PROTOCOL LAYERING

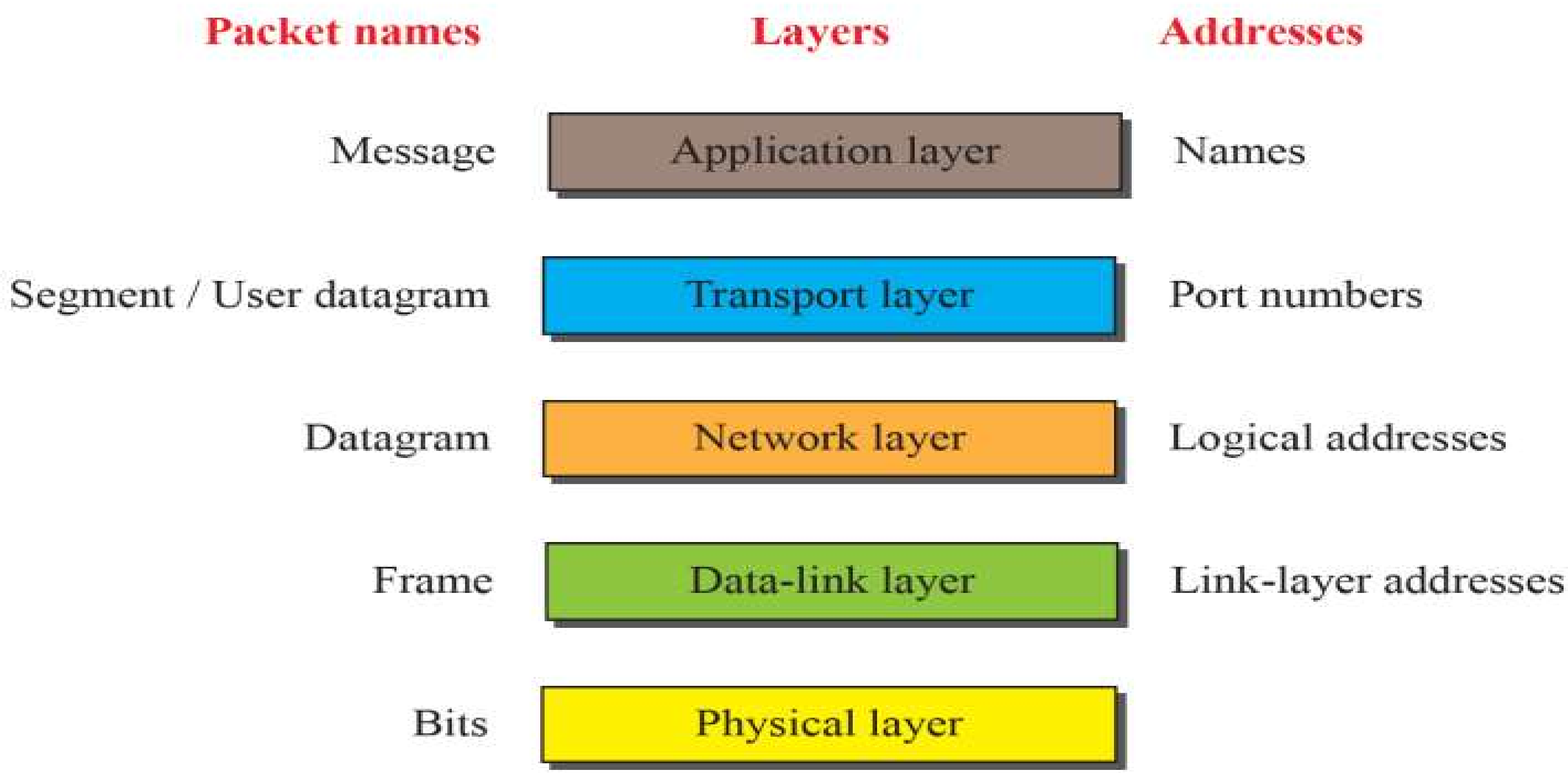
Addressing

- We have logical communication between pairs of layers in this model.
- Any communication that involves two parties needs two addresses: source address and destination address.
- Although it looks as if we need five pairs of addresses, one pair per layer, we normally have only four because the physical layer does not need addresses; the unit of data exchange at the physical layer is a bit, which definitely cannot have an address.

