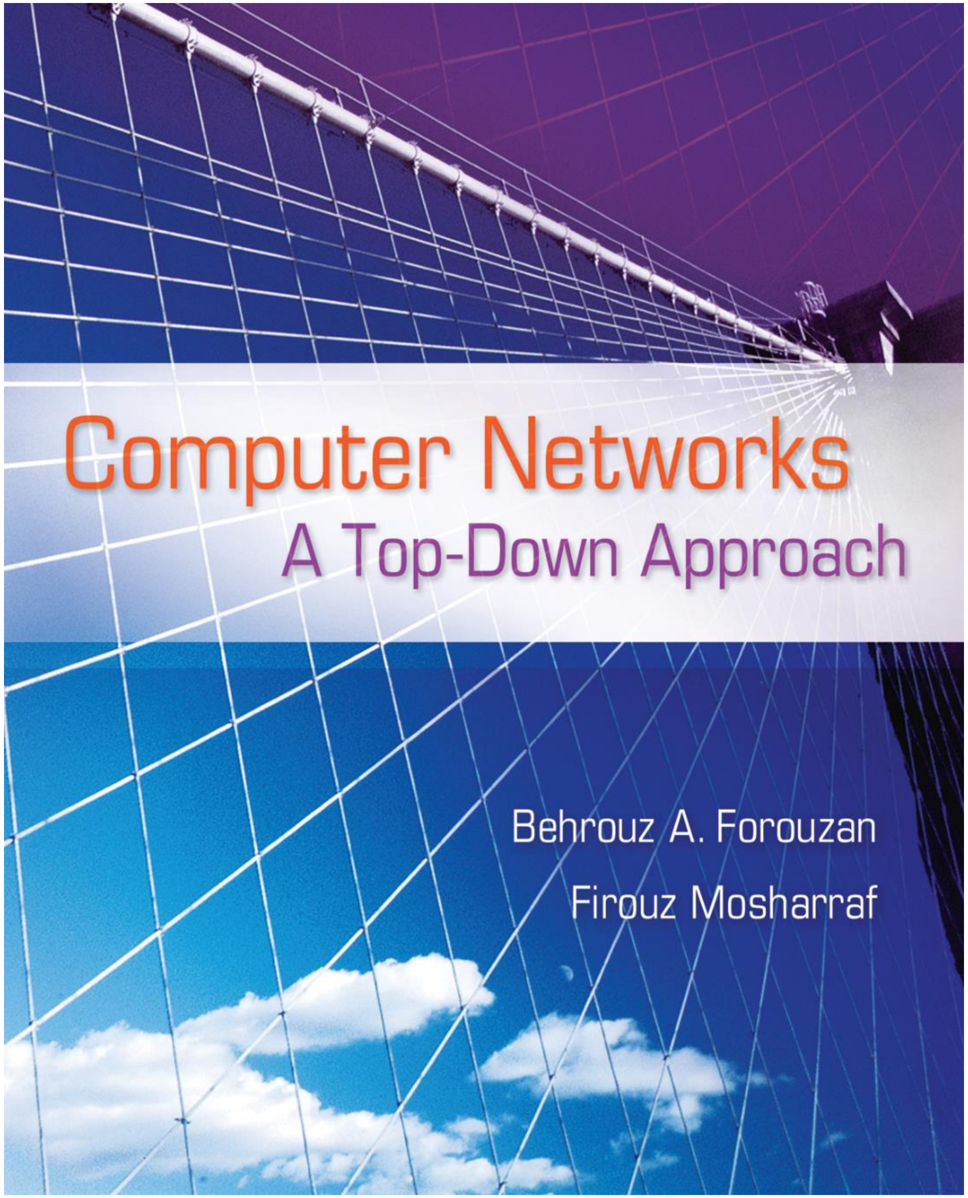
Chapter 1

Introduction



Chapter 1: Outline

1.1 Overview of the Internet

1.2 Network Models & Protocol Layering

OSI

TCP/IP

Circuit & Packet switching

1.3 Internet History

1.4 Standards and Administration

Chapter 1: Objective

- ***We introduce local area networks (LANs) and wide area networks (WANs) and show that an intranet or the Internet is a combination of these networks.***

- ***We introduce the concept of protocol layering to show how the task to be done by the Internet is divided into smaller tasks. We also discuss communication models OSI & TCP/IP protocol suite and show the duty of each layer.***

- ***Packet Switching & Circuit Switching***

- ***We give a brief history of the Internet.***

- ***We introduce the administration of the Internet and define the standards and their lifetime.***

1-1 OVERVIEW OF THE INTERNET

- First defining a network
- Connect networks to create small internetworks.
- Structure of the Internet and
- Study the Internet in the coming lectures

1.1.1 Networks

A network is the interconnection of a set of devices capable of communication.

A device can be a host such as a large computer, desktop, laptop, workstation, cellular phone, or security system.

A device in this definition can also be a connecting device such as a router, a switch, a modem that changes the form of data, and so on.

Types of Communication Networks

- Traditional
  - Traditional local area network (LAN)
  - Traditional wide area network (WAN)

- Higher-speed
  - High-speed local area network (LAN)
  - Metropolitan area network (MAN)
  - High-speed wide area network (WAN)
    - Point-to-Point WANs
    - Switched WANs

Characteristics of WANs

- Covers large geographical areas
- Circuits provided by a common carrier
- Consists of interconnected switching nodes
- Traditional WANs provide modest capacity
  - 64000 bps
  - Business subscribers using T-1 service – 1.544 Mbps
- Higher-speed WANs use optical fiber and transmission technique known as asynchronous transfer mode (ATM)
  - 10’s and 100’s of Gbps common

Characteristics of LANs

- Like WAN, LAN interconnects a variety of devices and provides a means for information exchange among them
- Traditional LANs
  - Provide data rates of 1 to 20 Mbps
- High-speed LANS
  - Provide data rates of 100 Mbps to 10 Gbps

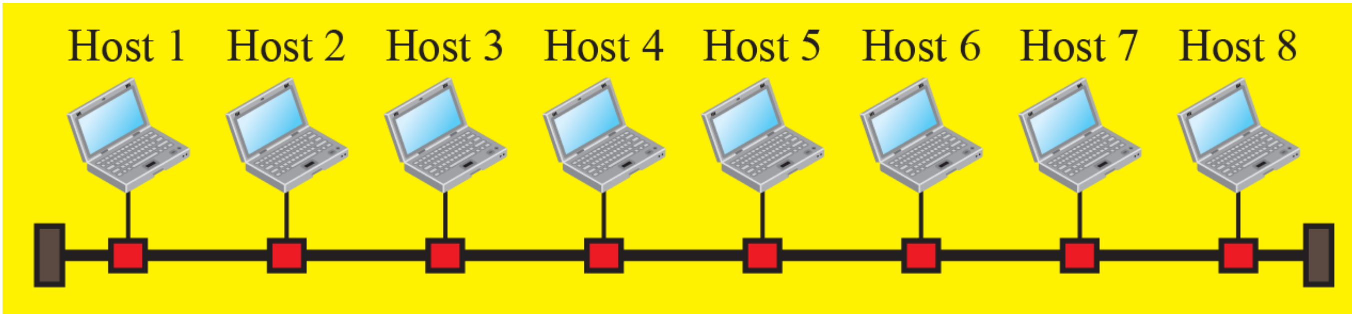
Differences between LANs and WANs

- Scope of a LAN is smaller
  - LAN interconnects devices within a single building or cluster of buildings
- LAN usually owned by organization that owns the attached devices
  - For WANs, most of network assets are not owned by same organization
- Internal data rate of LAN is much greater

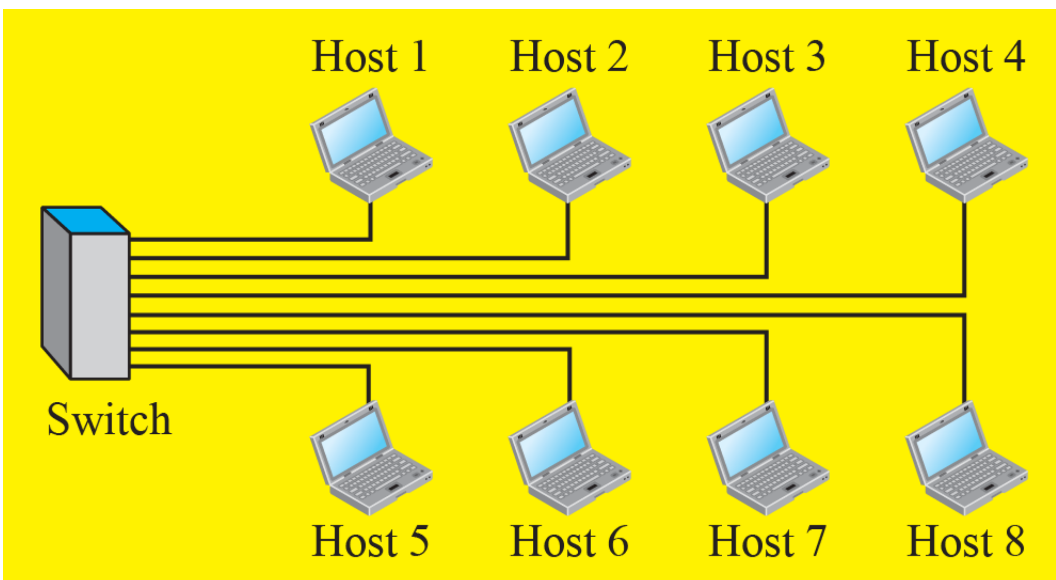
The Need for MANs

- Traditional point-to-point and switched network techniques used in WANs are inadequate for growing needs of organizations
- Need for high capacity and low costs over large area
- MAN provides:
  - Service to customers in metropolitan areas
  - Required capacity
  - Lower cost and greater efficiency than equivalent service from telephone company

Figure 1.1: *An Isolated LAN in the past and today*



a. LAN with a common cable (past)



b. LAN with a switch (today)

