Computer Networks - I

- **Introduction and Data Communication Fundamentals**

  Goals of Networking

  Applications and Classification of networks

  Transmission media

  Functions of Networking Devices

  Pulse Code Modulation (PCM)

  Asynchronous and Synchronous Transmission, Multiplexing

  Circuit Switching Versus Packet Switching Techniques

- **Local Area Networks**

  Characteristics of Networks

  LAN topologies

  Introduction to the IEEE standard

  Ethernet

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Computer Networks - I

- **Layered Protocols**

  Protocols, Protocol hierarchies

  Design issues for the layers

  The OSI reference model & TCP/IP reference model

  Protocols at different layers of the OSI reference model

  The Internet Protocol (IP), Subnets, Subnet Masks

  Transmission Control Protocol (TCP)

  User Datagram Protocol (UDP)

- **Domain Name Systems, Electronic Mail and World Wide Web**

  DNS, Resource records

  Electronic mail: Architecture and Services

  World Wide Web, Uniform Resource Locator and Cookies

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Goals of Networking

- **Resource and Load sharing**
  - Several machines can share printer, scanner, DVD drive, etc.
  - Network resources are available to user of the network.
- **Reduced cost**
  - Mainframe Vs Desktop Computers
  - Cost of network printer, scanner & DVD drive is less.
- **High reliability**
  - If a one machine goes down, another machine can take over.
- **Remotely Access I/O Devices**
  - Access devices through the Internet.
- **Scalability**
  - As workload increase easily extent the network by adding more micro processors.
- **Powerful Communication**
  - A file that was updated or modified on a network can be seen by the other users on the network immediately.

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- **Computer Networks**
  - "A network consists of two or more computers that are linked in order to share resources, exchange files, or allow electronic communications."
  - It is a collection of interconnected , but autonomous computers.
- **Distributed System**
  - A collection of independent computers that appear to the user of the system as single computer system.
- **Distributed System Vs Computer Networks**

– Computers are invisible to users	Computers are visible to users
– Login is not required	Login is required
– E.g. WWW	E.g. LAN

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internet Vs Internet

- **internet or internetwork**
  - A collection of interconnected networks that function as a single network
  - Establish communication link between two or more networks.

Internetworking = Interconnectivity + Interoperability

  - **Interconnectivity** – the ease and ability of connecting networks
  - **Interoperability** – the methodology applied to make data understand to computers that uses different OSs and Languages.

- **Internet**
  - A Network of networks
  - Used to connect universities, government offices, Banks etc.

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Historical Perspective

- 1967: ARPAnet –Advanced Research Projects Agency Network
- 1970: ALOHA (Additive Links On-line Hawaii Area) network in Hawaii
- 1973: Ethernet used in LAN
- 1983: TCP/IP
- 1990: WWW (Http)
- 2000: Ipv6
- 2005 : Social Networks
- 2007: Smartphone
- 2010: Broadband & Mobile Internet
- 2011: Cloud Computing
- 2014 : WiFi with higher speed
- 2016 : Internet of Things

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Networks Applications

- **Business Applications**
  - All programs, Data and Devices available to anyone on the network.
  - Connect individual network or host at different physical location through the VPN (Virtual Private Network)
  - Client – Server Model is used for network usage.

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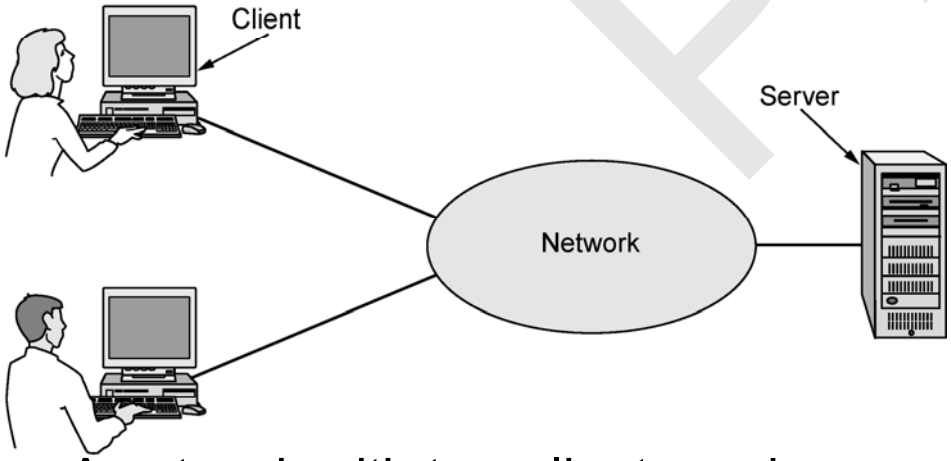
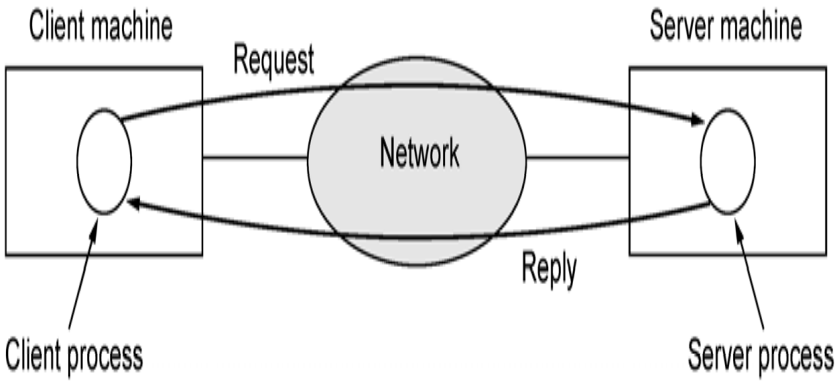


A network with two clients and one server.



The client-server model involves requests and replies.

Networks Applications

- **Business Applications**
  - E-mail, FTP, Messenger
  - IP Telephone or Voice over IP (VoIP)
  - Audio & Video Conferencing
  - Desktop sharing
  - E-commerce

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Networks Applications

- **Home Application**
  - Access to remote Information
    - Home shopping
    - Pay the bills
    - Manage bank account
    - Surfing for business, health, govt., news etc
  - Person to Person Communication
    - Email , Messenger, Audio / Video conference
  - Interactive Entertainment
    - Internet Radio, Video on demand, Youtube , Playing game
  - Social network
    - Face book, Twitter, LinkedIn

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Networks Applications

Home Application

- Door and Window Sensors
- Electricity, Gas & Water meter
- Smoke Detector
- Shower may record water usage
- Refrigerator reminds about buying vegetables
- Babysitter is sleeping
- Electric bulb tells us if it is going down
- Lamp dims itself when you are asleep
- Night lamp automatically switches on and off
- Smart Keys
- A phone receiver transfers the call automatically
- Control house via Internet or phone
- RFID (Radio Frequency Identification)

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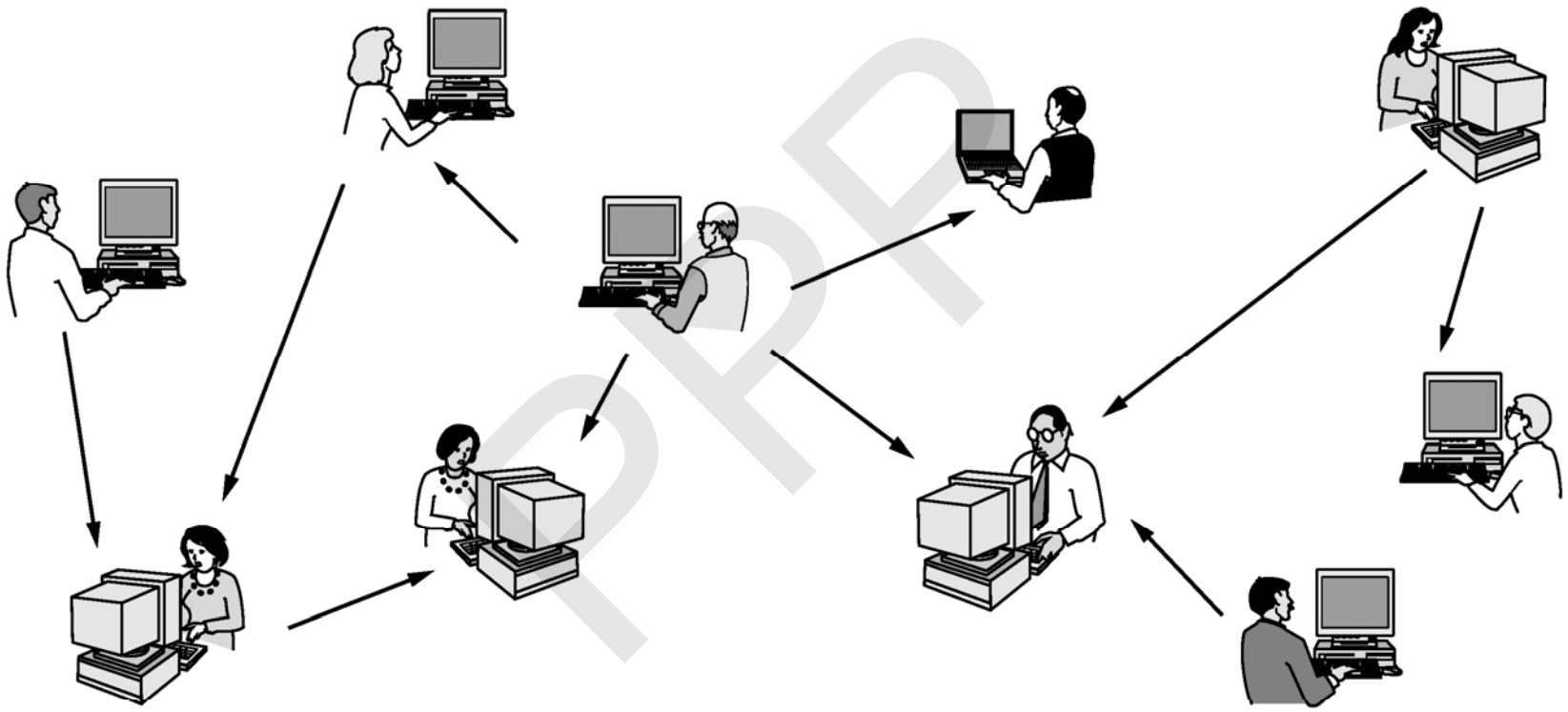
Networks Applications

Home Application:



In a peer-to-peer system there are no fixed clients and servers.

Networks Applications

Some forms of e-commerce.

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books online
B2B	Business-to-business	Car manufacturer ordering tires from supplier
G2C	Government-to-consumer	Government distributing tax forms electronically
C2C	Consumer-to-consumer	Auctioning second-hand products online
P2P	Peer-to-peer	Music sharing

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Networks Applications

Mobile Users

Wireless	Mobile	Typical applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in unwired buildings
Yes	Yes	Store inventory with a handheld computer

Combinations of wireless networks and mobile computing.

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Networks Applications

Mobile Users

- PDA with built in printer
- PDA with Barcode
- Vending Machine
- University Campus
- Military
- Conferences
- Location Dependent Services
- Electronic wallet
- SMS (Short Message Service)
- Taxi Drivers are independent businessman
- M-commerce

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Types of Transmission

- **Broadcasting**:
  - Single communication channel that is shared by all the machines on the network.
  - Every machine gets the packet but the machine for which it is broadcast only that machine accept other will reject it.
- **Multicasting**:
  - Transmission to subset of the machines.
- **Point-To-Point**:
  - Many connections between individual pairs of machines.
  - Packet may have to visit one or more intermediate machine.

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Types of Broadcasting

- **Static Broadcasting**
  - **To divide the time into discrete intervals and use round robin algo. which allowing each machine to broadcast only when its time slot comes up.**
  - **Problem :: Idle slot when machine has nothing to say.**
- **Dynamic Broadcasting**
  - **Centralize**
    - » **Single entity determines who goes next**
  - **Decentralize**
    - » **Each machine must decide for itself whether to transmit or not.**

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Transmission Mode

To define the direction of signal flow between linked devices.

- Simplex : Signal flow only in one direction.
- Half-Duplex : Signal flow in both direction but at a time in only one direction.
- Full-Duplex : Signal flow in both direction at the same time.

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Classification of Networks

- Scale :
  - According the distance covered by network.
- Connection Method :
  - Types of connection in network
- Functional Relationship
  - Relationship between technology of network.
- Network Topology
  - The way the network devices are physically or logically connected.

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Classification of Networks

Scale	Connection Method	Functional Relationship	Network Topology
Personal Area Network (PNA)	Ethernet	Client Server	Bus Network
Local Area Network (LAN)	Fiber Optics	Peer to Peer	Ring Network
Metropolitan Area Network (MAN)	Wireless Network		Star Network
Wide Area Network (WAN)	Satellite Network		Tree Network
			Mesh Network

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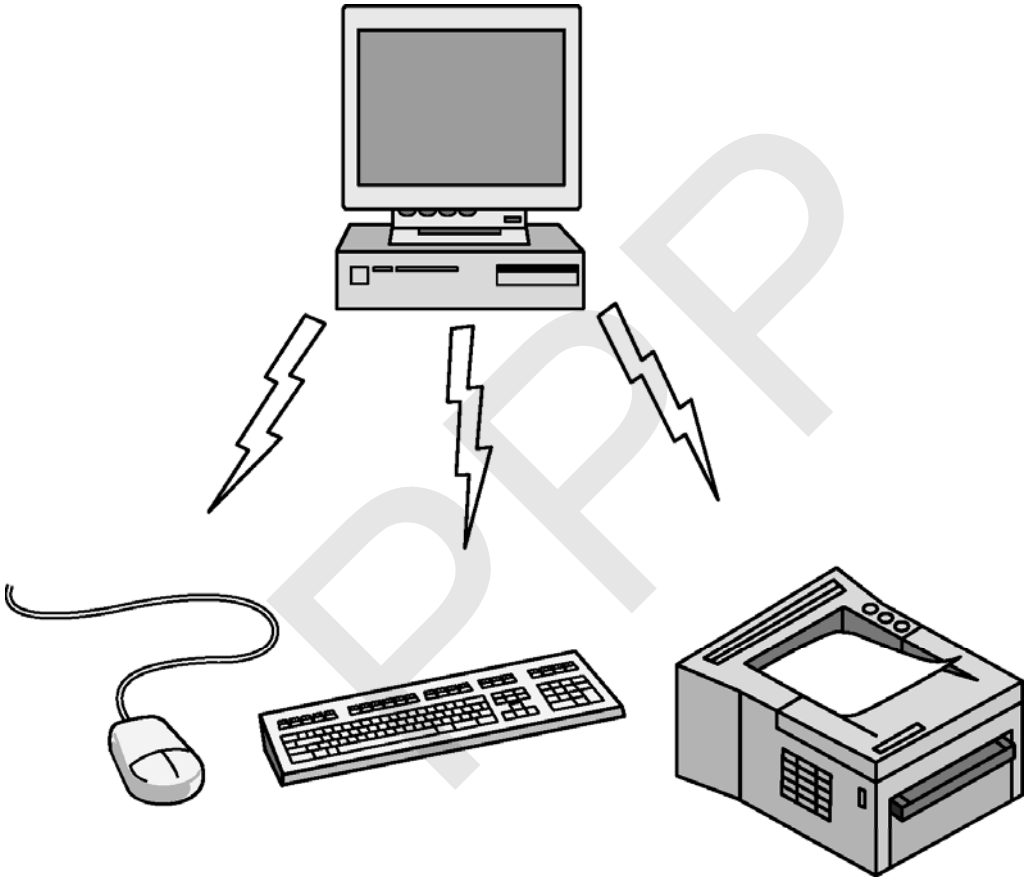
Personal Area Network



Bluetooth PAN configuration.

- Short range signals
- Master Slave concept

Local Area Network (LAN)

- Enterprise network
- Wi-Fi network
- Switch & Port
- Switched Ethernet (Broadcast)
- Classic Ethernet (Collision Resolution)

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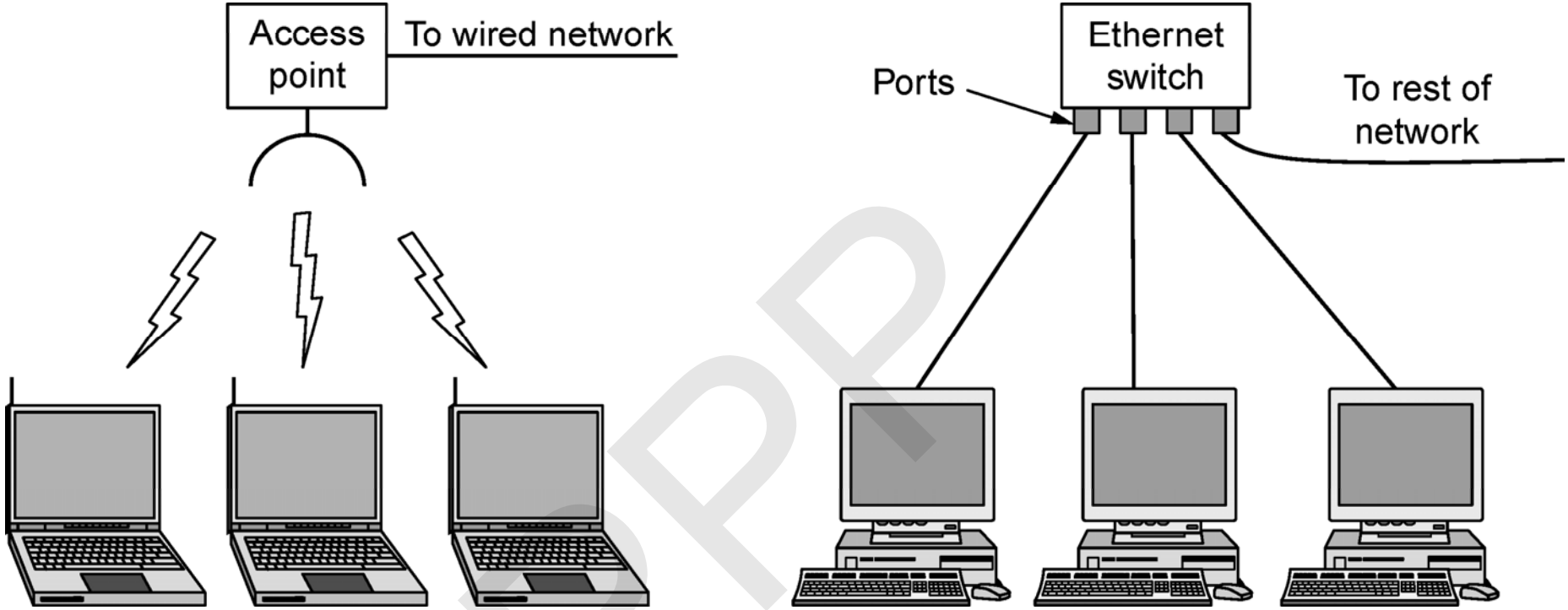
Wireless Network & Ethernet Network



Wireless and wired LANs. (a) 802.11. (b) Switched Ethernet.

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Topology

Configuration of cables, computers, and other peripherals

- Bus
- Ring
- Star
- Mesh
- Tree

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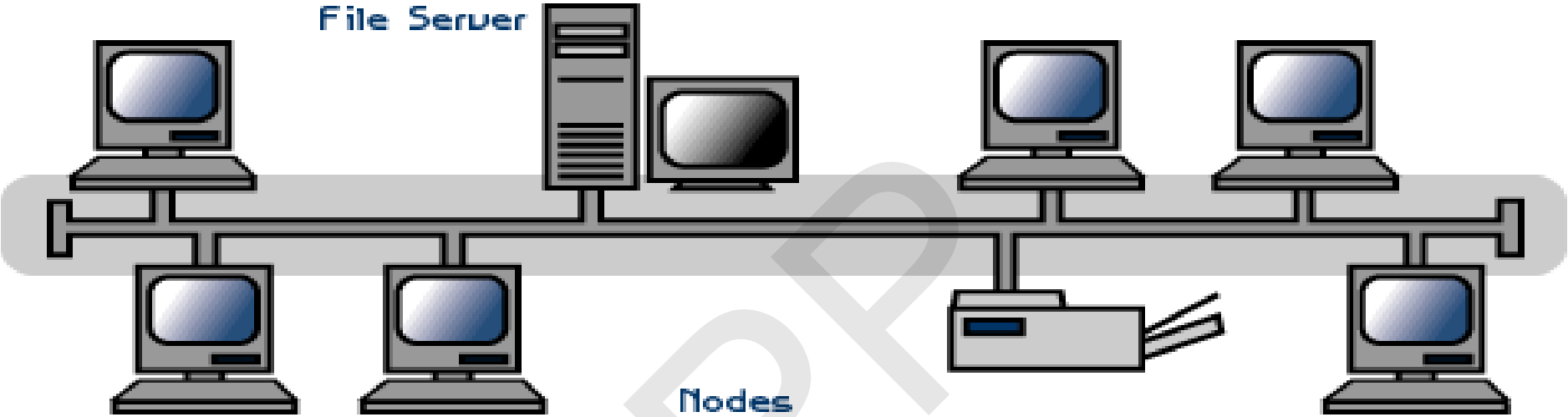
Bus Topology



Advantages

Simple , reliable in very small networks

Least amount of cable

Less expensive

Easy to extend

Disadvantages

Heavy network traffic

Difficult to fault isolation

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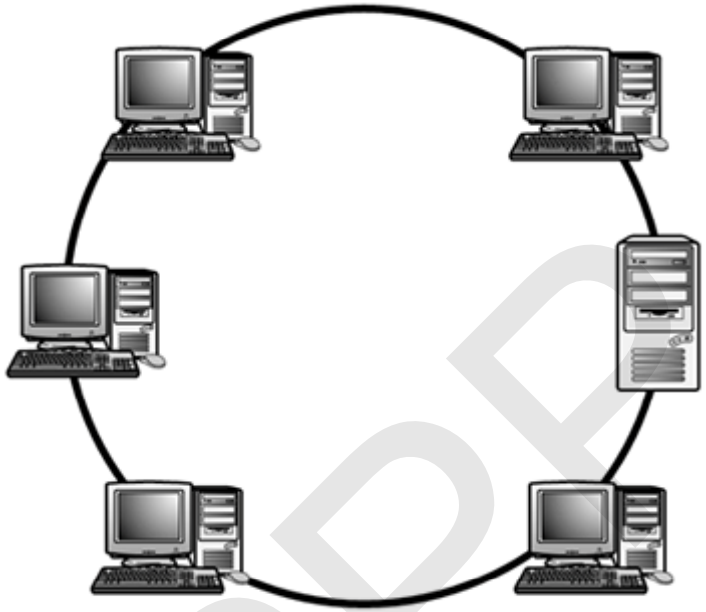
Ring Topology



Advantages

Every computer is given equal access to the token

Fault isolation is simplified

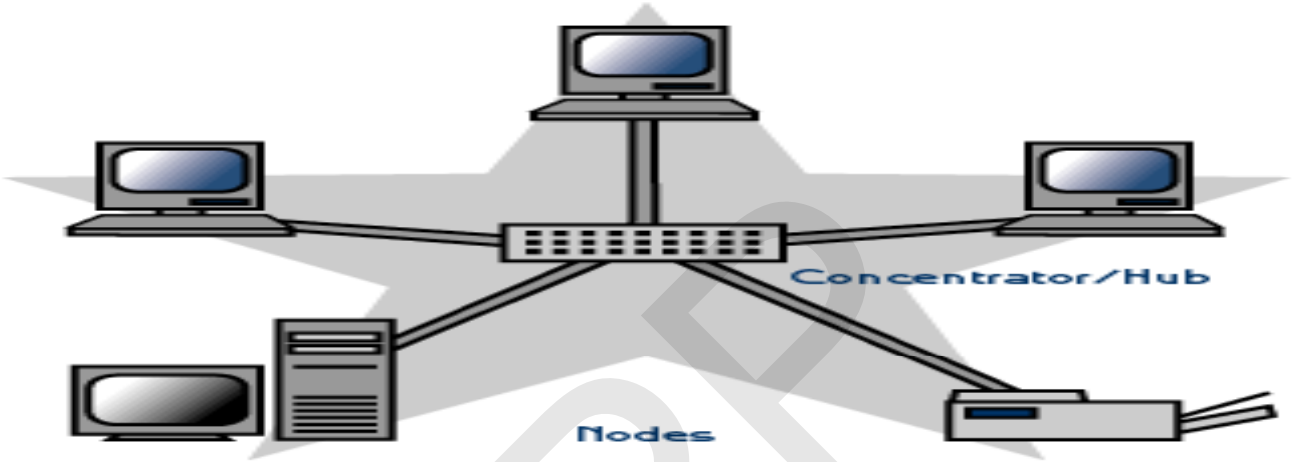
Easy to add or remove device

Disadvantages

Unidirectional traffic

Failure of one computer on the ring can affect the whole network.

Star Topology



Advantages

Easy to add and remove computers

Easy to fault isolation

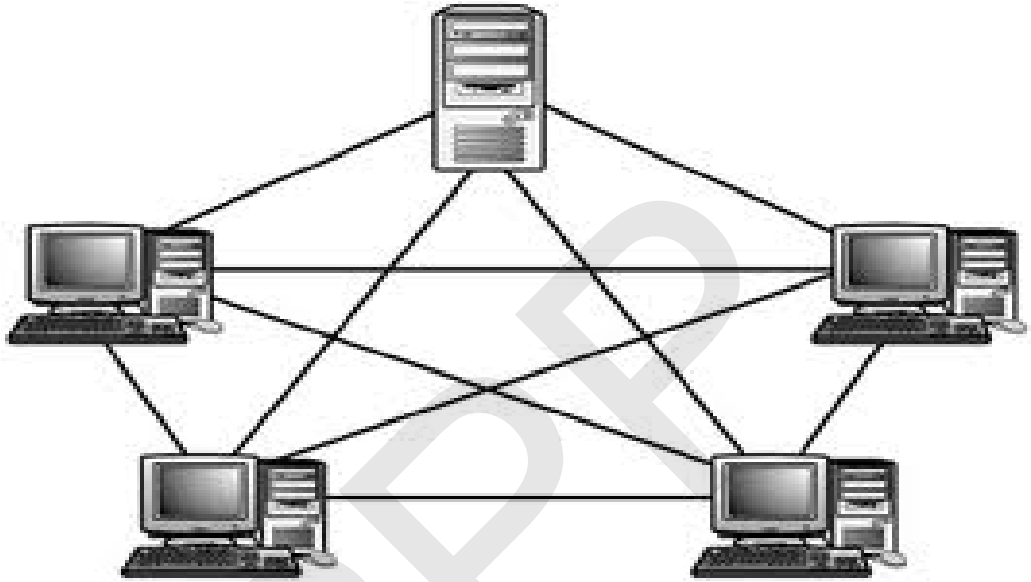
Single computer failure do not bring down the whole star network.

Disadvantages

If the central hub fails , the whole network fails to operate

More cable require

Mesh Topology



Advantages

No traffic problem

Robust

Privacy or Security

Easy fault identification and fault isolation

Disadvantages

More cabling and number of I/O ports required

More expensive

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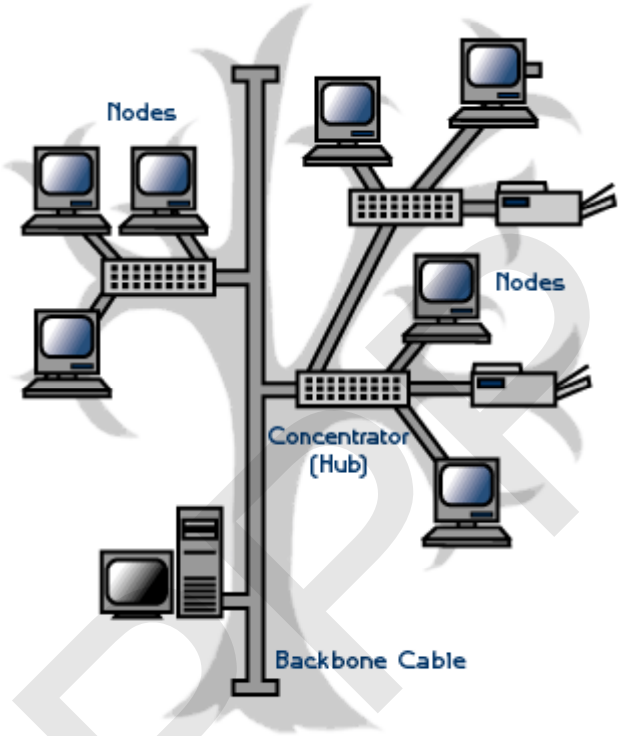
Tree Topology



Advantages

It allows the network to isolate and prioritize communications from different computers

It allows more devices to be attached to a single central hub

Disadvantages

If the backbone line breaks, the entire segment goes down.

- **Network Architecture**
  - A set of layers and protocols

- **Protocol**
  - It is an agreement between the communicating parties on how communication is to proceed.

- **Layer**
  - Most networks are organized as a stack of layers
  - The number of layers , name of each layers and function of each layers differ from network to network.

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- **Interface**
  - Between each pair of adjacent layers is an interface.
  - It defines which primitive operations and services the lower layer makes available to the upper one.

- **Entity**
  - Active element (h/w or s/w) in each layer are called entity
  - Entities in the same layer on different machines are called peer entities.

