CS 5550: COMPUTER NETWORKS

Fall 2018

Course personnel information

- Instructor:
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    - Class hours: TuTh: 6:30 - 7.45 PM, D-202
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    - Office hours: TBD

Course structure

- **Lectures:** The lectures will involve both slides and blackboard discussions. Attending all the lectures will be very important for the students to develop the concepts and skills, and also to be able to perform well in the exams, assignments, and quizzes.

- **Homework (25%):** Written homework will be assigned throughout the semester. Assignments will be due at the beginning of the lecture on the dates announced. It is your responsibility to keep track of assignments and their due dates.

- **Labs and Projects (20%):** There will be three labs (using Riverbed/OPNET network simulator) including one socket programming project. There is an option for a research project as well.

- **Quizzes (10%):** There will also be five unannounced pop quizzes during class hours containing 10-15 multiple choice questions. There will be no retake of the quizzes.

- **Exams (45%):** There will be one midterm exam and one final exam.
  - Midterm (20%) – March 16th. (Tentative)
  - Final exam (25%) – Week of May 22nd.

Course outline

- Network basics (4 lectures)
  - Introduction: Basic concepts, architecture, protocols, performance
  - Physical communication: Digital/Analog, multiplexing
- Data link network (5 lectures)
  - Encoding, framing, error detection, reliable transmission
  - P2P and shared access, Ethernet, MAC, random access
- Packet switching (2 lectures)
  - Switching: Datagram, virtual circuits
- Internetworking (6 lectures)
  - Addressing: IPv4, IPv6, Subnets, ARP, DHCP, NAT, VPN
  - Routing: Distance vector routing, link state routing, OSPF, CIDR, BGP
- End-to-end networking (5 lectures)
  - Transmission: UDP, TCP
  - Congestion control
- Applications (3 lectures)
  - HTTP, email, DNS, Overlay networks, CDN, P2P
- Network security (2 lectures)

What will we learn in this course?

- What is a computer network?
  - Architectures, protocols, physical communications
- How to connect to a network?
  - Switching, addressing
- How to scale a network?
  - Routing, transmission control
- How to allocate resources?
  - Congestion control, resource allocation, media access
- How to connect applications to the network?
  - Application protocols
- How to address the security threats to a network?
  - Threats, security strategies

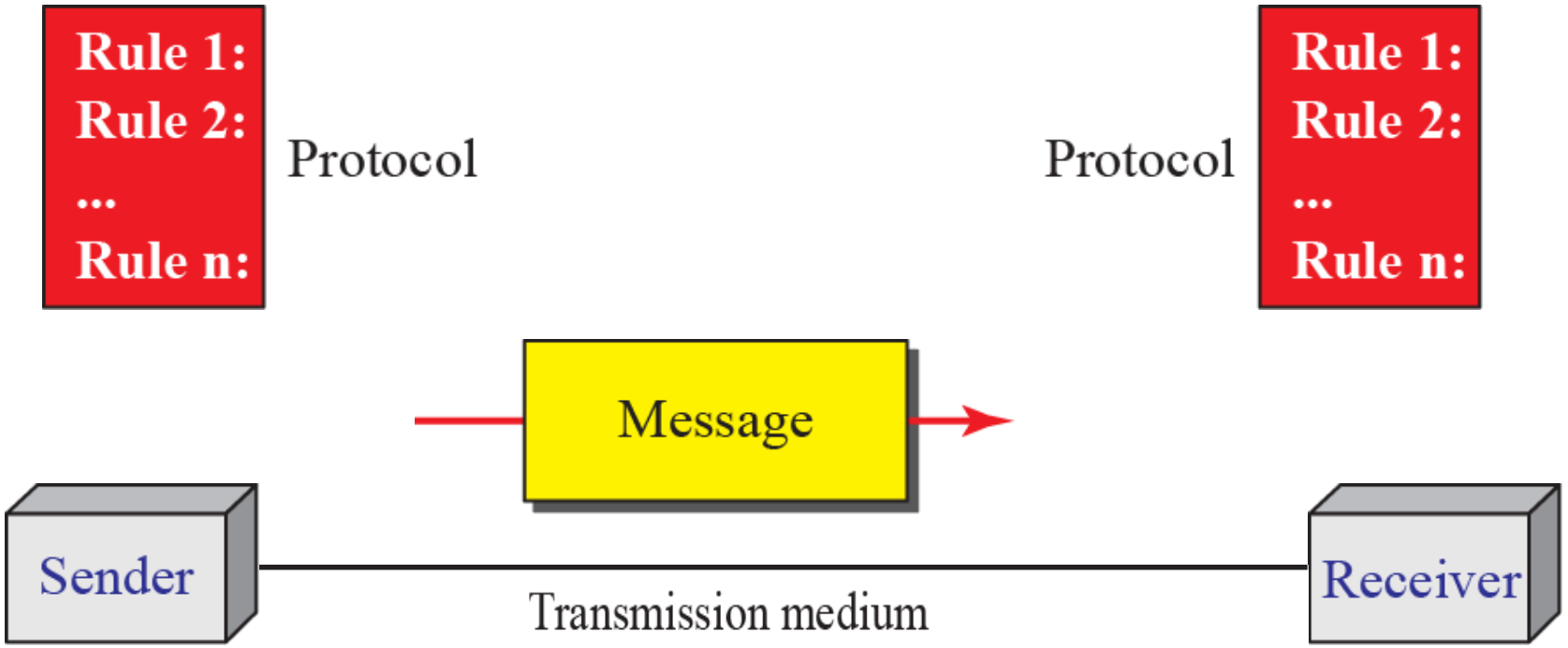
TOPIC I: NETWORK BASICS
SECTION I: INTRODUCTION

Slides adapted from Peterson (Chapter 1) and Forouzan (Chapters 1 and 2)

Section goals

- Introducing the basic concepts and terminologies of computer networking
- Exploring the requirements that different applications and different communities place on the computer network
- Introducing the Internet and the underlying protocols
- Introducing network architecture
- Define key metrics that will be used to evaluate the performance of computer networks

Basic components of data communication



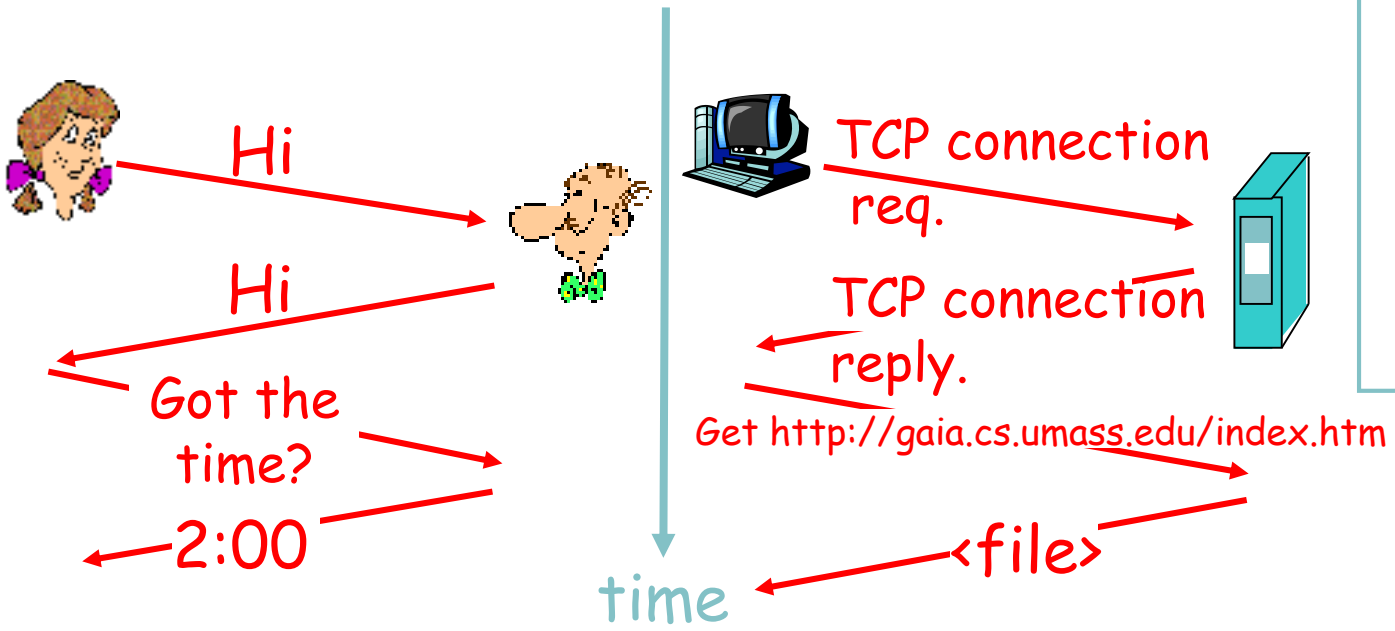
What's a protocol?

human protocols:

- introductions
- "I have a question"
- "what's the time?"

