Lecture 1

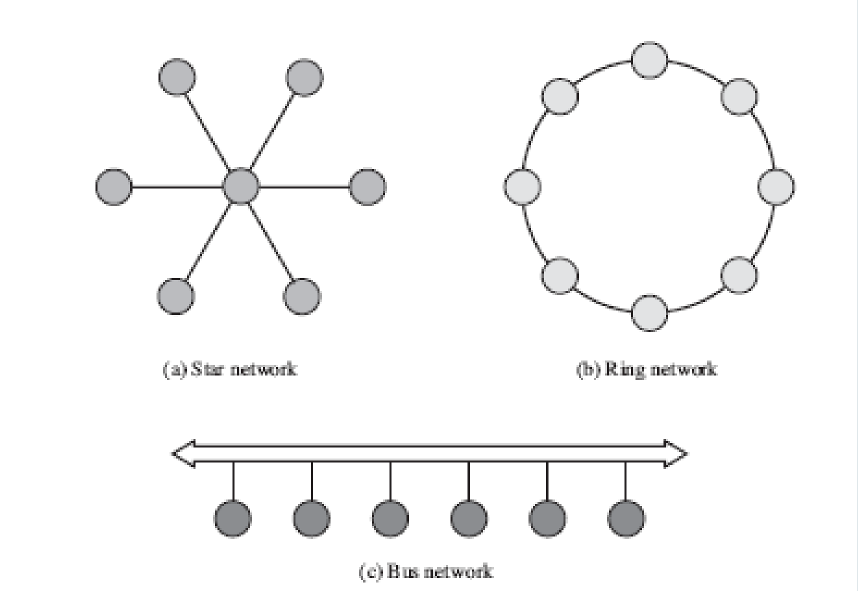
INTRODUCTION TO COMPUTER NETWORKS

Type of Networks

- PAN
- LAN
- MAN
- WAN

Network Topologies

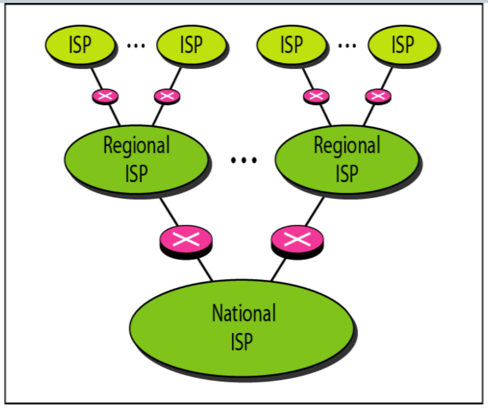
- Ring
- Bus
- Star
- Mesh



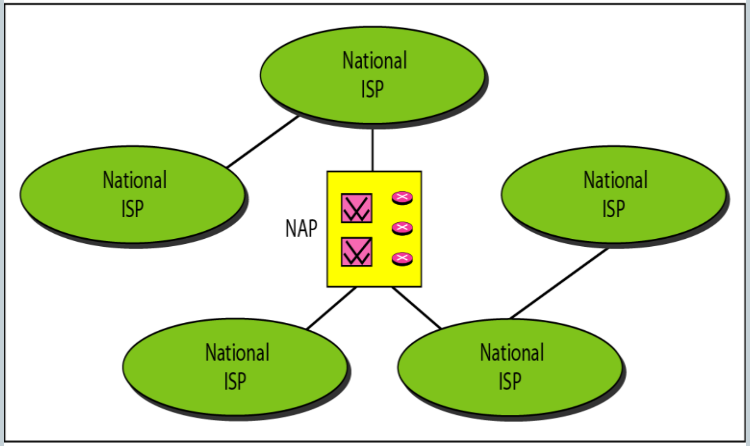
Topics

- What is Internet?
- What is Protocol?
- Network Structure
- OSI/TCP model
- Addressing

