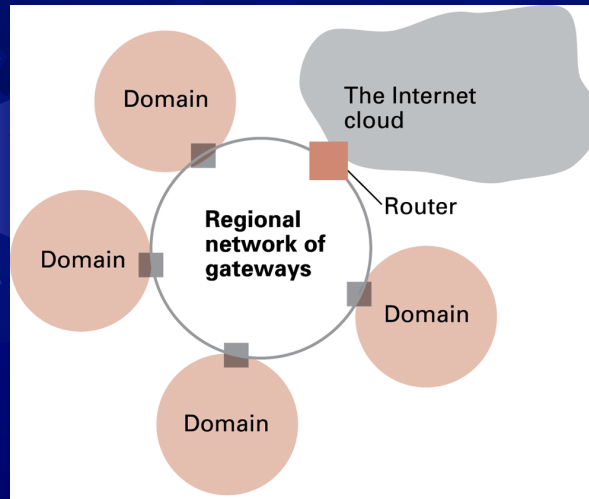
Domain

Domain

Domain

Connecting Strategies

- Large organization
  - Buy a direct connection
  - oc-xx: high capacity optical fiber
- Small organization or individual
  - Link domain to the domain of an ISP
  - oc-xx, Tx: lower capacity network cables
  - ISP: Internet Service Provider
- Individual
  - Temporarily link computer into ISP's domain
  - ADSL, cable modem, modem, Ethernet, WLAN
    - Access network

IP Addresses

- 32 bit identifier for a machine
  - In two parts
- Part 1. Network identifier
  - Subnet address
  - Assigned by ICANN
- Part 2. Host address
  - Host IP address
  - Assigned by domain owner according to the subnet address

Dotted Decimal Notation

- Standard for displaying IP addresses
- 4 numbers separated by 3 dots
- Example:
  - 192.207.177.133

- Each number can only be in between 0 to 255
  - {0~255}.{0~255}.{0~255}.{0~255}
  - 8 bits for each number
  - 32 bits network address in total

Subnet Address

- Roughly speaking
  - Host 192.207.177.133 belonging to
  - Subnet 192.207.177.x
- Formally defined as network prefix
  - Subnet 192.207.177.0/24
- Meaning
  - Hosts in this subnet share the same first 24 bits in their IP addresses
  - There can be 2^8 hosts using different IP addresses in this subnet at most.

Quiz Time!

Classes of IP address

* Secret is in the first byte

* 1− 126, 128 −223
  * Host address (Unicast)
* 127.0.0.1
  * localhost
  * loopback
* 224 − 239
  * Group address (Multicast)
* 240 − 255
  * For emergency (not for emergency only now)

Campus IP

* Campus FDDI core   140.112. 1.xxx
* Campus ATM core   140.112. 5.xxx
* Computing Center   140.112. 2.xxx
  Servers   140.112.254.xxx
* EE Department   140.112. 17.xxx ∼
                            140.112. 21.xxx

  EE II   140.112. 41.xxx
                            140.112. 42.128 ∼
                            140.112. 42.253
                            (ee.ntu.edu.tw)

Host Name

- Mnemonic (easy to remember) name
  - Example: nslab.ee.ntu.edu.tw
- Two parts
  - Domain name and machine name
- Domain name
  - Assigned by a registrar
  - Example: ee.ntu.edu.tw
- Individual machine names
  - Assigned by domain owner
  - Domain owner must run a name server

Internet Applications

- Electronic mail (SMTP)
- File Transfer (FTP)
- Remote login (Telnet)
- World Wide Web (HTTP)

Sending e-mails

- **Step 1-3. Mail sent from Alice**
  - Alice's email reader software delivers the mail to the local mail server
- **Step 3-5. Mail forwarded in the network**
  - Sending mail server delivers mail to the mail server of the receiver (SMTP)
- **Step 5-6. Mail received by Bob**
  - Bob connects to his local mail server with his email reader software.

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Mail Server

- **Set up by domain owner**
- **The after-@ part can be**
  - The mail server hostname
  - The domain name if the default mail server is set by the domain owner

To: bob@ms2.ntu.edu.tw
or
To: bob@ntu.edu.tw

ms2.ntu.edu.tw

bob

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File Transfer Protocol

- FTP client contacts FTP server
  - Client browses remote directory by sending commands over control connection.
  - When server receives a command for a file transfer, the server opens a data connection to client

FTP user interface — FTP client

TCP control connection port 21

FTP server

TCP data connection port 20

user at host

local file system

remote file system
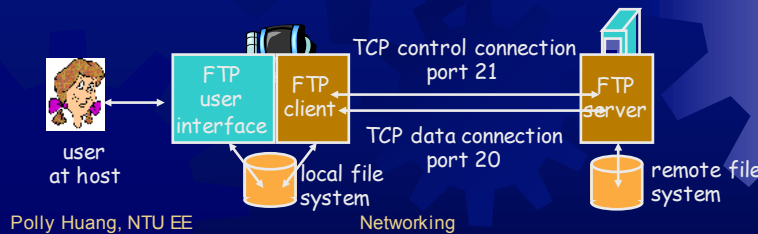
File Transfer

- Transfer in ASCII or BINARY forms
- Access modes
  - Restricted
    - Login with specific username and password
    - Specific access rights
  - Unrestricted
    - Anonymous FTP
    - Login as username: anonymous and password: [email address]

Remote Login

- ☀ Remote command line window
  - ☀ Text-based
- ☀ The local client is like a
  - ☀ Network virtual terminal (NVT)
  - ☀ A keyboard and monitor

Telnet Protocol

- ☀ Client sends command to server
- ☀ Server responds with results of the command
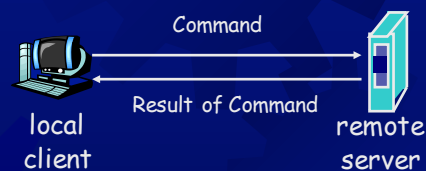
Command

Result of Command

local
client

remote
server

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- 4.3 The World Wide Web
- 4.4 Network Protocols
- 4.5 Security

A sequence of events result in the WWW today…

1989 HTML

1991 HTTP

1993 Mosaic

What's the WWW?

Internet + Information

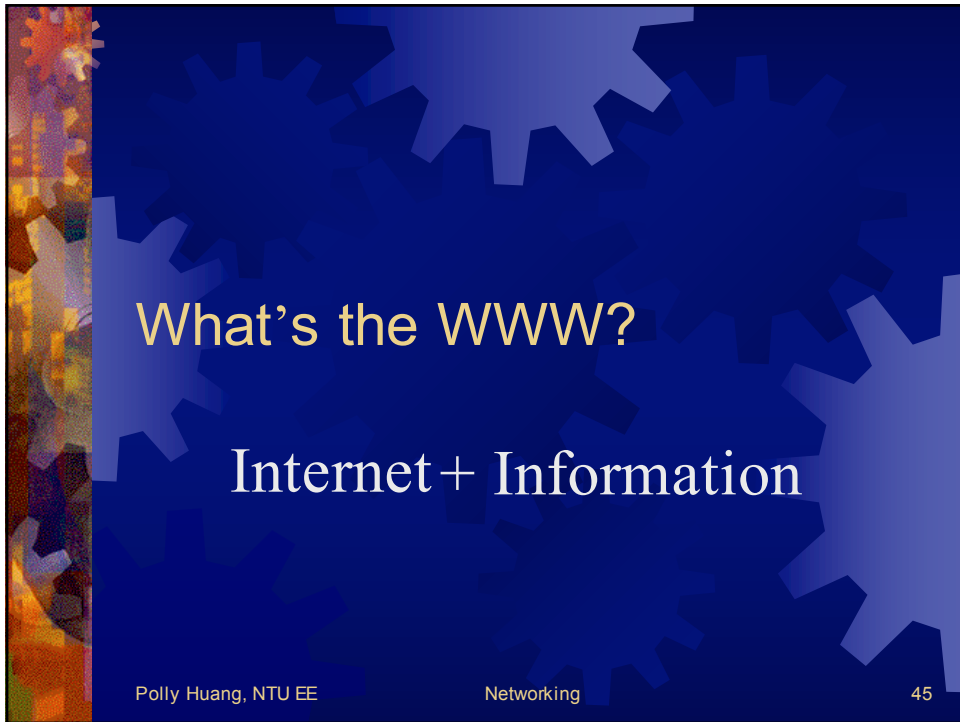**Nice-looking** Information
Available Over the **Internet**

