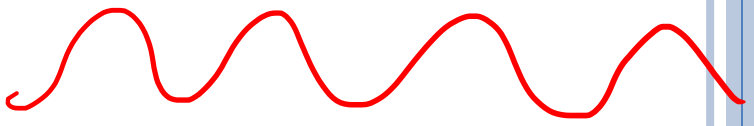
Unit – 2
Physical layer

1.1 Introduction

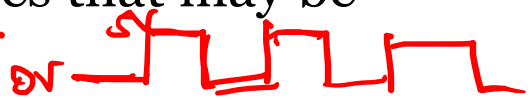
- Physical layer in the OSI model plays the role of interacting with actual hardware and signaling mechanism.
- Physical layer is the only layer of OSI network model which actually deals with the physical connectivity of two different stations.
- This layer defines the hardware equipment, cabling, wiring, frequencies, pulses used to represent binary signals etc.
- Information can be transmitted or received using cables. The main purpose of the physical layer is to transmit information (data or text or even animated pictures) from a source to a destination.
- Any form of such information cannot be transmitted as it is, just as in a postal service. Information is transmitted from a source computer to a destination computer in the form of electromagnetic signals using the transmission medium.

Introduction

- Some basic definition:
  - Signals: Electric or electromagnetic encoding of data.
  - Signaling: It is the act of propagating the signal along a suitable medium.
- Types of signal:

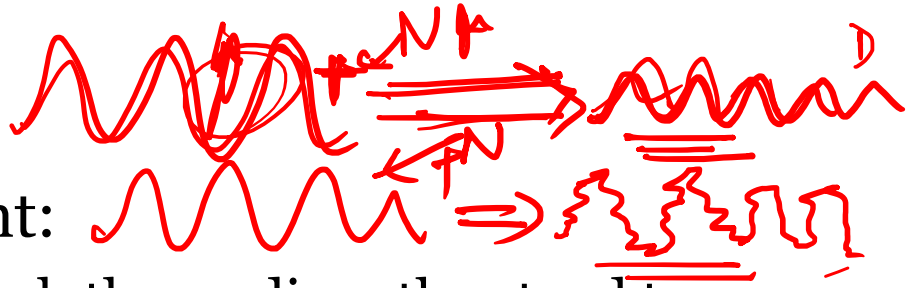


  - Analog signal and Digital signal
  - Analog signal – A continuously varying electromagnetic wave that may be propagated over a variety of medium depending on the spectrum (e.g., wire, twisted pair, coaxial cable, fiber optic cable and atmosphere or space propagation).
  - Digital signal – A sequence of voltage pulses that may be transmitted over a wire medium.



  - Note – Analog signals which represent analog data and Digital signals which represent digital data are **not the only possibilities.**

Introduction



- Transmission Impairment:
  - When signals travel through the medium they tend to deteriorate. This may have many reasons as given:

1. Attenuation of a signal:

  - The reduction or loss of signal strength (power) as it transferred across a system.
  - Attenuation is an increasing function of frequency.
  - The strength of the received signal must be strong enough for detection and must be higher than the noise to be received without error.

2. Dispersion:

  - As signal travels through the media, it tends to spread and overlaps.
  - The amount of dispersion depends upon the frequency used.

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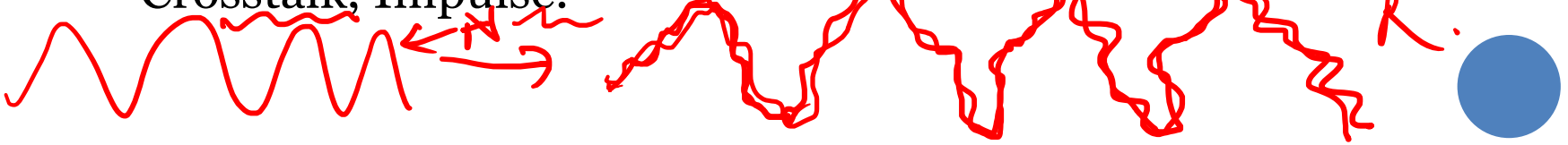
3. Delay distortion:

- Signals are sent over media with pre-defined speed and frequency.
- If the signal speed and frequency do not match, there are possibilities that signal reaches destination in arbitrary fashion.
- In digital media, this is very critical that some bits reach earlier than the previously sent ones.

4. Noise:

- Random disturbance or fluctuation in analog or digital signal is said to be Noise in signal, which may distort the actual information being carried. Noise can be characterized in one of the following class: Thermal Noise, Intermodulation, Crosstalk, Impulse.



Introduction

- Thermal Noise:
  - Heat agitates the electronic conductors of a medium which may introduce noise in the media.
  - Up to a certain level, thermal noise is unavoidable.
- Intermodulation:
  - When multiple frequencies share a medium, their interference can cause noise in the medium.
  - Intermodulation noise occurs if two different frequencies are sharing a medium and one of them has excessive strength or the component itself is not functioning properly, then the resultant frequency may not be delivered as expected.

Introduction

- Crosstalk:
  - This sort of noise happens when a foreign signal enters into the media.
  - This is because signal in one medium affects the signal of second medium.
- Impulse:
  - This noise is introduced because of irregular disturbances such as lightening, electricity, short-circuit, or faulty components.
  - Digital data is mostly affected by this sort of noise.

Introduction

- Analog and Digital Transmissions:
  - Transmissions: Communication of data by the propagation and processing of signals.
  - Both analog and digital signals may be transmitted on suitable transmission media.
- Analog transmission:
  - A means of transmitting analog signals without regard to their content (i.e., the signals may represent analog data or digital data).
  - Transmissions are attenuated over a distance.
  - Analog signal – The analog transmission system uses amplifiers to boost the energy in the signal.
  - Amplifiers boost the energy of the signal but they amplify the noise also.

Introduction

- Digital transmissions:
  - They are concerned with the digital content of the signal.
  - Attenuation is overcome without amplifying the noise.
  - With retransmission devices [repeater]at appropriate points the device recovers the digital data from the digital signal.
  - Digital signals – The digital repeaters are used to attain transmission at greater distances.
  - The digital repeater receives the digital signal, recovers the patterns of 0's and 1's and retransmits a new digital signal.

Introduction

- Digital versus Analog Transmissions:
  - Digital transmission advantages:-

1. Superior cost of digital technology
   – Low cost LSI/VLSI technology
   – Repeaters have low cost versus amplifiers costs
2. Superior quality {Data integrity}
   – Longer distances over lines with lower error rates
3. Capacity utilization
   – Economical to build high bandwidth links
   – High degree of multiplexing easier with digital techniques
4. Security & Privacy
   – Encryption techniques readily applied to digitized data
5. Integration
   – Can treat analog and digital data similarly
   – Economies of scale from integrating voice, video and data

Introduction

- Digital versus Analog Transmissions:
  - Analog transmission advantages:

    1. Digital signaling not as versatile or practical (digital impossible for satellite and microwave systems)

    2. LAN star topology limits the severity of the noise and attenuation problems.
- Channel Capacity:
  - The speed of transmission of information is said to be the channel capacity. We count it as data rate in digital world.
  - It depends on numerous factors such as:
    - **Bandwidth:** The physical limitation of underlying media.
    - **Error-rate:** Incorrect reception of information because of noise.
    - **Encoding:** The number of levels used for signaling.