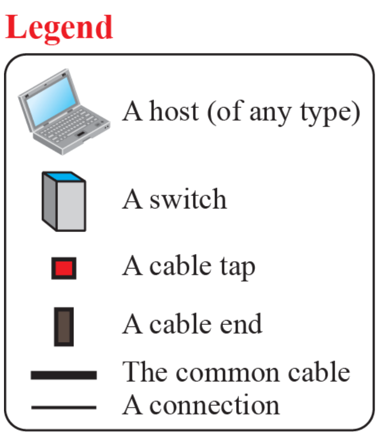


Figure 1.2: A Point-to-Point WAN

Figure 1.3: A Switched WAN

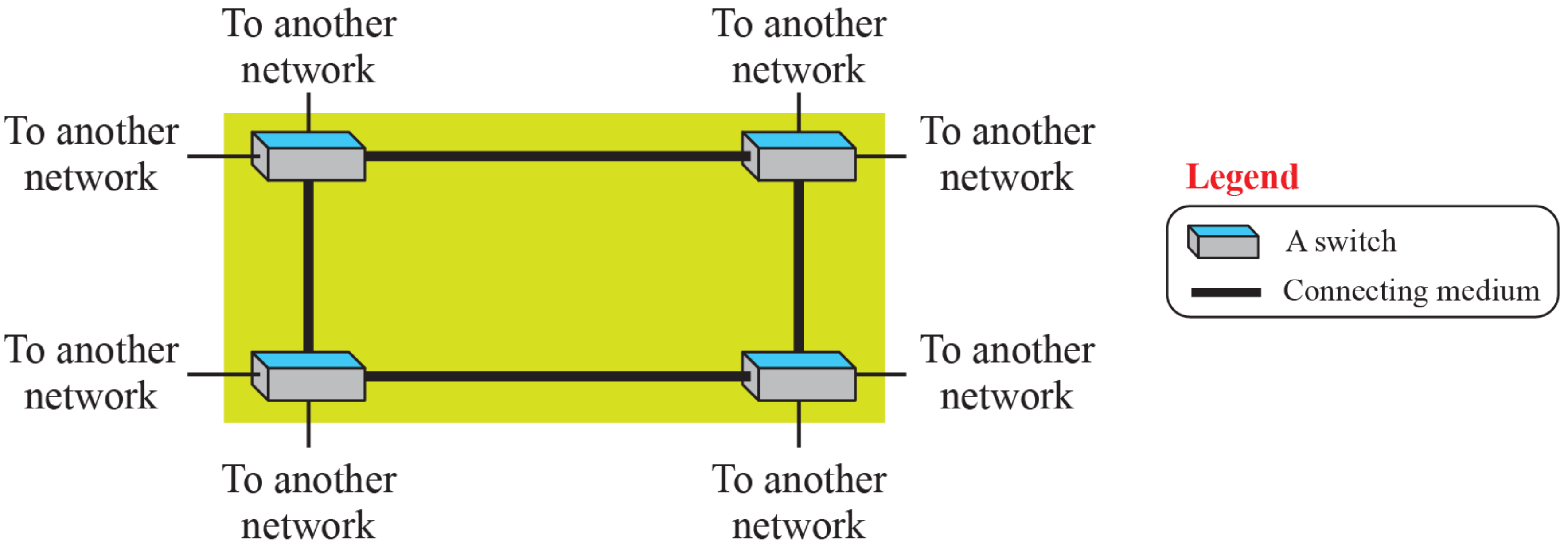


Figure 1.4: An internetwork made of two LANs and one WAN

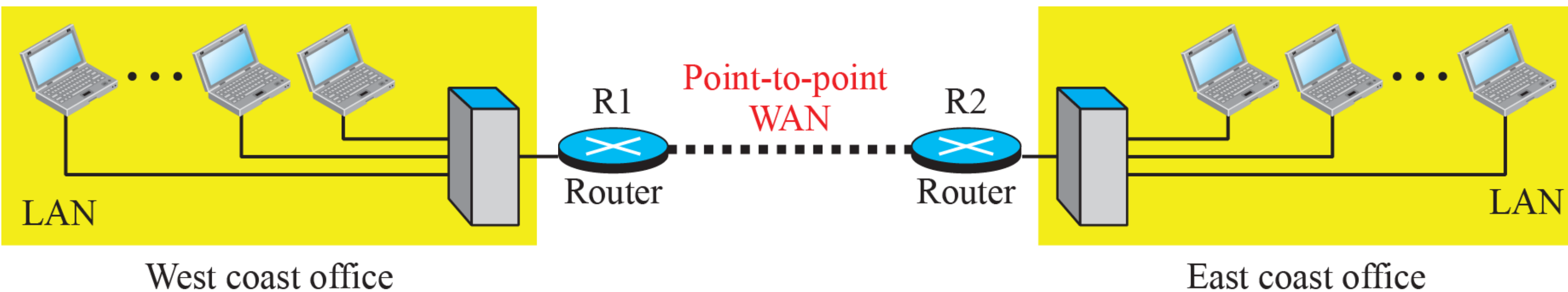
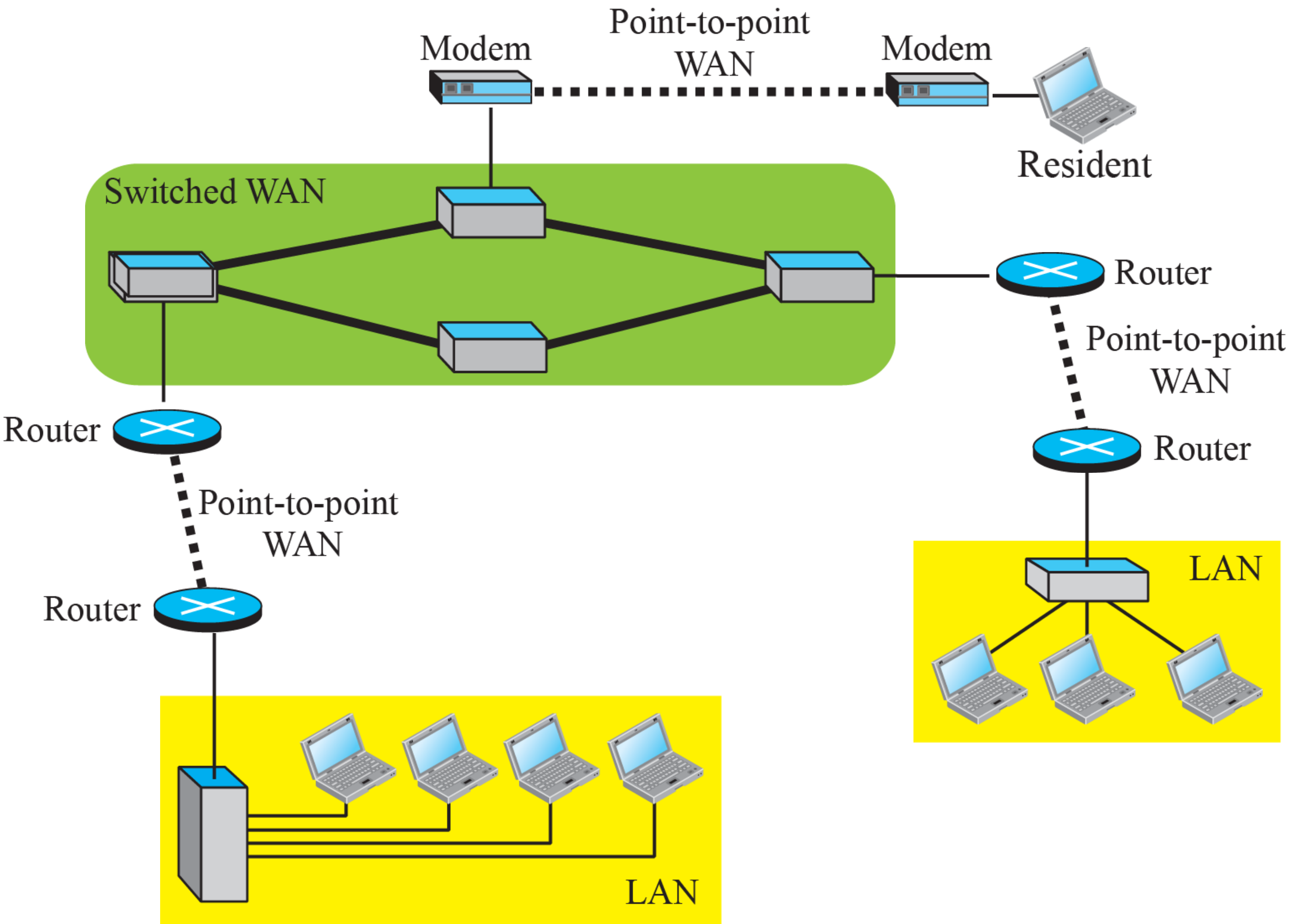


Figure 1.5: A heterogeneous network made of WANs and LANs



1.1.2 Switching

An internet is a switched network in which a switch connects at least two links together. A switch needs to forward data from a link to another link when required.

- ***Circuit-Switched Network***

- ***Packet-Switched Network***

Figure 1.6: A circuit-switched network

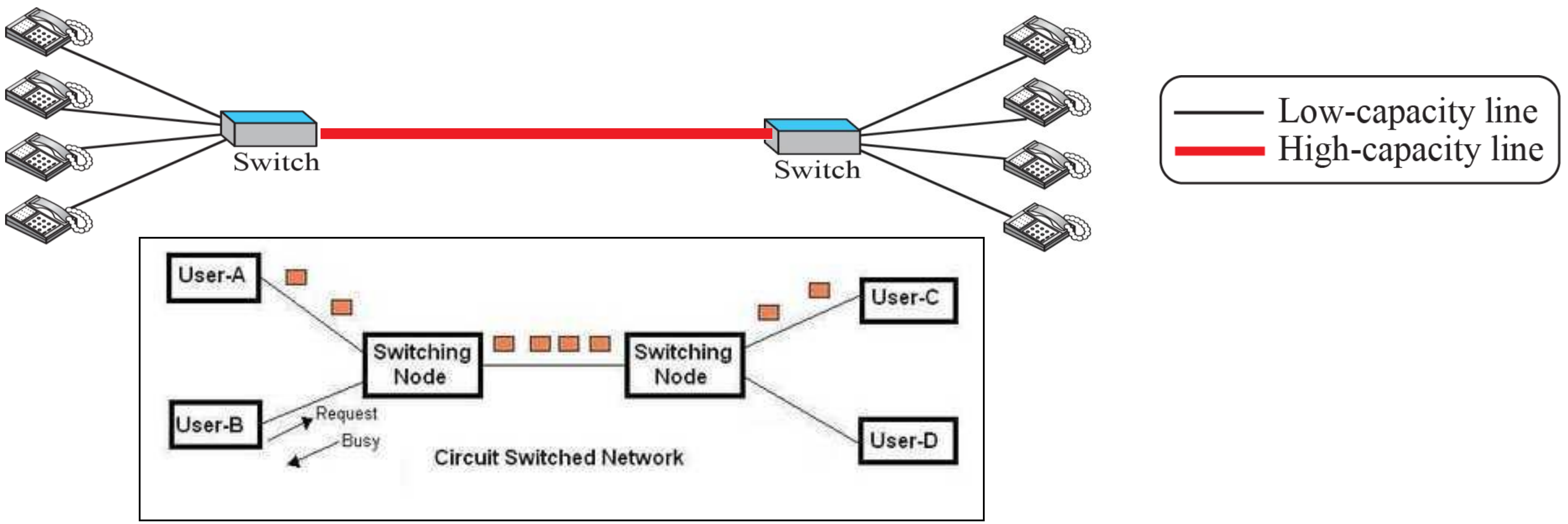
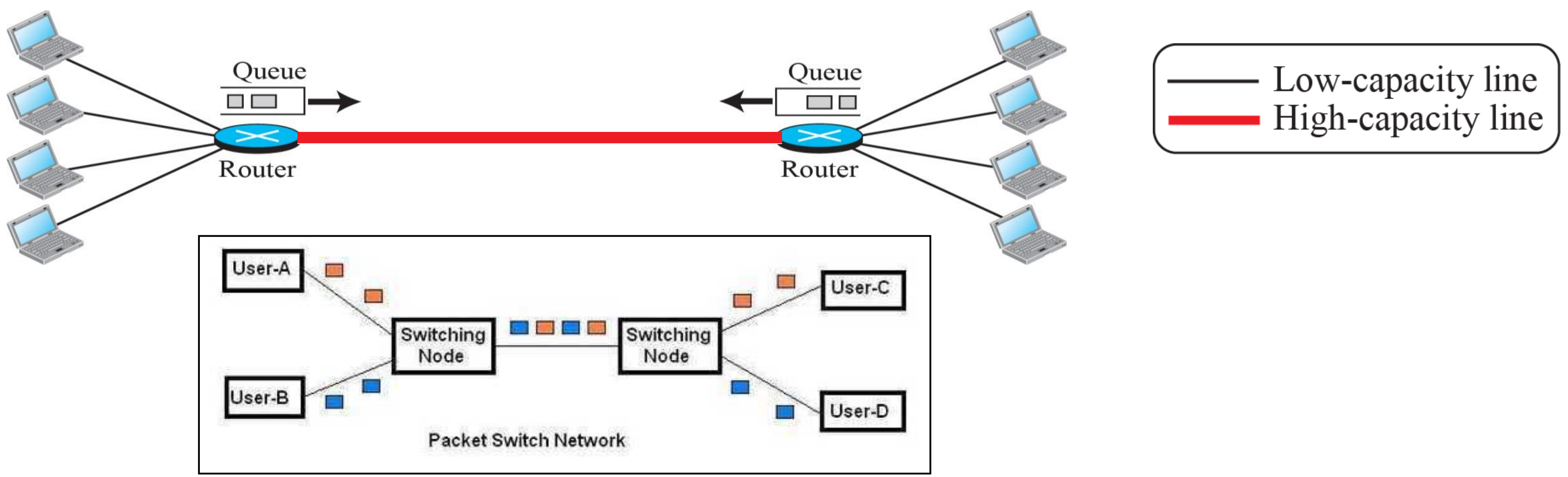


Figure 1.7: A packet-switched network



Switching Terms

- Switching Nodes:
  - Intermediate switching device that moves data
  - Not concerned with content of data
- Stations:
  - End devices that wish to communicate
  - Each station is connected to a switching node
- Communications Network:
  - A collection of switching nodes

Techniques Used in Switched Networks

- Circuit switching
  - Dedicated communications path between stations
  - e.g. public telephone network
- Packet switching
  - Message is broken into a series of packets
  - Each node determines next leg of transmission for each packet

Circuit Switching – connect phases

- Circuit **establishment**
  - An end to end circuit is established through switching nodes
  - Dedicated path for duration of connection,
    even when no data is being transmitted ! ?
- Information **Transfer**
  - Information transmitted through the network
  - Data may be analog voice, digitized voice, or binary data
- Circuit **disconnect**
  - Circuit is terminated (‘teardown’)
  - Each node de-allocates dedicated resources

