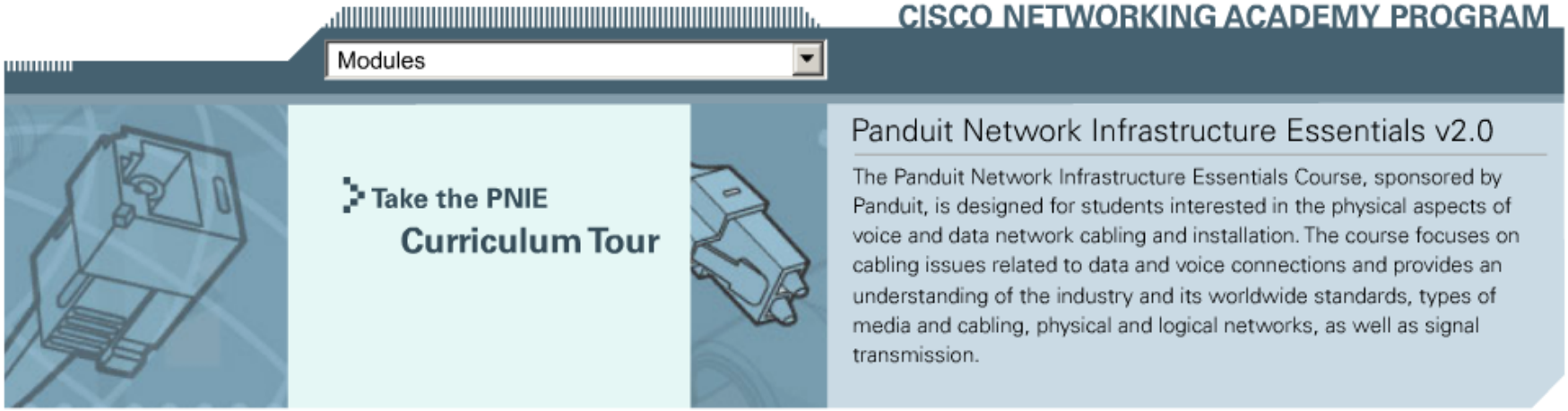


Panduit Network Infrastructure Essentials

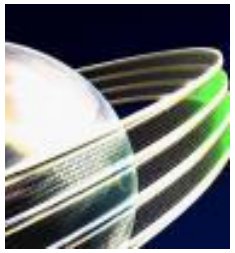
Networking Basics

What is a Network?

- A network is a connected system of objects or people.
- A PSTN (Public Switched Telephone Network) is an example of a network.
- Similarly, a computer network allows users to communicate with other users on that network by transmitting data on cables.
- A computer network is defined as having two or more devices linked together for the purpose of sharing information, resources or both.
- The link can be through copper or fiber-optic cable, or it can be a wireless connection that uses radio signals, lasers, infrared technology, or satellite transmission.

Benefits of Networking

- Sharing Input & Output Devices
- Sharing Storage Devices
- Sharing Modems & Internet Connections
- Sharing Data & Applications
- Reduced Expenditure

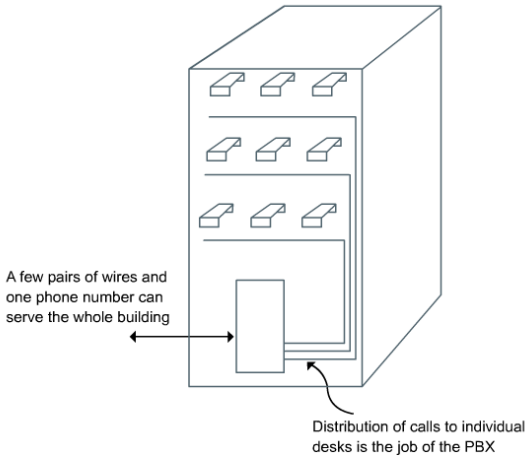


Telephony

- The science of converting sound to electrical signals and transmitting them between distant stations.
- Modern telcos use digital devices called **switches** to connect calls
- Calls between telcos are called **trunk call**s
- The last mile from the Central Office (CO) to the user is often called the **local loop**
- Typically, telephone cabling consists of two wires
- These two wires are twisted around each other to prevent signals from one pair leaking into the other. This type of wiring is called **twisted-pair**.

Local Voice Network

- A localized voice network is basically a private telephone network confined to an organization. These are called private branch exchanges (PBXs), and are found in many large organizations. They allow users to access other users on the network by only dialing their extension rather than the entire phone number.
- Users of the PBX share a certain number of outside lines for making telephone calls external to the PBX.



The Role of Cabling in a Network

- Cabling is essential to both data and voice networks. The transmission of data is accomplished by sending signals over the media.
- The most common medium is copper wiring, which uses electrical current to send signals.
- Fiber-optic cable is gaining in popularity. It uses pulses of light to transmit signals.
- Other networks communicate using radio, infrared, or microwave waves.
- Network cabling technicians must be familiar with each of these media, when each should be used, and how to connect them to the network.

Structured Cabling Systems

- In the past, data and voice networks were separate. Today, the wiring systems are integrated, creating organized and standards-driven *structured cabling systems.* Cable installers pull cables for both data and voice networks at the same time, sometimes even using the same kind of wiring for both.

- The quality of the cabling and installation will determine whether the data or voice connection is established and the quality of that connection.

The Quality of Cabling

- Cabling is the physical medium that connects modern communication and data systems together.
- Three costs that can be attributed to poor cabling:
  - The network might not work reliably or may run poorly
  - Increased maintenance
  - Increased risk of obsolescence (it is important to install all cable to meet accepted industry standards)
- Cabling costs less than 10% of the total network costs, yet has a life span of 10 – 15 years.

Emerging Cabling Technologies

- Wireless – 802.11
- Fiber-optic – 802.8
- High-speed access technologies: CATV, DSL (uses existing telephone copper lines to transmit)
- Data over electrical power lines
- PoE – Power over Ethernet
- Integrated wiring – The same type of wire is used for all types of traffic

Goals of the Network

The network should be:

- Simple
- Manageable
- Adaptable and scalable
- Reliable
- Transparent

Which Standards Do I Follow?

- Factors:
  - The specification dictated by the equipment manufacturer.
  - The standards used in the country of origin for the equipment.
  - Standards that may overlay national standards, such as special government or military standards.
- National Standards
- State Standards supersede National
- Local Standards supersede State

Which Standards?

- International Standards Organization / International Electrotechnical Commission (ISO/IEC) is the worldwide standard for telecommunications
- ANSI/TIA/EIA (American National Standards Institute / Telecommunication Industry Association / Electronic Industry Association) standards are effective in the United States and Canada.

The **ISO** created the **OSI** to help with the **IOS**.

TIA/EIA standards

Telecommunications Industry Association and Electronic Industries Association

- **TIA/EIA 568-A**: Commercial Building Telecommunications Wiring
- **TIA/EIA-568-B.1**: Commercial Building Telecommunications Cabling
- **TIA/EIA-568-B.2**: Commercial Building Telecommunications Cabling
- **TIA/EIA-568-B.3**: Optical Fiber Cabling Components Standard
- **TIA/EIA 569-A**: Commercial Building Standard for Telecommunications Pathways and Spaces
- **TIA/EIA 570-A**: Residential and Light Commercial Telecommunications Wiring
- **TIA/EIA-606**: Cable Labeling Standards
- **TIA/EIA-607**: Commercial Building Grounding and Bonding Requirements for Telecommunications

IEEE

Institute of Electrical and Electronics Engineers

- Non-profit, technical professional association of more than 377,000 individual members in 150 countries. Founded in 1884, the organization is composed of engineers, scientists, and students. Through its members, the IEEE is a leading authority in technical areas ranging from computer engineering, biomedical technology, and telecommunications to electric power, aerospace, and consumer electronics.
- IEEE has more than 860 active standards with 700 under development. The IEEE is best known for developing standards for the computer and electronics industry. In particular, the IEEE 802 standards for local-area networks are widely followed.

OSHA

- Occupational Safety and Health Administration (OSHA) - promotes a safe and healthy working environment by providing information and advice about occupational health and safety. OSHA is charged with job and worker safety.
- OSHA inspectors have the power to impose heavy fines and/or shut down a jobsite should they find serious safety violations.
- Anyone who works on, or is responsible for, a construction site or business facility needs to be familiar with OSHA regulations.