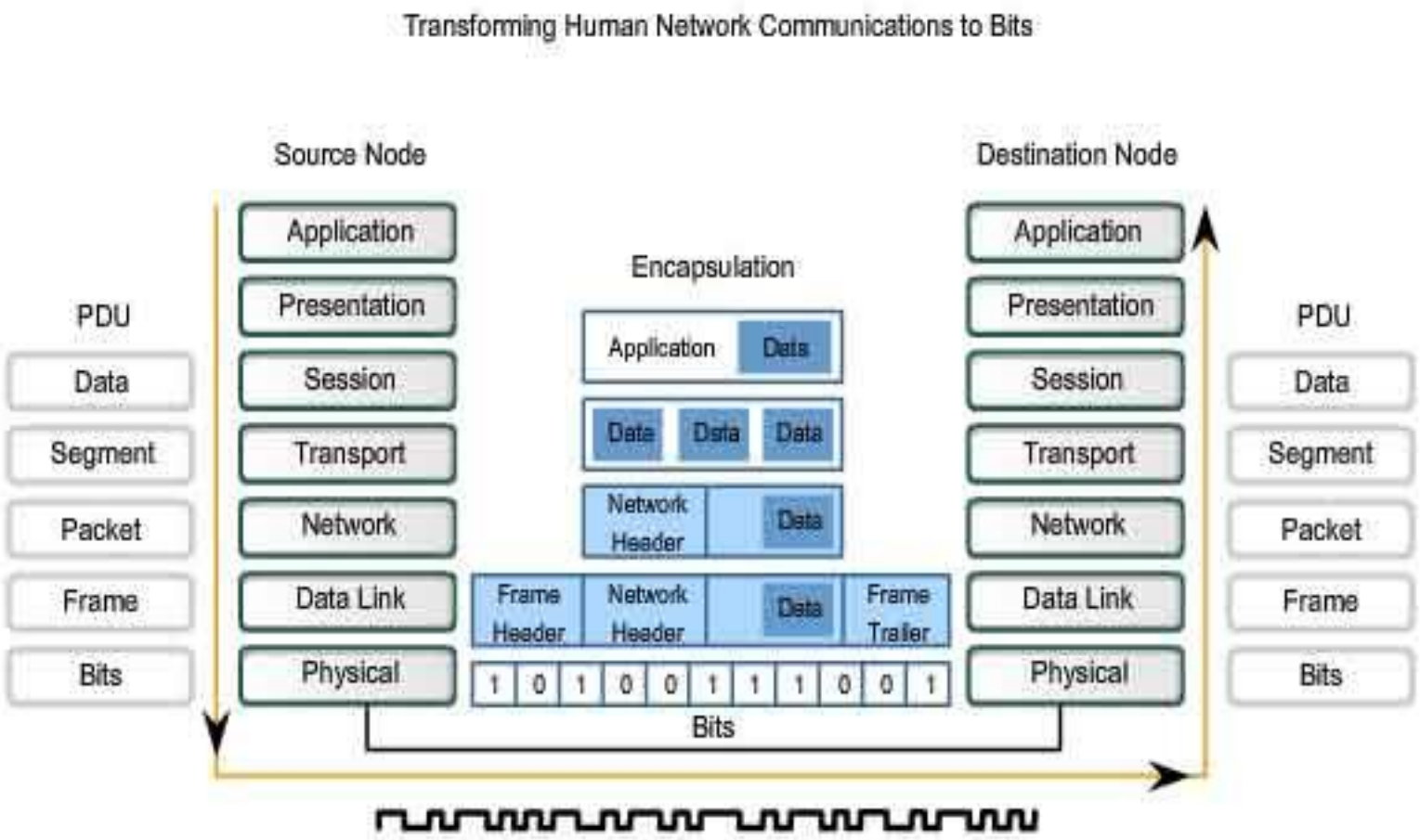
1.2 Physical layer - Purpose

- The OSI Physical layer provides the means to transport a signal across the network media the bits that make up a Data Link layer frame.
- This layer accepts a complete frame from the Data Link layer and encodes it as a series of signals that are transmitted onto the local media.
- The encoded bits that comprise a frame are received by either an end device or an intermediate device.
- The delivery of frames across the local media requires the following Physical layer elements:
  - The physical media and associated connectors.
  - A representation of bits on the media.
  - Encoding of data and control information.
  - Transmitter and receiver circuitry on the network devices.

1.2 Physical layer - Purpose

- At this stage of the communication process, the user data has been segmented by the Transport layer, placed into packets by the Network layer, and further encapsulated as frames by the Data Link layer.
- The purpose of the Physical layer is to create the electrical, optical, or microwave signal that represents the bits in each frame.
- These signals are then sent on the media one at a time.
- It is also the job of the Physical layer to retrieve these individual signals from the media, restore them to their bit representations, and pass the bits up to the Data Link layer as a complete frame.

1.2 Physical layer - Purpose



In diagrams, signals on the physical media are depicted by this line symbol.

1.3 Physical Layer - Operation

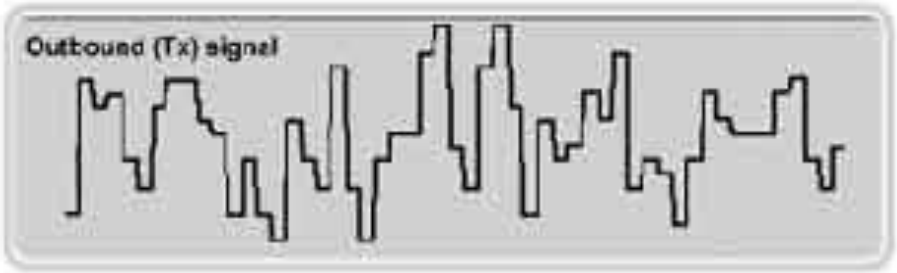
- The media does not carry the frame as a single entity. The media carries signals, one at a time, to represent the bits that make up the frame.
- There are three basic forms of network media on which data is represented:
  - Copper cable
  - Fiber
  - Wireless
- The representation of the bits - that is, the type of signal - depends on the type of media.
  - For copper cable media, the signals are patterns of electrical pulses.
  - For fiber, the signals are patterns of light.
  - For wireless media, the signals are patterns of radio transmissions.

1.3 Physical Layer - Operation

- Identifying a Frame:
  - When the Physical layer encodes the bits into the signals for a particular medium, it must also distinguish where one frame ends and the next frame begins.
  - Otherwise, the devices on the media would not recognize when a frame has been fully received.
  - In that case, the destination device would only receive a string of signals and would not be able to properly reconstruct the frame.
  - As described in the previous chapter, indicating the beginning of frame is often a function of the Data Link layer.
  - However, in many technologies, the Physical layer may add its own signals to indicate the beginning and end of the frame.
  - To enable a receiving device to clearly recognize a frame boundary, the transmitting device adds signals to designate the start and end of a frame.
  - These signals represent particular bit patterns that are only used to denote the start or end of a frame.