Characteristics of Circuit Switching

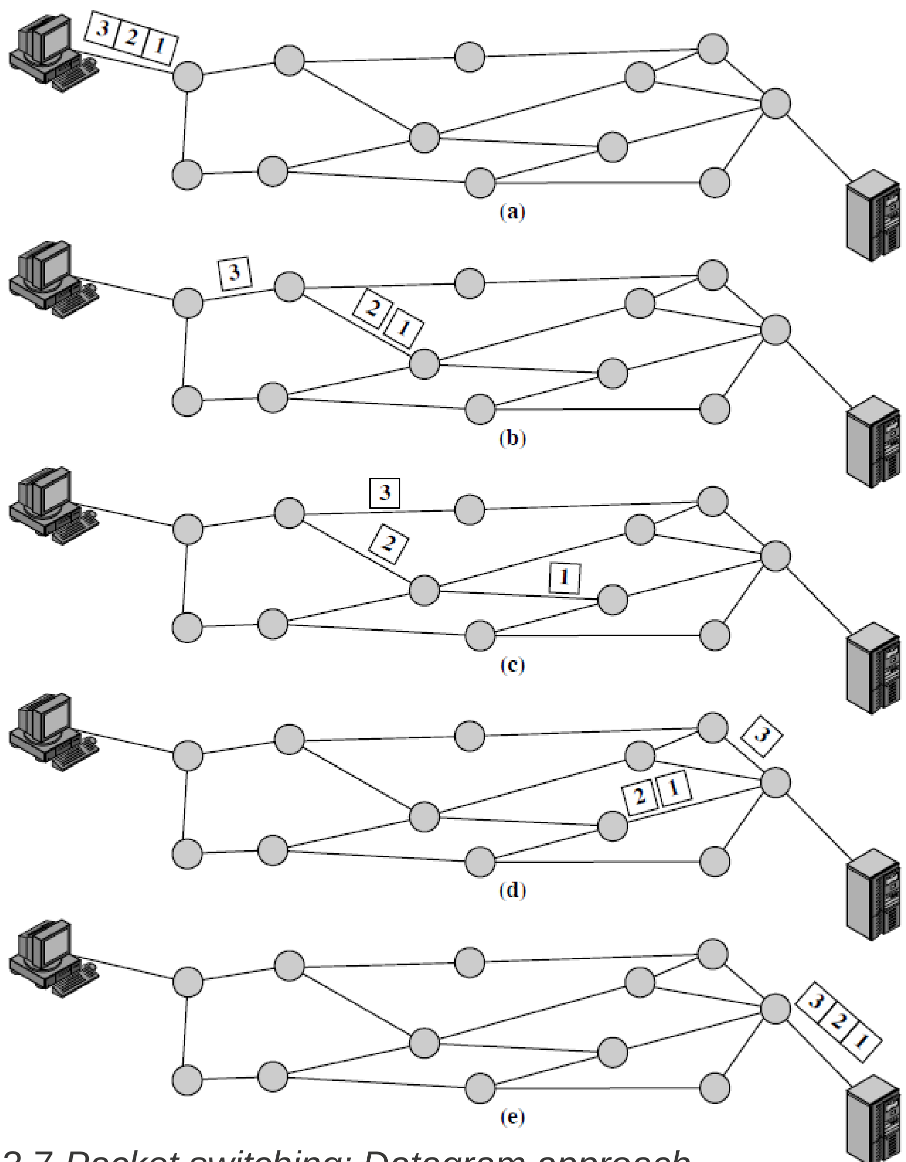
- Can be inefficient
  - Channel capacity dedicated for duration of connection
  - Utilization not 100%
  - Delay prior to signal transfer for establishment
- Once established, network is transparent to users
- Information transmitted at fixed data rate with only propagation delay

How Packet Switching Works

- Data is transmitted in blocks, called packets
- Before sending, the message is broken into a series of packets
  - Typical packet length is 1000 octets (bytes)
  - Packets consists of a portion of data plus a packet header that includes control information
- At each node en route, packet is received, stored briefly and passed to the next node

Packet Switching

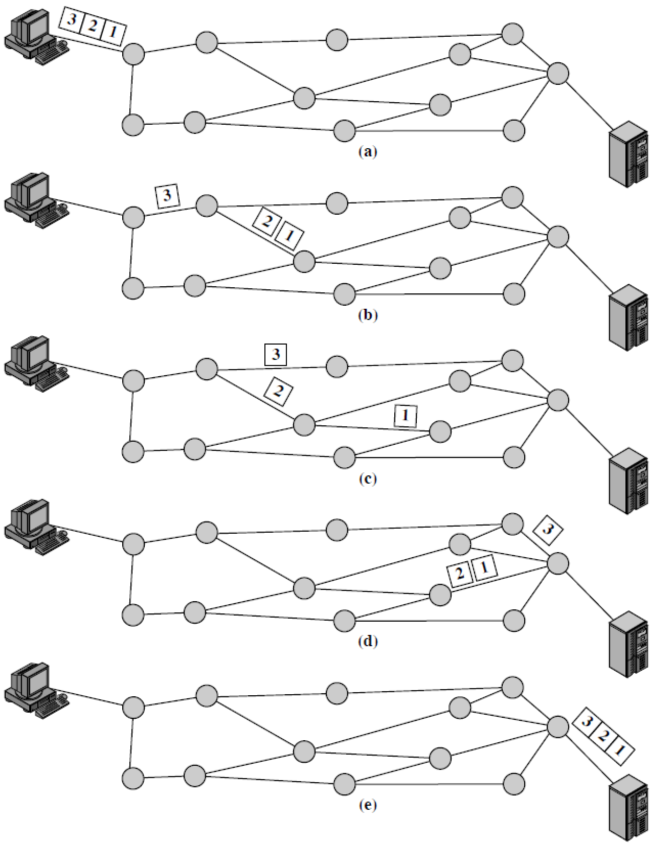
- No call setup or teardown
- Packets may take different paths
- Packets may arrive in different sequence or be lost in transit…
- New datagrams admitted even when network is congested!



Stallings – Fig 3.7 *Packet switching: Datagram approach*

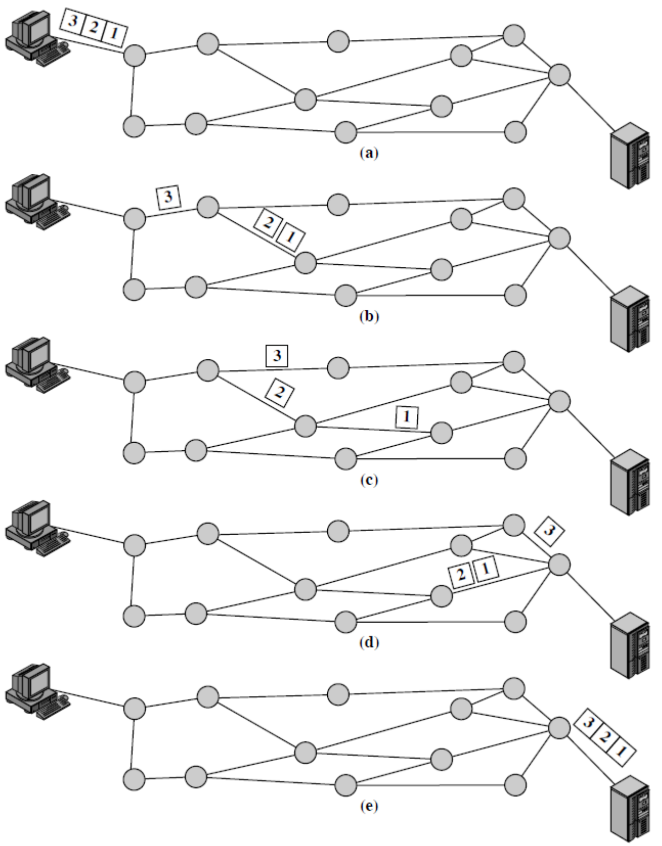
Packet Switching Advantages

- Line efficiency is greater
  - Many packets over time can dynamically share the same node to node link
- Packet-switching networks can carry out data-rate conversion
  - Two stations with different data rates can exchange information
- Unlike circuit-switching networks that block calls when traffic is heavy, packet-switching still accepts packets, but with increased delivery delay
- Priorities can be used



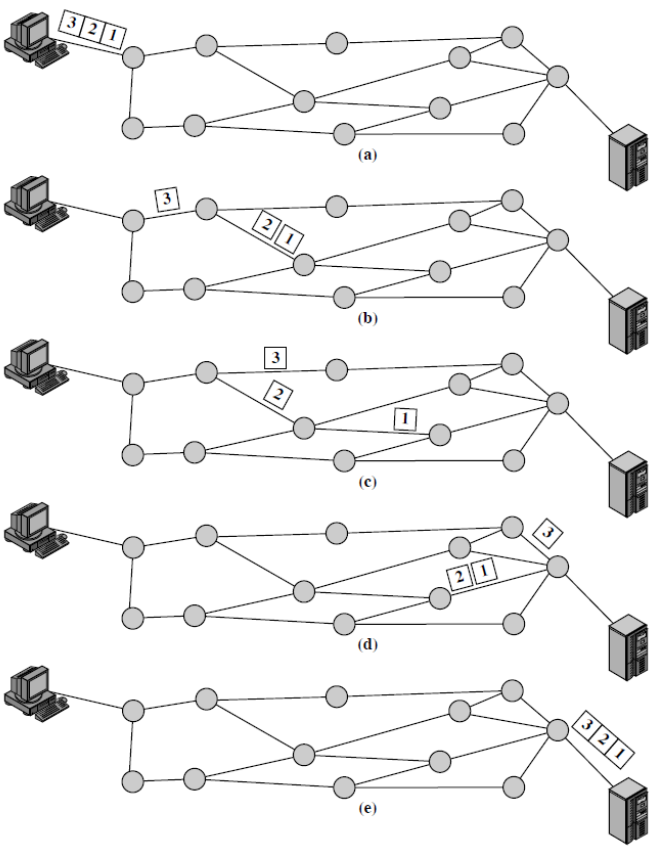
Disadvantages of Packet Switching

- Each packet switching node introduces a delay
- Overall packet delay can vary substantially
  - This is referred to as jitter
  - Caused by differing packet sizes, routes taken and varying delay in the switches
- Each packet requires overhead information
  - Includes destination and sequencing information
  - Reduces communication capacity
- More processing required at each node



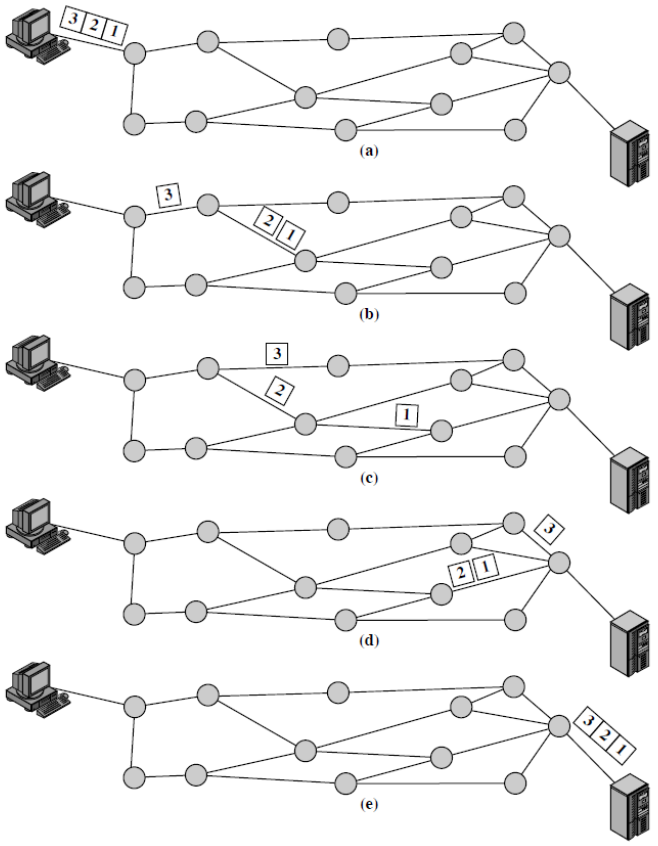
Packet Switching Networks - Datagram

- Each packet treated independently, without reference to previous packets
- Each node chooses next node on packet’s path
- Packets don’t necessarily follow same route and may arrive out of sequence
- Exit node usually restores packets to original order
- Responsibility of exit node or destination to detect loss of packet and take recover action (if any!)



Packet Switching Networks – Datagram

- Advantages:
  - Call setup phase is avoided
  - Because it's more primitive, it's more flexible
  - Datagram delivery is more reliable



Packet using Circuit switching

- Preplanned route established before packets sent
  - All packets between source and destination follow the same established route
- Routing decision not required by nodes for each packet
- Emulates a circuit in a circuit switching network but is not a dedicated path
  - Packets still buffered at each node and queued for output over a line
  - Only buffered, no routing..

