PROTOCOL LAYERING

- 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.

PROTOCOL LAYERING

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
  - Enables us to divide a complex task into several smaller and simpler tasks.
  - Modularity: means independent layers and a layer (module) can be defined as a black box with inputs and outputs, without concern about how inputs are changed to outputs.
  - Advantage: Allows us to separate the services from the implementation, Communication does not always use only two end systems - there are intermediate systems that need only some layers, but not all layers(less expensive).
  - Disadvantage: having a single layer makes the job easier

NEXT

PROTOCOL LAYERING

- First Scenario (Figure 1.9)
  - Assume Maria and Ann are neighbors with a lot of common ideas.
  - Communication between Maria and Ann takes place in one layer, face to face, in the same language.

Figure 1.9:* *A single-layer protocol

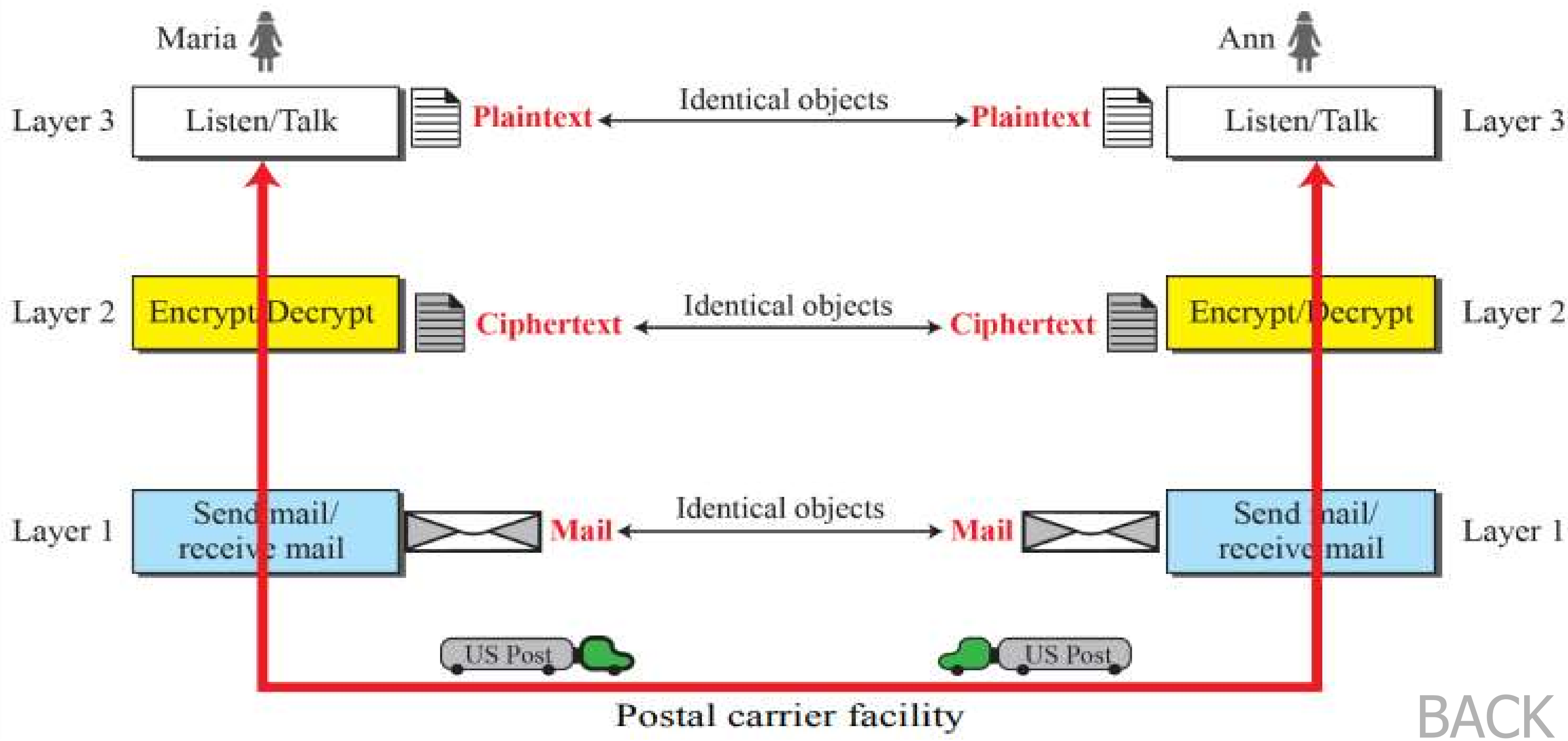
BACK

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

PROTOCOL LAYERING

- Second Scenario (Figure 1.10)