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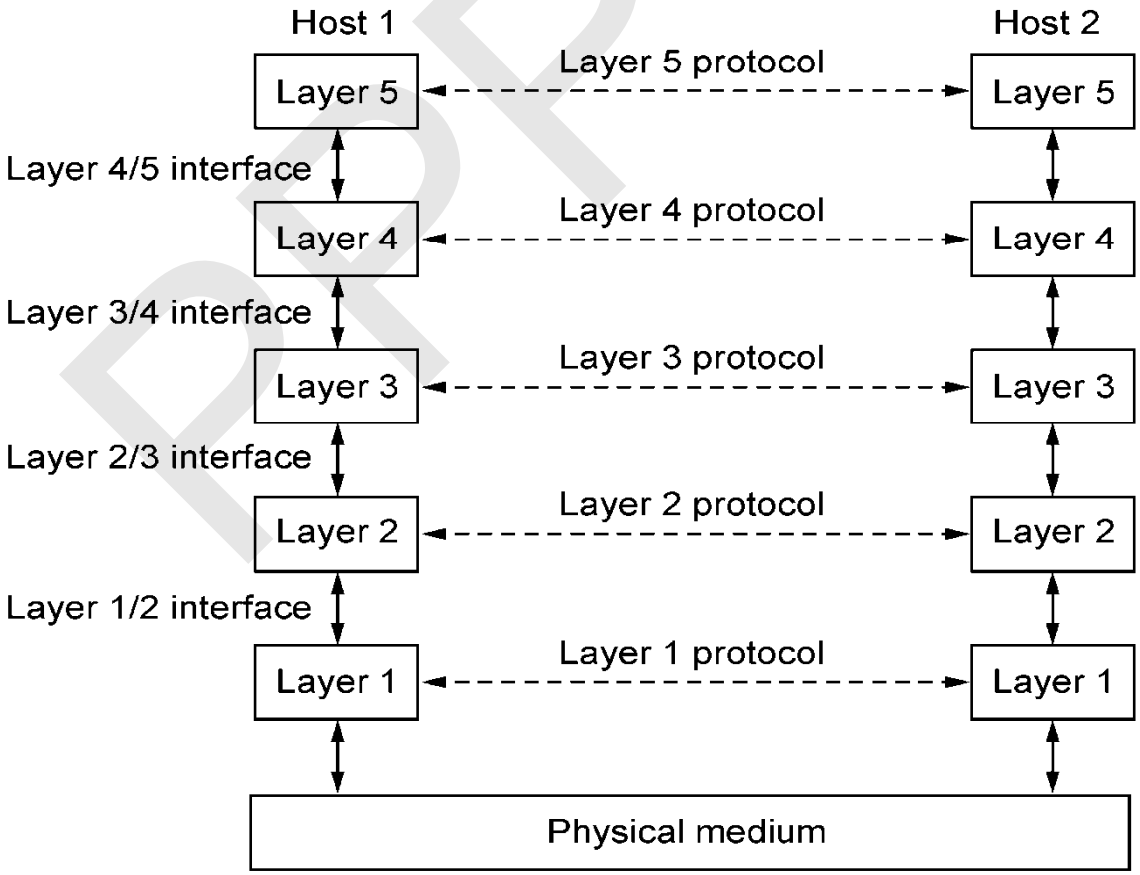
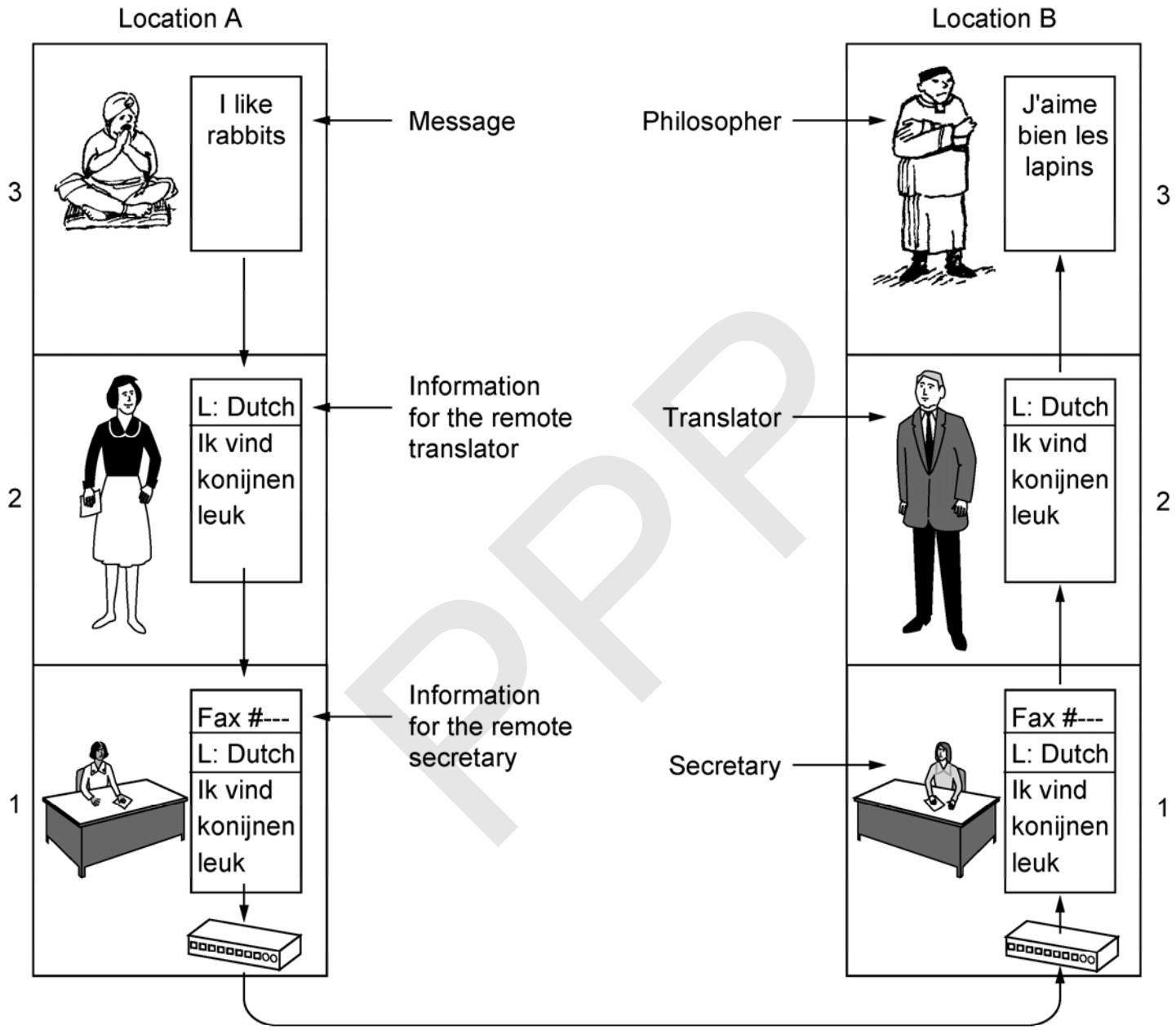
Protocol Layers

Protocol layering is the main structuring method used to divide up network functionality.

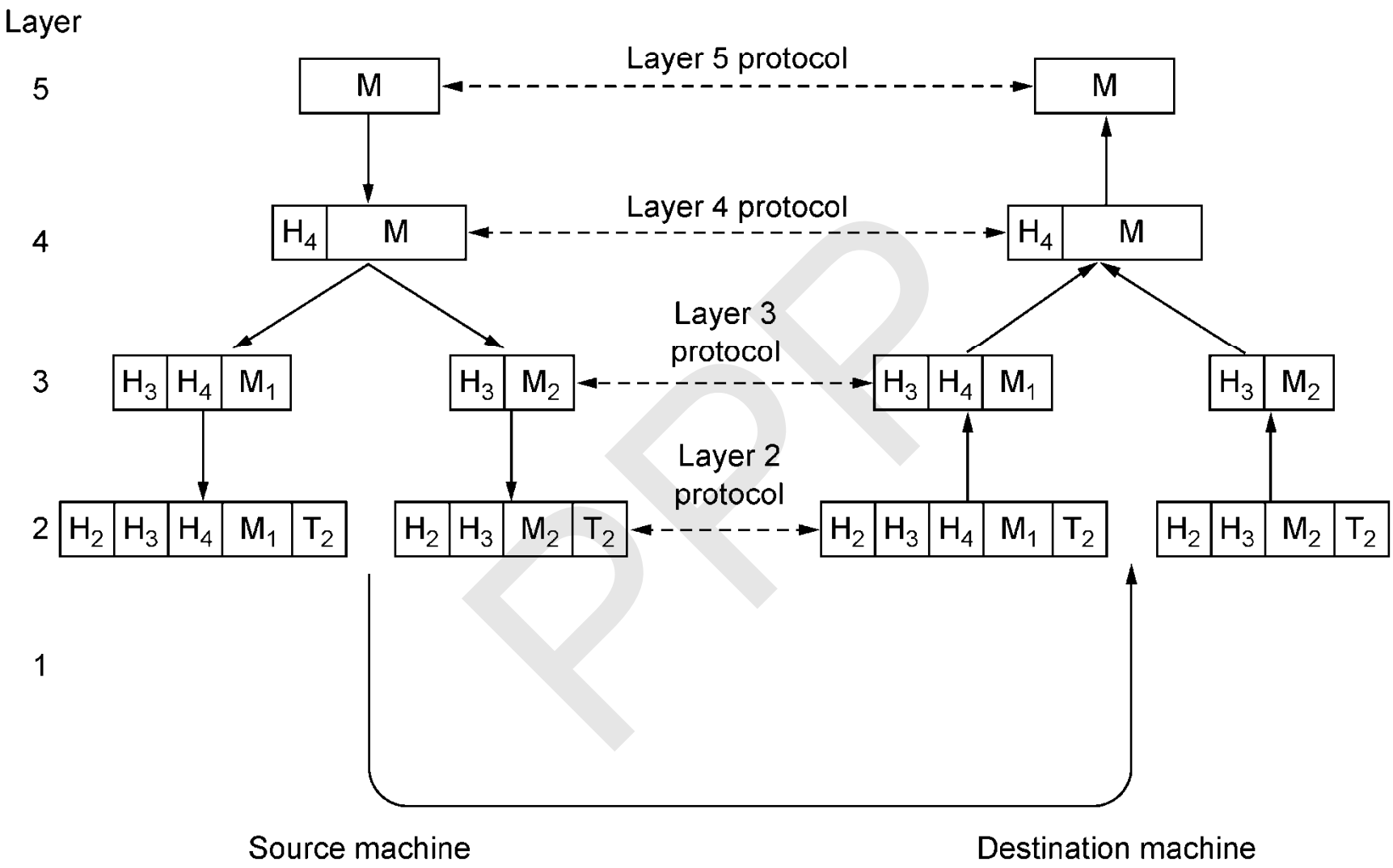
- Each protocol instance talks virtually to its peer
- Each layer communicates only by using the one below
- Lower layer services are accessed by an interface
- At bottom, messages are carried by the medium



Layers, protocols, and interfaces.



The philosopher-translator-secretary architecture.



Example information flow supporting virtual communication in layer 5.

Two important network architecture

- **OSI** (Open System Interconnection) reference model
  - Developed by ISO (International Standard Organization)
  - It is open system because , it deals with connecting open system.
  - Systems that are open for communication with other systems.
- **TCP / IP** reference model
  - It used in ARPANET and its successor , the world wide internet.
  - Two primary protocols : TCP & IP

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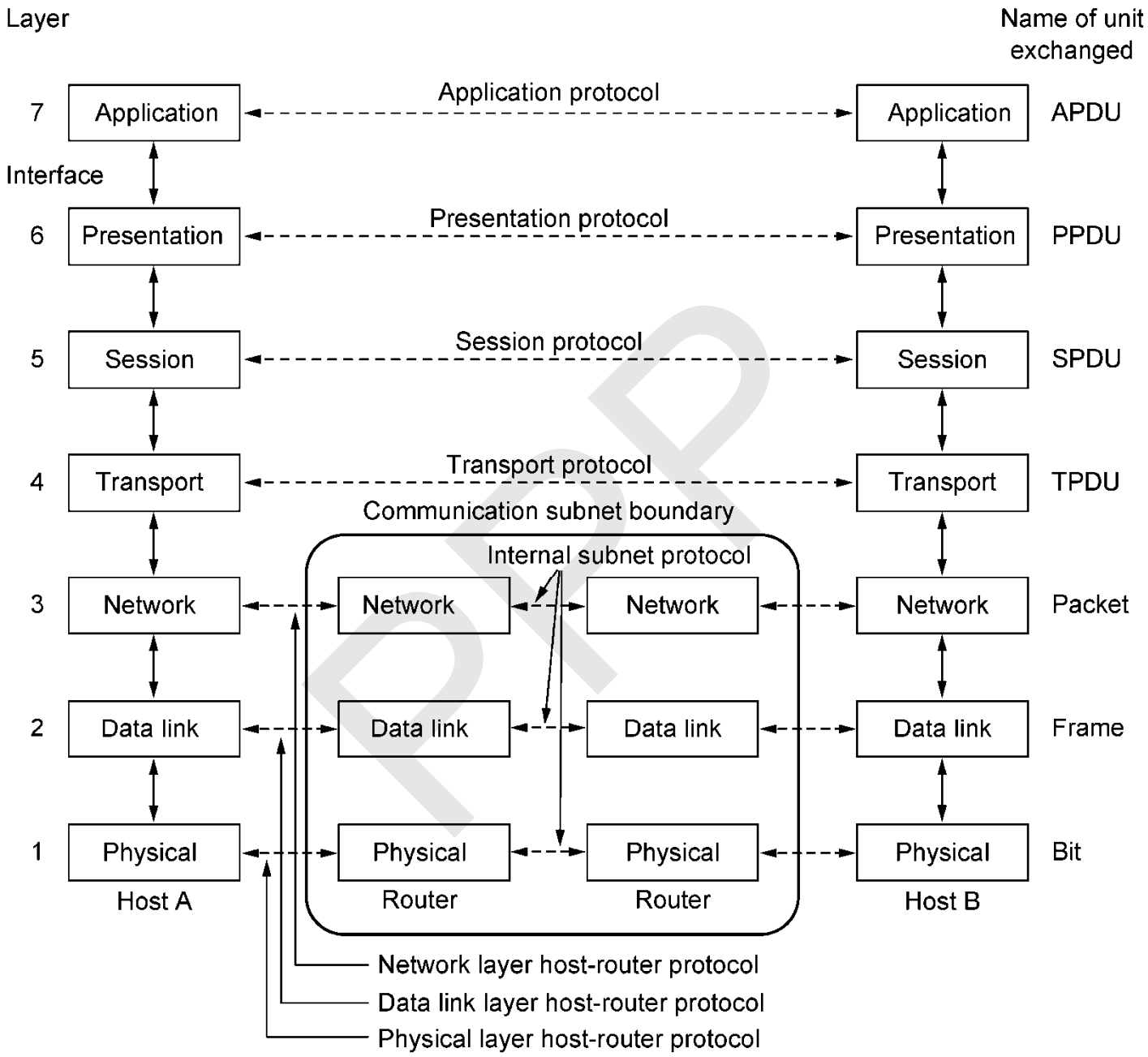

The OSI reference model.

Functions of OSI Layers

Physical Layer

->Row bit transmission
->Decide which voltages use for 0 as well as 1 bit
->Data rate
->Which medium is used and how many wires are there
->How communication is possible (Simplex , Half-Duplex , Full-Duplex)

Data link Layer

->Convert the row bit into frame
->special bit or byte for the boundary of the frame
->Flow Control
->Error Control
->Solve the problem occurs by damage , lost , duplication of frame

Network Layer

->Decide the route for the packet
->Congestion Control

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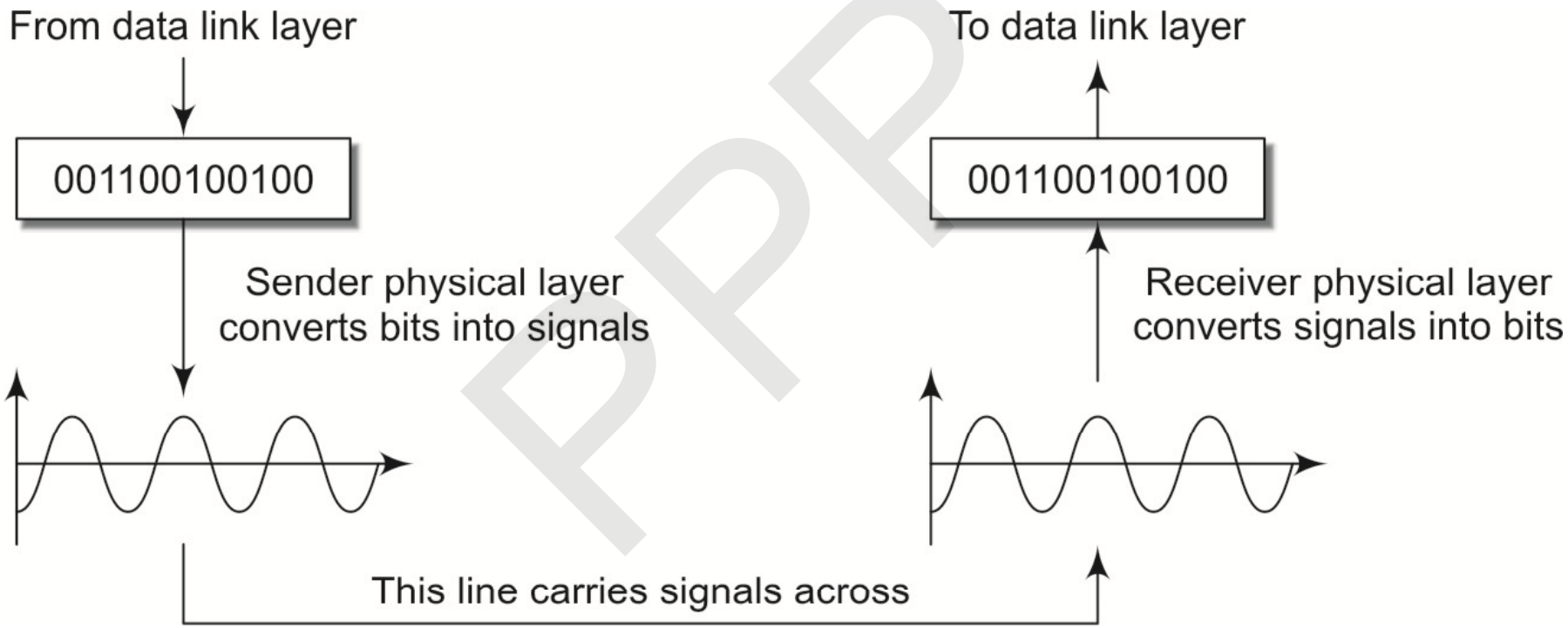
The Physical Layer



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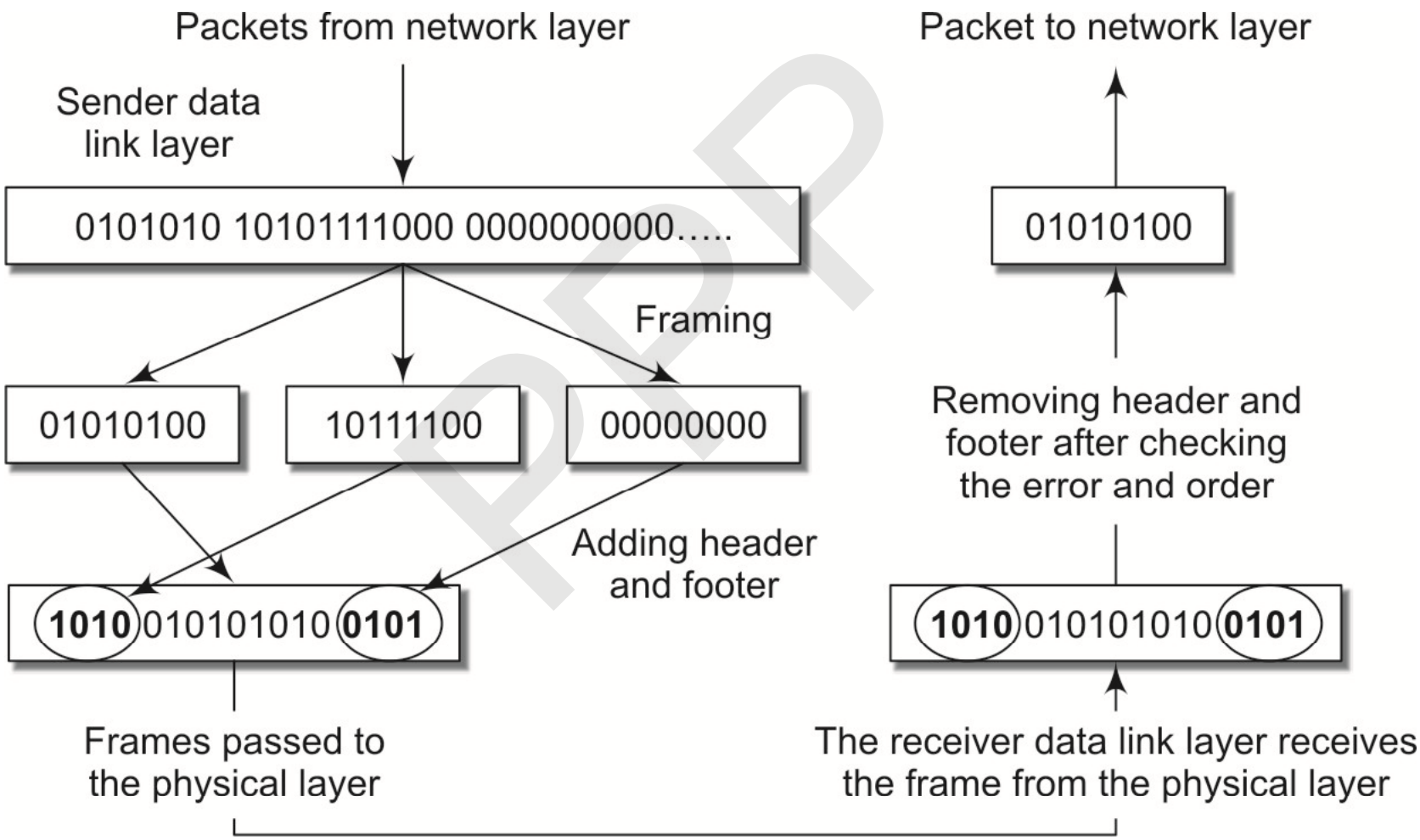
The Data Link Layer



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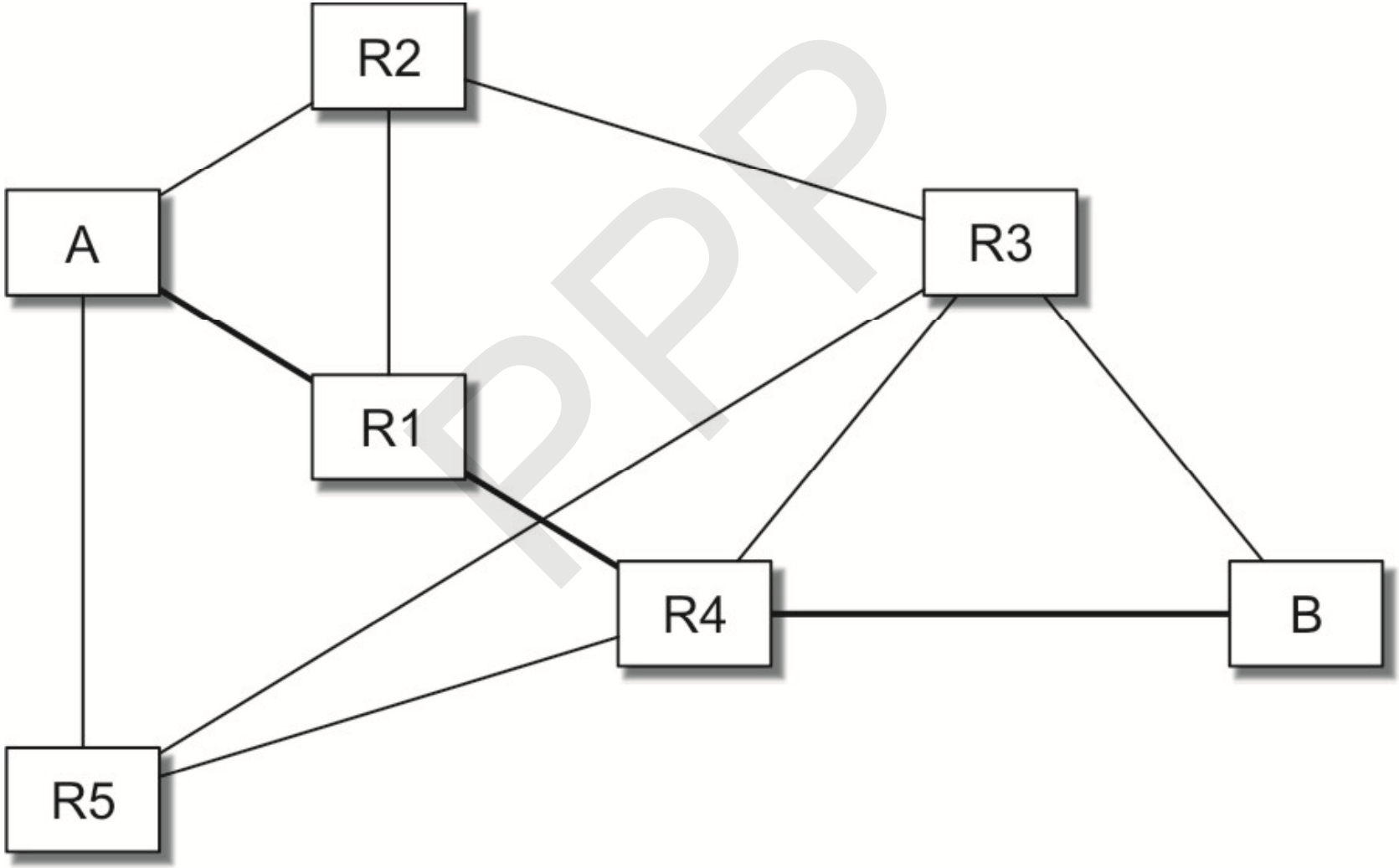
The Network Layer



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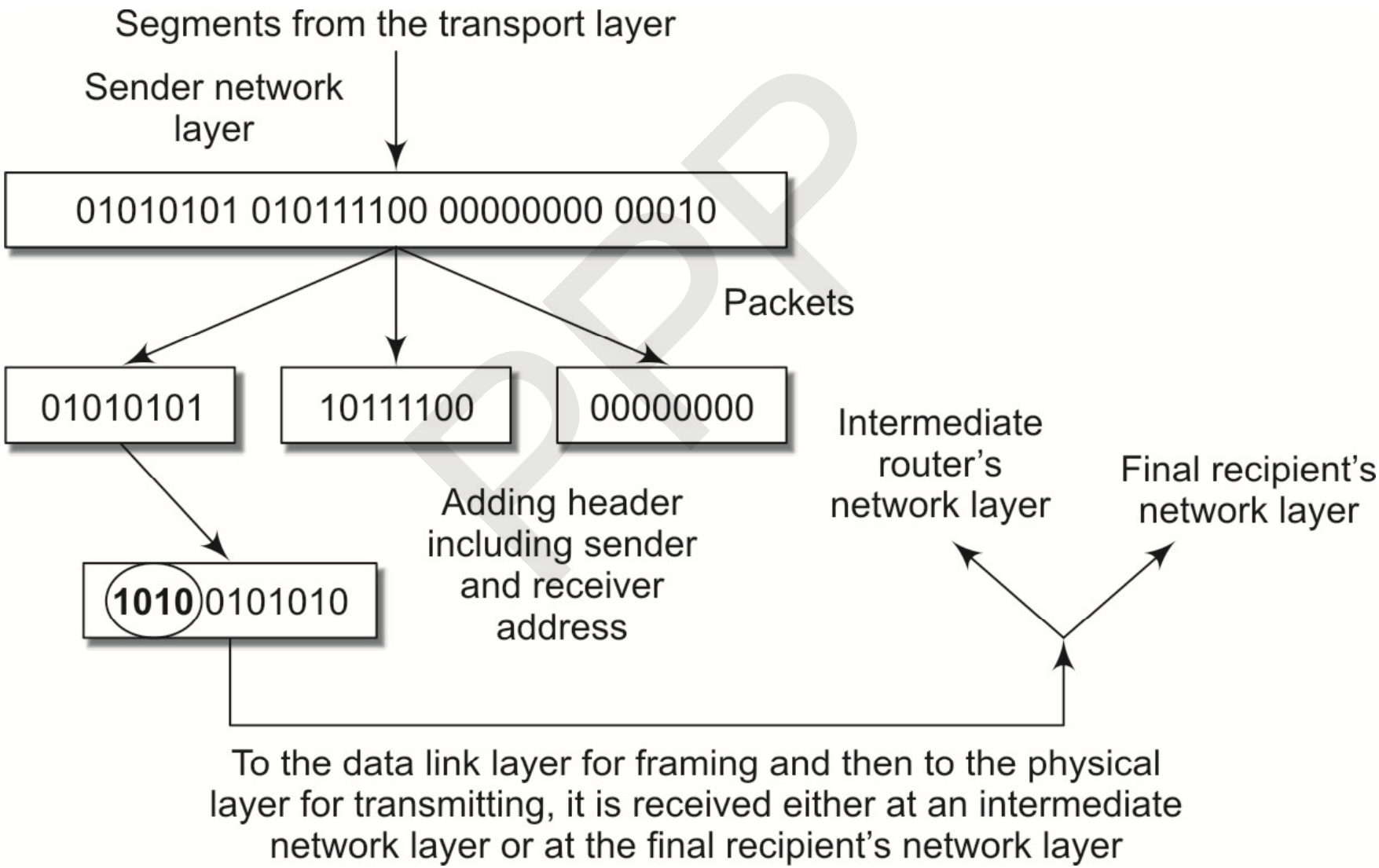
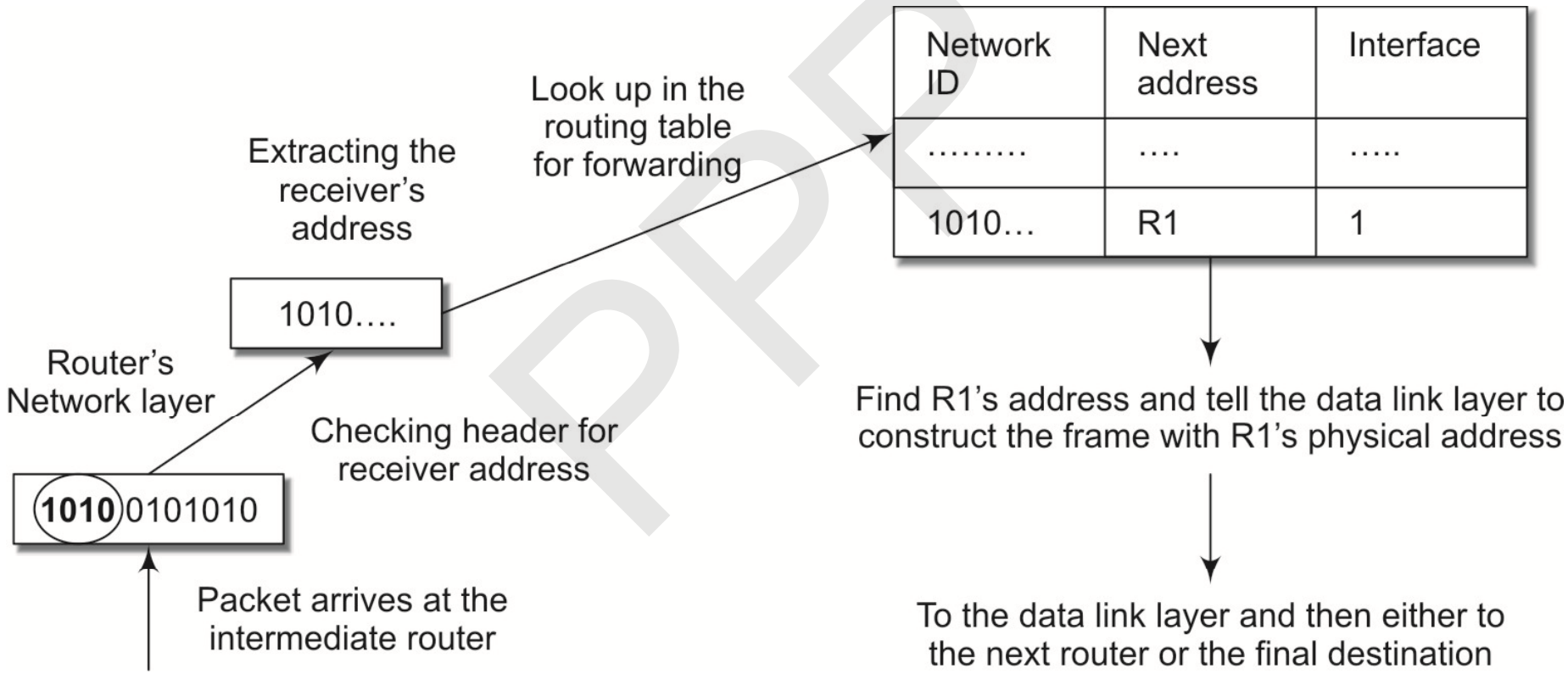
Network Layer Functioning