PROTOCOL LAYERING

Addressing

Figure 1.17: ***Addressing in the TCP/IP protocol suite***



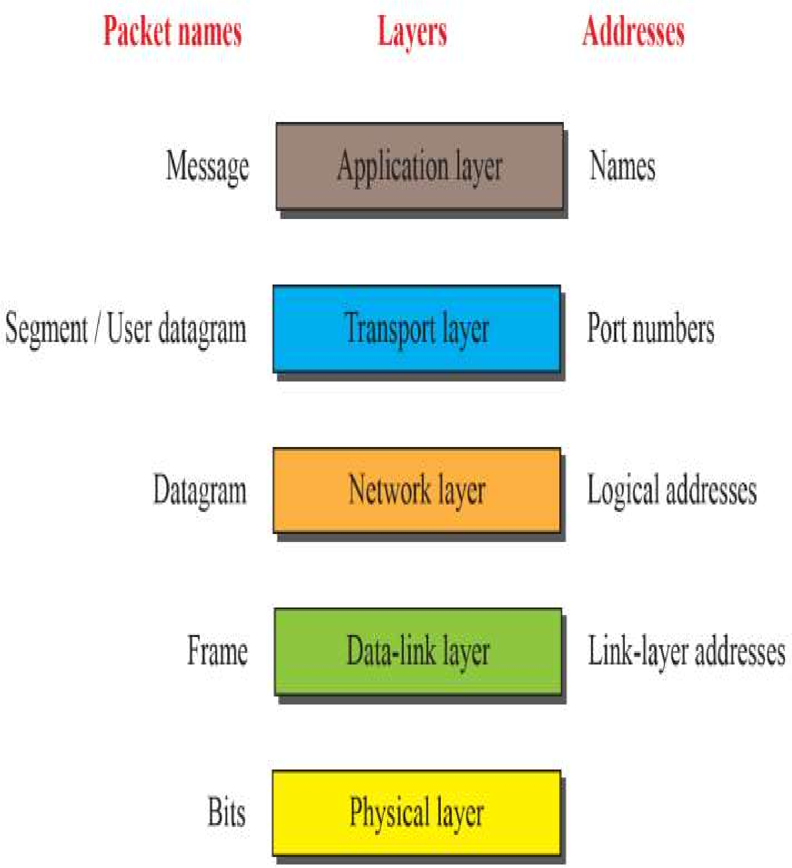
[Behrouz A Forouzan, Firouz Mosharraf, "Computer Networks: A top down Approach", McGraw Hill Education]

PROTOCOL LAYERING

Addressing

- At the application layer, we use names to define the site that provides services, such as someorg.com, or the e-mail address, such as somebody@coldmail.com.
- At the transport layer, addresses are called port numbers, and these define the application-layer programs at the source and destination.(FTP-20, HTTP-80, SMTP-2 etc. -16 bits)
- Port numbers are local addresses that distinguish between several programs running at the same time.

Figure 1.17: Addressing in the TCP/IP protocol suite

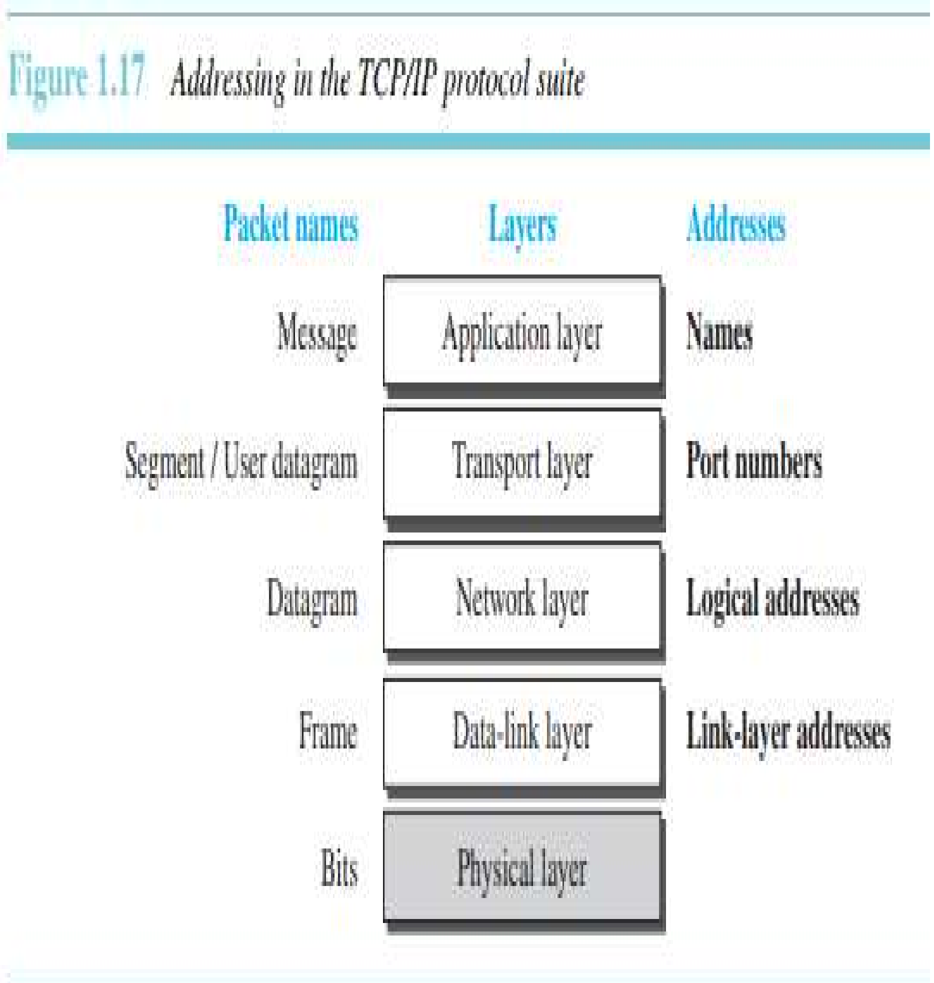


[Behrouz A Forouzan, Firouz Mosharraf, "Computer Networks: A top down Approach", McGraw Hill Education]