Underwriters Laboratories

- An independent, nonprofit product safety testing and certification organization
- Besides safety standards, UL also evaluates twisted-pair LAN cables for performance and safety

UL 444 – Standards for Communications Cable

Environmental Protection Agency

- Environmental Protection Agency (EPA) - responsible for enforcing environmental violations.
  - Toxic solvent disposal
  - Batteries
  - Plastic disposal
  - Computer disposal

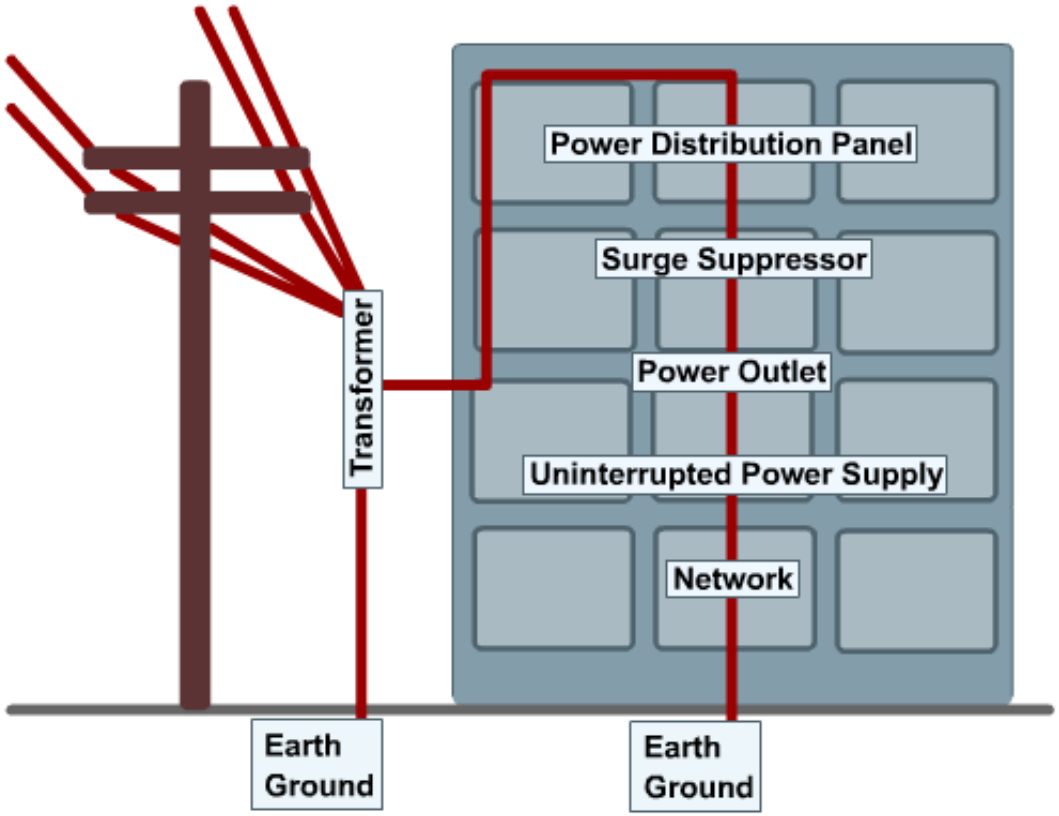
National Electrical Code

- National Electrical Code (NEC) – Ensure consistency across a country in the things people do to safeguard persons and property from hazards arising from the use of electricity
- Specifies rules for safe grounding, bonding, and separation of cables
- Cable burn rating:
  - Requires installation of clean-burning plenum-rated cable in areas that may spread toxic fumes if the cables burn

Grounding and Bonding Defined by the NEC

- Grounding
  - "A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes."
- Bonding
  - "The permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to conduct safely any current likely to be imposed."

Proper Grounding



- Attach the ground wire to an existing grounding busbar or main grounding wire.
- Grounding works by providing a direct path to the earth for any voltages that come in contact with it.

Bonding

- Bonding conductors are not intended to carry electrical load currents under normal conditions, but must carry fault currents so that electrical protection (circuit breakers) will operate properly.

Six Feet of Separation Rule

- There must be at least six feet of separation between voice/data cabling and grounding wire.
- There must be at least six feet of separation between voice/data cabling and high-voltage wiring such as power cables.
- There must be at least three feet of separation if the high voltage wire is in conduit.

TOPOLOGIES

Types of Networks

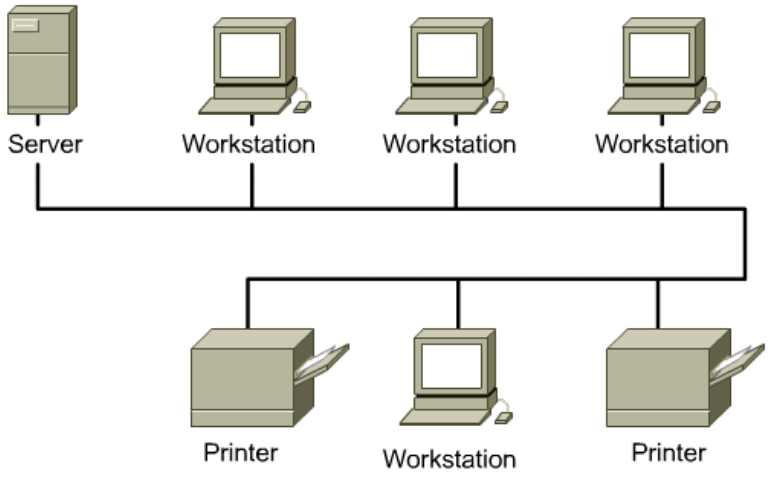
- **LAN** Local Area Network – Interconnects computers within a limited geographical area.
- **MAN** Metropolitan Area Network – Two or more LANs linked within a city or limited geographical area. (~50 miles)
- **WAN** Wide Area Network – Connects users across great distances without geographical limits. Typically represented as a cloud since the data transmission from a source to a destination computer is contingent on many factors. It uses the services of a communications provider such as a telco or ISP.

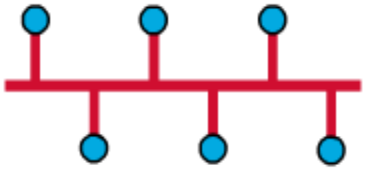
Network Topologies

- Computer networks have physical and logical topologies.
  - **Physical** topologies are the layout of the networking cables, devices, and workstations. Common topologies are the bus, ring, star, extended star, hierarchical, and mesh.
  - **Logical** topologies dictate the path data takes between devices and workstations (how data flows). Common logical topologies include the ring and the bus.
- Every network has both a logical and a physical topology.

Bus Topology

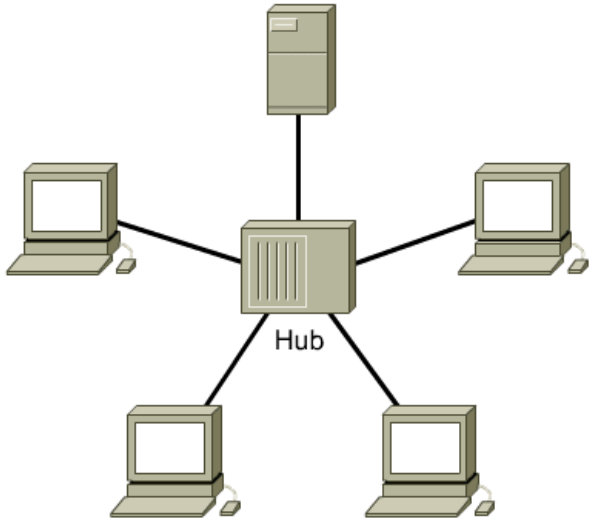
- Simplest topology
- Single length of cable end-to-end
- Requires terminators
- One end of the bus must be grounded
- If the cable breaks or rails, no devices can communicate
- Suitable for networks with few computers (10 or less)

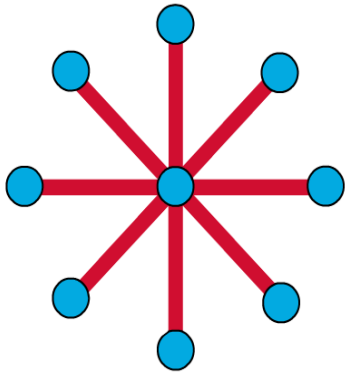




Star Topology

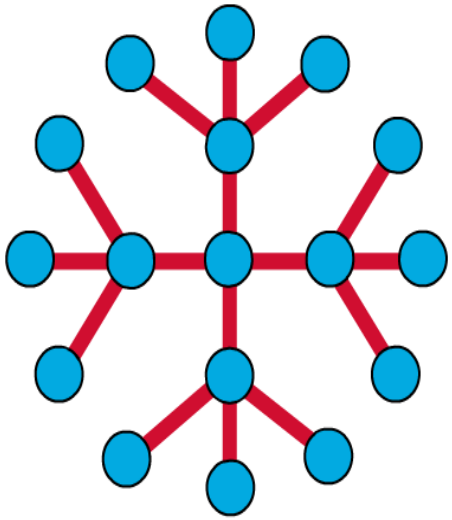
- Most popular.
- Connects all cables to a central point of concentration.
- Relies on the central device (hub, switch or router).
- Small to medium sized networks.
- Easy to add more workstations.
- If one cable fails the network will not fail.
- If the central hub fails, the entire network is affected.
- Easier to diagnose problems.