network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols



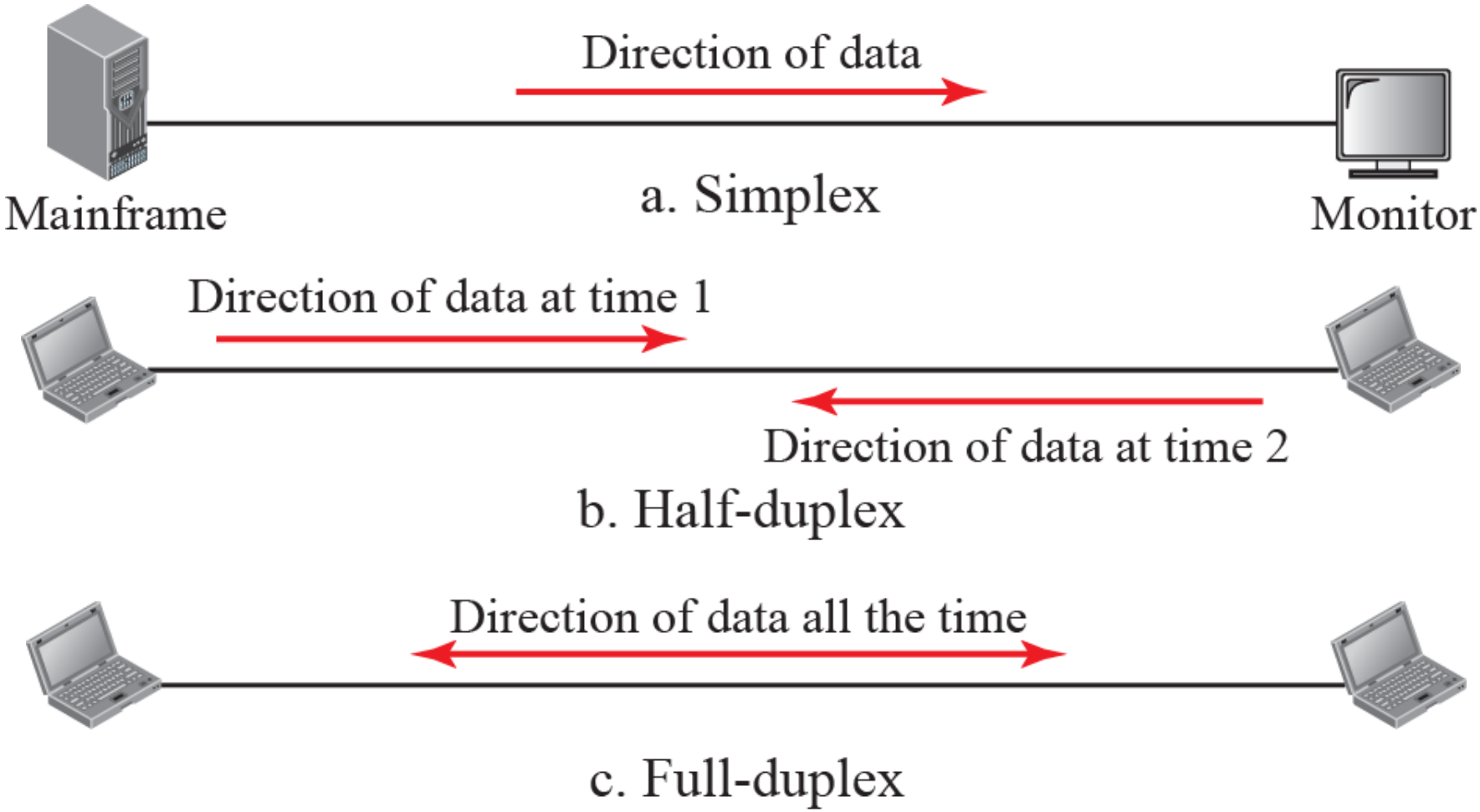
*protocols define format (**syntax, semantics**), order of msgs sent and received among network Entities (**timing**), and actions taken on msg transmission, receipt*

What's a Network: Key Features

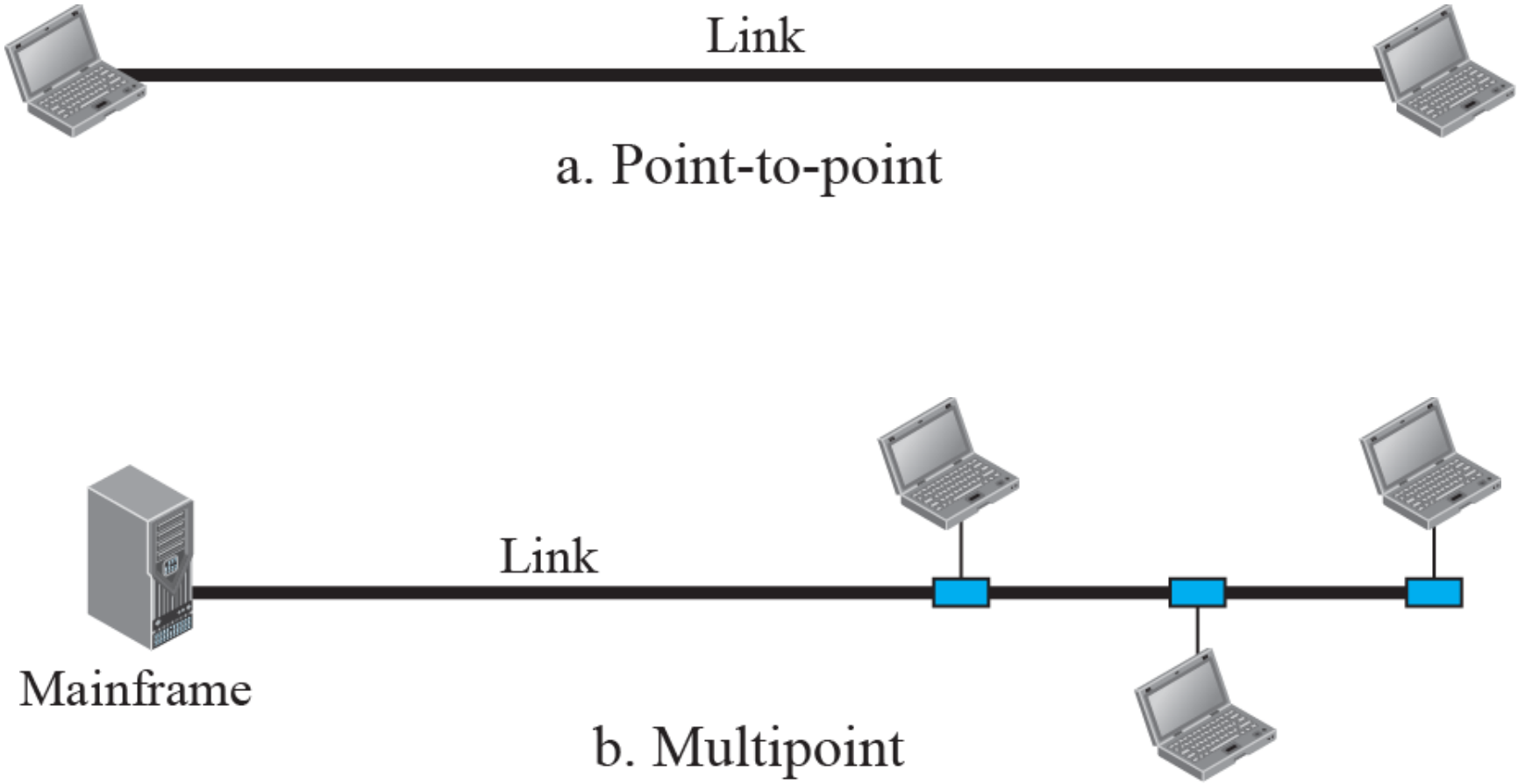
- Providing certain services
  - transport goods, mail, information or data communication
- Shared resources
  - used by many users, often concurrently
- Basic building blocks
  - nodes (active entities): process and transfer goods/data
  - links (passive medium): passive "carrier" of goods/data
- Typically "multi-hop"
  - two "end points" cannot directly reach each other
  - need other nodes/entities to relay

How to know that a communication network is effective ?

Data flow


Direction of data
Mainframe
Monitor
a. Simplex
Direction of data at time 1
Direction of data at time 2
b. Half-duplex
Direction of data all the time
c. Full-duplex

Types of network connection



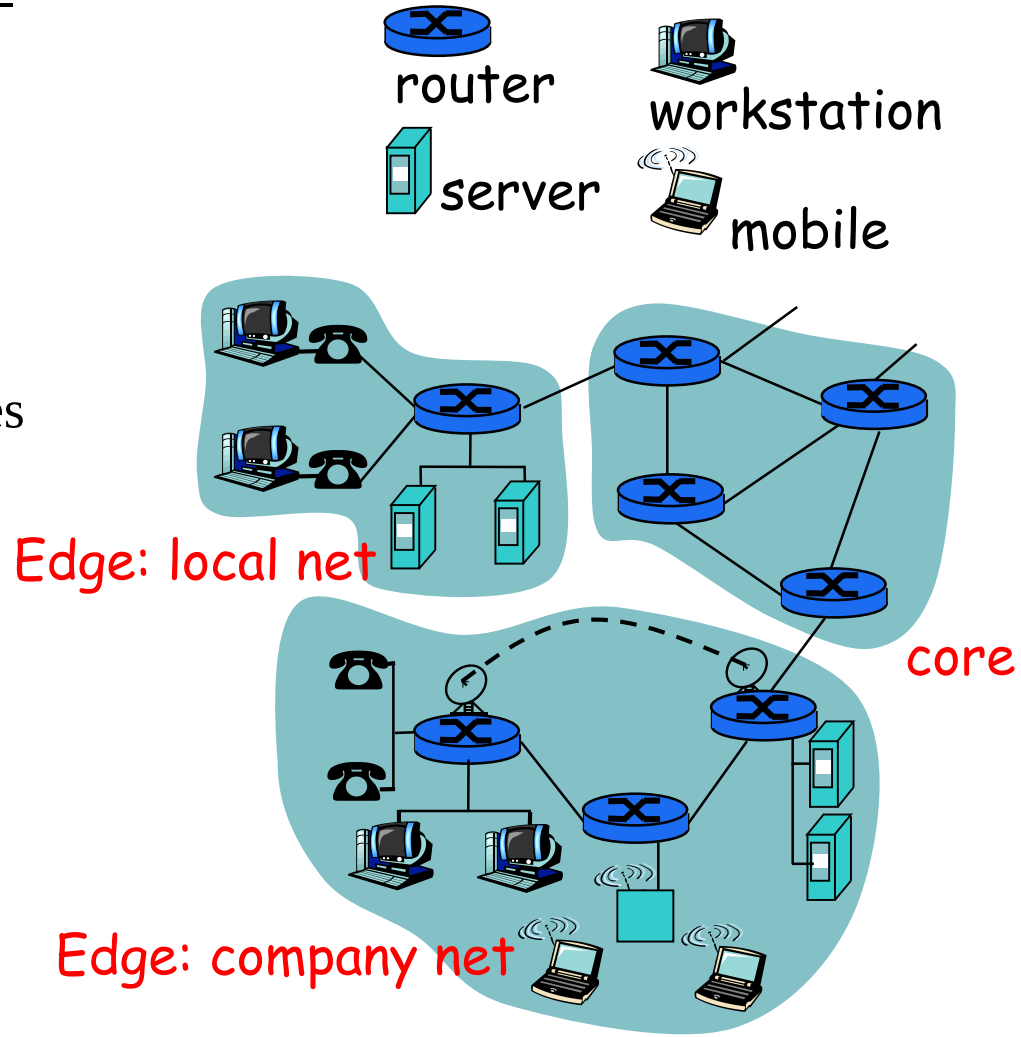
Internet alternate view

- *network edge:* millions of end-system devices:
  - pc's workstations, servers
  - PDA's, phones, toasters