PROTOCOL LAYERING

Addressing

- At the network-layer, the addresses are global, with the whole Internet as the scope.
- A network-layer address uniquely defines the connection of a device to the Internet.
- The link-layer addresses, sometimes called MAC addresses(48 bits), are locally defined addresses, each of which defines a specific host or router in a network (LAN or WAN).

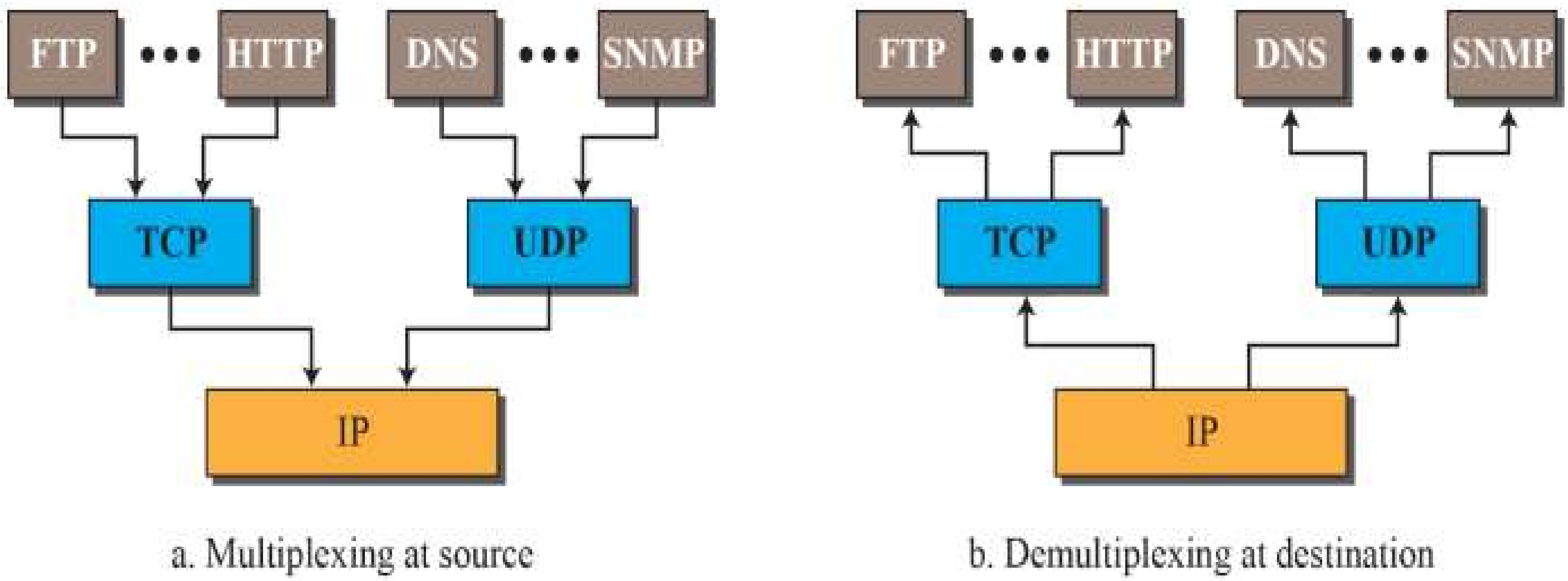


[Behrouz A Forouzan, Firouz Mosharraf, "Computer Networks: A top down Approach", McGraw Hill Education]

PROTOCOL LAYERING

Multiplexing and Demultiplexing

Figure 1.18: Multiplexing and demultiplexing



[Behrouz A Forouzan, Firouz Mosharraf, “Computer Networks: A top-down Approach”, McGraw Hill Education]

PROTOCOL LAYERING

Multiplexing and Demultiplexing

- We have 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).

PROTOCOL LAYERING

Multiplexing and Demultiplexing

- To be able to multiplex and demultiplex, a protocol needs to have a field in its header to identify to which protocol the encapsulated packets belong.
- At the transport layer, either UDP or TCP can accept a message from several application-layer protocols.
- At the network layer, IP can accept a segment from TCP or a user datagram from UDP. IP can also accept a packet from other protocols such as ICMP, IGMP, and so on.
- At the data-link layer, a frame may carry the payload coming from IP or other protocols such as ARP.

