OSI Reference Model - Lower Layers

by Sophia

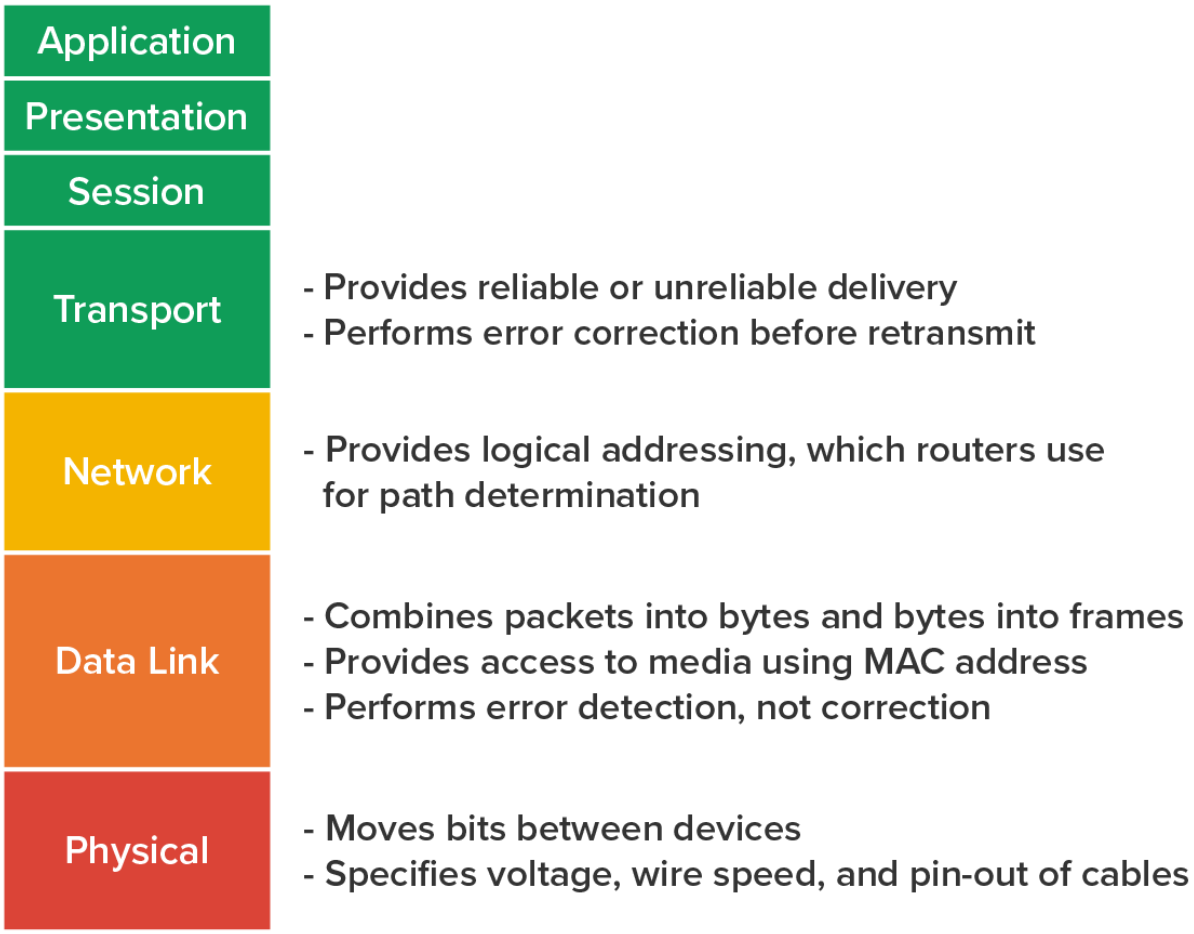
WHAT'S COVERED

In this lesson, you will continue to learn about the OSI reference model, and the primary functions of each of its lower four layers.