Presentation Matters

A
Introduction to Computer Science
Spring 2016, Class#: 901 10110 Session: 03
Latest News…

B
Introduction to Computer Science

Spring 2016
Class#: 901 10110 Session: 03

Latest News | Discussion Board | …

Therefore, HTML

```
<center>
<H1>Introduction to Computers</H1>
Spring 2016<br>
Class#: 901 901 10110 Session: 03
</center>
<P>
<A HREF="news.html">Latest News</A>
```

Introduction to Computers

Spring 2016
Class#: 901 10110 Session: 03

Latest News | Discussion Board | …

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HTTP

- ☀ HyperText Transport Protocol
- ☀ Another application layer protocol

- ☀ A simple way to transmit data through the so-called World Wide Web

This Simple

http://nslab.ee.ntu.edu.tw/courses/intro-cs-spring-16/

Connection

HTTP Request →

you

nslab.ee.ntu.edu.tw

← HTTP Reply (the page)

```
<center>
<H1>Introduction to Computers</H1>
Spring 2016<br>
...
```
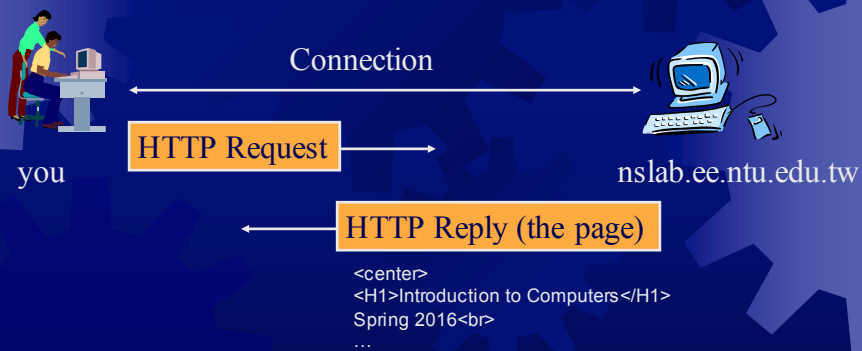
Mosaic

* First point-and-click browser
* For X windows at first
* Ported to Windows and Macintosh OS's

* Now we have Netscape, Internet Explorer, Firefox, etc

Web Browsers

* HTTP client
  * Takes URLs (Uniform Resource Locator)
    * Ex. http://nslab.ee.ntu.edu.tw/courses/intro-cs-spring-16/
  * Sends HTTP Requests
* HTML interpreter
  * Takes HTTP Replies (HTML files)
  * Renders nice-looking information

Web Servers

* Disseminates hypertext documents controlled by one organization or individual
* At same internet address
* Usually in HTML containing text, images, audio, video and etc components

The WWW flew from there.

In March of 1993, Web traffic accounts to 0.1% of all on the Internet.

More than 50% in the late 90's

Typical URL

```
http://ssenterprise.aw.com/authors/Shakespeare/Julius_Caesar.html
```

Mnemonic name of
host holding the
document

Document name

Protocol required
to access the
document. In
this case it is
hypertext transfer
protocol (http).

Directory path
indicating the
location of the
document within
the host's
file system
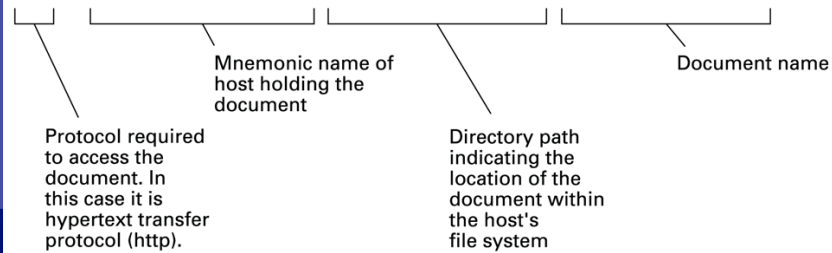
Hypertext Document Format

* Entire document is printable characters
* Contains tags to control display
  * Display appearance
  * Links to other documents and content
  * Dynamic functions

One Example

a. The page encoded using HTML.

Tag indicating beginning of document	`<html>`
	`<head>`
Preliminaries	`<title>demonstration page</title>`
	`</head>`
Part of the page that will be displayed by browser	`<body>`
	`<h1>My Web Page</h1>`
	`<p>Click here for another page.</p>`
	`</body>`
Tag indicating end of document	`</html>`

The Display

b. The page as it would appear on a computer screen.

> **My Web Page**
>
> Click here for another page.

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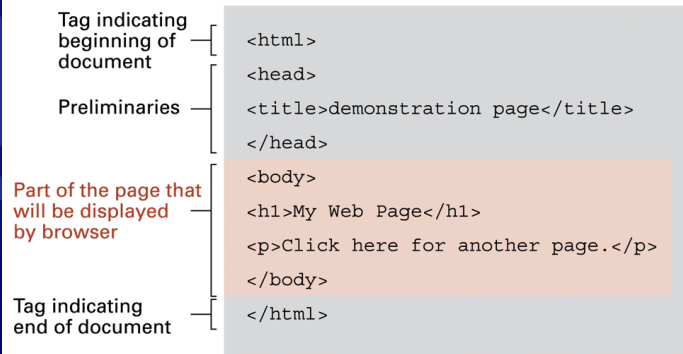
Enhanced Example

a. The page encoded using HTML.

```
<html>
<head>
<title>demonstration page</title>
</head>
<body>
<h1>My Web Page</h1>
<p>Click
   <a href="http://crafty.com/demo.html">
   here
   </a>
   for another page.</p>
</body>
</html>
```

Anchor tag containing parameter

Closing anchor tag

The Display

b. The page as it would appear on a computer screen.

My Web Page

Click here for another page.

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XML

* Extensible Markup Language
* Similar to HTML, but more general
* A descendant of SGML
* All sorts of display possible

Beethoven's Fifth Symphony


```
<staff clef="treble">
<key>C minor</key>
<time>2/4</time>
<measure>…</measure>
<measure>…</measure>
</staff>
```

```
<measure>
<rest>egth</rest>
<notes>egth G, egth G, egth G</notes>
</measure>


<measure>
<notes>hlf E</notes>
</measure>
```

Dynamic Web Pages

- Client-side
  - Computation at the client side
  - Examples: java applets, javascript, Macromedia Flash
- Server-side
  - Computation at the server side
  - Common Gateway Interface (CGI)
  - Servlets
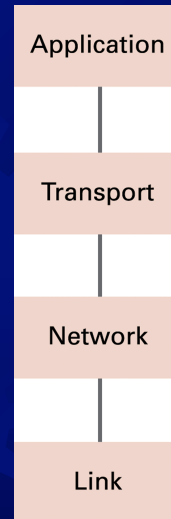 - PHP

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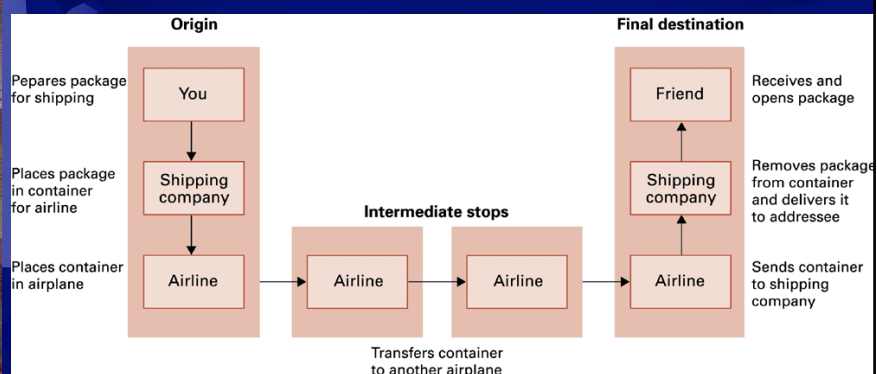- 4.5 Security