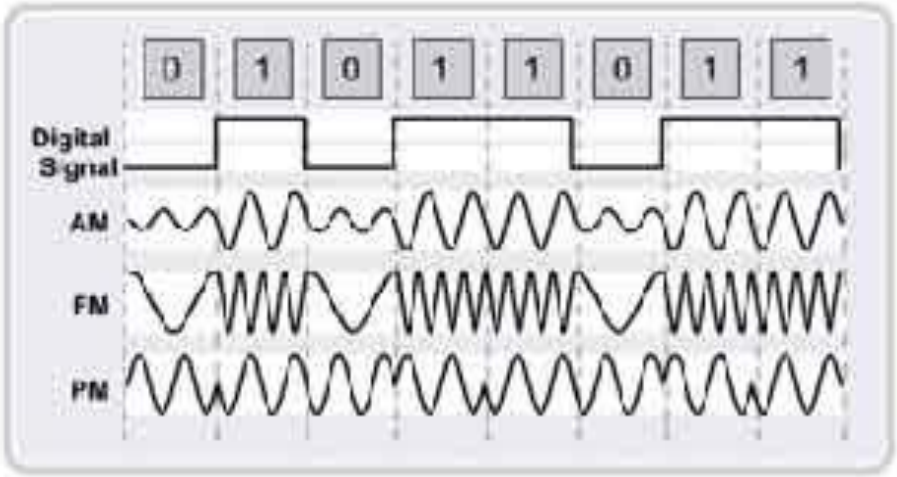
1.3 Physical Layer - Operation

Representations of Signals on the Physical Media



Sample electrical signals transmitted on copper cable

Representative light pulse fiber signals



Microwave (wireless) signals

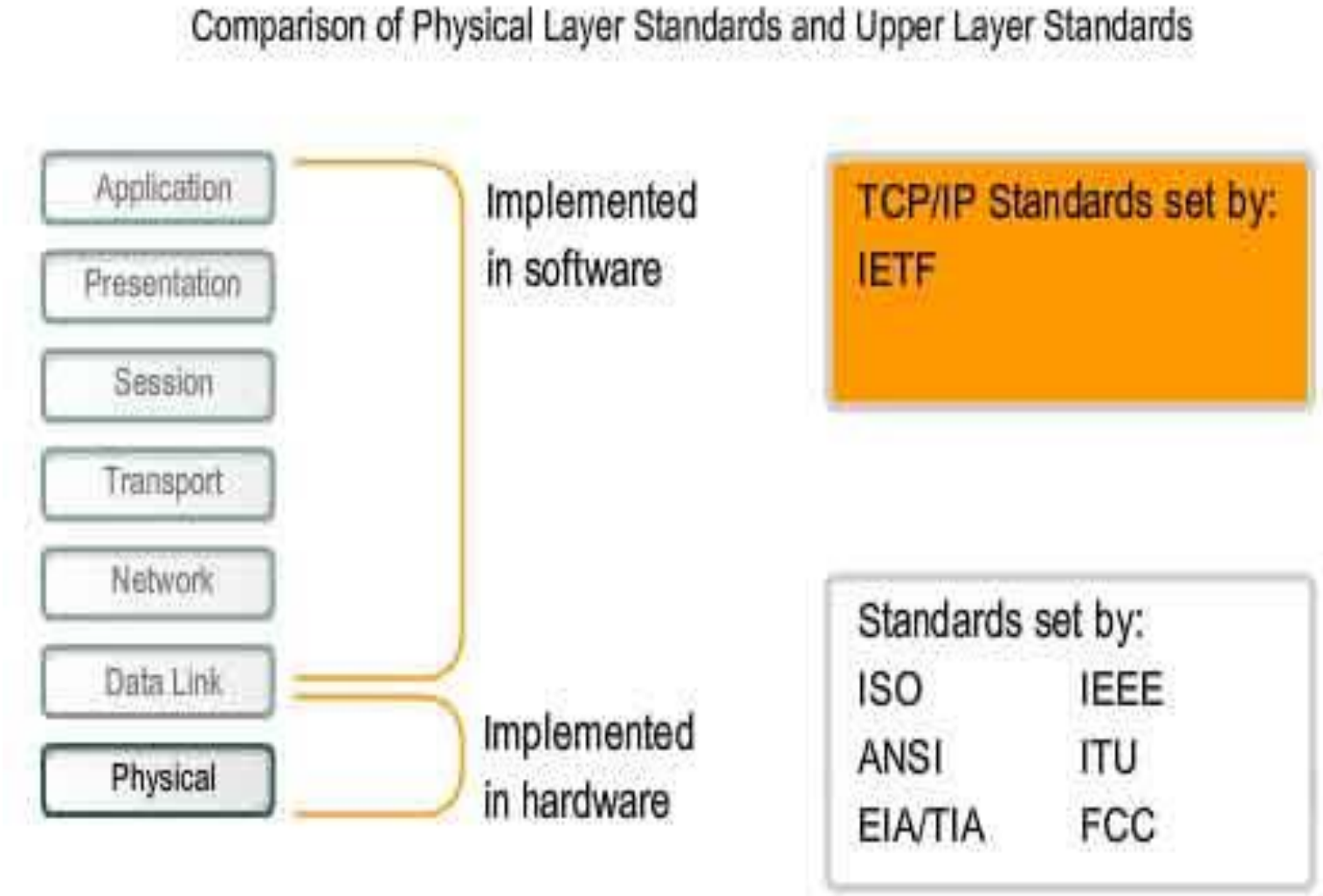
1.4 Physical Layer - Standards

- The Physical layer consists of hardware, developed by engineers, in the form of electronic circuitry, media, and connectors.
- Therefore, it is appropriate that the standards governing this hardware are defined by the relevant electrical and communications engineering organizations.
- By comparison, the protocols and operations of the upper OSI layers are performed by software and are designed by software engineers and computer scientists.
- The services and protocols in the TCP/IP suite are defined by the Internet Engineering Task Force (IETF) in RFCs.

1.4 Physical Layer - Standards

- Similar to technologies associated with the Data Link layer, the Physical layer technologies are defined by organizations such as:
  - The International Organization for Standardization (ISO)
  - The Institute of Electrical and Electronics Engineers (IEEE)
  - The American National Standards Institute (ANSI)
  - The International Telecommunication Union (ITU)
  - The Electronics Industry Alliance/Telecommunications Industry Association (EIA/TIA)
  - National telecommunications authorities such as the Federal Communication Commission (FCC) in the USA.

1.4 Physical Layer - Standards

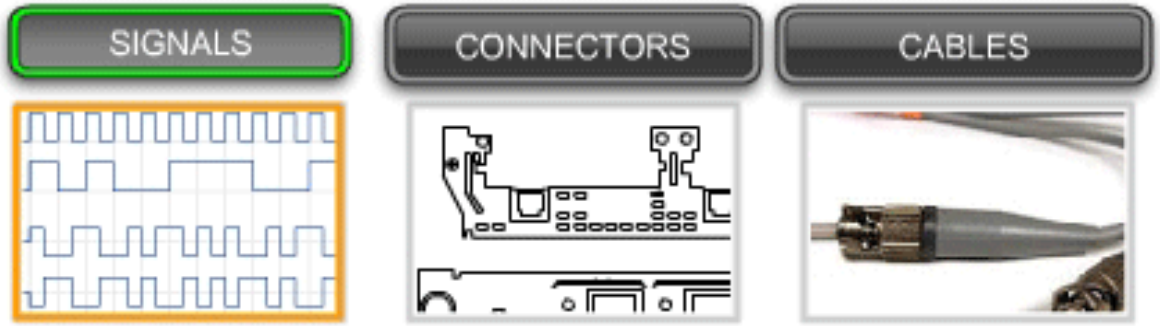


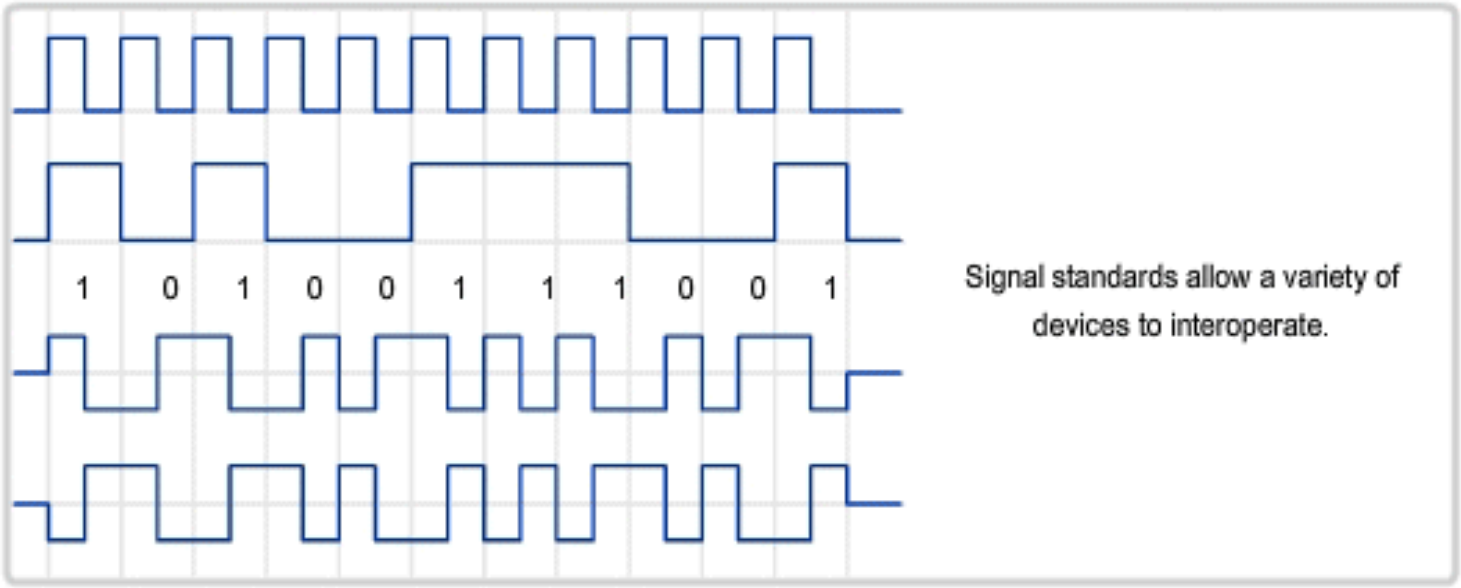
1.5 Physical Layer Technologies and Hardware