Routing At Network Layer



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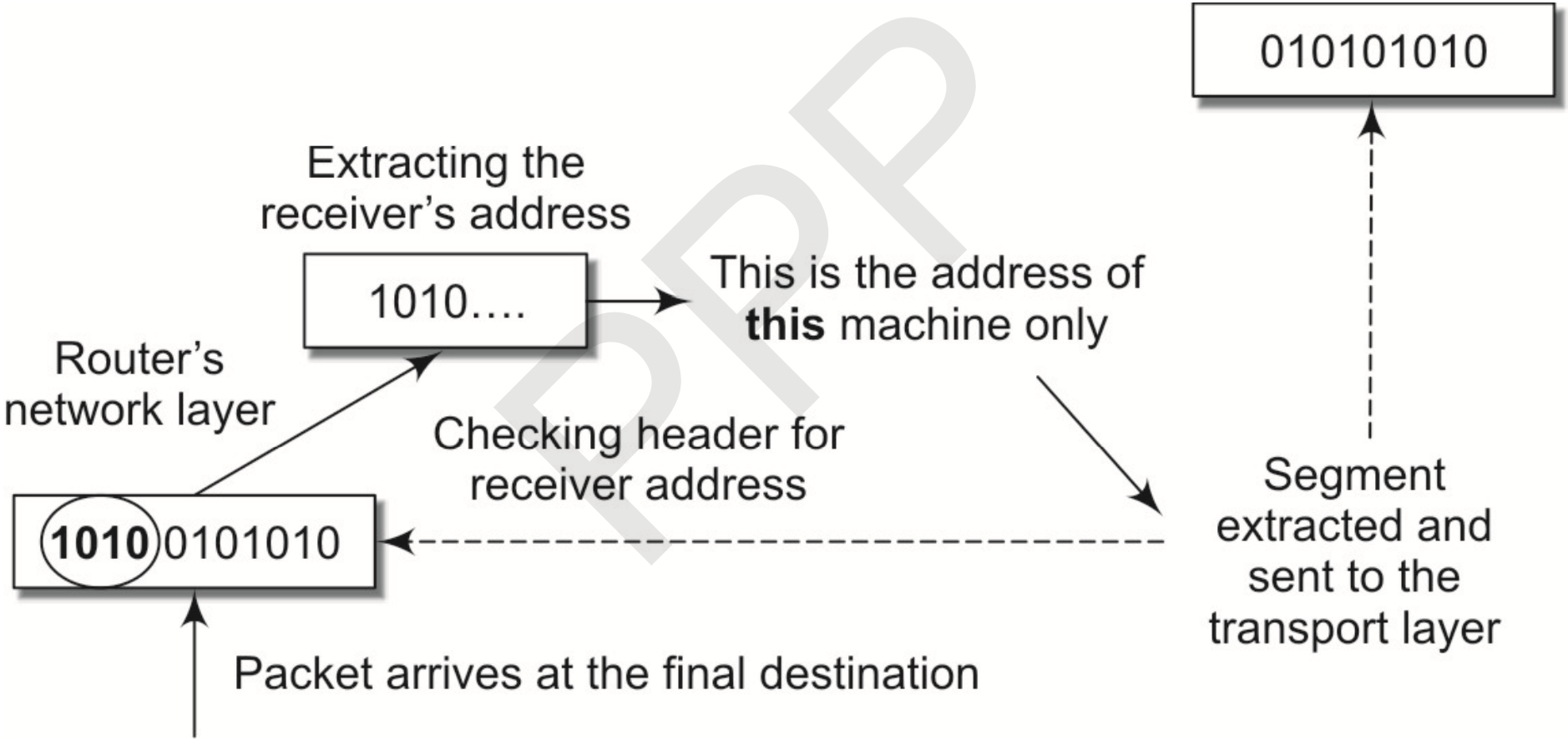
Extracting Prefix



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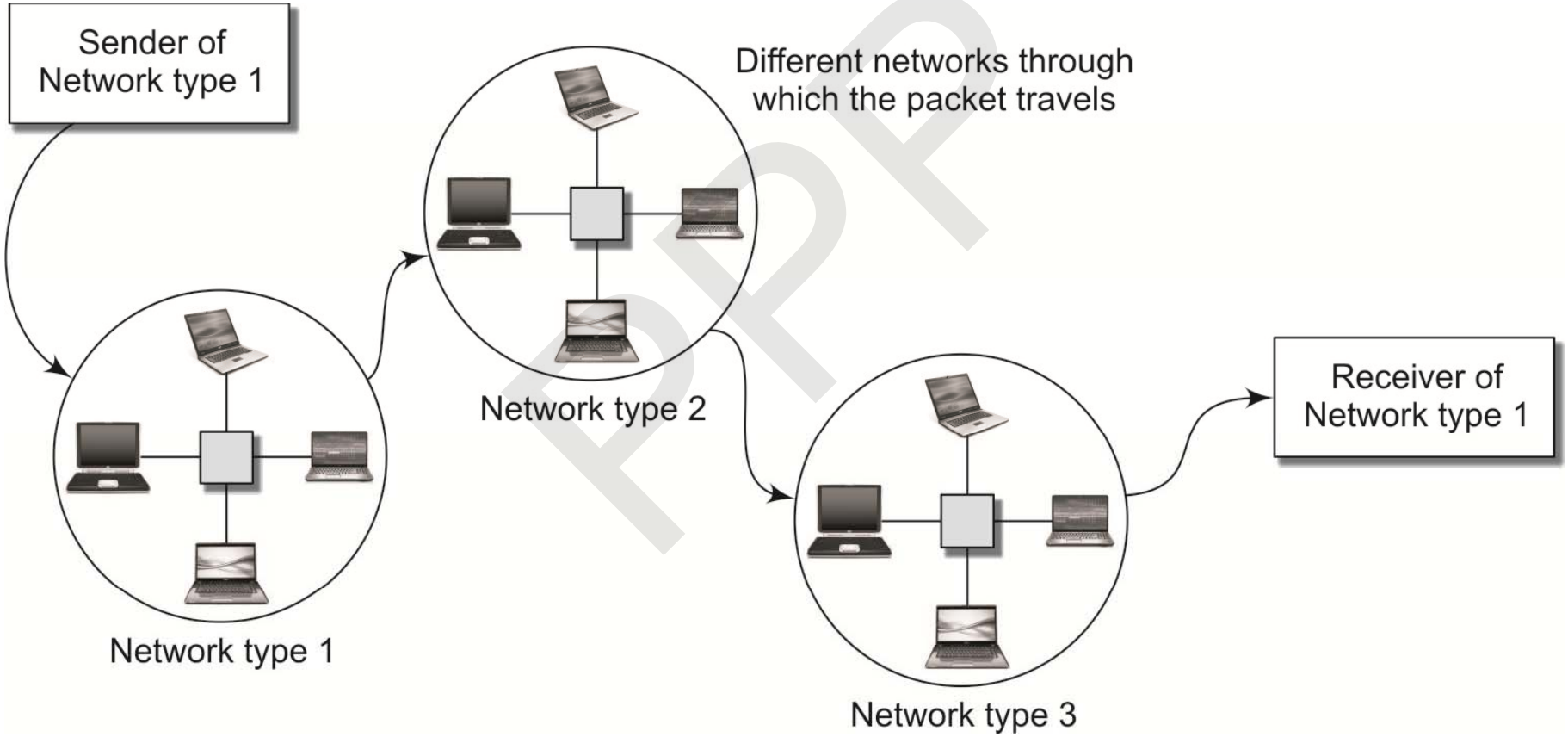
Routing Between Different Networks



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Functions of OSI Layers

Transport Layer

->Break data it receive from session layer and transfer to N/W Layer
->Segmentation & Reassembly
->Service Point Addressing
->Flow Control

Session Layer

->Keeping track which session's turn to transmit.
->Synchronization

Presentation Layer

->Translation
->Encrypted
->Encoded
->Compressed

Application Layer

->Application that develop for use across the internet
->Contain the protocol that are commonly needed by user (HTTP)

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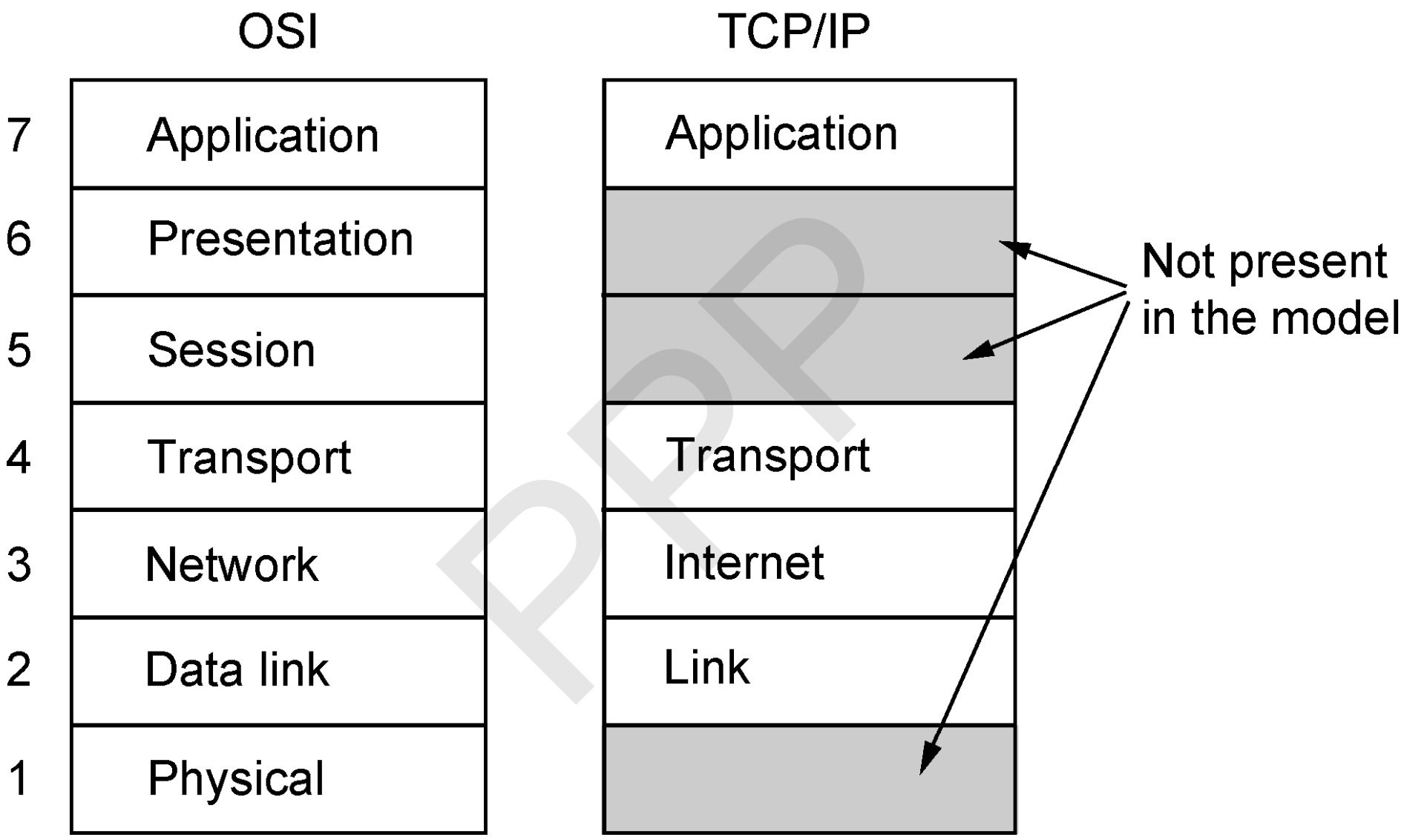

The TCP/IP reference model.

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Difference between OSI and TCP/IP Model

OSI	TCP/IP
1. Open System Interconnection	Transmission control protocol / Internet protocol
2. 7 layers	4 layers
3. Models was devised first	Protocols came first
4. N/W layer provide connection oriented and connection less service.	N/W layer provides only connectionless service.
5. Transport layer provides only and connection less service.	Transport layer provides connection oriented Connection less service.

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Design Issues for the Layers

Each layer solves a particular problem but must include mechanisms to address a set of recurring design issues.

Issue	Example mechanisms at different layers
Reliability despite failure	Codes for error detection / correction Routing around failure
Network growth and evaluation	Addressing & Naming protocol layering
Allocation of resources like bandwidth	Multiple access & Congestion control
Security against various	Confidentiality of message

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Networking Devices

- Amplifier (Physical Layer)
- Repeater (Physical Layer)
- Hub (Physical Layer)
- Bridge (Data Link Layer)
- Switch (Data Link Layer)
- Router (Network Layer)
- Gateway (Application Layer)

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Networking Devices

- **NIC (Network Interface Card)**
  - It is a hardware device that connect a computer with the network.
  - It is installed on the mother board.
  - It is responsible for developing a physical connection between the network and the computer.
  - Computer data is translated into electrical signals send to the network via Network Interface Cards.
  - Manage data-conversion function. It is software configured.

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Networking Devices

- **Amplifier**
  - A signal containing some information and after travelling some distance, signal get weakened (attenuated) due to energy loss in the medium. Therefore, it should be improved (or amplified). Amplifier is the circuit which magnifies the weak signal to a signal with more power.
  - An electronic device that can increase the power of a signal (a time-varying voltage or current). An amplifier functions by taking power from a power supply and controlling the output to match the input signal shape but with a larger amplitude.
  - Amplifies both signal and noise

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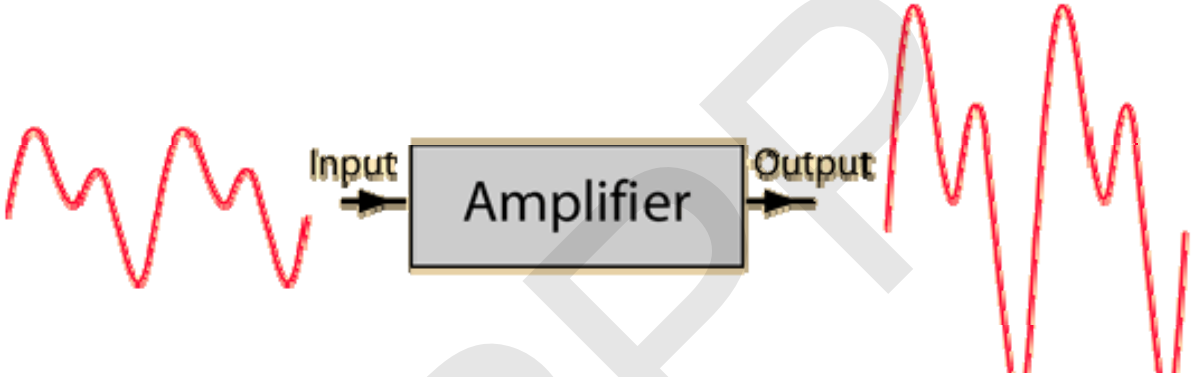
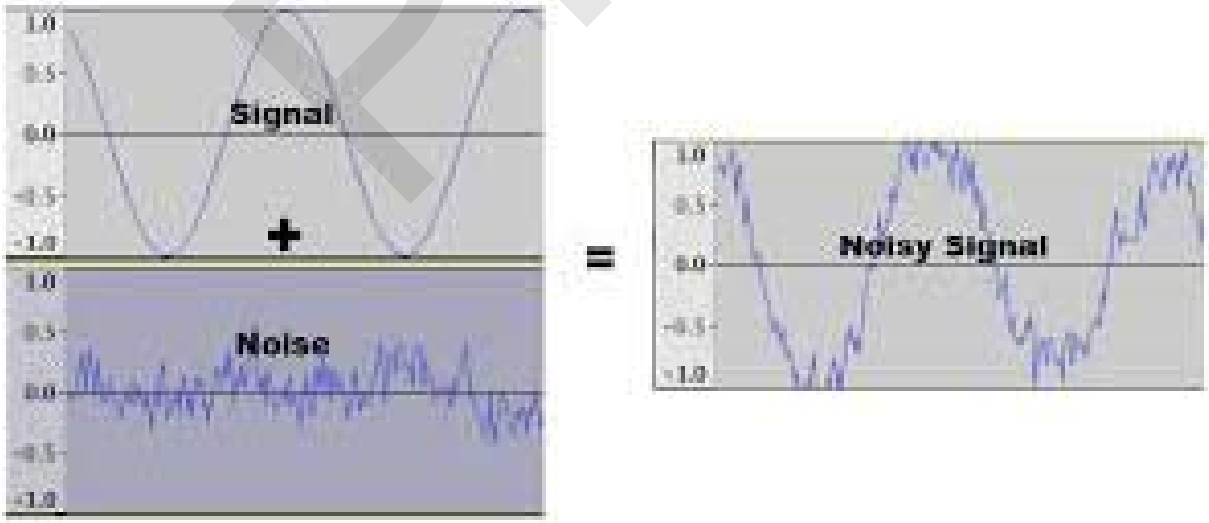
Networking Devices

Amplifier

- An amplifier is an electronic device that increases the voltage, current, or power of a signal.
- Amplifiers are used in wireless communications and broadcasting, and in audio equipment of all kinds.





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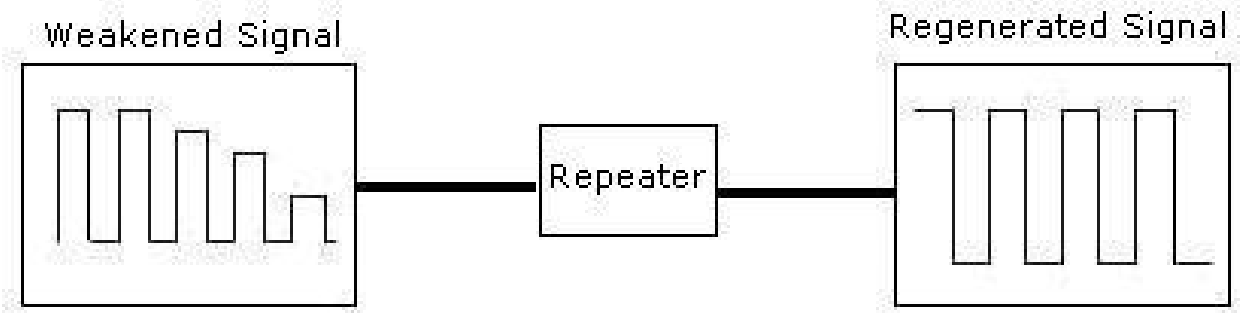
Networking Devices

- **Repeater**
  - An electronic device that regenerate the signal to maintain the strength of a signal up to long distance.
  - Used to increase the length of the network by removing the affect of attenuation on the signal.
  - It connects two segments of the same network, overcoming the distance limitations of the transmission media.
  - It just forward the frames it has no filtering capability.



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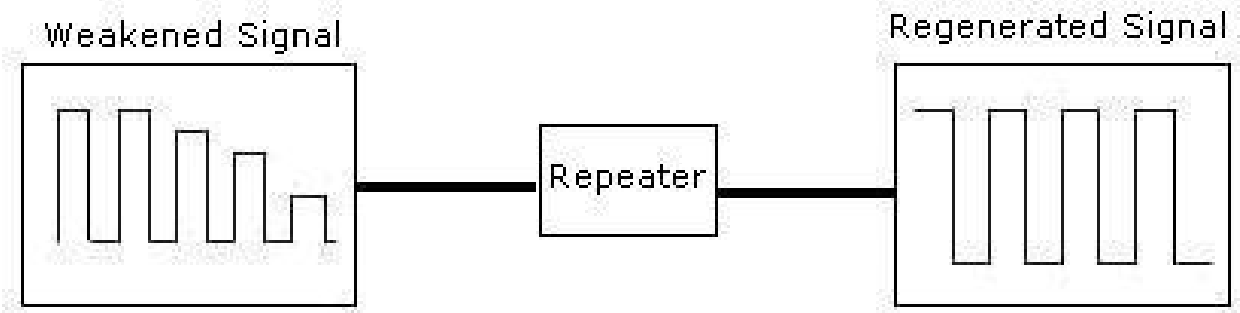
Networking Devices

- **Repeater**
  - Most telecommunications cables are now fiber optic cables which use optical repeaters.
  - Submarine cable repeater used in underwater submarine telecommunications cables.
  - To extend the coverage of a radio or television broadcasting stations.
  - Cellular repeater to receive the signals at base station from nearest cell tower and rebroadcast to nearby cell phones.



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Difference Between Amplifier and Repeater

- Amplifier is used to magnify a signal, whereas repeater is used to receive and retransmit a signal with a power gain.

- Repeater has an amplifier as a part of it.

- Sometimes, amplifiers introduce some noise to the signal, whereas repeaters contain noise eliminating parts.

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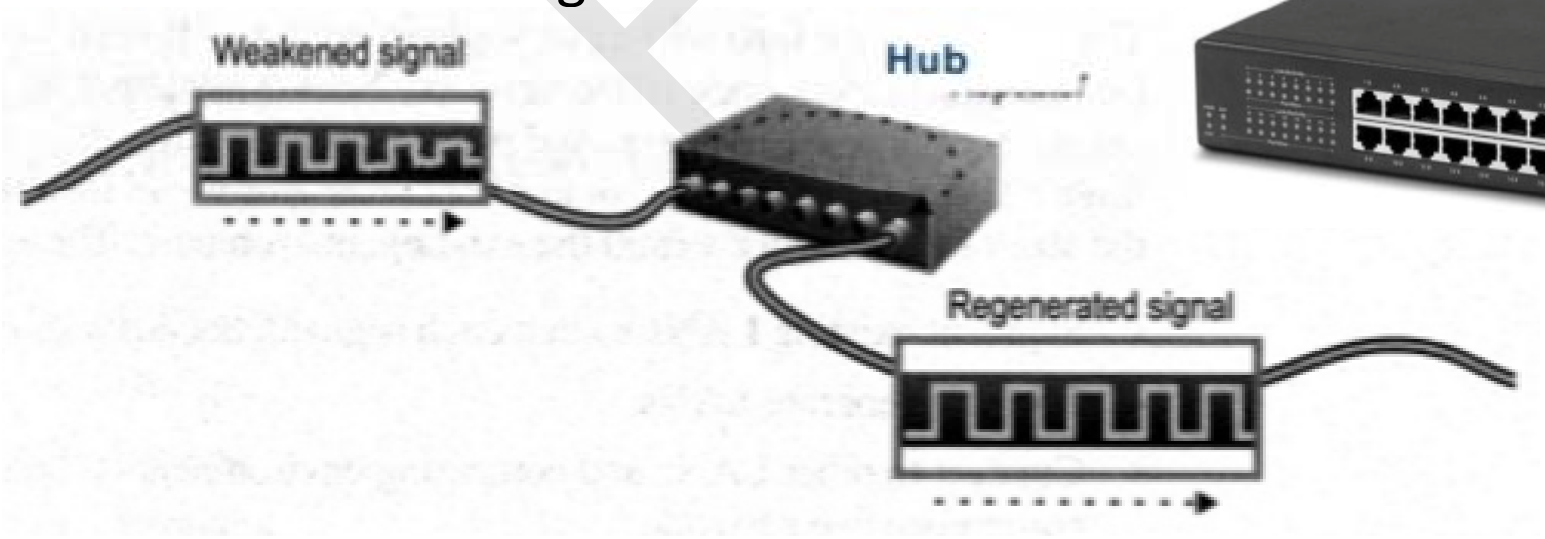
Networking Devices

- **Hub**
  - It regenerate data and broadcasts them to all ports.
  - When a frames arrives at one port, it is copied to the other ports so that all segments of the LAN can see all packets.
  - Network devices like printer, scanner, pc, server connected to the ports on hub.
  - **Passive hub** just pass the signal without amplify or regeneration.
  - **Active hub** pass the signal with amplify or regeneration.
  - All information broadcast to multiple ports can be a security risk.
  - Can not handle large data traffic.



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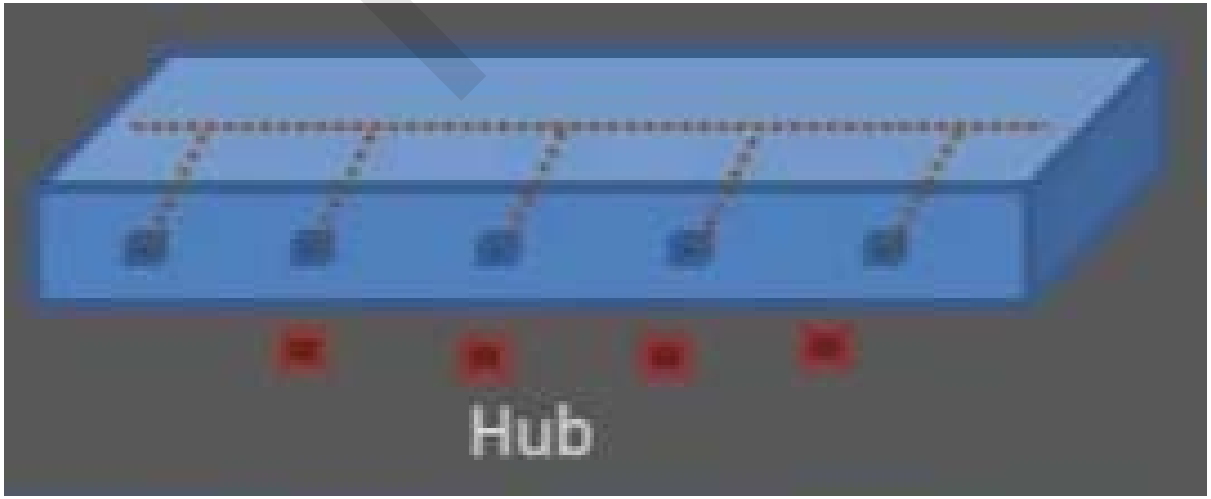
Difference between Repeater and Hub

- **Repeater :** A repeater is a device that has single input and single output port. (Bus Topology)
- **Hub :** A repeater with multiple input and multiple output ports. (Star Topology)



PPP

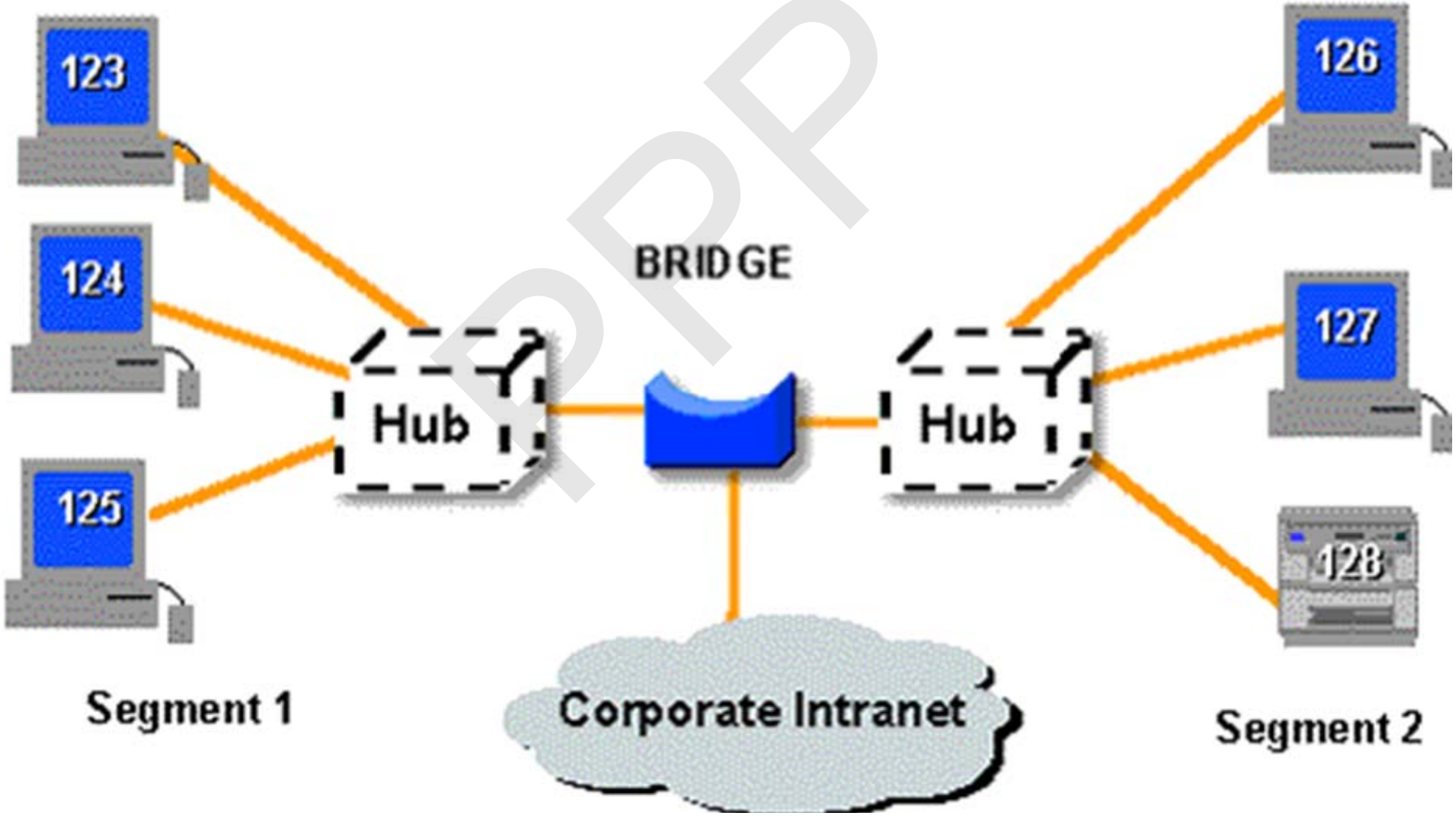
Networking Devices

Bridge

- A bridge is a computer networking device that builds the connection with the other bridge networks which use the same protocol.
- It works at the Data Link layer of the OSI Model and connects the different networks together and develops communication between them.
- It connects two local-area networks; two physical LANs into larger logical LAN or two *segments* of the same LAN that use the same protocol.