Packet using Circuit switching

- Advantages:
  - Packets arrive in original order
  - Packets arrive correctly
  - Packets transmitted more rapidly without routing decisions made at each node

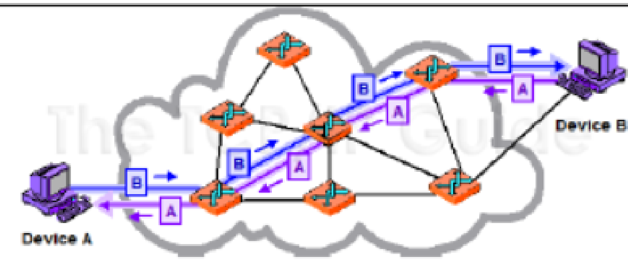
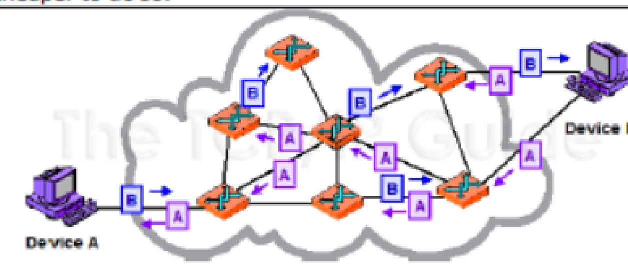
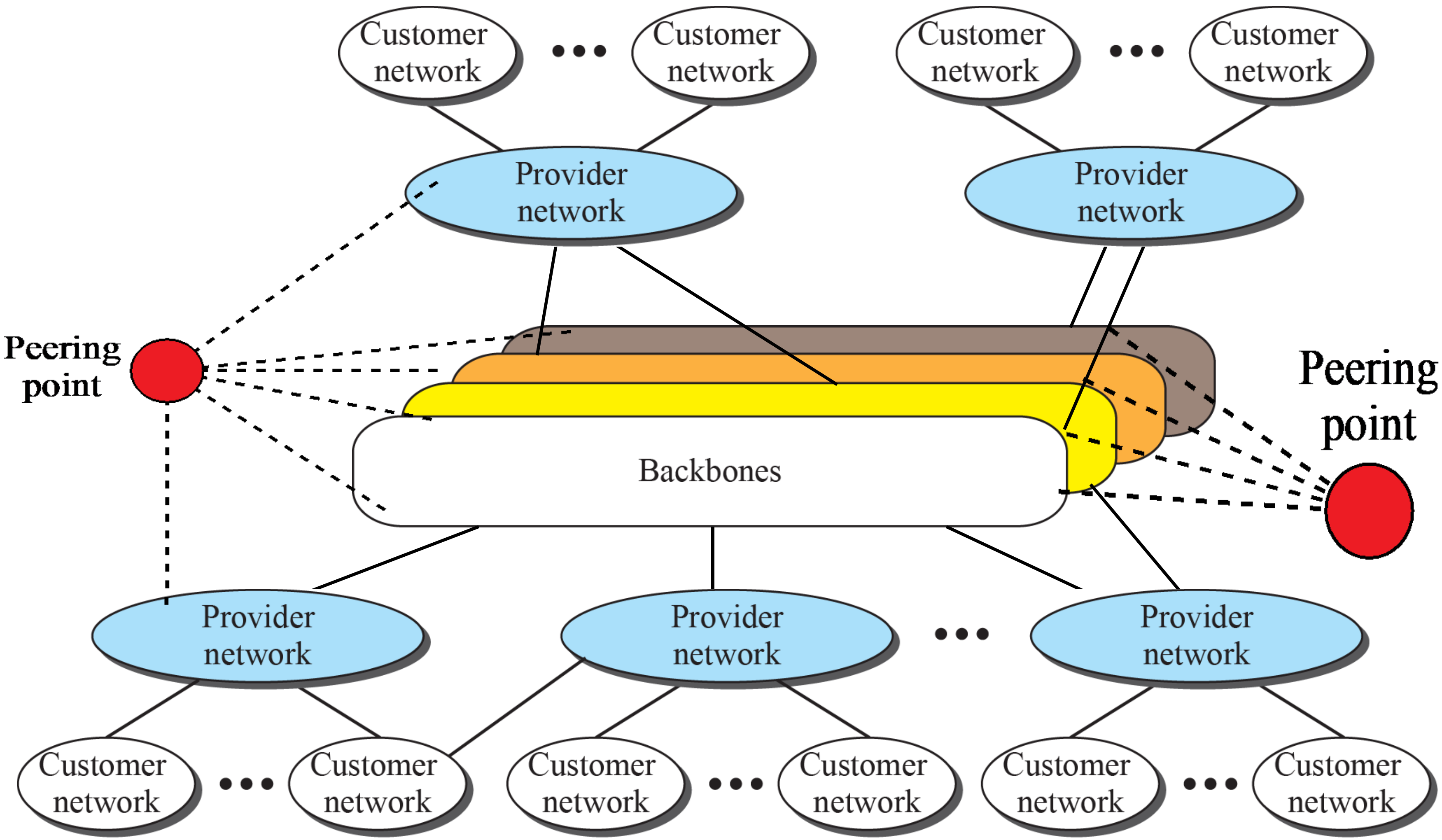
	Circuit Switching	Packet Switching
Dedicated "copper" path	Yes	No
Bandwidth Available	Fixed: BW is allocated in advance and is guaranteed for the entire transmission	Dynamic: BW is acquired and released dynamically on an as-needed basis. As packet-switched networks become overloaded with more traffic, delays and congestion are introduced.
Potentially wasted BW	Yes: network guarantees end-to-end BW. Hence, Circuit costs are independent of the amount of data being transmitted and hence any unused BW is wasted.	No end-to-end guarantee of BW and hence No BW is wasted, Hence Packet-switched network are more cost effective and offer better performance than circuit-switched networks.
Store-and-forward transmission	No	Yes
Each packet follows the same route/path	Yes	No
Call setup / VC	Required: Once the circuit is established, the full capacity of the circuit is available for use, and the capacity of the circuit will never be reduced due to other network activity	Not required: Several communications can occur between nodes concurrently using the virtual links over the same physical channel.
When will congestion occur	Only at setup time	On every packet
Charges	Per minute	Per Packet
Dedicated physical path	Yes: reserve end-to-end resources for a call.	No: Packets from different users share the network.
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Transparency	Yes	No
Physical Differences: Throughput	Throughout is heavily dependent on channels availability and costs	Easier to double or triple the throughput capacity and much cheaper to do so.
		
	In a circuit-switched network, before communication can occur between two devices, **a circuit is established** between them. This is shown as a thick **blue line** for the start of data from **Device *A* to Device *B***, and a matching **purple line** from ***B* back to *A*.** Once set up, all communication between these devices takes place over this circuit, even though there are other possible ways that data could possibly be passed over the network.	In a packet-switched network, **no circuit is set up prior to sending data between devices**. Blocks of data (Packets), even from the same file or communication, may take any number of paths as it journeys from one device to another.

Figure 1.8: The Internet today

The most notable internet is called the Internet and is composed of thousands of inter-connected networks. Figure1.8 shows a conceptual (not geographical) view of the Internet.



1.1.4 Accessing the Internet

- **Todays Internet is an internetwork that allows any user to become part of it.**
- **The user, however, needs to be physically connected to an ISP.**
- **The physical connection is normally done through a point-to-point WAN.**
- **In this section, we briefly describe how this can happen, but we postpone the technical details of the connection until Chapters 6 and 7.**

- ***Using Telephone Networks***
  - ***Dial-up Service***
  - ***DSL***
- ***Using Cable Networks***
- ***Using Wireless Networks***
- ***Direct Connection***

1.1.5 Hardware and Software

- *We have given the overview of the Internet structure.*
- *For communication to happen, we need both hardware and software.*
- *This is similar to a complex computation in which we need both a computer and a program.*
- *In the next section, we show how these combinations of hardware and software are coordinated with each other using protocol layering.*

1-2 PROTOCOL LAYERING

A word we hear all the time when we talk about the Internet is protocol.

- *A protocol defines the rules that both the sender and receiver and all intermediate devices need to follow to be able to communicate effectively.*
- *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.*

1.2.1 Scenarios

Let us develop two simple scenarios to better understand the need for protocol layering.

- ***First Scenario (Figure 1.9)***
- ***Second Scenario (Figure 1.10)***
- ***Principle of Protocol Layering***
- ***Logical Connections***

Figure 1.9: *A single-layer protocol*

Figure 1.10: *A three-layer protocol*

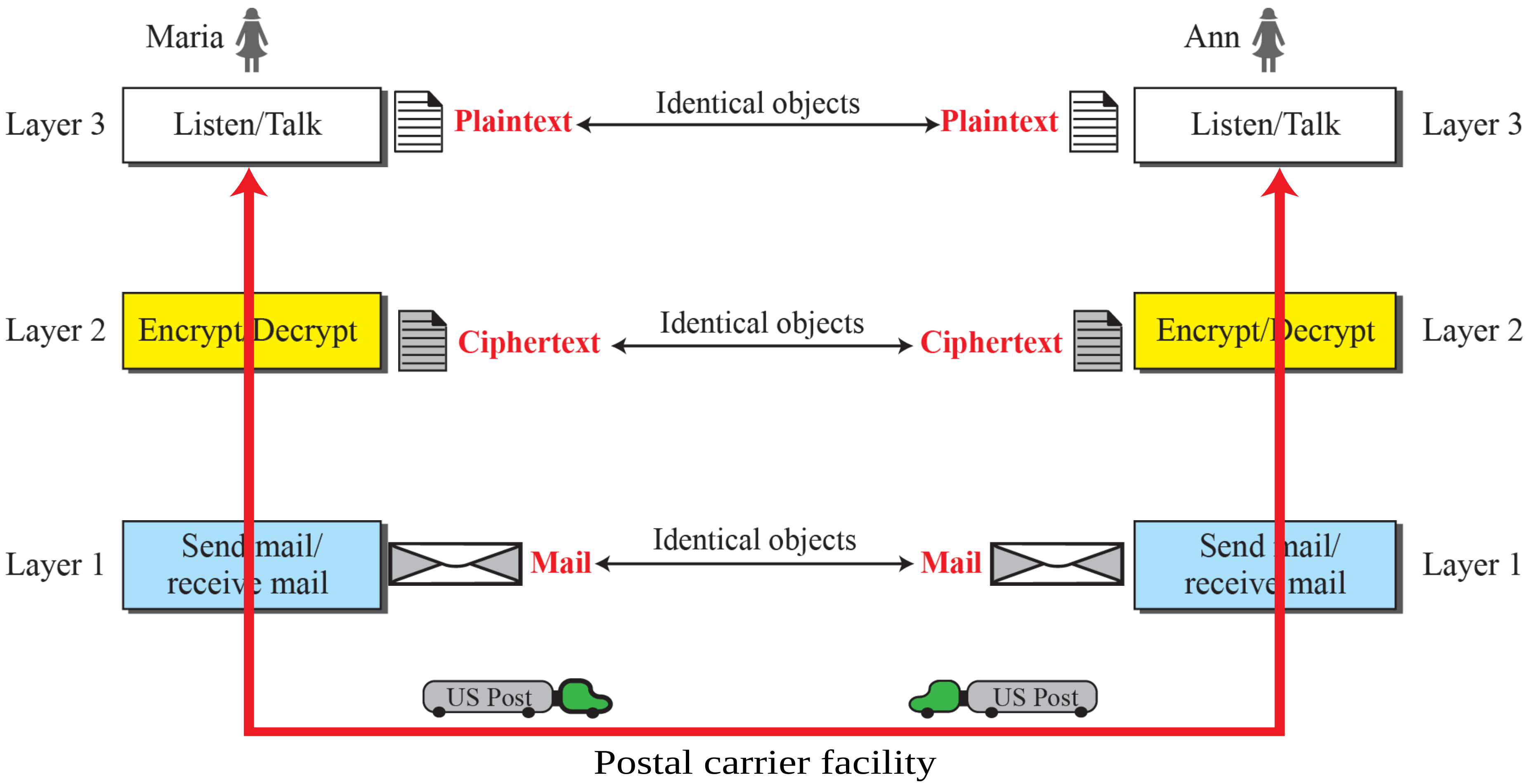
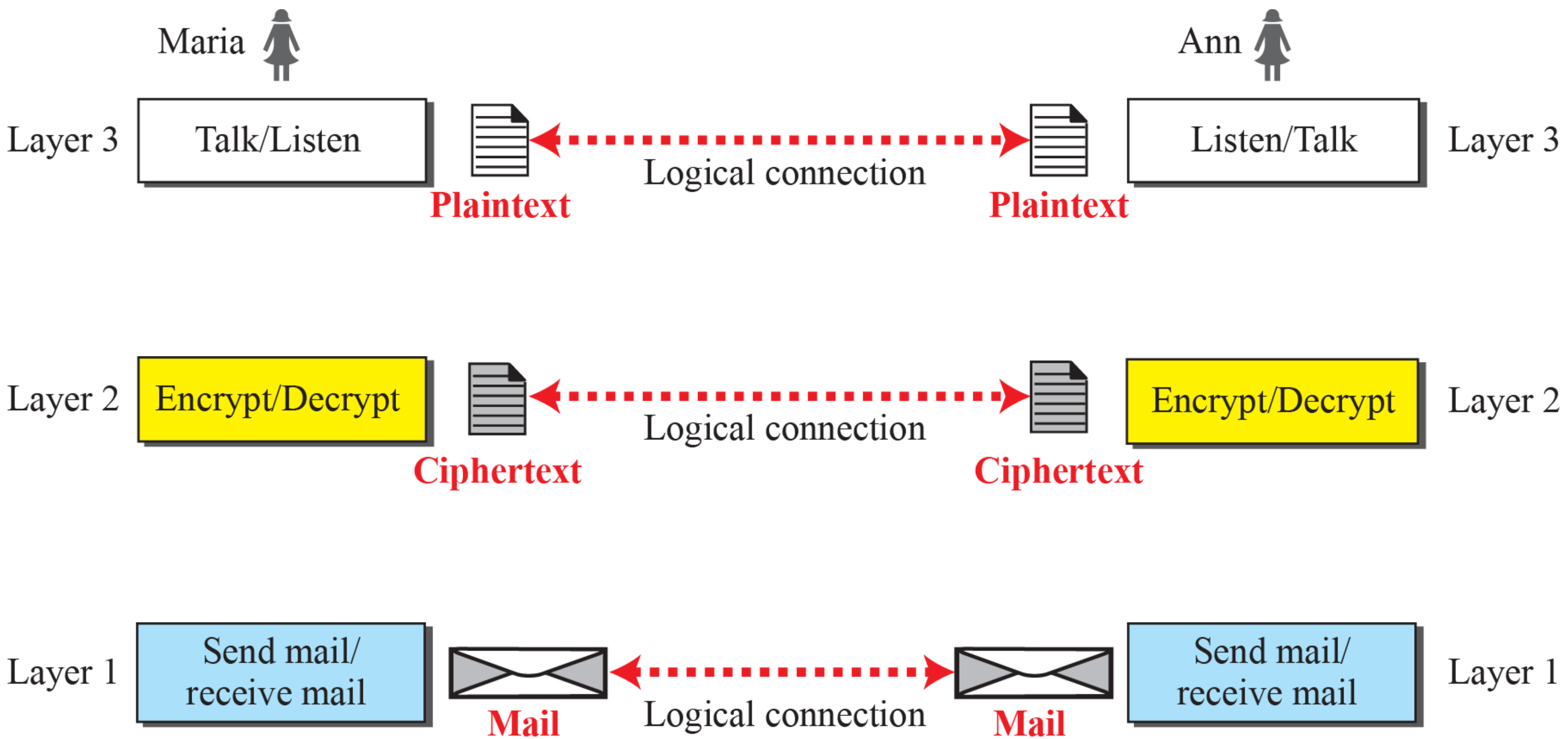