Figure 1.10:* *A three-layer protocol



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

PROTOCOL LAYERING

Principles of Protocol Layering

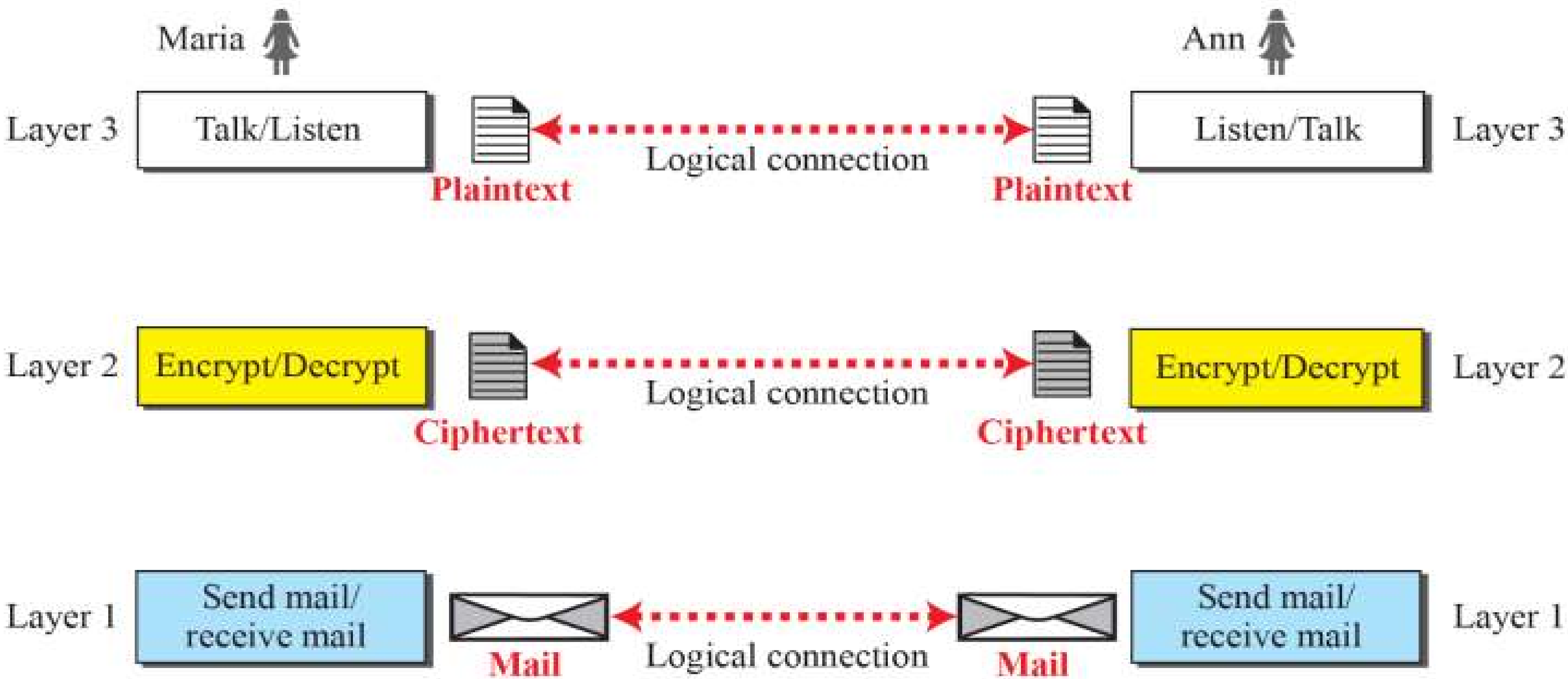
- The first principle dictates that if we want bidirectional communication, we need to make each layer so that it is able to perform two opposite tasks, one in each direction (Eg: encrypt/decrypt).
- The second principle that we need to follow in protocol layering is that the two objects under each layer at both sites should be identical (Eg: object under layer 3 at both sites should be a plaintext letter).

PROTOCOL LAYERING

Logical(imaginary) Connections

- This means that we have layer-to-layer communication.

Figure 1.11: ***Logical connection between peer layers***



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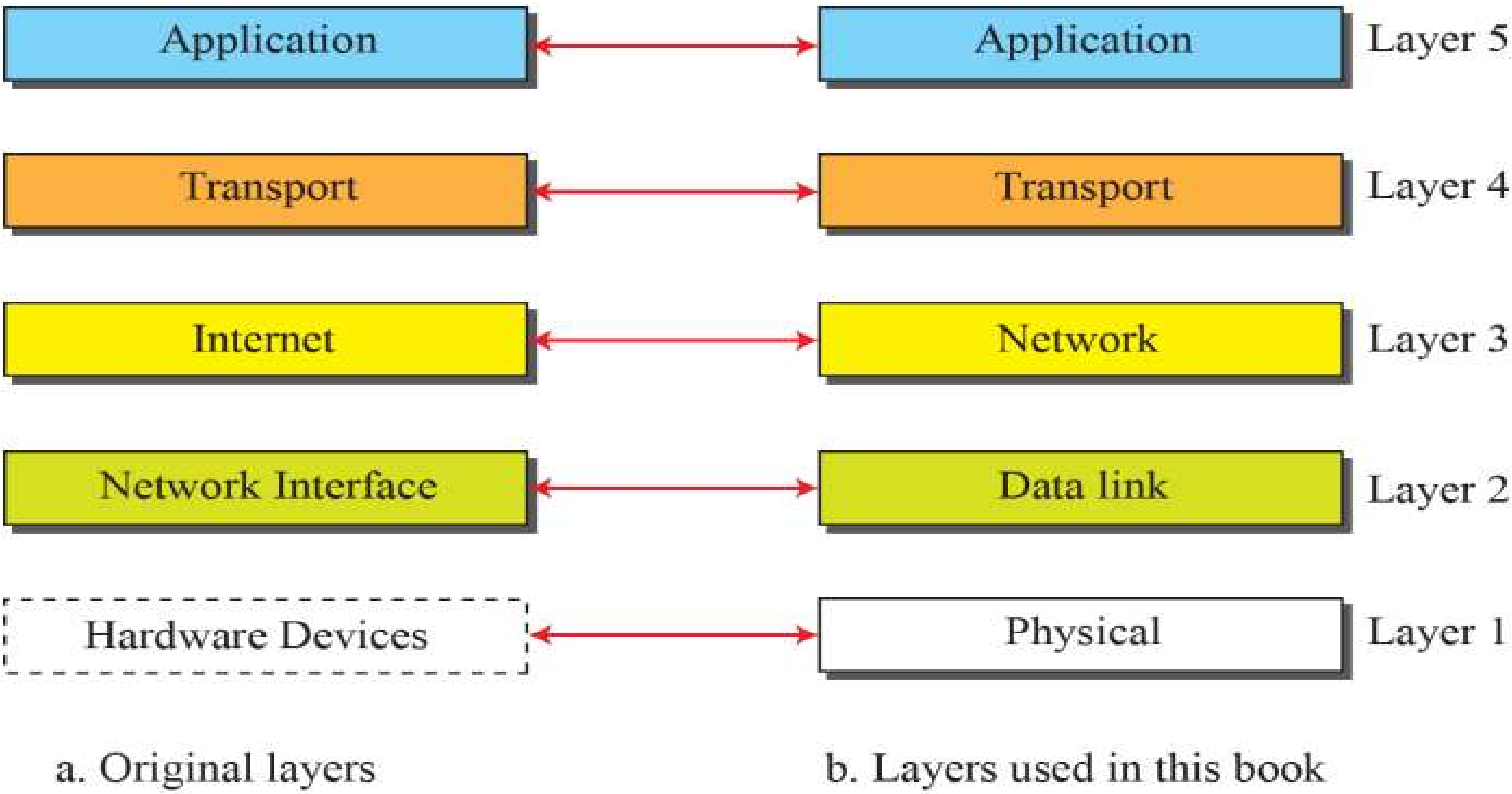
PROTOCOL LAYERING