- The technologies defined by these organizations include four areas of the Physical layer standards:
  - Physical and electrical properties of the media.
  - Mechanical properties (materials, dimensions, pin-outs) of the connectors.
  - Bit representation by the signals (encoding).
  - Definition of control information signals.
- Hardware components such as network adapters (NICs), interfaces and connectors, cable materials, and cable designs are all specified in standards associated with the Physical layer.

1.5 Physical Layer Technologies and Hardware

Standards for the Physical layer specify signal, connector, and cabling requirements.





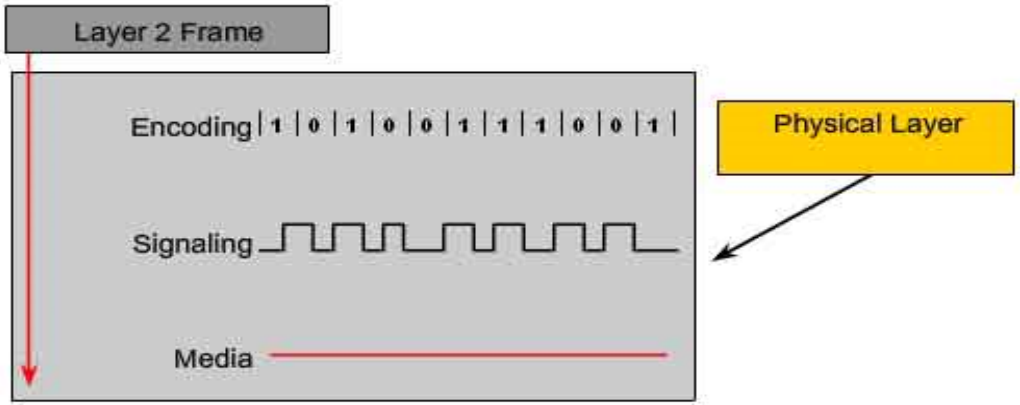
1.6 Physical layer Fundamental Principles

- The two fundamental functions of the Physical layer are:
  - Data encoding
  - Signaling
- Encoding:
  - Encoding is a method of converting a stream of data bits into a predefined code.
  - Codes are groupings of bits used to provide a predictable pattern that can be recognized by both the sender and the received.
  - Using predictable patterns helps to distinguish data bits from control bits and provide better media error detection.
  - In addition to creating codes for data, encoding methods at the Physical layer may also provide codes for control purposes such as identifying the beginning and end of a frame.
  - The transmitting host will transmit the specific pattern of bits or a code to identify the beginning and end of the frame.

1.6 Physical layer Fundamental Principles

- Signaling:
  - The Physical layer must generate the electrical, optical, or wireless signals that represent the "1" and "0" on the media.
  - The method of representing the bits is called the signaling method.
  - The Physical layer standards must define what type of signal represents a "1" and a "0".
  - This can be as simple as a change in the level of an electrical signal or optical pulse or a more complex signaling method.

Physical Layer Fundamental Principles



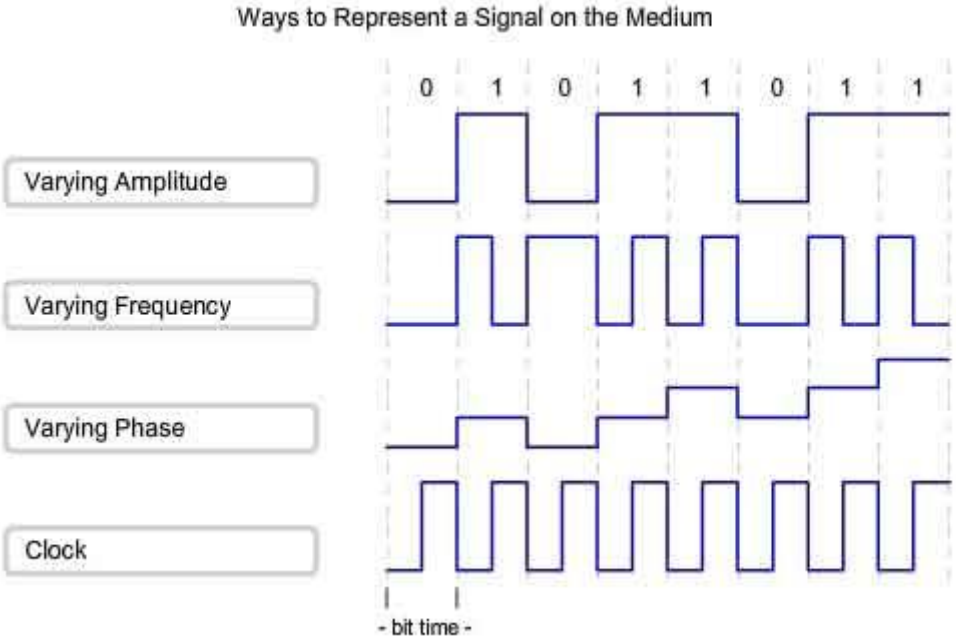
1.6 Physical layer Fundamental Principles

- Physical Signaling and Encoding: Representing Bits.
  - Signaling Bits for the Media:
    - The Physical layer represents each of the bits in the frame as a signal.
    - Each signal placed onto the media has a specific amount of time to occupy the media.
    - This is referred to as its bit time. Signals are processed by the receiving device and returned to its representation as bits.
    - At the Physical layer of the receiving node, the signals are converted back into bits.
    - The bits are then examined for the start of frame and end of frame bit patterns to determine that a complete frame has been received.
    - The Physical layer then delivers all the bits of a frame to the Data Link layer. Successful delivery of the bits requires some method of synchronization between transmitter and receiver.
    - The synchronization is accomplished by the use of a clock. In LANs, each end of the transmission maintains its own clock.