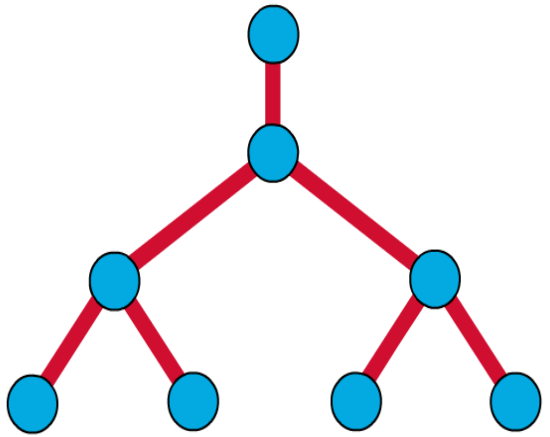
Extended Star

- Created by linking together several star topologies to a central point.
- Same advantages as the star topology.
- Considered the backbone topology of choice for structured cabling systems by the TIA/EIA organizations.



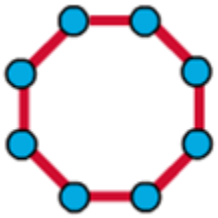
Hierarchical Topology

- Imposes order on the network by grouping hosts based on their physical location on the network.
- This is typical of many telephone networks, where groups of extensions map to floors of buildings, departments, or rank of personnel.
- Disadvantage is that if one cable fails it can affect all the hosts that use it to access other parts of the network.

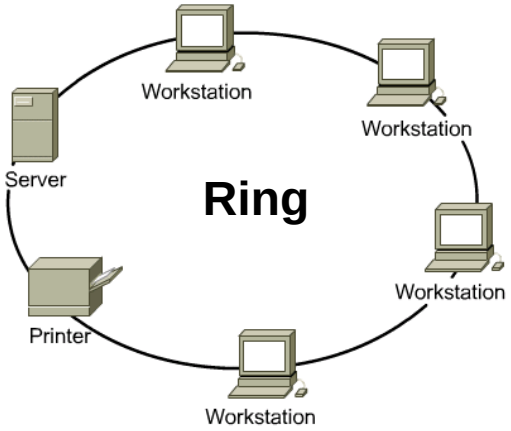


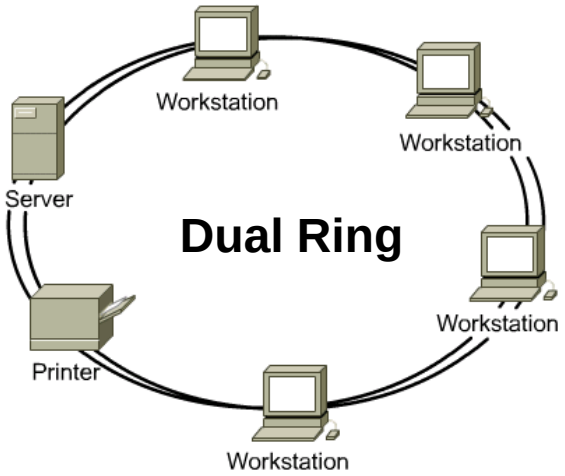
Ring and Dual Ring Topology

- Closed loop configuration
- Predictable paths



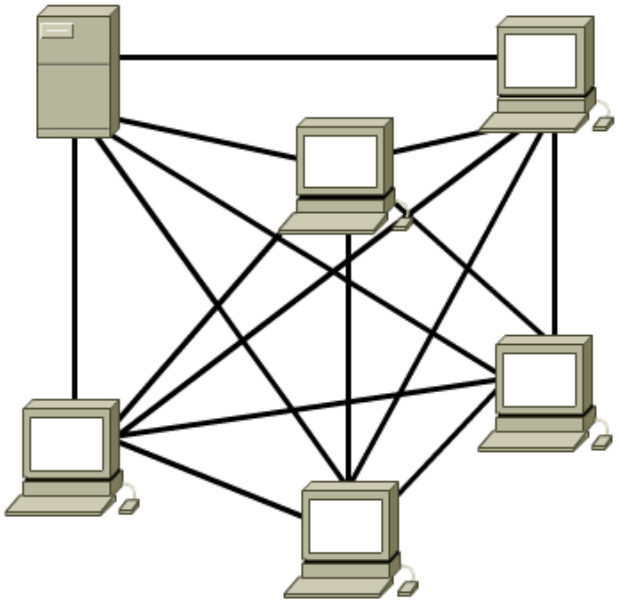
- FDDI:
  - Automatic sensors can seal off the bad section and restore connectivity with a dual ring.
  - Faster speeds with Fiber Optic

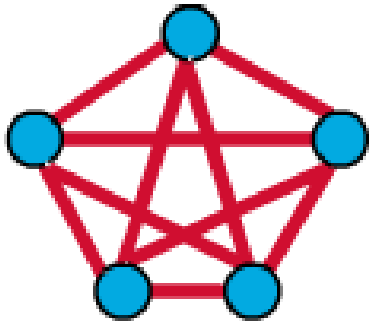




Mesh Topology

- A mesh topology provides total redundancy for a network by connecting each host to every other host



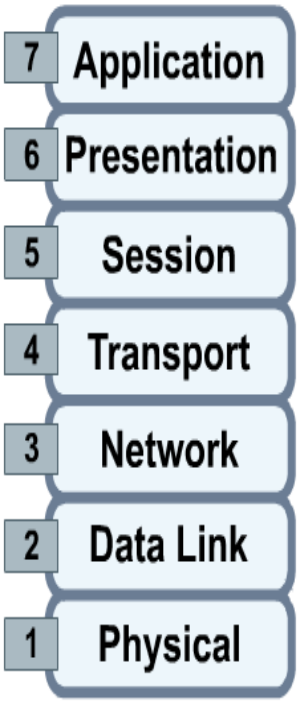


OSI MODEL

The OSI Model (Open System Interconnect)

- The OSI layers form a reference model that we use to speak of networking functions.
- It breaks the network process into seven manageable layers.
- The functions are defined by the **ISO** (International Organization for Standardization)
- The OSI model is used universally as a method for teaching and understanding network functionality.
- Following the OSI model when designing, building, upgrading, or troubleshooting will achieve greater compatibility and interoperability between various types of network technologies.