Specifically, this lesson will cover the following:

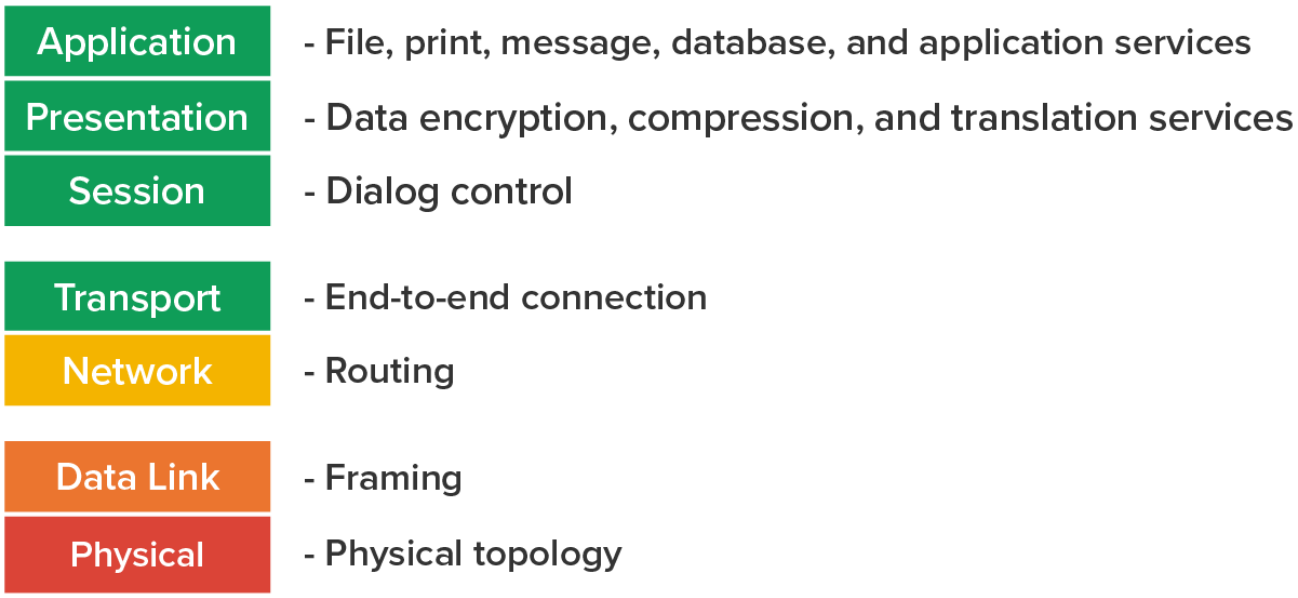
BEFORE YOU START

The OSI model is a conceptual model that we use as a reference to understand and talk about how data networks operate in theory.



1. The Open Systems Interconnection (OSI) Reference Model, Continued

The **OSI model** has seven layers, and each layer has its own specific functions. The seven layers are listed here from top to bottom:



TERM TO KNOW

OSI Model

A conceptual model that we use as a reference to understand and talk about how data networks operate in theory.

1a. OSI Layer 4: The Transport Layer

The **transport layer**, or **Layer 4**, segments and reassembles data into a data stream. Services located in the transport layer handle data from upper-layer applications and unite it with the same data stream. They provide end-to-end data transport services and can establish a logical connection between Layer 4 of the sending host and Layer 4 of the destination host on an internetwork.

KEY CONCEPT

An actual physical connection between devices happens only at **Layer 1**. All other OSI layers establish a logical connection, which is one that is not physical but acts as if it is.

The transport layer of a host sending data on the network uses a process of **segmentation**, **sequencing**, and **reassembly** to deliver application data to the transport layer of the host that is receiving the data. Segmentation means that the long stream of application layer data is cut into manageable pieces for transport. Units of data at the transport layer are called **segments**. Sequencing is the process of numbering each segment. Reassembly is the process of using the sequence numbers to figure out how to put the segments back in order as they may arrive somewhat randomly through the host computer receiving the data.