PPP

Bridge Example



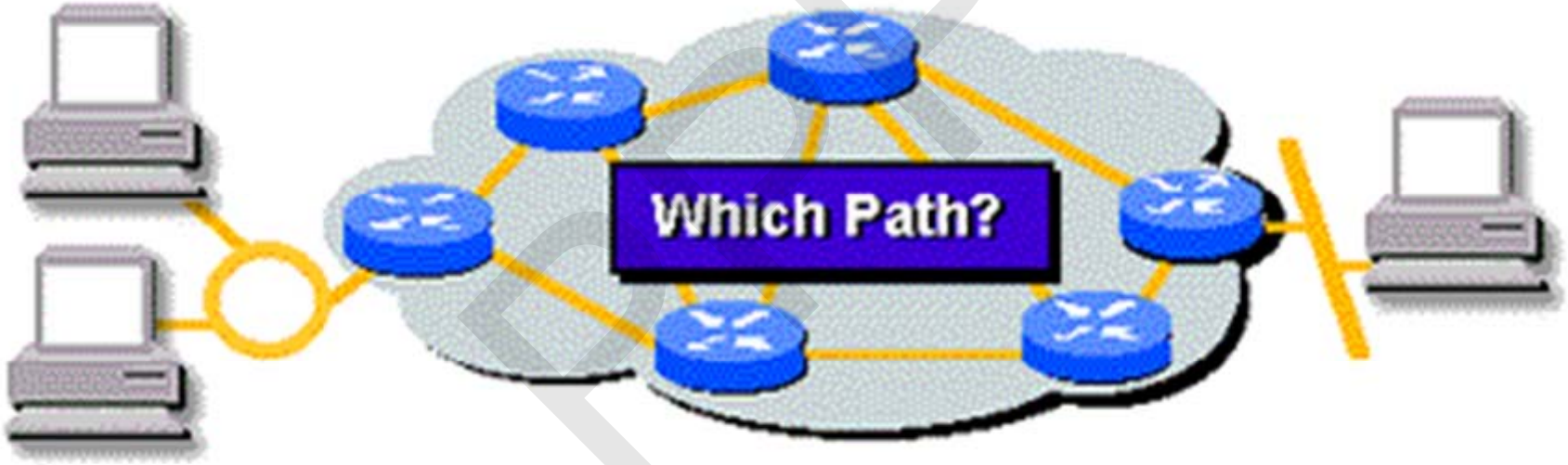
PPP

Networking Devices

- **Switch**
  - It is a more intelligent form of Bridge. It referred as multiport bridge.
  - No collision occurs in full-duplex switch.
  - L2 Switch (Frame) & L3 Switch (Packet)
  - Speed 1 Mbps, 10 Mbps, 100 Mbps, 1 Gbps
  - A **switch** transfers data only to that port which is connected to the destination device.
  - In this switching environment the entire packet is received and checked before being forwarded ahead.

RPP

Network Layer: Path Determination



- Layer 3 functions to find the best path through the internetwork

Networking Devices

- **Router**
  - Routers are network layer devices and are particularly identified as Layer- 3 devices of the OSI Model.
  - They process *logical* addressing (IP Address) information in the header of a packet.
  - It has the ability to connect dissimilar LANs on the same protocol.
  - A router has more than one network interface and routing software.
  - When a router receives the data, it determines the destination address by reading the header of the packet. Once the address is determined, it searches in its **routing table** to get know how to reach the destination and then forwards the packet to the next router on the path.

PPP

Networking Devices

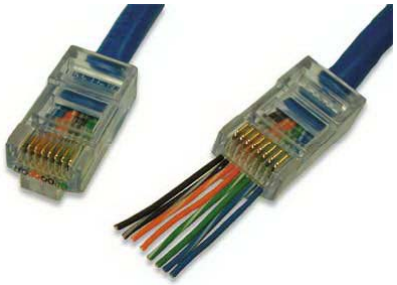
- **Gateway**
  - It is operate in all seven layers of OSI model.
  - Capable of converting frame and network protocols into the format needed by another network.
  - It is used to connect two different network systems.
  - It is a software installed in a router.
  - Transport gateway to connect two networks at transport layer.
  - Application gateway to connect two networks at application layer.
  - Both the computers of Internet users and the computers that serve pages to users are host nodes, while the nodes that connect the networks in between are gateways.

PPP

Networking Devices

- **Modem**
  - A modem is a computer peripheral that allows to connect and communicate with other computers through telephone lines.
  - Modem stands for Modulation & Demodulation.
  - Modulation : Convert binary signals into analog signals (Sender Side)
  - Demodulation : Convert analog signals into binary signals (Receiver Side)
  - Types of Modem : Internal & External

- **RJ-45 Connector**
  - RJ stands for Registered Jack.
  - It is 8 wire connector used to connect computers on LAN



PPP

Transmission Media

- Two types of transmission media
  - Guided Transmission Media
  - Unguided Transmission Media (Wireless Transmission)
- Guided Media
  - Magnetic media
  - Twisted Pairs
  - Coaxial Cable
  - Power lines
  - Fiber Optics
- Wireless Transmission
  - E-M Spectrum
  - Radio Transmission
  - Microwave Transmission
  - Infrared Transmission
  - Light Transmission

PPP

Magnetic Media

Magn. Tape or removable media(DVD)

Storage Capacity :

4.7 GB on single-layer/single-sided media of data

9.4GB on single-layer/double-sided discs.

In future 17GB DVD writing will become a reality.

Ultrium tape can store 800 Gegabytes.

Box 60*60*60 cm can hold 1000 tapes.

So total capacity 800 terabytes or 800 * 8 = 6400 terabits or 6.4 petabits

Federal Express and other Companies delivered it anywhere in US 24 hrs

So 6400 / 24 * 60 * 60 = 70 Gbps (Gigabits / sec).

If dest. Is only hour away by road

6400 / 24 = 1700 Gbps(Gigabits / sec)

PPP

Magnetic Media

Useful for a bank with many Gigabytes of data to be backed up daily.

Cost : $40 if purchase in bulk. Tape can be reused atleast 10 times.

So cost may be $4000 per box per usage + $1000 for shipping

Total = $5000 to ship 800terabytes.

B.W. :: 70 Gbps (gigabits/sec)

Cost : $5000 to ship 800terabytes.

Application : Banking

Delay : 1hr to 24 hr. (Disadvantage)

PPP

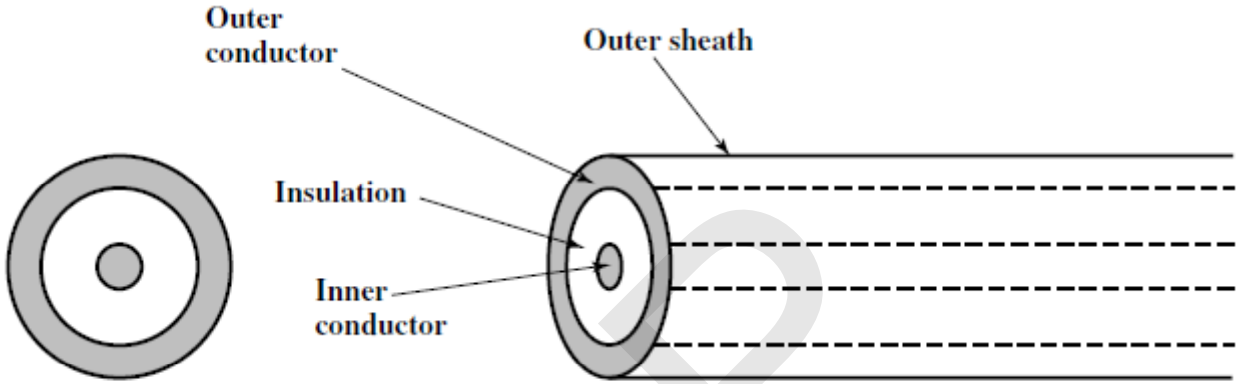
UTP advantages

(a) Twisted pair

- Twists help cancel out crosstalk result in better quality of signal for longer distance.
- Inexpensive (Rs. 2 to 5 per meter)
- Possible to bend the UTP
- Same technology used in Telephone networks
- There is less attenuation in UTP cables
- Cat-3 (25 Mbps), Cat-5 (100 Mbps Or 1 Gbps)
- Cat-6 (10 Gbps) Cat-7 (10 – 100 Gbps)

PPP

Co-Axial Cable



- Diameter of from 1 to 2.5 cm.
- Used over longer distances
- Using FDM, A coaxial cable can carry over 10,000 voice channels simultaneously.
- Application:
  - Television distribution
  - Long-distance telephone transmission

PPP

Fiber Optics

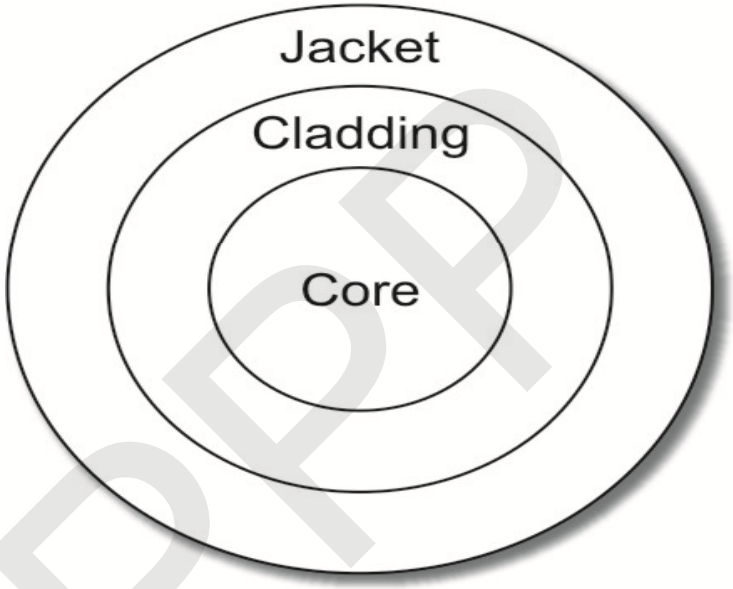
- It is made up of pure glass (Higher Dense)
- Easily bent without breaking
- Least resistance to the light passing through it
- Light

  A form of electromagnetic energy , travels at 300 m/sec in a vacuum.
- Refraction

  If a ray of light traveling through one substance suddenly enters another substance, its speed changes abruptly, causing the ray to change direction. This change is called refraction.

PPP

Fiber cable structure



PPP

- Core made up of pure glass
- Cladding is made up of a glass with lower refractive index than core.
- Interface bet'n core & cladding is responsible for refracting the light back into cable.
- Jacket shields the cladding and core to protect against noise signal

Incidence , Refracted , Critical & Reflected Angle

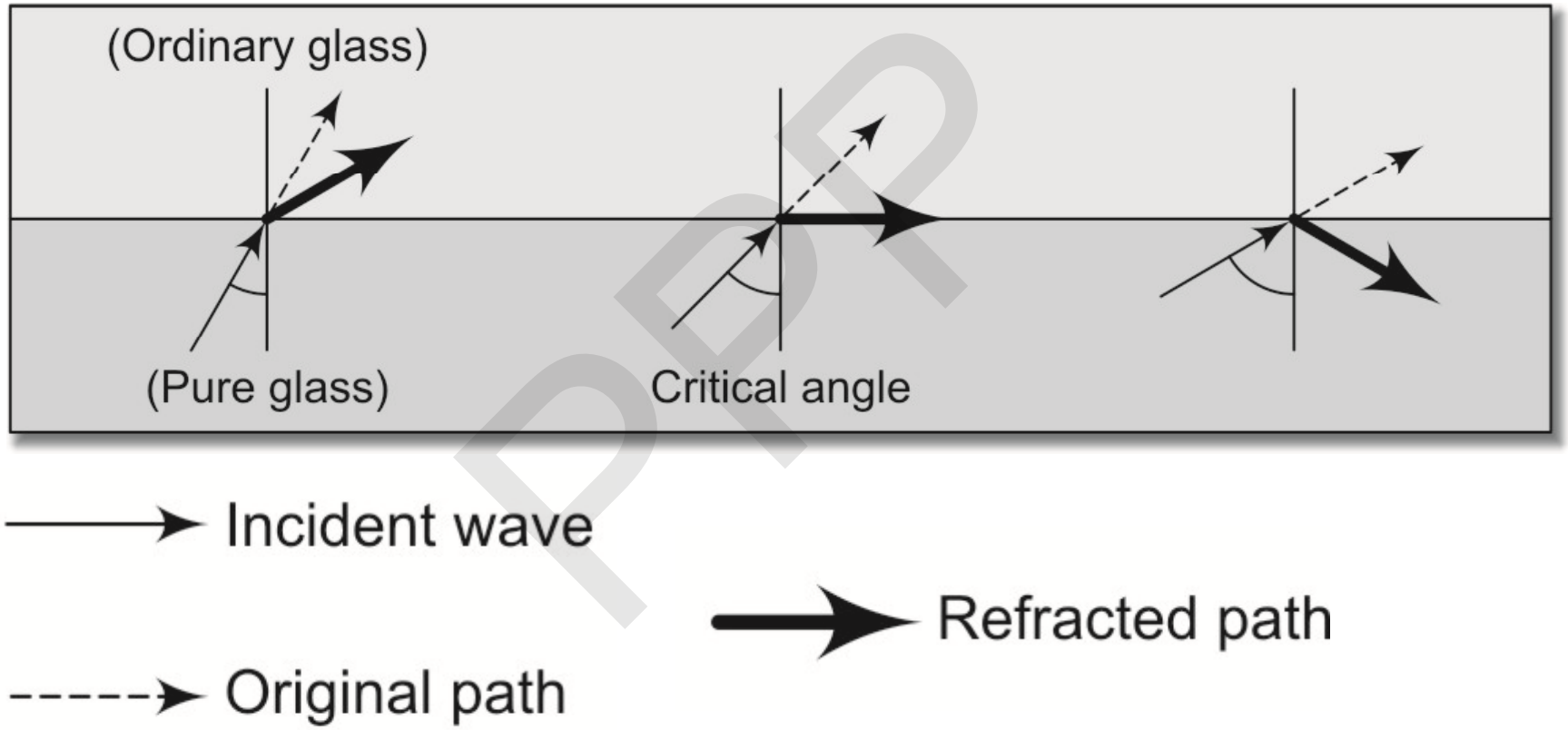
- The two angles made by the beam of light in relation to the vertical axis are called I , for **incident** , and R , for **refracted**.

- The incident angle at which the refracted angle becomes 90 is known as **critical angle**.

- When the angle of incidence becomes greater than the critical angle , a new phenomenon occurs called **reflection**.

PPP

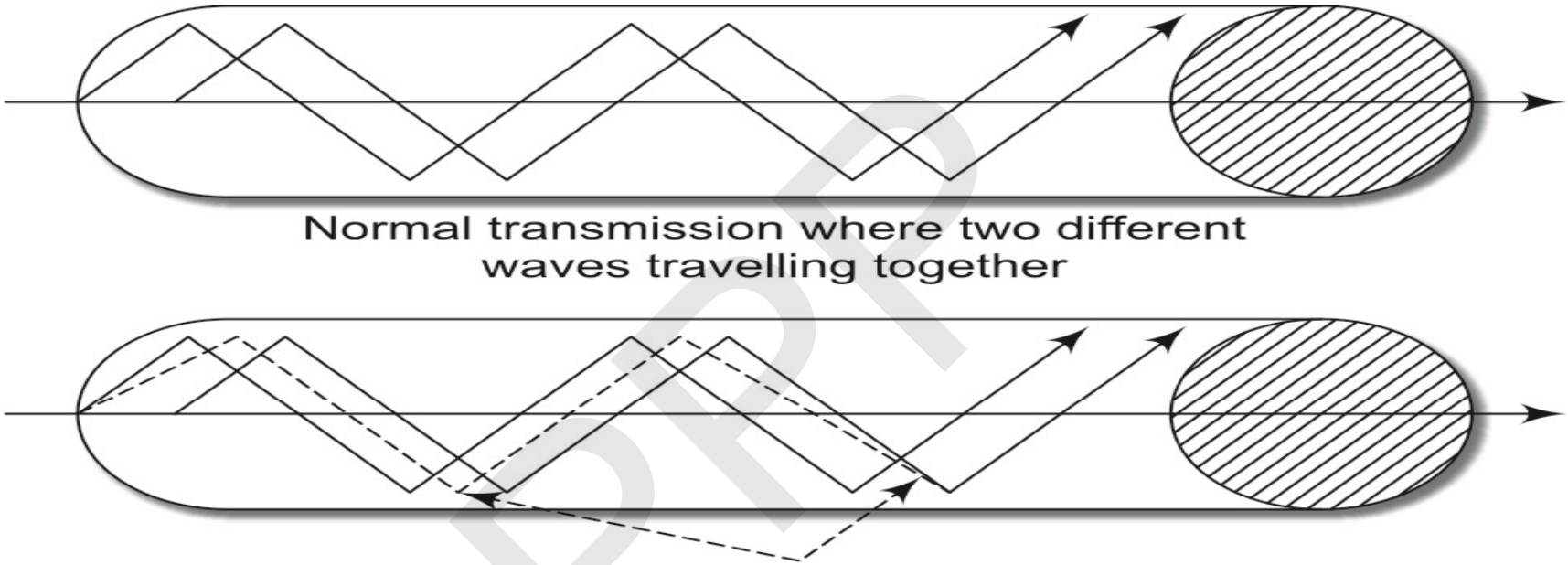
Total Internal Reflection



Pure Glass: More Dense

Ordinary glass : Less Dense

Dispersion in fiber optic

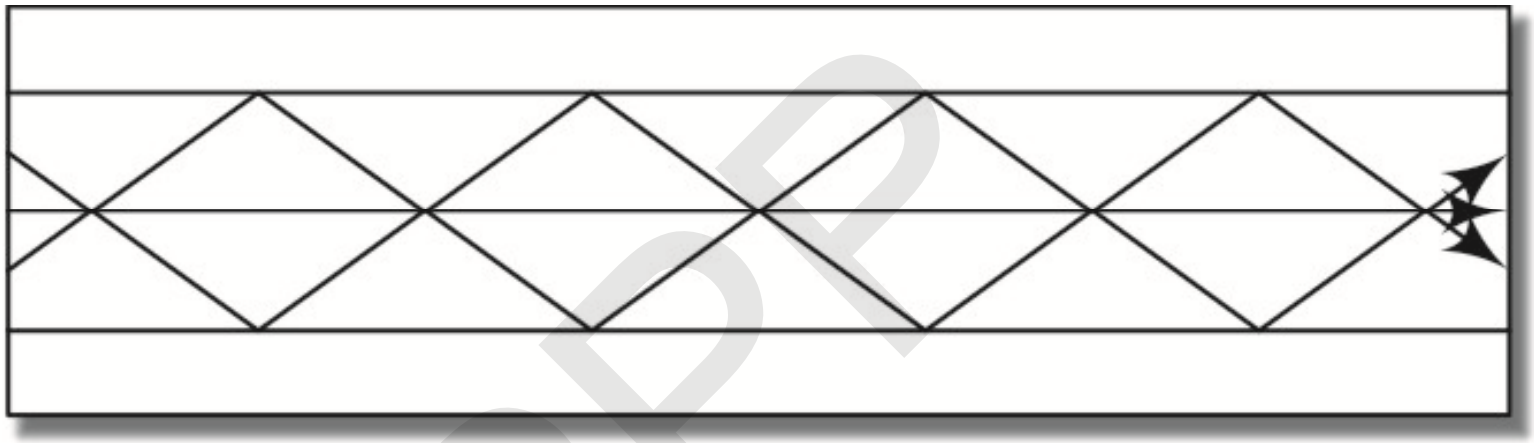


Dispersion first wave merged with second wave.

Solution: Increase the distance between waves

PPT

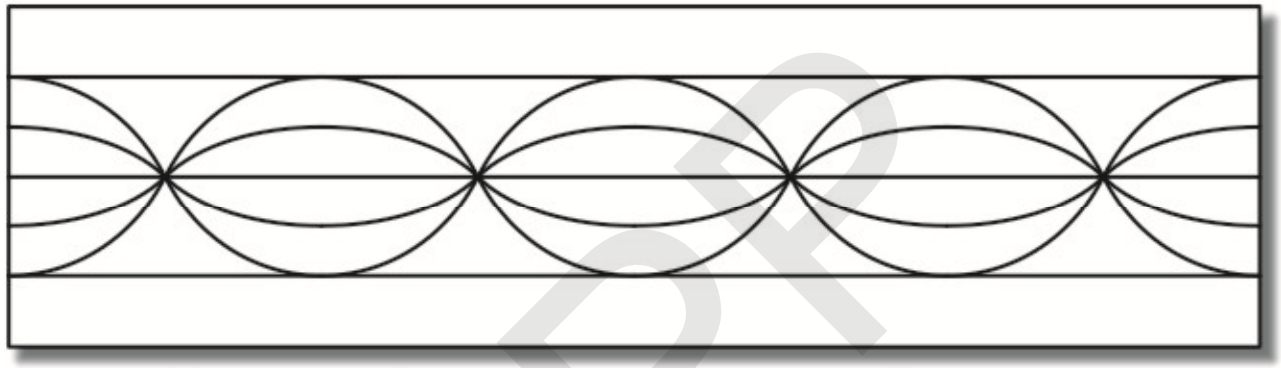
Multimode - 1



a. Single step index multimode fiber

PPP

Multimode - 2



b. Graded index multimode fiber

In graded index multimode fiber, the refractive index of the glass reduces gradually as we move from the core towards the cladding.

Single Mode

c. Single mode

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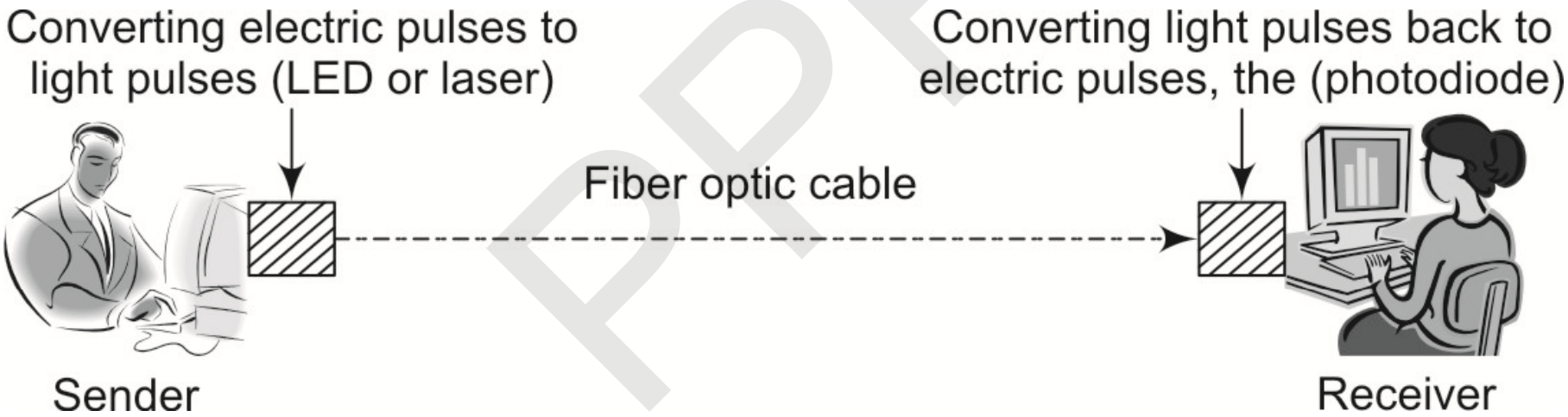
Speed of 50 Gbps upto 100 km
Laser signals

Sending and receiving devices



PPP

A comparison of semiconductor diodes and LEDs as light sources.

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multi-mode	Multi-mode or single-mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

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Comparison: UTP vs. FO

- Thickness
- Weight
- Photons vs. electrons
- Attenuation
- Effect of EM interference
- Leaking
- Bandwidth
- Cost
- Need for skilled engineer

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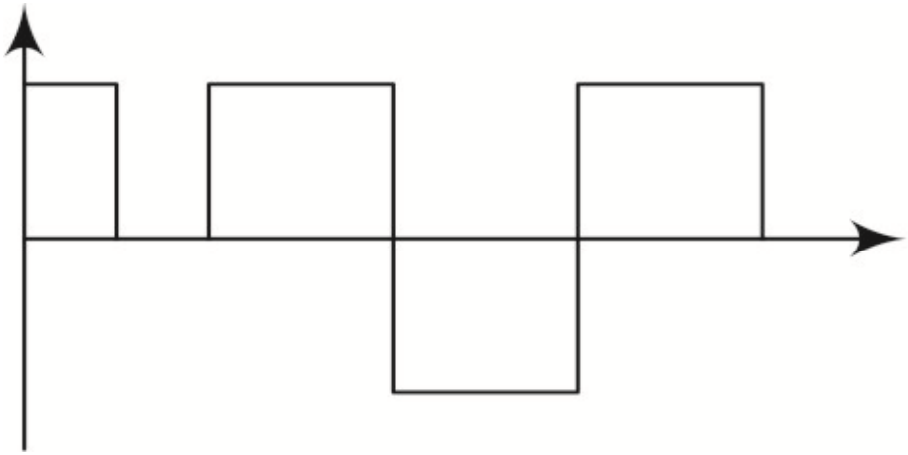
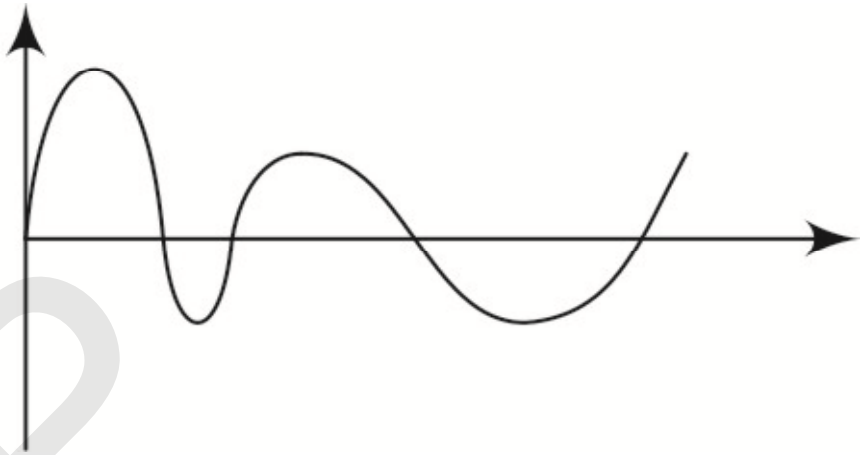
Digital and analog wave





- Signal

  It is an electric current or electromagnetic field used to convey data from one place to another.

- Analog Signal

  It is continuous wave form that changes smoothly over time.

- Digital Signal

  It is discrete. It has only limited values 1 and 0.

  The transition of a signal from value to value is instantaneously

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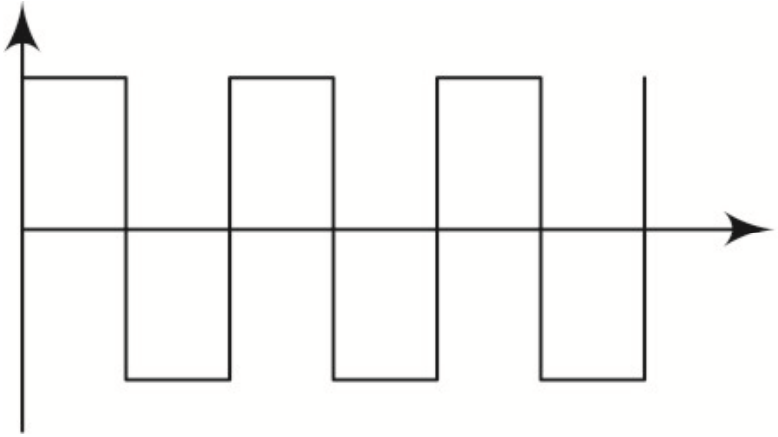
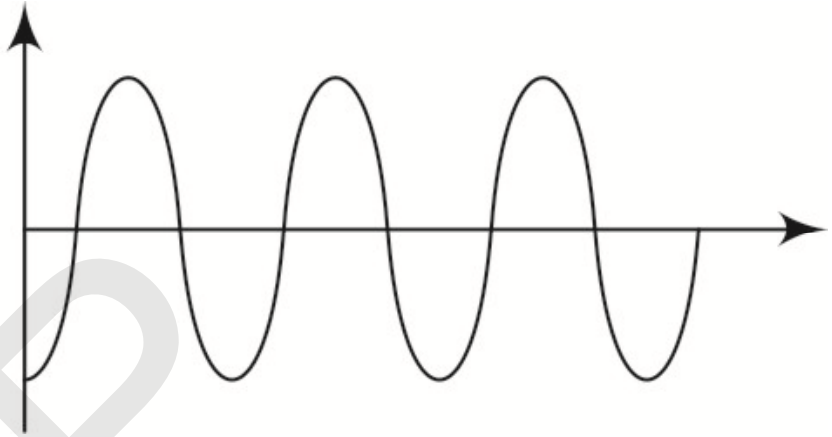
Periodic waves, digital and analog





- Cycle

  Completion of one full pattern is called a cycle.

- Period

  Require time to complete one cycle.

- Periodic Signal

  It completes a pattern within a period & repeats that pattern.