  running network apps

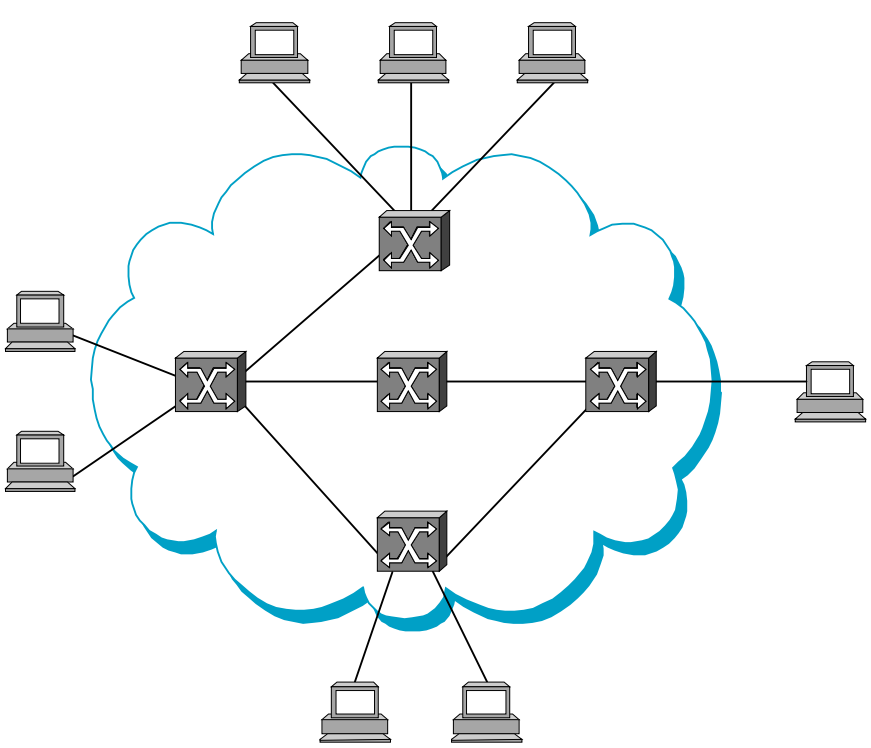
- *network core:* routers, switches forwarding data
  - *packets:* packet switching
  - *calls:* circuit switching

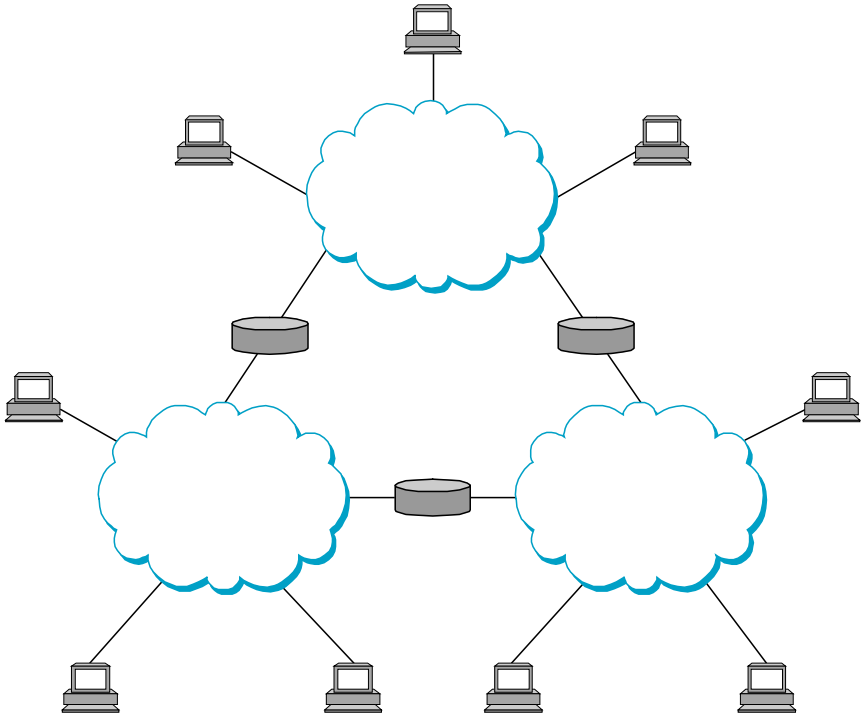
- *communication links, access networks*
  - fiber, copper, radio, …



Network types

- A network can be defined recursively as...
  - two or more nodes connected by a link
  - two or more networks connected by a node

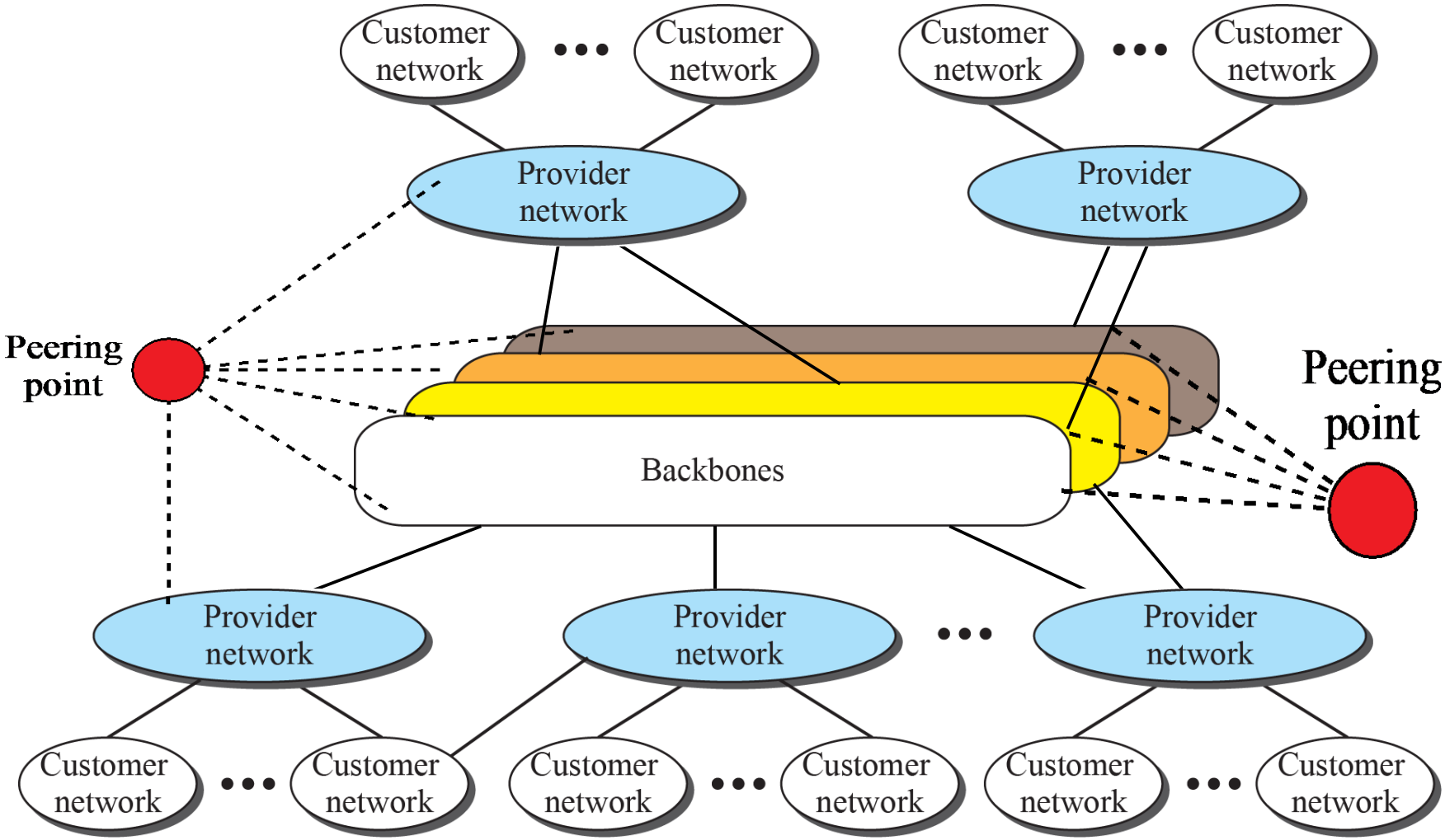




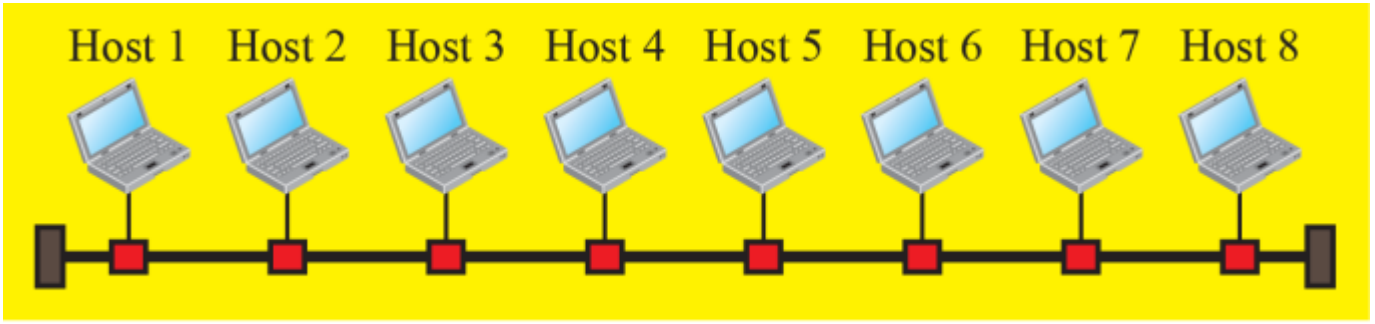
Brief History of the Internet

- 70's: started as a research project, 56 kbps, < 100 computers
- 80-83: ARPANET and MILNET split,
- 85-86: NSF builds NSFNET as backbone, links 6 Supercomputer centers, 1.5 Mbps, 10,000 computers
- 87-90: link regional networks, NSI (NASA), ESNet(DOE), DARTnet, TWBNet (DARPA), 100,000 computers
- 90-92: NSFNET moves to 45 Mbps, 16 mid-level networks
- 94: NSF backbone dismantled, multiple private backbones
- Today: backbones run at >10 Gbps, >600 millions computers in >190 countries