Both **Transmission Control Protocol (TCP)** and **User Datagram Protocol (UDP)** work at the transport layer. TCP provides a reliable service, which means that it guarantees delivery. UDP provides a **best-effort service** that does not guarantee delivery, which works best for real-time applications like streaming video or gaming. These two protocols give application developers delivery options because they have a choice between a guaranteed delivery or a best effort but not guaranteed delivery when they are working with **TCP/IP** protocols.

BIG IDEA

The transport layer can be connectionless or connection-oriented, but it is especially important for you to really understand the connection-oriented portion of the transport layer. So, let's review TCP, the connection-oriented protocol of the transport layer now.

TCP is a **connection-oriented** protocol, which means that it guarantees delivery. TCP makes sure that the data will be transmitted until its receipt is acknowledged by the destination host. The process is similar to sending a certified letter with a return receipt at a United States Postal Service (USPS) office. UDP is a **connectionless** protocol, which means that it does not send an acknowledgement of receipt to the computer sending the message, and so delivery is not guaranteed. The network will attempt to deliver the data just once, but if there is an error that causes data loss, then the data is lost. UDP's best-effort service is like dropping a letter into a USPS mailbox. The post office will do its best to deliver the letter but there is no guarantee that it will arrive at its destination **address**.

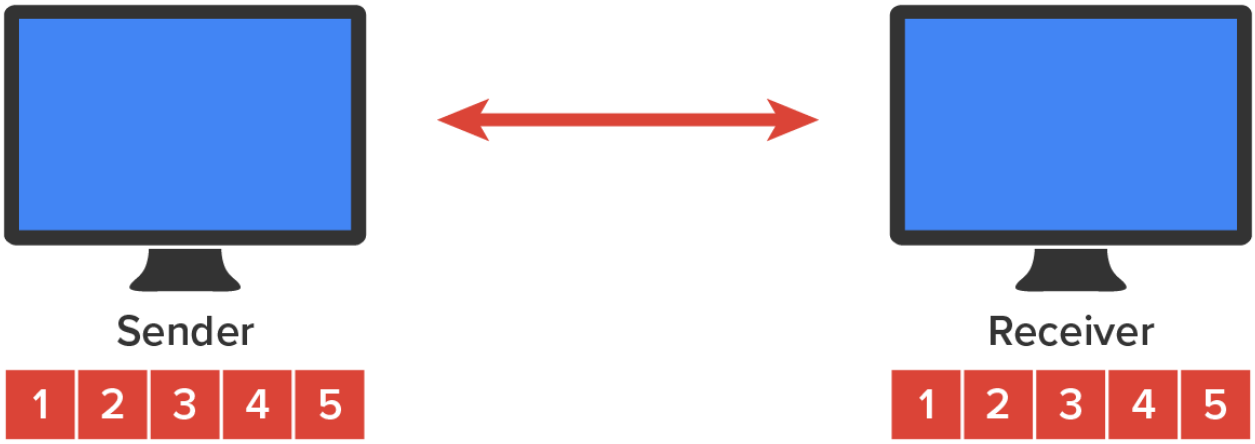
BIG IDEA

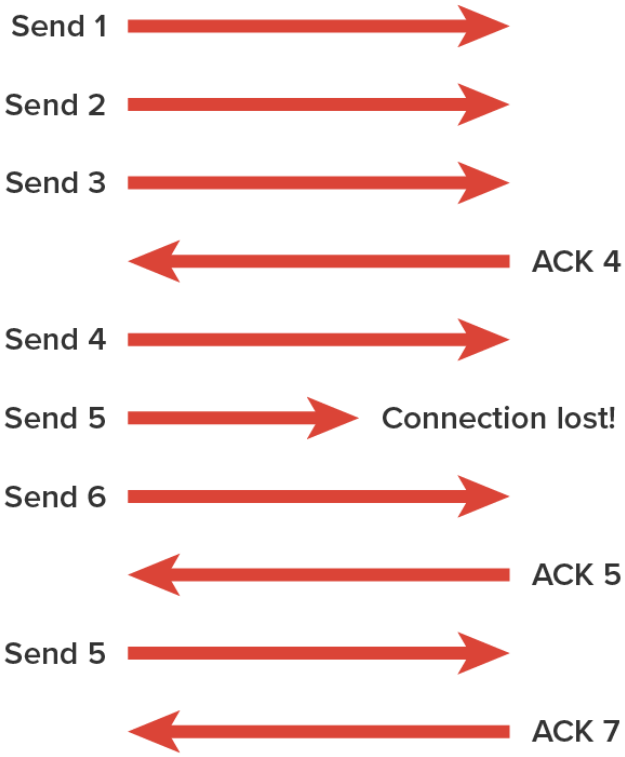
Layer 4 protocol TCP guarantees delivery, while UDP offers only a best-effort service with no guarantee of delivery.