1.6 Physical layer Fundamental Principles

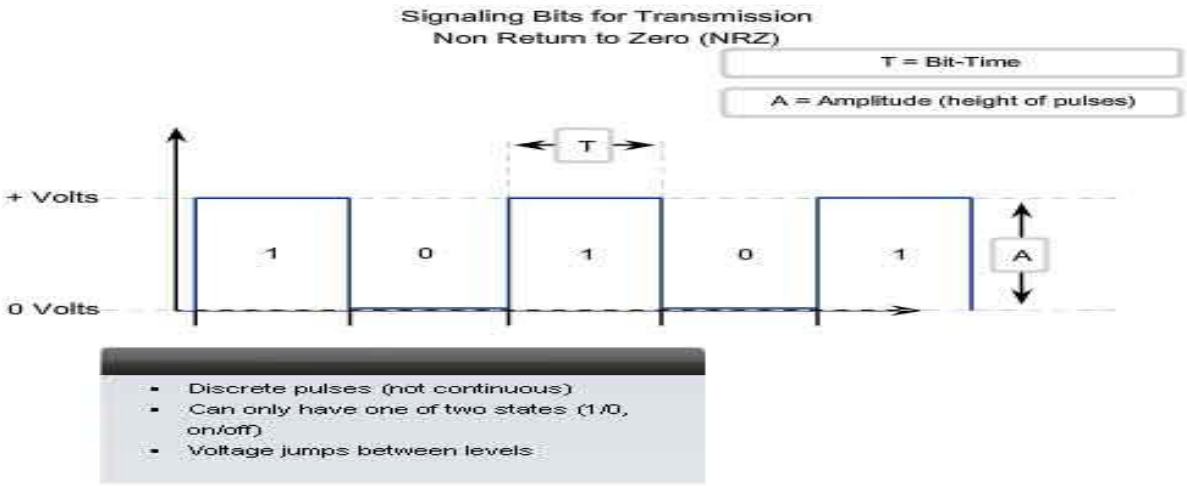
- Signaling Methods:
  - Bits are represented on the medium by changing one or more of the following characteristics of a signal:

- Amplitude
- Frequency
- Phase



1.6 Physical layer Fundamental Principles

- NRZ Signaling: Non Return to Zero (NRZ).
  - In NRZ, the bit stream is transmitted as a series of voltage values.
  - A low voltage value represents a logical 0 and a high voltage value represents a logical 1.
  - NRZ signaling uses bandwidth inefficiently and is susceptible to electromagnetic interference.
  - Additionally, the boundaries between individual bits can be lost when long strings of 1s or 0s are transmitted consecutively.
  - In that case, no voltage transitions are detectable on the media.



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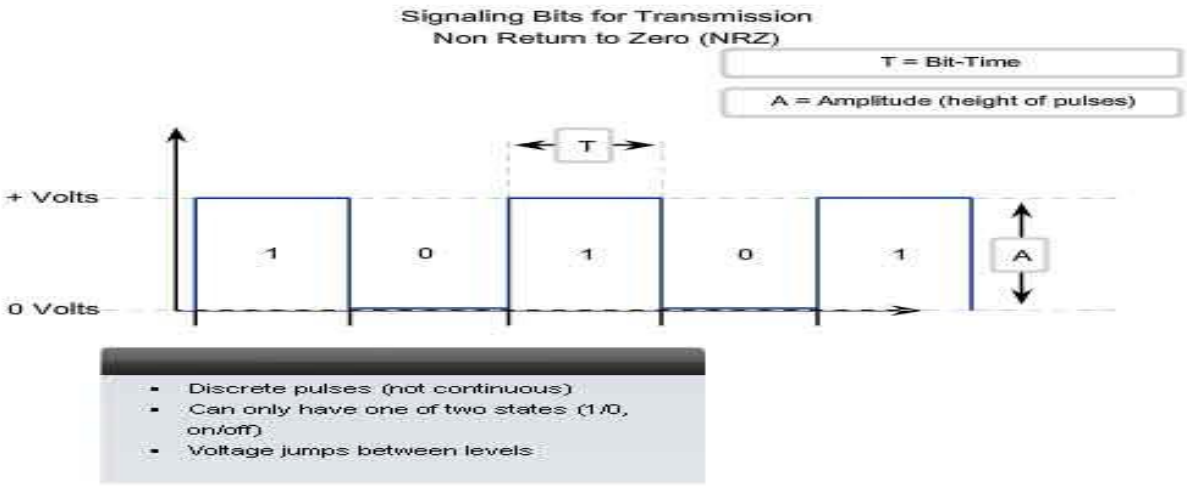
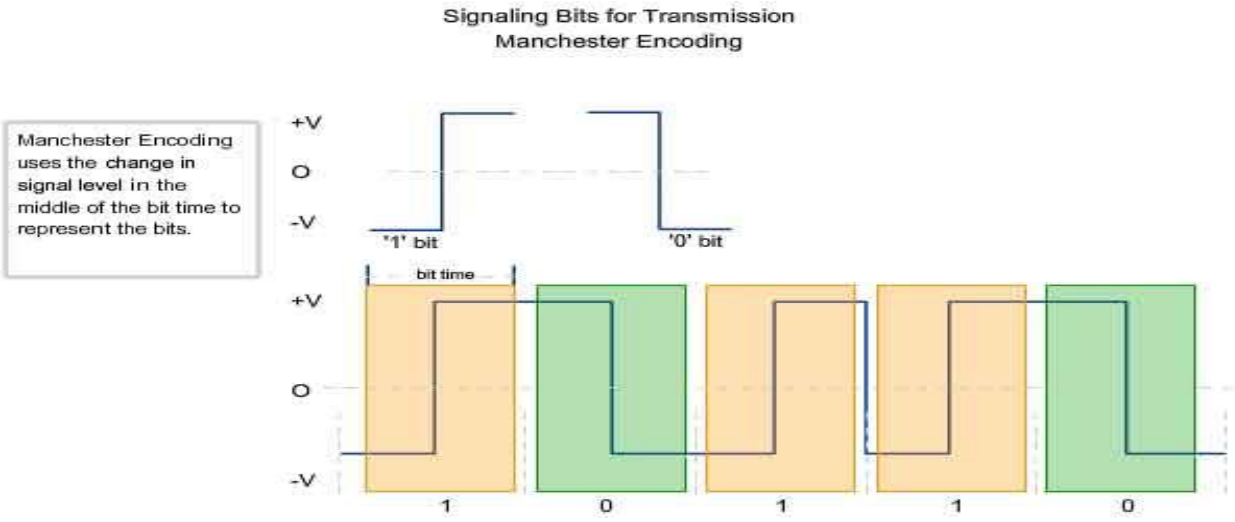


1.6 Physical layer Fundamental Principles

- Manchester Encoding:
  - Instead of representing bits as pulses of simple voltage values, in the Manchester Encoding scheme, bit values are represented as voltage transitions.
  - For example, a transition from a low voltage to a high voltage represents a bit value of 1.
  - A transition from a high voltage to a low voltage represents a bit value of 0.

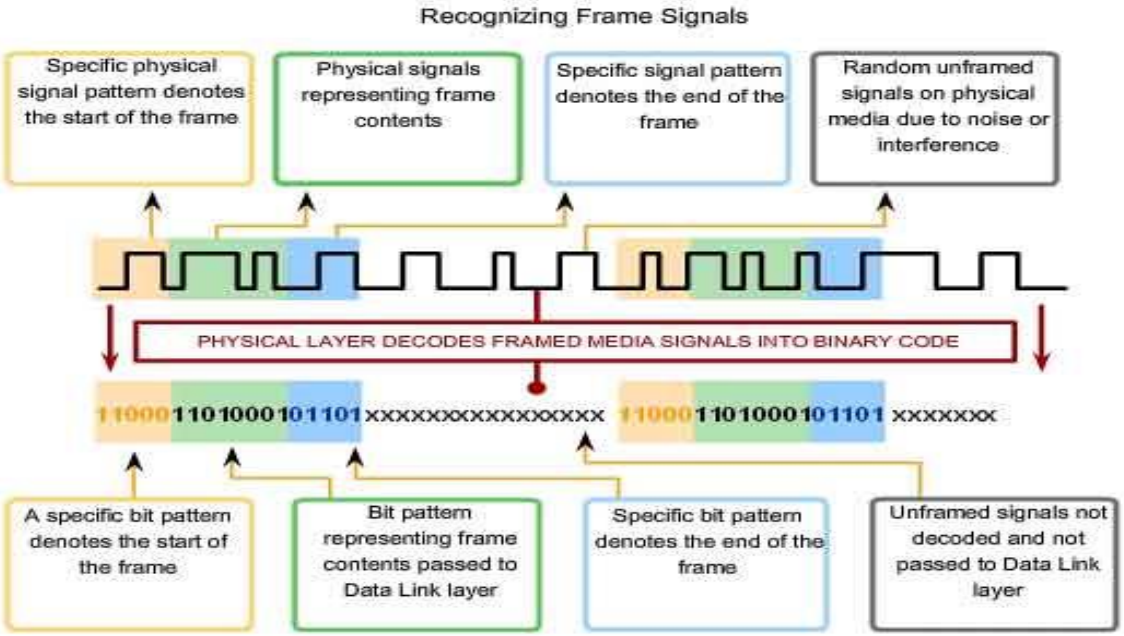


1.6 Physical layer Fundamental Principles

- Encoding - Grouping Bits:
  - In the prior section, we describe the signaling process as how bits are represented on physical media.
  - In this section, we use of the word encoding to represent the symbolic grouping of bits prior to being presented to the media.
  - By using an encoding step before the signals are placed on the media, we improve the efficiency at higher speed data transmission.
  - As we use higher speeds on the media, we have the possibility that data will be corrupted. By using the coding groups, we can detect errors more efficiently.
  - Additionally, as the demand for data speeds increase, we seek ways to represent more data across the media, by transmitting fewer bits.
  - Coding groups provide a method of making this data representation.