PPP

Analog signal characteristics.

- Amplitude

  Value of a signal at any point on the wave.

  Measured in volts, Amperes, Watts

- Frequency

  Number of periods in one second.

  Number of cycles per second. $F = 1 / T$

  Electric power distribute in India at 50 Hz while US having 60 Hz

  Aircraft often uses 400 Hz as the fundamental frequency

  Voltage in India for AC signal is 220 While US having 120

  Unit of period : s , ms , μs , ns , ps

  Unit of frequency : Hz, KHz , MHz , GHz , THz

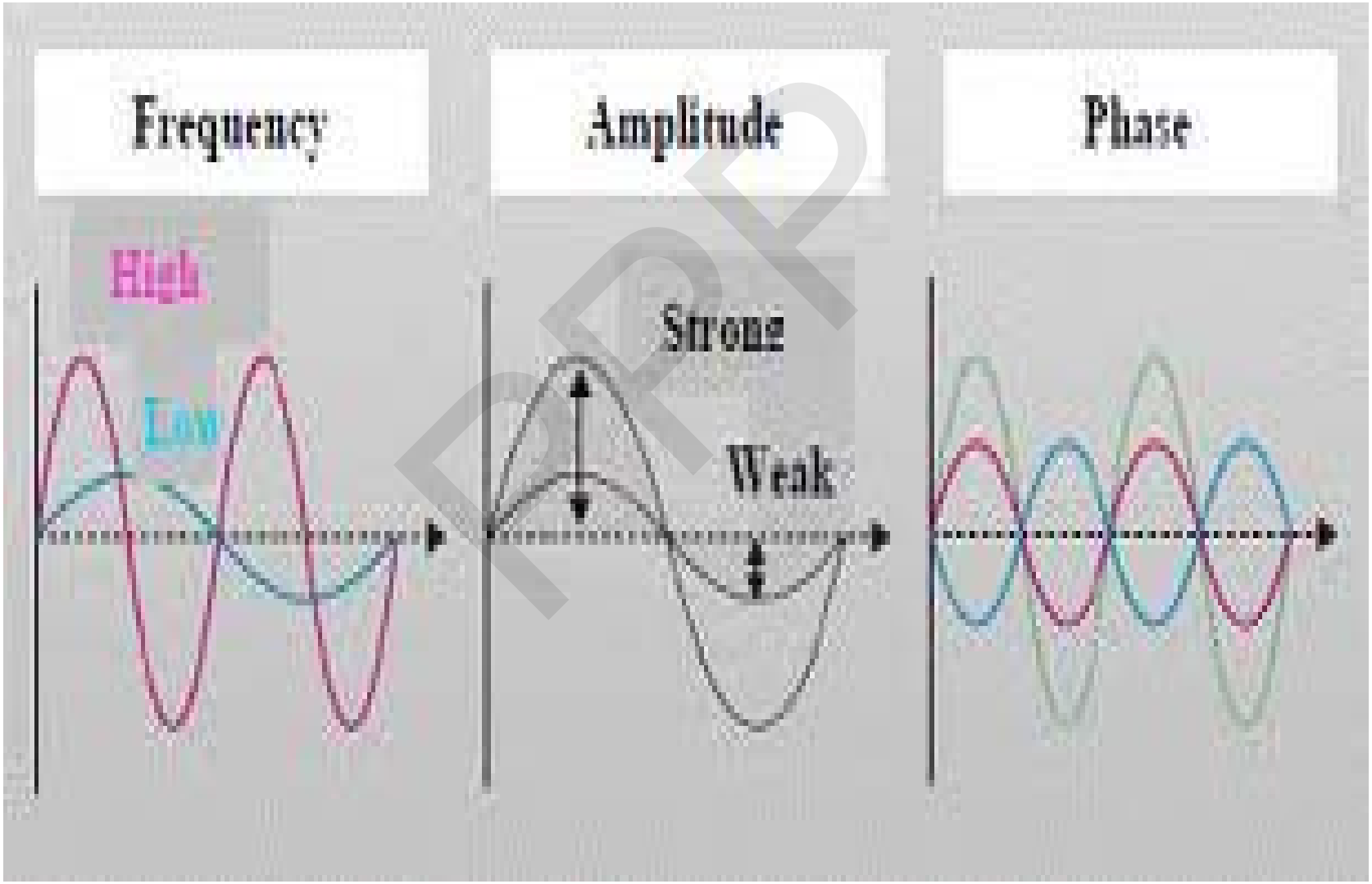
- Phase

  Position of the waveform relative to the zero.

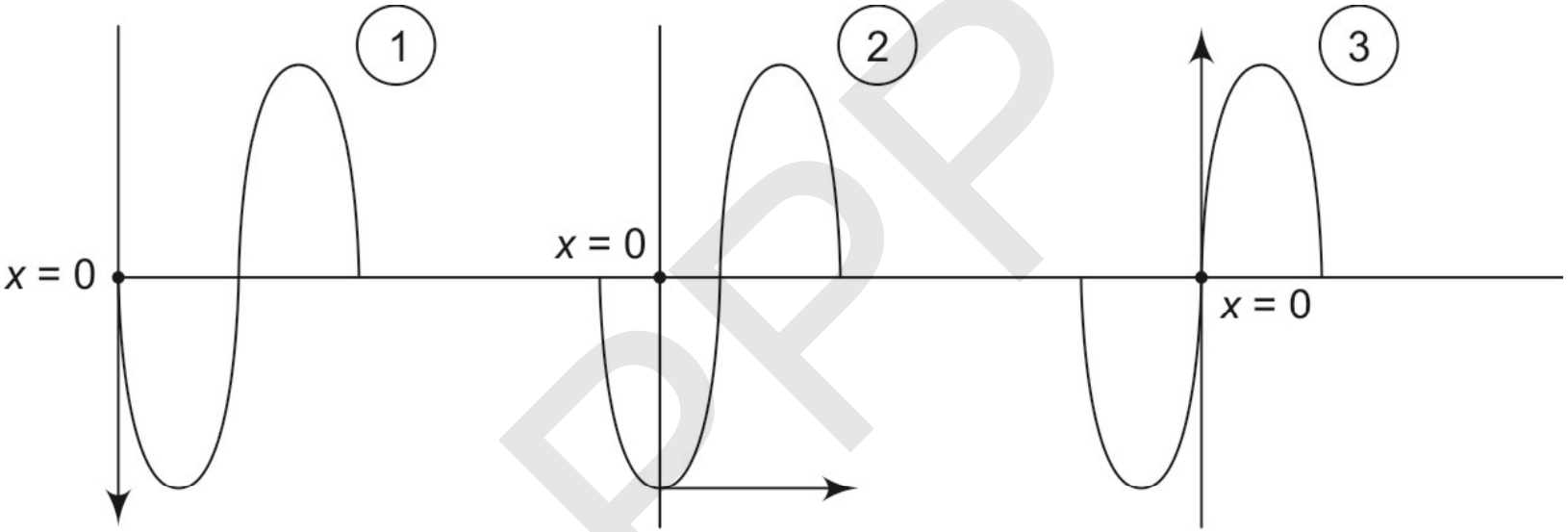
  It measured in degrees or radians

PPP

Analog signal characteristics.



Phase



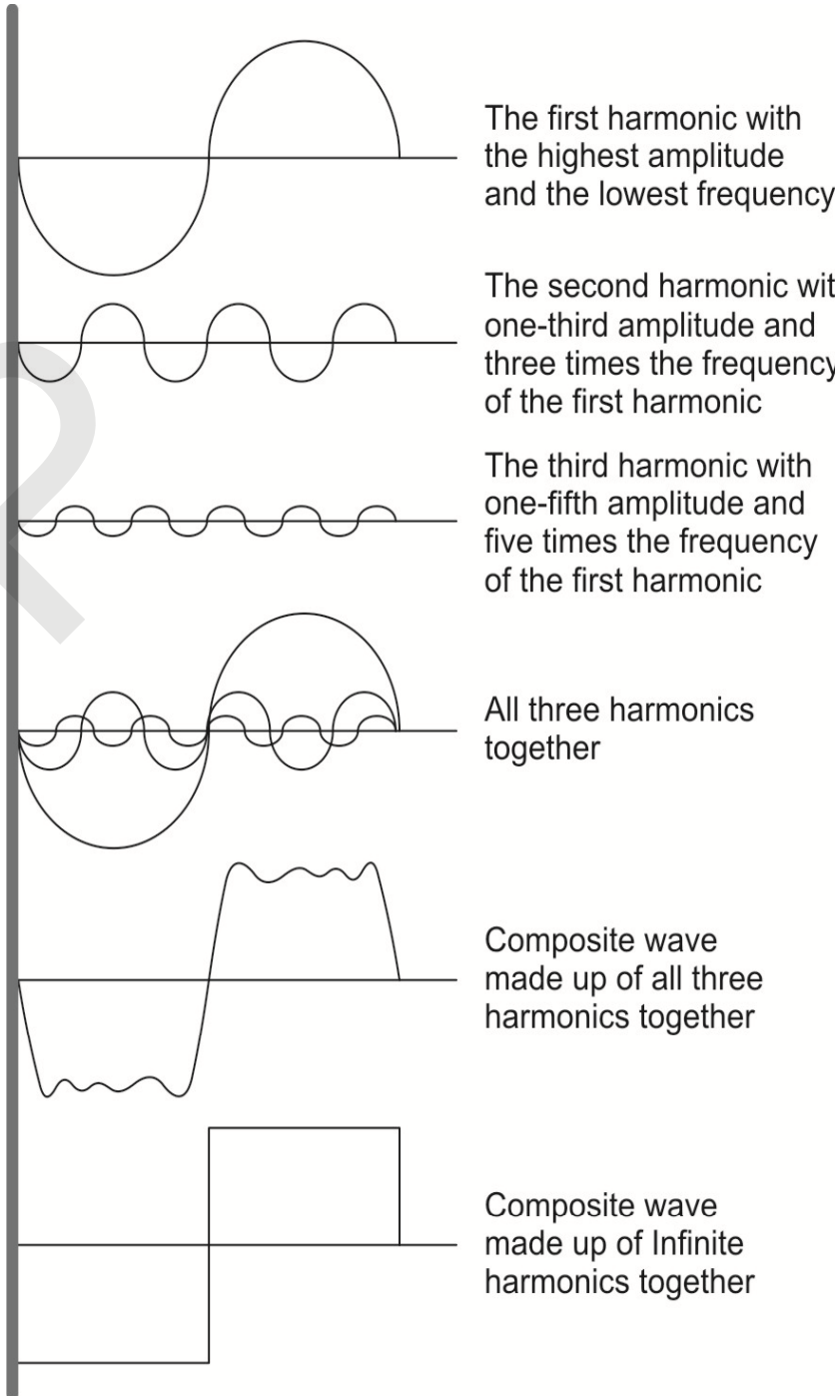
0 Degree **90 Degree** **180 Degree**

PPP

Harmonic and composite wave

Harmonic:
A sine wave component of a periodic wave

Composite signal
A signal contains multiple frequencies



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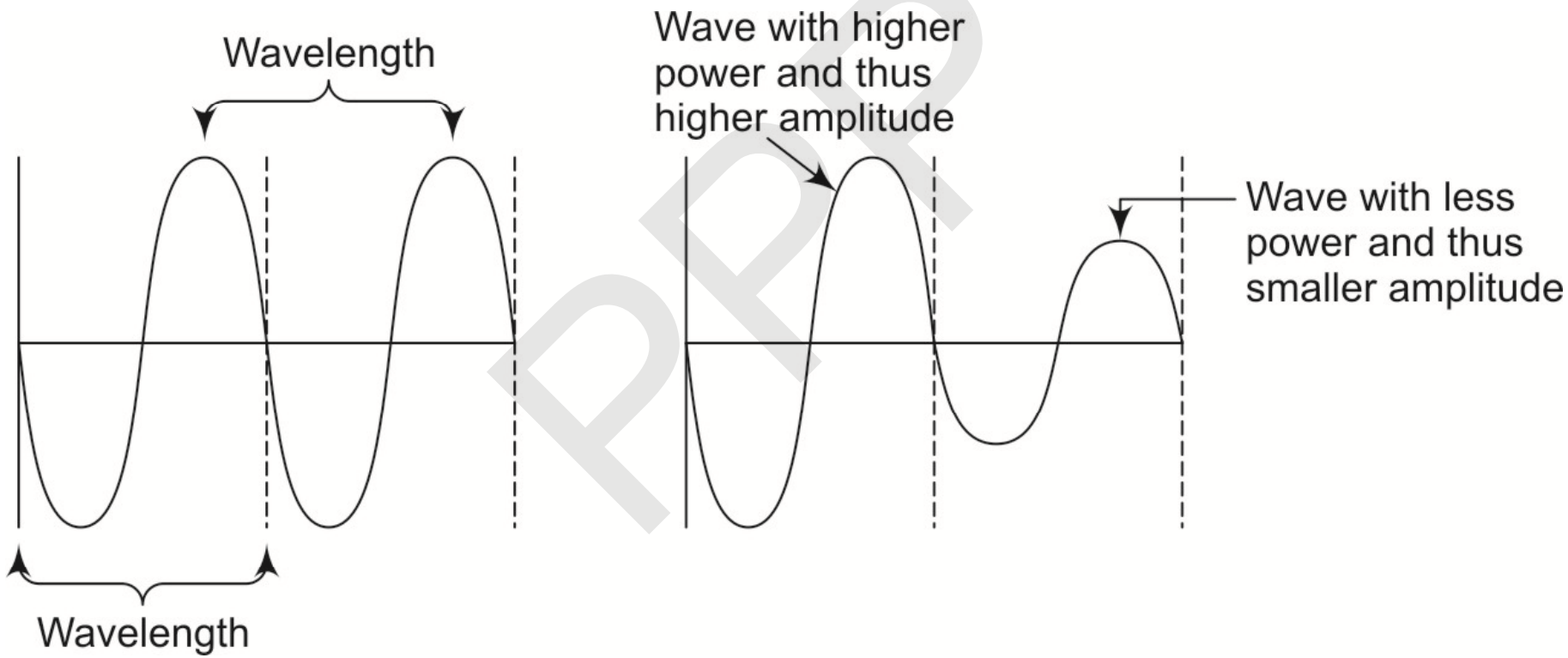
Wavelength



PPP

Relation between f & λ

- (f) Frequency :
  - No. of oscillations / Sec
  - Measured in Hz.
- (w or λ) Wave Length :
  - Distance between Two maxims or Two minims
  - It is measured in meters.
- $C = f * \lambda$
  - c= velocity of light = $3 * 10^8$ m/sec
- E.g.
  - waves with f = 100 MHz are 3 meters long.
  - waves with f = 1000 MHz are 0.3 meters long.
  - waves with f = 30 KHz are 10 km long.
  - waves with f = 300 KHz are 1 km long.

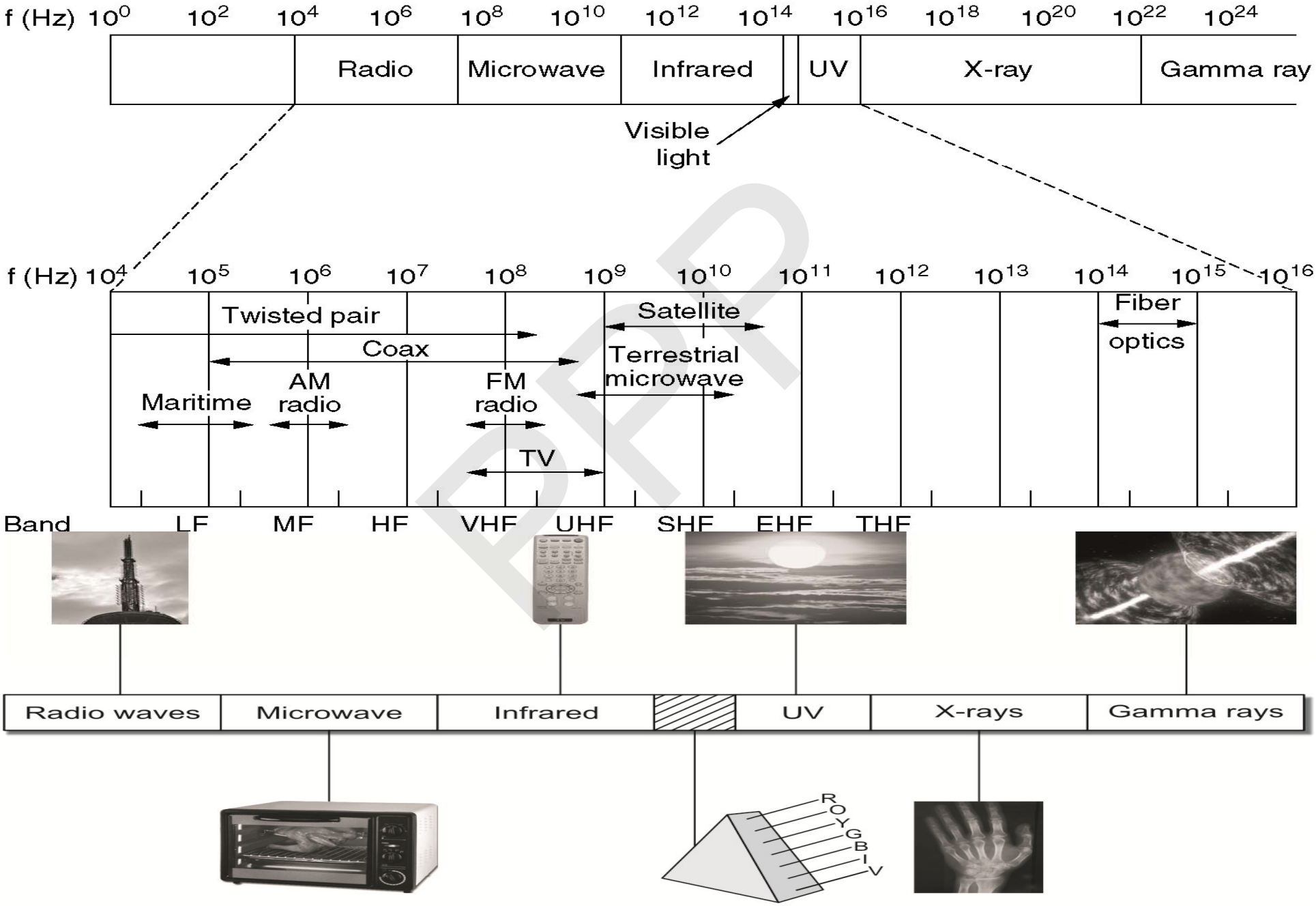
PPP

The Electromagnetic Spectrum

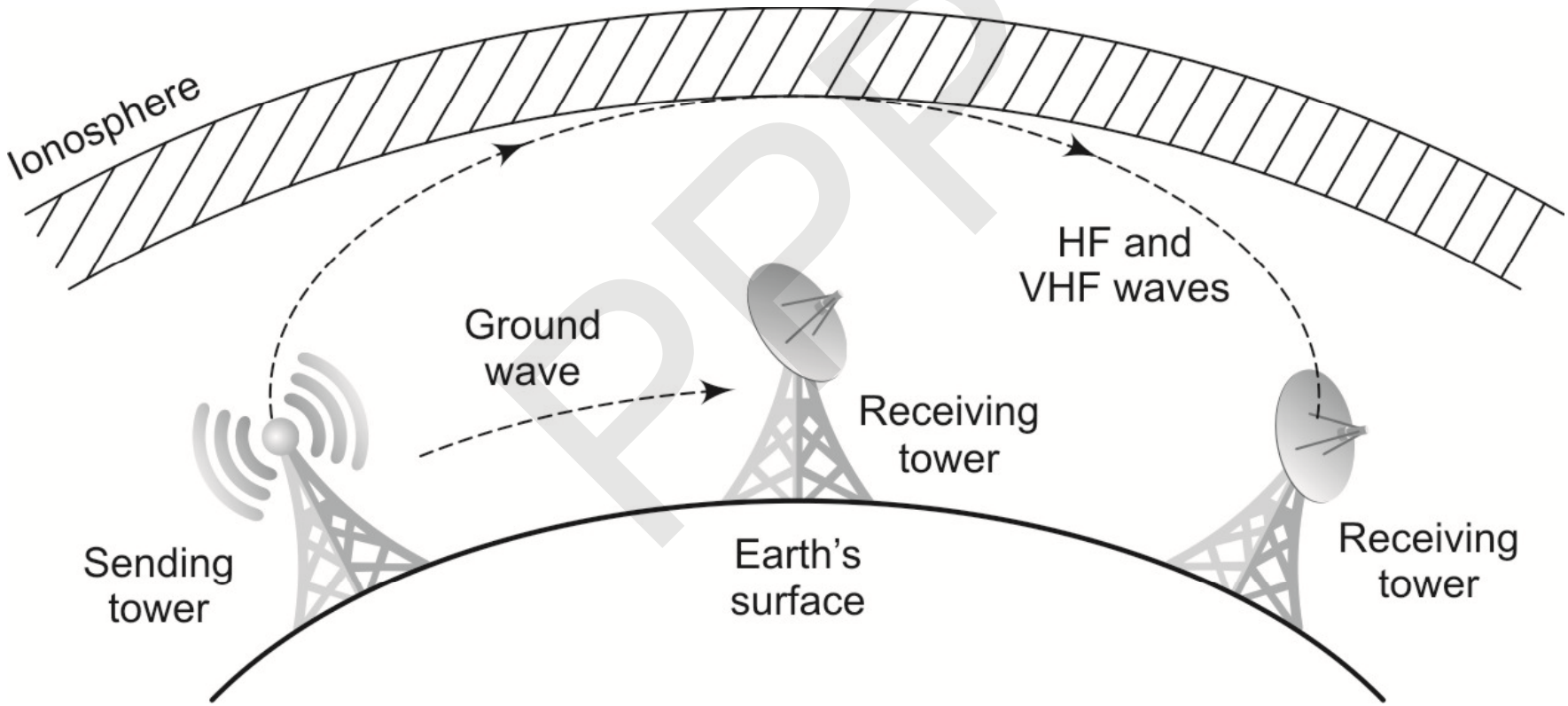
- Radio Waves
- Microwaves
- Infrared and Millimeter Waves
- The ISM Bands
- The optical light

PPP

E-M Spectrum


f (Hz) 10^0 10^2 10^4 10^6 10^8 10^{10} 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{22} 10^{24}
Radio
Microwave
Infrared
UV
X-ray
Gamma ray
Visible light
f (Hz) 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16}
Twisted pair
Coax
Maritime
AM radio
FM radio
TV
Satellite
Terrestrial microwave
Fiber optics
Band LF MF HF VHF UHF SHF EHF THF
Radio waves
Microwave
Infrared
UV
X-rays
Gamma rays
R
O
Y
G
B
I
V

Radio Waves


Ionosphere
HF and
VHF waves
Ground
wave
Receiving
tower
Sending
tower
Earth's
surface
Receiving
tower

Radio Waves

- 10^4 to 10^8 Hz
- Frequency is less and waves are long
- Travel in all directions (omnidirectional)
- Passing through obstacles
- Travels a long distance
- Poor for data transmissions

PPP

Radio Waves

- Subdivided into VLF, LF, MF , HF , and VHF
- VLF, LF, and MF waves are known as ground waves
- HF and VHF travel in straight line
- HF and VHF refracted back by ionosphere

RPP

Microwaves

- 10^8 to 10^{11} Hz
- Travel straighter and not in all directions
- The *line of sight (LoS) requirement*.
- Get more and more focused as the wavelength decreases

PPP

Microwaves

- Parabolic antennas
- Do not penetrate through the walls; have a tendency to bounce off the obstacles
- Waves above 4 GHz absorbed by raindrops.
- *multipath fading*
- No wiring between the sender and receiver
- Repeaters at 50 to 60 KM

PPP

Microwaves

- Relatively inexpensive
- Licensing is required
- FCC (Federal Communications Commission) in US does this job. In India, this is done by DoT (Department of Telecommunications)

PPP

Infrared & Millimeter waves

- Infrared (TV remote control)
- Millimeter waves
  - Easy to produce and use
  - Travel straight and cannot pass through obstacles.
  - Cannot work outdoors
  - License is not required
  - Short range devices (Toys, VCRS, Stereos)

PPP

Other part of the spectrum

- **ISM bands**
  - **902 to 928 MHz**
  - Garage door openers
  - Cordless phones
  - Wireless mouse
  - Toys Remote Control

  2.4 to 2.48 GHz
  802.11b (home N/W)
  (11 Mbps)
  802.11g
  (54 Mbps)
  microwave ovens

  5.736 to 5.860 GHz
  802.11a (Bus. N/W)
  (54 Mbps)

  - Only restriction is the range of power.

- **Free Space Optics (FSO) using visible light**
  - Communication in outer space (**1Gbps up to 2 KM**)
  - Communication between spacecrafts.
  - Aircraft to communicate with satellites
  - Atmospheric condition affect the quality of FSO (Rain, Fog, Heat, Dust)

PPP

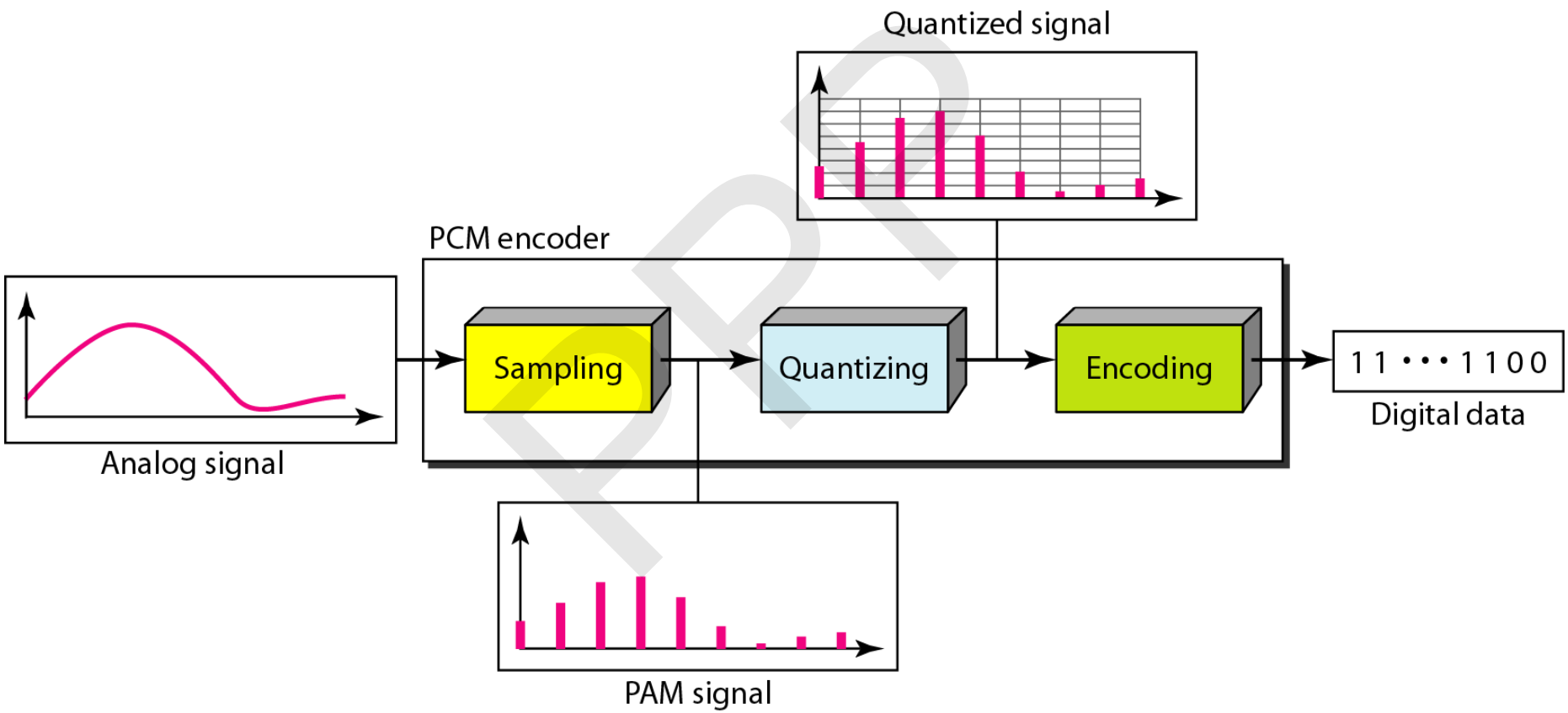
PCM (Pulse Code Modulation)

- ***A digital signal is superior to an analog signal because it is more robust to noise and can easily be recovered, corrected and amplified. For this reason, the tendency today is to change an analog signal to digital data.***

- PCM consists of four steps to digitize an analog signal:
  1. Sampling
  2. Quantization
  3. Binary encoding
  4. Line Coding

PPP

Components of PCM encoder



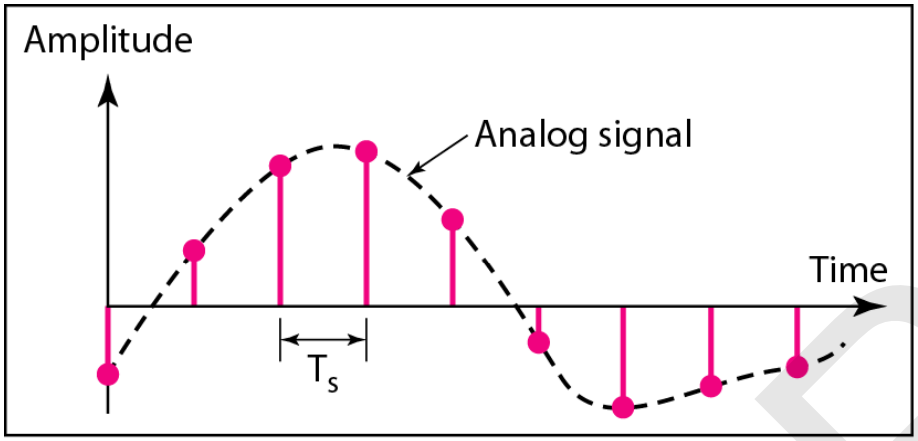
PPP

Sampling

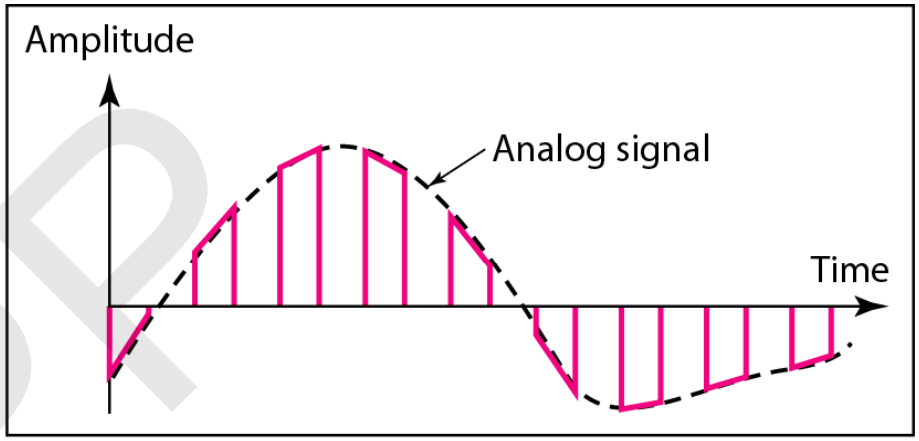
- Analog signal is sampled every T_S secs.
- T_s is referred to as the sampling interval.
- $f_s = 1/T_s$ is called the sampling rate or sampling frequency.
- There are 3 sampling methods:
  - Ideal - an impulse at each sampling instant
  - Natural - a pulse of short width with varying amplitude
  - Flattop - sample and hold, like natural but with single amplitude value
- The process is referred to as pulse amplitude modulation PAM and the outcome is a signal with analog (non integer) values