Reliable data delivery ensures the integrity of a data stream being sent from one machine to the other. It guarantees that the data won't be lost. This is achieved through something called positive acknowledgment with retransmission. This is a technique that requires a receiving host to communicate with the transmitting host by sending an acknowledgment message back to the sender, when it receives data. The sender then documents each segment, sends, and waits for this acknowledgment before sending the next segment. When it sends a segment, the transmitting machine starts a timer and retransmits if it expires, before an acknowledgment is returned from the receiving end.

In the diagram below, the sending machine transmits segments 1, 2, and 3. The receiving node acknowledges it has received them by requesting segment 4. When it receives the acknowledgment (ACK), the sender then transmits segments 4, 5, and 6. If segment 5 does not arrive at the destination, the receiving node acknowledges that event with a request for the segment to be sent again. The sending machine will then resend the lost segment and wait for an acknowledgment, which it must receive in order to move on to the transmission of segment 7.

The following is an example:





TERMS TO KNOW

Transport Layer

Sets up end-to-end network connections, and manages segmentation, sequencing, and reassembly.

OSI Layer 4

Transport Layer

OSI Layer 1

Physical Layer

Segmentation

The process of dividing long application layer data streams into pieces.

Sequencing

The process of numbering segments.

Reassembly

The process of putting numbered segments into the correct order.

Segment

A unit of data at Layer 4.

Transmission Control Protocol (TCP)

A connection-oriented layer 4 protocol.

User Datagram Protocol (UDP)

A connectionless Layer 4 protocol.

Best-Effort Service

A network transmission via a connectionless protocol that does not guarantee delivery.

TCP/IP

A suite of networking protocols

Connection-Oriented

Data delivery is guaranteed.

Connectionless

Data delivery is not guaranteed.

Address

A number identifying a location on the internet or other network.

1b. OSI Layer 3: The Network Layer

The **network layer or Layer 3** manages logical device addressing, tracks the location of devices on the network, and determines the best way to move data from one network to another network. This means that the network layer must forward traffic between devices that are not part of the local area network (LAN). Layer 3 devices operate at the network layer and provide the routing services within an internetwork. In other words, **routers** forward data packets from one network to another network based on the destination host's **Internet Protocol (IP) address**. Units of data at the network layer are called **packets**.

When a packet is received on a router interface, the destination IP address is checked. If the packet isn't destined for that particular router, the router looks up the destination network address in the routing table. Once the router chooses an exit interface, the packet is sent to that interface to be framed and sent out on the local network. If the router cannot find an entry for the packet's destination network in the routing table, the router drops the packet. This process is sort of like how the USPS sorts mail. It looks at the ZIP code and forwards the letter or package to the correct truck or airplane for delivery to the correct post office and on to its destination address.

The network layer provides the ability to send data from a host on one network to a host on another network.

TERMS TO KNOW

Network Layer
Layer 3 of the OSI model where routers forward packets to hosts on other networks based on IP address.

OSI Layer 3
Network layer

Router
A Layer 3 device that forwards packets based on IP address.

Internet Protocol (IP)
A network layer protocol that enables connectivity between different networks.

IP Address
An address that identifies a host computer at Layer 3.

Packet
A unit of data at Layer 3.