1.6 Physical layer Fundamental Principles

- Signal Patterns:
  - One way to provide frame detection is to begin each frame with a pattern of signals representing bits that the Physical layer recognizes as denoting the start of a frame.
  - Another pattern of bits will signal the end of the frame. Signal bits not framed in this manner are ignored by the Physical layer standard being used.



1.7 Physical media

- Signal Patterns:
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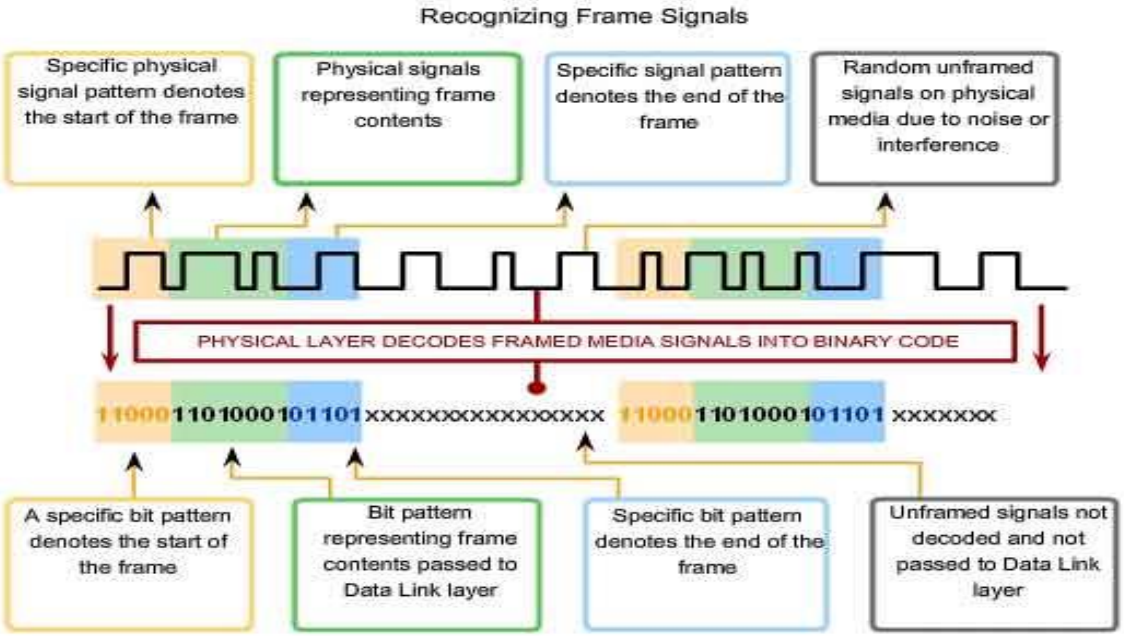


1.8 SWITCHING

- Switching techniques:
  - In large networks, there can be multiple paths from sender to receiver. The switching technique will decide the best route for data transmission.
  - Switching technique is used to connect the systems for making one-to-one communication.
  - The different switching techniques used in networking are:

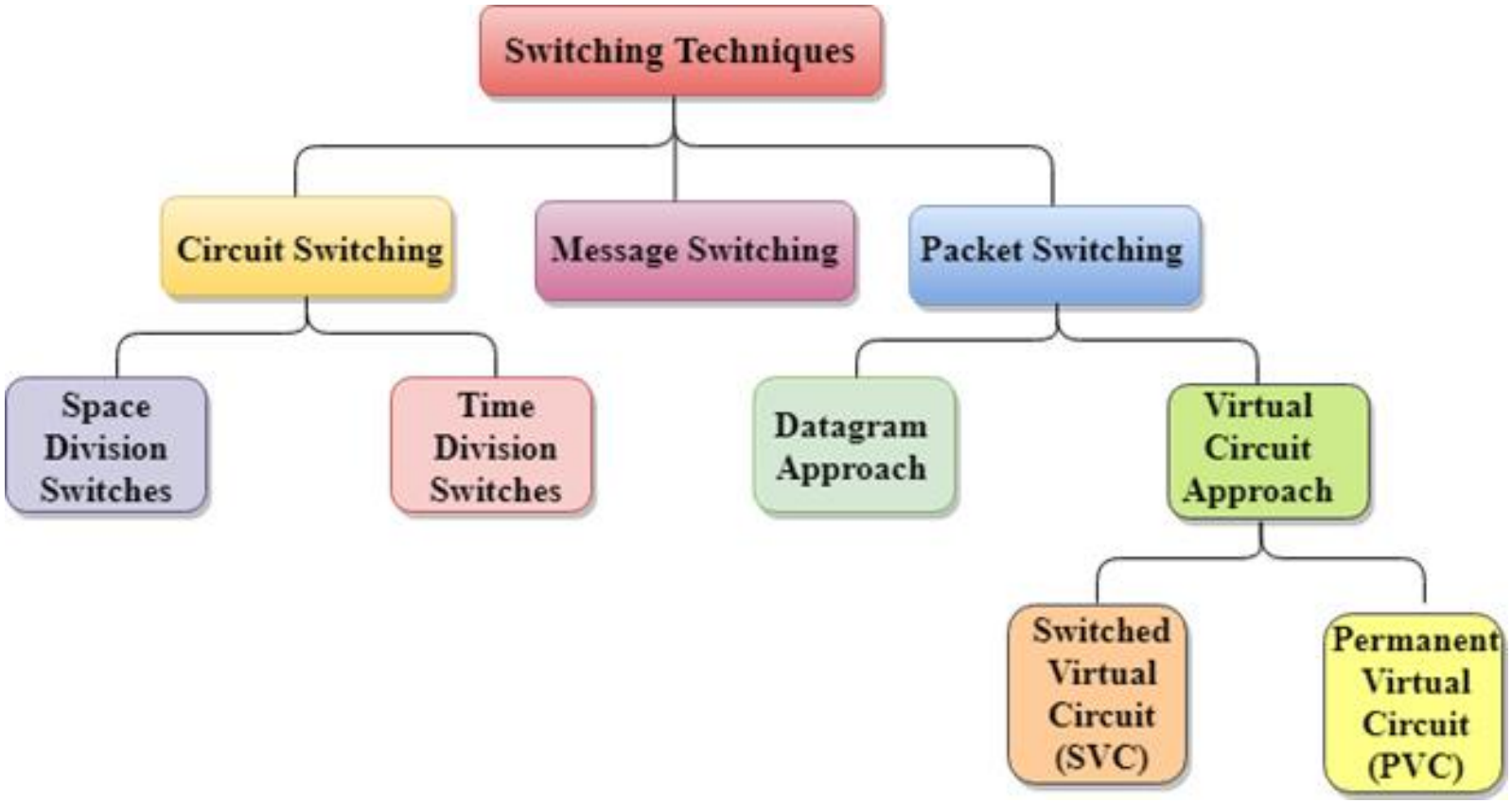
    (1) Circuit switching,

    (2) Packet switching, and

    (3) Message switching.