The Internet today

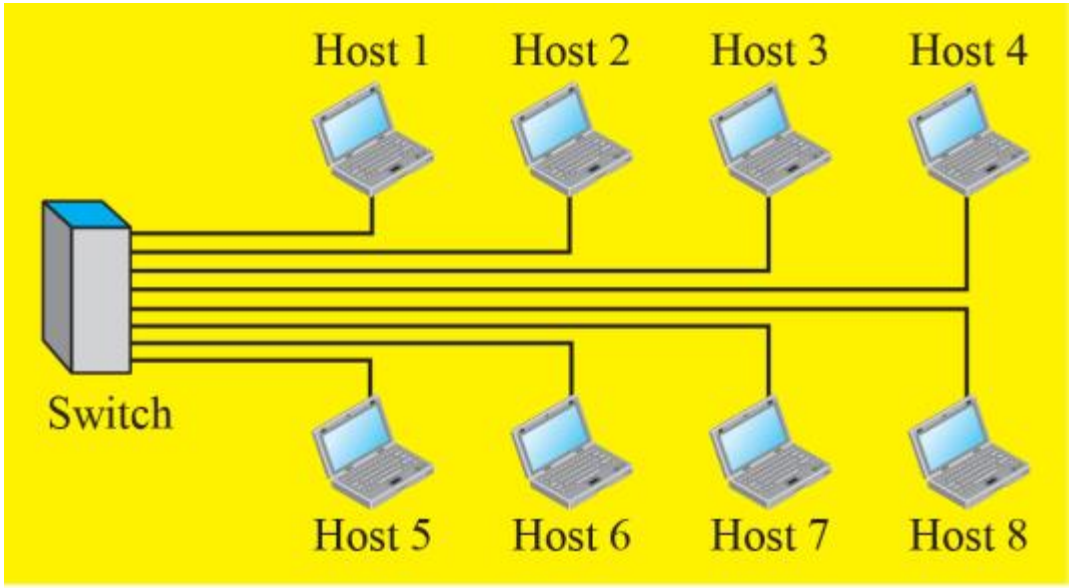


Switching in Local Area Networks



a. LAN with a common cable (past)

A **Local Area Network (LAN)** is usually privately owned and connects some hosts in a single office, building, or campus. Depending on the needs of an organization, a LAN can be as simple as two PCs and a printer in someone's home office, or it can extend throughout a company and include audio and video devices. Each host in a LAN has an identifier, an address, that uniquely defines the host in the LAN. A packet sent by a host to another host carries both the source host's and the destination host's addresses.

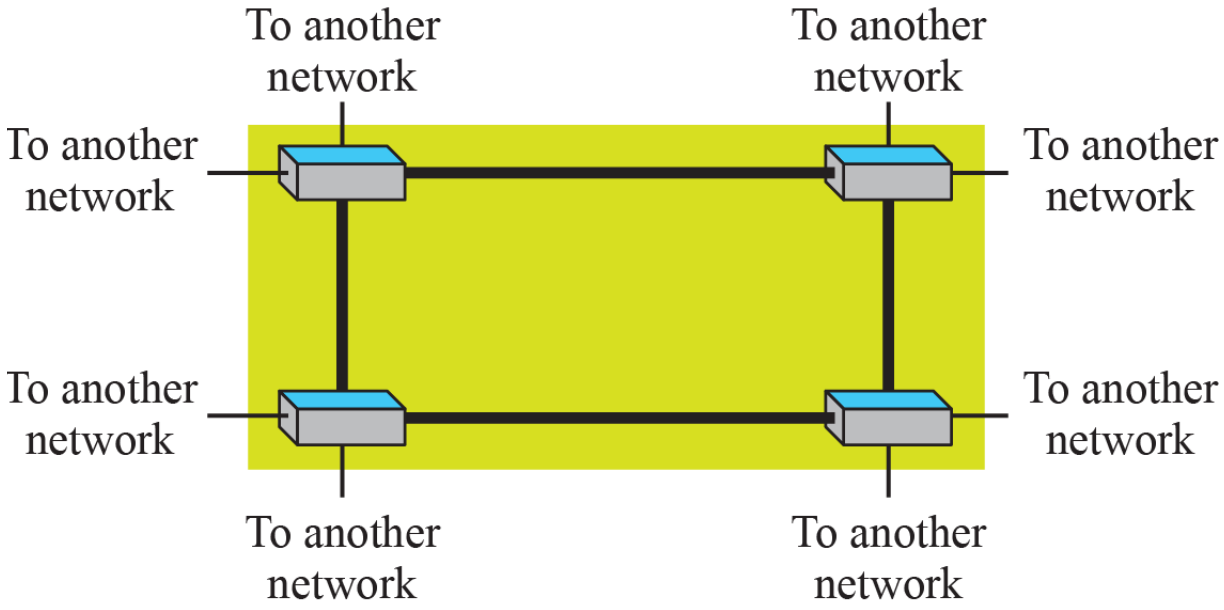


b. LAN with a switch (today)

Switching in Wide Area Networks

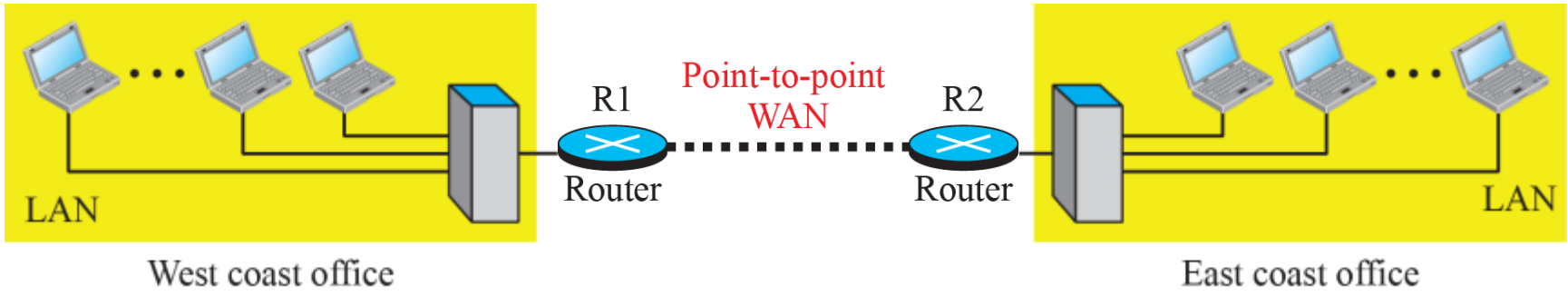
Point-to-point WAN

A **Wide Area Network (WAN)** is also an connection of devices capable of communication. However, there are some differences between a LAN and a WAN. A LAN is normally limited in size; a WAN has a wider geographical span, spanning a town, a state, a country, or even the world. A LAN interconnects hosts; a WAN interconnects connecting devices such as switches, routers, or modems. A LAN is normally privately owned by the organization that uses it; a WAN is normally created and run by communication companies and leased by an organization that uses it.



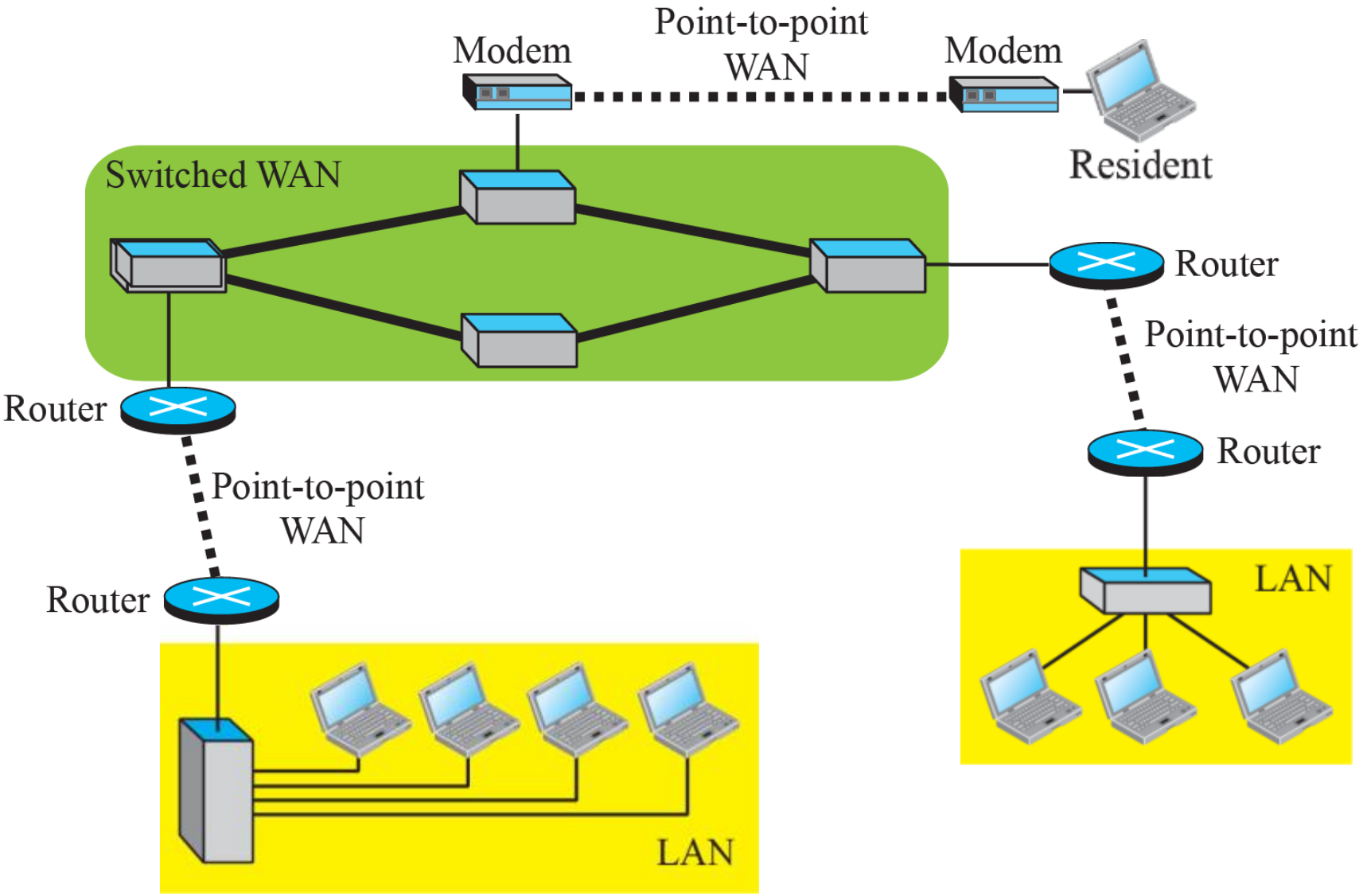
Switched WAN

Point-to-point and switching



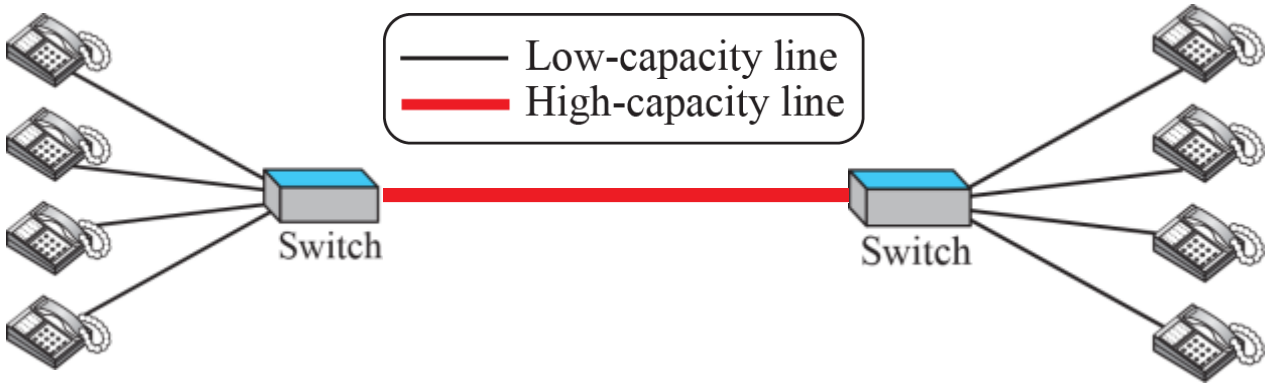
Two switched LANs connected through P2P WANs