Internet Software Layers

- Application layer
  - HTTP, FTP
- Transport layer
  - TCP, UDP
- Network layer
  - Routing
- Link layer
  - Token ring or Ethernet

Application
Transport
Network
Link

Package-Shipping by Air

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Message-Shipping by Internet
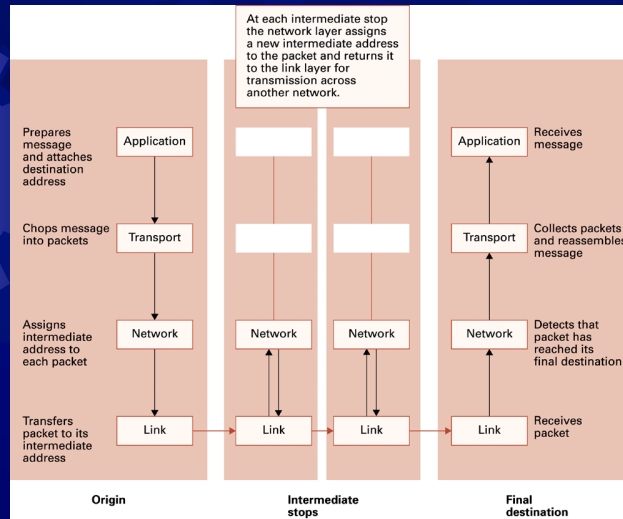
Link Layer

- Token ring: one-way communication around ring network
- Ethernet:
  - Uses carrier sense, multiple access with collision detection (CSMA/CD)
  - Popular for bus networks
  - Like having a conversation in a group

Quiz Time!

Ethernet

- Port hub – bus
  - Collision ← Collision avoidance
  - 100Mbps shared
  - Cheap
- IP switch - star
  - No collision
  - 100Mbps each
  - Not as cheap

The Mechanisms
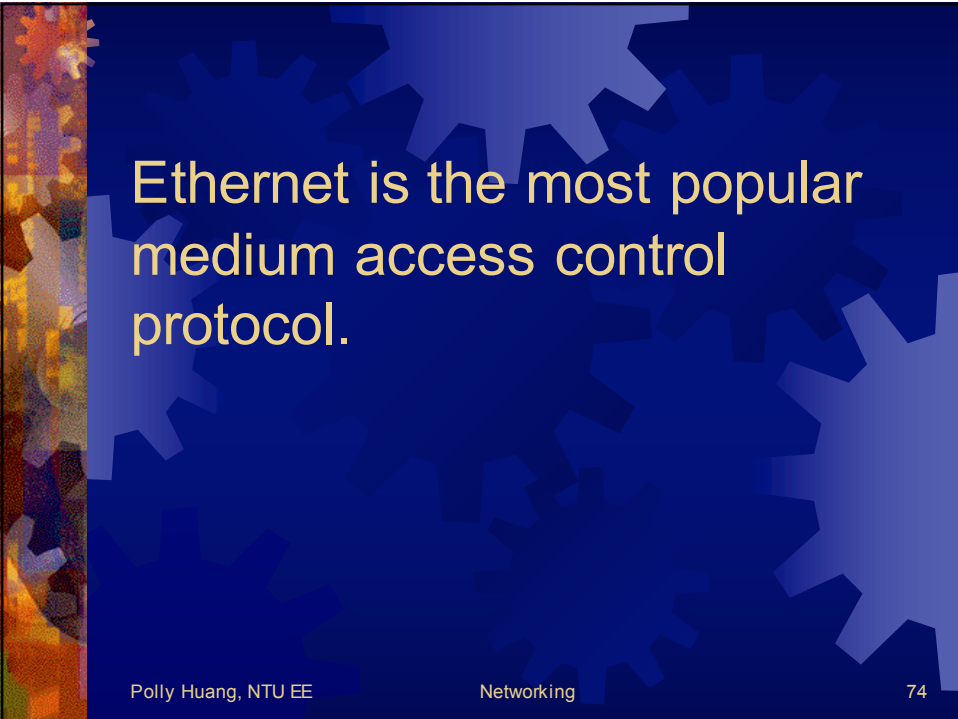
- Each computer listens on the Ethernet
  - If not sensing data on the carrier, OK to send its own data
  - If sensing data on the carrier, check whether the data is addressed for itself
- In case of simultaneous transmissions, (collisions)
  - The computer waits a random period of time before re-send

Properties

- Simple
- Cheap

- The more computers on the LAN, the higher the chance of data colliding

Protocol :
Common Rules Obeyed by All Parties

Ethernet is the most popular medium access control protocol.

MAC

* **M**edium **A**ccess **C**ontrol
* The class of protocols that handle medium access problems
* Example
  * Ethernet (IEEE 802.3)
  * Wireless LAN (IEEE 802.11)
  * Bluetooth (IEEE 802.15),

Network Layer
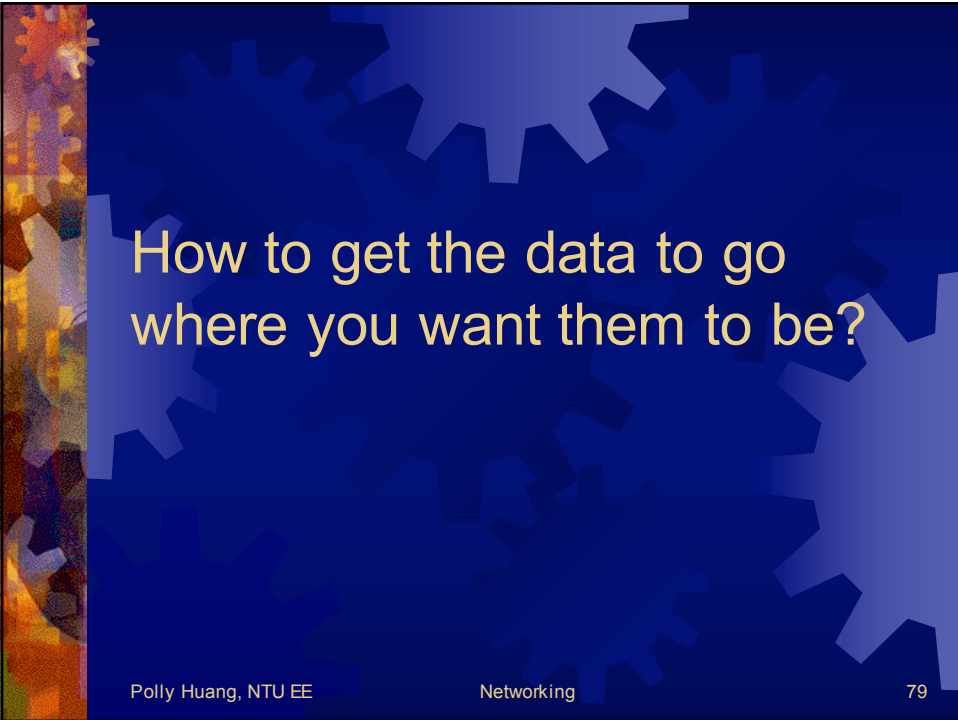
* Dealing with the bigger network
* As opposed to just a link

WAN

- **W**ide **A**rea **N**etwork
- A large number (usually) of connected computers spreading across a wide area

- Connecting LANs
  - A LAN connects to a WAN via a router
- Irregular

Any Shape You Like
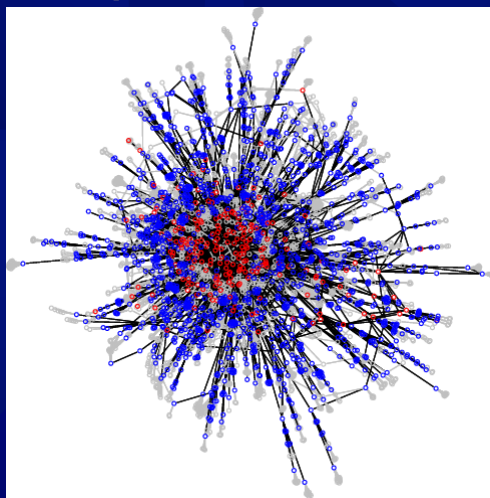
How to get the data to go where you want them to be?

