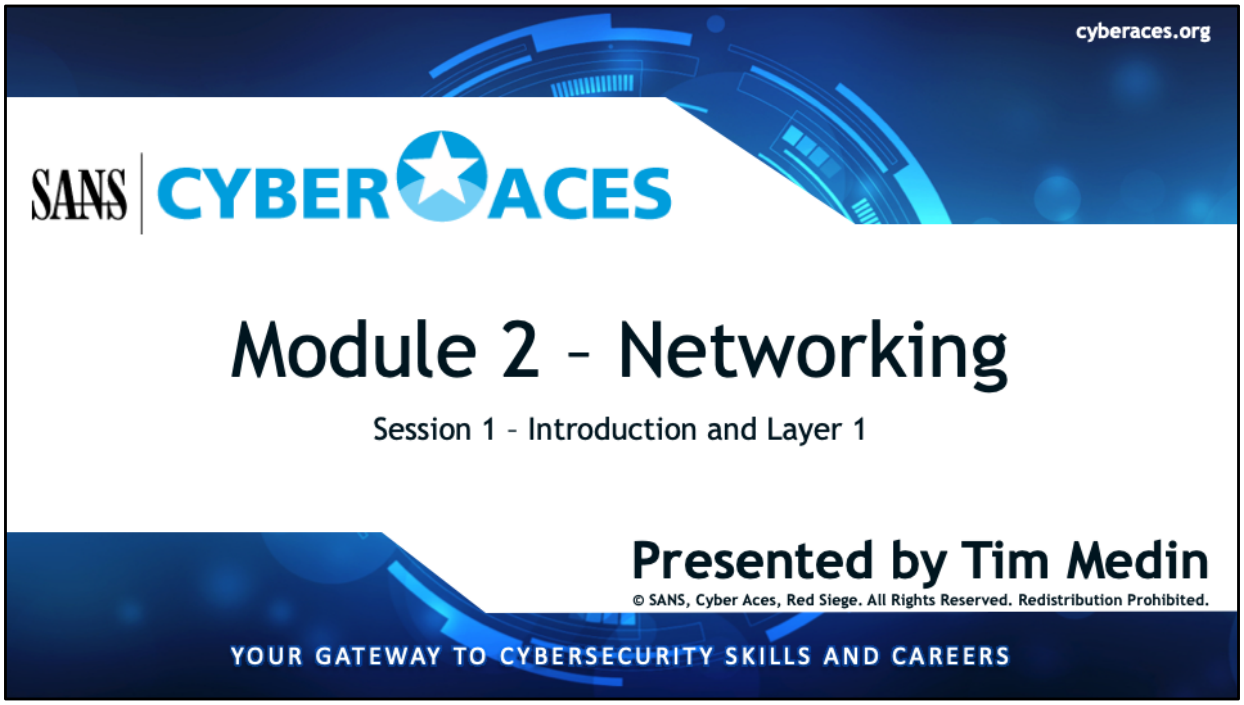
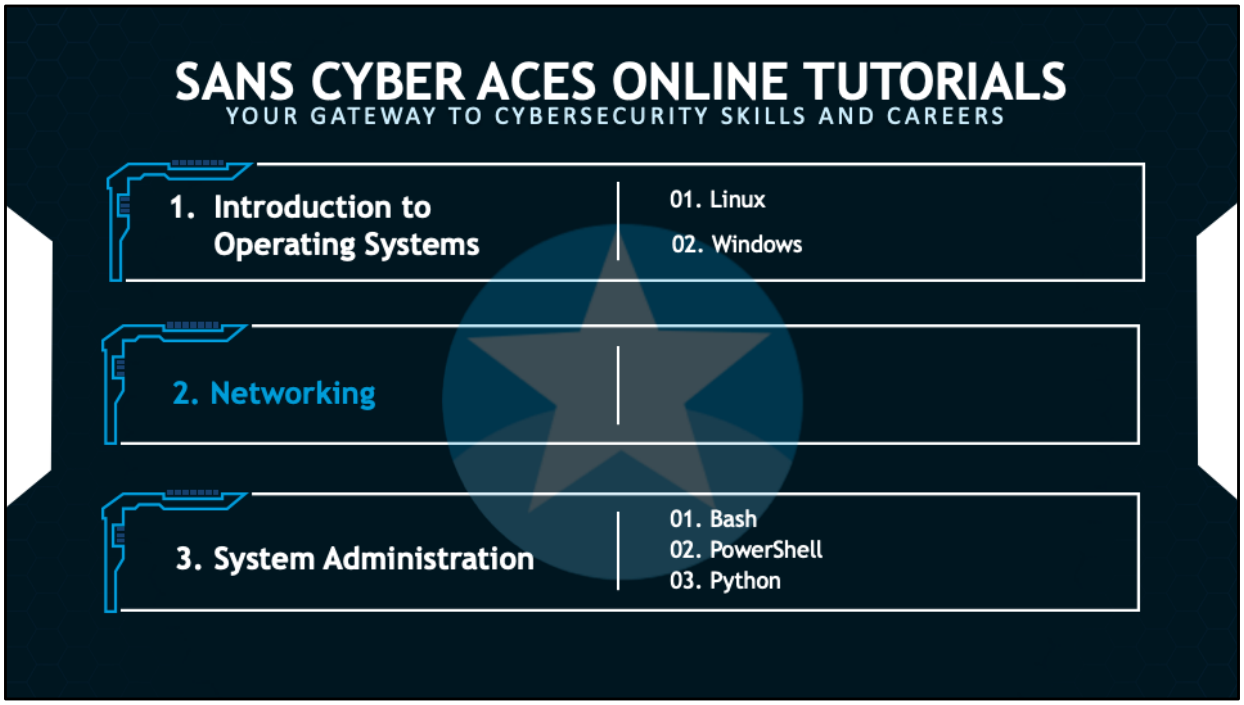


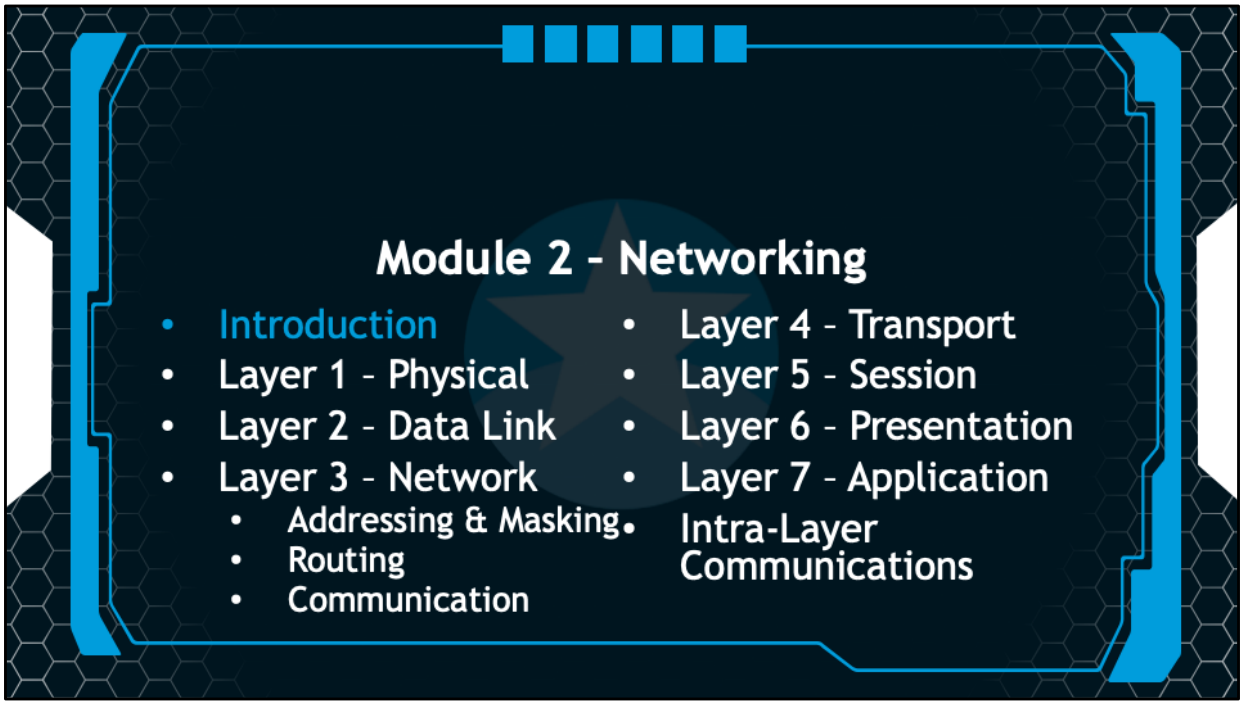
Welcome to Cyber Aces Module 2! A firm understanding of network fundamentals is essential to being able to secure a network or attack one. This section provides a broad overview of networking, covering the fundamental concepts needed to understand computer attacks and defenses from a network perspective. Specifically, in this tutorial we'll discuss introductory topics as well as Layer 1, the Physical Layer.