PPP

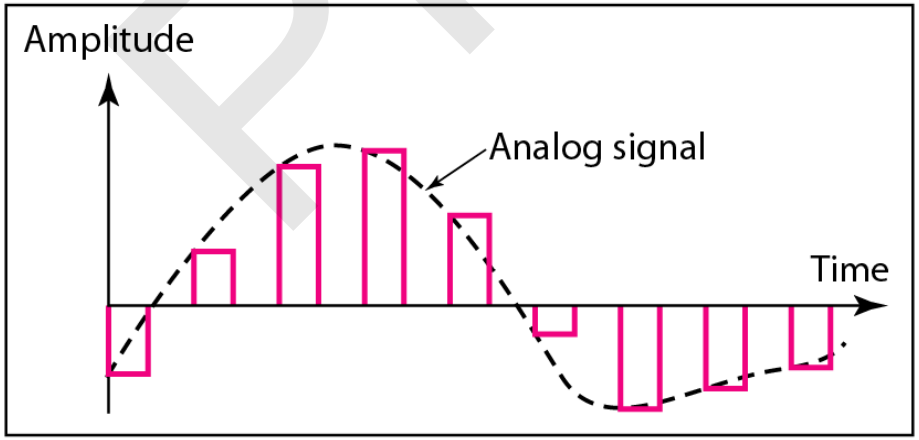
Three different sampling methods for PCM



a. Ideal sampling



b. Natural sampling



c. Flat-top sampling

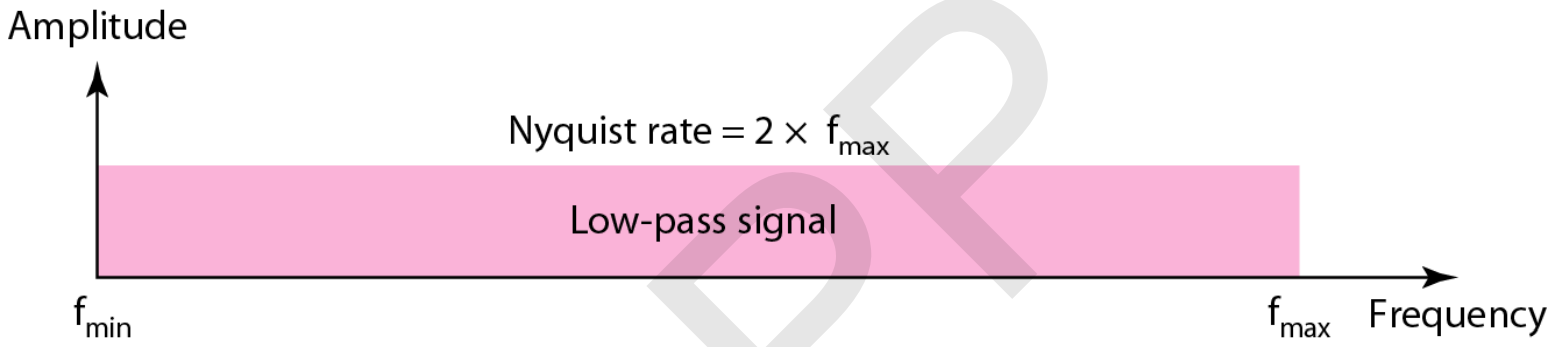
PPP

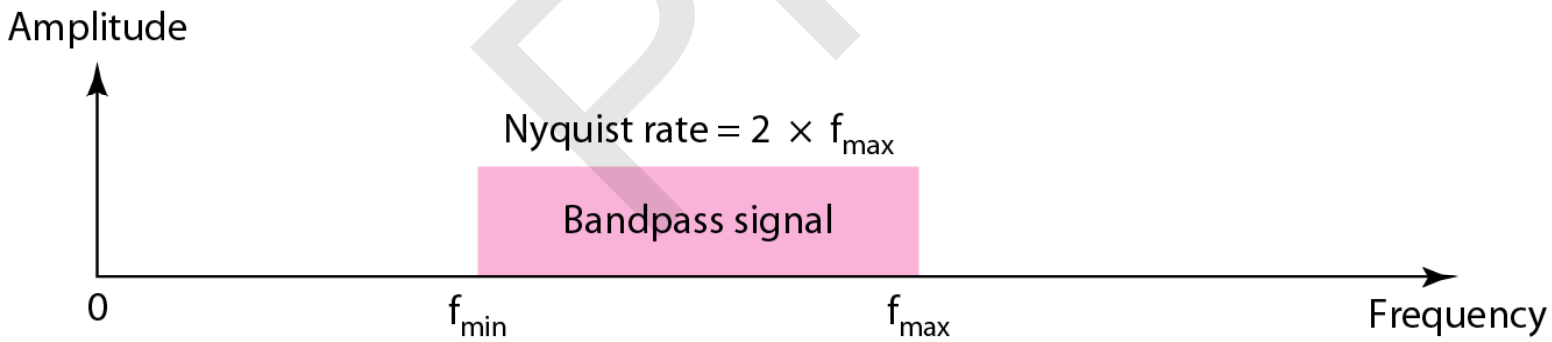
Nyquist Theorem

The sampling rate must be at least 2 times the highest frequency contained in the signal.

PPP

Nyquist sampling rate for low-pass and bandpass signals





PPP

Proof of Nyquist Theorem

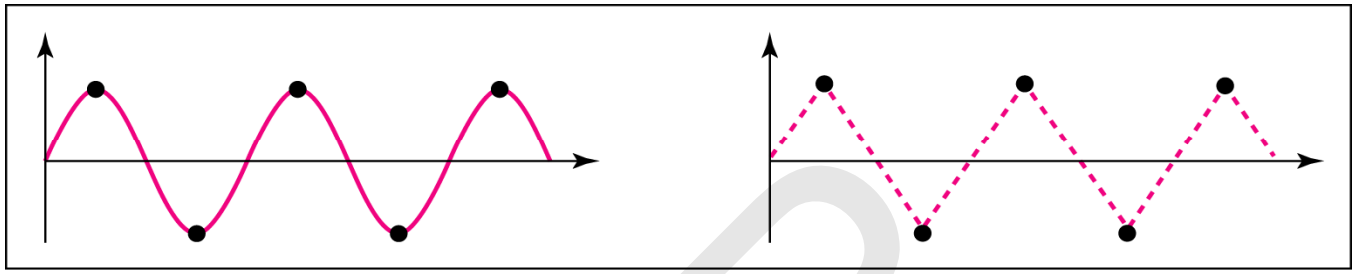
For example of the Nyquist theorem,

let us sample a simple sine wave at three sampling rates:

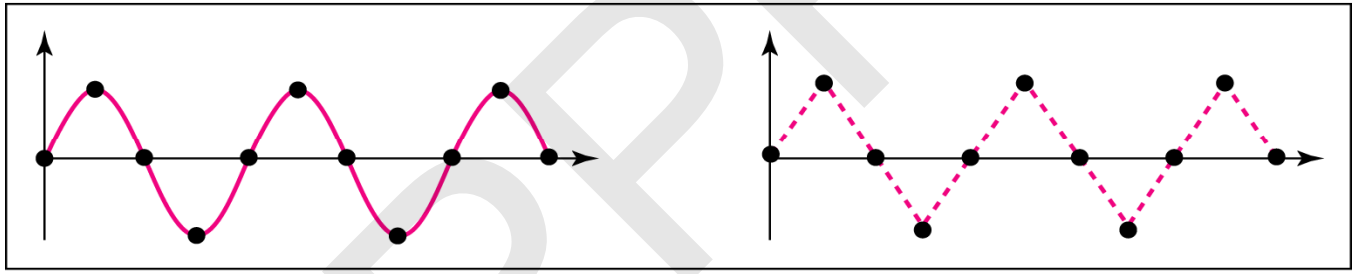
$f_s = 4f$ ***(2 times the Nyquist rate),***
$f_s = 2f$ ***(Nyquist rate), &***
$f_s = f$ ***(one-half the Nyquist rate).***

PPP

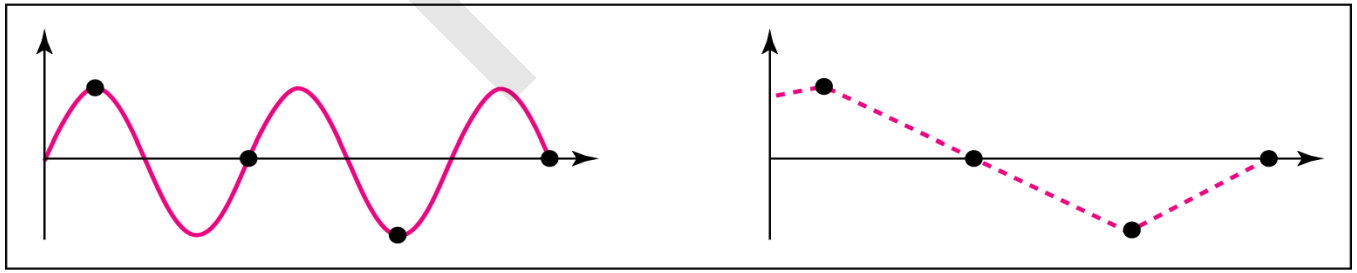
Sampled sine wave for different sampling rates



a. Nyquist rate sampling: $f_s = 2\ f$



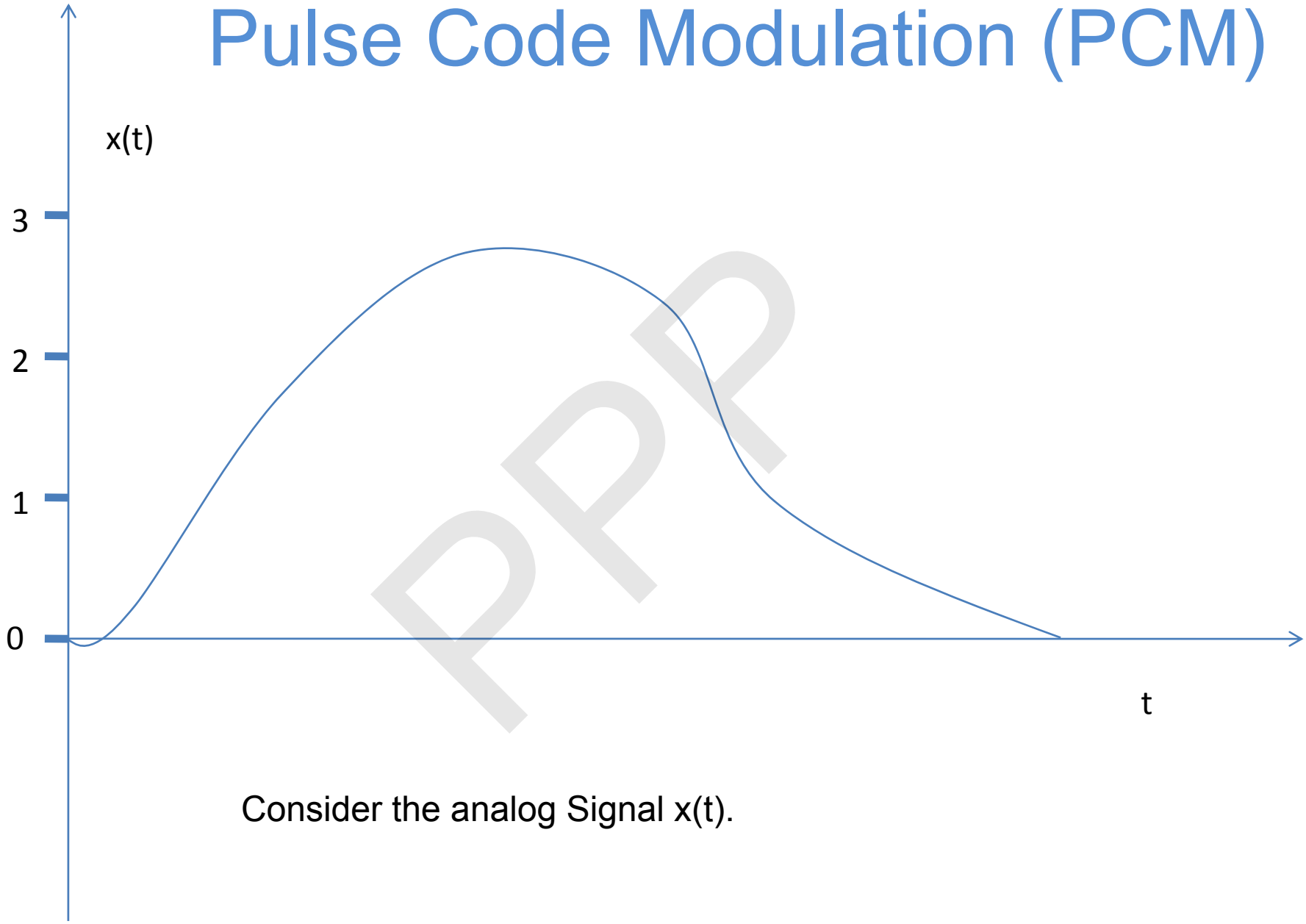
b. Oversampling: $f_s = 4\ f$



c. Undersampling: $f_s = f$

PPP

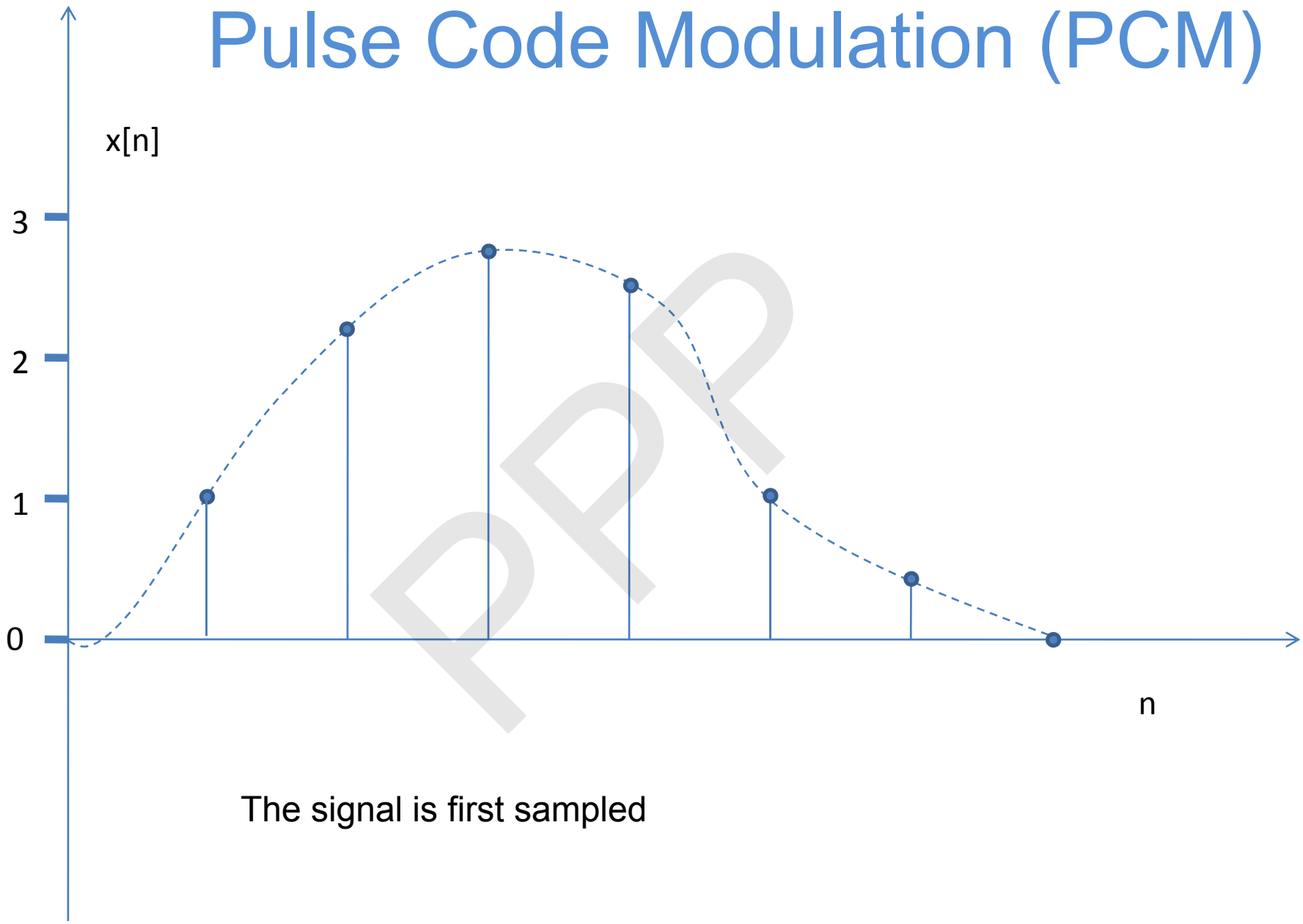
Pulse Code Modulation (PCM)



Consider the analog Signal x(t).

PPP

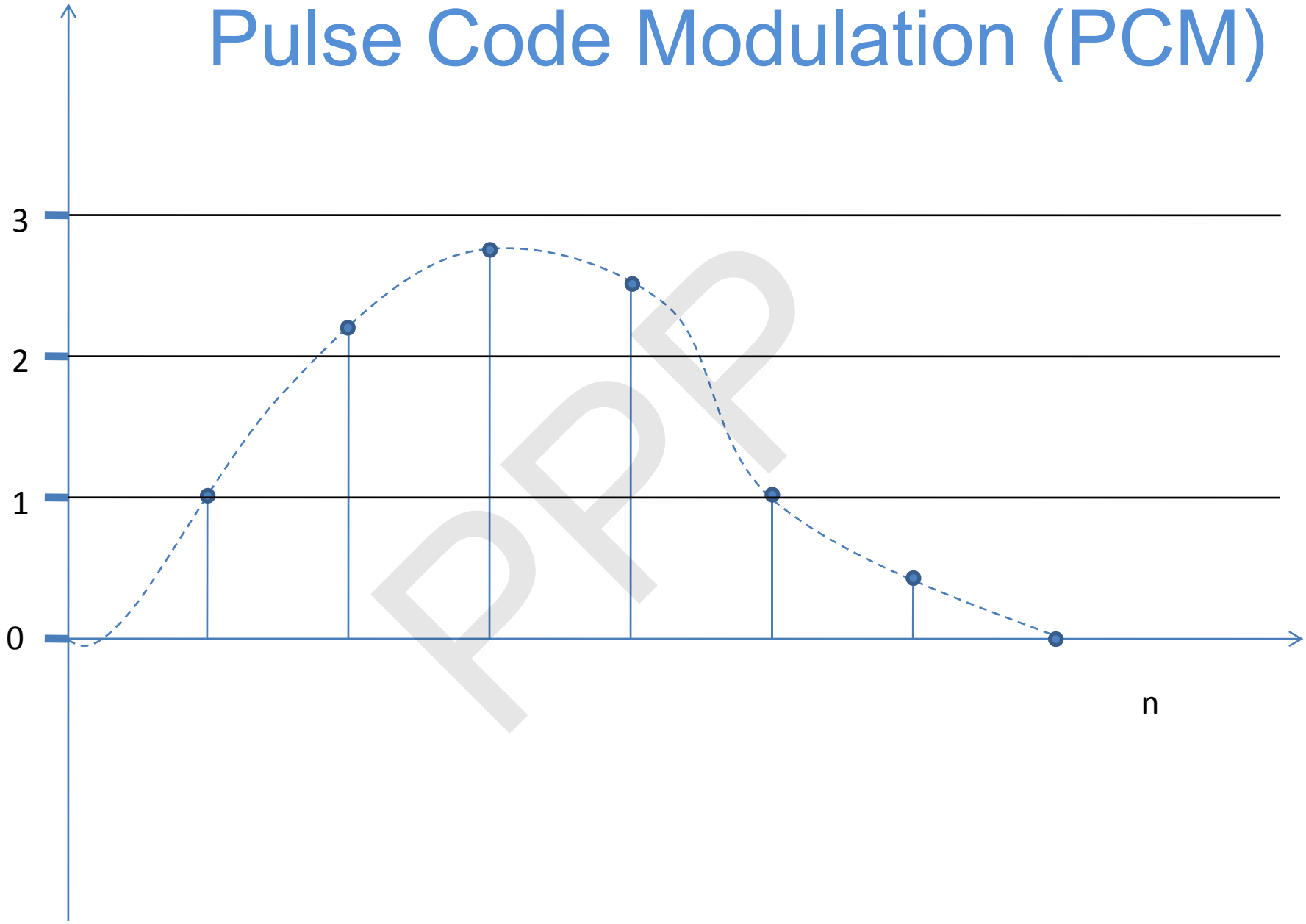
Pulse Code Modulation (PCM)



The signal is first sampled

PPP

Pulse Code Modulation (PCM)



PPP

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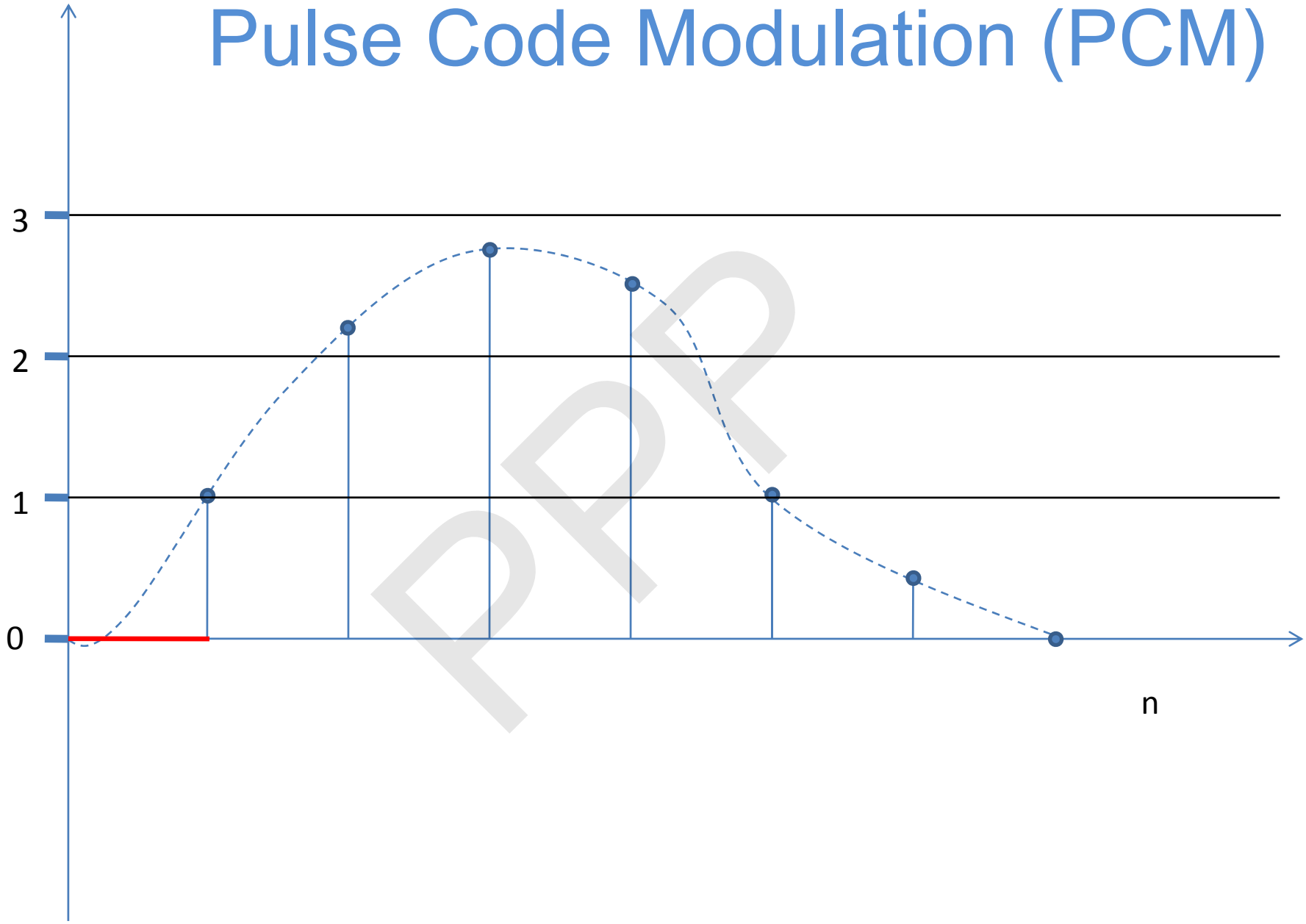
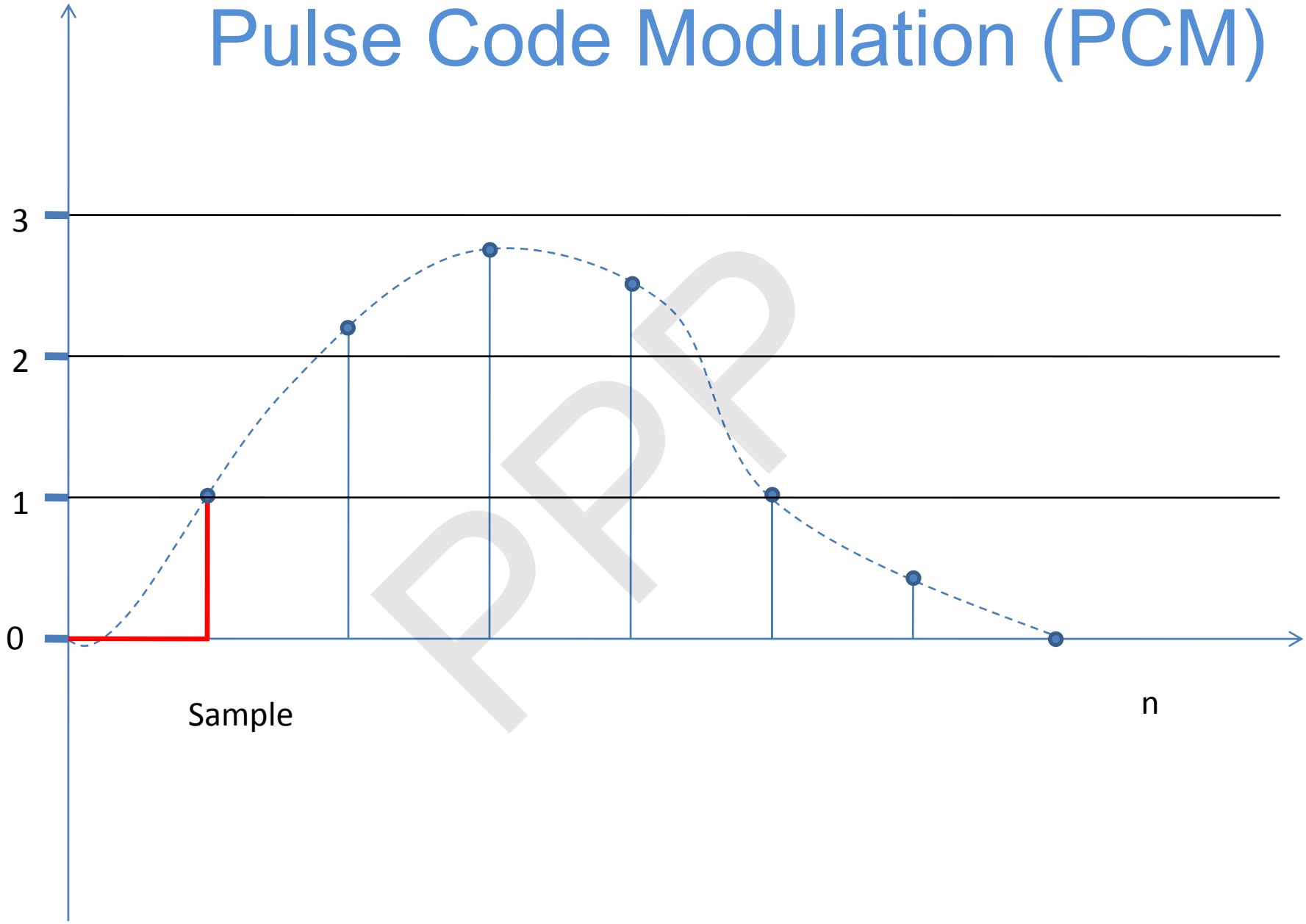