TCP/IP (Transmission Control Protocol/Internet Protocol) 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.

PROTOCOL LAYERING

Figure 1.12: ***Layers in the TCP/IP protocol suite***



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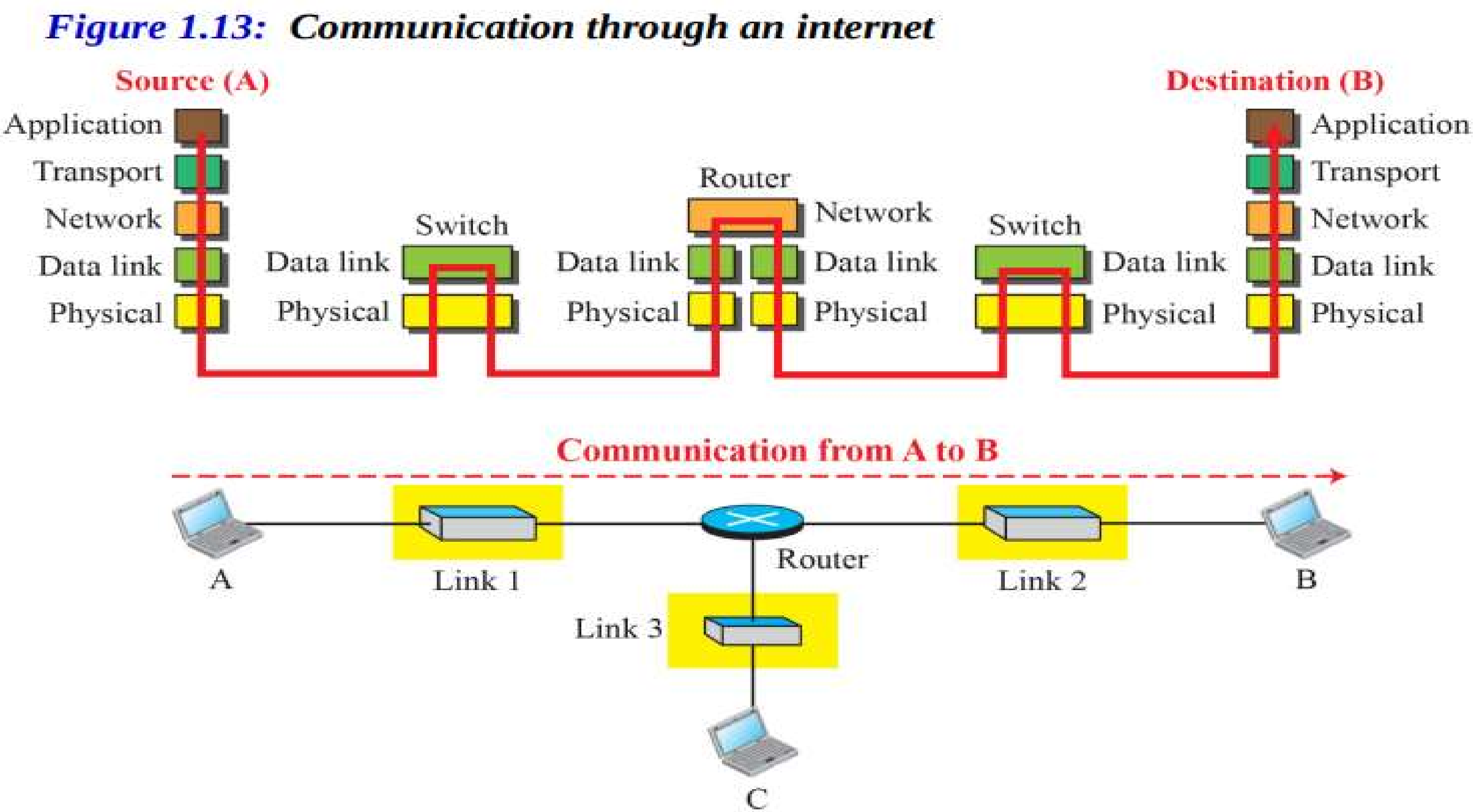
PROTOCOL LAYERING

TCP/IP Protocol Suite

- Layered Architecture
  - To show how the layers in the TCP/IP protocol suite are involved in communication between two hosts, we assume that we want to use the suite in a small internet made up of three LANs (links), each with a link-layer switch. (Figure 1.13)
  - The router is involved only in three layers; there is no transport or application layer in a router as long as the router is used only for routing.
  - A link-layer switch in a link, however, is involved only in two layers, data-link and physical.