PROTOCOL LAYERING

OSI Model

- An ISO (International Organization for Standardization) standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model.
- ISO is the organization; OSI is the model.
- An open system is a set of protocols that allows any two different systems to communicate regardless of their underlying architecture.
- The purpose of the OSI model is to show how to facilitate communication between different systems without requiring changes to the logic of the underlying hardware and software.

PROTOCOL LAYERING

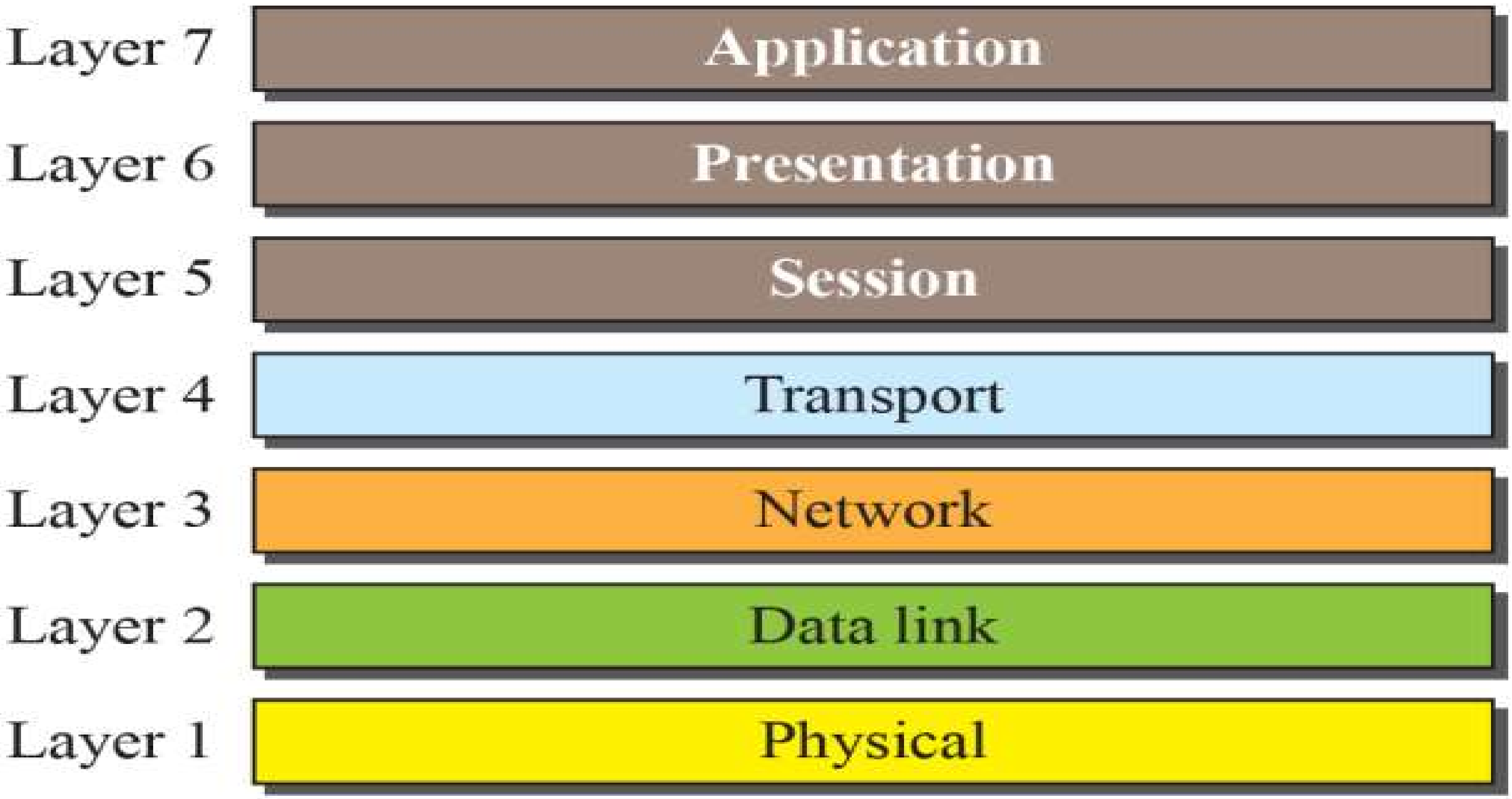
OSI Model

- The OSI model is a model for understanding and designing a network architecture that is flexible, robust, and interoperable.
- The OSI model was intended to be the basis for the creation of the protocols in the OSI stack.
- The OSI model is a layered framework for the design of network systems that allows communication between all types of computer systems.
- It consists of seven separate but related layers, each of which defines a part of the process of moving information across a network

PROTOCOL LAYERING

OSI Model

Figure 1.19:* *The OSI model



[Behrouz A Forouzan, Firouz Mosharraf, "Computer Networks: A top down Approach", McGraw Hill Education]

PROTOCOL LAYERING

- Let's consider the two additional layers present in the OSI reference model—the presentation layer and the session layer.
- The role of the presentation layer is to provide services that allow communicating applications to interpret the meaning of data exchanged. (syntax and semantics)
- These services include data compression and data encryption as well as data translation (frees the applications from having to worry about the internal format in which data are represented/stored—formats that may differ from one computer to another).
- The session layer provides for delimiting and synchronization of data exchange, including the means to build a checkpointing and recovery scheme. (Provides synchronization and dialog control.)