Reasons for using the OSI Model

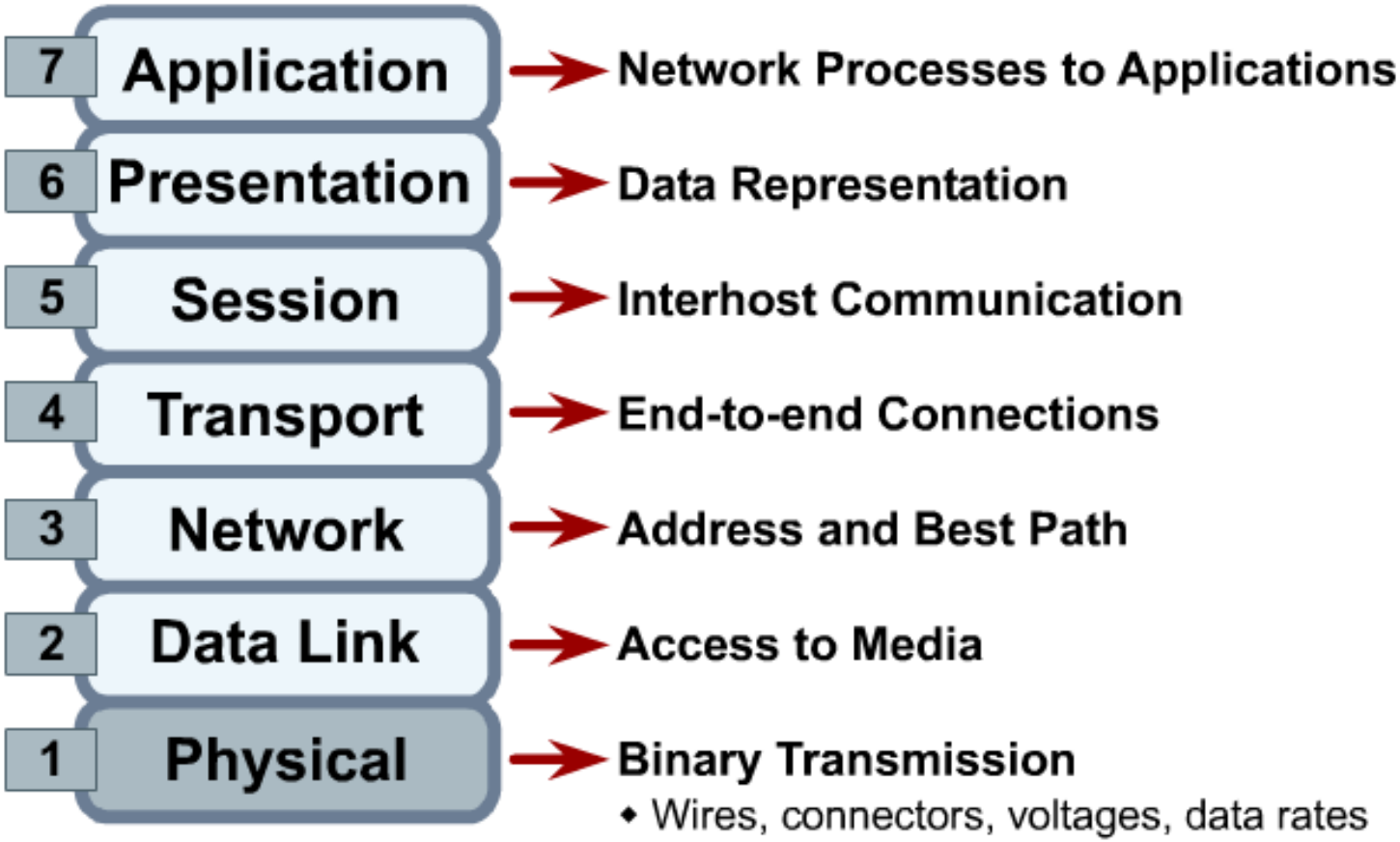


- Reduces complexity
- Standardizes interfaces
- Facilitates modular engineering
- Ensures interoperable technology
- Accelerates evolution
- Simplifies teaching and learning

- Divides the aspects of network operation into less complex elements.
- Enables engineers to specialize design/development efforts on specific functions.
- Prevents changes in one area from affecting other areas.
- Allows network designers to choose the right networking devices.
- Helps with test and troubleshooting the network.

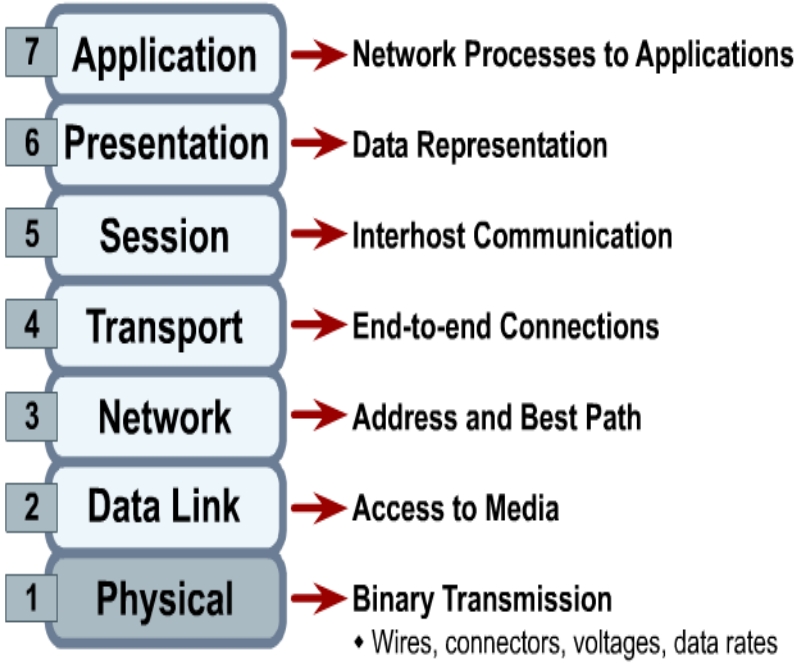
The 7 layers of the OSI Model

(Please do not throw sausage pizza away)



Physical Layer (Layer 1)

- Converts information into bits, 0s, and 1s.
- Repeaters, hubs, and tranceivers work at this layer.
- Uses twisted pair, fiber-optic, or coaxial to operate.
- Provides the electrical, mechanical, procedural, and functional means for activating and maintaining whatever physical link exists between hosts.



Cable installers primarily work is this layer.

Layer 1 Problems

- When there are problems with a network, troubleshooting should begin with Layer 1.
- Most network problems are layer 1 problems. Many of these could be avoided when installing cable.

Placement of Cables

- One of the most common wiring errors by cable installers is laying cables near other wires, particularly power cables, or sources of power. Power cables emit background noise, which can interfere with the signals on network cables. Other sources of electromagnetic noise like fluorescent lights and machines can also cause problems with signals on wires.
- Signals weaken as they travel across the media. This is known as attenuation.

Termination of Cable

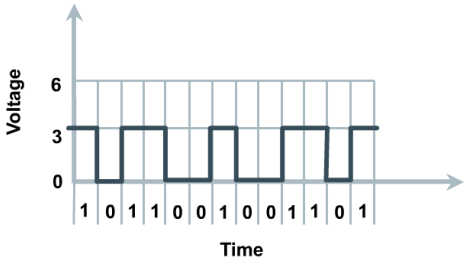
- Another common error is improperly terminating wire to jacks and plugs. This can lead to the wires emitting signals that interfere with the signals on other wires, a condition called crosstalk. When errors are caused by crosstalk, data is usually lost and must be retransmitted.

Handling of Cable

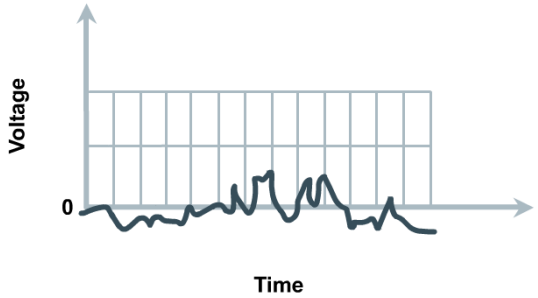
- Wires can be damaged as they are pulled into place. Pulling cables too tightly, nicking them, or bending them can cause problems that may not be apparent immediately, but can cause the electrical properties of the wire to change slowly over time.