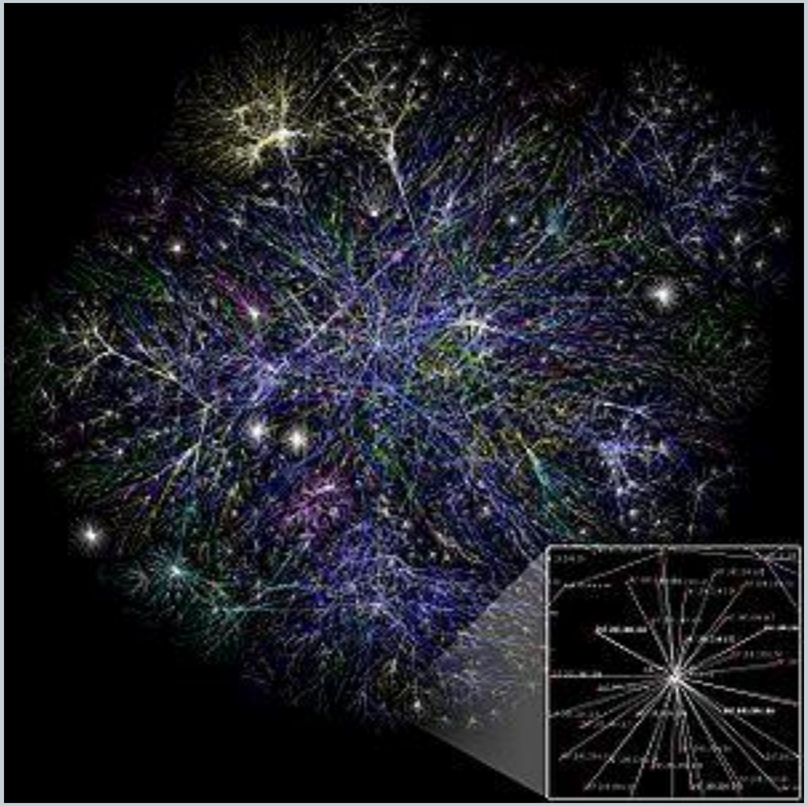
What is Internet

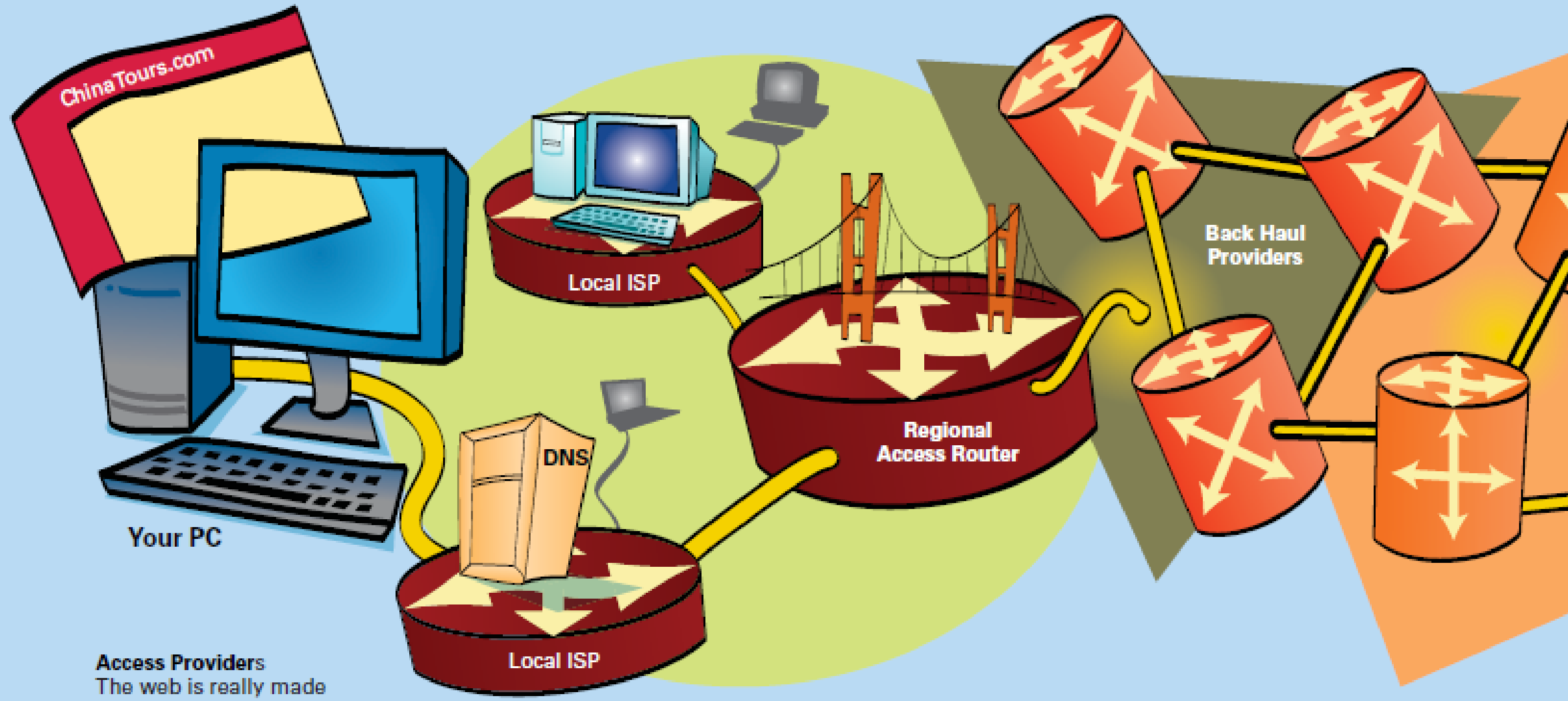


a. Structure of a national ISP



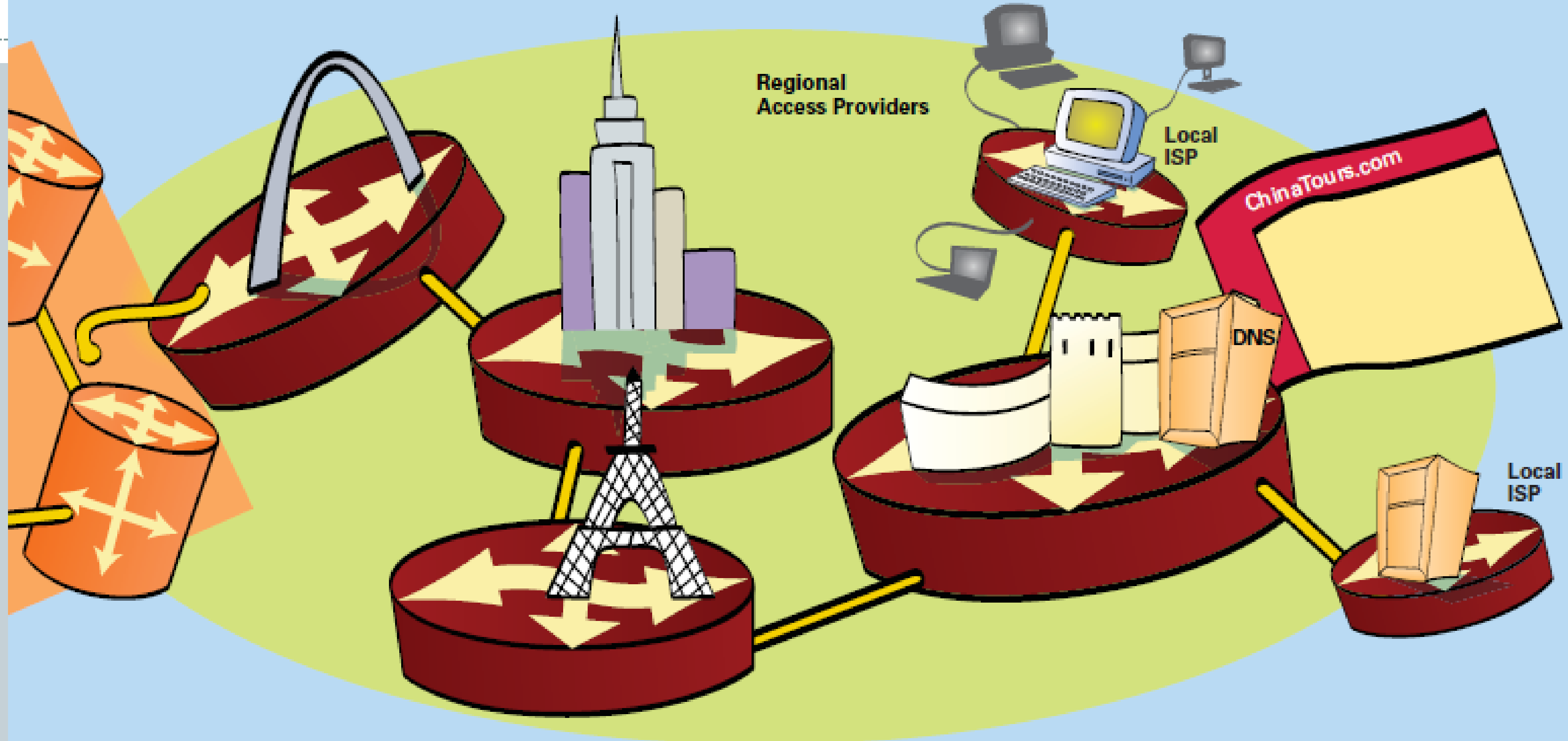
b. Interconnection of national ISPs





Access Providers
The web is really made of many networks connected in a hierarchy. Local Internet service providers (ISPs) typically give residential and small business access to the Internet. Regional providers typically connect several local ISPs to each other and to back haul providers that connect with other regional providers.

Domain Name Server (DNS)
This server maps domain names to their IP addresses. One of the reasons that the Internet has taken off in use and popularity is because www.cisco.com is much easier to remember than 25.156.10.4.



Web Servers
All web pages are stored on computers called web servers. Thousands of these servers can be dedicated servers for companies, hosting servers that house many personal pages, or even single computers housing individual pages.

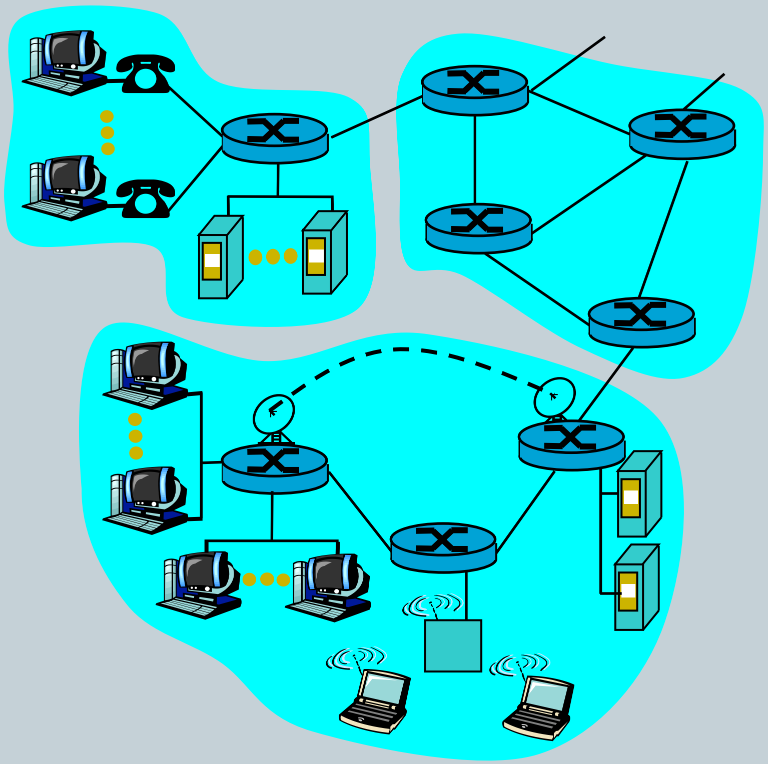
Back Haul Providers
A few back haul providers comprise the high-speed backbone of the Internet. Only a handful of these providers are capable of handling the massive amounts of Internet traffic that continues to grow. Many parts of the back haul providers overlap with each other, which improves both the speed and reliability of the network.

What is Protocol

- Protocols is a set of rules that govern data communications. A protocol defines what is communicated, how it is communicated and when it is communicated. The key elements
  - Syntax: structure or format data. Ex: 8 bits to be address of sender, 8 bits to be address of receiver
  - Semantics : the meaning of each section of bits, how is a particular pattern to be interpreted and what action is to be taken based on the interpretation?
  - Timing: when should be sent and how fast they can be sent

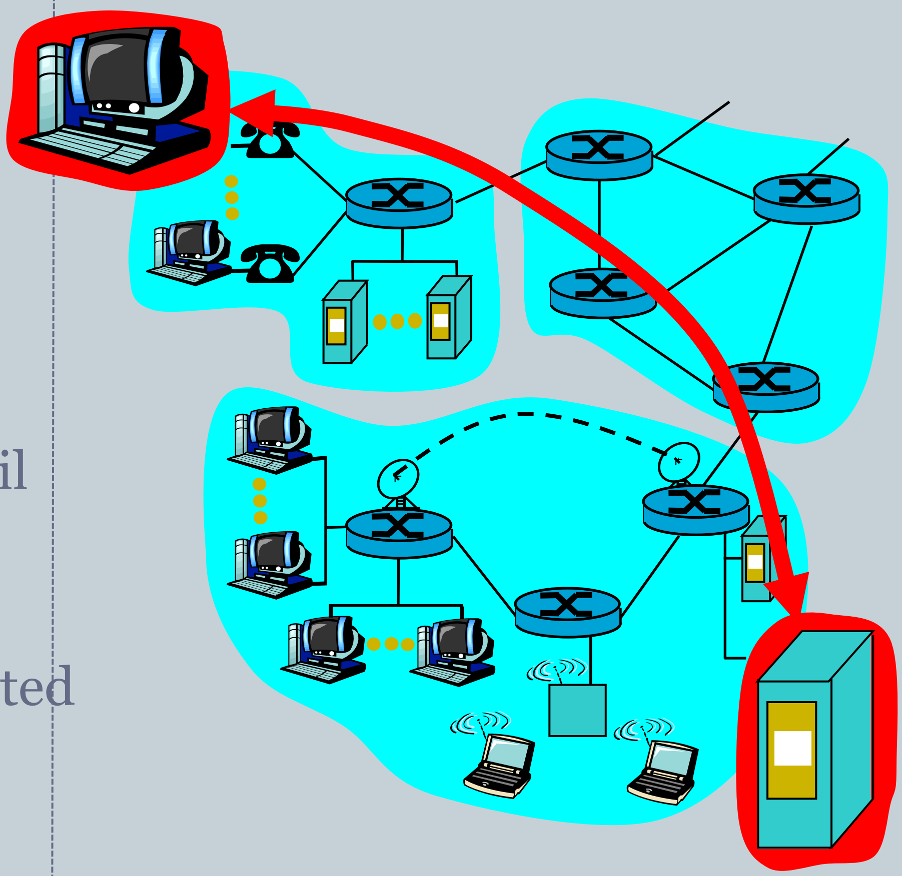
Network Structure

- network edge: applications and hosts
- network core:
  - routers
  - network of networks
- access networks, physical media: communication links



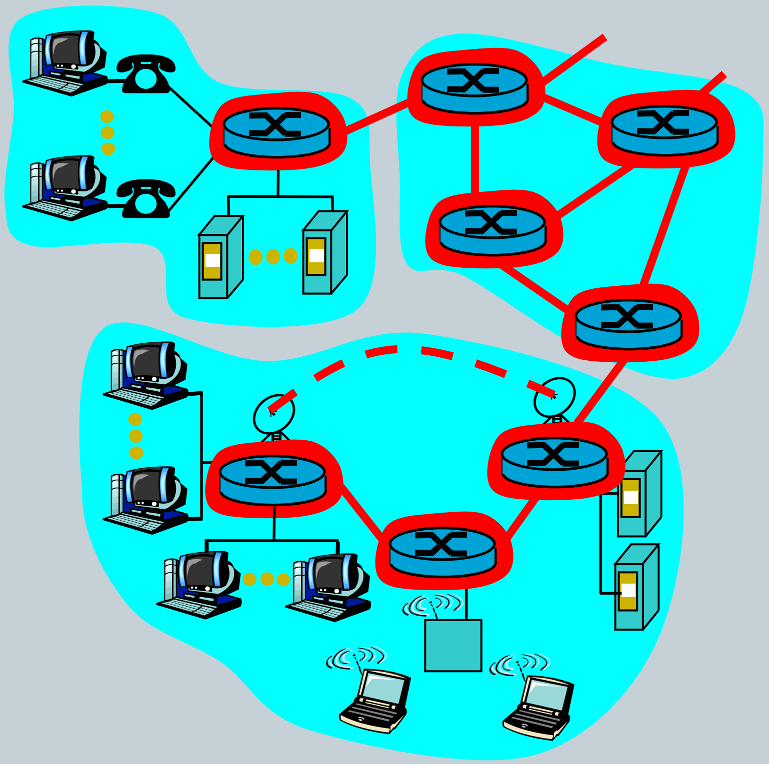
The Network Edge

- end systems (hosts):
  - run application programs
  - e.g. Web, email
  - at "edge of network"
- client/server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server
- peer-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Gnutella, KaZaA



The Network Core

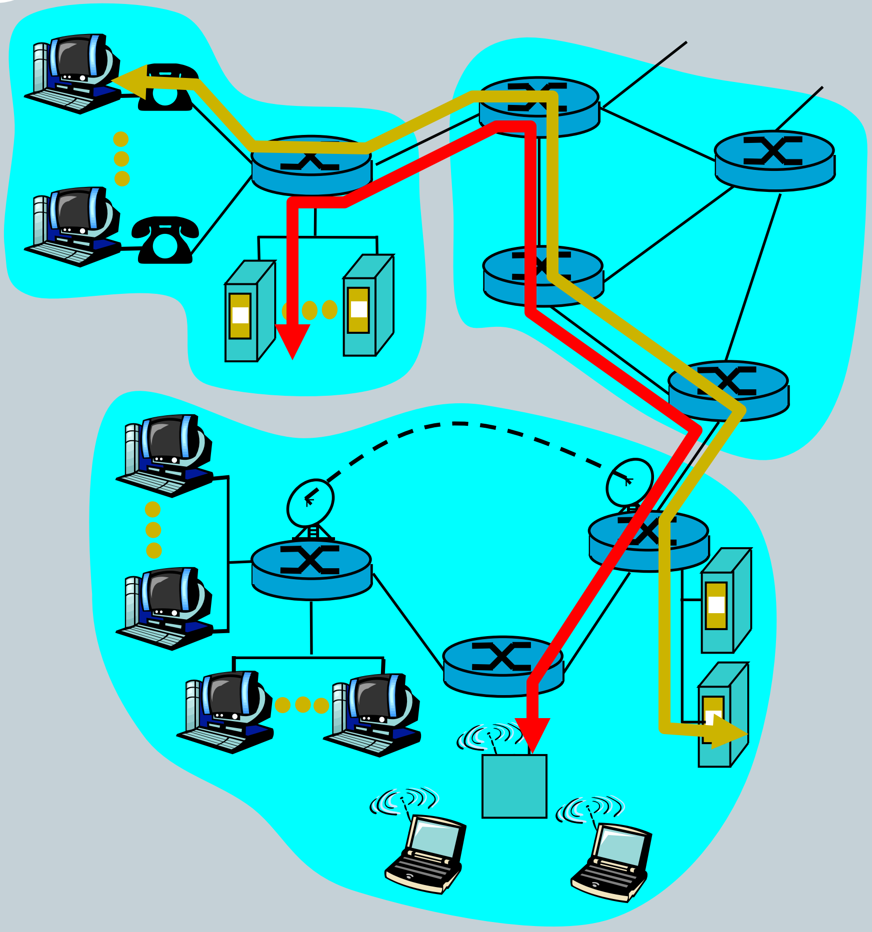
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete "chunks"



Network Core: Circuit Switching

End-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



Network Core: Packet Switching

each end-end data stream divided into *packets*

- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*

Bandwidth division into "pieces"
Dedicated allocation
Resource reservation

resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding

Open Systems Interconnection I

- In the past, computers could typically communicate only with computers from the same manufacturer. For example, companies ran either a complete DECnet solution or an IBM solution
- In the late 1970s, the *Open Systems Interconnection* (OSI) reference model was created by the *International Organization for Standardization* (ISO) to break this barrier
- The OSI model describes how data and network information are communicated from an application on one computer through the network media to an application on another computer.