Figure 1.11: *Logical connection between peer layers*



1.2.2 TCP/IP Protocol Suite

- *TCP/IP is a protocol suite used in the Internet today*
- *It is a hierarchical protocol made up of interactive modules.*
- *Each of which provides a specific functionality.*
- *The term hierarchical means that each upper level protocol is supported by the services provided by one or more lower level protocols.*
- *The original TCP/IP protocol suite was defined as four software layers built upon the hardware.*
- *Today, however, TCP/IP is thought of as a five-layer model.*

1.2.2 TCP/IP Protocol Suite (continued)

- ***Layered Architecture***
- ***Layered in the Suite***
- ***Description of Each Layer***
  - ***Application Layer***
  - ***Transport Layer***
  - ***Network Layer***
  - ***Data-link Layer***
  - ***Physical Layer***

1.2.2 TCP/IP Protocol Suite (continued)

- ***Encapsulation and Decapsulation***
  - ***Encapsulation at the Source Host***
  - ***Decapsulation and Encapsulation at Router***
  - ***Decapsulation at the Destination Host***
- ***Addressing***
- ***Multiplexing and Demultiplexing***

Figure 1.12: Layers in the TCP/IP protocol suite

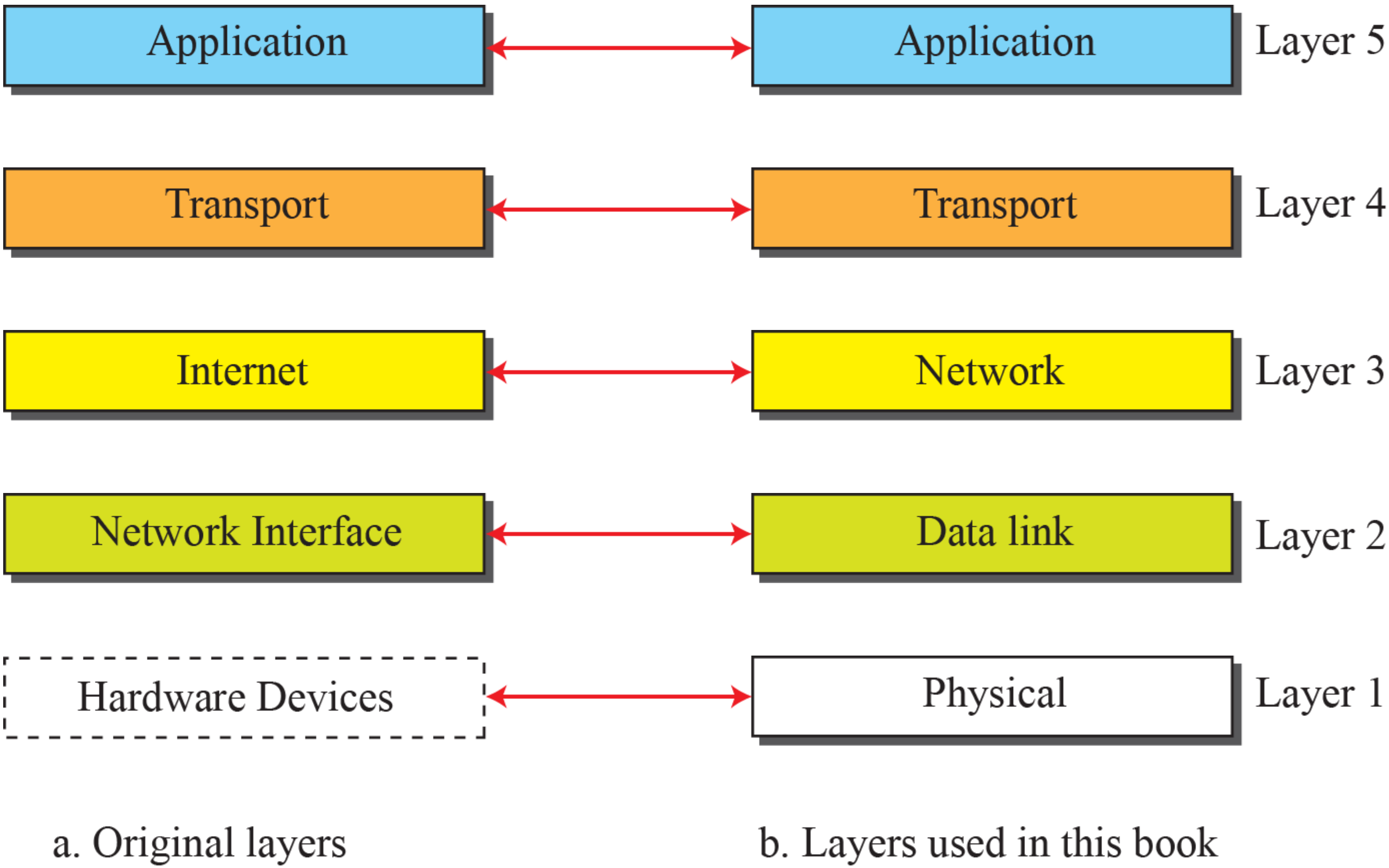


Figure 1.13: Communication through an internet

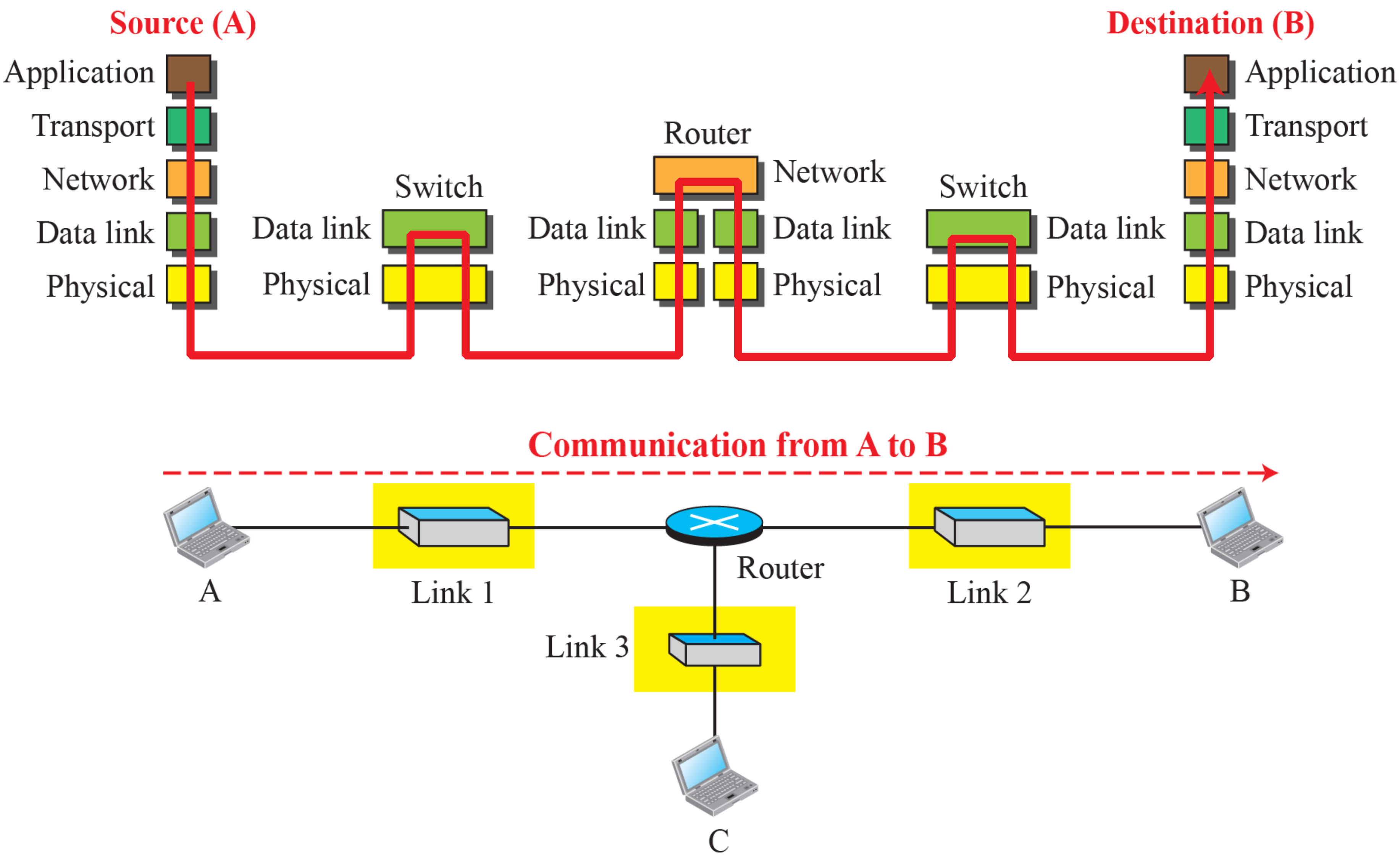


Figure 1.14: Logical connections between layers in TCP/IP

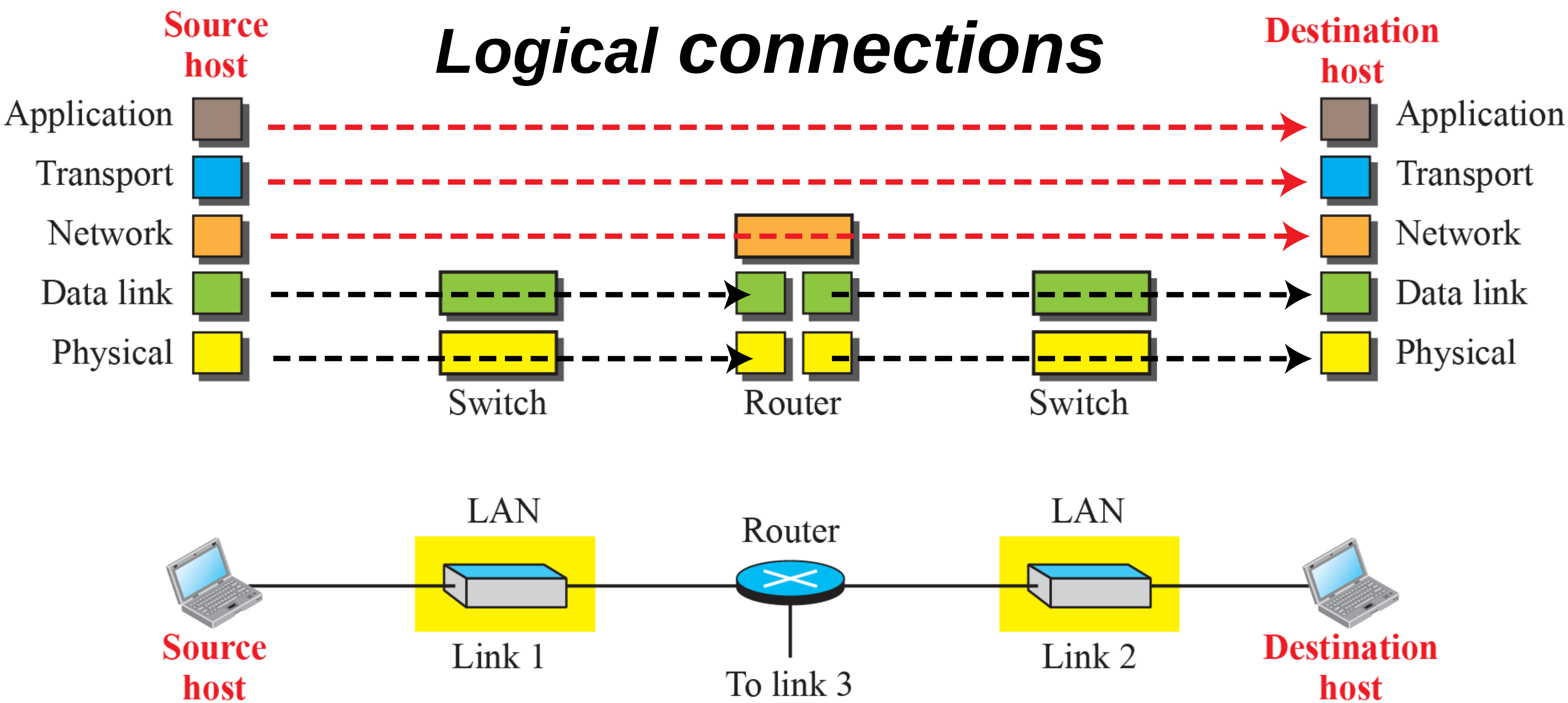


Figure 1.15: Identical objects in the TCP/IP protocol suite

Notes: We have not shown switches because they don't change objects.