Signals

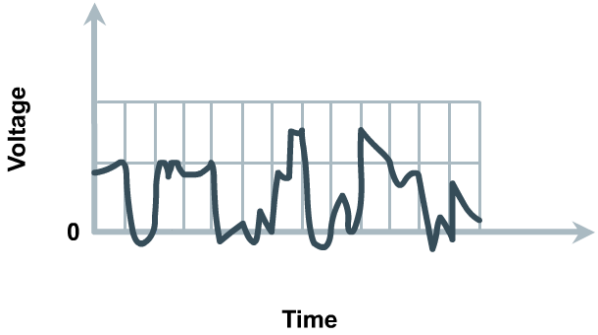
- Digital Signal



- Electrical Noise



- Digital Signal & Electrical Noise

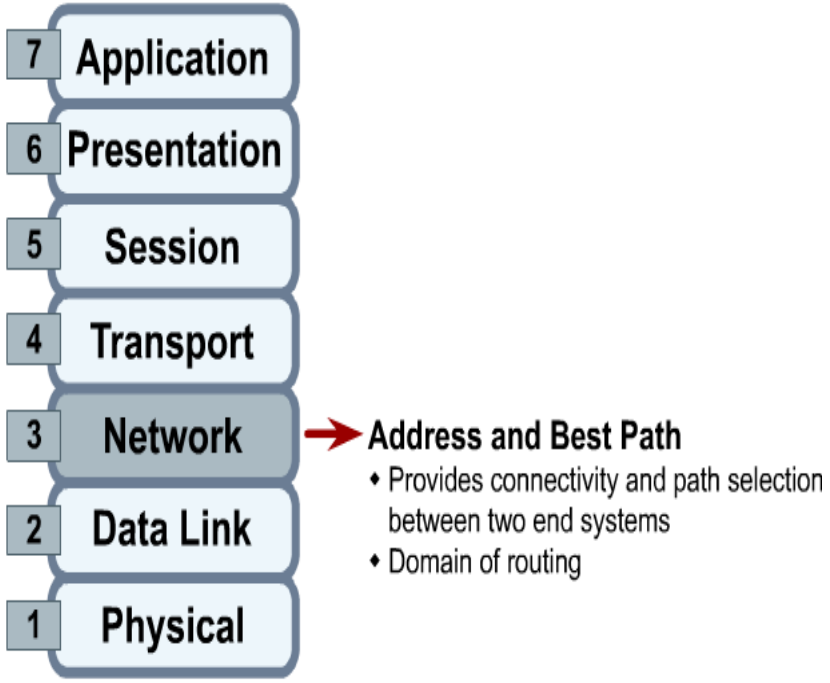


Data Link Layer (Layer 2)

- Speed of transmission
- Flow Control
- Error Identification
- Physical Topology
- Bridges and Switches
- This layer recognizes special identifiers that are unique to each computer, called media access control (MAC addresses)
- Physical address (hexadecimal) 03-55-1A-F5-3C-4B

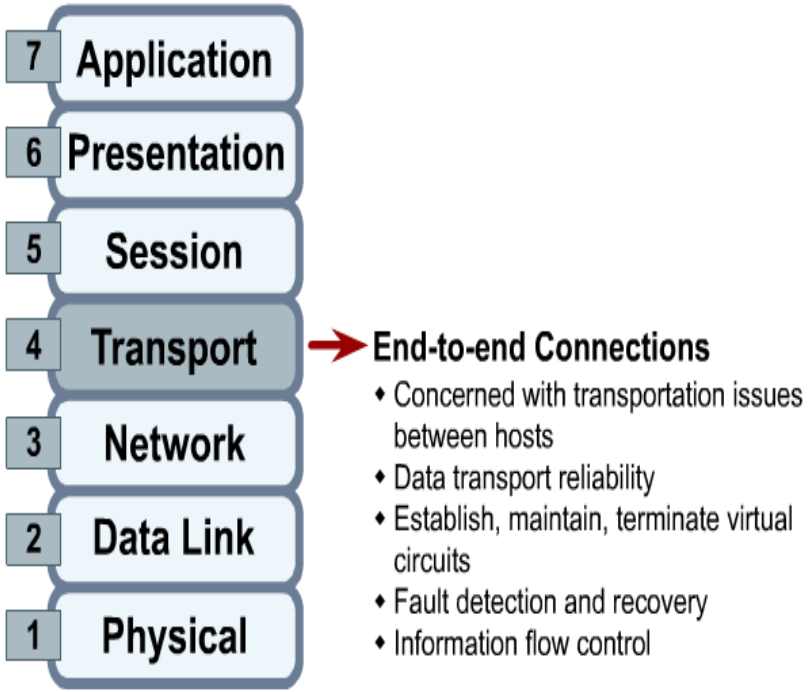
Network Layer (Layer 3)

- Deals with higher-level addressing schemes and path determination.
- Logical Topology
- Routers examine the IP address of the computer.
- Indicates to which network and subnetwork a computer belongs.
- In addition to logical addressing, another function is to determine the best path a data packet will take through the LAN or WAN.
- Routing

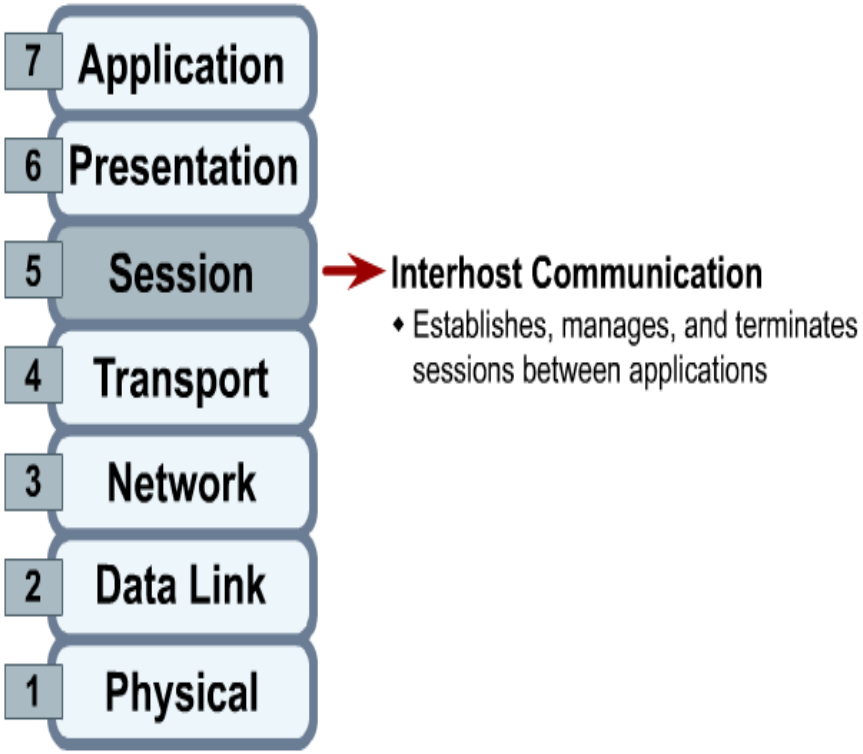


Transport Layer (Layer 4)

- Responsible for segmenting the data file and regulating the flow of information.
- Reliable & guaranteed delivery of data from source to destination.
- Responsible for delivery of data between two hosts.
- End-to-end control is provided by the following techniques (QoS):
  - Sequence numbers
  - Acknowledgements
  - Windowing



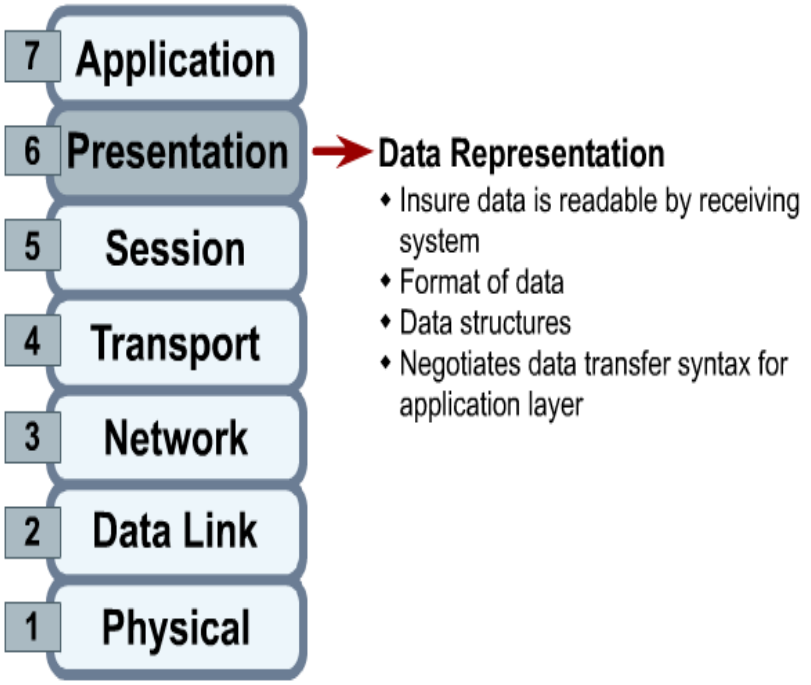
Session Layer (Layer 5)