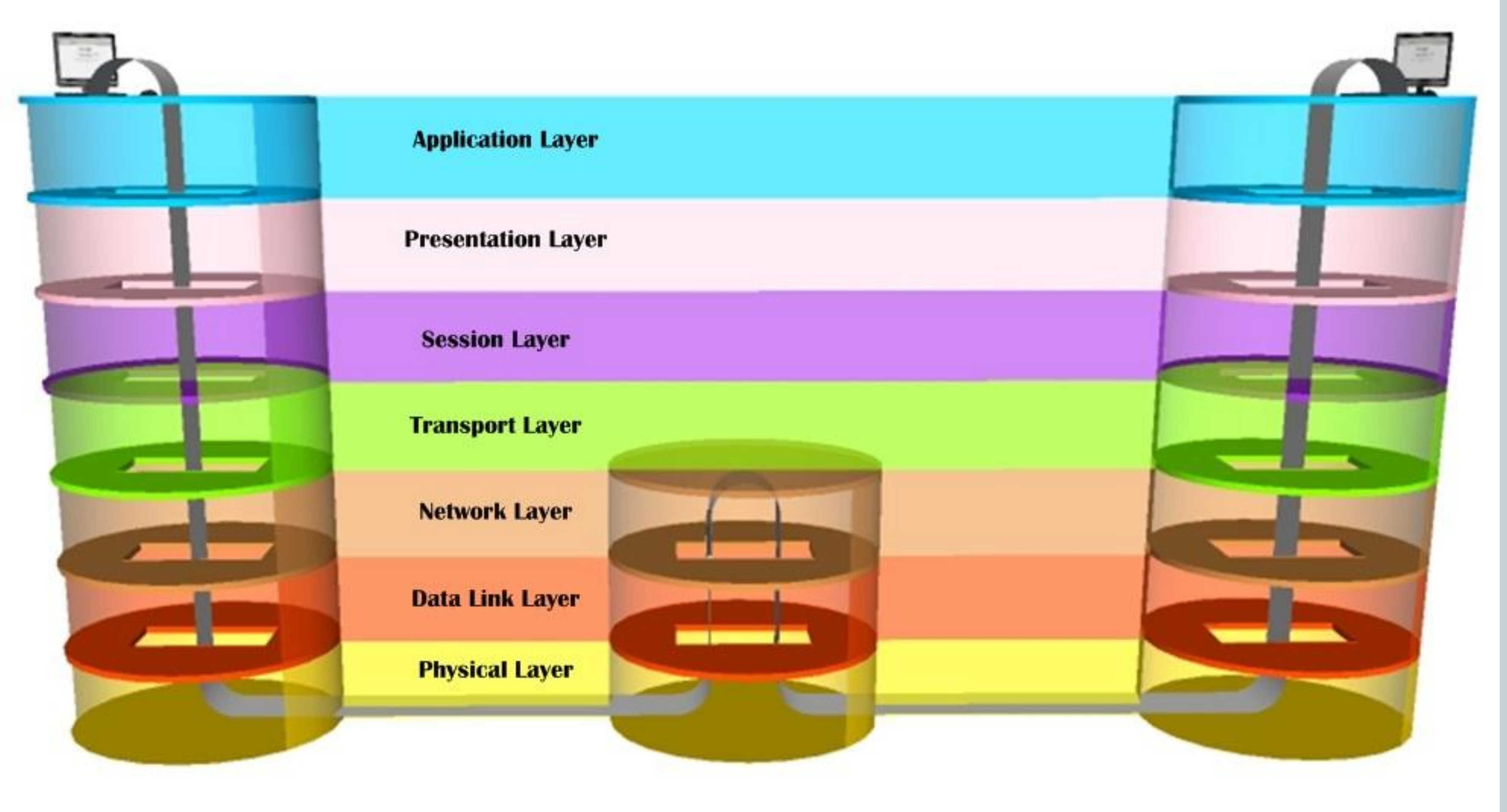
Advantages of Reference Models

- It divides the network communication process into smaller and simpler components, thus aiding component development, design, and troubleshooting.
- It allows multiple-vendor development through standardization of network components.
- It encourages industry standardization by defining what functions occur at each layer of the model.
- It allows various types of network hardware and software to communicate.
- It prevents changes in one layer from affecting other layers, so it does not hamper development.

The OSI Reference Model

- The OSI has seven different layers, divided into two groups.
  1. The top three layers define how the applications within the end stations will communicate with each other and with users.
  2. The bottom four layers define how data is transmitted end-to-end.

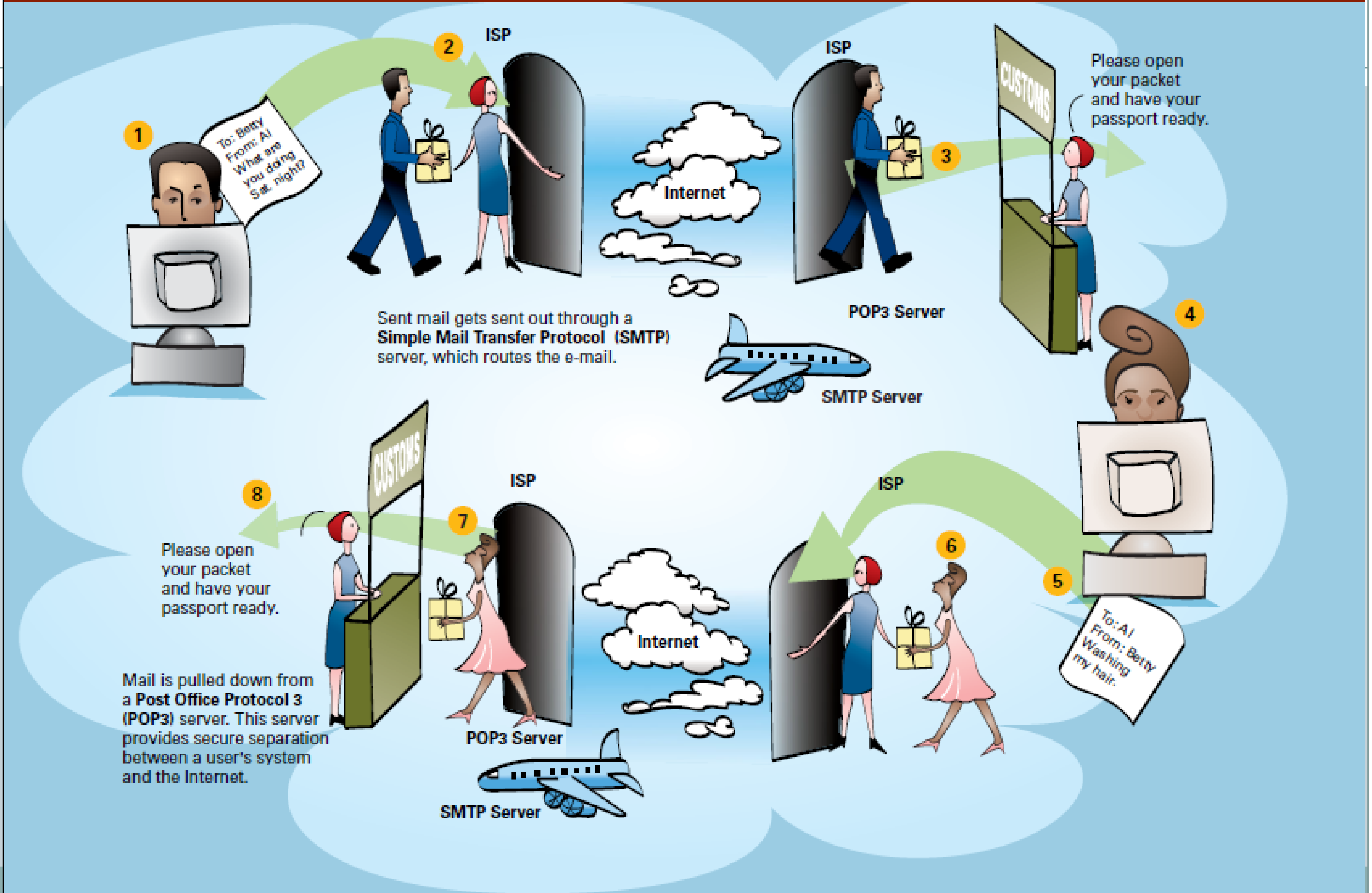
OSI Layers


Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

The Application Layer

- The *Application layer* of the OSI model marks the spot where users actually communicate to the computer.
- Take the case of Internet Explorer (IE). You could uninstall every trace of networking components from a system, such as TCP/IP, NIC card, and so on, and you could still use IE to view a local HTML document—no problem.
- But things would definitely get messy if you tried to do something like view an HTML document that must be retrieved using HTTP or nab a file with FTP or TFTP.

E-Mail



1
To: Betty
From: Al
What are you doing Sat. night?
2
ISP
Sent mail gets sent out through a **Simple Mail Transfer Protocol (SMTP)** server, which routes the e-mail.
Internet
ISP
POP3 Server
SMTP Server
3
CUSTOMS
Please open your packet and have your passport ready.
4
5
To: Al
From: Betty
Washing my hair.
6
ISP
Internet
7
ISP
POP3 Server
SMTP Server
CUSTOMS
8
Please open your packet and have your passport ready.
Mail is pulled down from a **Post Office Protocol 3 (POP3)** server. This server provides secure separation between a user's system and the Internet.

The Presentation Layer

- It presents data to the Application layer and is responsible for data translation and code formatting.
- The OSI has protocol standards that define how standard data should be formatted. Tasks like data compression, decompression, encryption, and decryption are associated with this layer.
- Some Presentation layer standards are involved in multimedia operations too.