PROTOCOL LAYERING

OSI versus TCP/IP

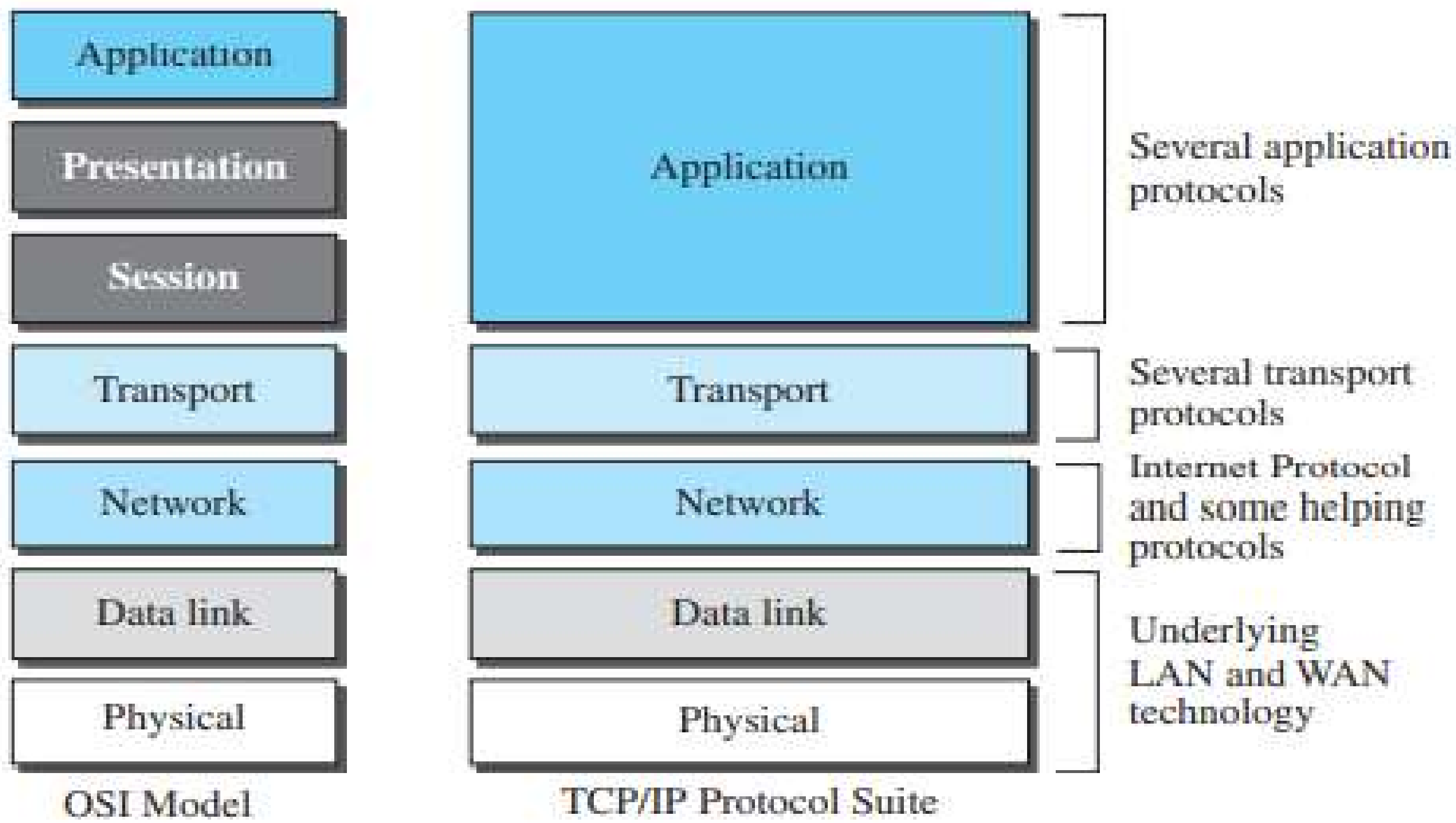


Figure 1.20 *TCP/IP and OSI model*

[Behrouz A Forouzan, Firouz Mosharraf, "Computer Networks: A top down Approach", McGraw Hill Education]

PROTOCOL LAYERING

OSI versus TCP/IP

- The application layer in the suite is usually considered to be the combination of three layers in the OSI model.