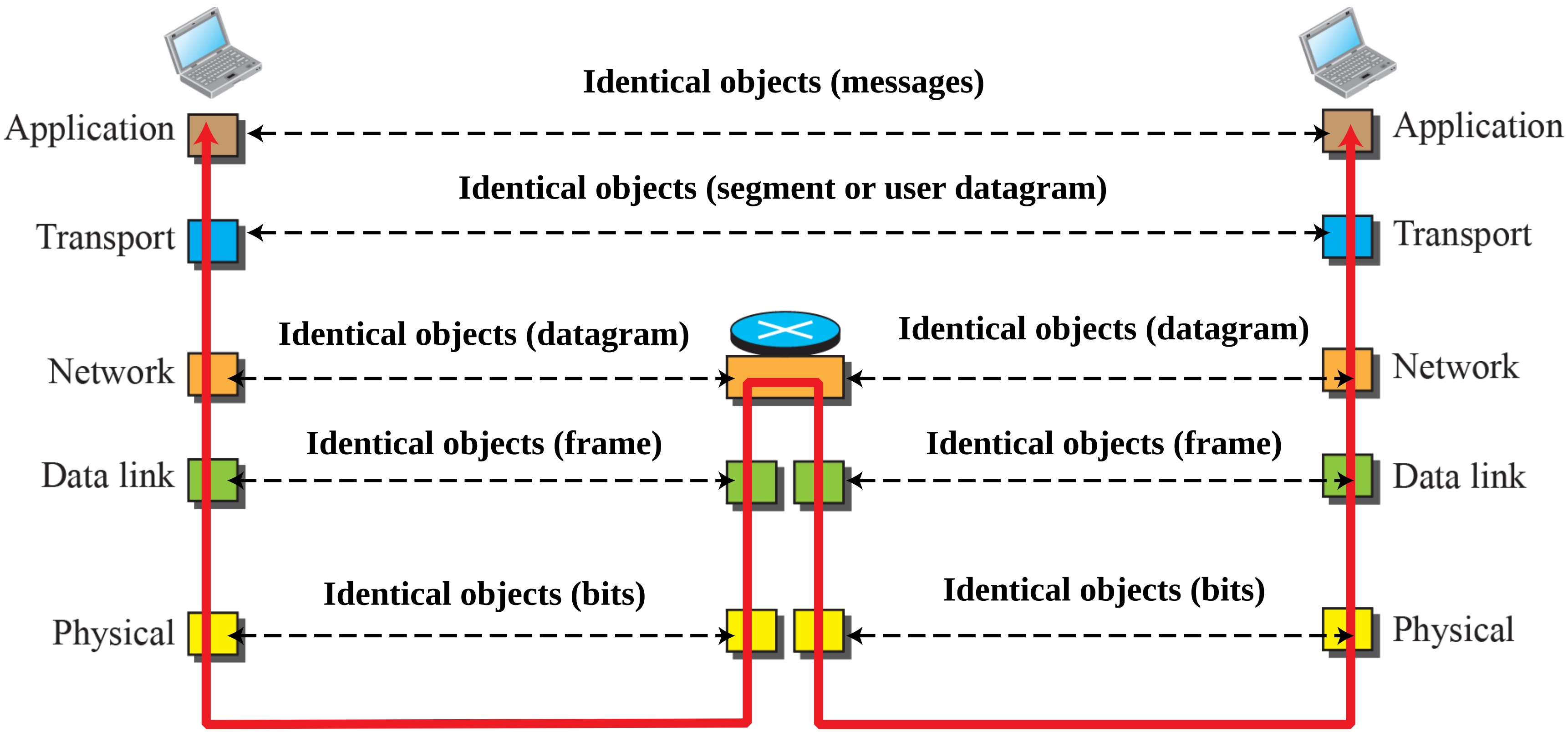


Figure 1.16: Encapsulation / Decapsulation

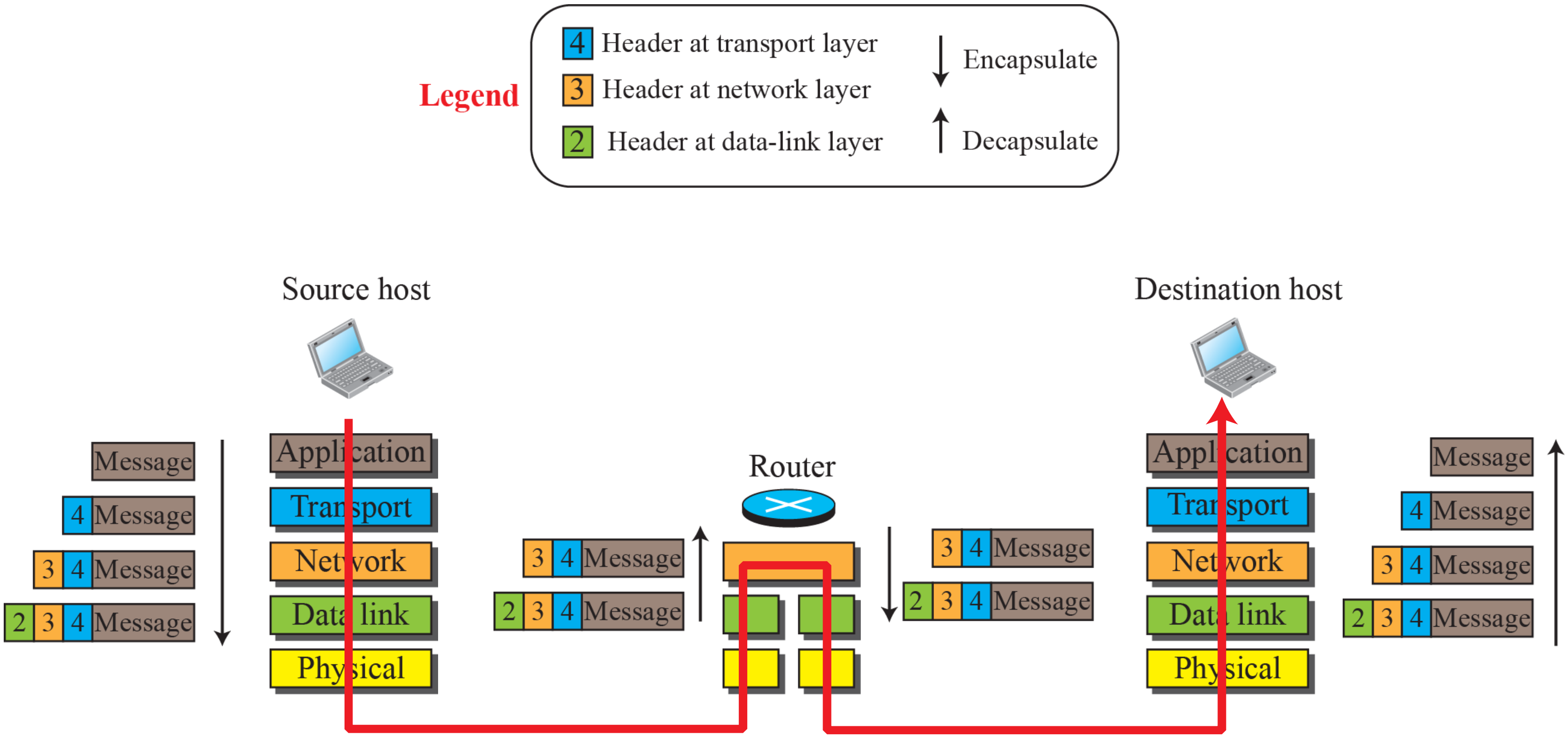


Figure 1.17: Addressing in the TCP/IP protocol suite

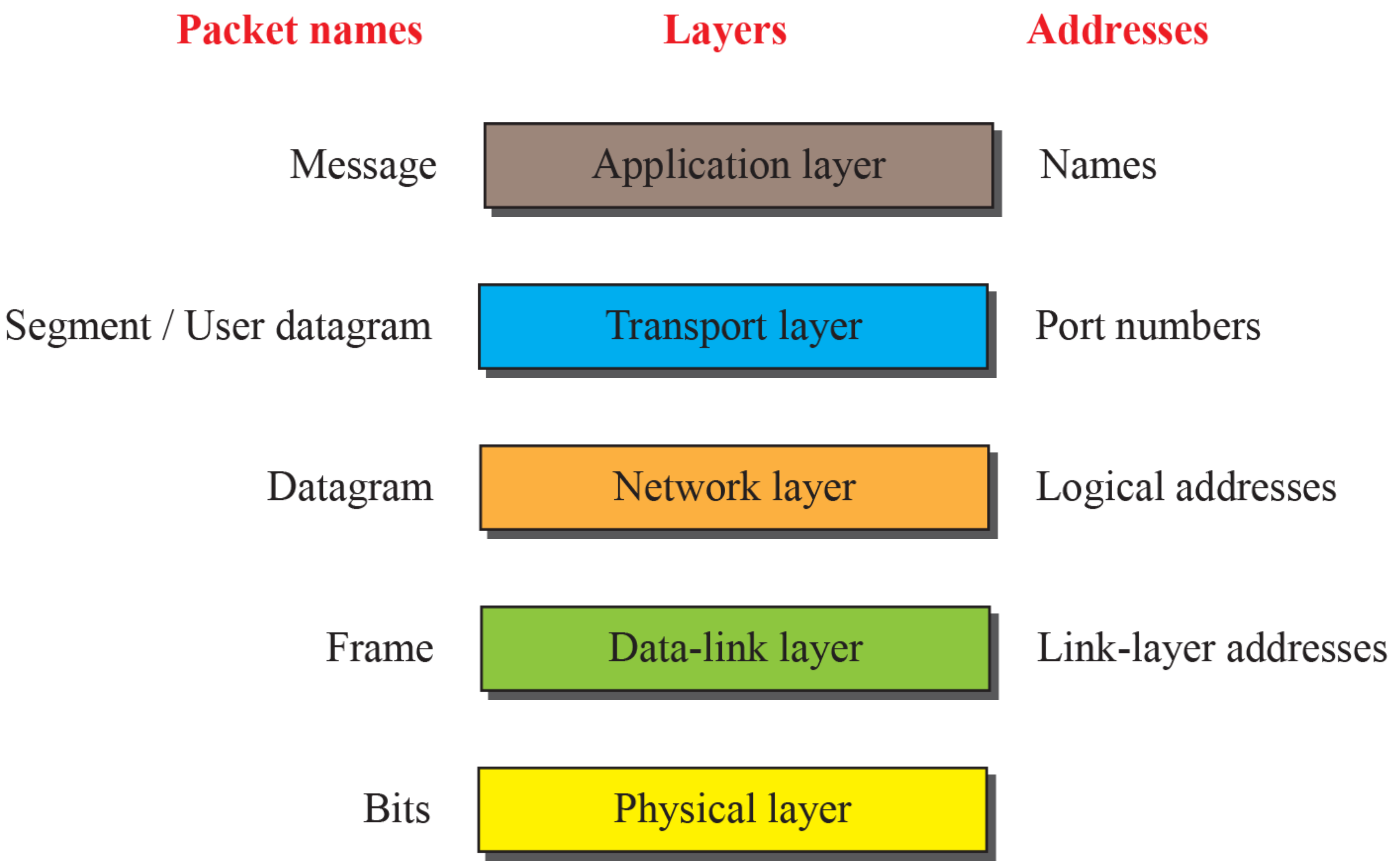
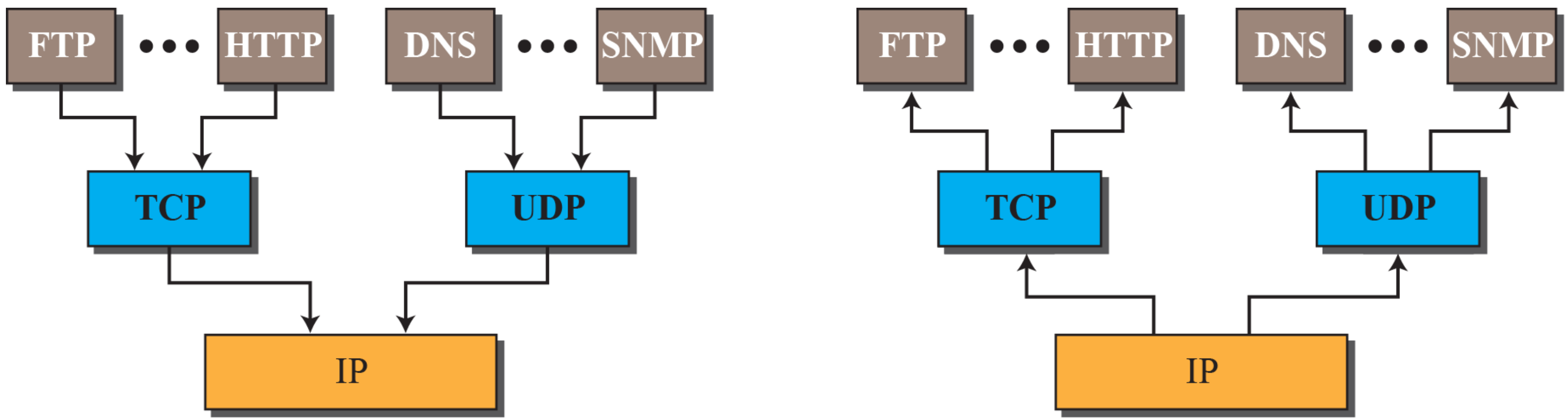