Point-to-point and switching

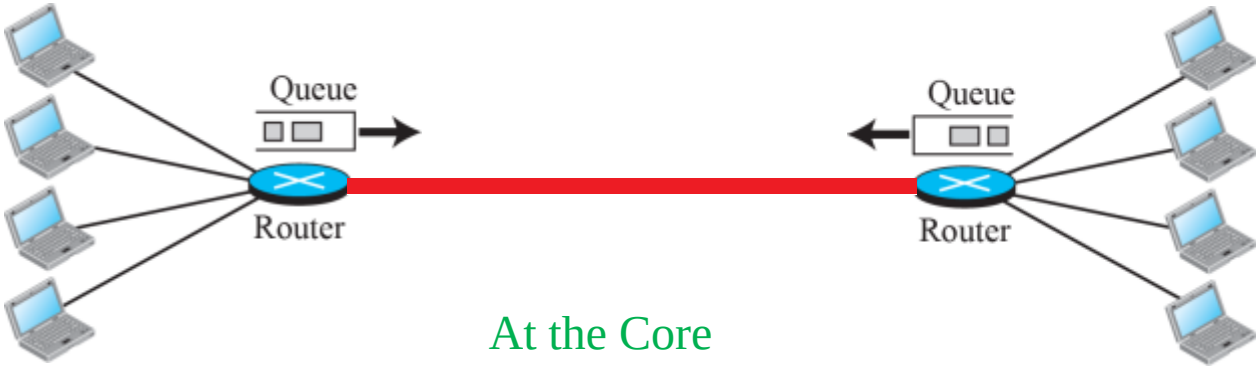


Circuit switching and packet switching

- Circuit switching: dedicated links carry bit streams
  - original telephone network



- Packet switching: Multi-access store-and-forward messages
  - Internet

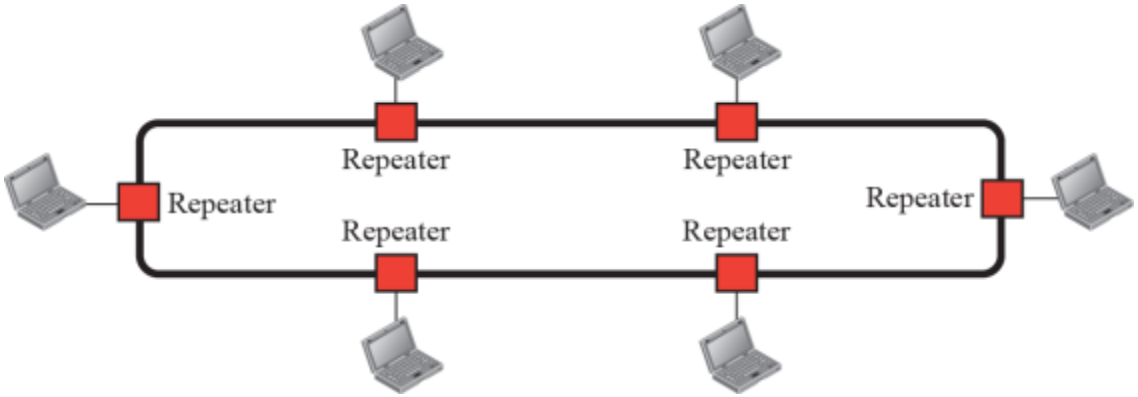


At the Core

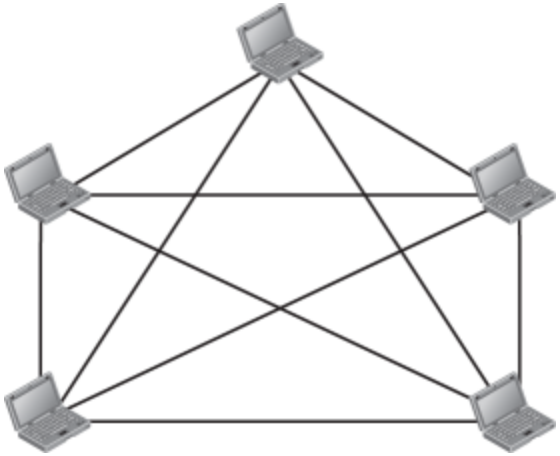
The devil is in the details

- URL
  - Uniform resource locater
  - http://www.cs.princeton.edu/~llp/index.html
- HTTP
  - Hyper Text Transfer Protocol
- TCP
  - Transmission Control Protocol
- 17 messages for one URL request
  - 6 to find the IP (Internet Protocol) address
  - 3 for connection establishment of TCP
  - 4 for HTTP request and acknowledgement
    - Request: I got your request and I will send the data
    - Reply: Here is the data you requested; I got the data
  - 4 messages for tearing down TCP connection