PROTOCOL LAYERING

TCP/IP Protocol Suite



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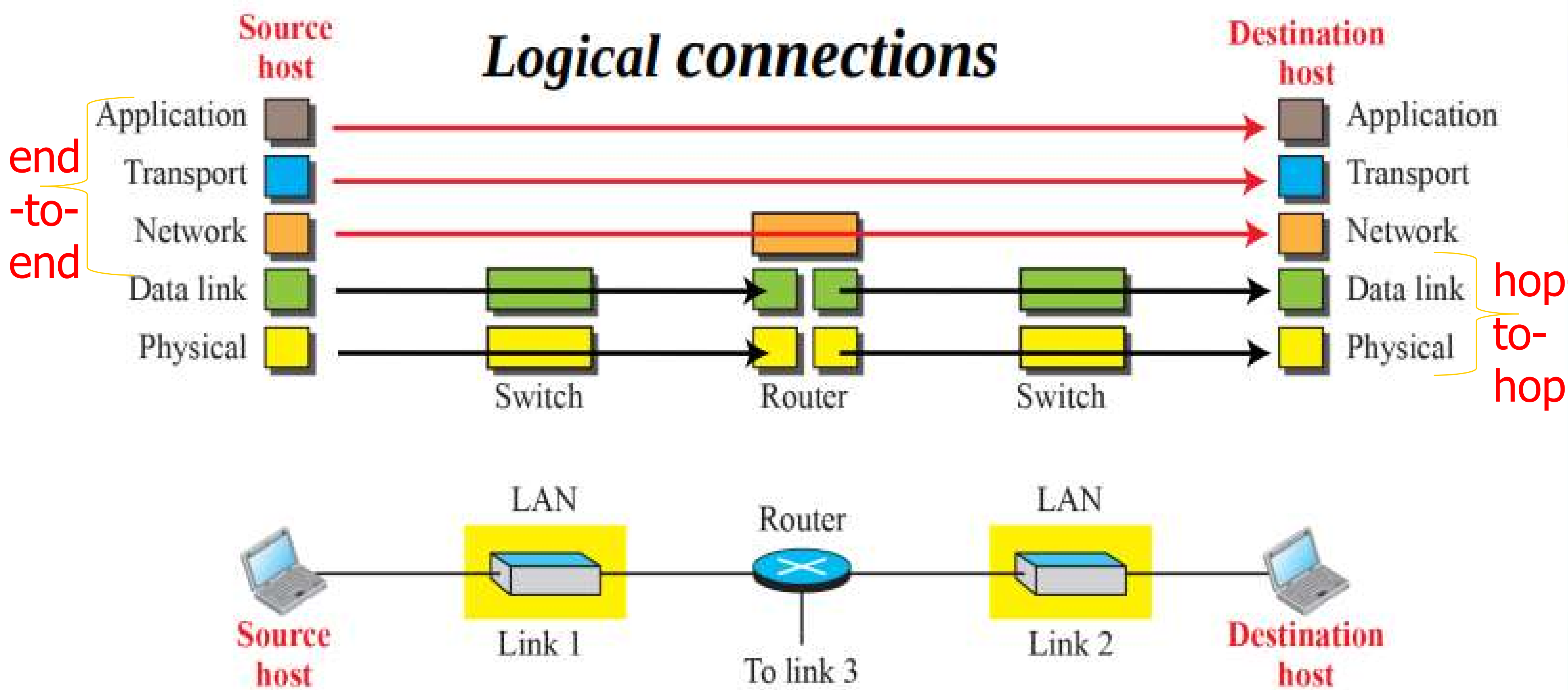
PROTOCOL LAYERING

- Layers in the TCP/IP Protocol Suite

Figure 1.14: ***Logical connections between layers in TCP/IP***



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PROTOCOL LAYERING

TCP/IP Protocol Suite

Layers in the TCP/IP Protocol Suite

- The duty of the application, transport and network layers is end-to-end.
- The duty of the data-link and physical layers is hop-to-hop, in which a hop is a host or router.
- In short, the domain of duty of the top three layers is the internet, and the domain of duty of the two lower layers is the link.