The Session Layer

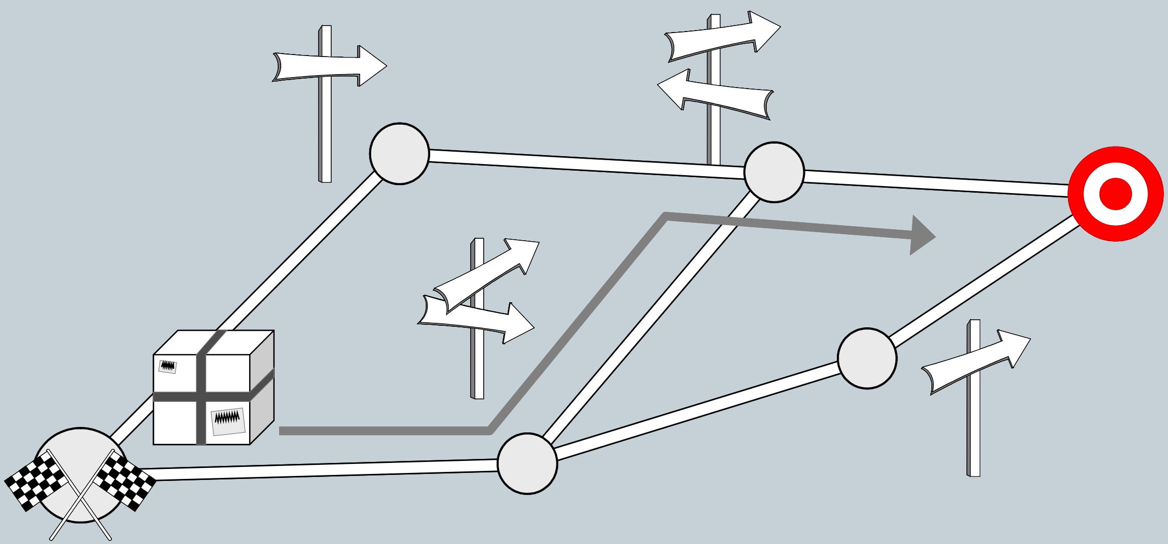
- The Session layer is responsible for setting up, managing, and then tearing down sessions between
- Presentation layer entities.
- It coordinates communication between systems and serves to organize their communication by offering three different modes: *simplex*, *half duplex*, and *full duplex*.

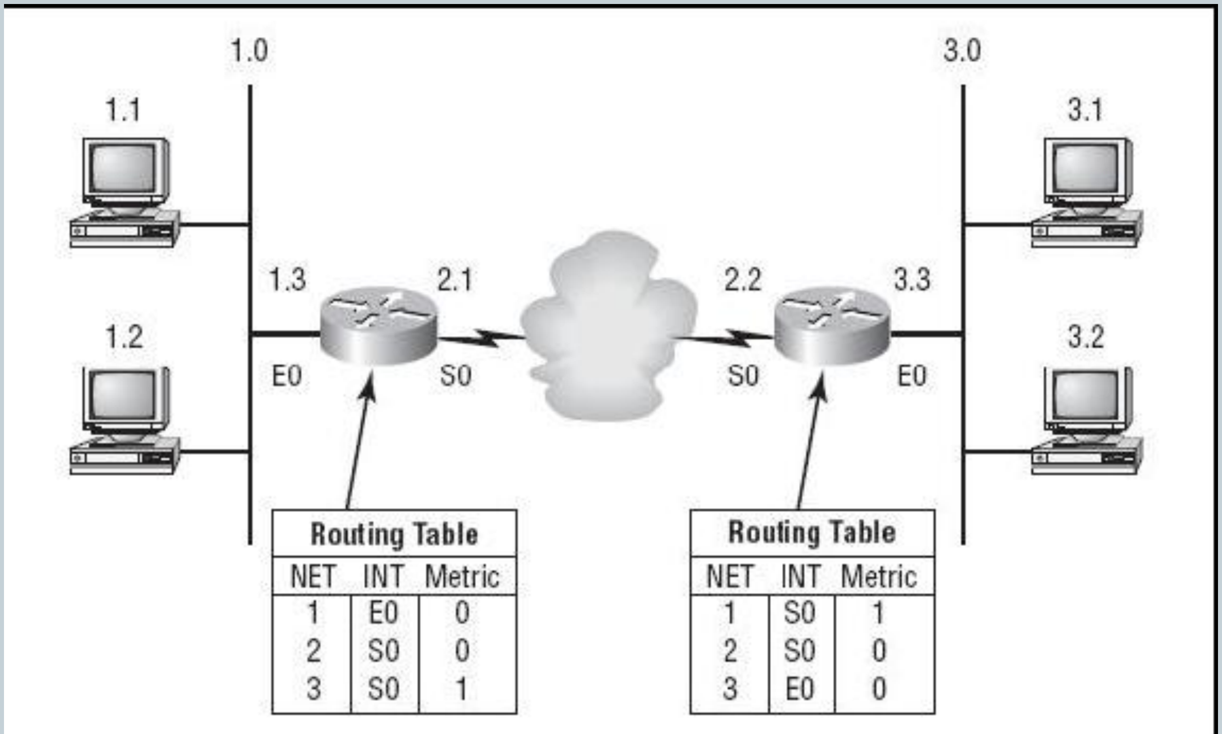
The Transport Layer I

- The Transport layer segments and reassembles data into a data stream. Services located in the Transport layer segment and reassemble data from upper-layer applications and unite it into the same data stream.
- They provide end-to-end data transport services and can establish a logical connection between the sending host and destination host on an internetwork.
  - Ex. TCP and UDP (will be discussed later)

The Network layer

- The Network layer (also called layer 3) manages device addressing, and determines the best way to move data
- Routers (layer 3 devices) are specified at the Network layer and provide the routing services within an internetwork.



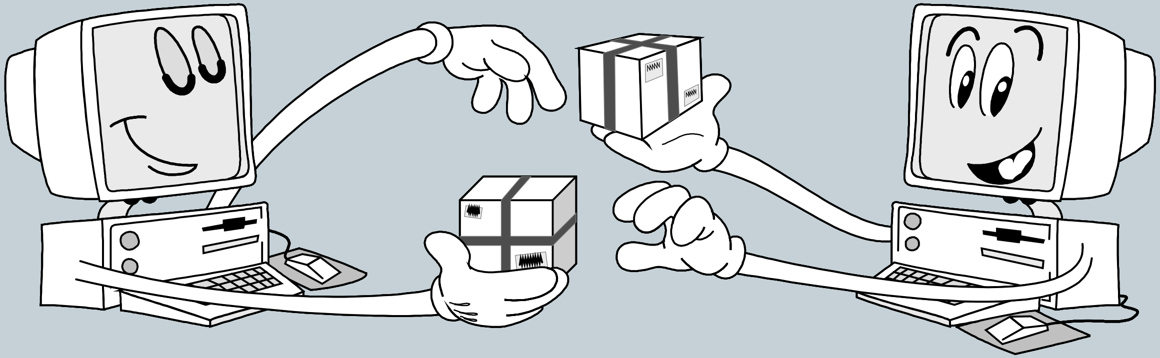

1.0
3.0
1.1
3.1
1.3
2.1
2.2
3.3
1.2
3.2
E0
S0
S0
E0
Routing Table
NET INT Metric
1 E0 0
2 S0 0
3 S0 1
Routing Table
NET INT Metric
1 S0 1
2 S0 0
3 E0 0

Data Link layer

- The Data Link layer provides the physical transmission of the data and handles error notification, network topology, and flow control.
- The Data Link layer formats the message into pieces, each called a data frame, and adds a customized header containing the hardware destination and source address.

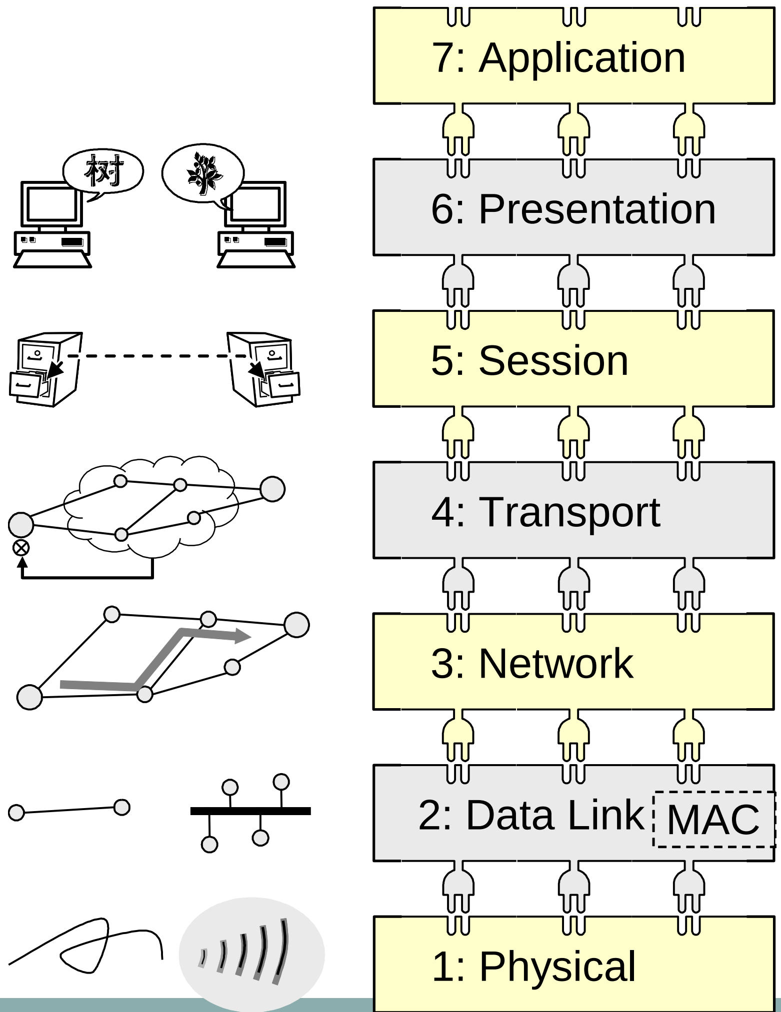
The Physical layer

- The *Physical layer* does **two** things: It sends bits and receives bits.
- The Physical layer specifies the electrical, mechanical, procedural, and functional requirements for activating, maintaining, and deactivating a physical link between end systems.