Routing

Finding a route
from the source to the destination

A to B
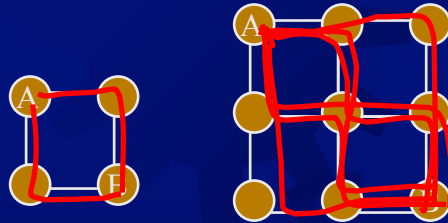
Not That Easy….

Don't have the view of entire network

Quiz Time!

I tell my neighbors.
You tell yours

The Rules - Initial

* Determine initial table
  * Route and distance to itself and the neighbors
* Select one router to start telling its table to the neighbors

---

Initial State

Destinations

	A	B	C	D
Next	A	B		D
Cost	0	1	999	1

	A	B	C	D
Next	A	B	C	---
Cost	1	0	1	999

A --- B
| |
D --- C

	A	B	C	D
Next	A	---	C	D
Cost	1	999	1	0

	A	B	C	D
Next	---	B	C	D
Cost	999	1	0	1

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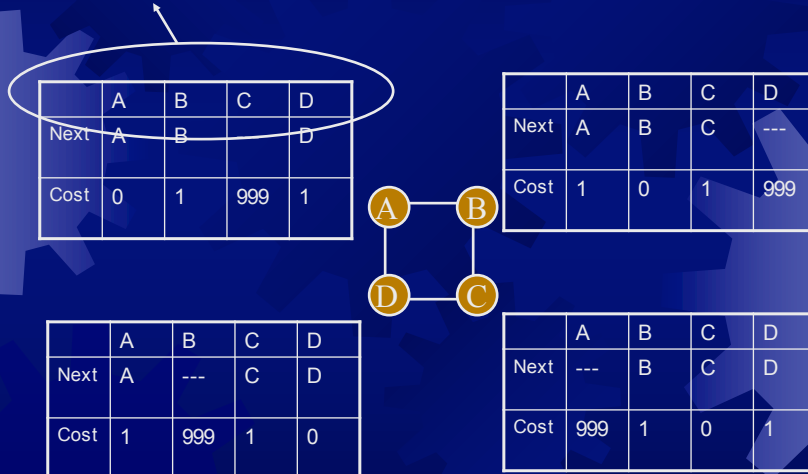
The Rules - Propagation

- ☀ Upon receiving a table,
- ☀ Check if there exists a shorter path to any destination
- ☀ If yes, update table and tell the neighbors of the updated table
- ☀ If not, do nothing (already the shortest path table)

A Tells the Neighbors

B tells neighbors
D tells neighbors

	A	B	C	D
Next	A	B	---	D
Cost	0	1	999	1

	A	B	C	D
Next	A	B	C	---
Cost	1	0	1	999

A — B
D — C

	A	B	C	D
Next	A	---	C	D
Cost	1	999	1	0

	A	B	C	D
Next	A	A	C	A
Cost	1	2	1	2

	A	B	C	D
Next	B	C	D	
Cost	1	0	1	0
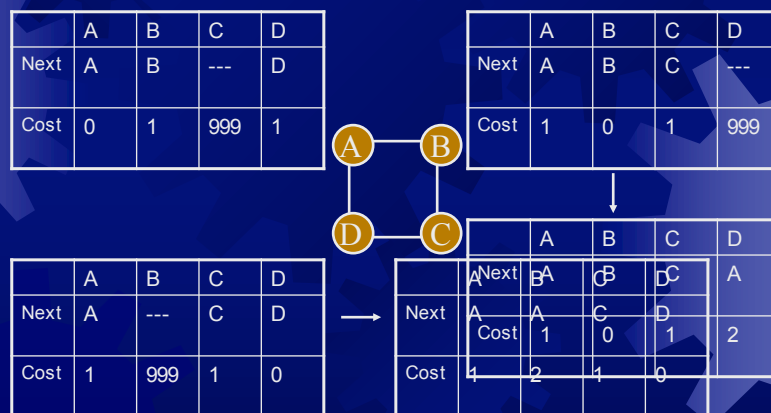
B Tells the Neighbors

D tells neighbors
A tells neighbors
C tells neighbors

	A	B	C	D
Next	A	B	---	D
Cost	0	1	999	1

	A	B	C	D
Next	A	B	C	A
Cost	1	0	1	2

	A	B	C	D
Next	A	B	B	C	D
Cost	0	1	2	1

	A	B	C	D
Next	B	B	C	D
Cost	2	1	0	1

	A	B	C	D
Next	---	B	C	D
Cost	999	1	0	1
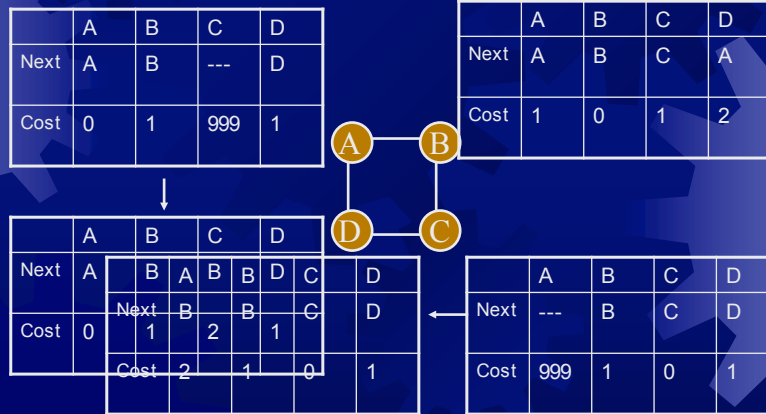
D Tells the Neighbors

A tells neighbors
C tells neighbors
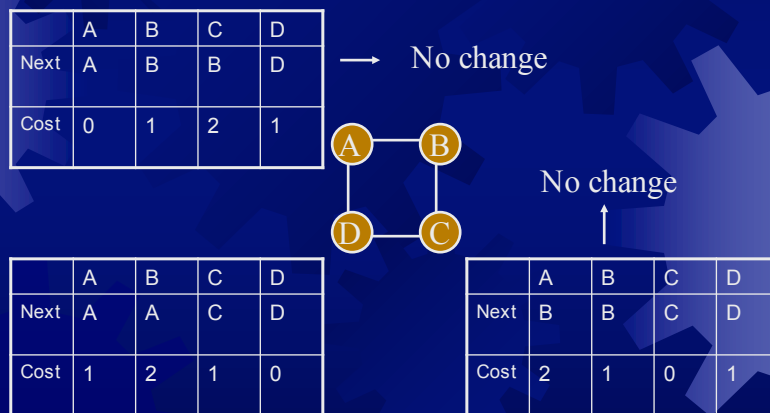
	A	B	C	D
Next	A	B	B	D
Cost	0	1	2	1

No change

	A	B	C	D
Next	A	A	C	D
Cost	1	2	1	0

No change

	A	B	C	D
Next	B	B	C	D
Cost	2	1	0	1

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A Tells the Neighbors

	A	B	C	D
Next	A	B	B	D
Cost	0	1	2	1

	A	B	C	D
Next	A	B	C	A
Cost	1	0	1	2

↓ No change

	A	B	C	D
Next	A	A	C	D
Cost	1	2	1	0

→ No change

Polly Huang, NTU EE   Networking   91
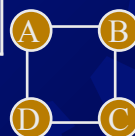
C Tells the Neighbors

No change ←

	A	B	C	D
Next	A	B	C	A
Cost	1	0	1	2

No change ↑

	A	B	C	D
Next	A	A	C	D
Cost	1	2	1	0

	A	B	C	D
Next	B	B	C	D
Cost	2	1	0	1

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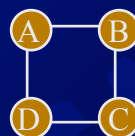
Final State