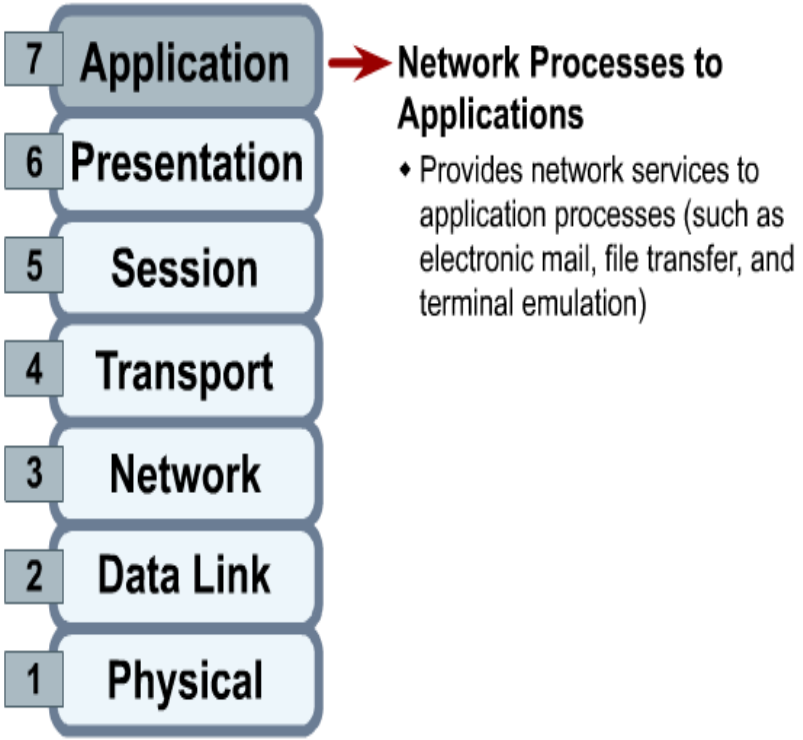
- Establishes, maintains, and manages conversations called sessions between two or more applications on different computers.
- This includes starting, stopping, and re-synchronizing two computers as they communicate, a process called *dialogue control.*
- Provides services to the presentation layer.

Presentation Layer (Layer 6)

- Facilitates communication between applications on diverse computer systems to occur in such a way that it is transparent to the applications.
- Data Formatting:
  - Encryption / De-encryption
  - Compression / De-compression
  - Syntax



Application Layer (Layer 7)



- Layer closest to the end user.
- Does not provide services to any other OSI layer
- Provides services to applications used by the end user.
  - Telnet
  - FTP
  - HTTP
  - Work processing programs
  - Spreadsheet programs
  - E-mail

DEVICES

Repeater – Layer 1

- A **repeater** is an electronic device that receives a signal and retransmits it at a higher level and/or higher power so that the signal can cover longer distances.
- Does not attempt to interpret the data being transmitted.

Hub – Layer 1

- A Hub is a multiport repeater
- Works at 10/100MB
- OK for 10 or less devices

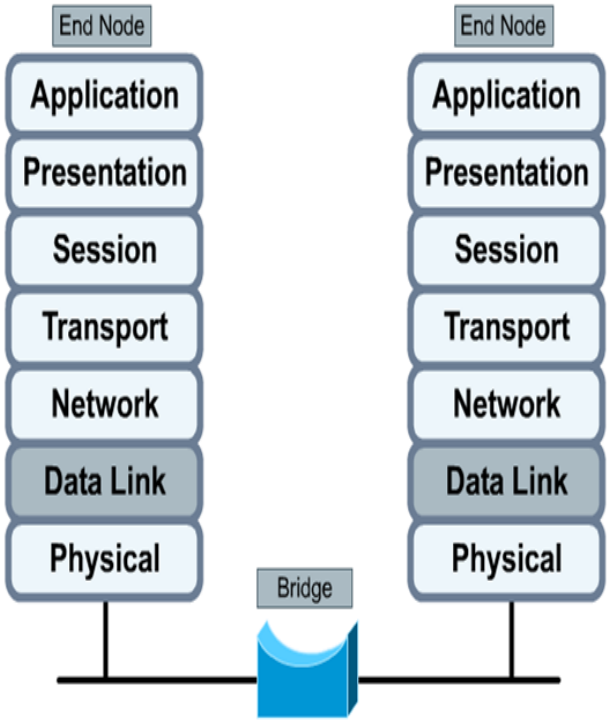
Transceiver – Layer 1

- Transceivers are called Medium Attachment Units (MAUs)
- Converts one medium to another
- Connects to the Auxilary Unit Interface (AUI) of a router.

Bridges – Layer 2

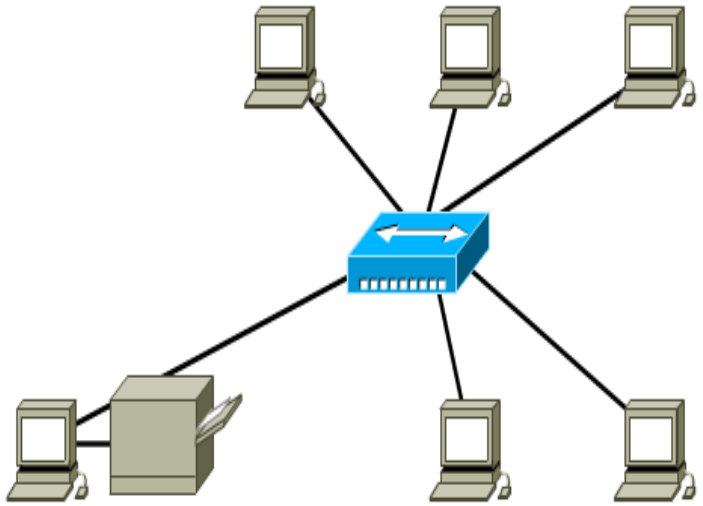
Large collision domains increase the amount of traffic and the number of collisions.

- Provides filtering based on the MAC address.
- Helps solve network congestion.
- Keeps a table with all MAC addresses on the network.
- Keeps traffic destined for one side of the bridge to that side.
- Frames are not forwarded throughout the whole network, but are contained in the appropriate network segment.
- Less traffic means less collisions.



Switches – Layer 2 (Multi-port Bridge)

- Provides filtering based on the MAC address.
- Micro-segments the network
- The number of segments depend on the number of ports.
- Allows multiple connections within it.
- Several ports can be grouped together into a VLAN (virtual local area network.
- VLANS can be used to secure certain parts of the network.



Routers – Layer 3

- A router is a Layer 3 networking device that connects network segments or entire networks
- It is considered more intelligent than Layer 2 devices because it makes decisions based on information received about the network as a whole
- A router examines the IP address of the destination computer to determine which path is best to take to reach the destination

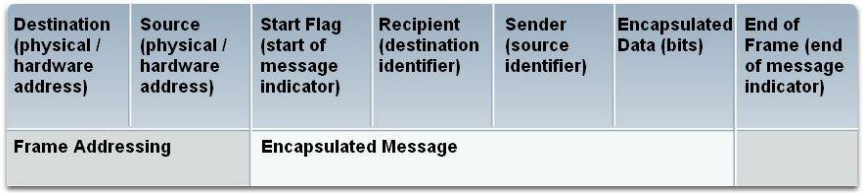
Firewalls - Layer 4

- A **firewall** is a device designed to permit or deny network transmissions based upon a set of rules.
- Frequently used to protect networks from unauthorized access while permitting legitimate communications to pass.