1c. OSI Layer 2: The Data Link Layer

The data link layer or **Layer 2** provides the physical transmission of the data and handles error notification, network topology, and flow control. This means the data link layer ensures that messages are delivered to the proper device on a LAN using hardware **media access control (MAC) addresses** and translates messages from the network layer into bits for the physical layer to transmit.

The data link layer formats the message into pieces, each called a data **frame**, and adds a customized header containing the destination and source hardware addresses. The header added to the data by each layer of the OSI model contains instructions for its peer layer on the host computer that is receiving the data. In other words, the data link layer of the sending computer is communicating information in the header of the frame that is useful to the data link layer on the host computer that is receiving the data.

Routers, which work at the network layer, do not care about where a particular host is located. They are only concerned about where *networks* are located and the best way to reach them. The datal ink layer is responsible for the unique identification of each device that resides on a local area network.

For a host to send packets to individual hosts on a local network as well as transmit packets between routers, the data link layer uses hardware addressing. Each time a packet is sent between routers, it is framed with control information at the data link layer. However, that information is stripped off at the receiving router, and only the original packet is left completely intact. This framing of the packet continues for each hop until the packet is finally delivered to the correct receiving host. The packet itself is never altered along the route; it is only encapsulated with the type of control information required for it to be properly passed on to the different media types.

BIG IDEA

The data link layer provides the ability to deliver data to a specific host, or set of hosts, on a local area network (LAN).

The data link layer has two sublayers when using the **Ethernet** protocol: the **media access control (MAC) sublayer** and the **logical link control (LLC) sublayer**. The MAC sublayer defines how packets are placed on the media. Physical addressing is defined here. Each network interface has a unique MAC address, which enables delivery of frames to the destination host. The LLC is responsible for identifying network layer protocols and then encapsulating them. An LLC header tells the data link layer on the destination host what to do with a packet once a frame is received.

TERMS TO KNOW

OSI Layer 2

Data Link Layer

Media Access Control (MAC) Address

A physical address that uniquely identifies a device at Layer 2.

Frame

A unit of data at Layer 2.

Ethernet

A Layer 2 protocol for wired local area networks.

Media Access Control (MAC) Sublayer

Defines how packets are placed on the media by the data link layer.

Logical Link Control (LLC) Sublayer

Responsible for identifying network layer protocols and then encapsulating them at the data link layer.

1d. OSI Layer 1: The Physical Layer

The **physical layer** specifies the layout of the transmission **media**, otherwise known as its topology. A physical topology describes the way the cabling is physically laid out. The various physical topologies include bus, star, ring, and mesh that were described in a previous lesson.

The physical layer transmits and receives **bits**. Bits come only in values of 1 or 0. The physical layer communicates directly with the various types of physical communication media, including wired and wireless media. Different kinds of media represent these bit values in different ways. Some use pulses of light, and others employ state transitions like changes in voltage from high to low and low to high. Specific protocols are needed for each type of media to describe the proper bit patterns to be used, how data is encoded into media signals, and the various qualities of the physical media's attachment interface. The physical layer's connectors and different physical topologies are defined by the specific **technical standards**, allowing disparate systems to communicate.

BIG IDEA

The physical layer provides the wired or wireless infrastructure to enable the transmission of signals that represent data from one host to another host.

TRY IT

There are OSI layer-specific names for units of data being sent on a network. Let's review!

What do we call data at OSI Layer 4? +

Segments

What do we call data at OSI Layer 3? +

Packets

What do we call data at OSI Layer 2? +

Frames

What do we call data at OSI Layer 1? +

Bits

REFLECT

The bottom four layers of the OSI model support transmission of Layer 7 (application) data across a network. Layer 4 supports connection-oriented and connectionless transport. Layer 3 forwards IP packets between different networks based on IP address. Layer 2 enables local area network delivery of data based on MAC address. Finally, Layer 1 provides the physical media that carries signals that represent data to the destination device.

TERMS TO KNOW

Physical Layer

Layer 1 of the OSI model where signals representing data are transmitted across a physical media like wired cables or wireless radio frequency.

Media

Wired cables or wireless radio frequency.