	A	B	C	D
Next	A	B	B	D
Cost	0	1	2	1

	A	B	C	D
Next	A	B	C	A
Cost	1	0	1	2

	A	B	C	D
Next	A	A	C	D
Cost	1	2	1	0

	A	B	C	D
Next	B	B	C	D
Cost	2	1	0	1

A — B
| |
D — C
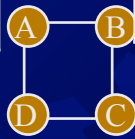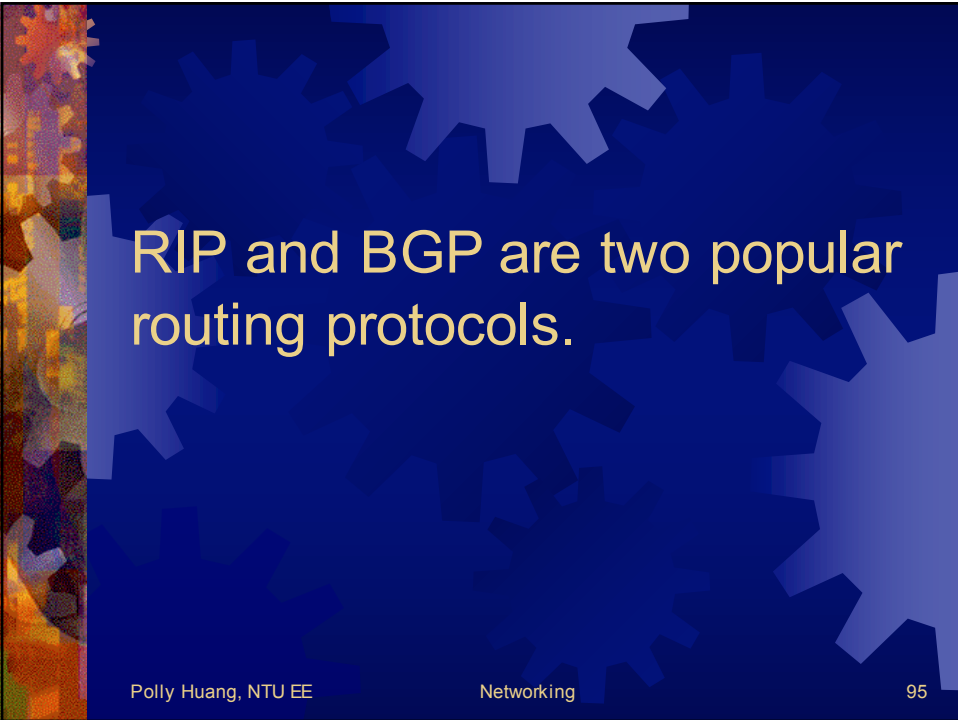
Distance Vector Routing

- RIP
- BGP (strictly, path vector)

- Distance Vector − the table in the example
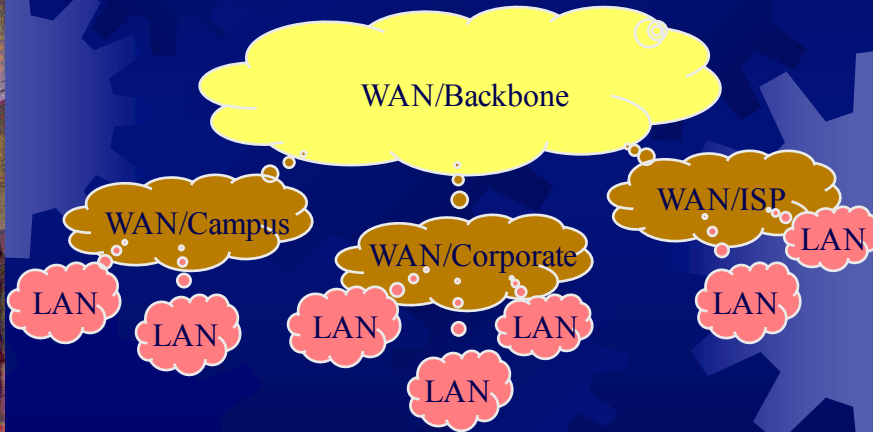
RIP and BGP are two popular routing protocols.

IP Routing

* **I**nternet **P**rotocol Routing
* The class of protocols that handle routing problems
* Example
  * RIP (IETF RFC 1058)
  * BGP (IETF RFC 1771)
  * OSPF (IETF RFC 2328)

Internet – Structural View

WAN/Backbone

WAN/Campus

WAN/Corporate

WAN/ISP

LAN

LAN

LAN

LAN

LAN

LAN

LAN

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Internet - Protocol View

BGP

RIP

OSPF

OSPF

Wireless LAN

Ethernet

Ethernet

Wireless LAN
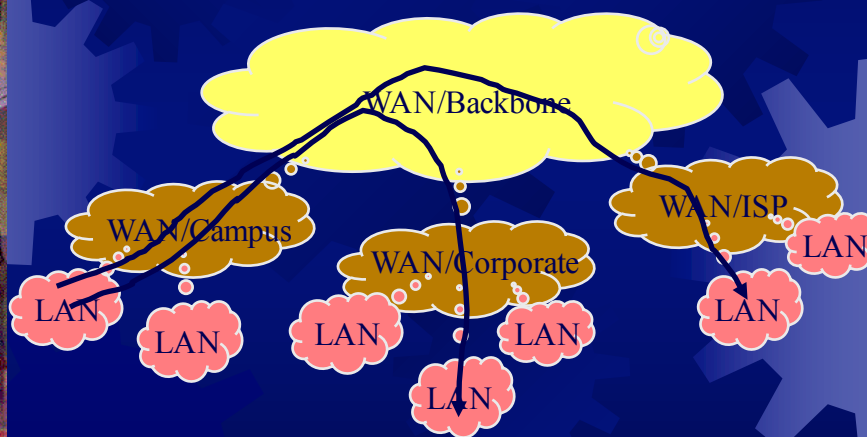
Ethernet

Token Ring

Wireless LAN

Polly Huang, NTU EE   Networking   98

Transport Layer

* Transport data through connections
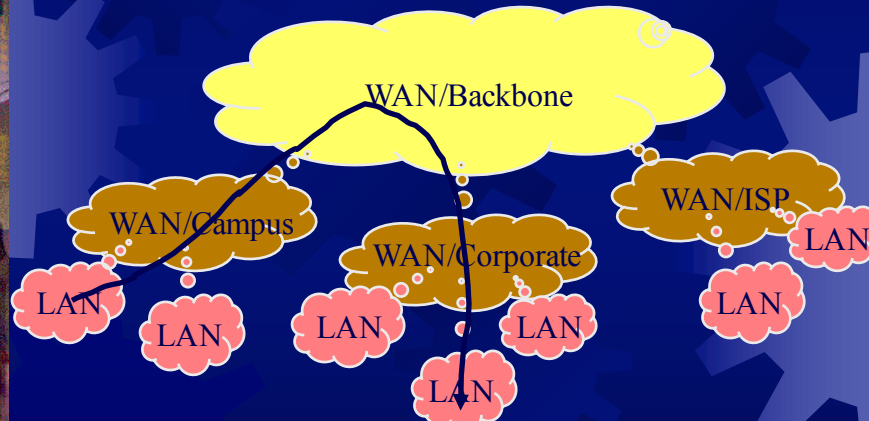* Additional quality of service

Internet – Structural View

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Yah, you wish…

Where Did It Go?