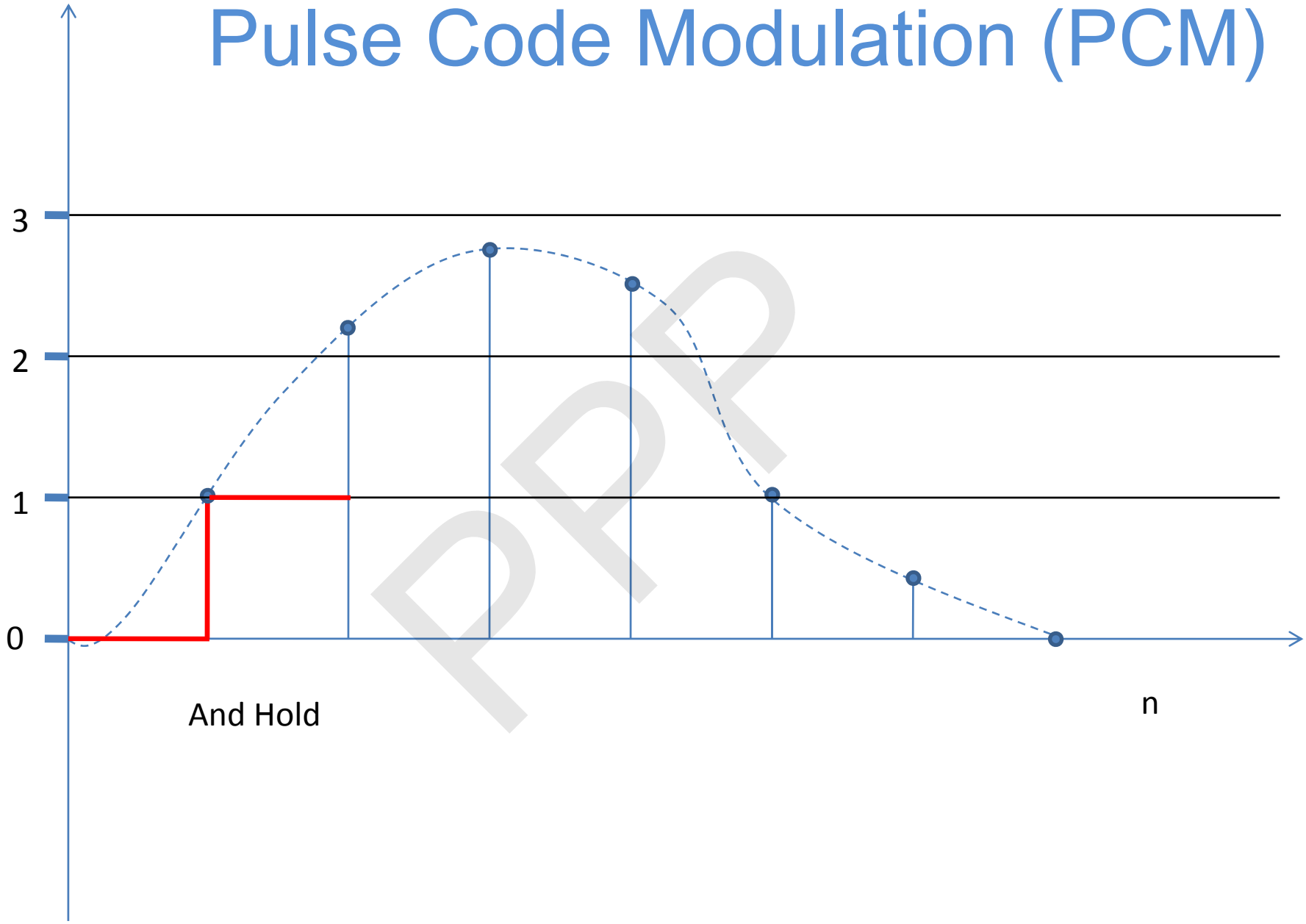
PPP

Pulse Code Modulation (PCM)



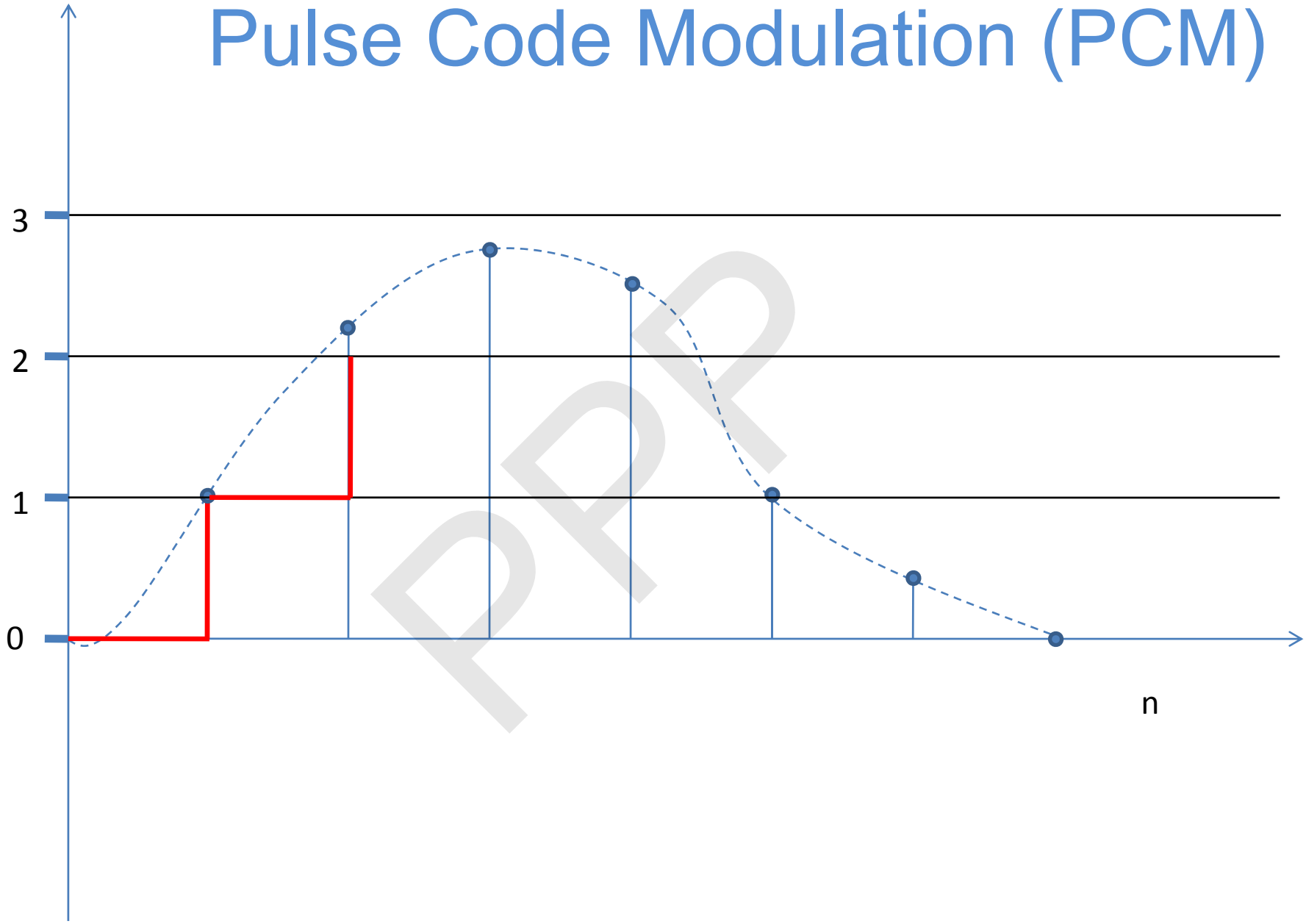
PPP

Pulse Code Modulation (PCM)



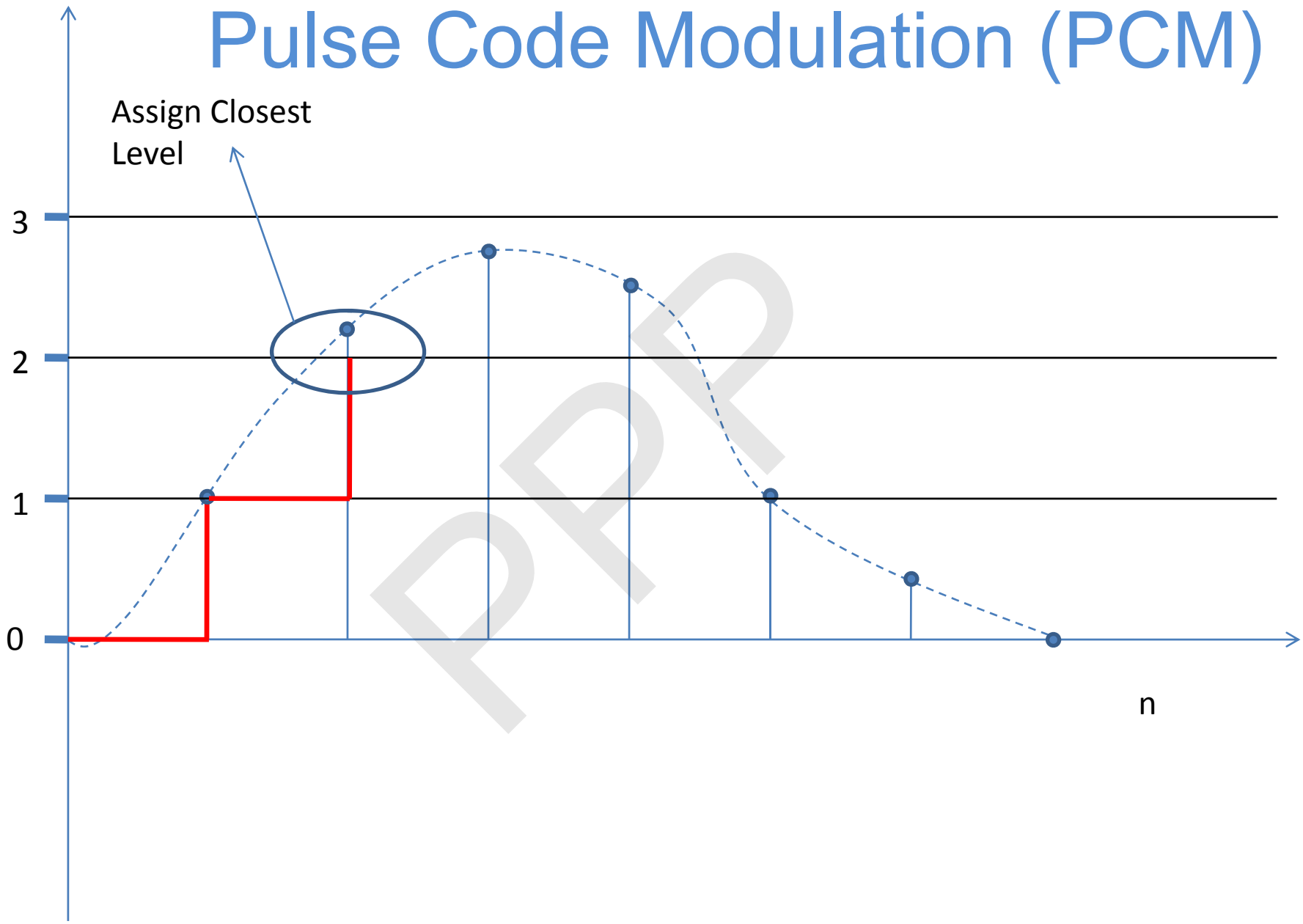
PPP

Pulse Code Modulation (PCM)



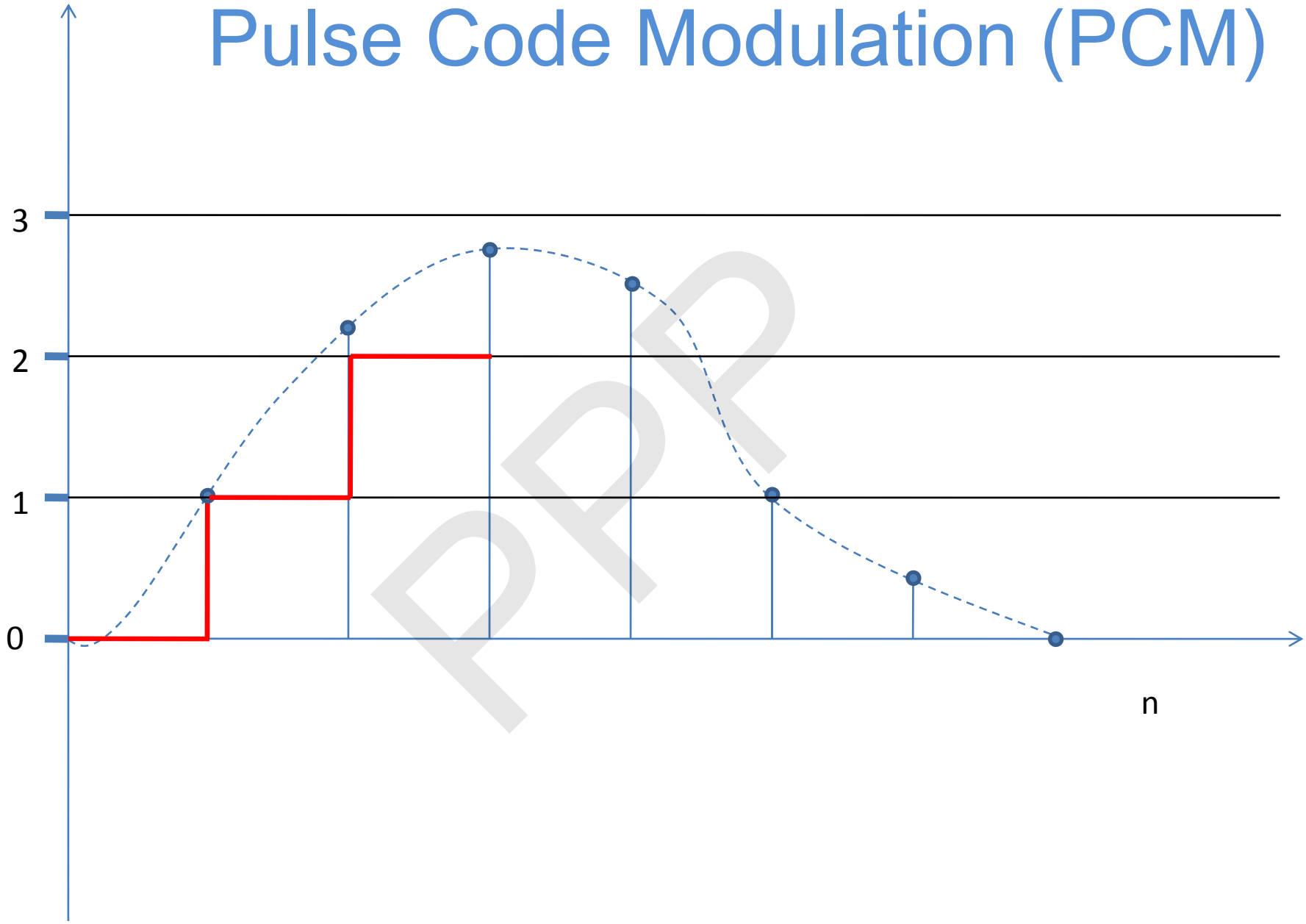
PPP

Pulse Code Modulation (PCM)



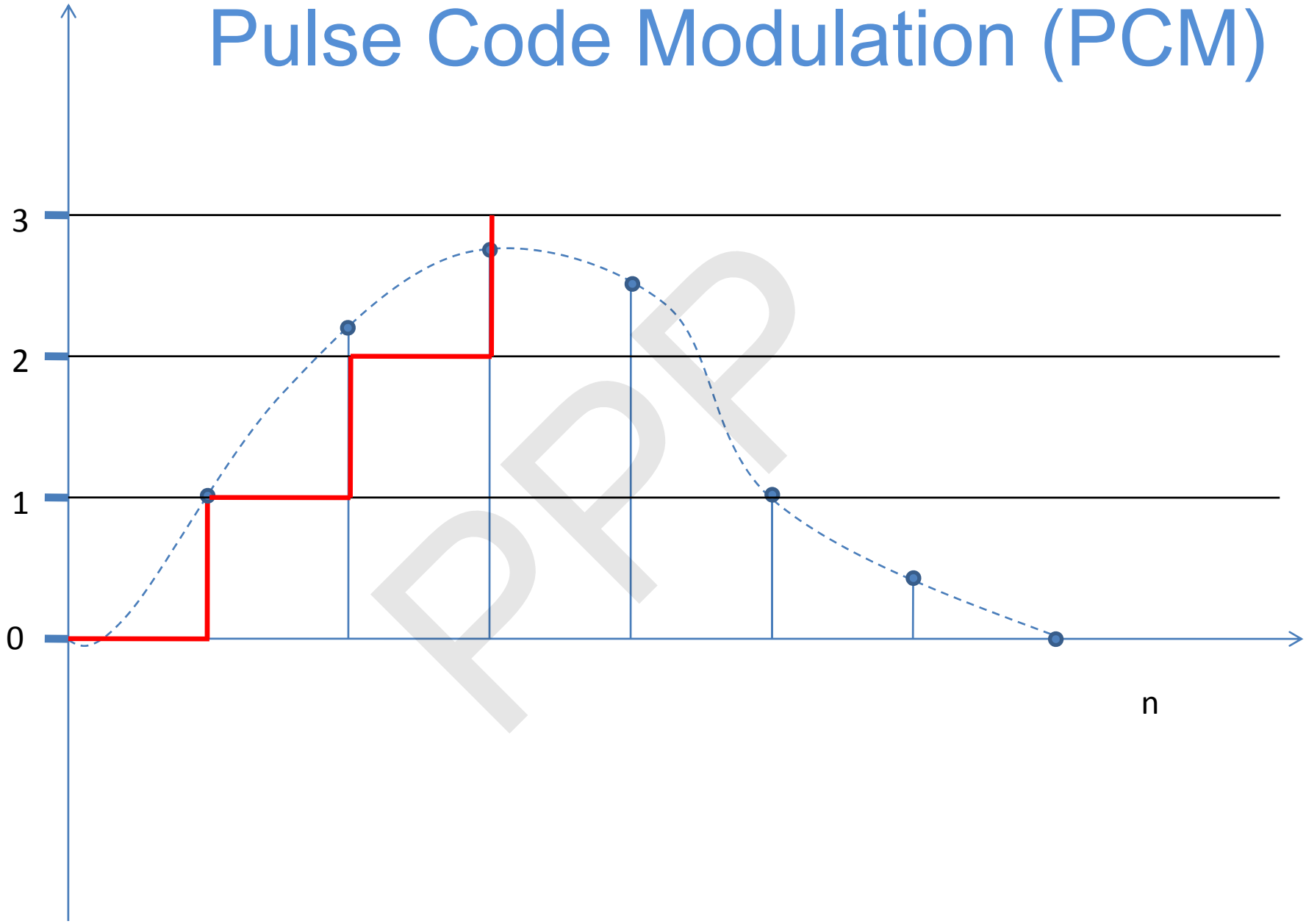
PPP

Pulse Code Modulation (PCM)



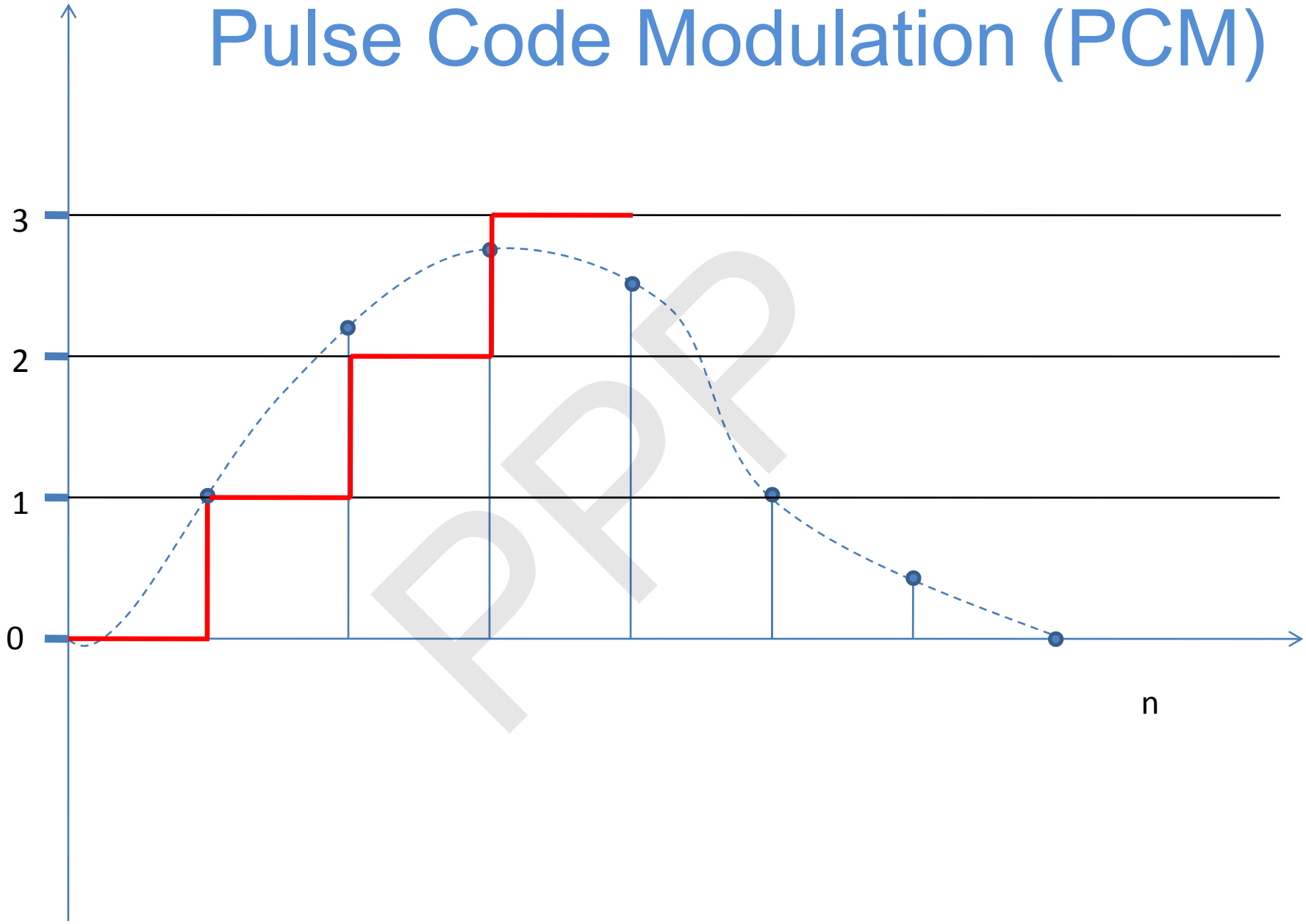
PPP

Pulse Code Modulation (PCM)



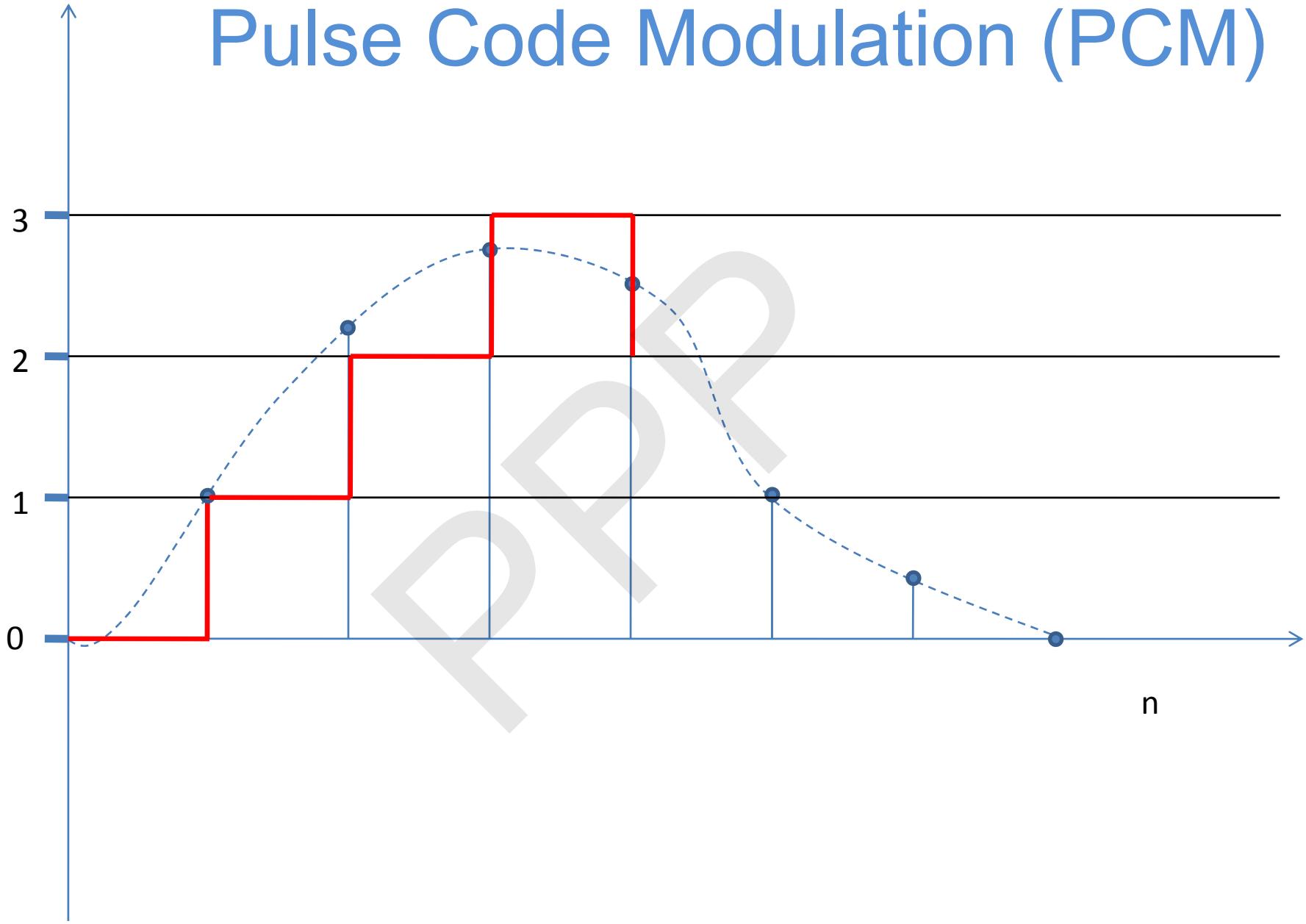
PPP

Pulse Code Modulation (PCM)



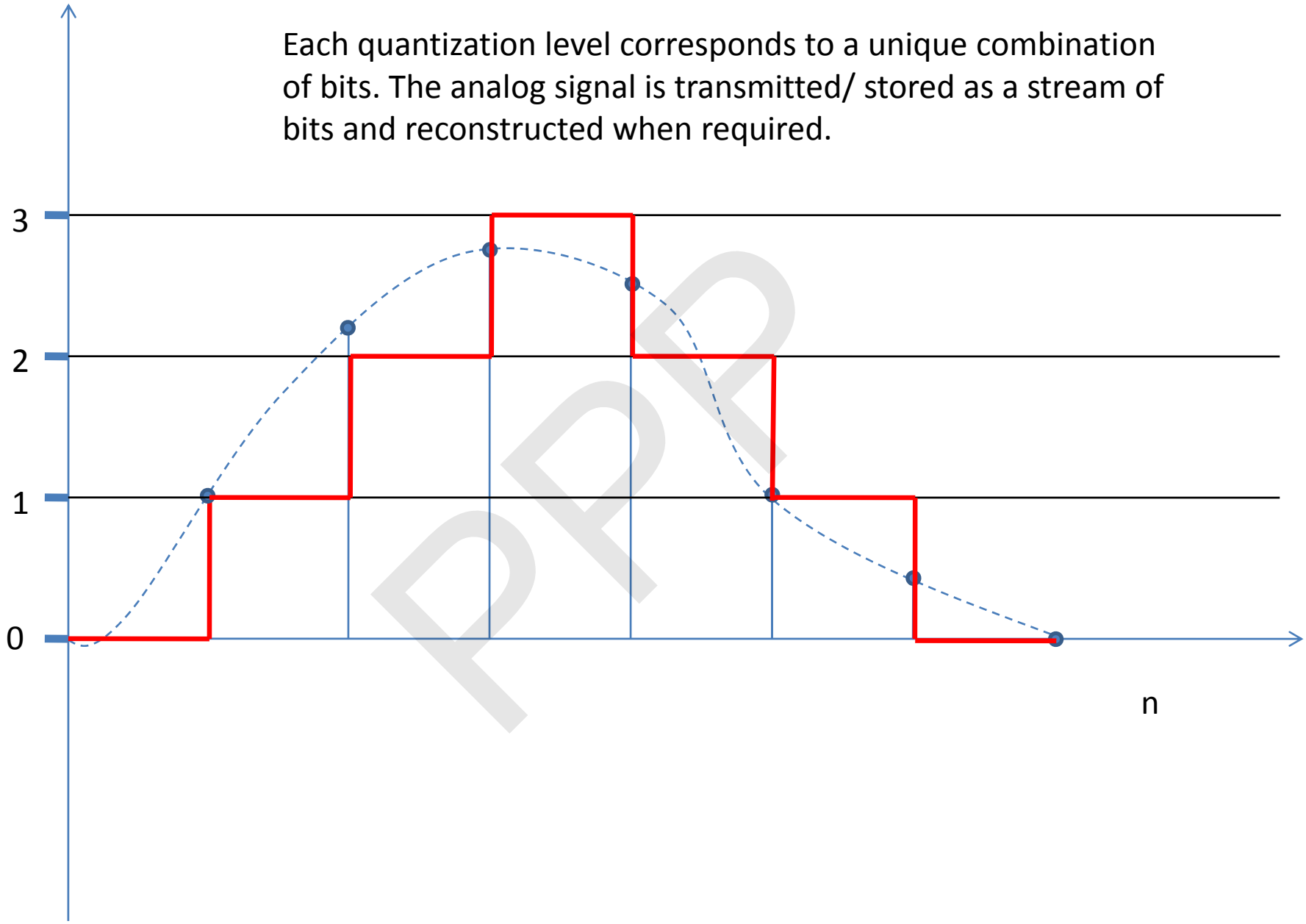
PPP

Pulse Code Modulation (PCM)



PPP

Each quantization level corresponds to a unique combination of bits. The analog signal is transmitted/ stored as a stream of bits and reconstructed when required.