ENCAPSULATION

Communication Protocols

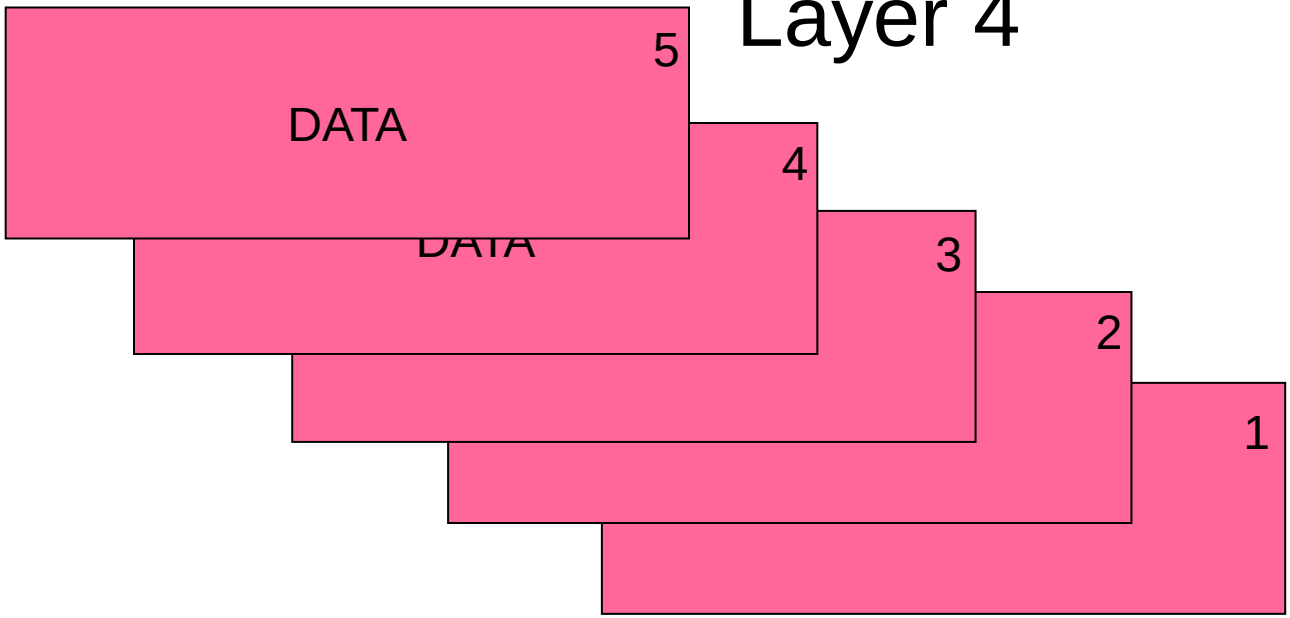
- **Encapsulation** is the process of placing one message format into another format so that the message can be delivered.
- Encapsulation allows computers to communicate data. **Protocol Data Unit** (PDUs) is another name we often use for the same process.
- As the data moves down through the layers of the OSI model, it receives headers, footers, and other information.
- The word "header" means that address information has been added. It is control information placed before data when encapsulating that data for network transmission



Encapsulation
Layers 5-7

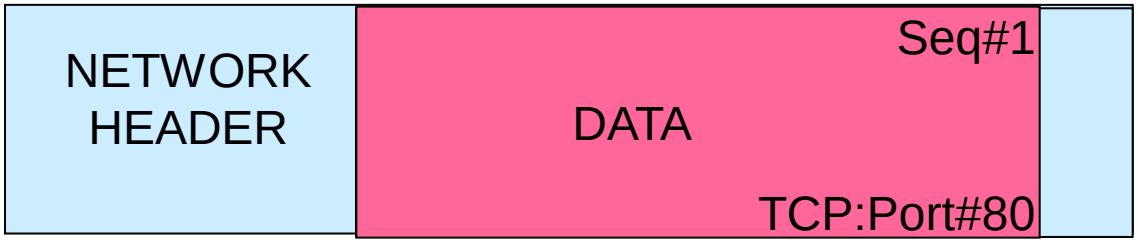
- **DATA** - alphanumeric characters are converted to data that can traverse the internetwork.

Encapsulation
Layer 4



- **SEGMENTS** - Package the data for end-to-end transport. By using segments, the transport function ensures that the message hosts at both ends of the e-mail system can reliably communicate.

Encapsulation
Layer 3

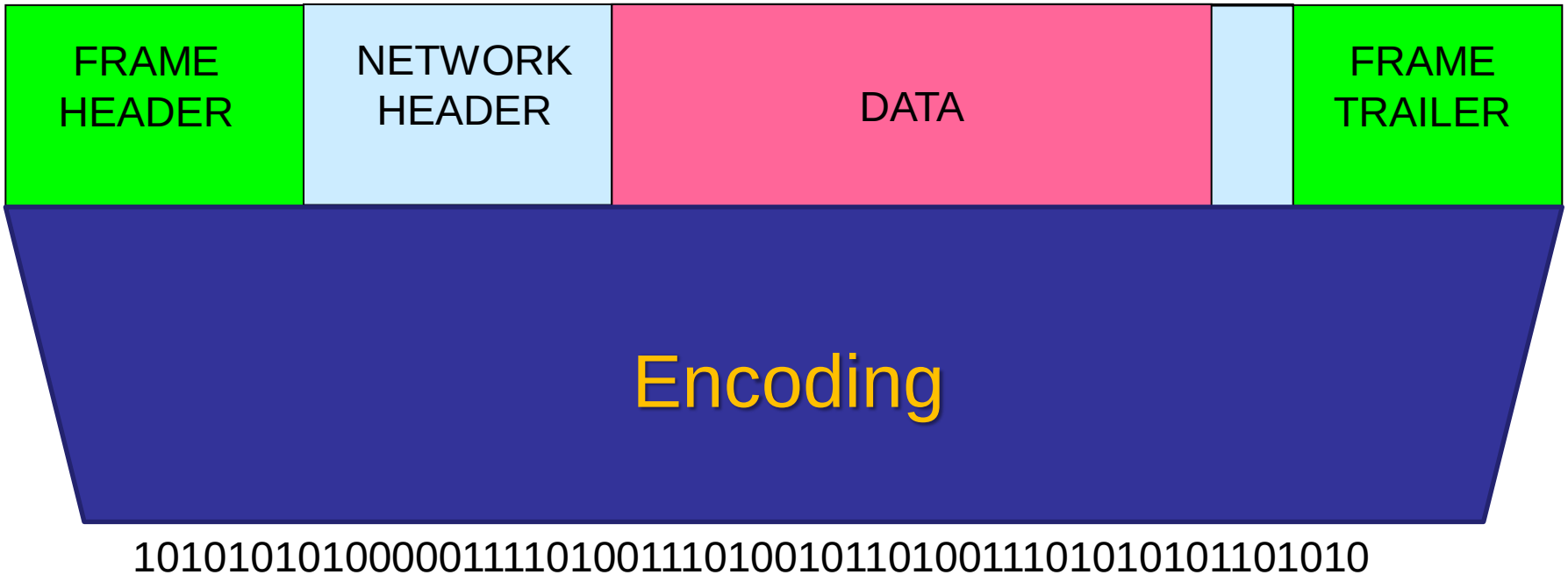


- **PACKETS** - The data is put into a packet or datagram that contains a network header with source and destination logical addresses (IP).

Encapsulation
Layer 2

- **FRAMES** - The frame allows connection to the next directly connected network device on the link. The *frame* header contains information (e.g. physical addresses) required to complete the data link functions.