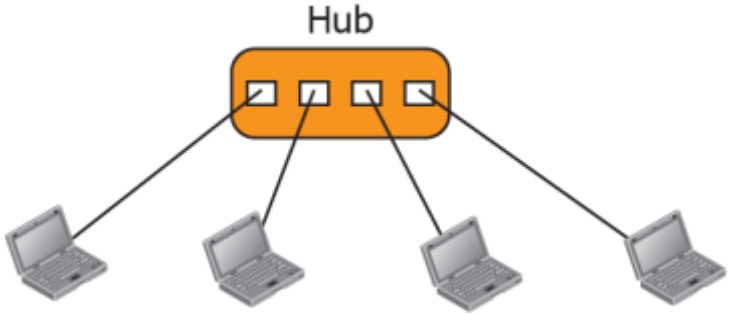
Network topologies



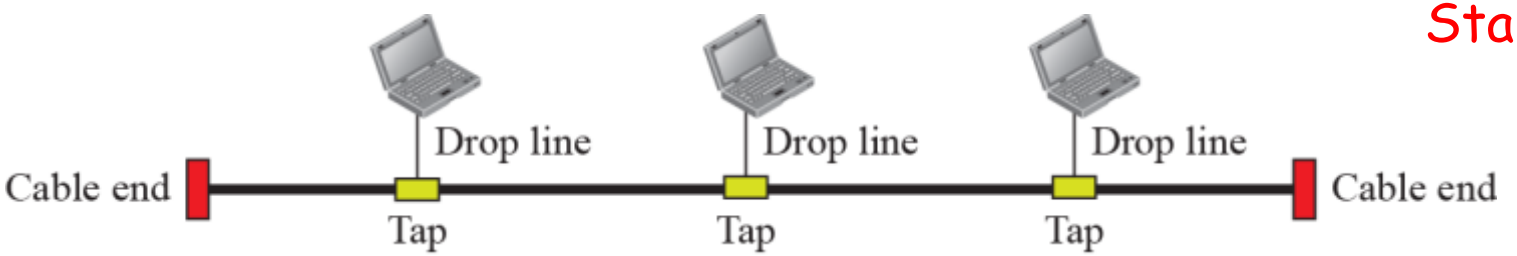
Ring



Mesh



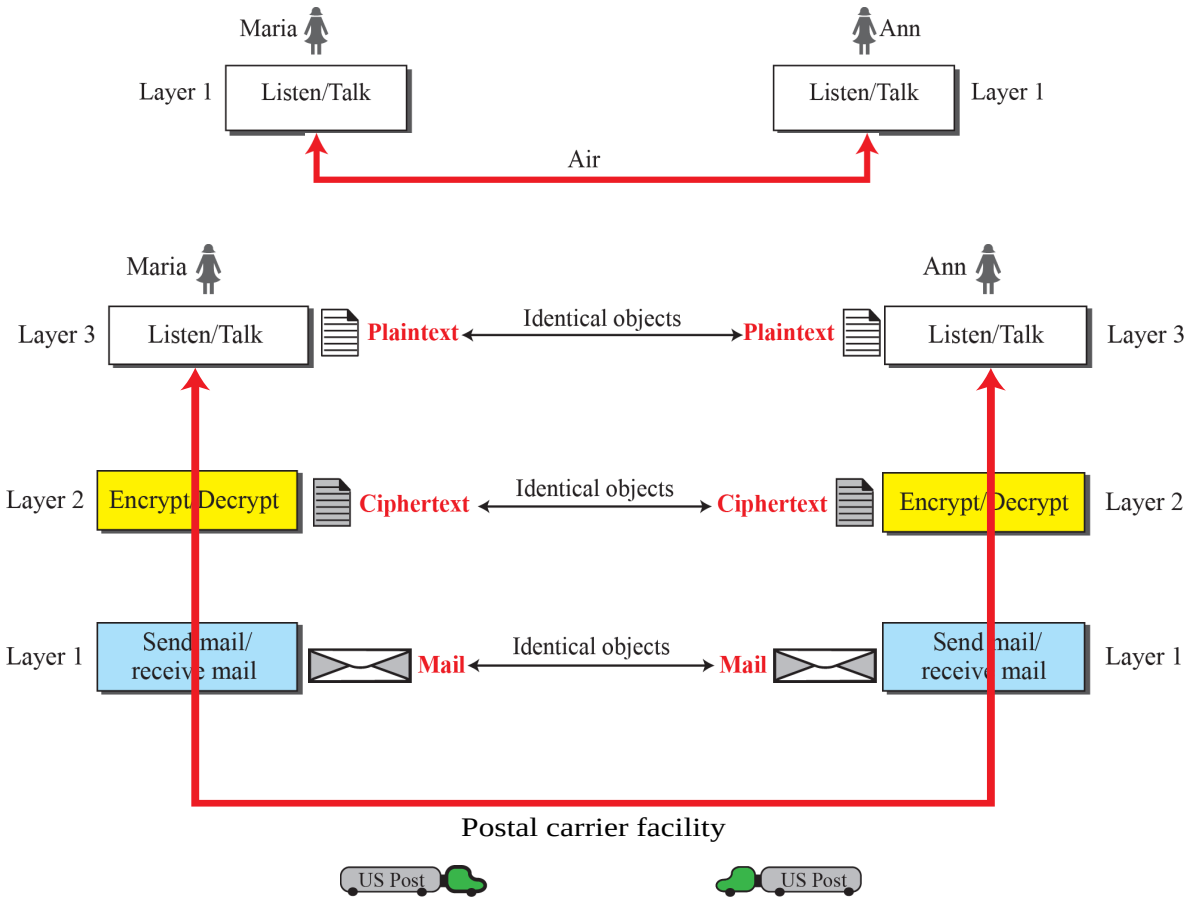
Star



Bus

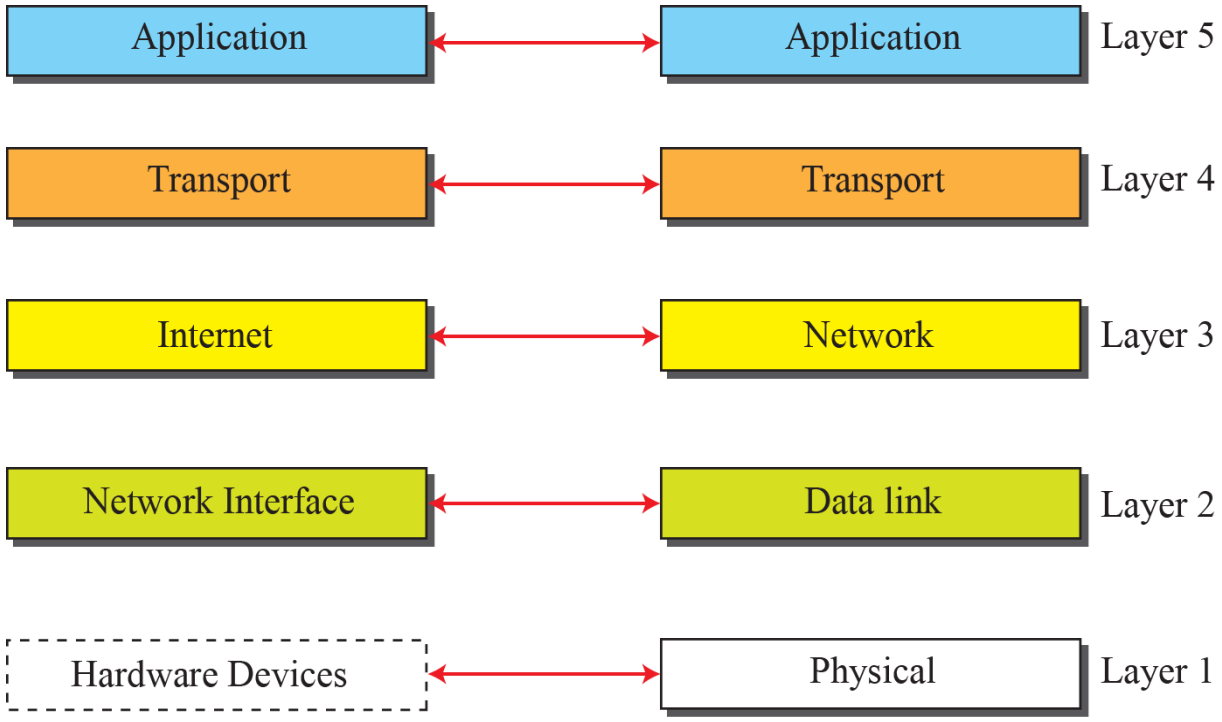
Protocol layering

When communication is simple, we may need only one simple protocol; when the communication is complex, we need a protocol at each layer, or protocol layering.



Maria and Ann can think that there is a logical (imaginary) connection at each layer through which they can send the object created from that layer. The concept of logical connection helps us better understand the task of layering. This enables layer-to-layer communication.

TCP/IP protocol suite



Application: supporting network applications

- FTP, SMTP, HTTP

Transport: host-host data transfer

- TCP, UDP

Network: routing of datagrams from source to destination

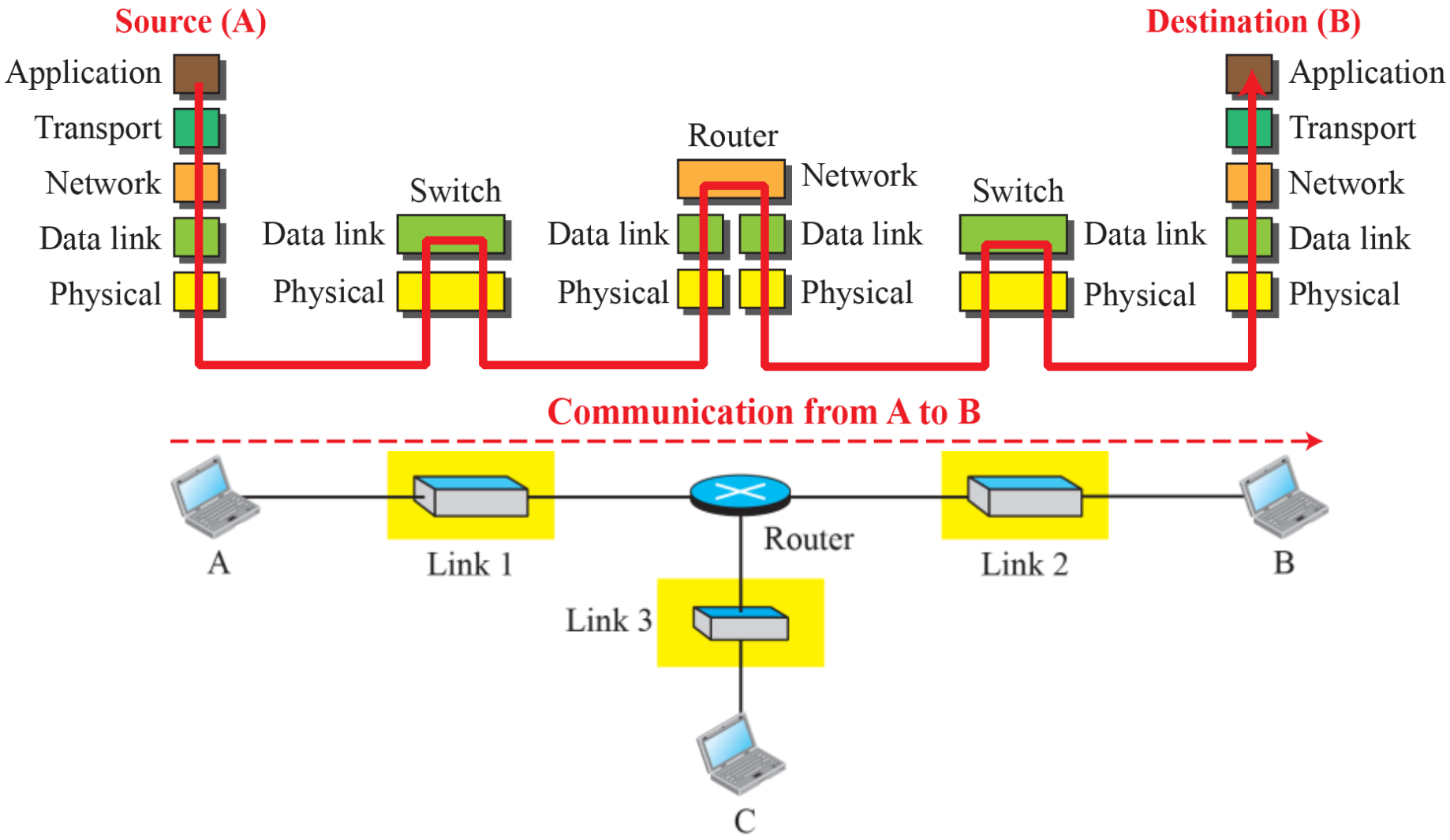
- IP, Routing protocols

Data link: data transfer between neighboring network elements

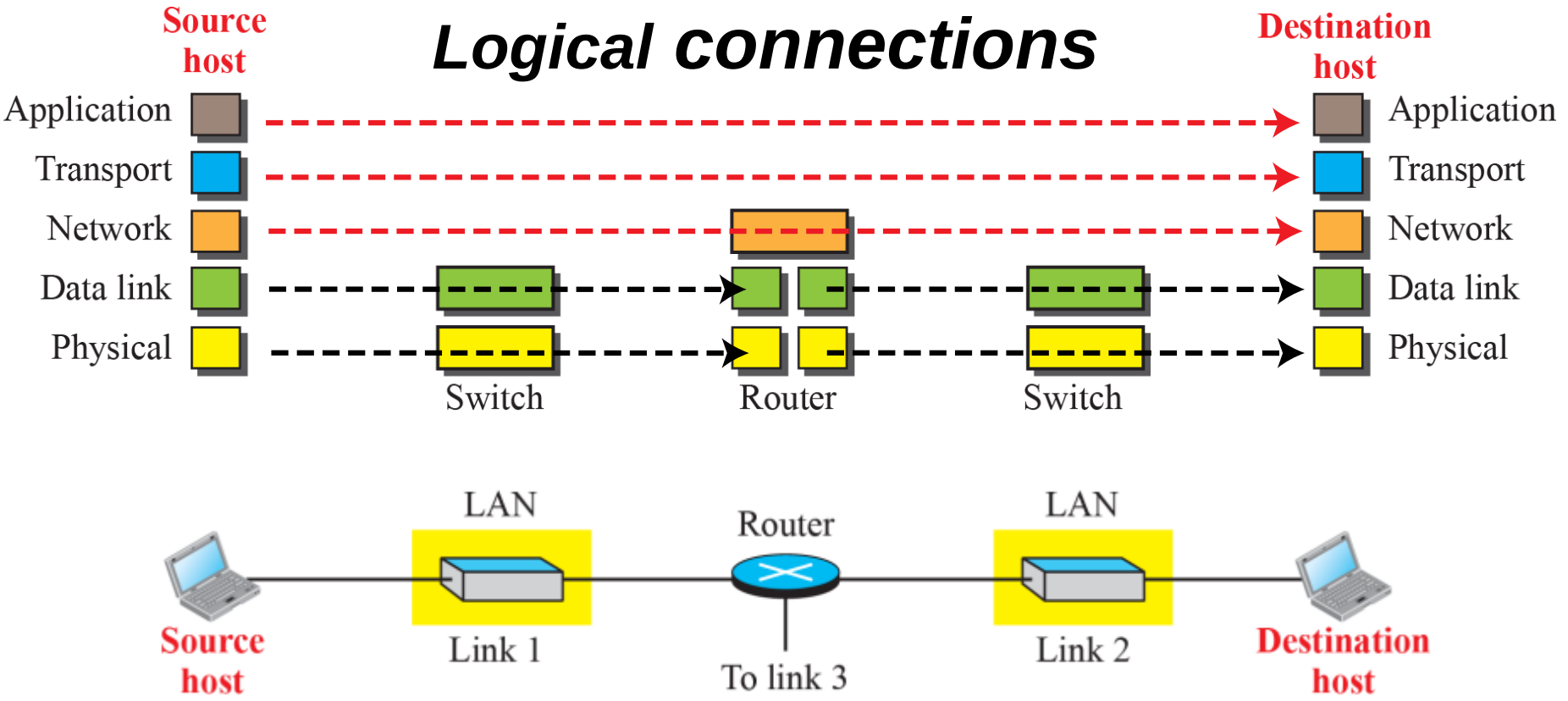
- PPP, Ethernet

Physical: bits "on the wire"