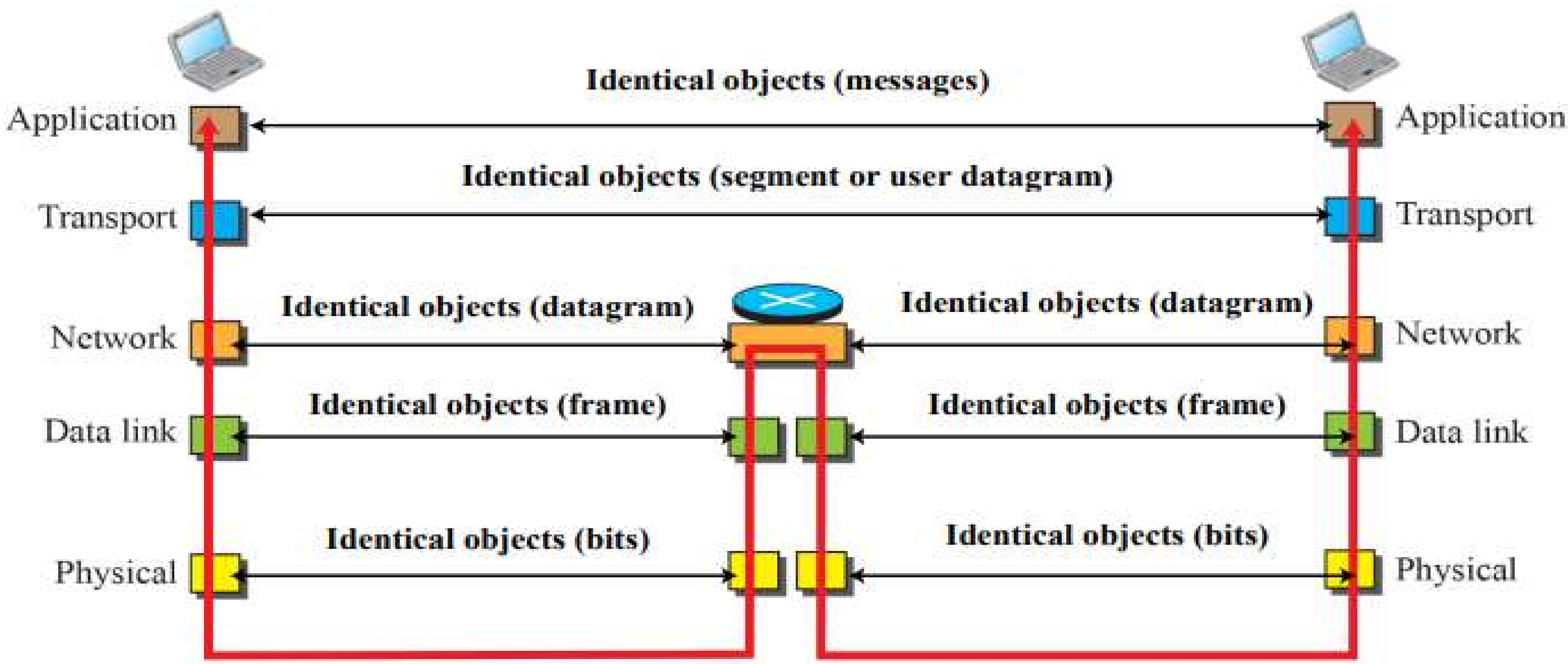
PROTOCOL LAYERING

TCP/IP Protocol Suite

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

(The second principle)

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



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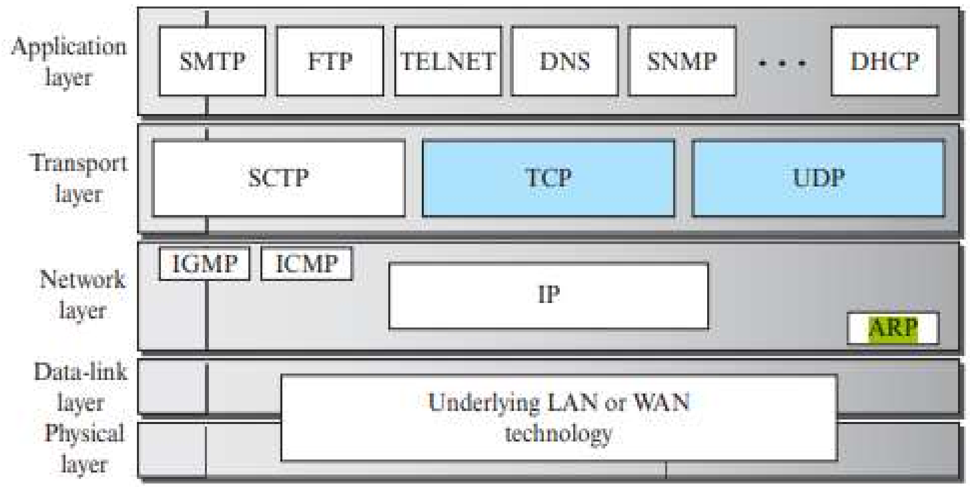
PROTOCOL LAYERING

TCP/IP Protocol Suite

Description of Each Layer in TCP/IP

- Application Layer
- Transport Layer
- Network Layer
- Data-link Layer
- Physical Layer



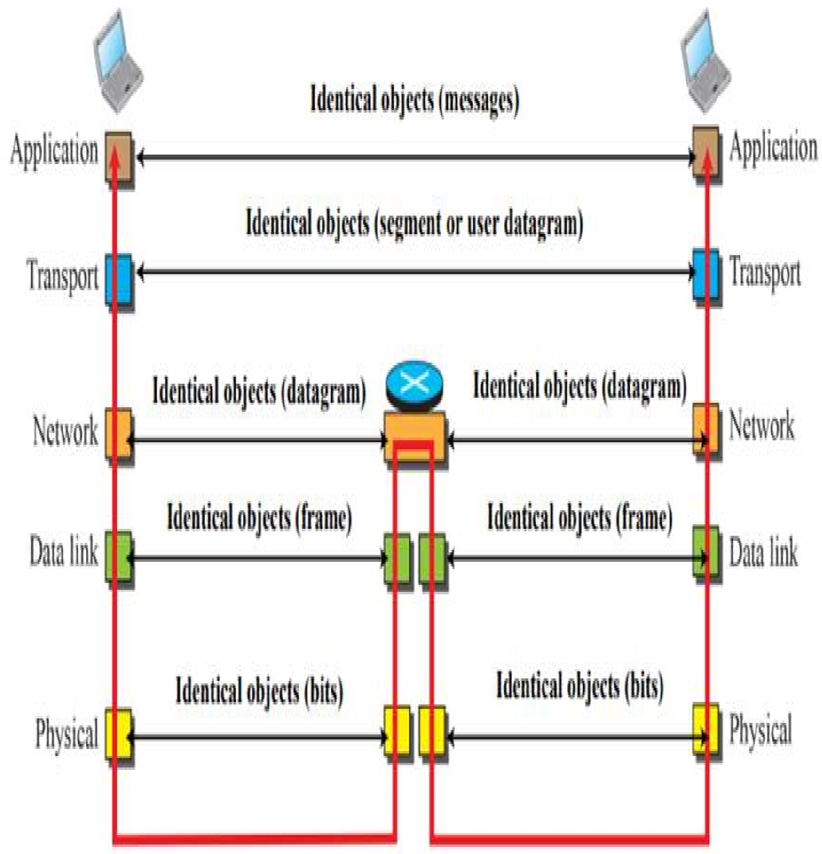
PROTOCOL LAYERING

TCP/IP Protocol Suite

Description of Each Layer in TCP/IP

1. Application Layer

- Logical connection between the two application layers is end to-end.
- The two application layers exchange messages between each other as though there were a bridge between the two layers.
- Communication at the application layer is between two processes (two programs running at this layer).