ISO OSI Protocol Stack

Visit http://en.wikipedia.org/wiki/OSI_model for more details on the OSI Reference Architecture



- Application services (SIP, FTP, HTTP, Telnet, …)

- Data translation (MIME)
- Encryption (SSL)
- Compression

- Dialog control
- Synchronization

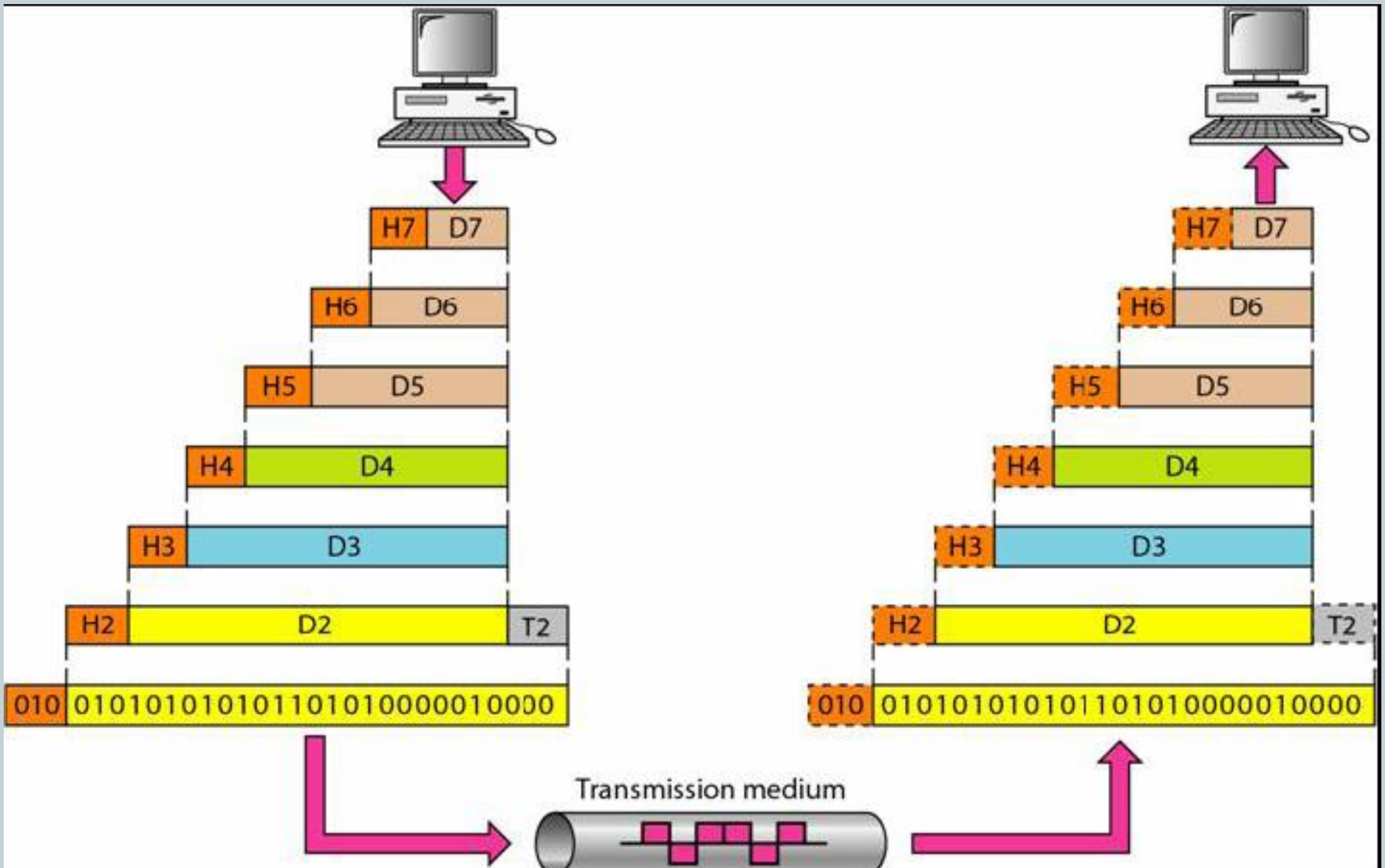
- Reliable (TCP)
- Real-time (RTP)

- Source-to-destination (IP)
- Routing
- Address resolution

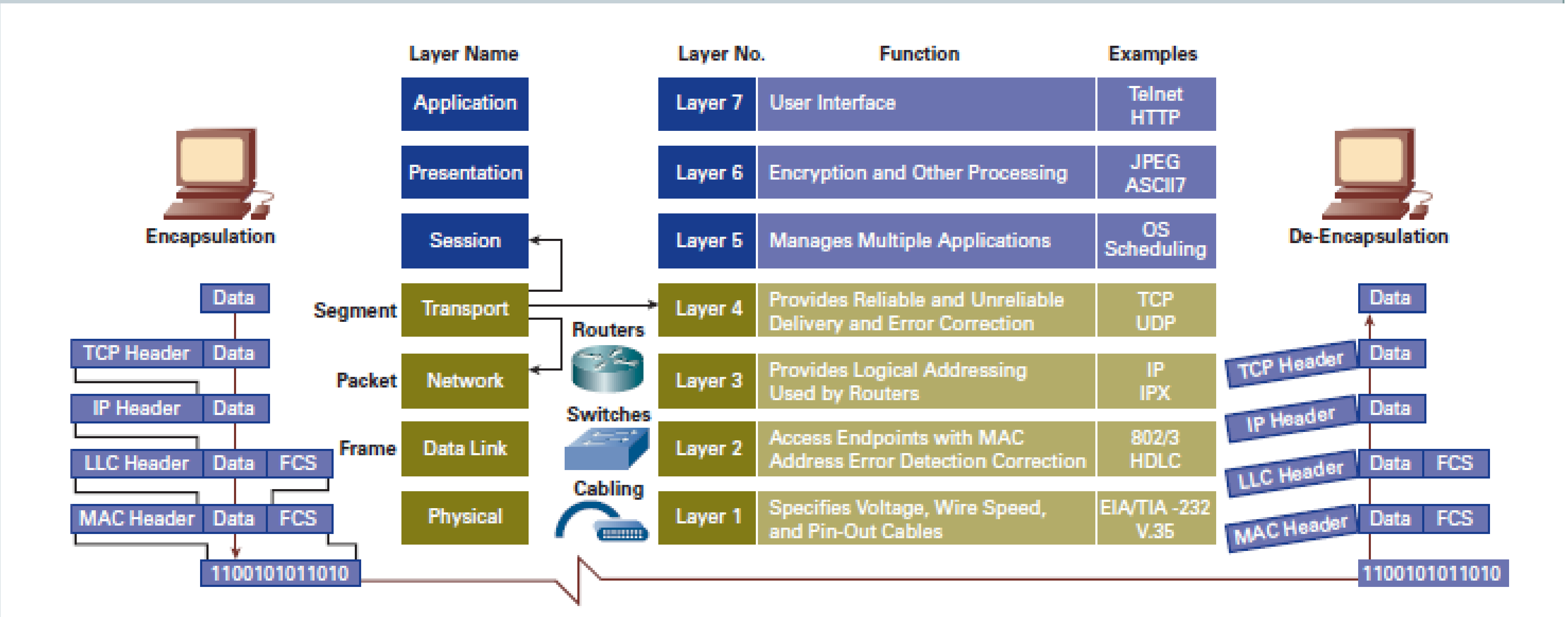
- Wireless link (WiFi)
- Wired link (Ethernet)

- Radio spectrum
- Infrared
- Fiber
- Copper

An exchange using the OSI model



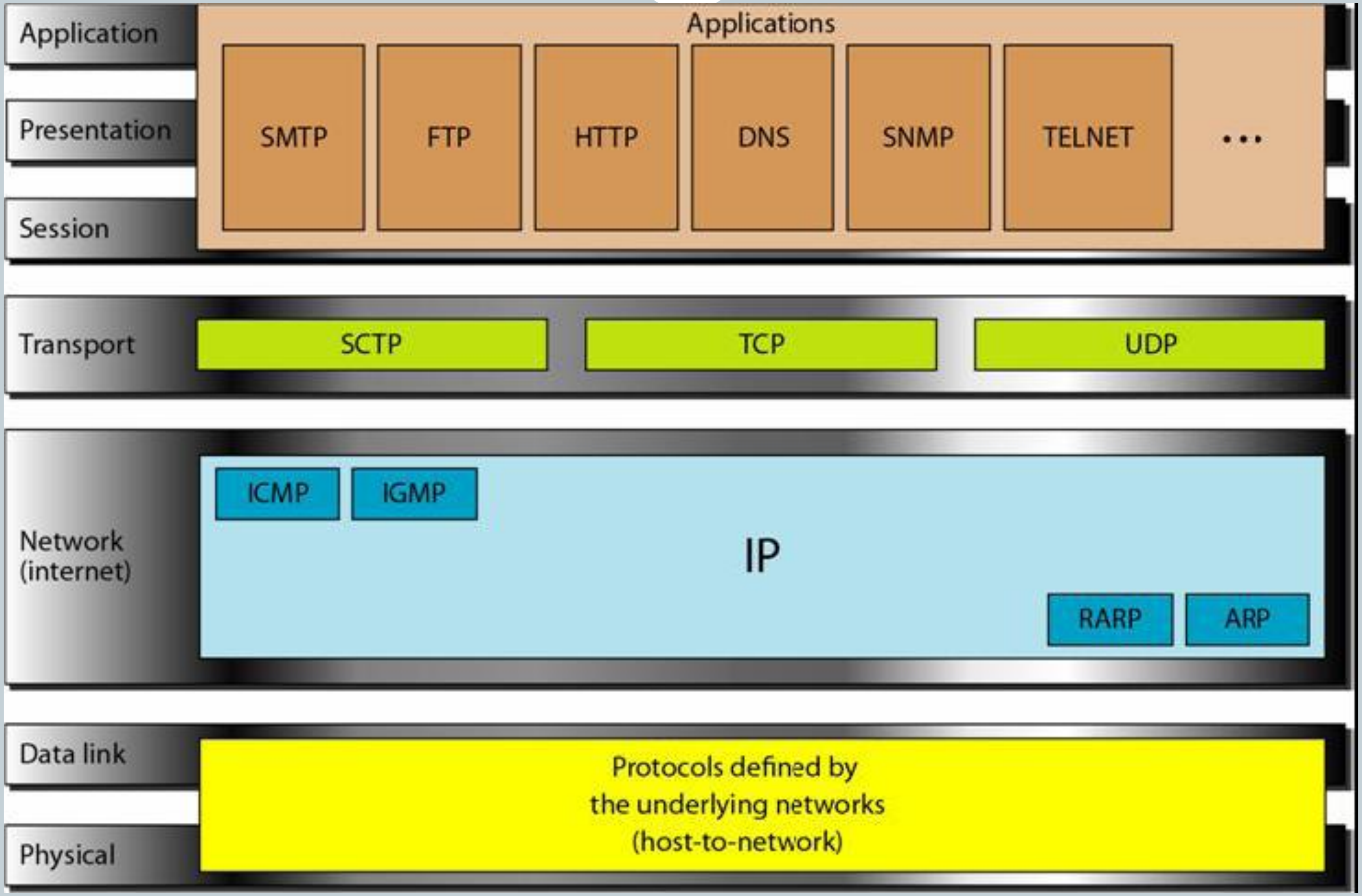
Layer Naming



TCP/IP Protocol Architecture I

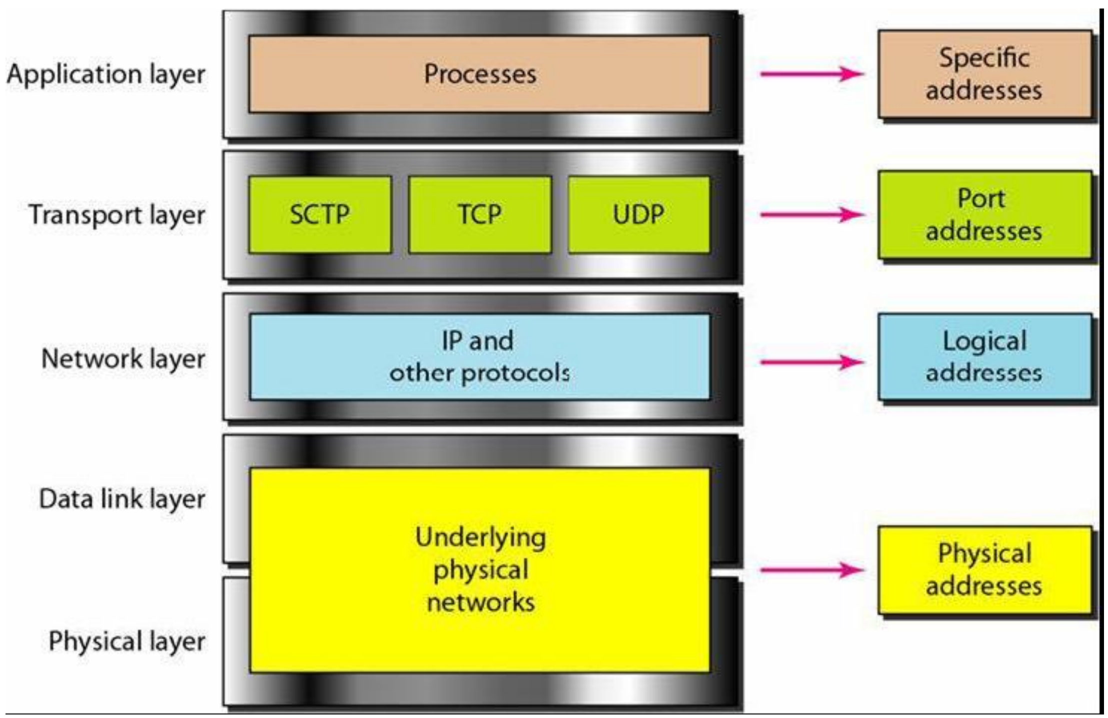
- Practical Used
- TCP/IP is generally viewed as being composed of fewer layers than the seven used in the OSI model.
- The original TCP/IP protocol suite was defined as having four layers: *host-to-network*, *internet*, *transport*,and *application*.
- However, when TCP/IP is compared to OSI, we can say that the TCP/IP protocol suite is made of five layers: *physical*, *data link*, *network*, *transport*, and *application*.