Bit

A unit of data at Layer 1.

Technical Standard

A set of norms or requirements for a repeatable technical works where it uses common and repeated use of rules and guidelines for products, processes, or management systems practices.

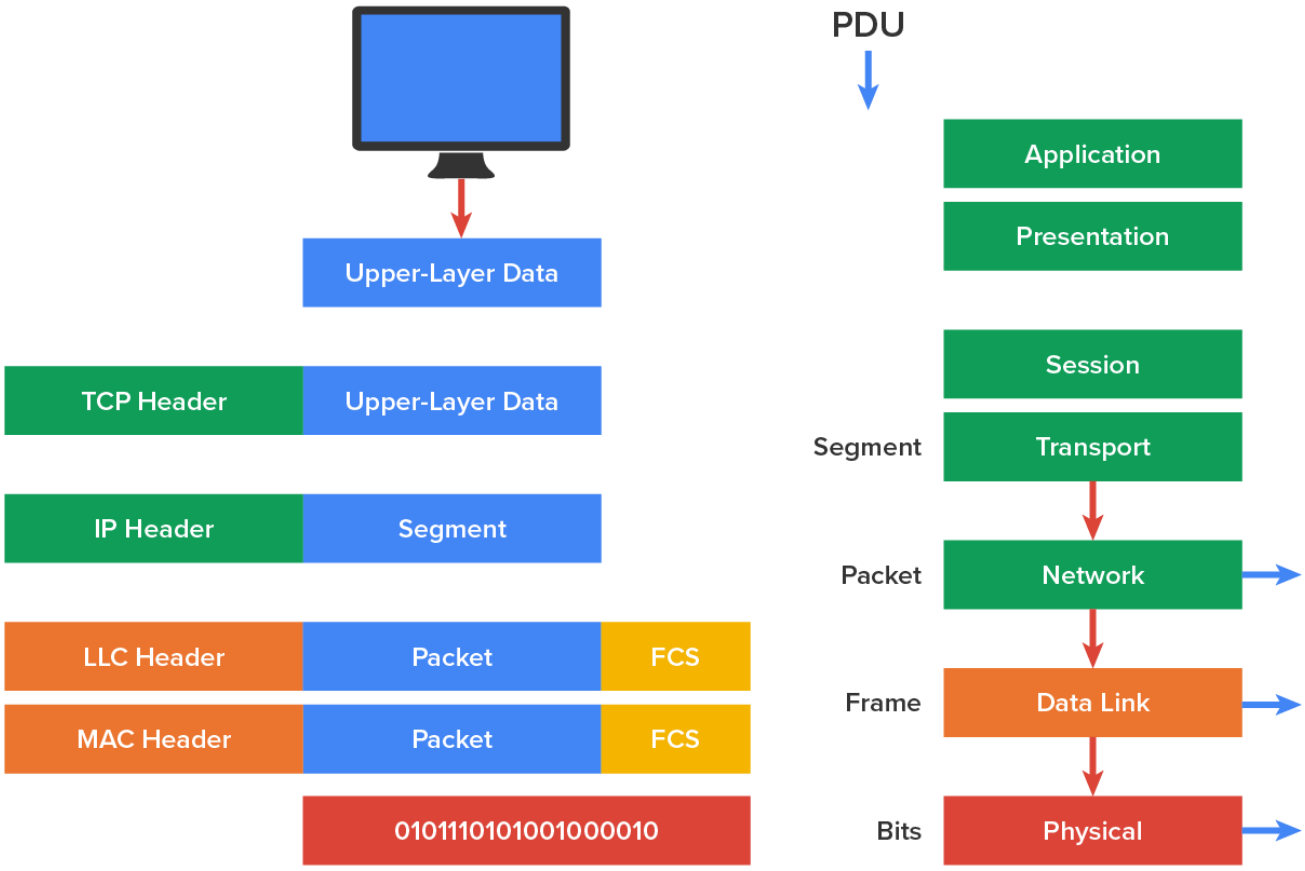
2. Introduction to Encapsulation

When a host transmits data across a network to another device, the data goes through **encapsulation**. It is wrapped with protocol information at each layer of the OSI model. Each layer communicates only with its peer layer on the receiving device. To communicate and exchange information, each layer uses **protocol data units** (PDUs). These hold the control information attached to the data at each layer of the model. They are usually attached to the header in front of the data field but can also be in the trailer, or the end, of it.