1.8 SWITCHING

- Classification Of Switching Techniques:

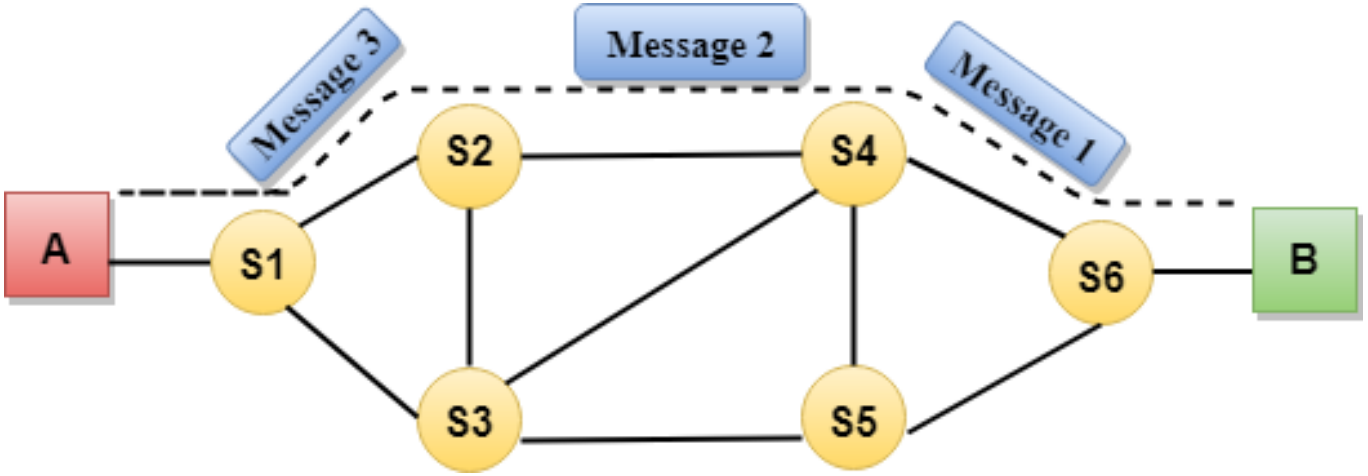


1.8 SWITCHING

- Circuit Switching:
  - Circuit switching is a switching technique that establishes a dedicated path between sender and receiver.
  - In the Circuit Switching Technique, once the connection is established then the dedicated path will remain to exist until the connection is terminated.
  - Circuit switching in a network operates in a similar way as the telephone works.
  - A complete end-to-end path must exist before the communication takes place.
  - In case of circuit switching technique, when any user wants to send the data, voice, video, a request signal is sent to the receiver then the receiver sends back the acknowledgment to ensure the availability of the dedicated path. After receiving the acknowledgment, dedicated path transfers the data.

1.8 SWITCHING

- Circuit Switching:
  - Circuit switching is used in public telephone network. It is used for voice transmission.
  - Fixed data can be transferred at a time in circuit switching technology.
  - Communication through circuit switching has 3 phases:
    - Circuit establishment
    - Data transfer
    - Circuit Disconnect



1.8 SWITCHING

- Circuit Switching:
  - Circuit Switching can uses technology:
    - Space-division circuit switching.
- Space-division circuit switching:
  - Space Division Switching is a circuit switching technology in which a single transmission path is accomplished in a switch by using a physically separate set of cross points.
  - Space Division Switching can be achieved by using crossbar switch.
  - The crossbar switch has intersection points known as cross points.
  - A crossbar switch is a metallic cross point or semiconductor gate that can be enabled or disabled by a control unit.
  - The Crossbar switch is made by using the semiconductor.
  - Space Division Switching has high speed, high capacity, and non-blocking switches.

1.8 SWITCHING

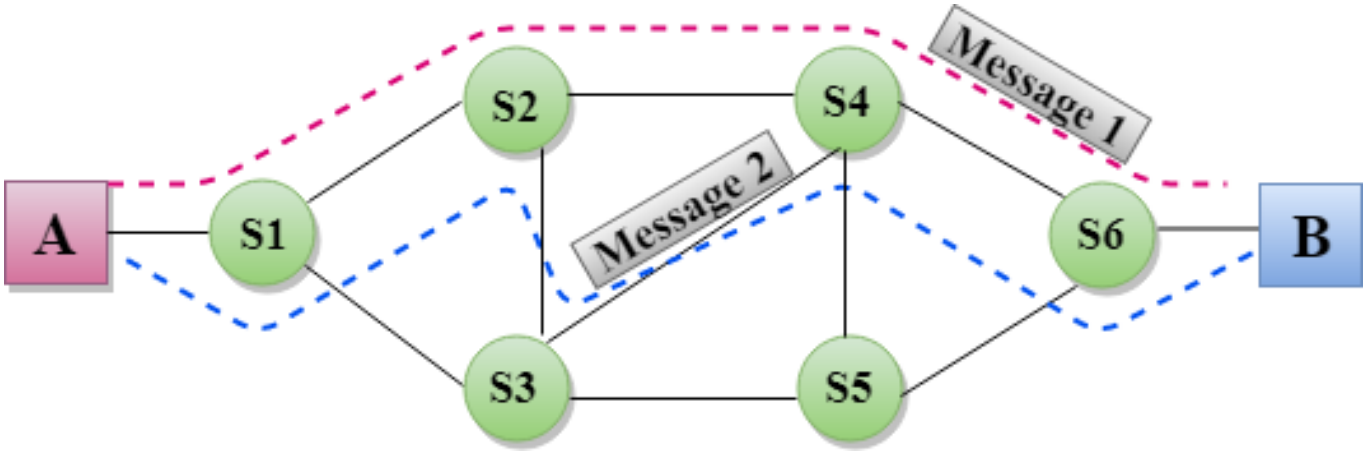
- Advantages Of Circuit Switching:
  - In the case of Circuit Switching technique, the communication channel is dedicated.
  - It has fixed bandwidth.
- Disadvantages Of Circuit Switching:
  - Once the dedicated path is established, the only delay occurs in the speed of data transmission.
  - It takes a long time to establish a connection approx 10 seconds during which no data can be transmitted.
  - It is more expensive than other switching techniques as a dedicated path is required for each connection.
  - It is inefficient to use because once the path is established and no data is transferred, then the capacity of the path is wasted.
  - In this case, the connection is dedicated therefore no other data can be transferred even if the channel is free.

1.8 SWITCHING

- Message Switching:
  - Message Switching is a switching technique in which a message is transferred as a complete unit and routed through intermediate nodes at which it is stored and forwarded.
  - In Message Switching technique, there is no establishment of a dedicated path between the sender and receiver.
  - The destination address is appended to the message. Message Switching provides a dynamic routing as the message is routed through the intermediate nodes based on the information available in the message.
  - Message switches are programmed in such a way so that they can provide the most efficient routes.

1.8 SWITCHING

- Message Switching:
  - Each and every node stores the entire message and then forward it to the next node. This type of network is known as store and forward network.
  - Message switching treats each message as an independent entity.



1.8 SWITCHING

- Advantages Of Message Switching:
  - Data channels are shared among the communicating devices that improve the efficiency of using available bandwidth.
  - Traffic congestion can be reduced because the message is temporarily stored in the nodes.
  - Message priority can be used to manage the network.
  - The size of the message which is sent over the network can be varied. Therefore, it supports the data of unlimited size.
- Disadvantages Of Message Switching:
  - The message switches must be equipped with sufficient storage to enable them to store the messages until the message is forwarded.
  - The Long delay can occur due to the storing and forwarding facility provided by the message switching technique.