- Two reasons were mentioned for this decision.
- First, TCP/IP has more than one transport-layer protocol. Some of the functionalities of the session layer are available in some of the transport-layer protocols.
- Second, the application layer is not only one piece of software. Many applications can be developed at this layer. If some of the functionalities mentioned in the session and presentation layers are needed for a particular application, they can be included in the development of that piece of software.

INTERNET HISTORY

Early History

- Birth of Packet-Switched Networks
- Advanced Research Projects Agency Network (ARPANET)

Birth of the Internet

- TCP/IP
- Military Network (MILNET)
- Computer Science Network (CSNET)
- National Science Foundation Network (NSFNET)
- Advanced Network Services Network (ANSNET)

Internet Today

- World Wide Web
- Multimedia
- Peer-to-Peer Applications

INTERNET HISTORY

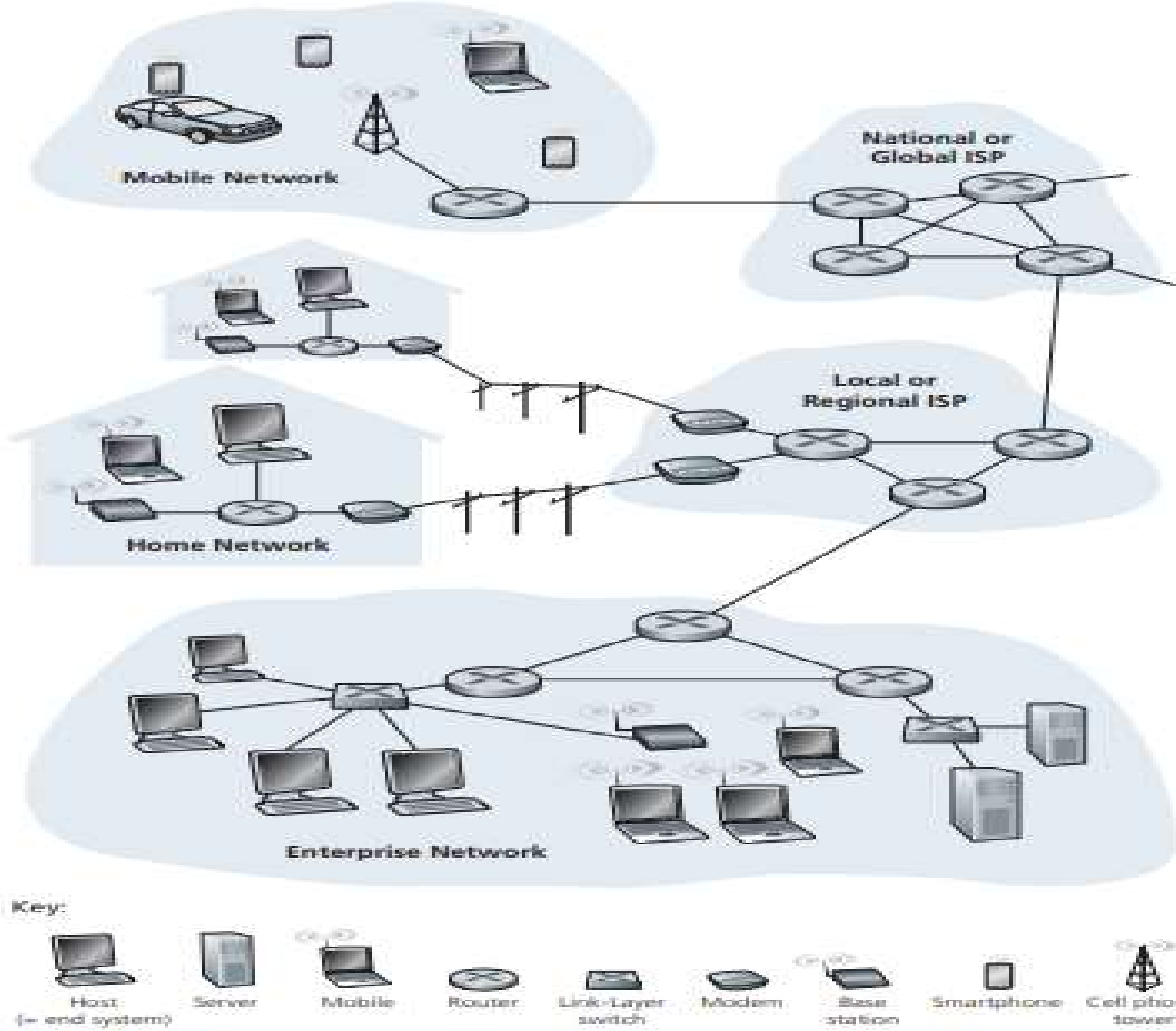


Figure 1.21 Some pieces of the Internet

James F Kurose and Keith W Ross, “Computer Networking: A Top - Down Approach”, Pearson Education; 6 th Edition (2017)

INTERNET HISTORY

- Internet standards are developed by the Internet Engineering Task Force (IETF).
- The IETF standards documents are called requests for comments (RFCs).
- RFCs started out as general requests for comments (hence the name) to resolve network and protocol design problems that faced the precursor to the Internet.
- RFCs define protocols such as TCP, IP, HTTP (for the Web), and SMTP (for e-mail).
- There are more than 6,000 RFCs.
- Other bodies also specify standards for network components, like IEEE 802 LAN/MAN Standards Committee, for example, specifies the Ethernet and wireless WiFi standards.