PROTOCOL LAYERING

TCP/IP Protocol Suite

1. Application Layer

- To communicate, a process sends a request to the other process and receives a response.
- Process-to-process communication is the duty of the application layer.
- The application layer in the Internet includes many predefined protocols, but a user can also create a pair of processes to be run at the two hosts.

PROTOCOL LAYERING

TCP/IP Protocol Suite

1. Application Layer

- The Hypertext Transfer Protocol (HTTP) is a vehicle for accessing the World Wide Web (WWW).
- The Simple Mail Transfer Protocol (SMTP) is the main protocol used in electronic mail (e-mail) service.
- The File Transfer Protocol (FTP) is used for transferring files from one host to another.
- The Terminal Network (TELNET) and Secure Shell (SSH) are used for accessing a site remotely.
- The Simple Network Management Protocol (SNMP) is used by an administrator to manage the Internet at global and local levels.
- The Domain Name System (DNS) is used by other protocols to find the network-layer address of a computer.
- The Internet Group Management Protocol (IGMP) is used to collect membership in a group.

PROTOCOL LAYERING

TCP/IP Protocol Suite

2. Transport Layer

- The logical connection at the transport layer is also end-to-end.
- The transport layer at the source host gets the message from the application layer, encapsulates it in a transport layer packet (called a segment or a user datagram in different protocols) and sends it, through the logical (imaginary) connection, to the transport layer at the destination host.
- Transport layer is responsible for giving services to the application layer: to get a message from an application program running on the source host and deliver it to the corresponding application program on the destination host.

PROTOCOL LAYERING

TCP/IP Protocol Suite

2. Transport Layer

Why we need an end-to-end transport layer when we already have an end-to-end application layer?

- The reason is the separation of tasks and duties.
- The transport layer should be independent of the application layer.
- In addition, we have more than one protocol in the transport layer, which means that each application program can use the protocol that best matches its requirement.

PROTOCOL LAYERING

TCP/IP Protocol Suite

2. Transport Layer

- Transmission Control Protocol (TCP) is a connection-oriented protocol that first establishes a logical connection between transport layers at two hosts before transferring data.
- It creates a logical pipe between two TCPs for transferring a stream of bytes.
- TCP provides flow control (matching the sending data rate of the source host with the receiving data rate of the destination host to prevent overwhelming the destination), error control (to guarantee that the segments arrive at the destination without error and resending the corrupted ones), and congestion control to reduce the loss of segments due to congestion in the network.

PROTOCOL LAYERING

TCP/IP Protocol Suite

2. Transport Layer

- User Datagram Protocol (UDP) is a connectionless protocol that transmits user datagrams without first creating a logical connection.
- In UDP, each user datagram is an independent entity without being related to the previous or the next one (the meaning of the term connectionless).
- UDP is a simple protocol that does not provide flow, error, or congestion control.
- Its simplicity is attractive to an application program that needs to send short messages and cannot afford the retransmission of the packets involved in TCP, when a packet is corrupted or lost.
- A new protocol, Stream Control Transmission Protocol (SCTP) is designed to respond to new applications that are emerging in the multimedia.

PROTOCOL LAYERING

TCP/IP Protocol Suite

3. Network Layer

- The network layer is responsible for creating a connection between the source computer and the destination computer.
- Since there can be several routers from the source to the destination, the routers in the path are responsible for choosing the best route for each packet.
- Network layer is responsible for host-to-host communication and routing the packet through possible routes.

PROTOCOL LAYERING

TCP/IP Protocol Suite

3. Network Layer

- Why we need the network layer?

We could have added the routing duty to the transport layer and dropped this layer.

- One reason is the separation of different tasks between different layers.
- The second reason is that the routers do not need the application and transport layers.
- Separating the tasks allows us to use fewer protocols on the routers.

PROTOCOL LAYERING

TCP/IP Protocol Suite

3. Network Layer

- The network layer in the Internet includes the main protocol, Internet Protocol (IP), that defines the format of the packet, called a datagram at the network layer.
- IP also defines the format and the structure of addresses used in this layer.
- IP is also responsible for routing a packet from its source to its destination, which is achieved by each router forwarding the datagram to the next router in its path.

PROTOCOL LAYERING

TCP/IP Protocol Suite

3. Network Layer

- IP is a connectionless protocol that provides no flow control, no error control, and no congestion control services.
- This means that if any of these services is required for an application, the application should relay only on the transport-layer protocol.
- The network layer also includes unicast (one-to-one) and multicast (one-to-many) routing protocols.
- The network layer also has some auxiliary protocols that help IP in its delivery and routing tasks.

PROTOCOL LAYERING

TCP/IP Protocol Suite

3. Network Layer

- The Internet Control Message Protocol (ICMP) helps IP to report problems when routing a packet.
- The Internet Group Management Protocol (IGMP) is another protocol that helps IP in multitasking.
- The Dynamic Host Configuration Protocol (DHCP) helps IP to get the network-layer address for a host.
- The Address Resolution Protocol (ARP) is a protocol that helps IP to find the link-layer address of a host or a router when its network-layer address is given.