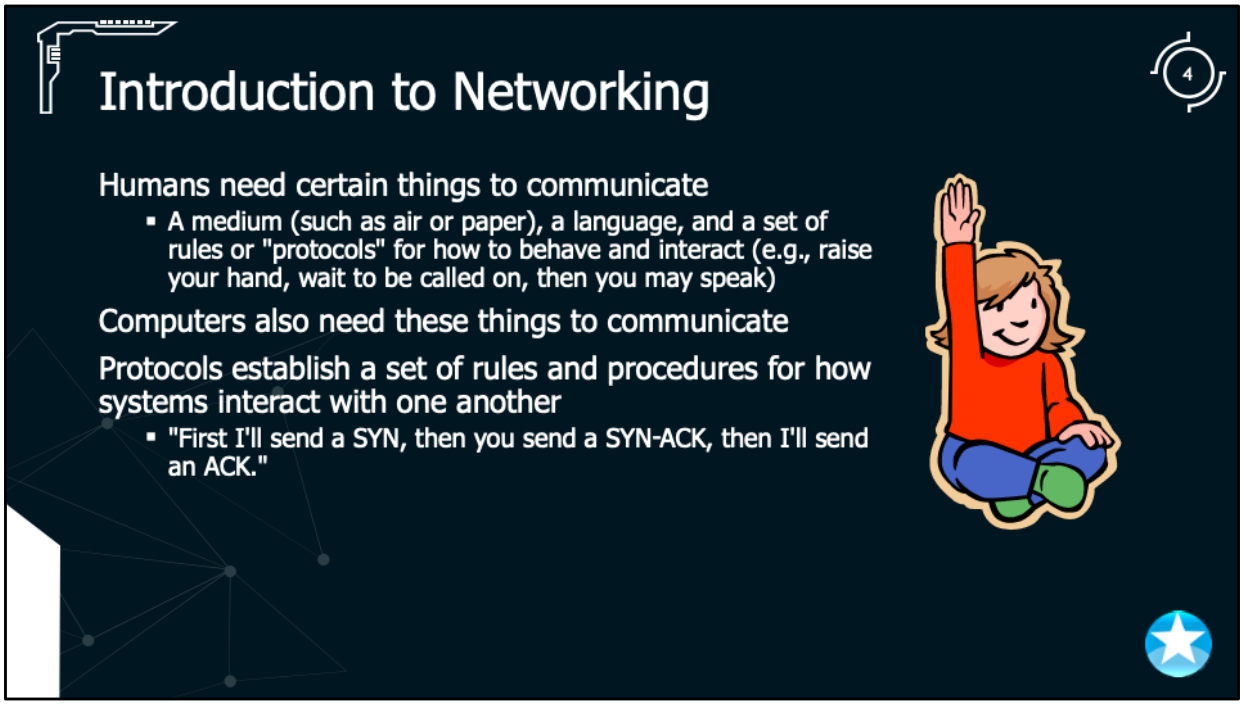
This training material was originally developed to help students, teachers, and mentors prepare for the Cyber Aces Online Competition. This module focuses on the basics of networking. This session is part of Module 2, Networking.

The three modules of Cyber Aces Online are Operating Systems, Networking, and System Administration.

For more information about the Cyber Aces program, please visit the Cyber Aces website at https://CyberAces.org/.

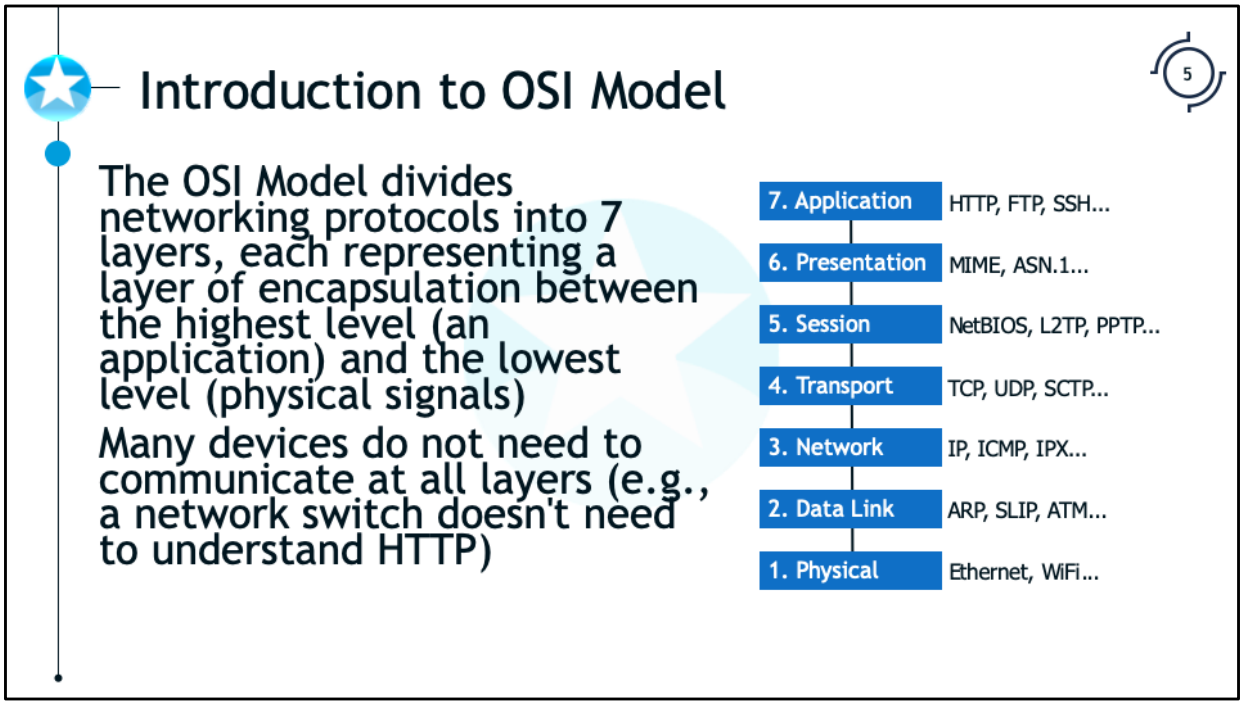


Is this section, you will be introduced to basic networking concepts, as well as the OSI model. You will also learn about encapsulation, a key concept about data moving between layers.



If you had no electronics available and you wanted to communicate with another human being, you would need a few things. First, you need a way of physically getting that message to the person. If you are in the same room, you could use sound waves to carry your speech or use a piece of paper to carry your written message. You also need the other person to speak the same language or you'd need to have a translator present. Last, you both have to establish several 'protocols'. Protocols define how we behave and interact with each other. Without protocols, people might try speaking at the exact same time, speaking at inaudible volumes, turning their back to the person as they speak, or other crazy things. Our social protocols seem simple to us because they are engrained culturally and sometimes even biologically. But, as engineers try to mimic human behavior with computers, those protocols often present them with the biggest challenges.

Like humans, our computers need to have well established mechanisms and protocols for communications. Computer Protocols are established by a body such as the IEEE or introduced by corporations. As data is transmitted between two computers, it traverses layers of protocols where encapsulation for the protocol at that layer occurs. Today most network communications occur with TCP encapsulated inside of IP encapsulated inside of Ethernet.