False Claim

WAN/Backbone

WAN/Campus

WAN/ISP

WAN/Corporate

LAN

LAN

LAN

LAN

LAN

LAN

LAN
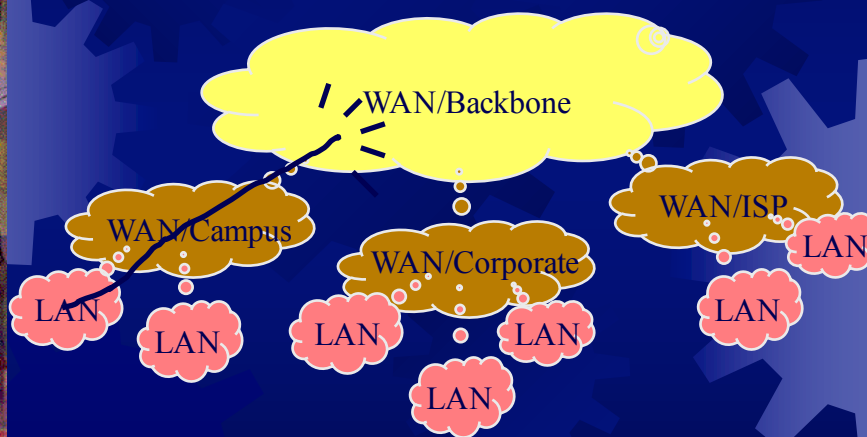
Nope, I didn't get it.
The Internet must drop it somewhere.
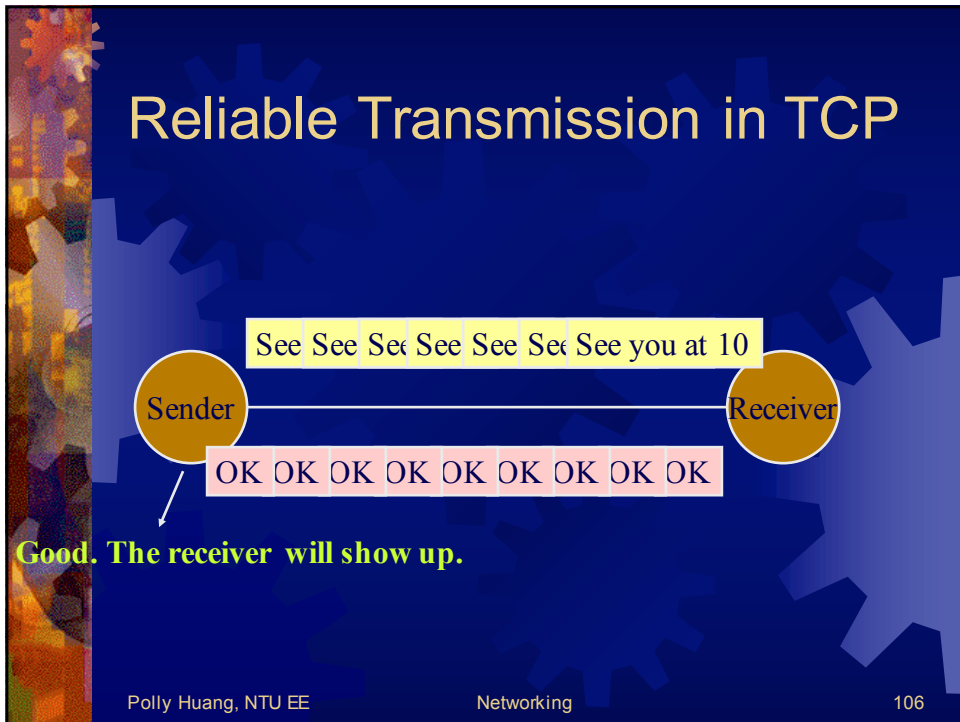
Hmm.. What can we do?

52

Quiz Time!

Reliable Transmission in TCP

See See See See See See See you at 10

Sender　　　　　　　　　　　　**Receiver**

OK OK OK OK OK OK OK OK OK

Good. The receiver will show up.

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In Case of Loss

See See See See you at 10 e you at 10

Sender

Receiver

OK OK OK OK OK OK OK OK OK
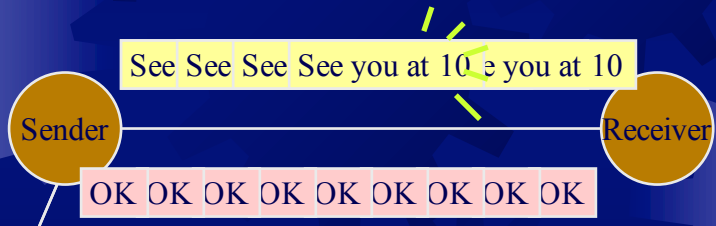
Good. The?receiver will show up.

Congestion Control in TCP

Bring lunch

Bring drinks

Bring camera

Bring umbrella

Bring jacket

See you at 10

Bring lunch

Bring drinks Bri Bri Bri Bring umbrella

Bring camera ri Bri Bri Bring jacket

Sender

Receiver

OK OK OK OK OK OK OK OK OK
OK OK OK OK OK OK OK OK OK

Good. I'll send even more.

In Case of Congestion

Bring lunch
Bring drinks
Bring camera
Bring umbrella
Bring jacket
See you at 10

Brii Brii Brii Bring umbrella
Bring jacket Bring jacket ee you at 10

Sender   Receiver

OK OK OK OK OK OK OK OK OK

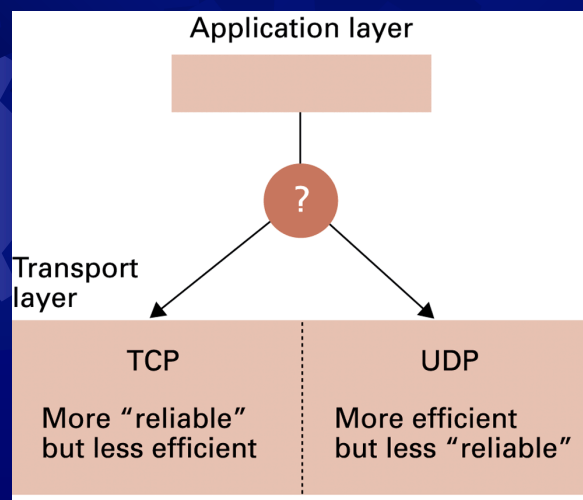Good Better slow down more.
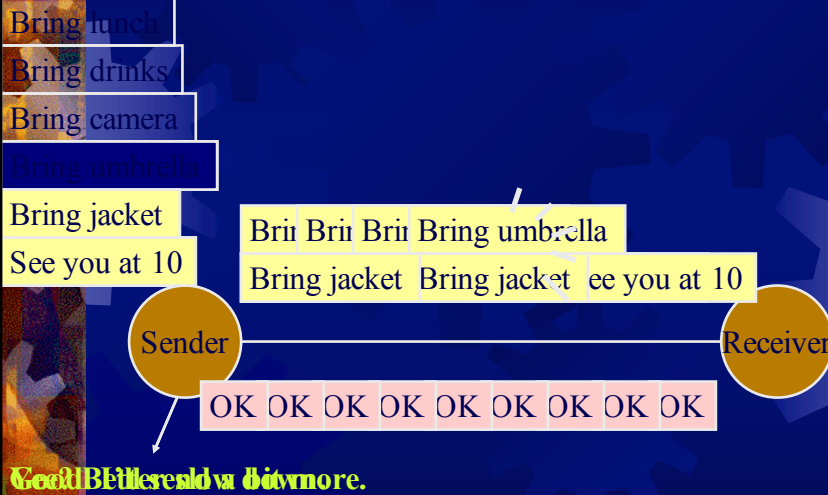
TCP

- Transmission Control Protocol
- Reliable transmission
  - Retransmit lost data
- Congestion control
  - Speed up when continue to receive acknowledgements
  - Slow down when experience data lost
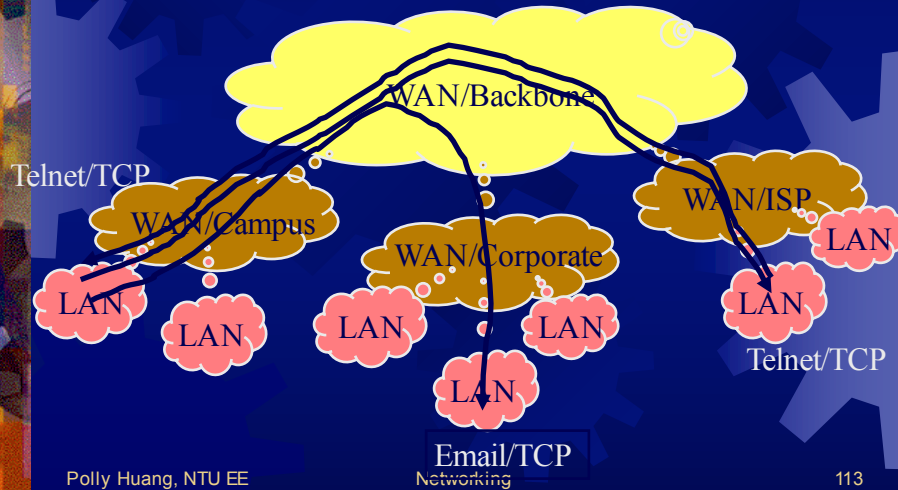
- Enhanced registered letters

UDP

- User Datagram Protocol
- No reliable transmission
- No congestion control

- Regular letters

TCP vs. UDP

Application layer

?