EXAMPLE At a transmitting device, the data encapsulation method works like this:

- User information from the application layer is converted to data for transmission on the network.
- Data is converted to segments by the transport layer, and a reliable connection is set up between the transmitting and receiving hosts.
- Segments are converted to packets by the network layer, and an IP address is placed in the header so each packet can be routed to the correct network. A packet carries a segment of data.
- Packets are converted to frames by the data link layer for transmission on the local network. MAC addresses are used to uniquely identify hosts on a local network segment. Frames carry packets.
- Frames are converted to bits by the physical layer for transmission as signals onto a wired or wireless physical medium.

The following is an image of how encapsulation works:



TERMS TO KNOW

Encapsulation

The adding of a header of layer specific information to the data passed down from an upper layer.

Protocol Data Units (PDUs)

Protocol-specific information used in the encapsulation process.

SUMMARY

In this lesson, along with the previous one, you learned about the Open Systems Interconnection (OSI) reference model, which is a conceptual framework for understanding how one computer or digital device can communicate with another computer or digital device across a data network. This lesson explained the **lower four layers of the OSI model**, as well as the **encapsulation** process.

Source: This content and supplemental material has been adapted from CompTIA Network+ Study Guide: Exam N10-007, 4th Edition. Source Lammle: CompTIA Network+ Study Guide: Exam N10-007, 4th Edition - Instructor Companion Site (wiley.com)

TERMS TO KNOW

Address

A number identifying a location on the internet or other network.

Best-Effort Service

A network transmission via a connectionless protocol that does not guarantee delivery.

Bit

A unit of data at Layer 1.

Connection-oriented

Data delivery is guaranteed.

Connectionless

Data delivery is not guaranteed.

Encapsulation

The adding of a header of layer specific information to the data passed down from an upper layer.

Ethernet

A Layer 2 protocol for wired local area networks.

Frame

A unit of data at Layer 2.

IP Address

An address that identifies a host computer at Layer 3.

Internet Protocol (IP)

A network-layer protocol that enables connectivity between different networks.

Logical Link Control (LLC) Sublayer

Responsible for identifying network-layer protocols and then encapsulating them at the data link layer.

Media

Wired cables or wireless radio frequency.

Media Access Control (MAC) Address

A physical address that uniquely identifies a device at Layer 2.

Media Access Control (MAC) Sublayer

Defines how packets are placed on the media by the data link layer.

Network Layer

Layer 3 of the OSI model where routers forward packets to hosts on other networks based on IP address.

OSI Layer 1

Physical layer

OSI Layer 3

Network layer

OSI Layer 4

Transport layer

OSI Model

A conceptual model that we use as a reference to understand and talk about how data networks operate in theory.

Packet

A unit of data at Layer 3.

Physical Layer

Layer 1 of the OSI model where signals representing data are transmitted across a physical media like wired cables or wireless radio frequency.

Protocol Data Units (PDUs)

Protocol specific information used in the encapsulation process.

Reassembly

The process of putting numbered segments into the correct order.

Router

A Layer 3 device that forwards packets based on IP address.

Segment

A unit of data at Layer 4.

Segmentation

The process of dividing long application-layer data streams into pieces.

Sequencing

The process of numbering segments.

TCP/IP

A suite of networking protocols.

Technical Standard

A set of norms or requirements for a repeatable technical works where it uses common and repeated use of rules and guidelines for products, processes, or management systems practices.

Transmission Control Protocol (TCP)

A connection-oriented Layer 4 protocol.

Transport Layer

Sets up end-to-end network connections, and manages segmentation, sequencing, and reassembly.

User Datagram Protocol (UDP)

A connectionless Layer 4 protocol.