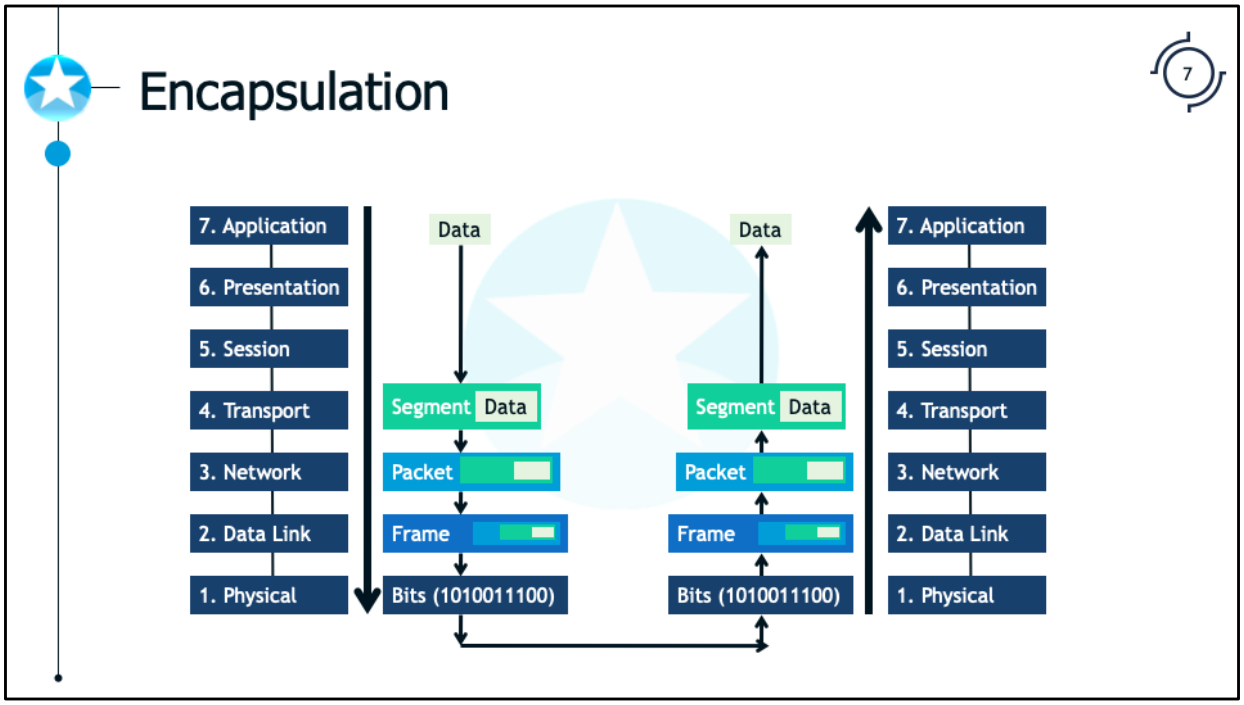


To get a better understanding of standard protocols, let's look at the network from the ground up. The OSI model is a framework for dividing the communications between network devices into seven layers. We will begin our discussion of networking by going through each of the layers, understanding their purpose and their implementation in modern networks. The 7 layers of the OSI model are Physical, Data Link, Network, Transport, Session, Presentation and the Application layer. People will often remember this through the use of a mnemonic, such as "Please Do Not Throw Sausage Pizza Away" (bottom to top) or "All People Seem To Need Data Processing" (top to bottom). Here is a brief description of each layer:

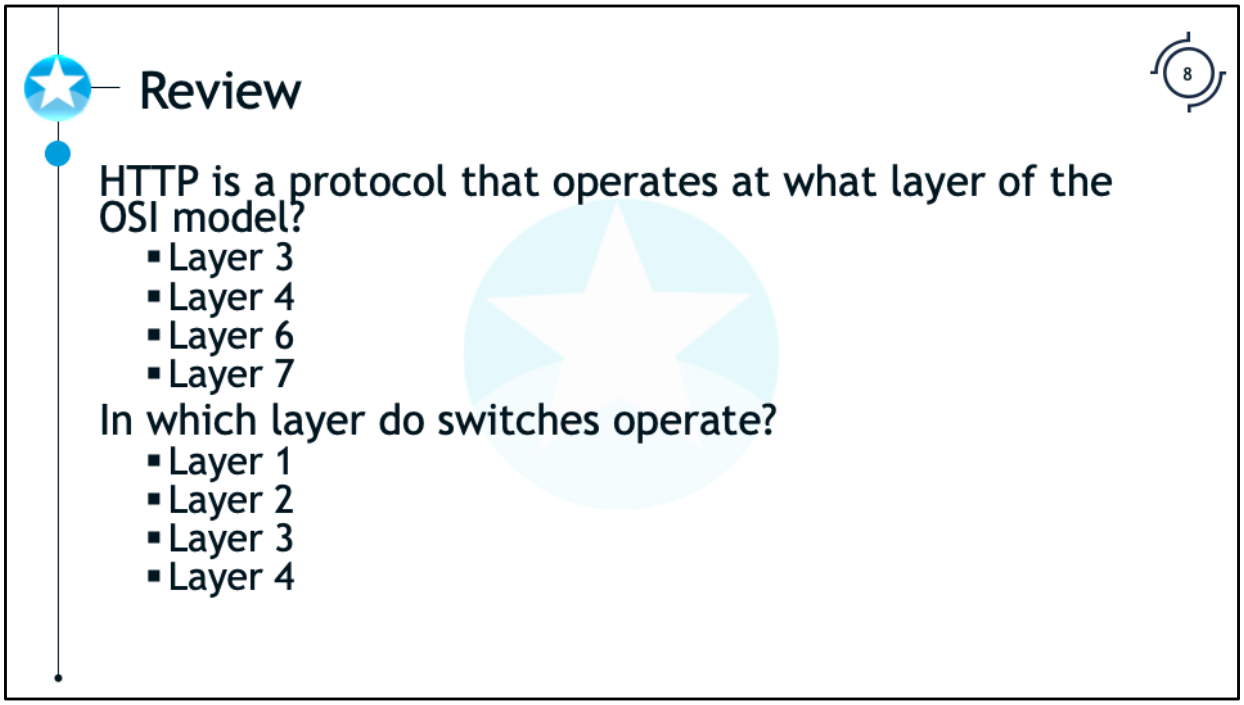
- The Application Layer generates data to send across the network, and is the closest to the end user.
- The Presentation Layer formats, encodes, and decodes data.
- The Session Layer helps sort out which program on a machine accesses data from the network.
- The Transport Layer helps ensure reliable delivery.
- The Network Layer delivers packets end-to-end, routing them between networks.
- The Data Link Layer carries packets across a single network hop, from computer to computer, or from computer to router.
- The Physical Layer is made up of the physical devices that carry the data (such as wires or radio transmitters).

Many devices do not need to communicate at all layers. For example, a network switch only needs to operate at the Data Link and Physical layers; it doesn't need to understand higher layers (such as HTTP) to be able to do its job. Likewise, an

application (such as a web browser) does not need to be able to handle the lower



Let's say that an application, such as a web browser, needs to send a request for a web page. The browser crafts an HTTP request, which gets sent to the operating system's TCP/IP stack. The HTTP request is then encapsulated inside a TCP segment, which is then encapsulated inside an IP packet. The IP packet is then encapsulated inside a frame, and then the frame is transmitted as bits across a physical medium (such as an Ethernet cable or a wireless network) in raw binary form. When the frame reaches its destination, it is then deencapsulated one step at a time until the receiving application receives its data.