INTERNET HISTORY

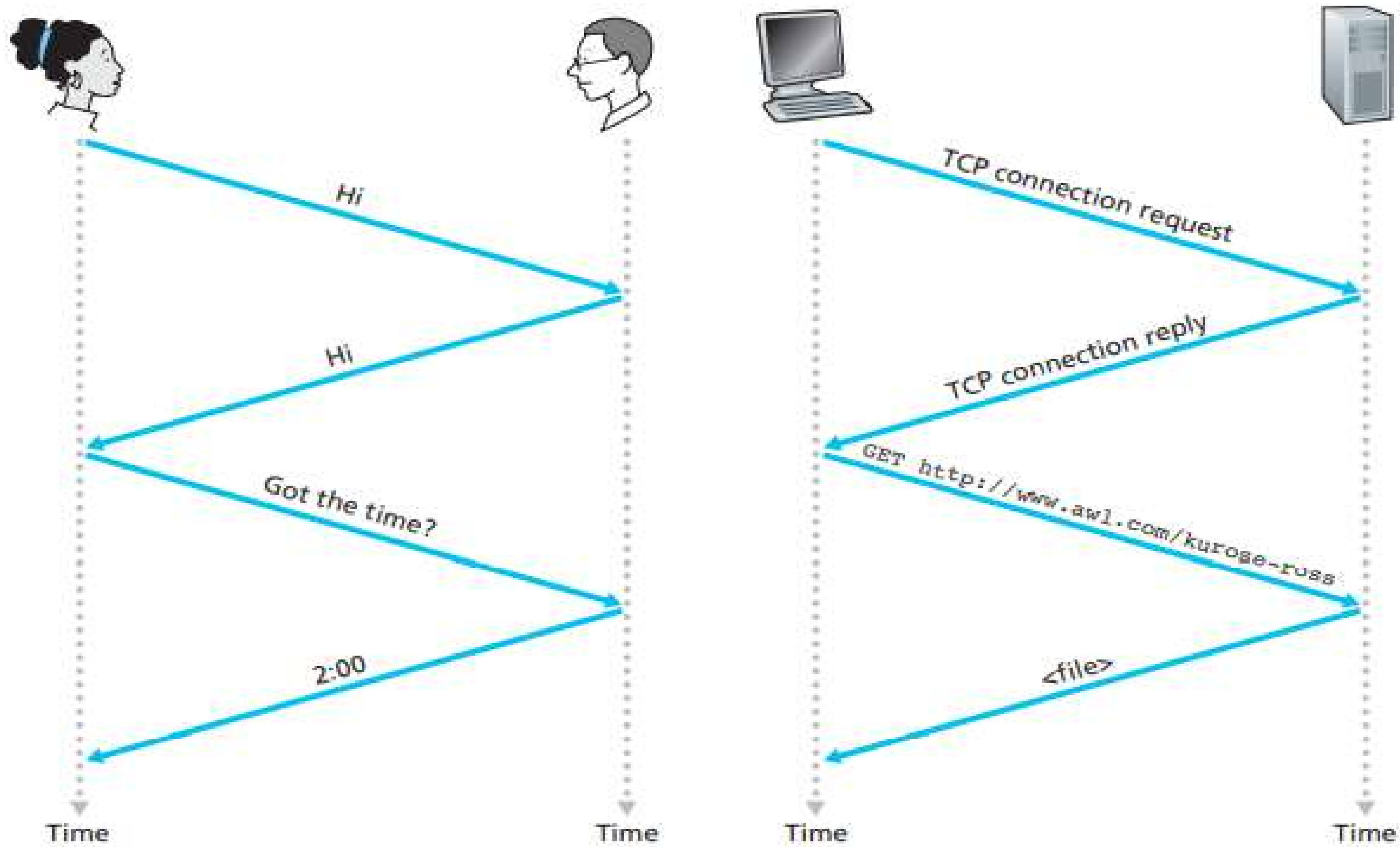


Figure 1.2 2 A human protocol and a computer network protocol

- A protocol defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event.