TCP/IP and OSI model



Addressing

- Four levels of addresses are used in an internet employing the TCP/IP protocols: physical, logical, port, and specific.



Physical Address

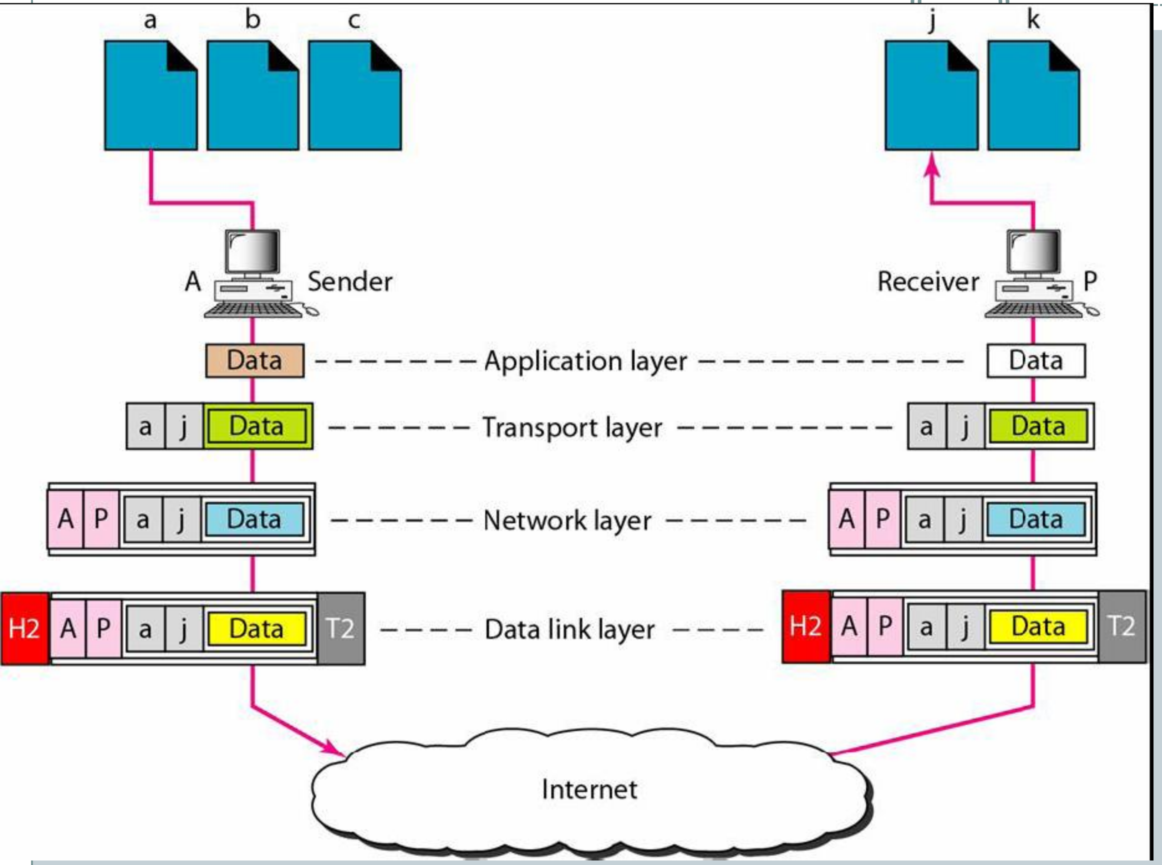
- Most local-area networks use a 48-bit (6-byte) physical address written as 12 hexadecimal digits
  - Example 07:01:02:01:2C:4B

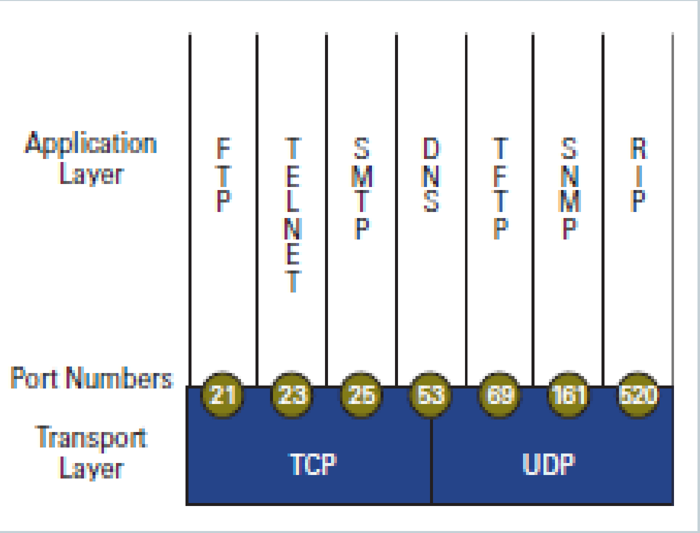
IP Address (Logical Address)

- An IP address is a numeric identifier assigned to each machine on an IP network. It designates the specific location of a device on the network.
- IP addressing was designed to allow hosts on one network to communicate with a host on a different network regardless of the type of LANs the hosts are participating in.

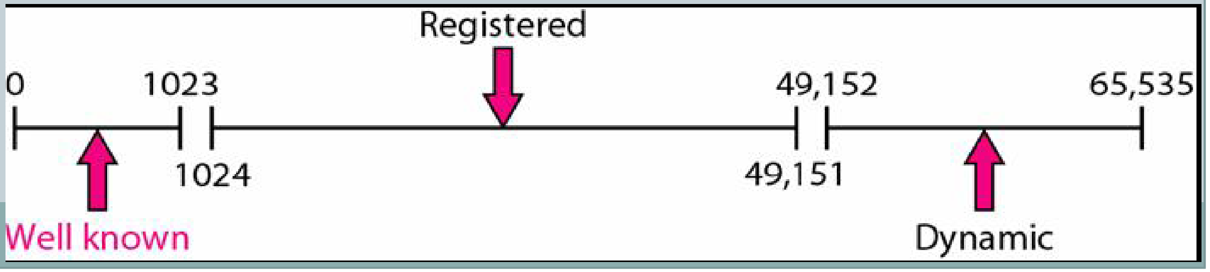
Classes	First Octet Range	Network Bits	Possible Networks	Host Bits	No. of Hosts per Network
A	1–126	8	126	24	16,777,216
B	128–191	16	16,384	16	65,536
C	192–223	24	2,097,152	8	256

Port addresses



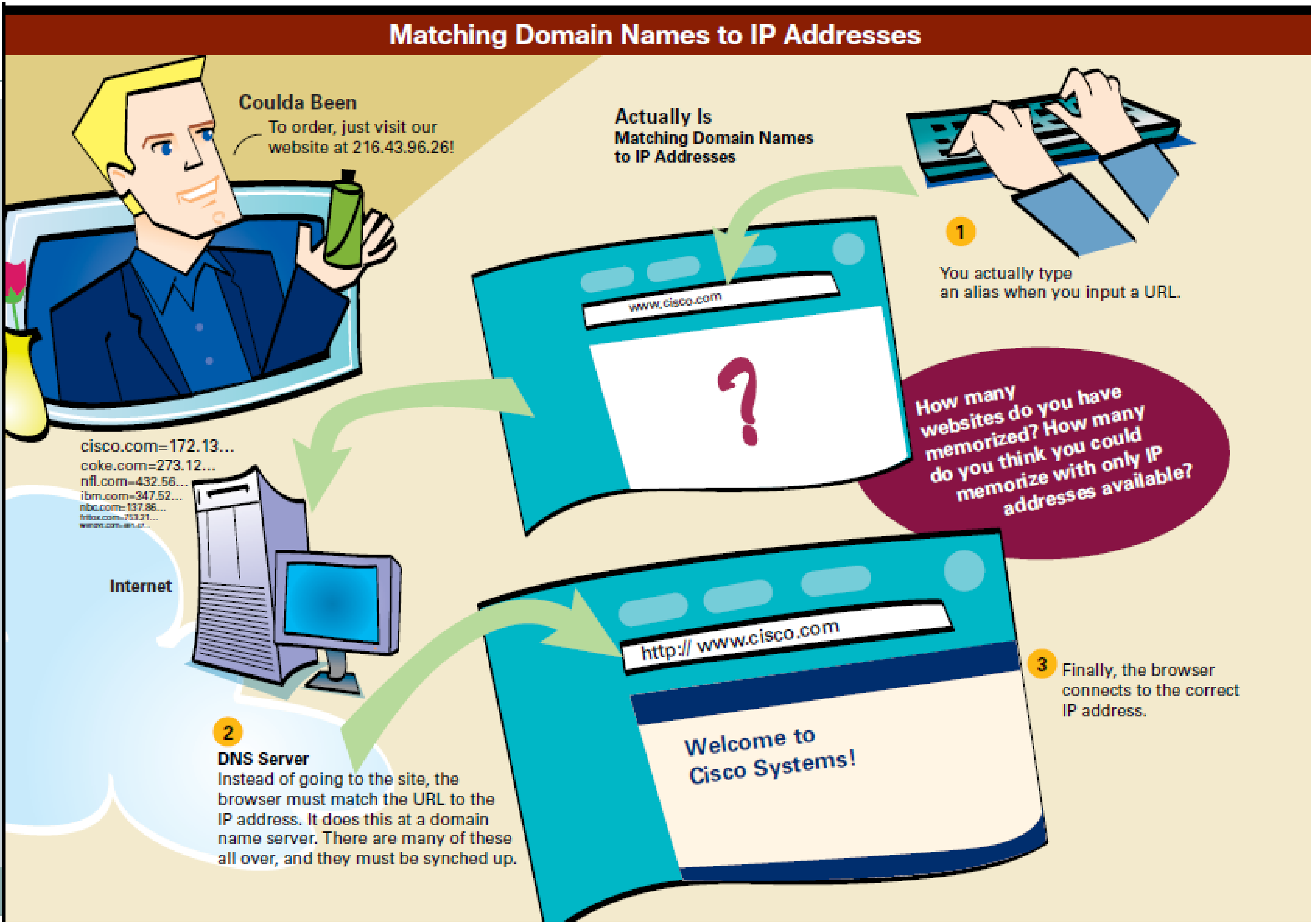


Port Number Ranges



Specific addresses

- User friendly address such as www.kku.ac.th (URL) or your email address

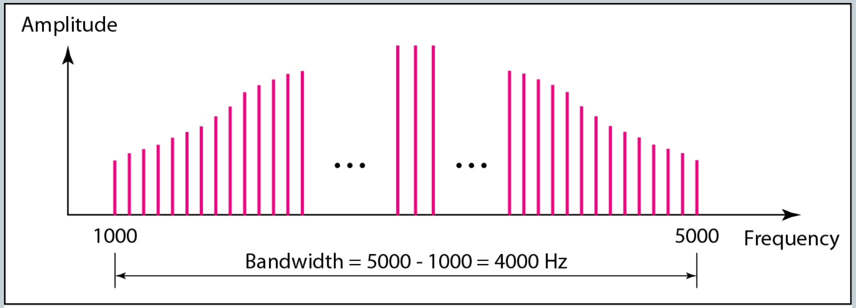

Matching Domain Names to IP Addresses
Coulda Been
To order, just visit our website at 216.43.96.26!
Actually Is
Matching Domain Names to IP Addresses
1
You actually type an alias when you input a URL.
www.cisco.com
?
How many websites do you have memorized? How many do you think you could memorize with only IP addresses available?
cisco.com=172.13...
coke.com=273.12...
nfl.com=432.56...
ibm.com=347.52...
nbc.com=137.86...
Internet
2
DNS Server
Instead of going to the site, the browser must match the URL to the IP address. It does this at a domain name server. There are many of these all over, and they must be synched up.
http:// www.cisco.com
Welcome to Cisco Systems!
3
Finally, the browser connects to the correct IP address.