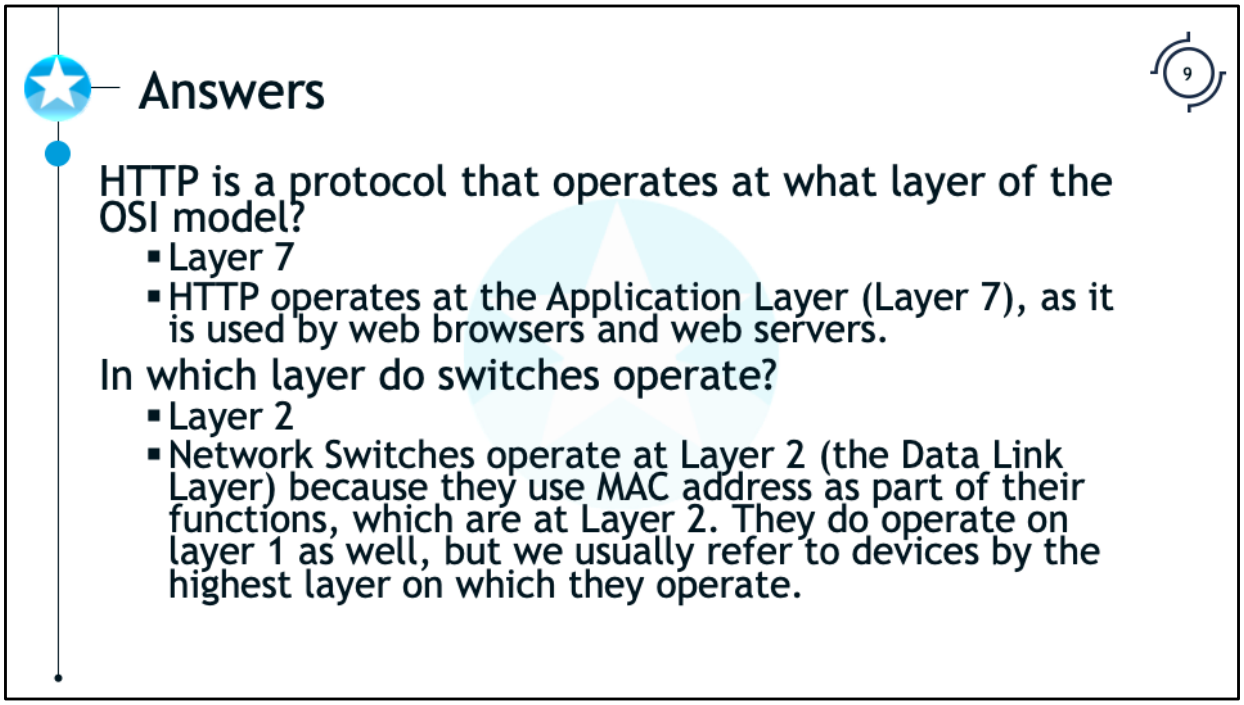


HTTP is a protocol that operates at what layer of the OSI model?

- Layer 3
- Layer 4
- Layer 6
- Layer 7

In which layer do switches operate?

- Layer 1
- Layer 2
- Layer 3
- Layer 4



HTTP is a protocol that operates at what layer of the OSI model?

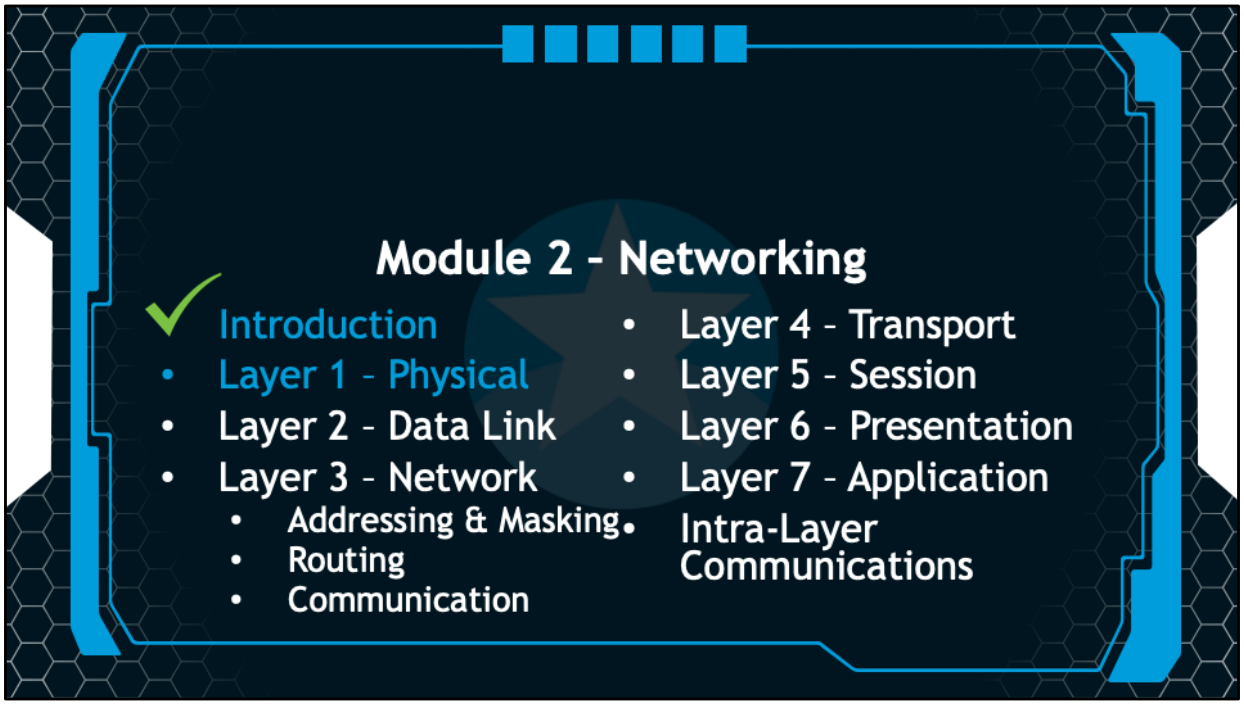
Layer 7

HTTP operates at the Application Layer (Layer 7), as it is used by web browsers and web servers.

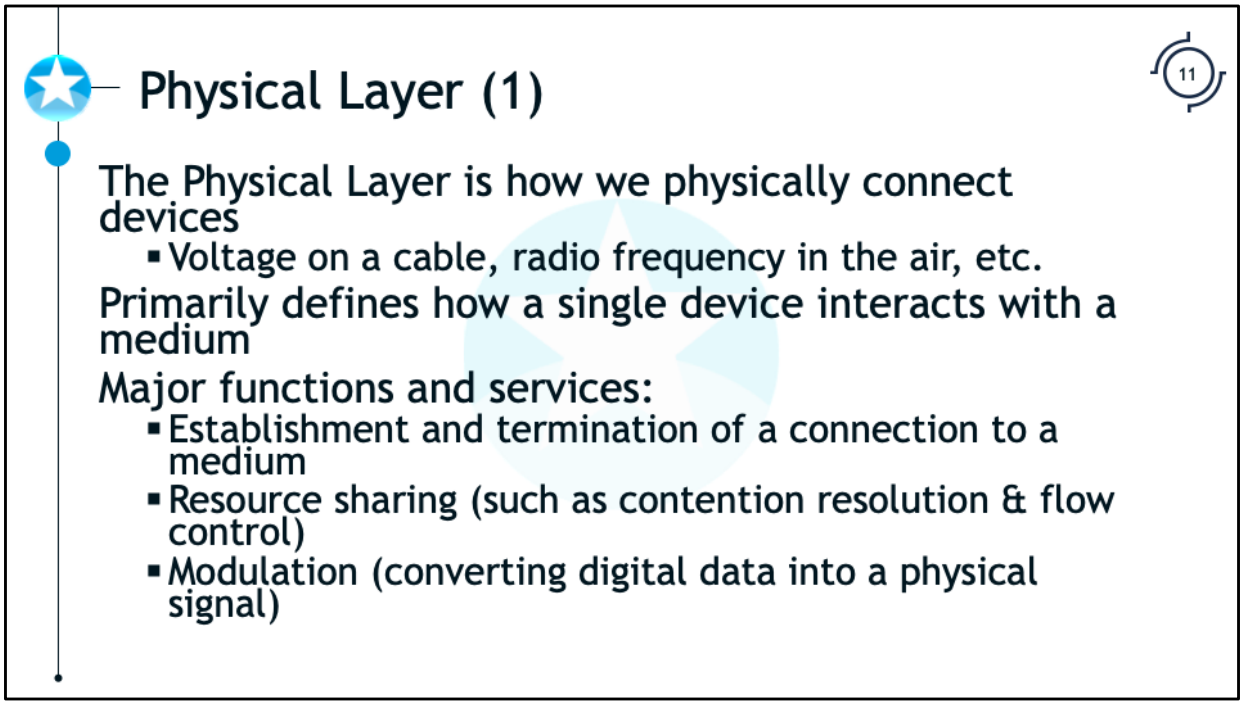
In which layer do switches operate?

Layer 2

Network Switches operate at Layer 2 (the Data Link Layer) because they use MAC addresses as part of their functions, which are at Layer 2. They do operate on layer 1 as well, but we usually refer to devices by the highest layer on which they operate.