PROTOCOL LAYERING

TCP/IP Protocol Suite

4. Data-link Layer

- An internet is made up of several links (LANs and WANs) connected by routers.
- The routers are responsible for choosing the best links.
- When the next link to travel is determined by the router, the data-link layer is responsible for taking the datagram and moving it across the link.
- The link can be a wired LAN with a link-layer switch, a wireless LAN, a wired WAN, or a wireless WAN.
- Data link layer is responsible for moving the packet through the link.

PROTOCOL LAYERING

TCP/IP Protocol Suite

4. Data-link Layer

- TCP/IP does not define any specific protocol for the data-link layer. It supports all the standard and proprietary protocols.
- The data-link layer takes a datagram and encapsulates it in a packet called a frame.
- Each link-layer protocol may provide a different service.
- Some link-layer protocols provide complete error detection and correction, some provide only error correction.

PROTOCOL LAYERING

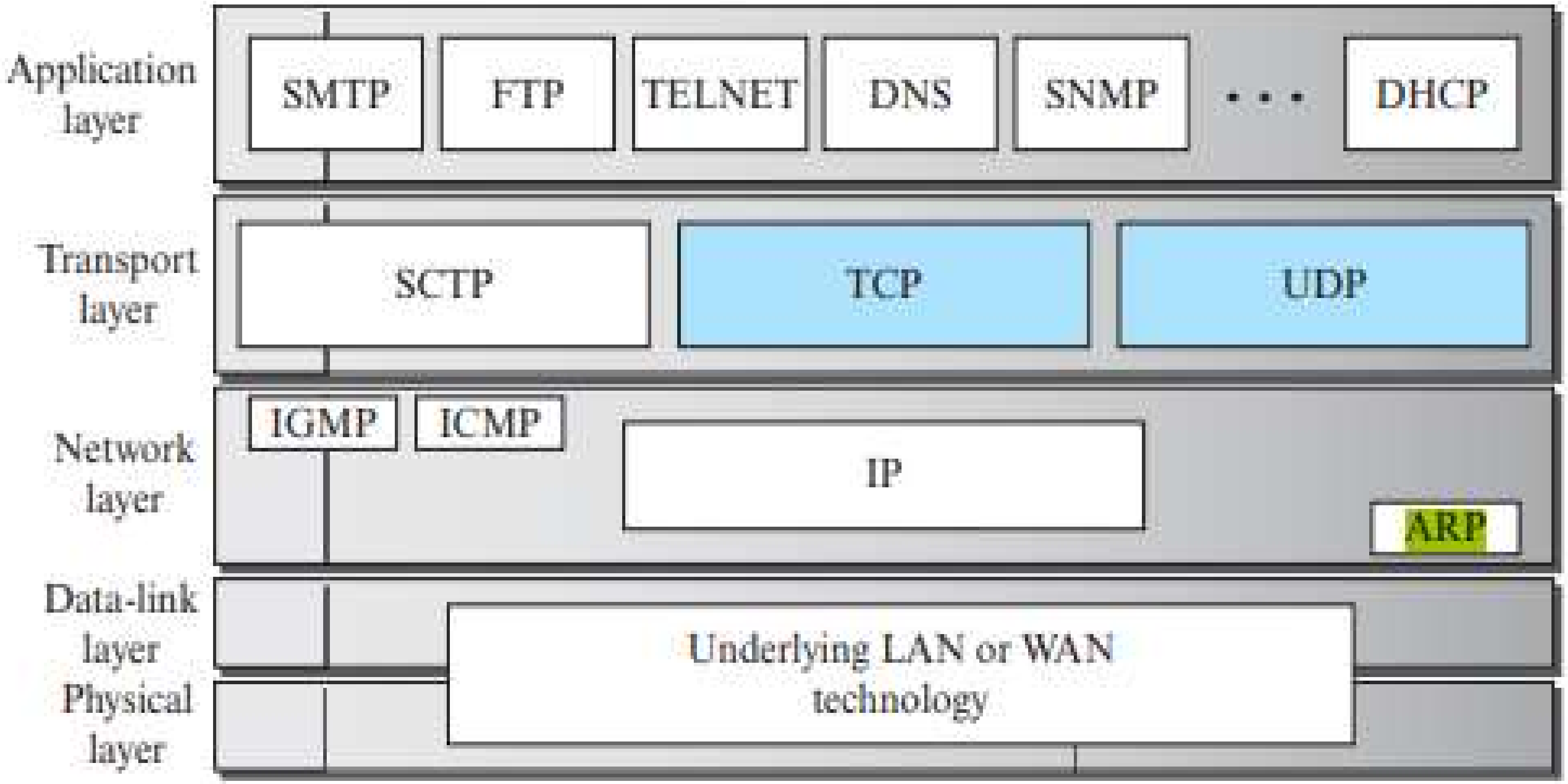
TCP/IP Protocol Suite

5.Physical Layer

- Physical layer is responsible for carrying individual bits in a frame across the link.
- Two devices are connected by a transmission medium (cable or air).
- We need to know that the transmission medium does not carry bits; it carries electrical or optical signals.
- So the bits received in a frame from the data-link layer are transformed and sent through the transmission media, but we can think that the logical unit between two physical layers in two devices is a bit.
- There are several protocols that transform a bit to a signal.