Transport layer

TCP	UDP
More "reliable" but less efficient	More efficient but less "reliable"

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TCP/IP Network

Telnet/TCP

WAN/Backbone

WAN/Campus

WAN/Corporate

WAN/ISP

LAN

LAN

LAN

LAN

LAN

LAN

LAN

LAN

Telnet/TCP

Email/TCP

TCP/IP Suite

| Application Layer | ☀ SMTP (Email), Telnet |
TCP Layer	☀ UDP, TCP
IP Layer	☀ RIP/OSPF, BGP
Link Layer	☀ Ethernet, Wireless LAN
Physical Layer	☀ Twisted pair, coaxial, microwave

Chapter 4: Networking and the Internet

Network Security

* Privacy of communication
  * Public-key encryption
* Integrity of machine exposed to internet
  * Attacks: the pests
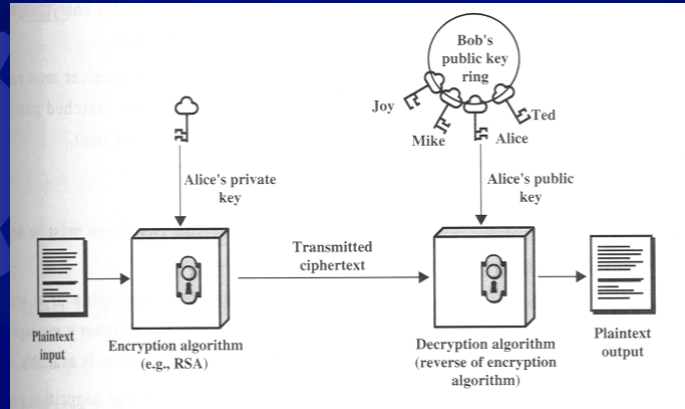 * Defense: filters and anti-pest utilities

Public-Key Encryption

* Public key is used to encode messages and is known by all people authorized to generate messages

* Private key is required to decode messages and is known by only the person who is to receive messages

Privacy
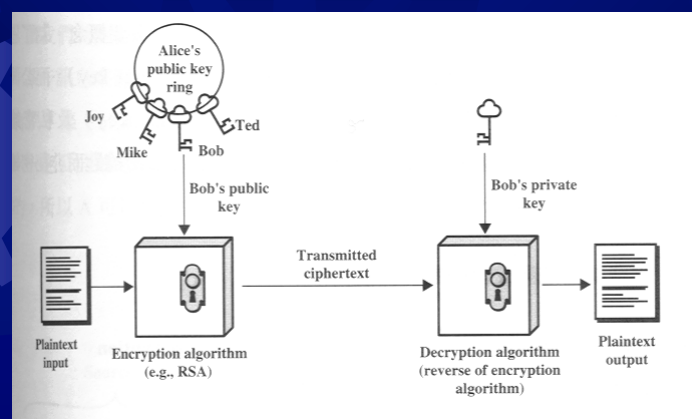
Authentication

Quiz Time!

60

The pests

Undesired code that might cause damage to your computer system

Pests in 3 Major Forms

- Undesired code that might cause damage to your computer system

- Trojan horse
- Virus
- Worm

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Different Properties

* Propagation
* Spreading model
* Damage caused

Trojan Horse

* Propagation
  * A program that **does not replicate**
* Spreading model
  * Someone emails a Trojan Horse to you
  * You copy a program with embedded Trojan Horse home
* Damage caused
  * Joke programs
  * Software of some sort that causes damage to your system.

Virus

- ☀ Propagation
  - ☀ A program or code that **replicates**
  - ☀ By inserting itself or attaching itself to another program, boot sector, partition sector, or document that supports macros
- ☀ Spreading model
  - ☀ Someone emails infected programs/documents to you
  - ☀ You copy infected program/documents home
- ☀ Damage caused
  - ☀ Most viruses only replicate
  - ☀ Though, many do a large amount of damage as well.

Worm

- ☀ Propagation
  - ☀ A program that makes copies of itself
  - ☀ From one disk drive to another,
- ☀ Spreading model
  - ☀ Copy itself using email or another transport mechanism
- ☀ Damage caused
  - ☀ Joke program
  - ☀ Software of some sort that causes damage.

Distinction

- **Trojan horse** vs. the other two
  - No self-replication
- **Virus** vs. Worm
  - Fast spreading within a system
- **Worm**
  - Fast spreading across systems
  - Most frequently seen among email threats

Types of Email Worms

- Worm
  - Causing physical damage
  - Example: erasing hard disks
- Joke
  - Causing inconvenience
  - Example: unusual activities to display on your computer (unexpected screensaver)
- Hoax
  - Causing uneasy nerves
 - Example: claiming devastating, highly unlikely virus (no attachment, no reference)

Preventing Pests

- Avoid reading **strange** emails
  - Strange sender
  - Strange subject
  - strange attachment files
- Avoid downloading/copying files **not necessary**
  - Clicking the "No" button by default
- Avoid using **Microsoft/MacOS** software >"<
- Filters or firewall

Firewalls

- Filter the traffic entering or passing through a machine
- Examples
  - Scan all incoming traffic and reject messages containing certain words
  - Reject all traffic from or to a given port number
  - Filter out all messages from certain IP addresses
- Placed on gateway or individual machines

Internet Client

Firewall

Internet

Local Network

Telnet Server   Local Client
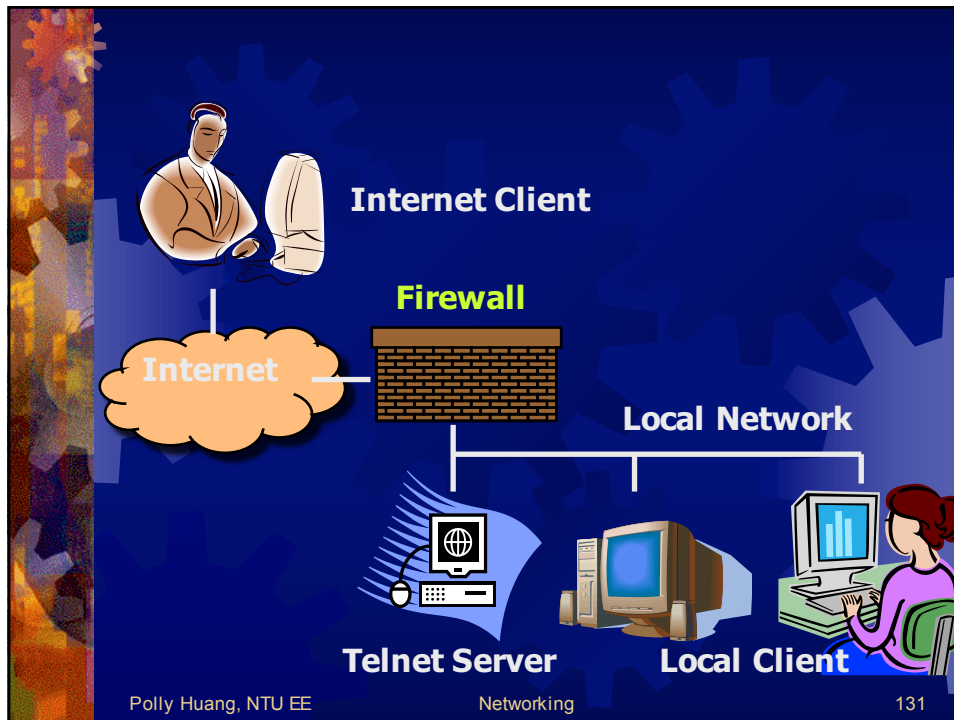
Recovering from Infection

* If the hard disk not damaged
    * Delete the joke or malicious program
    * Usually **not easy to clean** completely
* If the hard disk damaged
    * Hope you do have a **backup** of the data on your hard disk

Utility Software

* Deleting junk or malicious programs
  * **Anti-virus** utility programs
  * Ex. Norton, VirusScan, McAfee, etc
* Restoring from backups
  * **Backup** utility programs
  * Ex. Handy Backup, etc

Should you do something?

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Depends

- If you or your organization can afford
  - Mail filters
- Else if you do have important data on the PC
  - Both anti-virus and backup utility
- Else
  - Just anti-virus utility

Questions?