Network Properties

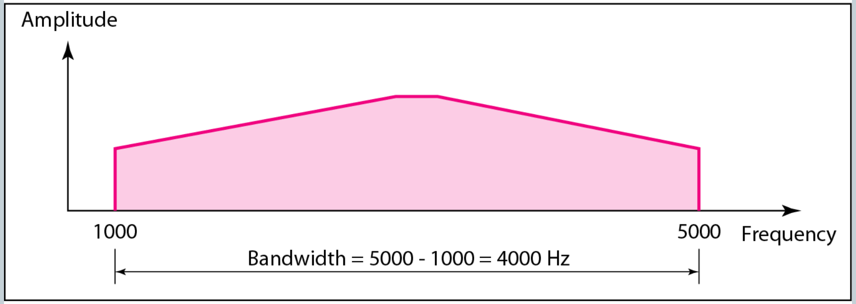
- Bandwidth
- Throughput
- Propagation delay
- Transmission delay
- Queueing delay
- Processing delay
- Loss

Bandwidth

- The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.
- Bandwidth has been defined as the amount of information that can flow through a network in a given time
- In digital systems, the basic unit of bandwidth is bits per second (bps)
- In analog systems, bandwidth is measured by how much of the electromagnetic spectrum is occupied by each signal
- The basic unit of analog bandwidth is hertz (Hz), or cycles per second



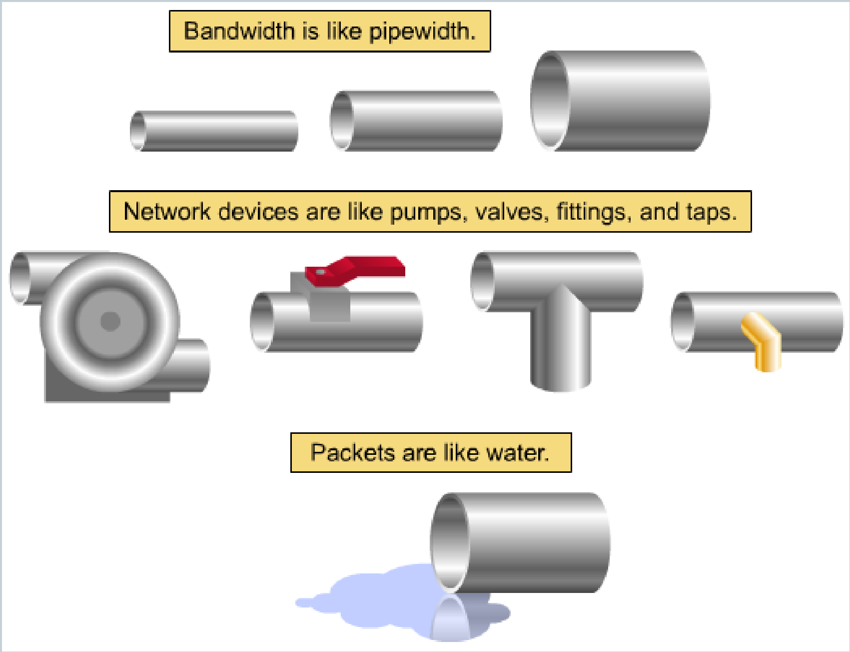
a. Bandwidth of a periodic signal



b. Bandwidth of a nonperiodic signal

Why bandwidth is important?

- Bandwidth is limited by physics and technology
- Bandwidth is not free
- Bandwidth requirements are growing at a rapid rate
- Bandwidth is critical to network performance



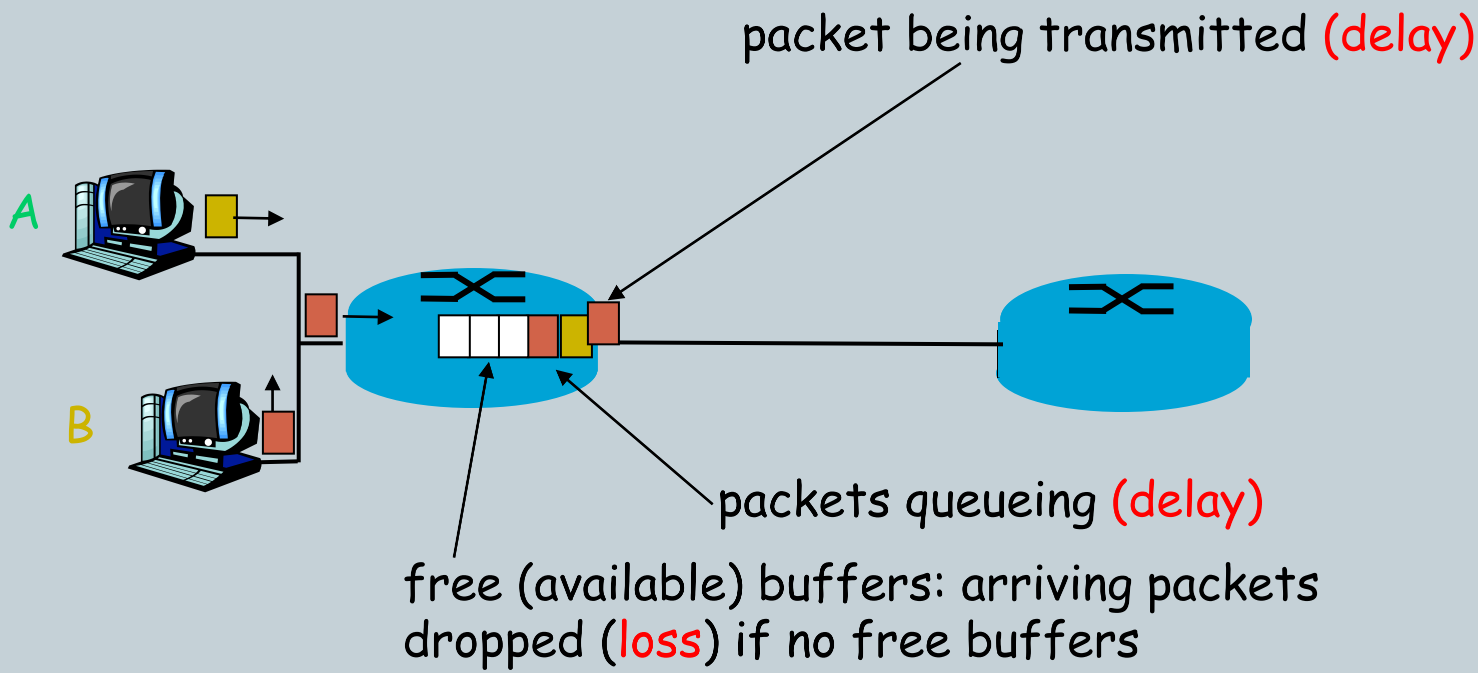
Thoughput

- Throughput refers to actual measured bandwidth, at a specific time of day (bits/time unit)
- Throughput is less than or equal to bandwidth
  - *instantaneous:* rate at given point in time
  - *average:* rate over long(er) period of time

How do loss and delay occur?

packets *queue* in router buffers

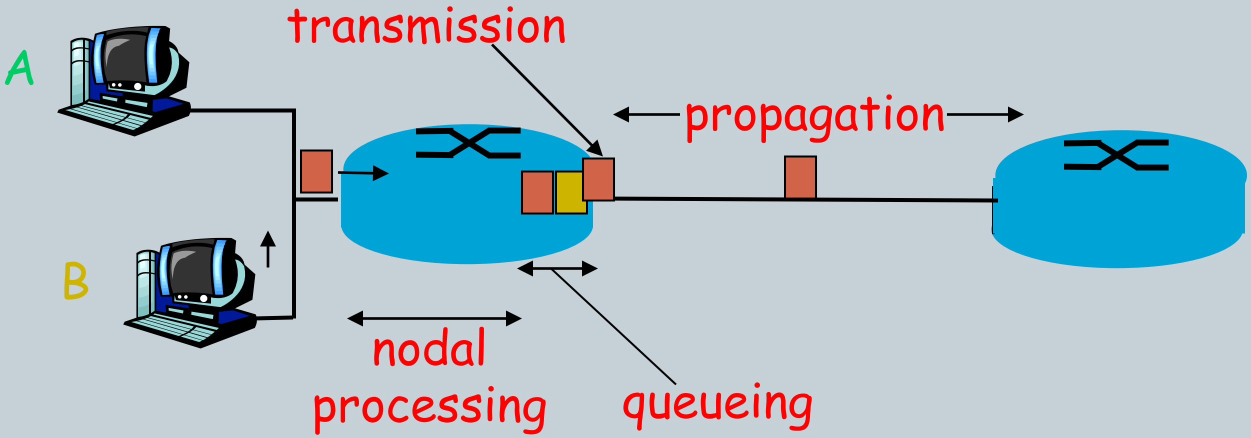
- packet arrival rate to link exceeds output link capacity
- packets queue, wait for turn



Four sources of packet delay

- 1. nodal processing:
  - check bit errors
  - determine output link

- 2. queueing
  - time waiting at output link for transmission
  - depends on congestion level of router



Delay in packet-switched networks

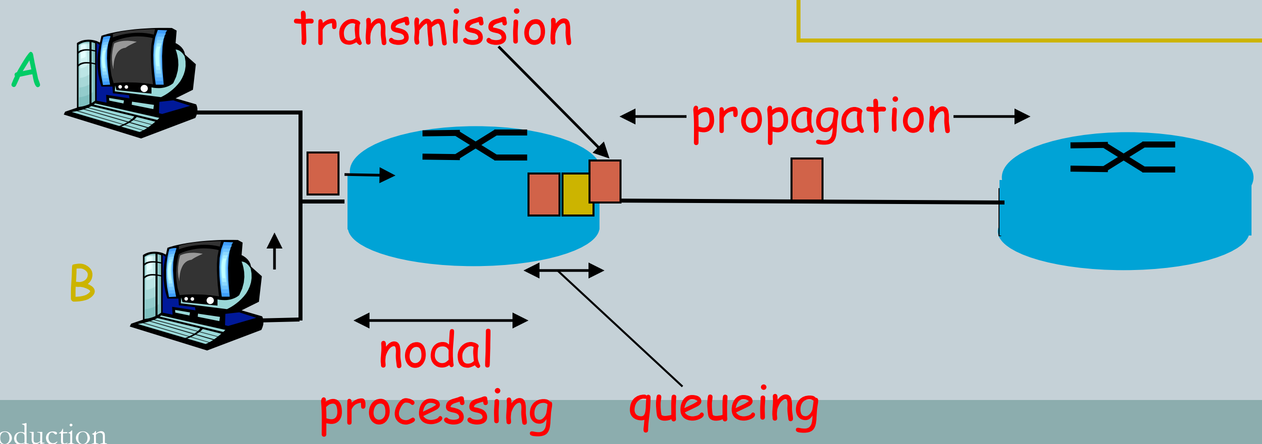
3. Transmission delay:

- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

4. Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~2x10^8 m/sec)
- propagation delay = d/s

Note: s and R are *very* different quantities!