Figure 1.18: Multiplexing and demultiplexing



a. Multiplexing at source

b. Demultiplexing at destination

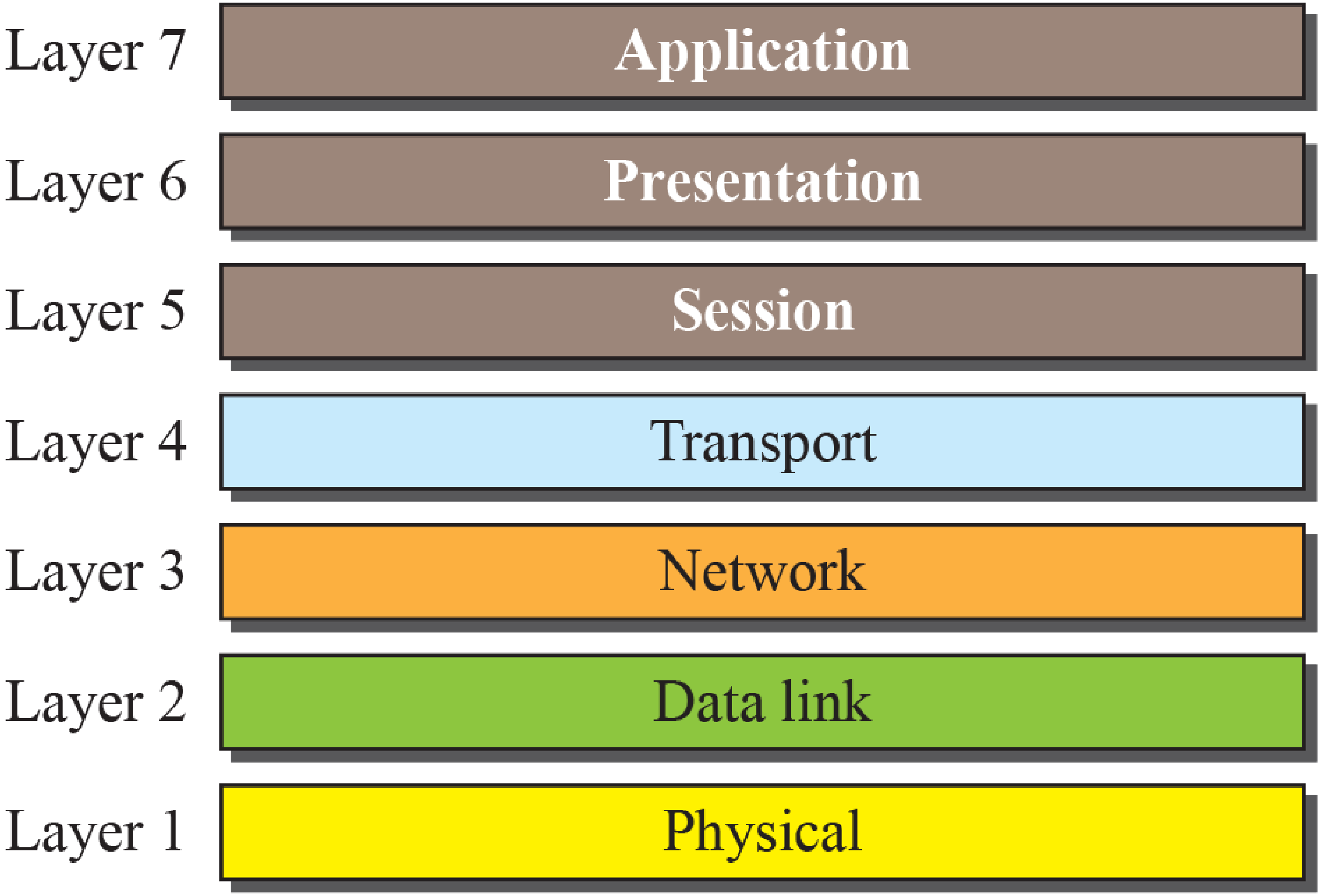
1.2.2 The OSI Model

- *OSI model established in 1947*
- *ISO is a multinational body dedicated to worldwide agreement on international standards.*
- *An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model.*
- *It was first introduced in the late 1970s.*

❑ ***OSI versus TCP/IP***

❑ ***Lack of OSI Model's Success***

Figure 1.19: The OSI model



Layer 1: Physical Layer

- Modulation, electrical, optical, radio-frequency and physical definition of the host to network interface.
- Modulation converts the digital data representation into a specific signal format imposed on the electrical, optical or radio-frequency channel.
- Contention between nodes for the transmission medium is usually handled in the physical layer.
- The definition of cables, connectors, and other physical components is part of the physical layer.
- The physical later determines most of the characteristics of point-to-point links used in a network.

Physical Layer - Examples

- 10-Base-5 (Thick-Ethernet)OR 10-Base-2 Thin-Ethernet – using BNCs.
- 10-Base-T Ethernet – Twisted pair using RJ connectors.
- 100-Base-T Ethernet - Twisted pair using RJ connectors.
- 1000-Base-T or 1-Gigabit Ethernet - Twisted pair using RJ connectors.
- 10-Gigibit Ethernet - Twisted pair using RJ connectors.

- RS-232C – EIA +/- 12V signalling using DB-9, DB-25.
- USB bus – TTL signalling using USB connectors.
- IEEE 1394 Firewire – using Firewire connectors.
- FDDI - Optical signalling
- ADSL – electrical over telephone cables

Layer 2: Data Link Layer

- Provides a functional / procedural way of transferring data between network nodes and detecting (and often correcting errors Physical layer transmission errors).
- An addressing scheme is used, which is typically hardcoded or preprogrammed in the network interface.
- In Ethernet (802.3) networks, the DLL is further subdivided into the Medium Access Control (MAC) layer and the IEEE 802.2 Logical Link Control (LLC) layer.
- Transmission protocols designed for DLL are typically strongly optimised for the specific physical layer they operate with.
- The DLL thus includes packet structures, and protocols for exchanging packets.
- *Switches* are layer 2 devices.

Layer 3: Network Layer

The Network layer will provide:

- A mechanism for transporting data payloads across one or more datalink layer networks.
- A mechanism for Quality of Service as required by upper layers.
- Fragmentation and defragmentation mechanisms to accommodate different Layer 2 network packet sizes.
- Route discovery and route maintenance mechanisms for the network.
- Error messaging or delivery management.
- *Routers* are layer 3 devices.

Layer 4: Transport Layer

The Transport layer will provide:

- A mechanism for the transparent transfer of data between end users.
- A mechanism for reliable/unreliable data transfer.
- In reliable protocols, error control (retransmission management) and flow control mechanisms.
- In reliable protocols, management of state information for virtual circuits across the network.
- Examples of Layer 4 protocols are
  - the Transmission Control Protocol (TCP) which is reliable, and
  - the User Datagram Protocol (UDP), which is unreliable.

Layer 5: Session Layer

The Session layer will provide:

- Control of dialogues or sessions between network hosts.
- Establishment, management and termination of connections between local and remote applications.
- Possibly duplex or half-duplex operation.
- Establishment of checkpointing, adjournment, termination, and restart procedures.
- Checkpointing and recovery of sessions is often not implemented.
- In the TCP/IP suite, session close functions are performed in TCP.

Layer 6: Presentation Layer

The Presentation layer will provide:

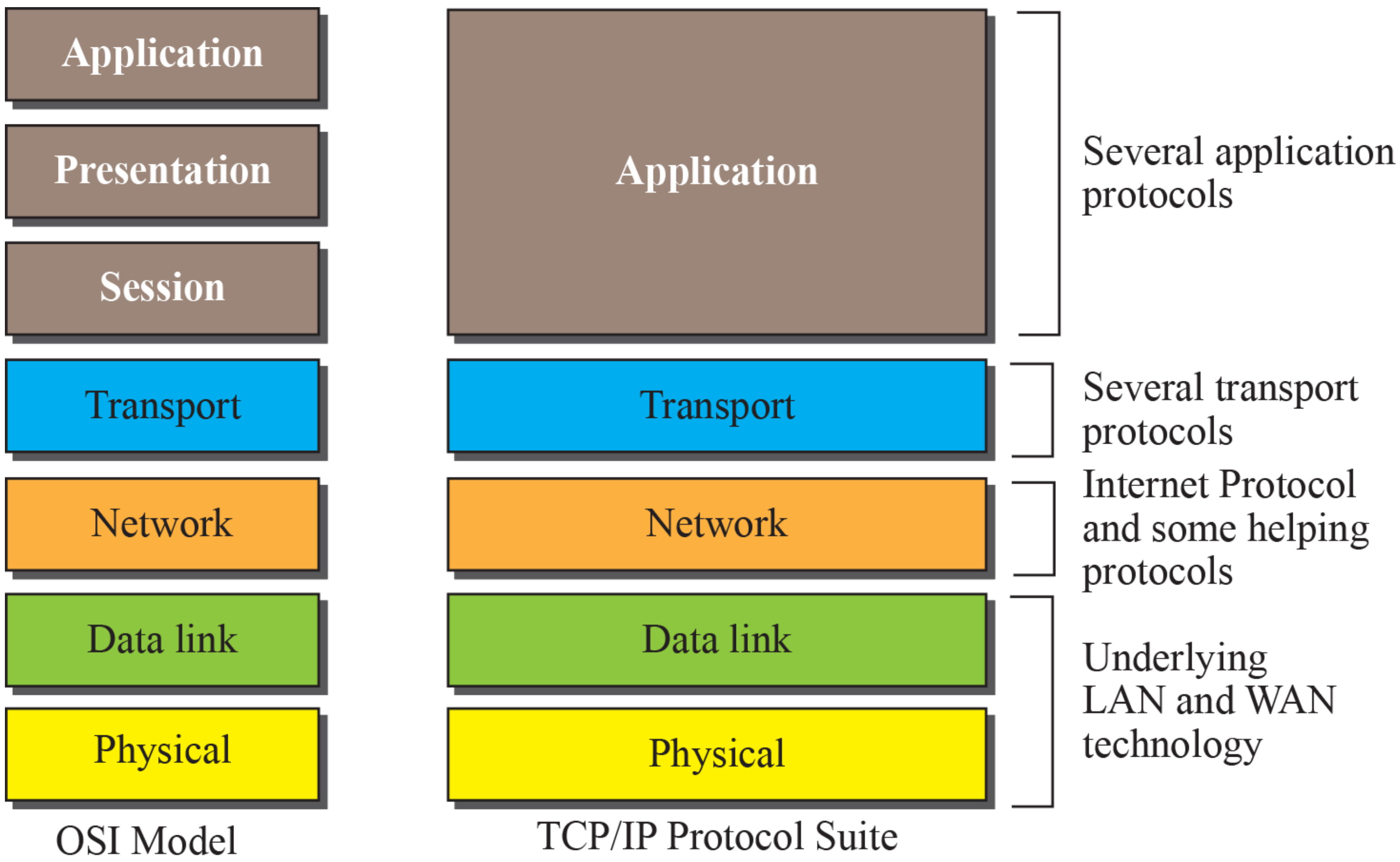
- Transformation of data formats intended to provide a standard or common interface for the Application layer.
- This is necessary to ensure that applications can handle data which may otherwise be in incompatible formats.
- Examples include the:
  - NFS (Network File System)
  - XDR (eXternal Data Representation) protocol which handles byte ordering and word sizes,
  - email MIME encoding,
  - data compression, Data encoding / decoding
  - data encryption techniques, IBM EBCDIC to ASCII conversion and vice versa.
- Presentation layer functions are often embedded in applications, such as browsers or mailers.