Telephone Network

* Telephones connected by cables

* Conversations are transmitted through cables
* Burry the cables once and then no person needs to carry letters around

Computer Network

* Computers connected by cables

* Data are transmitted through cables
* Burry the cables once and then no person needs to carry data around

But…

How does voice or data go from one end of a cable to another end?

Believe it or not!

Digital

Frequency

Amplitude

Analog

Pulses or Waves

* Going through the cables
* Carrying the 0/1 information

* Called **carrier pulses** or **carrier waves**
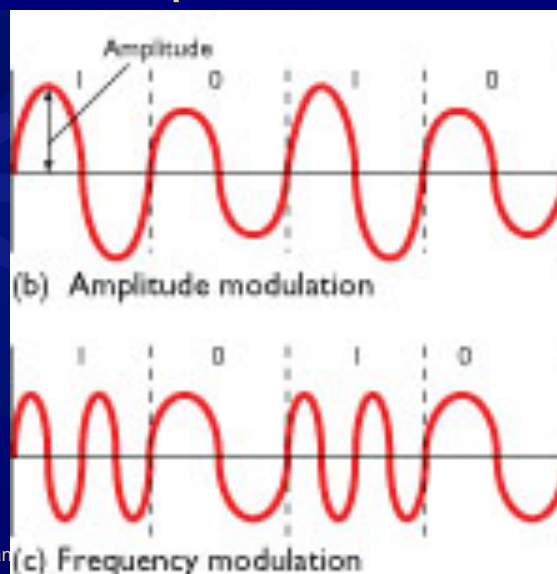
Going Through the Cables

* Electrical currents
* Optical waves

* EE's
    * Electronics engineering
    * Electrical-optical engineering

Carrying 0 and 1

* Embody information in the waves
* The more, the merrier
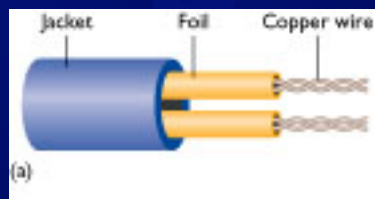

* EE's
  * Communication engineering

For Example

(b) Amplitude modulation

(c) Frequency modulation

Transmission Media

☀ Twisted pair
☀ Coaxial
☀ Fiber optic
☀ Microwave
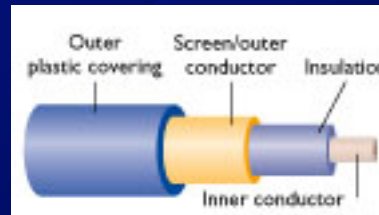
Twisted Pair

☀ Electrical waves
☀ Copper
☀ Noise

☀ Voice analog
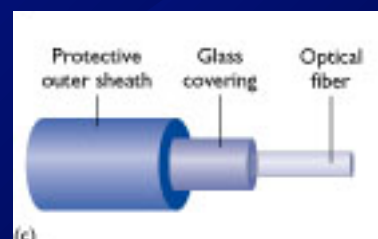☀ Cheap
☀ Example
  ☀ Telephone

Coaxial Cable

* Electrical pulses
* Copper
* Little noise

* Data digital
* Inexpensive
* Example
  * Cable TV
  * Ethernet cable

Fiber Optic

* Light rays
* Fibers
* No noise
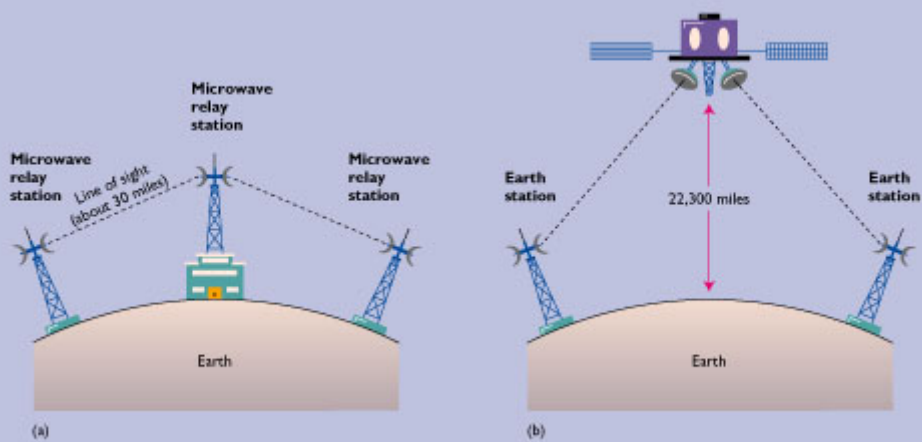
* Data digital
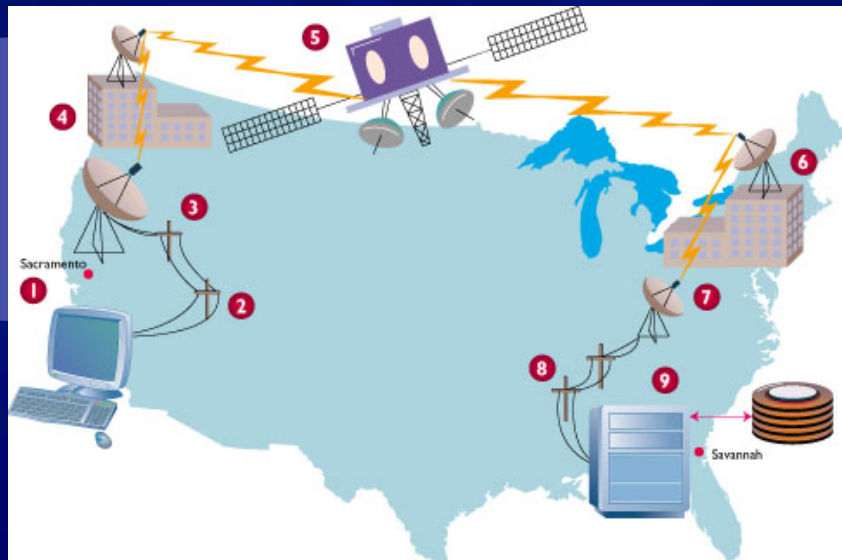* Inexpensive
* Example
  * Backbone cable

Microwave

- Microwaves
- Line of sight
- Lots of noise

- Data digital
- Expensive
- Example
  - Cellular phone, Satellite

Satellite

Microwave relay station

Microwave relay station

Line of sight (about 30 miles)

Microwave relay station

Earth

Earth station

22,300 miles

Earth station

Earth

(a)

(b)

Traversing the Media

Bandwidth

- Capacity
  - Max amount of data to be transmitted over a given time interval
- Depends on
  - Media type (microwave, twisted pair, coaxial, optical)
  - Coding of 0/1 information

PC to Medium Interface

- Twisted pair
  - Modem, ISDN, DSL
- Coaxial
  - Cable modem, NIC
- Optical
  - …
- Microwave
  - Cellular modem

Modem

- For transmission over the telephone network
- Convert digital data to analog signal
- Sender side
  - Digital to analog
  - **Mo**dulation
- Receiver side
  - Analog to digital
  - **Dem**odulation
- 56Kbps

DSL

* **D**igital **S**ubscriber **L**ine
* For transmission over the telephone network
* Digital-analog conversion
* Sending data over multiple frequencies
* Several times faster than 56Kbps
  * provider dependant
* No one standard
  * ADSL, RADSL, etc

ISDN

* **I**ntegrated **S**ervices **D**igital **N**etwork
* For transmission over the telephone network
* No conversion
* 128Kbps

Cable Modem

* For transmission over cable TV network
* Digital-analog conversion
* Always on
* 10Mbps
* Users sharing cables also share bandwidth

NIC

* **N**etwork **I**nterface **C**ard
* For transmission over the data network
* No Conversion
* 100Mbps

Cellular Modem

- For transmission over wireless cellular network
- Analog-digital conversion
- Slower than modem

Access Network

- Ways for users to connect to the Internet
- Depending on
  - Where you are
  - What bandwidth required
  - How much they cost
- Select from below
  - Modem, ISDN, DSL
  - Cable modem, NIC
  - Cellular modem

Questions?