1.8 SWITCHING

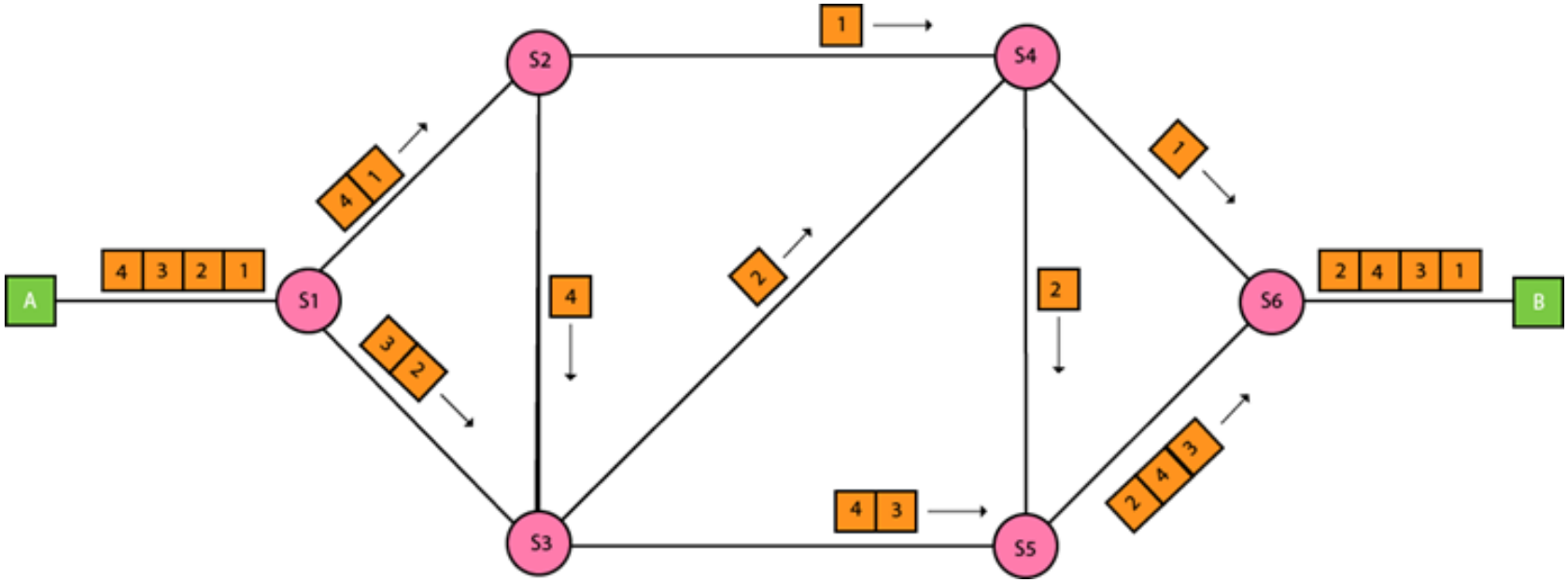
- Packet Switching:
  - The packet switching is a switching technique in which the message is sent in one go, but it is divided into smaller pieces, and they are sent individually.
  - The message splits into smaller pieces known as packets and packets are given a unique number to identify their order at the receiving end.
  - Every packet contains some information in its headers such as source address, destination address and sequence number.
  - Packets will travel across the network, taking the shortest path as possible.
  - All the packets are reassembled at the receiving end in correct order.
  - If any packet is missing or corrupted, then the message will be sent to resend the message.
  - If the correct order of the packets is reached, then the acknowledgment message will be sent.

1.8 SWITCHING

- Approaches Of Packet Switching:
  - There are two approaches to Packet Switching:
    - Datagram Packet switching
    - Virtual Circuit Switching
- Datagram Packet switching:
  - It is a packet switching technology in which packet is known as a datagram, is considered as an independent entity.
  - Each packet contains the information about the destination and switch uses this information to forward the packet to the correct destination.
  - The packets are reassembled at the receiving end in correct order.

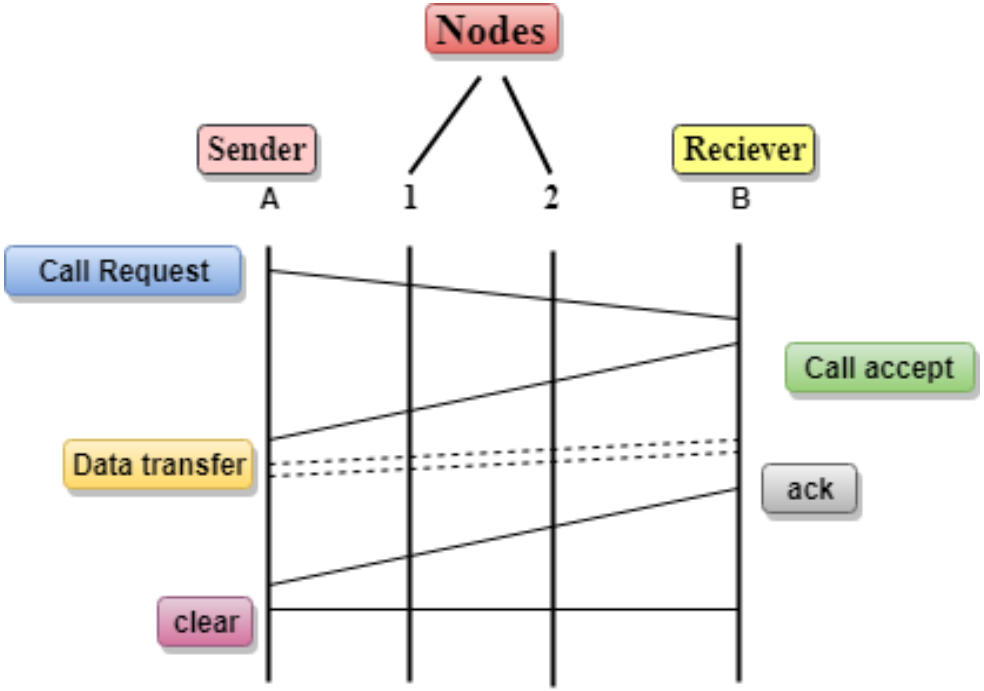
1.8 SWITCHING

- In Datagram Packet Switching technique, the path is not fixed.
- Intermediate nodes take the routing decisions to forward the packets.
- Datagram Packet Switching is also known as connectionless switching.



1.8 SWITCHING

- Virtual Circuit Switching
  - Virtual Circuit Switching is also known as connection-oriented switching.
  - In the case of Virtual circuit switching, a preplanned route is established before the messages are sent.
  - Call request and call accept packets are used to establish the connection between sender and receiver.
  - In this case, the path is fixed for the duration of a logical connection.



1.8 SWITCHING

- Let's understand the concept of virtual circuit switching through a diagram:
  - In the diagram, A and B are the sender and receiver respectively. 1 and 2 are the nodes.
  - Call request and call accept packets are used to establish a connection between the sender and receiver.
  - When a route is established, data will be transferred.
  - After transmission of data, an acknowledgment signal is sent by the receiver that the message has been received.
  - If the user wants to terminate the connection, a clear signal is sent for the termination.

1.8 SWITCHING

- Advantages Of Packet Switching:
  - Cost-effective: In packet switching technique, switching devices do not require massive secondary storage to store the packets, so cost is minimized to some extent. Therefore, we can say that the packet switching technique is a cost-effective technique.
  - Reliable: If any node is busy, then the packets can be rerouted. This ensures that the Packet Switching technique provides reliable communication.
  - Efficient: Packet Switching is an efficient technique. It does not require any established path prior to the transmission, and many users can use the same communication channel simultaneously, hence makes use of available bandwidth very efficiently.
- Disadvantages Of Packet Switching:
  - Packet Switching technique cannot be implemented in those applications that require low delay and high-quality services.
  - The protocols used in a packet switching technique are very complex and requires high implementation cost.
  - If the network is overloaded or corrupted, then it requires retransmission of lost packets. It can also lead to the loss of critical information if errors are nor recovered.

Thank You