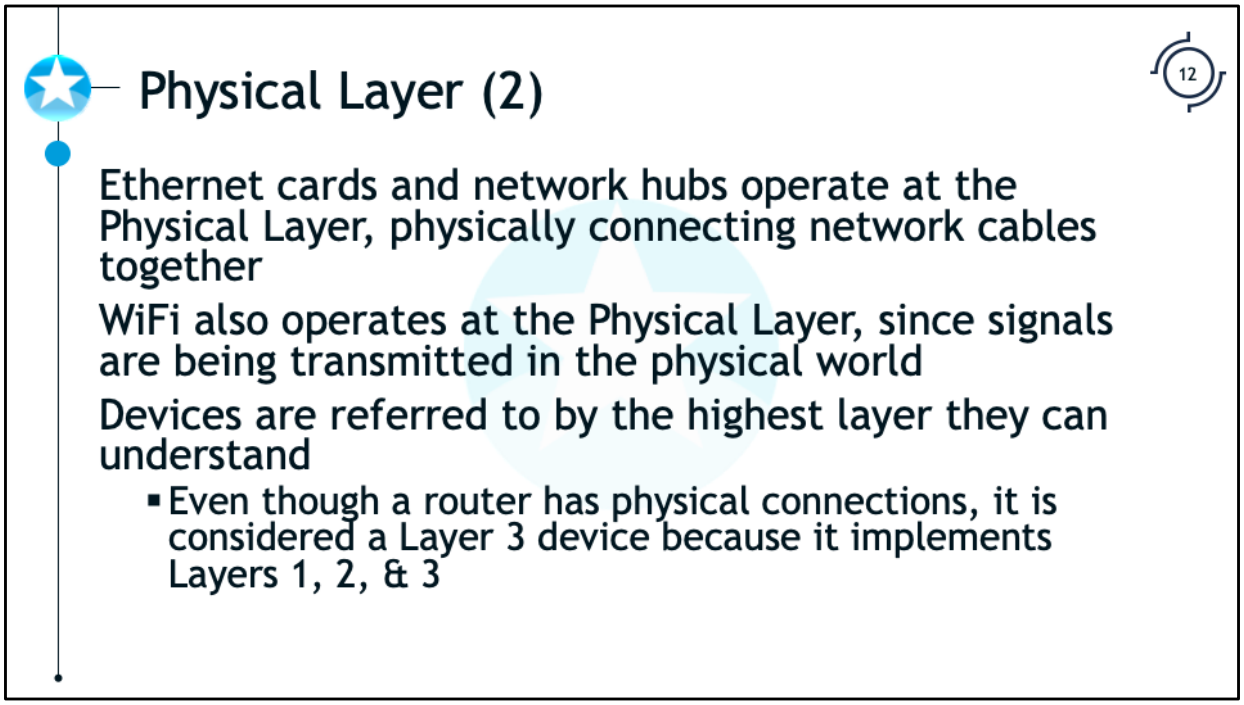
In this next section, you'll learn about the Physical Layer, including devices that operate at this layer and different network topologies.



The Physical layer, as the name implies, is how we physically connect devices. It is responsible for the manifestation of our data in the physical world in the form of voltage, beams of light, radio frequency, or something else as it passes from one device to another. The Physical Layer is responsible for the actual transmission of data (in the form of bits) from one point to another. It primarily defines how a single device interacts with a physical medium, such as how an Ethernet card transmits data across network cables.

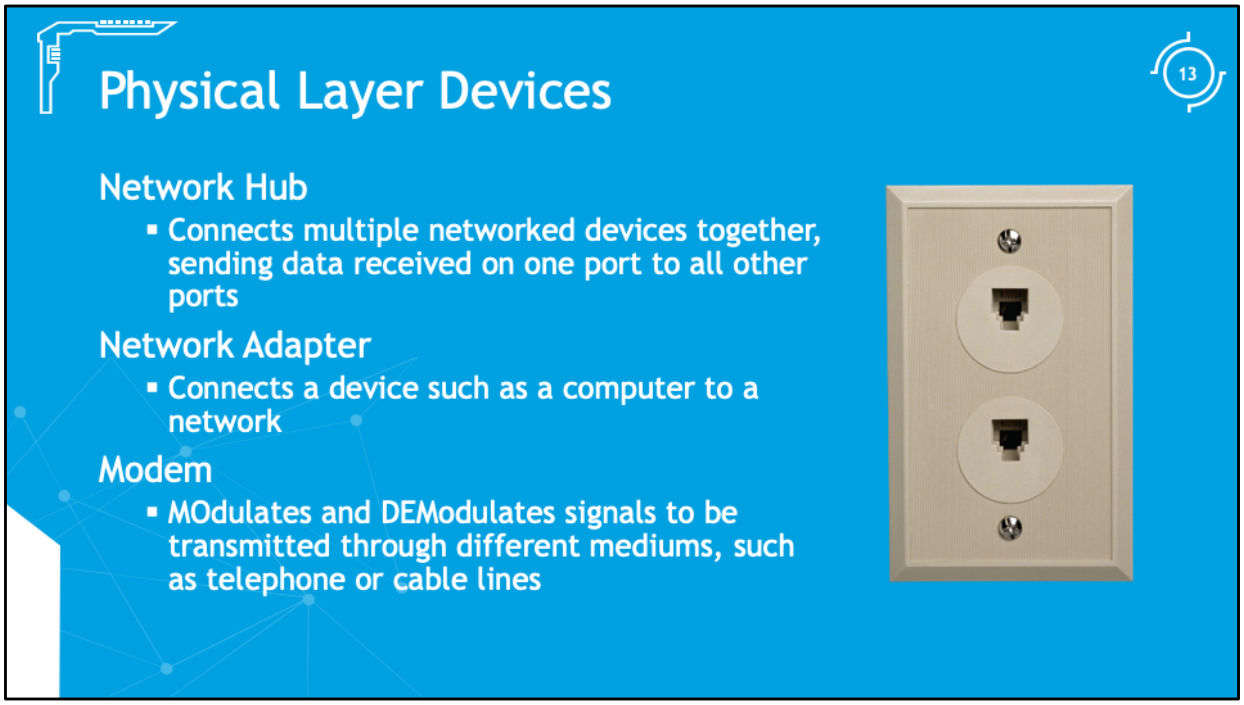
The major functions and services provided by the Physical Layer are:

- Establishment and termination of a connection to a communications medium
- Resource sharing, including contention resolution & flow control, to ensure that multiple devices are able to communicate without interfering with one another
- Modulation, the process of converting digital data to and from physical signals (such as voltage, light beams, or radio frequency)



Network cables, cards, and hubs all operate at the Physical Layer. A hub operates at the physical layer by electronically connecting the wires of multiple network cards. WiFi also operates in the Physical Layer even though it doesn't involve physical cables, since it uses radio signals to transmit data through the physical world.

Networking hubs are increasingly rare and are being replaced by switches. Switches operate at Layer 2 of the OSI model. This is sometimes confusing as people think, "A switch operates at Layer 2, but I know it provides physical connections. So isn't that Layer 1?" You are correct. Network equipment such as hubs, switches, routers and firewalls are referred to by the highest layer of the OSI model that they are capable of supporting. Therefore, a switch is a "Layer 2" device, because it implements both Layer 2 and Layer 1. Likewise, a router is a "Layer 3" device even though it implements Layers 1, 2 and 3.

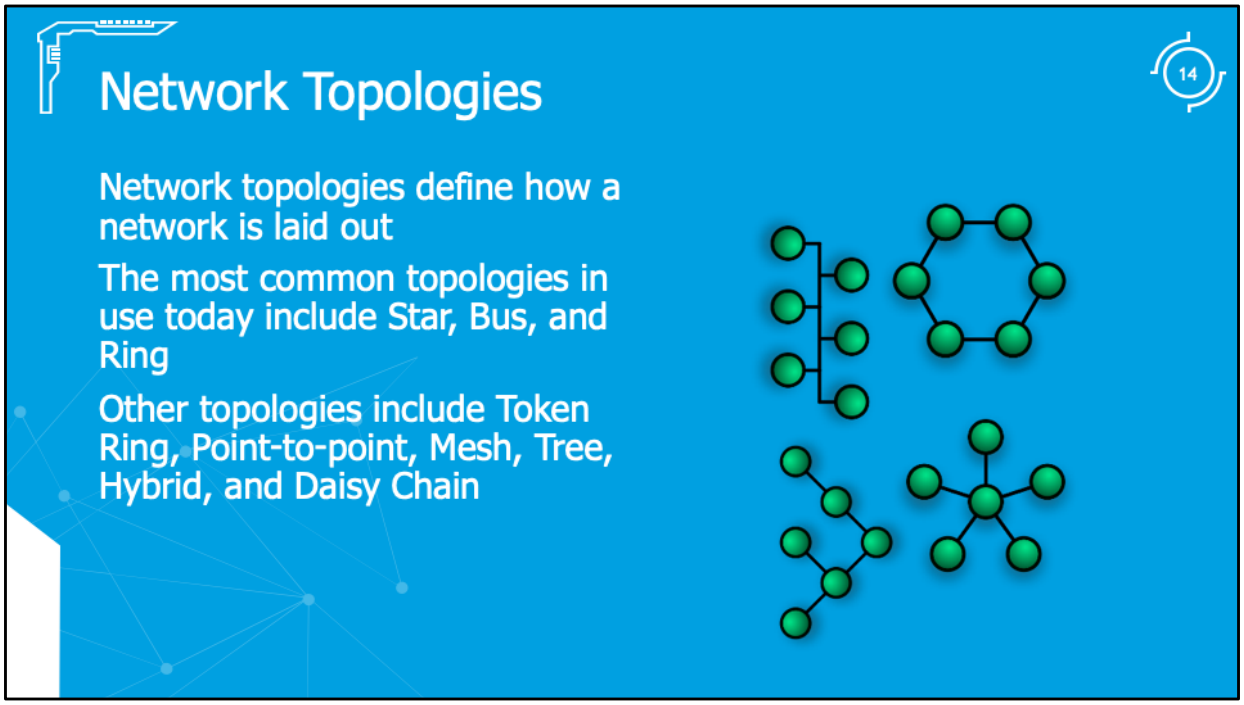


Here are some commonly found devices that operate at the Physical Layer:

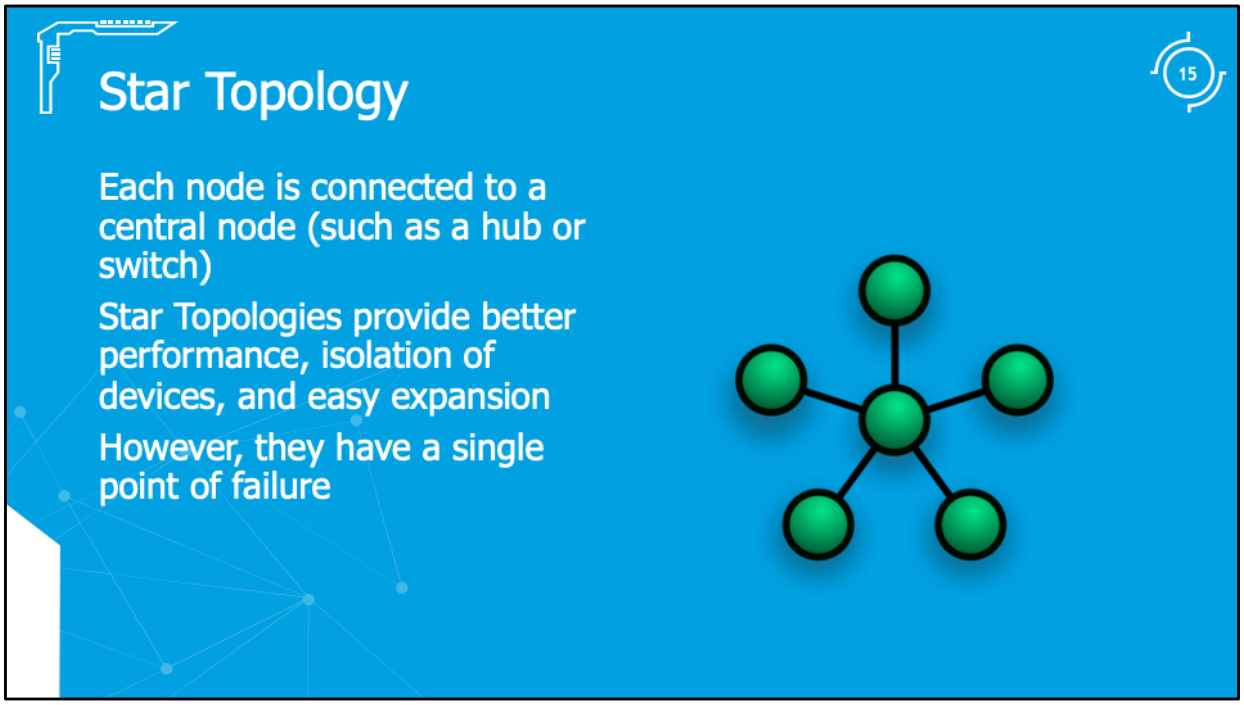
Network Hub: A hub is a device that connects multiple networked devices together. It typically contains a number of ports on it, allowing two or more network cables to be connected together. A hub operates only at the physical layer, and does not perform any sort of intelligent routing; it simply replicates the packets received on any one port to all other ports.

Network Adapter: A network adapter is a device that connects a device such as a computer to a network. An Ethernet adapter, for example, modulates data into electrical signals and transmits them over a network cable. A wireless adapter modules data into radio frequency (RF) signals and transmits them through the air.

Modem: A modem (short for **mo**dulator-**dem**odulator) is a device that modulates and demodulates data, allowing it to be transmitted through different sorts of mediums. For example, a traditional analog modem converts data into audio signals that can be transmitted over traditional phone lines, and a cable modem converts data into signals that can be carried over coaxial cable lines.

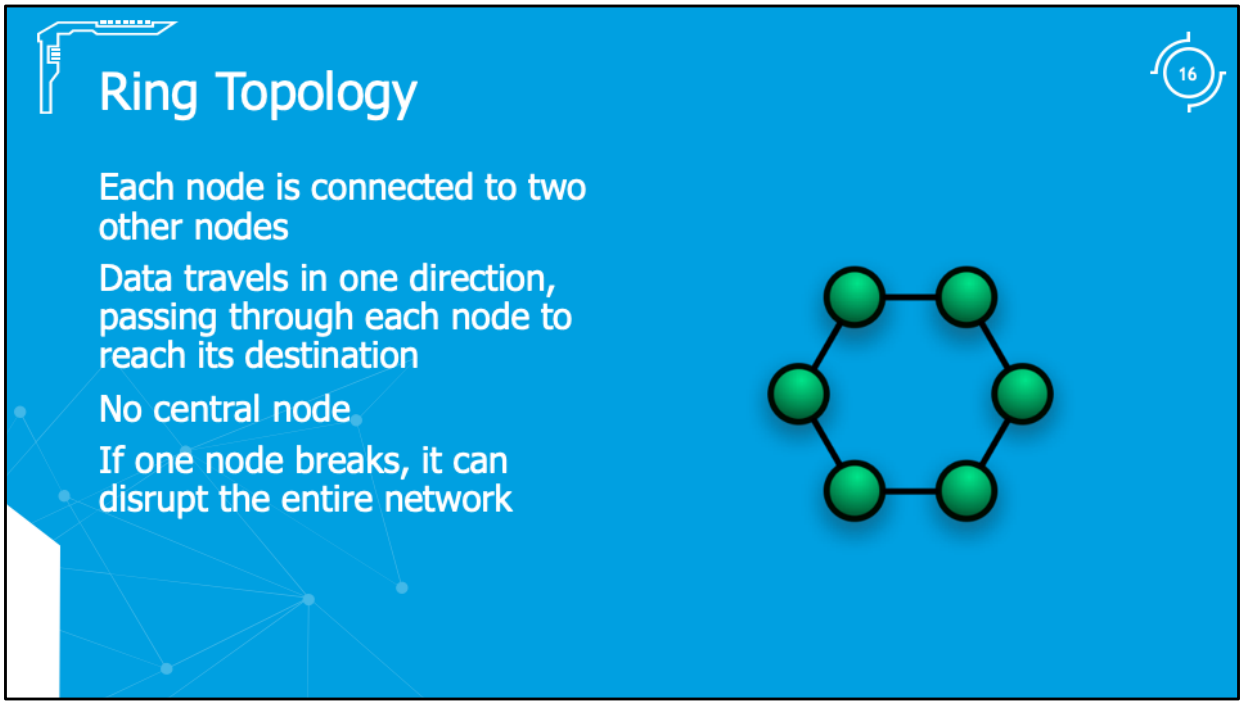


If you look at a topology map of the Earth, you will see mountains, valleys, and rivers. The topology map shows you how the surface of the Earth is physically laid out. Networks also have a topology. Networks can be physically or logically laid out in different ways. Common topologies we see today include the Star, Bus, and Ring. Other topologies include Token Ring, Point-to-point, Mesh, Tree, Hybrid, and Daisy Chain.