Layer 7: Application Layer

The Application layer will provide:

- A mechanism for accessing information on the network via an application.
- The primary interface between user applications.
- Examples include Telnet for remote logins, File Transfer Protocol (FTP) for file transfers, Simple Mail Transfer Protocol (SMTP) for email and Hypertext Transfer Protocol (HTTP) for web browsing.
- It is important to distinguish the protocol from the application.
- We might say 'use telnet to log in remotely' but this really means 'use an application program which can communicate using telnet protocol to log in remotely'.

Figure 1.20: TCP/IP and OSI model



1-3 INTERNET HISTORY

- ***Now that we have given an overview of the Internet and its protocol.***
- ***Let us give a brief history of the Internet.***
- ***This brief history makes it clear how the Internet has evolved from a private network to a global one in less than forty years.***

1.3.2 Early History

- ***There were some communication networks, such as telegraph and telephone networks, before 1960.***
- ***These networks were suitable for constant-rate communication at that time, which means that after a connection was made between two users, the encoded message (telegraphy) or voice (telephony) could be exchanged.***

- ***Birth of Packet-Switched Networks***

- ***ARPANET***

1.3.3 Birth of the Internet

- *In 1972, Vint Cerf and Bob Kahn, both of whom were part of the core ARPANET group, collaborated on what they called the Inter-netting Project.*
- *They wanted to link dissimilar networks so that a host on one network could communicate with a host on another.*
- *There were many problems to overcome:*
  - ☞ *diverse packet sizes,*
  - ☞ *diverse interfaces,*
  - ☞ *diverse transmission rates, as well as*
  - ☞ *differing reliability requirements.*

1.3.3 Birth of the Internet (continued)

- *TCP/IP*
- *MILNET*
- *CSNET*
- *NSFNET*
- *ANSNET*

1.3.3 Internet Today

- ***Today, we witness a rapid growth both in the infrastructure and new applications.***
- ***The Internet today is a set of pier networks that provide services to the whole world.***
- ***What has made the Internet so popular is the invention of new applications.***

❑ ***World Wide Web***

❑ ***Multimedia***

❑ ***Peer-to-Peer Applications***

1-4 STANDARDS AND ADMINISTRATION

- ***In the discussion of the Internet and its protocol, we often see a reference to a standard or an administration entity.***

- ***In this section, we introduce these standards and administration entities to familiarize***

1.4.1 Internet Standards

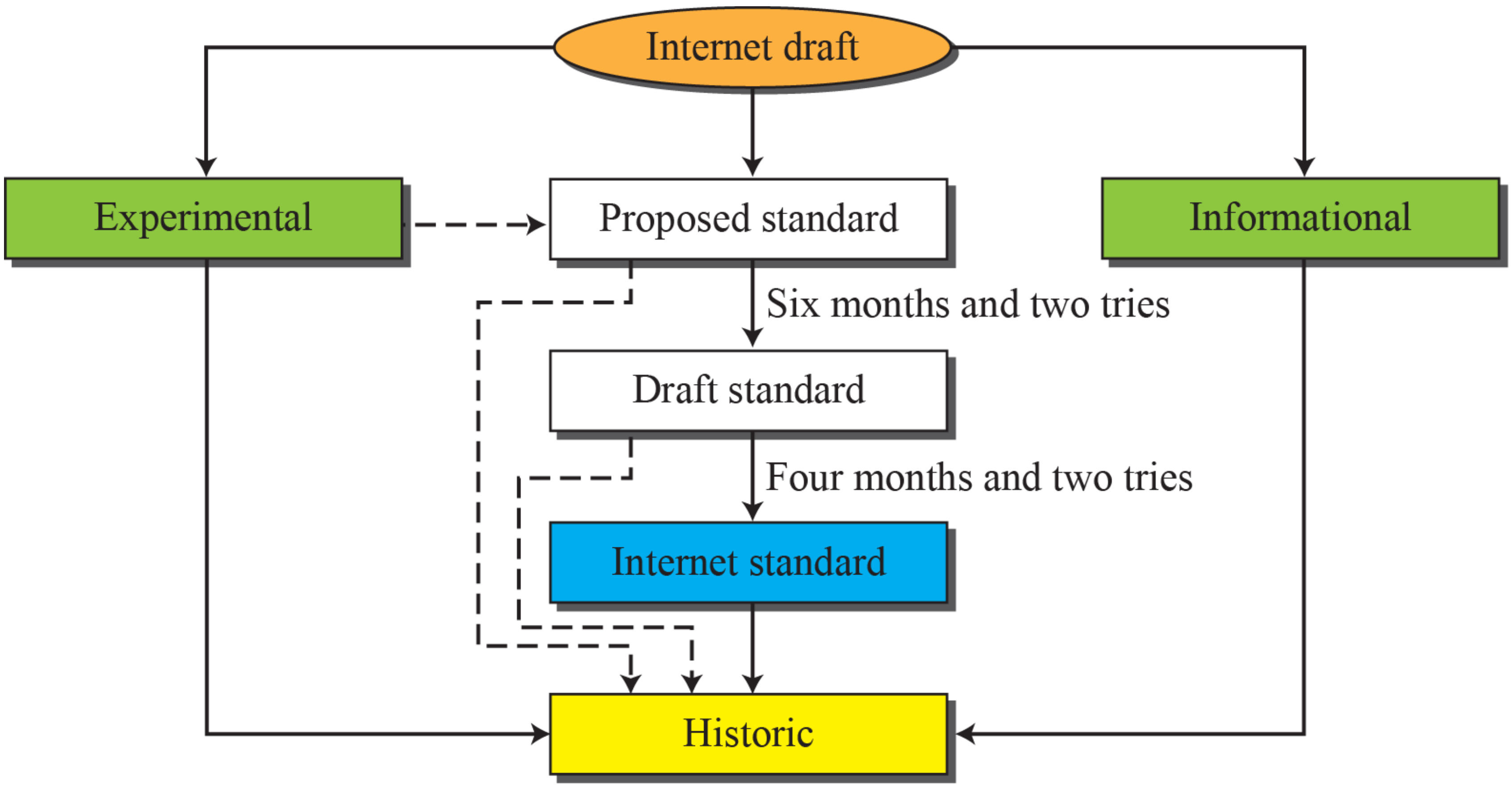
- ***An Internet standard is a thoroughly tested specification.***
- ***That is useful to and adhered to by those who work with the Internet.***
- ***It is a formalized regulation that must be followed.***
- ***There is a strict procedure by which a specification attains Internet standard status.***
- ***A specification that begins as a Internet draft.***

1.4.1 Internet Standards (Continued)

- ***Maturity Levels***
  - *Proposed Standard*
  - *Draft Standard*
  - *Internet Standard*
  - *Historic*
  - *Experimental*
  - *Informational*

- ***Requirement Levels***
  - *Required*
  - *Recommended*
  - *Elective*
  - *Limited Use*
  - *Not Recommended*

Figure 1.21: Maturity levels of an RFC



1.4.2 Internet Administration

- ***The Internet, with its roots primarily in the research domain, has evolved and gained a broader user base with significant commercial activity.***

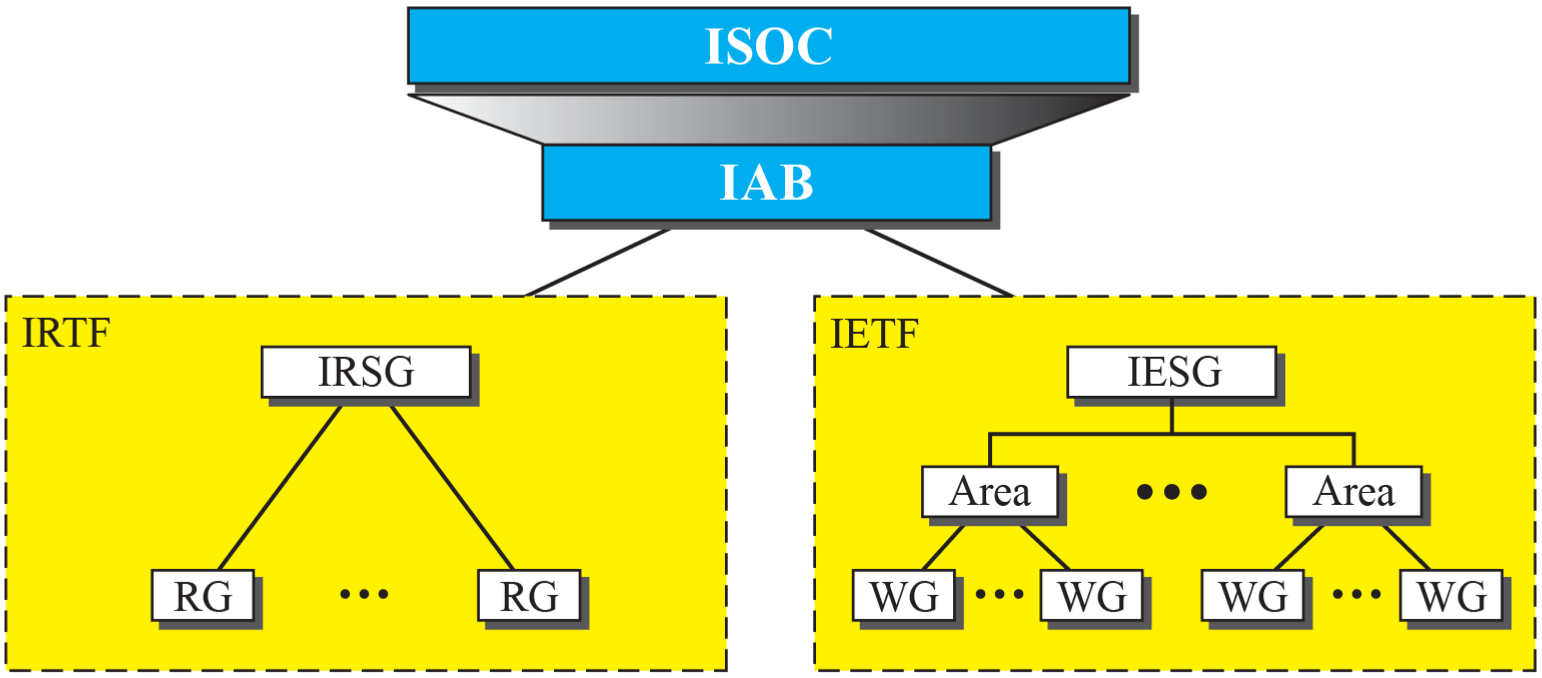
- ***Various groups that coordinate Internet issues have guided this growth and development.***

- ***Appendix D in the recommended textbook gives the addresses, e-mail addresses, and telephone numbers for some of these groups.***

1.4.2 Internet Administration (continued)

- ISOC
- IAB
- IETF
- IANA and ICANN
- Network Information Center (NIC)

Figure 1.22: Internet administration



Chapter 1: Summary

- ***A network is a set of devices connected by communication links.***
- ***The Internet today is made up of many WANs and LANs networks joined by connecting devices and switching stations.***
  - ***Most end users who want Internet connection use the services of Internet service providers (ISPs).***
  - ***There are backbone ISPs, regional ISPs, and local ISPs.***
- ***A protocol is a set of rules that governs communication. In protocol layering, we need to follow two principles to provide bidirectional communication.***
- ***OSI 7 – layer communication model***
- ***TCP/IP is a hierarchical protocol suite made of five layers: application, transport, network, data-link, and physical.***

Chapter 1: Summary (continued)

- ***The Internet history of internetworking started***
  - ***with ARPA in the mid-1960s.***
  - ***The birth of the Internet can be associated with the work of Cerf and Kahn and the invention of a gateway to connect networks.***
- ***The Internet administration has evolved with the Internet.***
  - ***We discussed ISOC, IAB, IETF, IRTF, ICANN, and NIC.***
- ***An Internet standard is a thoroughly tested specification.***
  - ***An Internet draft is a working document with no official status and a six-month lifetime.***
  - ***A draft may be published as a Request for Comment (RFC). RFCs go through maturity levels and are categorized according to their requirement level.***

References

- Computer Networks A Top-Down Approach by Behrouz A. Forouzan & Firouz Mosharraf by Mc Graw Hill 1st edition 2012
- Open Systems Interconnection Reference Model (OSI) - http://en.wikipedia.org/wiki/OSI_model
- Kopp C., *An introduction to cable modems*, *Cable Modem Technology*, Asia/Pacific Open Systems Review, Sydney Australia, August 1996, 60-63, 4pp.
- Kopp C., *Digital subscriber line technologies - The technical issues,* Asia/Pacific Open Systems Review, Sydney Australia, September 1996, 50-51, 2pp.
- Kopp C., *Networking - A perspective, PPP Protocol,* Asia/Pacific Open Systems Review, Sydney Australia, November 1996, 24-28, 5pp.