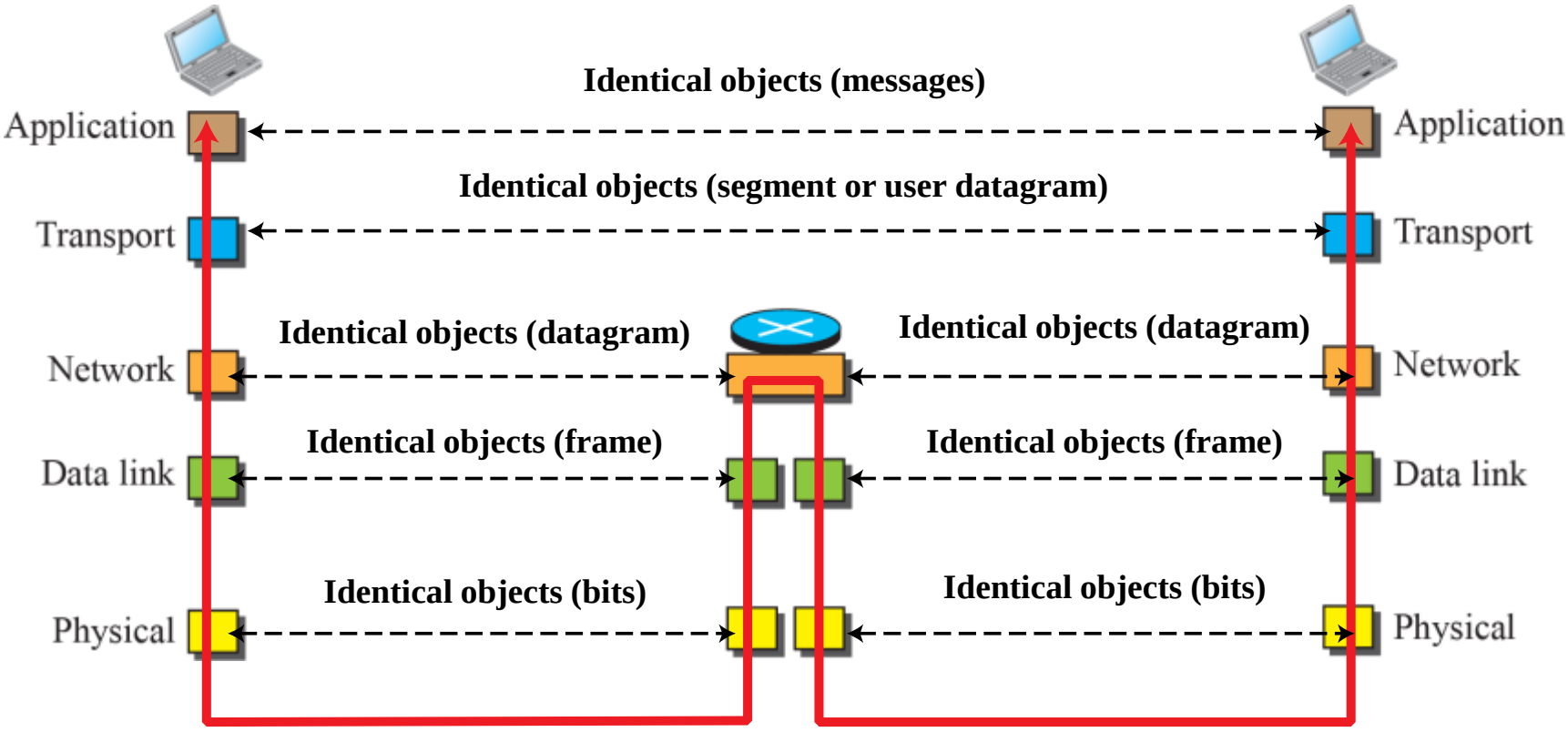
Communication through Internet



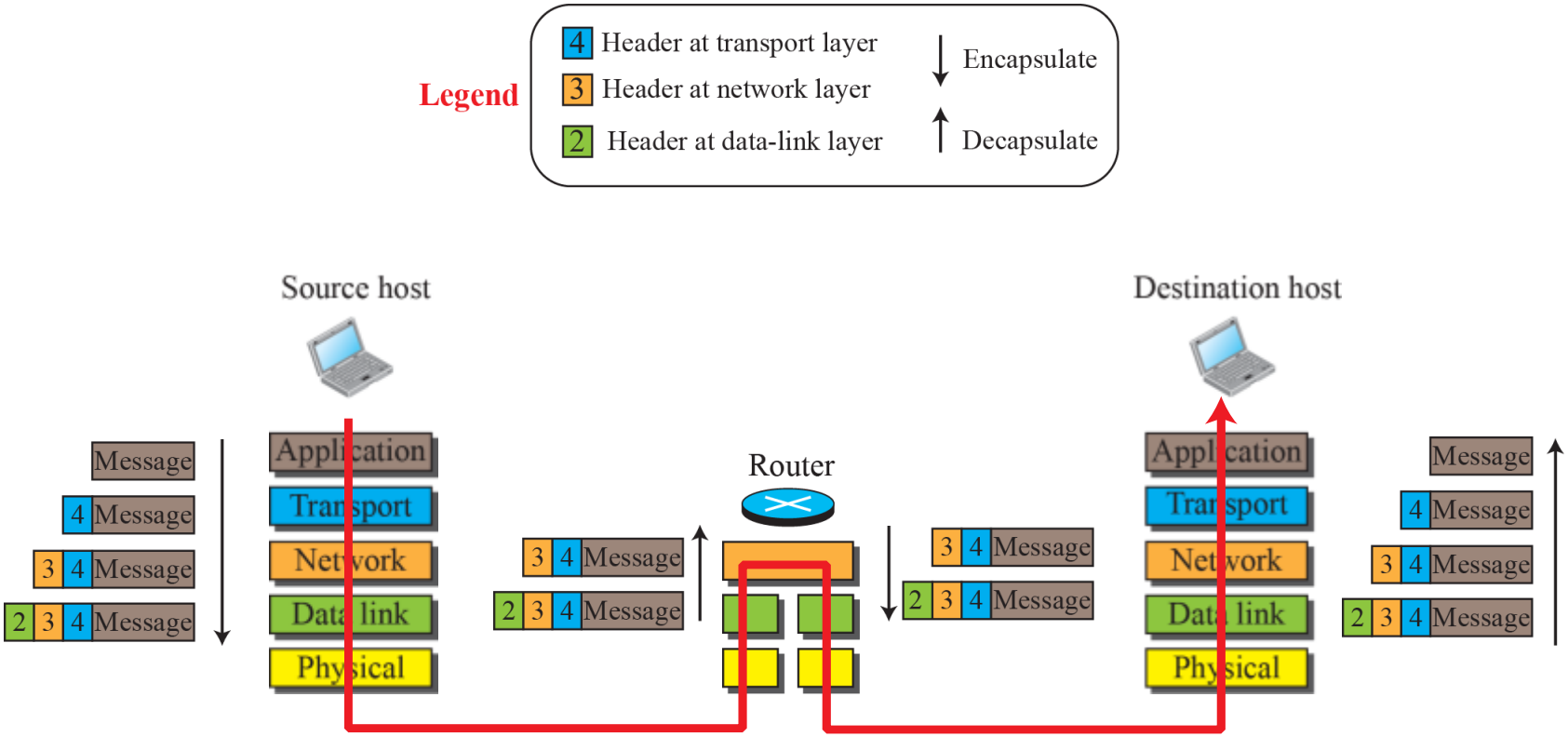
Logical connection between layers in TCP/IP



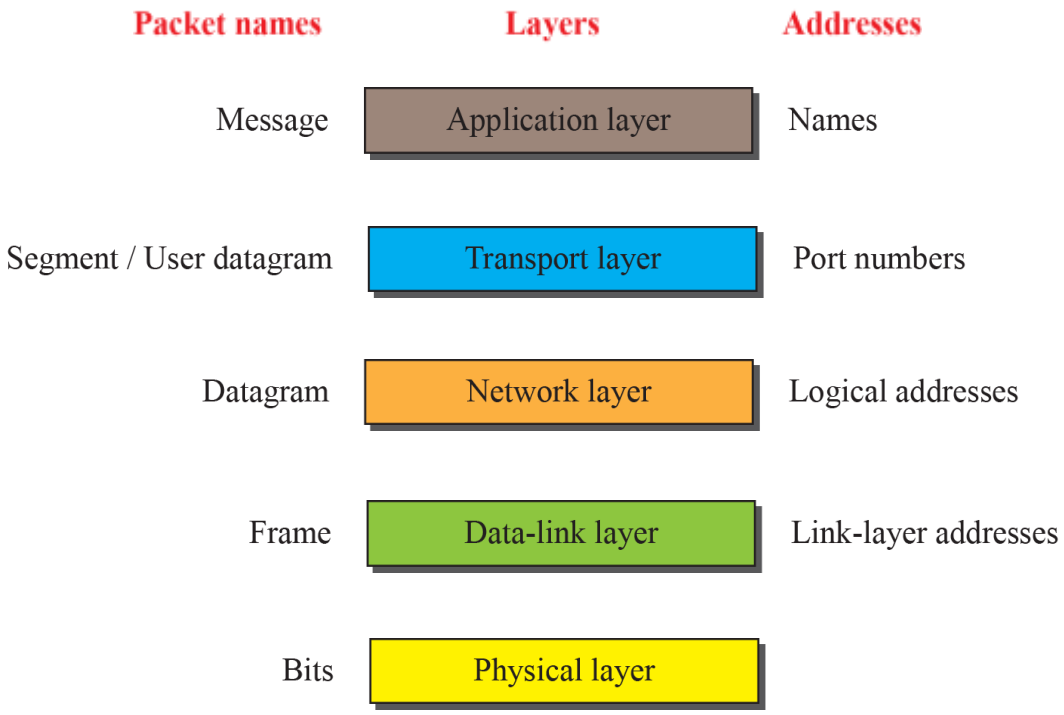
Identical objects between layers in TCP/IP