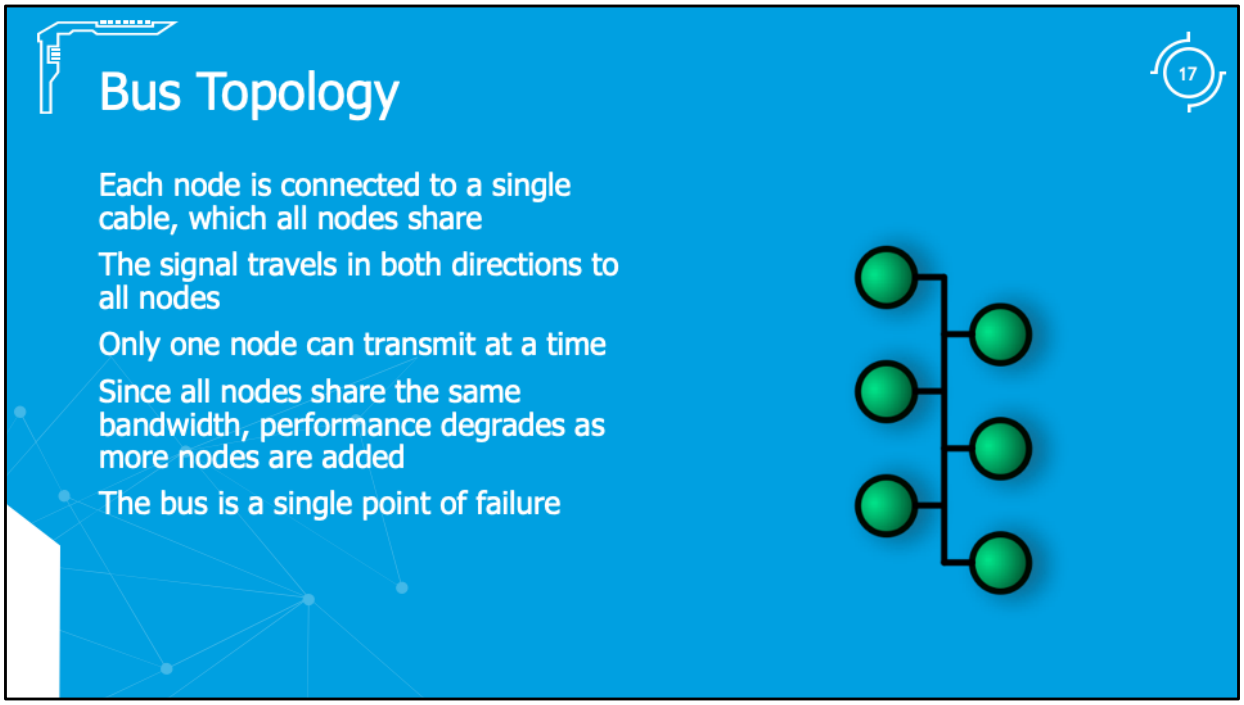
In a Star Topology, each node on the network (such as a computer or printer) is directly connected to a central node, such as a network hub or switch. This topology is generally the easiest to implement, as each device only requires a single connection to the central node. They provide for better performance, since packets should only have to travel through a few hops to get from their source, through the central node and to their destination. Their centralized nature also allows for easy isolation of devices, since there is a central location they can be disconnected from without affecting any other device. Star topologies also allow for easy expansion, since the central node can be expanded or replaced without needing to re-wire other nodes throughout the network. However, the central node is a single point of failure; if it goes down, the whole network comes down.

Examples of star technology include hubs and switches.



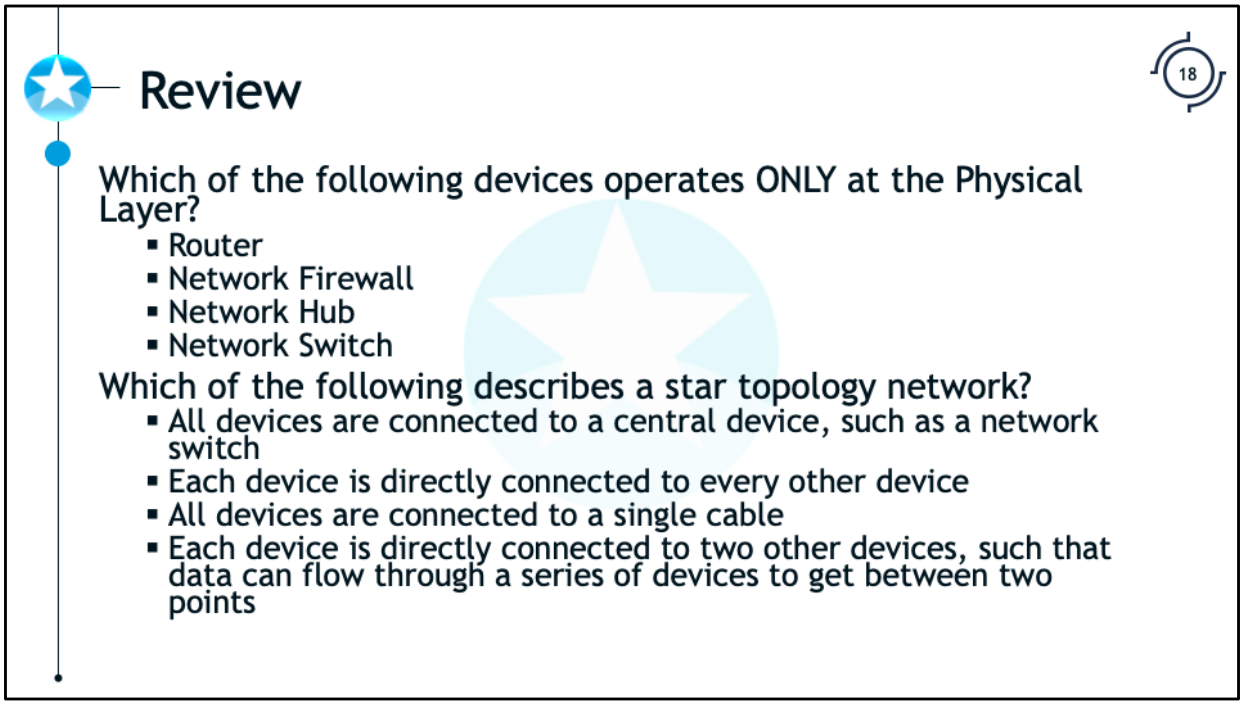
In a Ring Topology, each node on a network is connected to two other nodes, typically its closest neighbors. Packets travel in a single direction, passing through each node between the source and the destination. Ring topologies do not have any sort of central node, since each node is connected to every other through the ring. Ring networks are very orderly, giving every device access and the opportunity to transmit, and they perform better than bus topologies under heavy load. However, if any node on the network breaks, it could interrupt communication through the entire network (since there is only one path for data to take). Ring networks make expansion more difficult, since the cabling of existing nodes will have to be changed to connect to the new devices. Bandwidth is also shared by all nodes, and the communication delay is directly proportional to the number of nodes on the network.

Examples of ring technology include FDDI, SONET, and legacy Token Ring. Some ring protocols, such as FDDI, have the capability to continue to work even if the network is severed in one area or node.



In a Bus Topology, all nodes are connected to a single physical cable, which is shared between all nodes. Unlike Ring networks, the signal travels in both directions, reaching all nodes. Having a single cable reduces initial costs, and allows for easy expansion. However, only one node can transmit at a time, and all nodes on the network share the bandwidth of the single cable. The more nodes there are, the less bandwidth each has available to it, and each node can transmit less frequently. The bus cable is also a single point of failure; if it breaks, the entire network breaks. The bus also requires proper termination to close any open loops; if a node is removed, it either has to be replaced or its connection has to be terminated with a terminator.

Examples of bus technology include legacy 10Base-2 (Thin Net) and 10Base-5 (Thick Net).