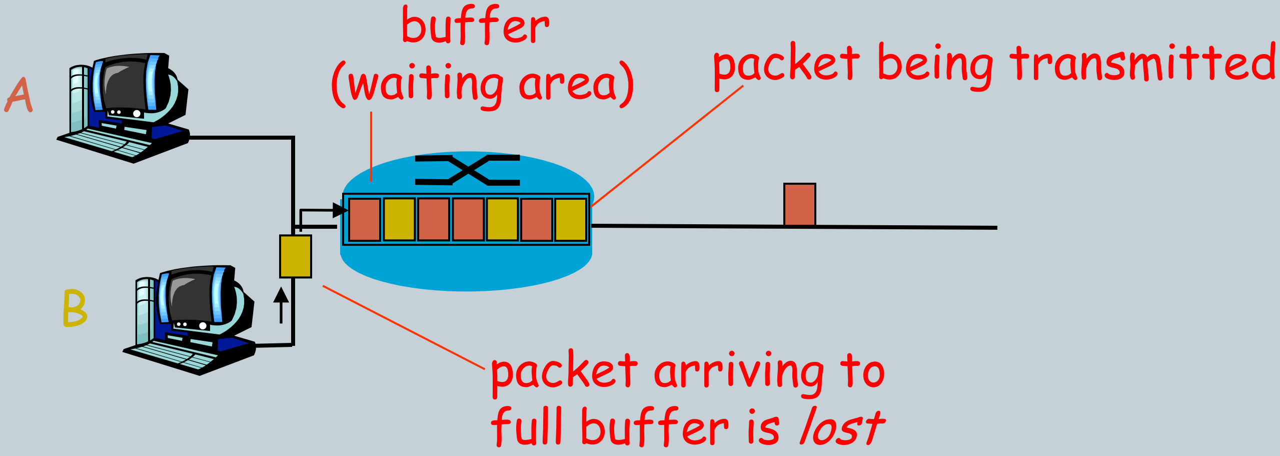
Nodal delay

$$\boxed{d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}}$$

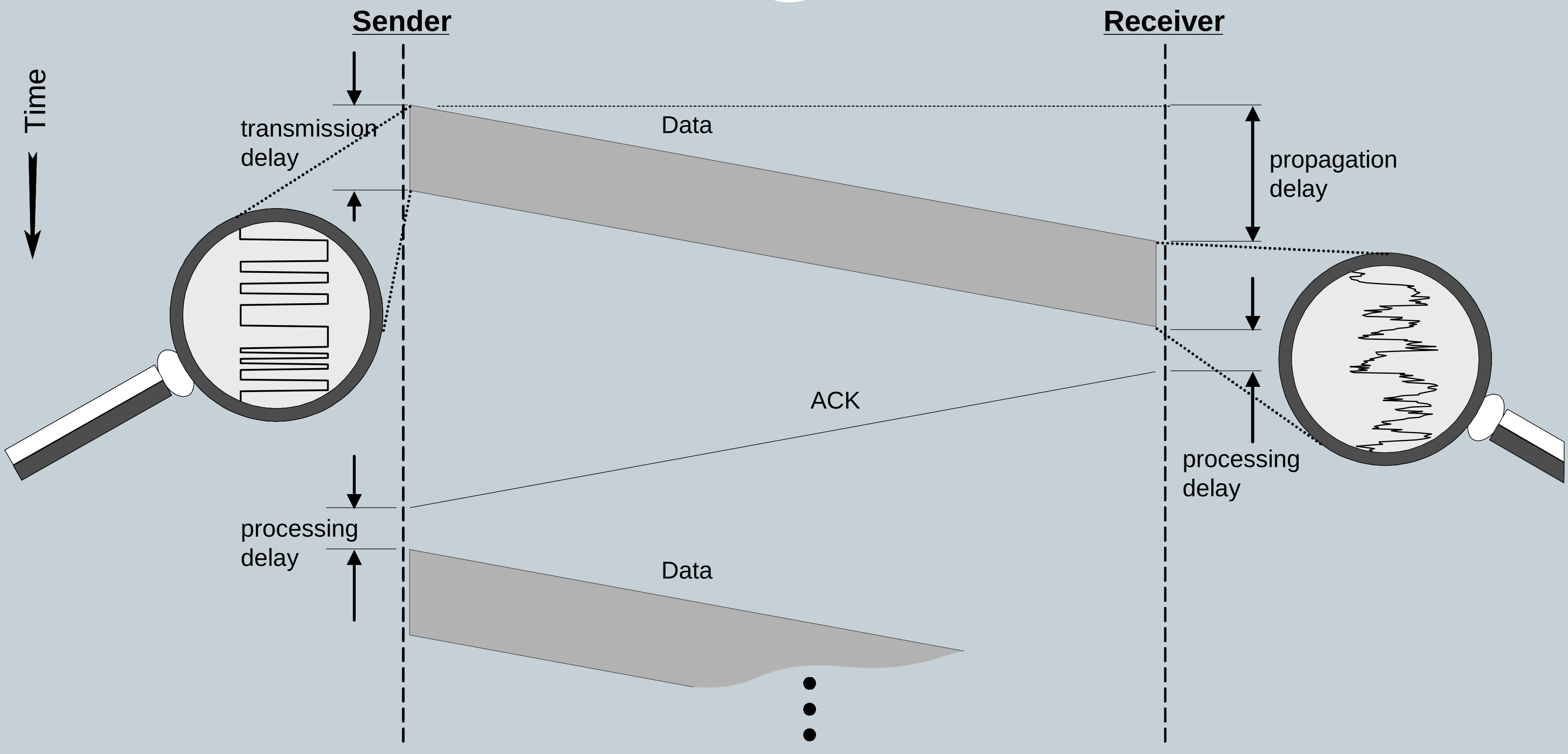
- d_{proc} = processing delay
  - typically a few microsecs or less
- d_{queue} = queuing delay
  - depends on congestion
- d_{trans} = transmission delay
  - = L/R, significant for low-speed links
- d_{prop} = propagation delay
  - a few microsecs to hundreds of msecs

Packet loss

- queue (buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



Packet Transmission (2)



Transmission and Propagation Delays

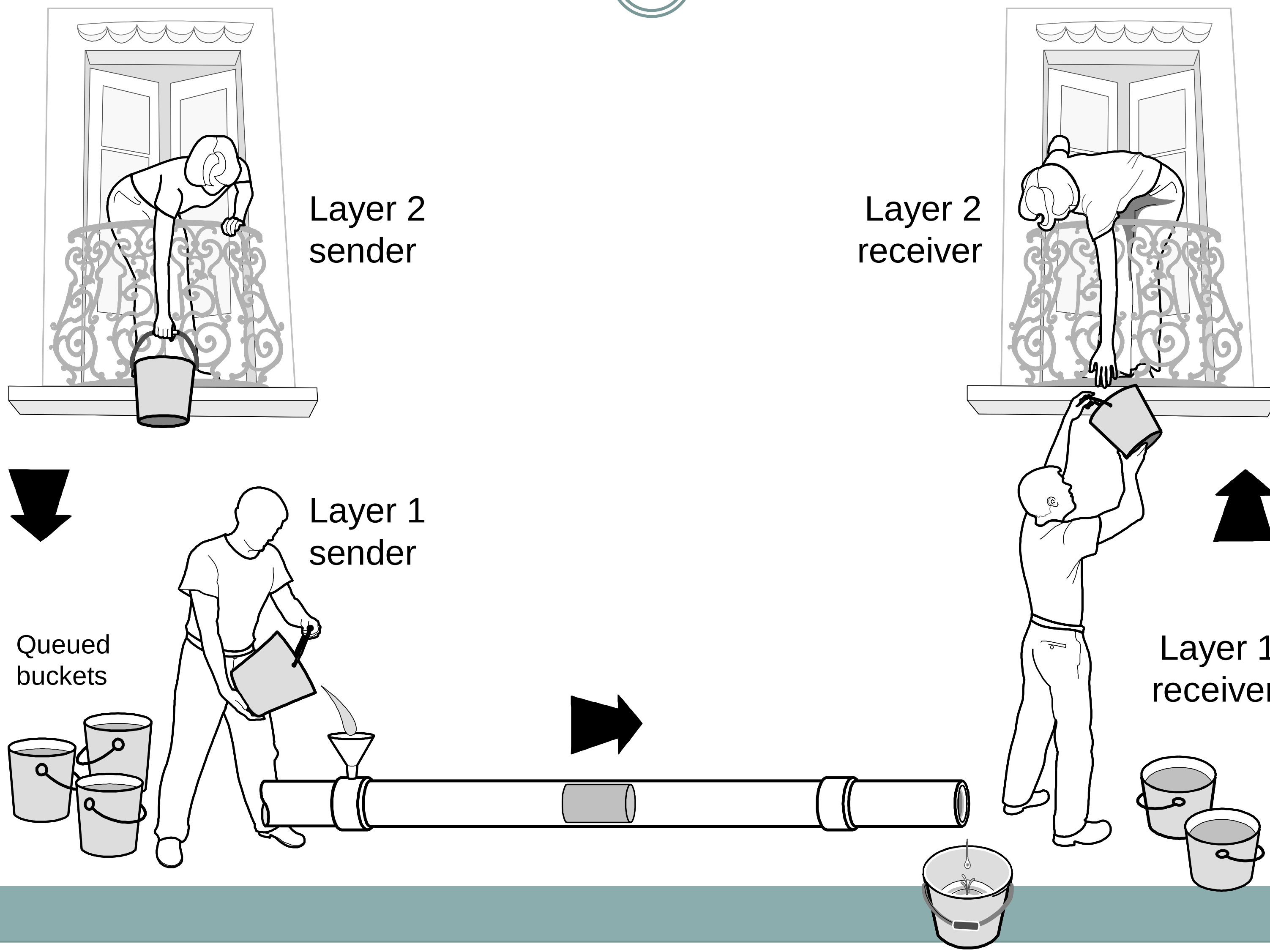
Transmission delay:

$$t_x = \frac{\text{packet length}}{\text{bandwidth}} = \frac{L\ \text{(bits)}}{R\ \text{(bits per second)}}$$

Propagation delay:

$$t_p = \frac{\text{distance}}{\text{velocity}} = \frac{d\ \text{(m)}}{v\ \text{(m/s)}}$$

Fluid Flow Analogy



Standards

- Standards Organizations
  - ISO, ITU-T, CCITT, ANSI, IEEE, EIA
- Regulatory Agencies
  - Federal Communications Commission(FCC)
- Internet Standards
  - Internet drafts = working document no official status, 6-month lifetime
  - Request for Comment (RFC) edited, assigned a number, made available to all interested parties.