James F Kurose and Keith W Ross, "Computer Networking: A Top - Down Approach", Pearson Education; 6 th Edition (2017)

The Network Core

- In a network application, end systems exchange messages with each other.
- To send a message from a source end system to a destination end system, the source breaks long messages into smaller chunks of data known as packets.
- Between source and destination, each packet travels through communication links and packet switches (for which there are two predominant types, routers and link layer switches).
- Packets are transmitted over each communication link at a rate equal to the full transmission rate of the link.
- If a source end system or a packet switch is sending a packet of L bits over a link with transmission rate R bits/sec, then the time to transmit the packet is L/R seconds.

The Network Core

Store-and-Forward Transmission

- Most packet switches use store-and-forward transmission at the inputs to the links.
- Store-and-forward transmission means that the packet switch must receive the entire packet before it can begin to transmit the first bit of the packet onto the outbound link.

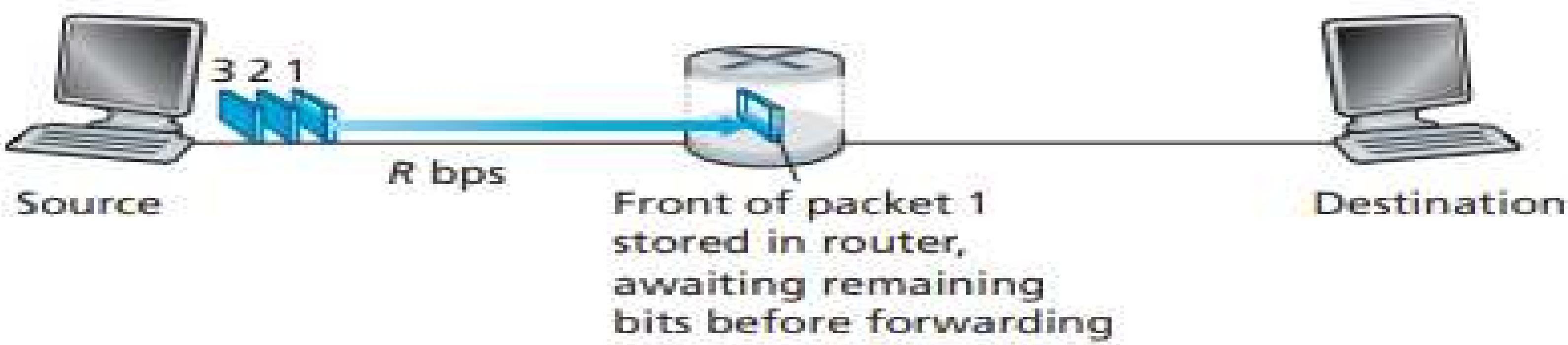


Figure 1.23 Store-and-forward packet switching

James F Kurose and Keith W Ross, "Computer Networking: A Top - Down Approach", Pearson Education; 6 th Edition (2017)

The Network Core

Store-and-Forward Transmission

Qn: Calculate the amount of time that elapses from when the source begins to send the packet until the destination has received the entire packet. (Here we will ignore propagation delay—the time it takes for the bits to travel across the wire at near the speed of light)

The Network Core

Store-and-Forward Transmission

Qn: Calculate the amount of time that elapses from when the source begins to send the packet until the destination has received the entire packet. (Here we will ignore propagation delay—the time it takes for the bits to travel across the wire at near the speed of light)

- The source begins to transmit at time 0; at time L/R seconds, the source has transmitted the entire packet, and the entire packet has been received and stored at the router (since there is no propagation delay).

The Network Core

Store-and-Forward Transmission

- At time L/R seconds, since the router has just received the entire packet, it can begin to transmit the packet onto the outbound link towards the destination; at time 2L/R, the router has transmitted the entire packet, and the entire packet has been received by the destination.
- Thus, the total delay is 2L/R.
- If the switch instead of router forwarded bits as soon as they arrive (without first receiving the entire packet), then the total delay would be L/R since bits are not held up at the router.

The Network Core

Store-and-Forward Transmission

- Calculate the amount of time that elapses from when the source begins to send the first packet until the destination has received all three packets.

The Network Core

Store-and-Forward Transmission

- Calculate the amount of time that elapses from when the source begins to send the first packet until the destination has received all three packets.
- As before, at time L/R, the router begins to forward the first packet.
- But also at time L/R the source will begin to send the second packet, since it has just finished sending the entire first packet.
- Thus, at time 2L/R, the destination has received the first packet and the router has received the second packet.
- Similarly, at time 3L/R, the destination has received the first two packets and the router has received the third packet.
- Finally, at time 4L/R the destination has received all three packets!

The Network Core

Store-and-Forward Transmission

- Consider the general case of sending one packet from source to destination over a path consisting of N links each of rate R (thus, there are N-1 routers between source and destination). What is the end-to-end delay?

The Network Core

Store-and-Forward Transmission

- Consider the general case of sending one packet from source to destination over a path consisting of N links each of rate R (thus, there are N-1 routers between source and destination).
- Applying the same logic as above, we see that the end-to-end delay is:

$$d_{\text{end-to-end}} = N\frac{L}{R}$$