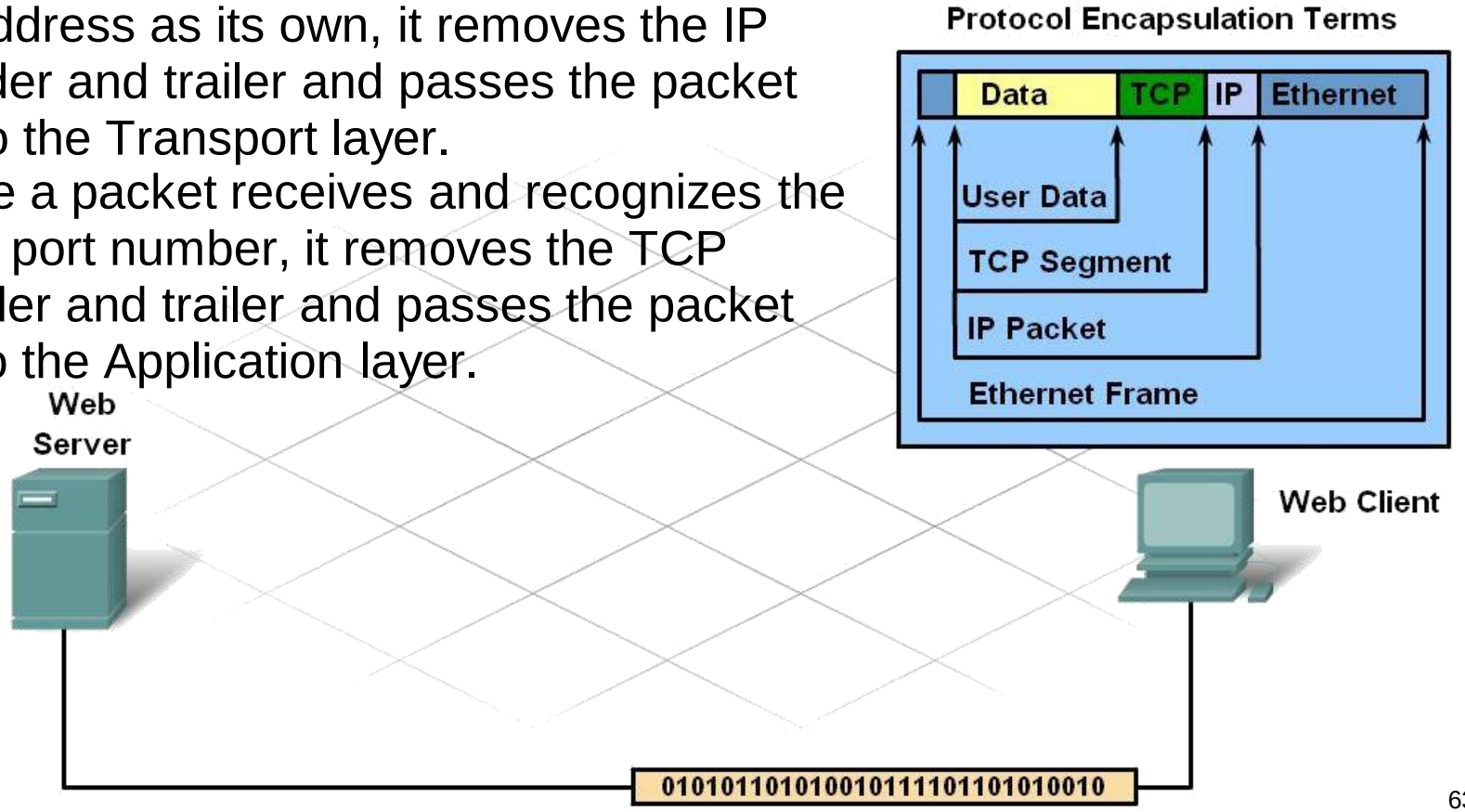
Encapsulation
Layer 1



- **BITS** - The binary (electrical or optical) information sent over a medium.

TCP/IP De-Encapsulation Process

- Once a device receives an Ethernet frame and recognizes the MAC address as its own, it removes the Ethernet header and trailer and passes the packet up to the Internet layer.
- Once a packet receives and recognizes the IP address as its own, it removes the IP header and trailer and passes the packet up to the Transport layer.
- Once a packet receives and recognizes the TCP port number, it removes the TCP header and trailer and passes the packet up to the Application layer.



PROTOCOLS

Layer 2

- ARP
- RARP
- CDP
- Ethernet 802.3
- FDDI 802.5
- Frame Relay
- HDLC
- Wireless IEEE 802.11
- PPP
- STP
- Token ring
- VTP

Protocols

Layer 3

Routing Protocols

- EGP
  - BGP
- IGP
  - RIP
  - IGRP
  - EIGRP
  - IS-IS
  - OSPF

Routed Protocols

- ICMP
- IGMP
- IPv4
- IPv6
- IPSec
- IPX
- AppleTalk

Layer 4

- TCP
- UDP

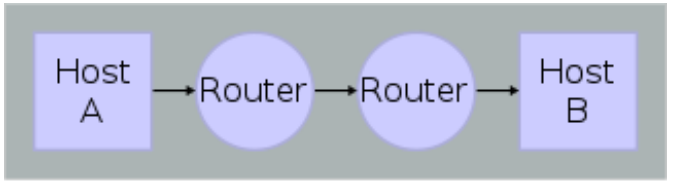
Layer 7

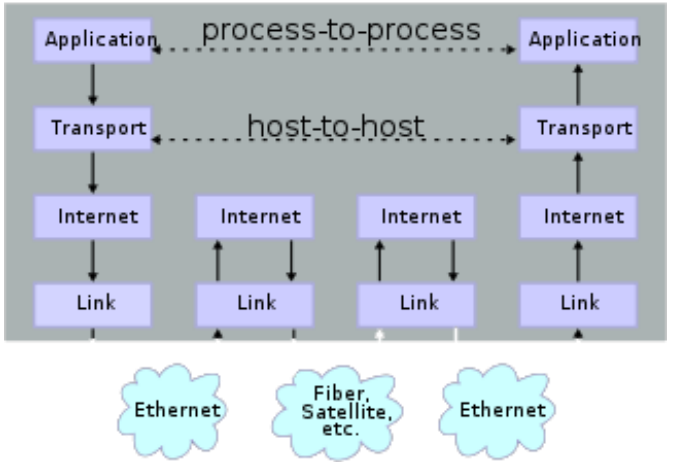
- DNS
- DHCP
- FTP
- HTTP
- HTTPS
- IMAP
- POP3
- RDP
- SMTP
- Telnet
- TFTP

TCP/IP MODEL

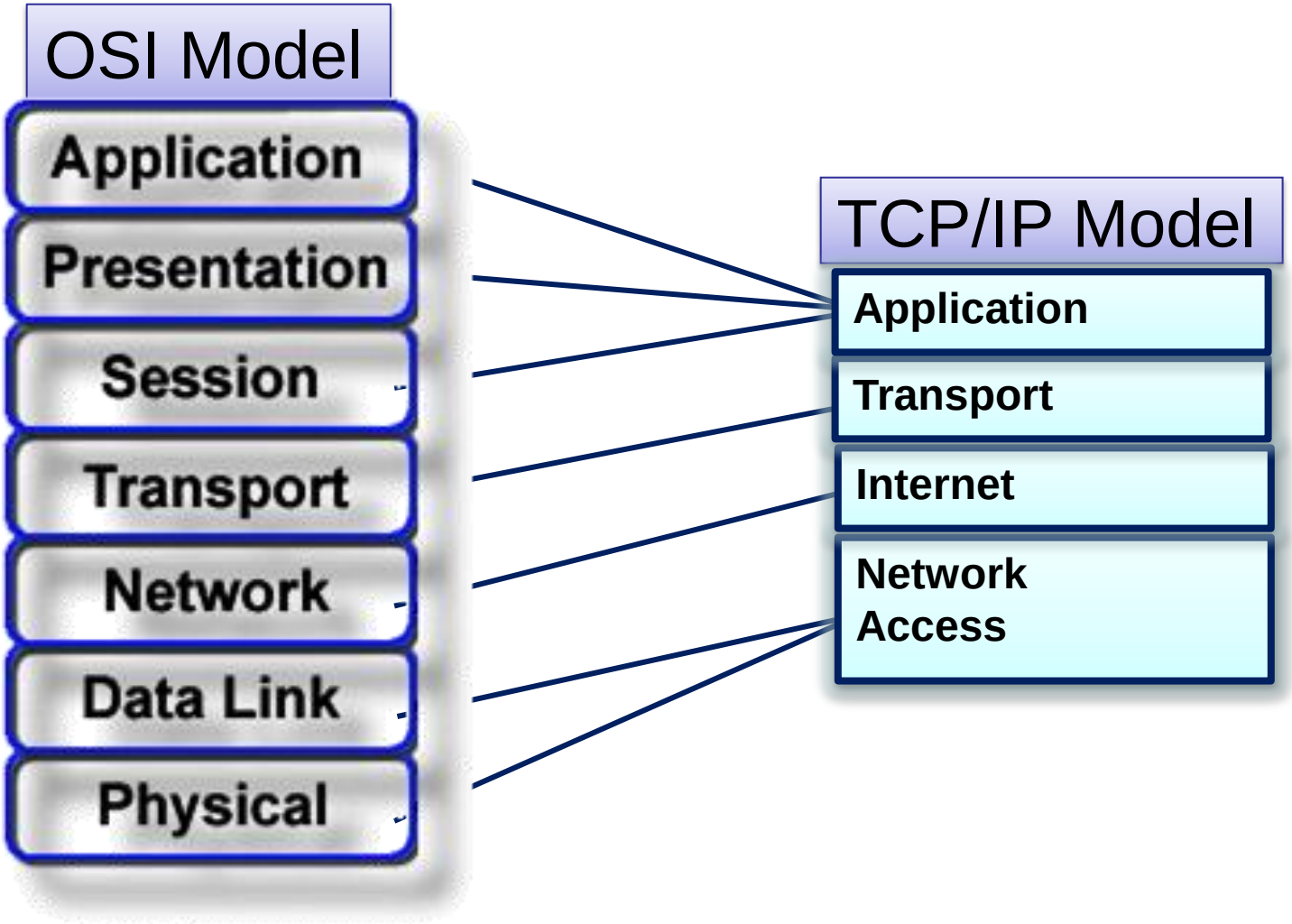
TCP/IP

- The TCP/IP model describes a set of general design guidelines and implementations of specific networking protocols to enable computers to communicate over a network.
- Broken down into 4 layers
  - Network Access Layer (1& 2)
  - Internet Layer (3)
  - Transport Layer (4)
  - Applications Layer (5-7)





Comparing the Models

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