Identical objects between layers in TCP/IP



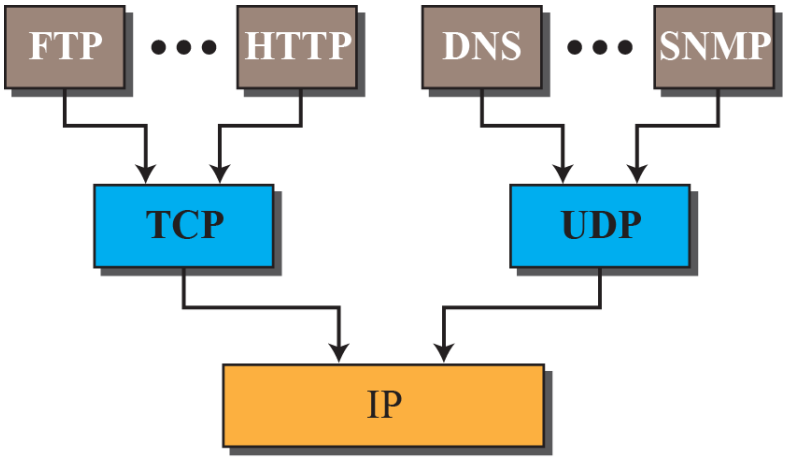
Addressing and layering



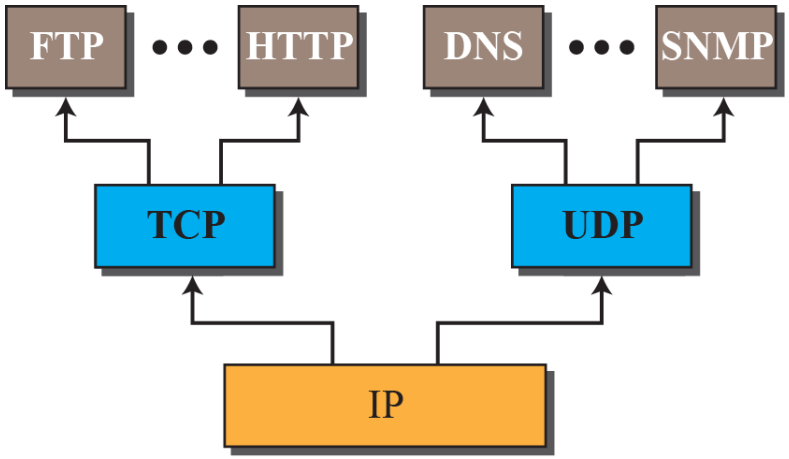
Any logical communication that involves two parties needs two addresses: source address and destination address. As the logical communications are between same layers at both destination and source, every layer in the TCP/IP stack needs an address except for the physical layer.

Multiplexing/Demultiplexing → Encapsulation

Since the TCP/IP protocol suite uses several protocols at some layers, effective communication needs multiplexing at the source and demultiplexing at the destination. Multiplexing means that a protocol at a layer can encapsulate a packet from several next-higher layer protocols (one at a time); demultiplexing means that a protocol can decapsulate and deliver a packet to several next-higher layer protocols (one at a time).

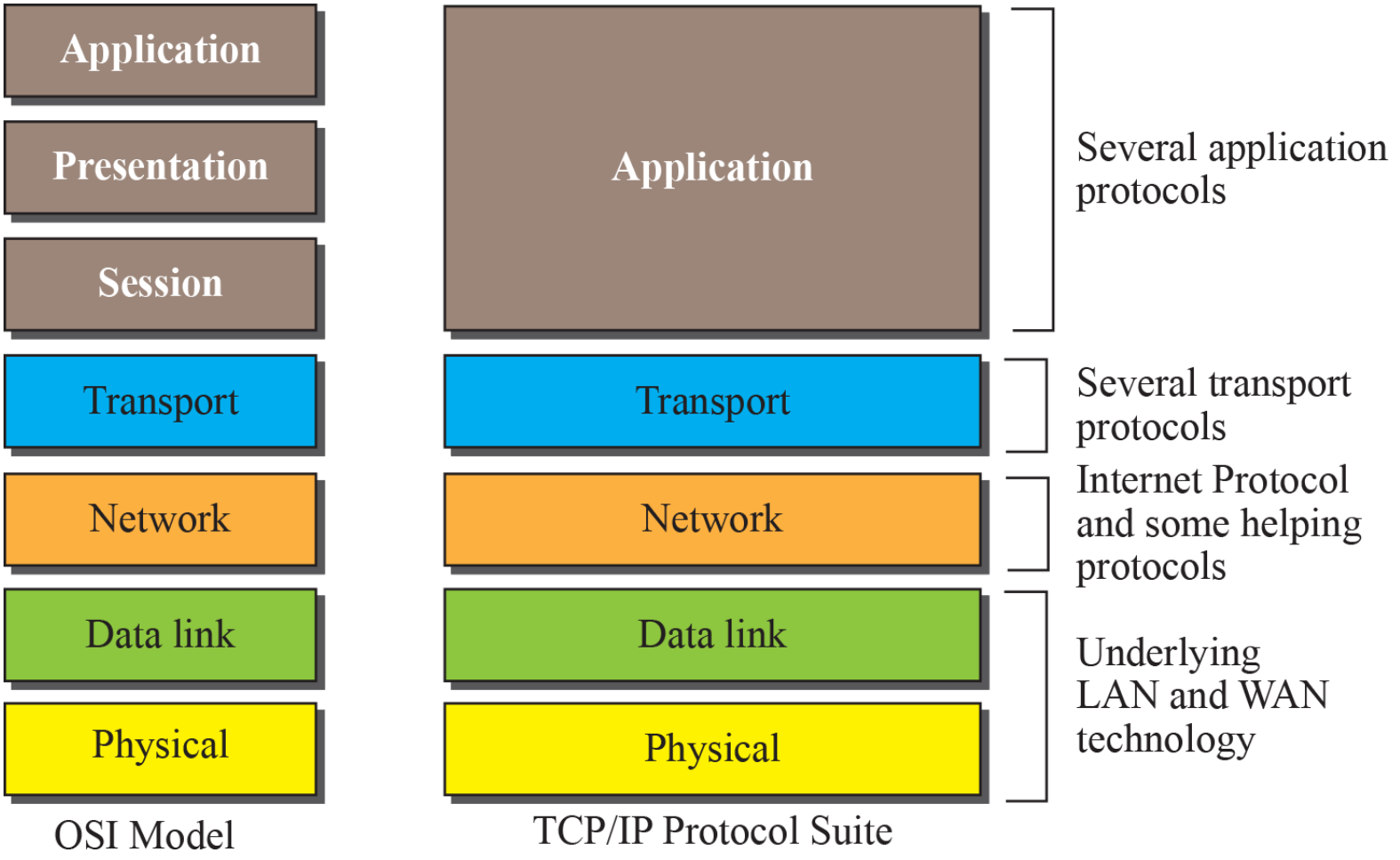


a. Multiplexing at source



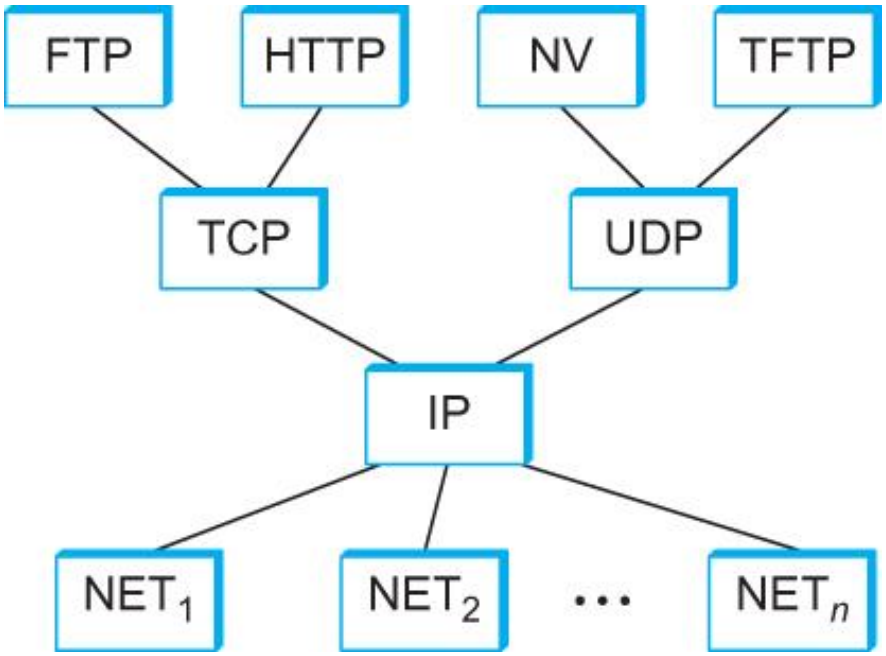
b. Demultiplexing at destination

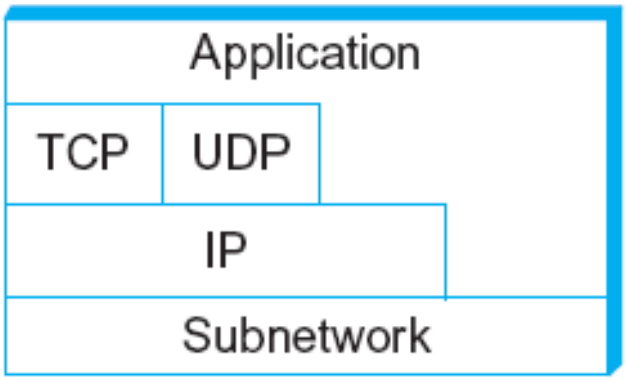
TCP/IP vs. OSI model



Internet protocol architecture

- Defined by Internet Engineering Task Force (IETF)
- *Hourglass Design*
- Application vs Application Protocol (FTP, HTTP)





Alternative view of the Internet architecture. The "Network" layer shown here is sometimes referred to as the "sub-network" or "link" layer.

Implications of the hourglass

A single Internet layer module:

- Allows all networks to interoperate
  - all networks technologies that support IP can exchange packets
- Allows all applications to function on all networks
  - all applications that can run on IP can use any network
- Simultaneous developments above and below IP

The Future:

https://www.youtube.com/watch?v=LY_70PRgGzg