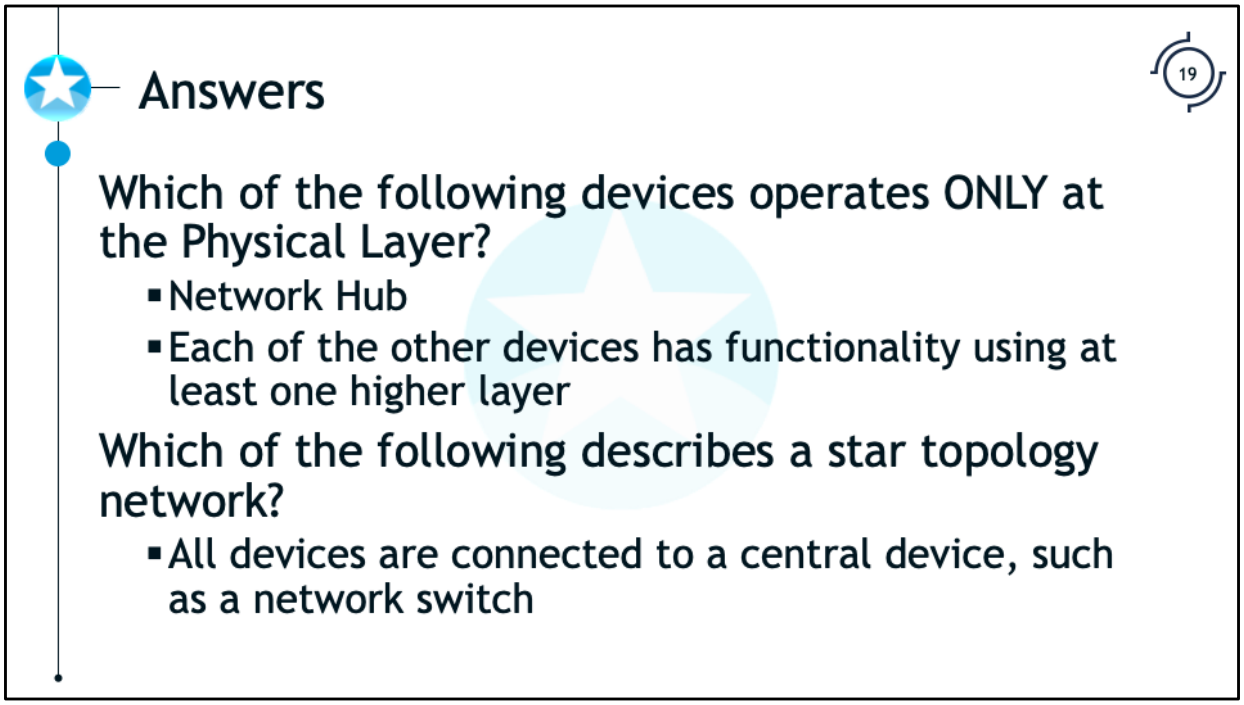


Which of the following devices operates ONLY at the Physical Layer?

- Router
- Network Firewall
- Network Hub
- Network Switch

Which of the following describes a star topology network?

- All devices are connected to a central device, such as a network switch
- Each device is directly connected to every other device
- All devices are connected to a single cable
- Each device is directly connected to two other devices, such that data can flow through a series of devices to get between two points



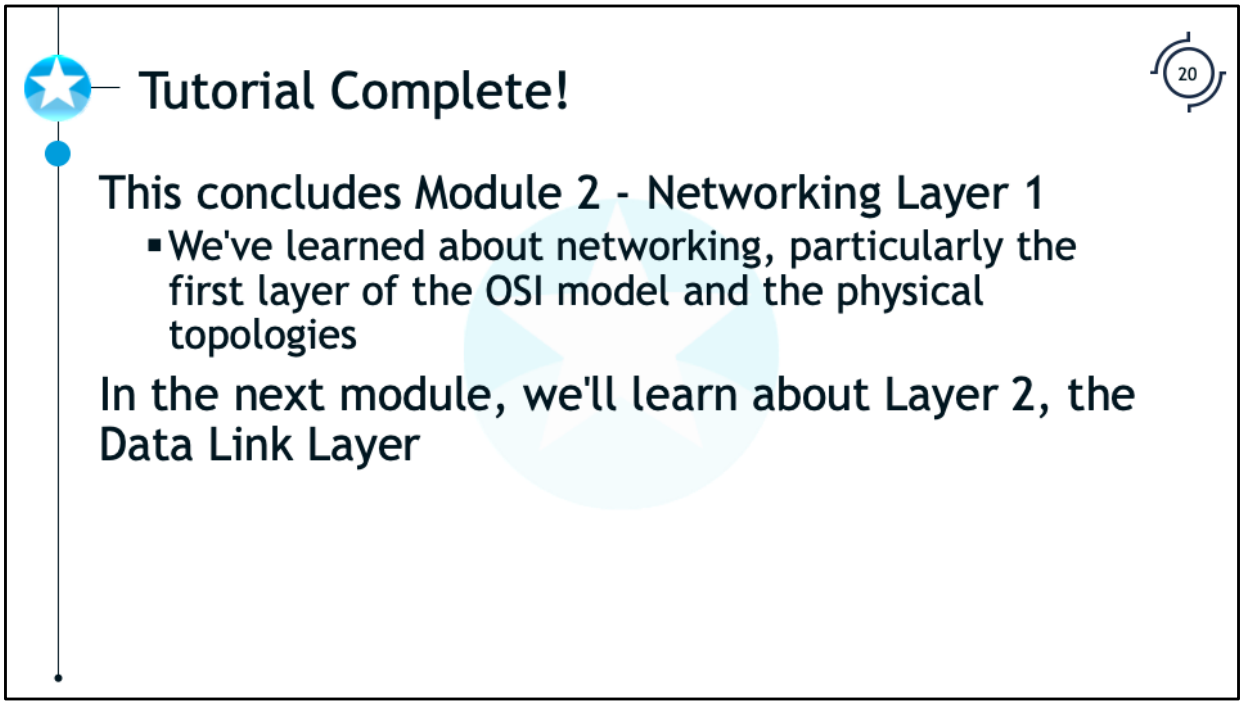
Which of the following devices operates ONLY at the Physical Layer?

Network Hub

Each of the other devices has functionality using at least one higher layer

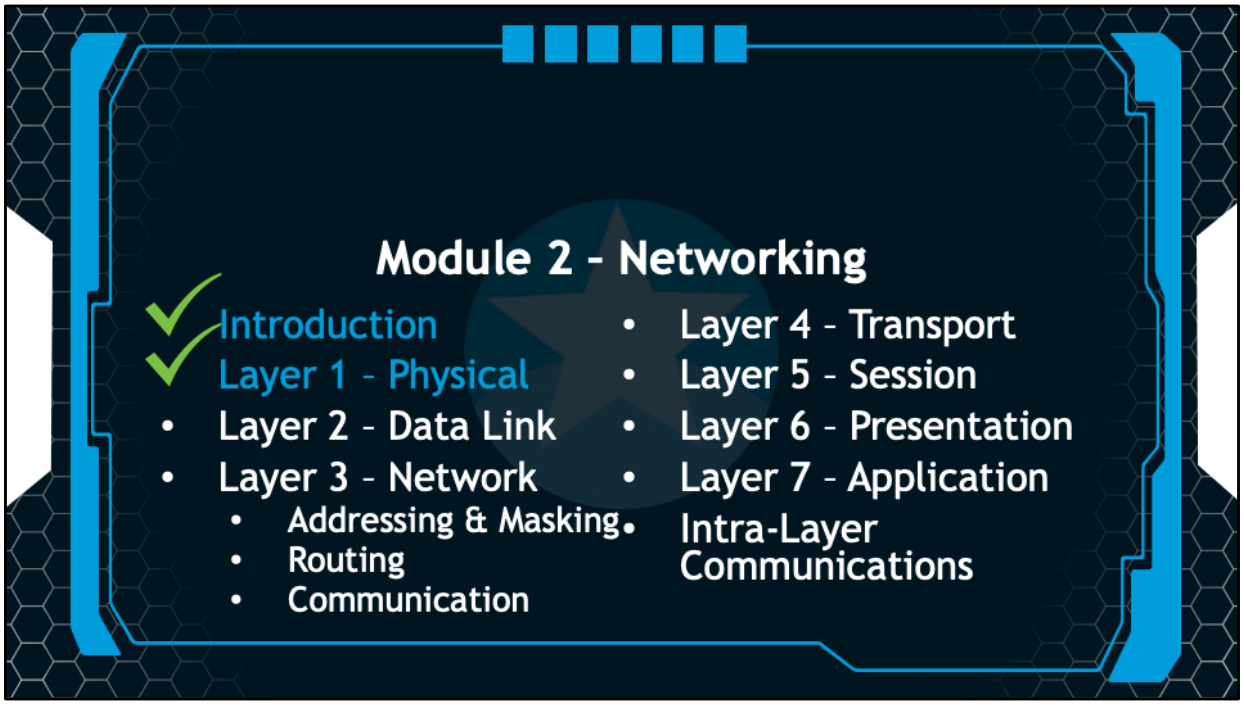
Which of the following describes a star topology network?

All devices are connected to a central device, such as a network switch



This concludes the introduction and discussion about Layer 1. Specifically, we discussed the topologies commonly used at Layer 1 and the pros and cons of each.

In the next tutorial we'll discuss the next layer in the OSI model.



You've completed the introduction to networking and the physical later. In the next module, we'll discuss Layer 2, the Data Link Layer.