PROTOCOL LAYERING

TCP/IP Protocol Suite



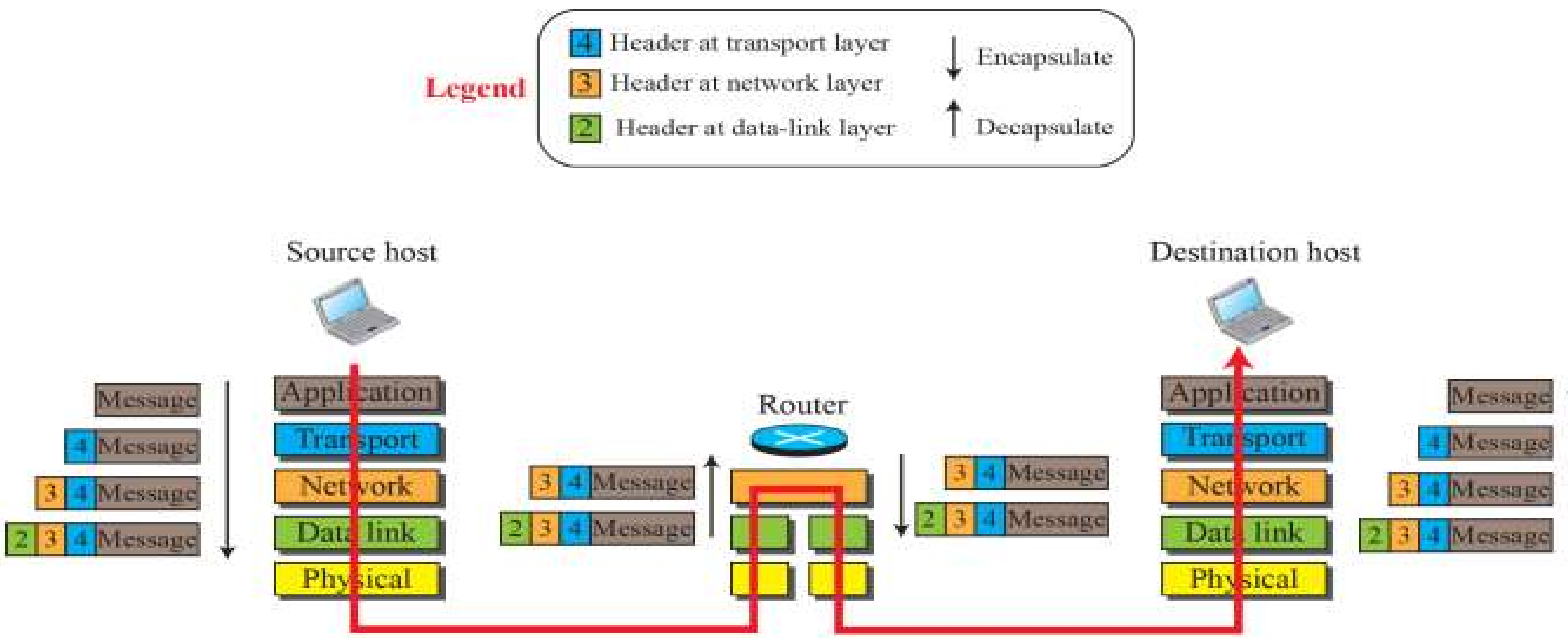
[Behrouz A Forouzan, Firouz Mosharraf, "Computer Networks: A top down Approach", McGraw Hill Education]

PROTOCOL LAYERING

Encapsulation and Decapsulation

- One of the important concepts in protocol layering in the Internet is encapsulation/ decapsulation

Figure 1.16: Encapsulation / Decapsulation



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

PROTOCOL LAYERING

Encapsulation and Decapsulation

- Not shown the layers for the link-layer switches because no encapsulation/ decapsulation occurs in this device.
- Show the encapsulation in the source host, decapsulation in the destination host, and encapsulation and decapsulation in the router.

  - Encapsulation at the Source Host
  - Decapsulation and Encapsulation at Router
  - Decapsulation at the Destination Host

PROTOCOL LAYERING

a. Encapsulation at the Source Host

At the source, we have only encapsulation.

1. At the application layer, the data to be exchanged is referred to as a message. The message is passed to the transport layer.
2. The transport layer takes the message as the payload, the load that the transport layer should take care of. It adds the transport layer header to the payload, such as information needed for flow, error control, or congestion control. The result is the transport-layer packet, which is called the segment (in TCP) and the user datagram (in UDP). The transport layer then passes the packet to the network layer

PROTOCOL LAYERING

a. Encapsulation at the Source Host

3. The network layer takes the transport-layer packet as data or payload and adds its own header to the payload. The header contains the addresses of the source and destination hosts and some more information used for error checking of the header, fragmentation information, and so on. The result is the network-layer packet, called a datagram. The network layer then passes the packet to the data-link layer.

4. The data-link layer takes the network-layer packet as data or payload and adds its own header, which contains the link-layer addresses of the host or the next hop (the router). The result is the link-layer packet, which is called a frame. The frame is passed to the physical layer for transmission

PROTOCOL LAYERING

b. Decapsulation and Encapsulation at Router

At the router, we have both decapsulation and encapsulation because the router is connected to two or more links.

1. After the set of bits are delivered to the data-link layer, this layer decapsulates the datagram from the frame and passes it to the network layer.
2. The network layer only inspects the source and destination addresses in the datagram header and consults its forwarding table to find the next hop to which the datagram is to be delivered. The datagram is then passed to the data-link layer of the next link.
3. The data-link layer of the next link encapsulates the datagram in a frame and passes it to the physical layer for transmission.

PROTOCOL LAYERING

c. Decapsulation at the Destination Host

- At the destination host, each layer only decapsulates the packet received, removes the payload, and delivers the payload to the next-higher layer protocol until the message reaches the application layer.
- Decapsulation in the host involves error checking.