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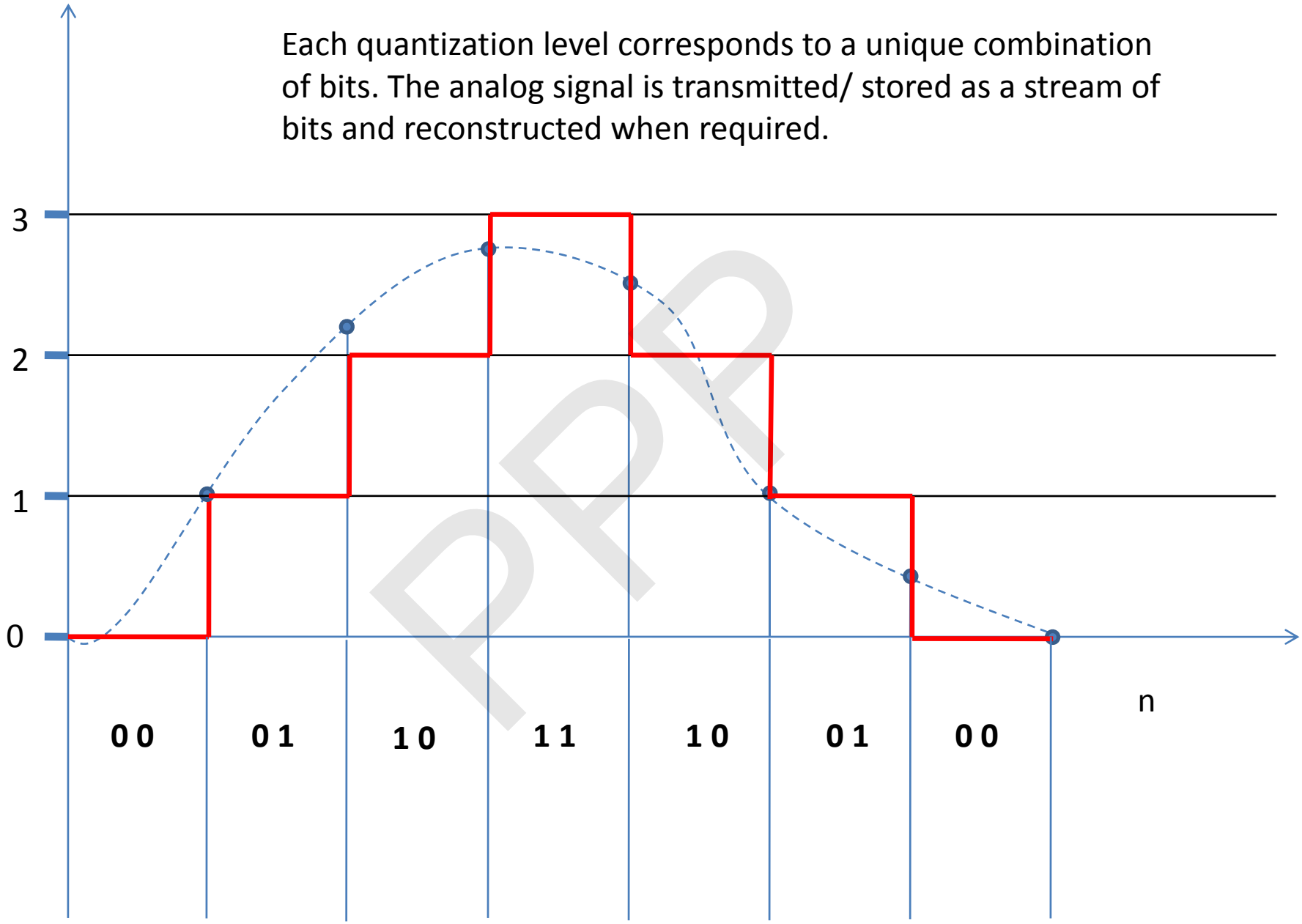
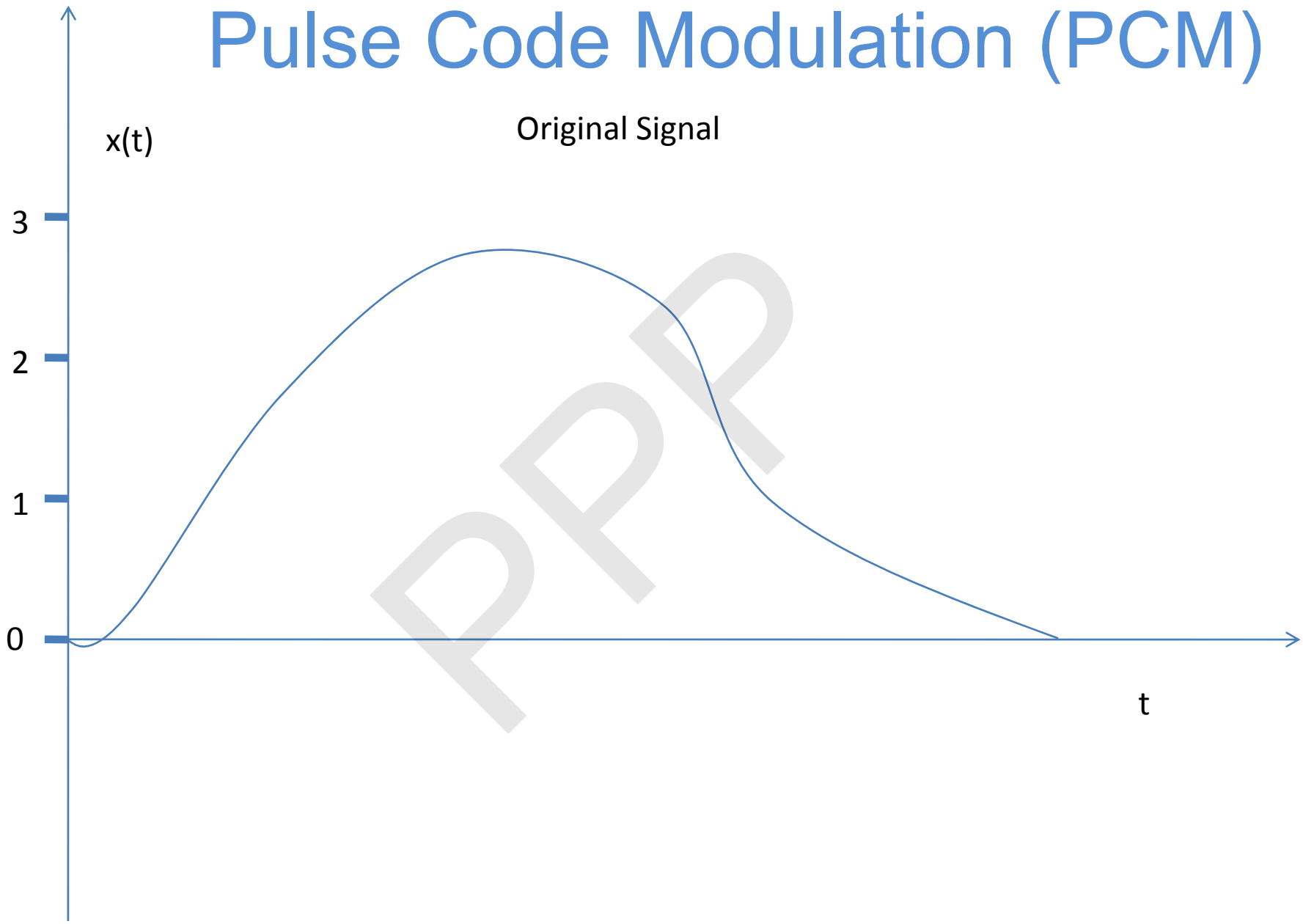


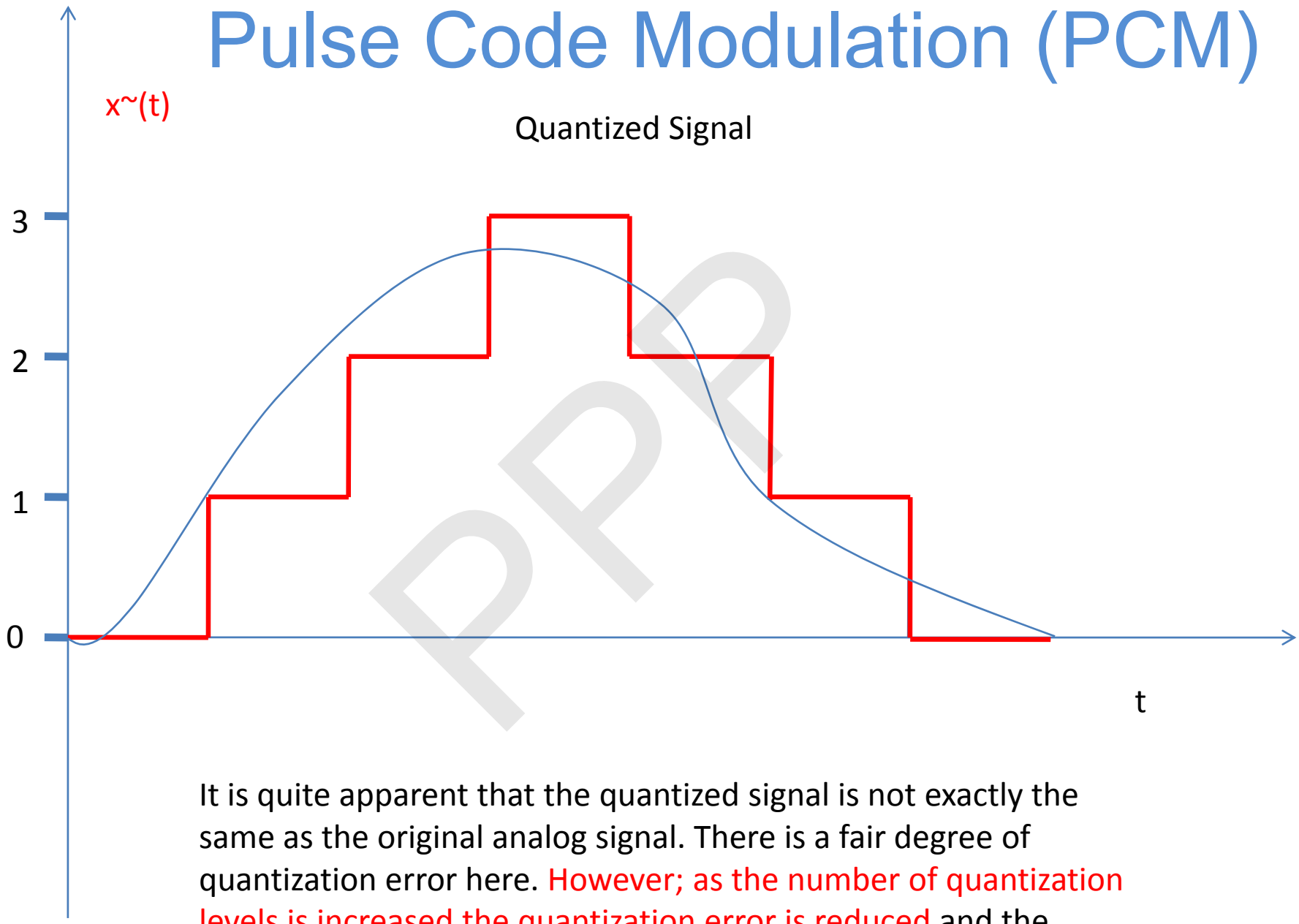
PPP

Pulse Code Modulation (PCM)



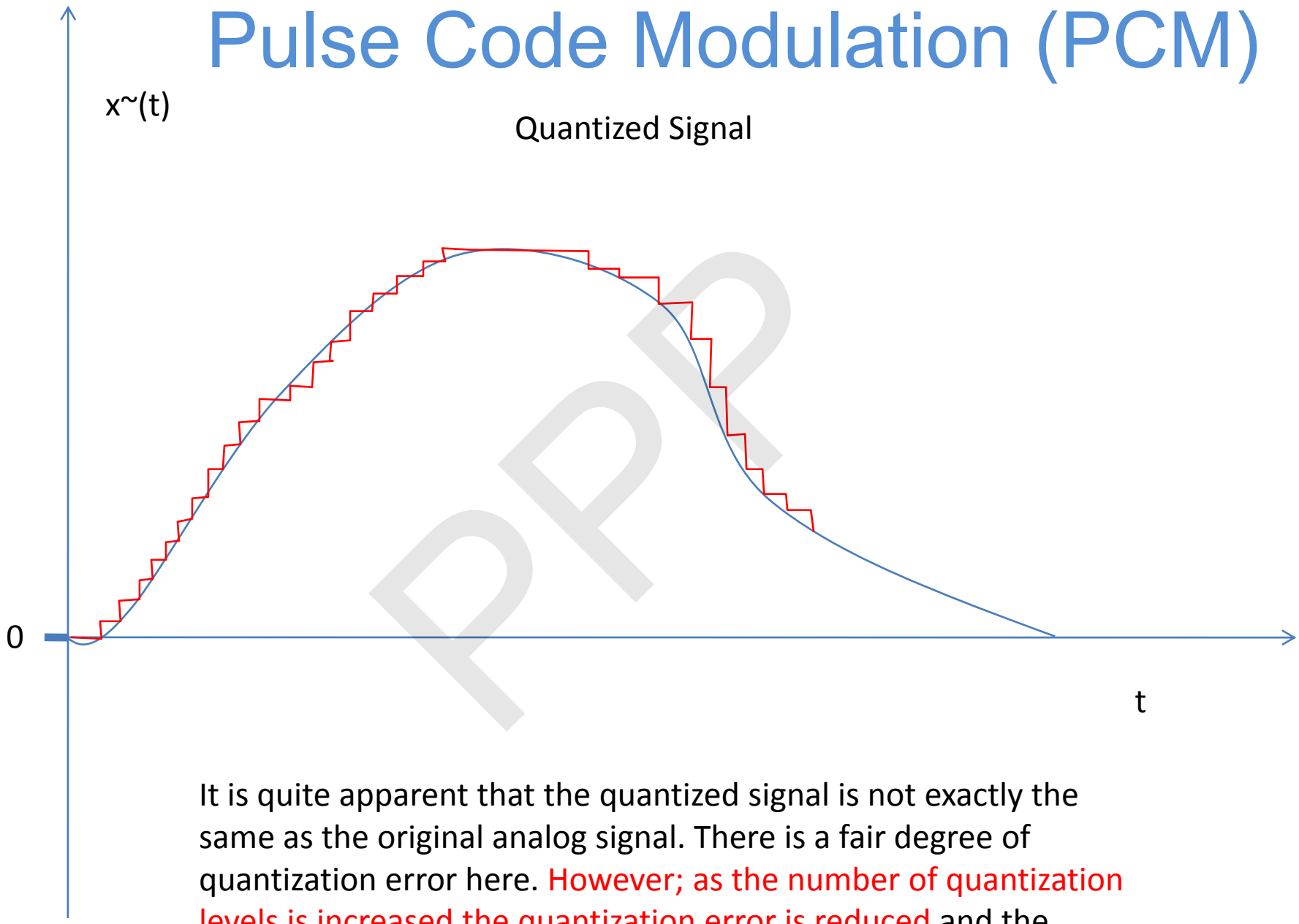
PPP

Pulse Code Modulation (PCM)



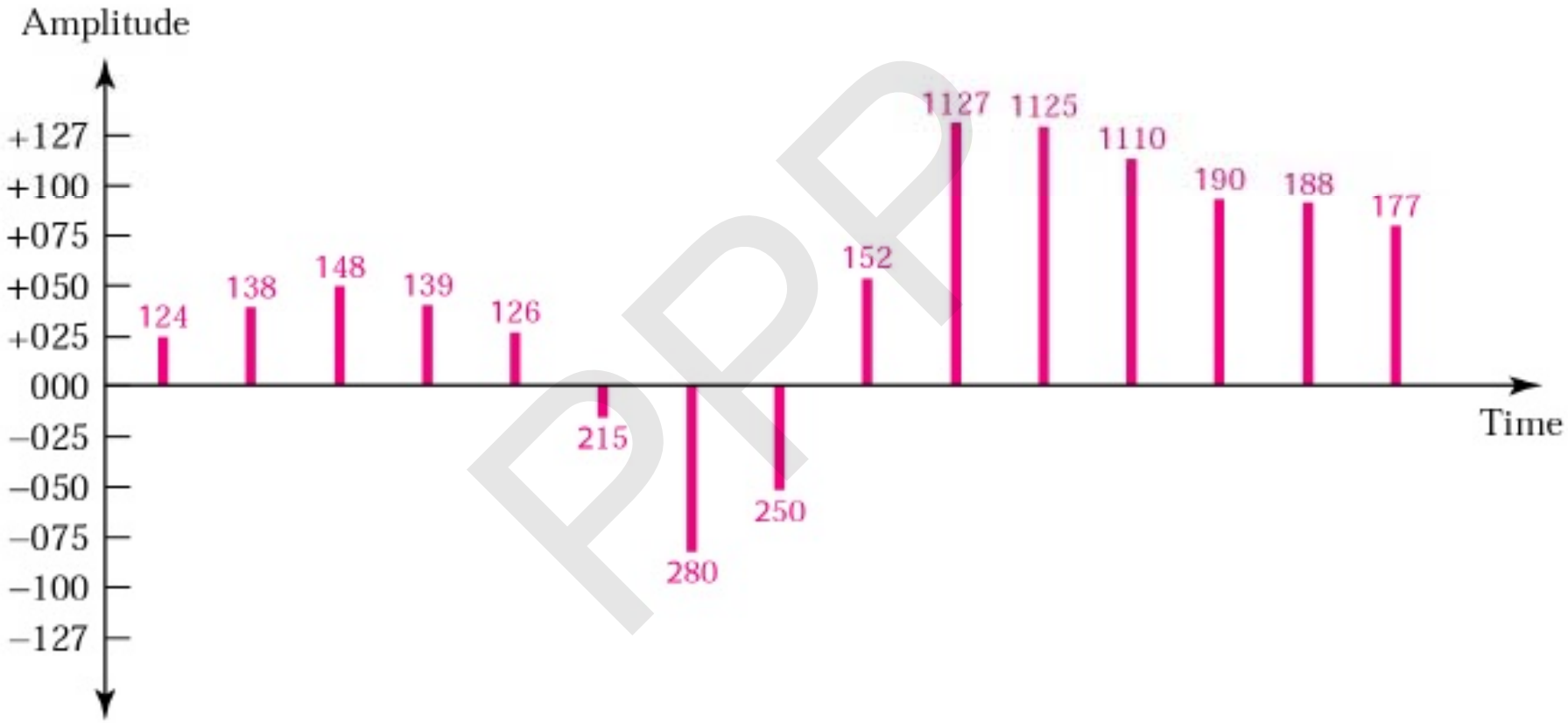
It is quite apparent that the quantized signal is not exactly the same as the original analog signal. There is a fair degree of quantization error here. However; as the number of quantization levels is increased the quantization error is reduced and the quantized signal gets closer and closer to the original signal

Pulse Code Modulation (PCM)



It is quite apparent that the quantized signal is not exactly the same as the original analog signal. There is a fair degree of quantization error here. However; as the number of quantization levels is increased the quantization error is reduced and the quantized signal gets closer and closer to the original signal

Quantized PAM Signal



PPP

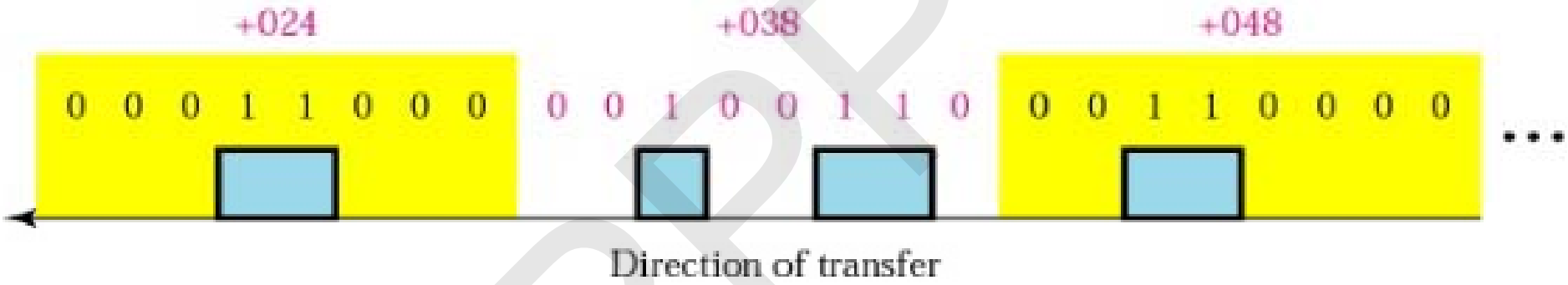
Quantizing using sign and magnitude

+024	00011000	–015	10001111	+125	01111101
+038	00100110	–080	11010000	+110	01101110
+048	00110000	–050	10110010	+090	01011010
+039	00100111	+052	00110110	+088	01011000
+026	00011010	+127	01111111	+077	01001101

Sign bit
+ is 0 – is 1

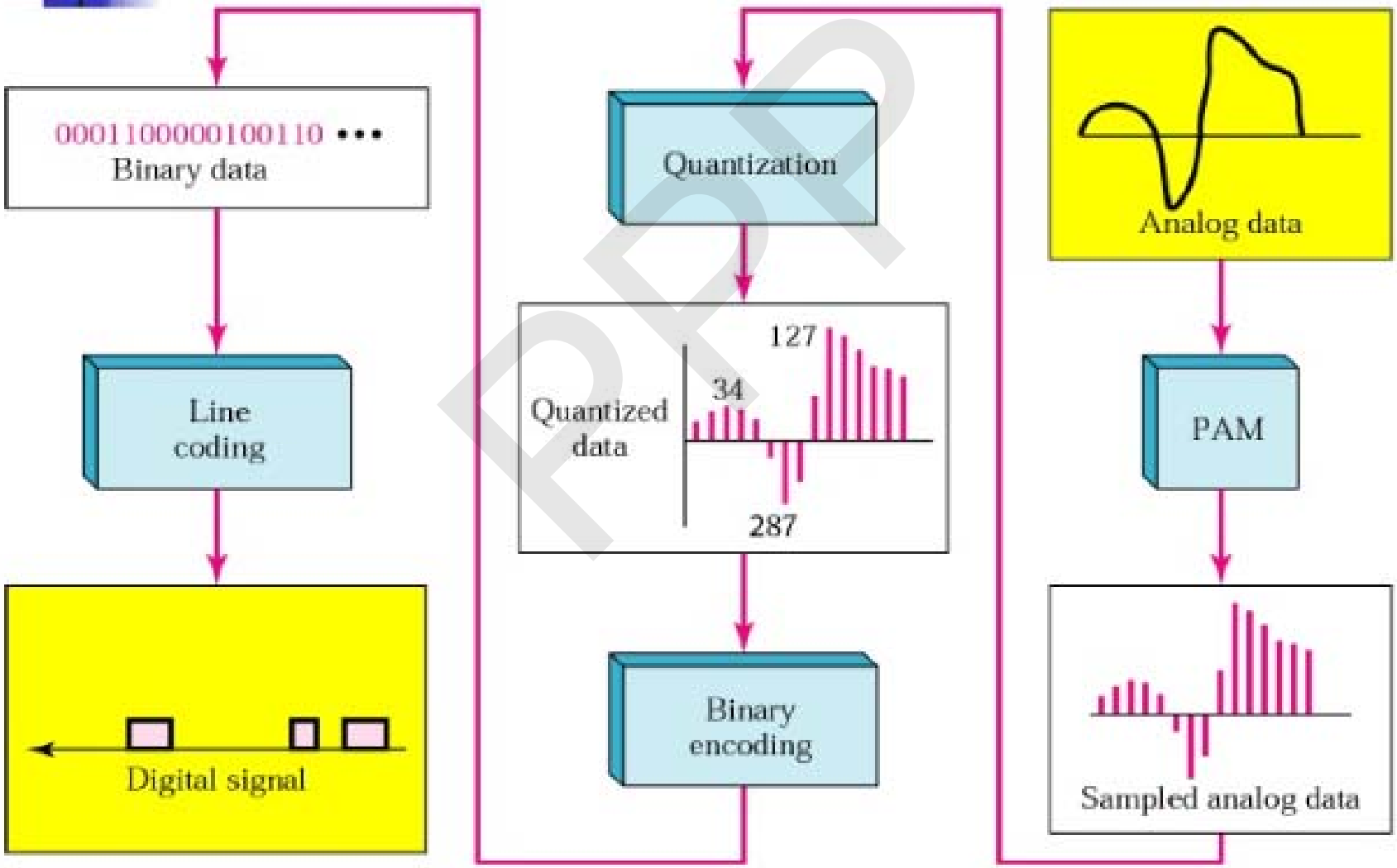
RPP

PCM


+024
+038
+048
0 0 0 1 1 0 0 0
0 0 1 0 0 1 1 0
0 0 1 1 0 0 0 0
...
Direction of transfer

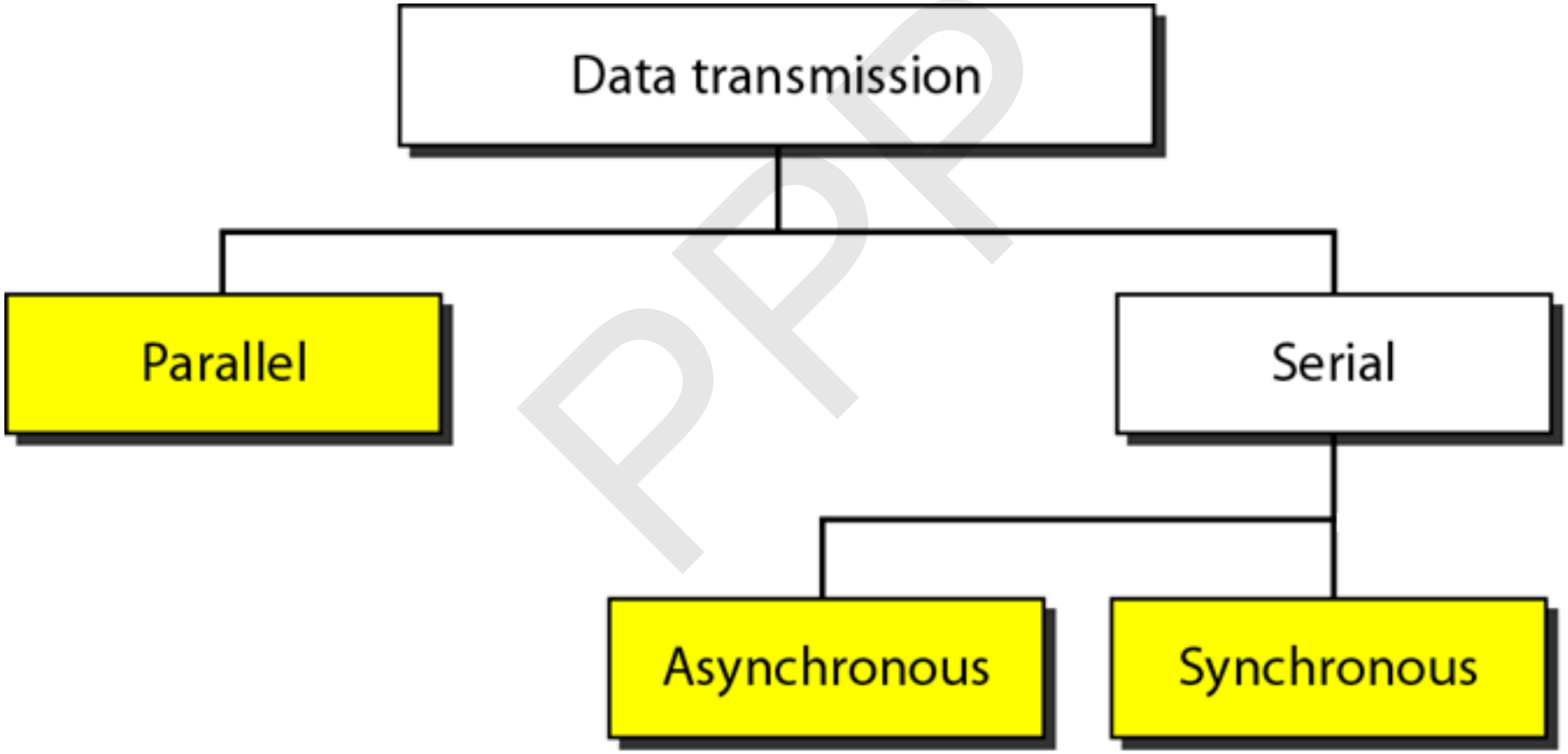
PPP

From analog signal to PCM digital code



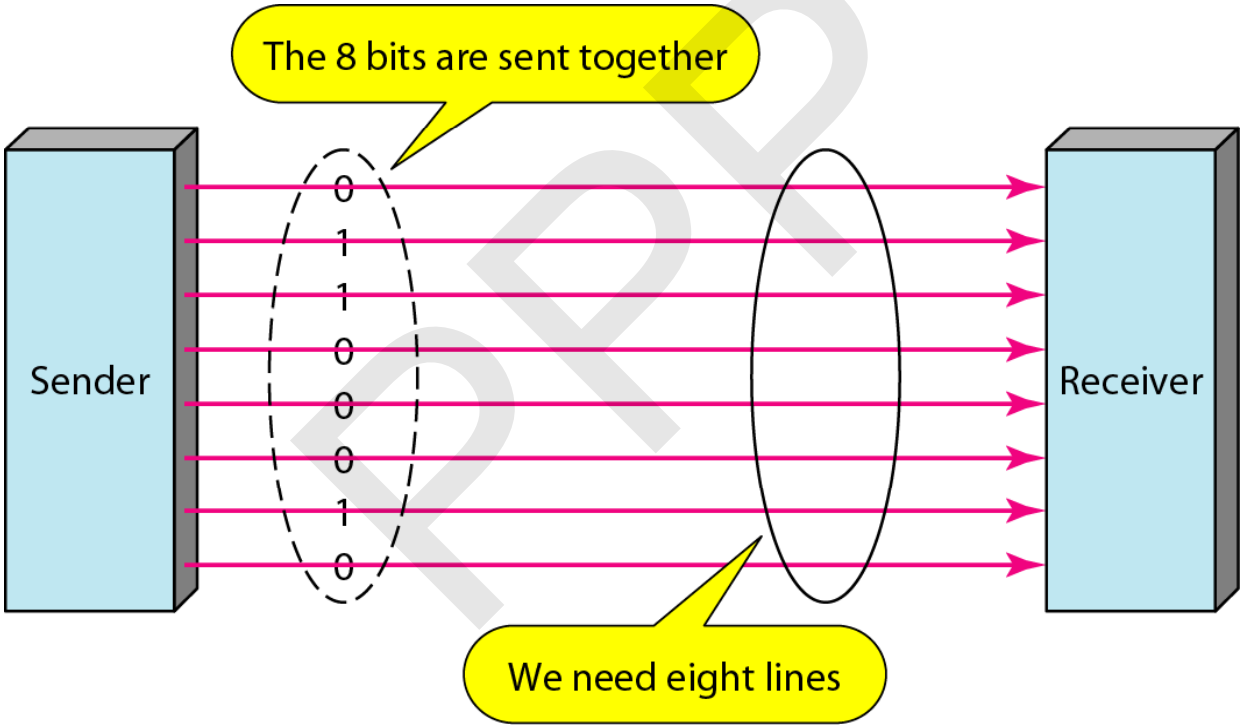
RPP

Data transmission and modes



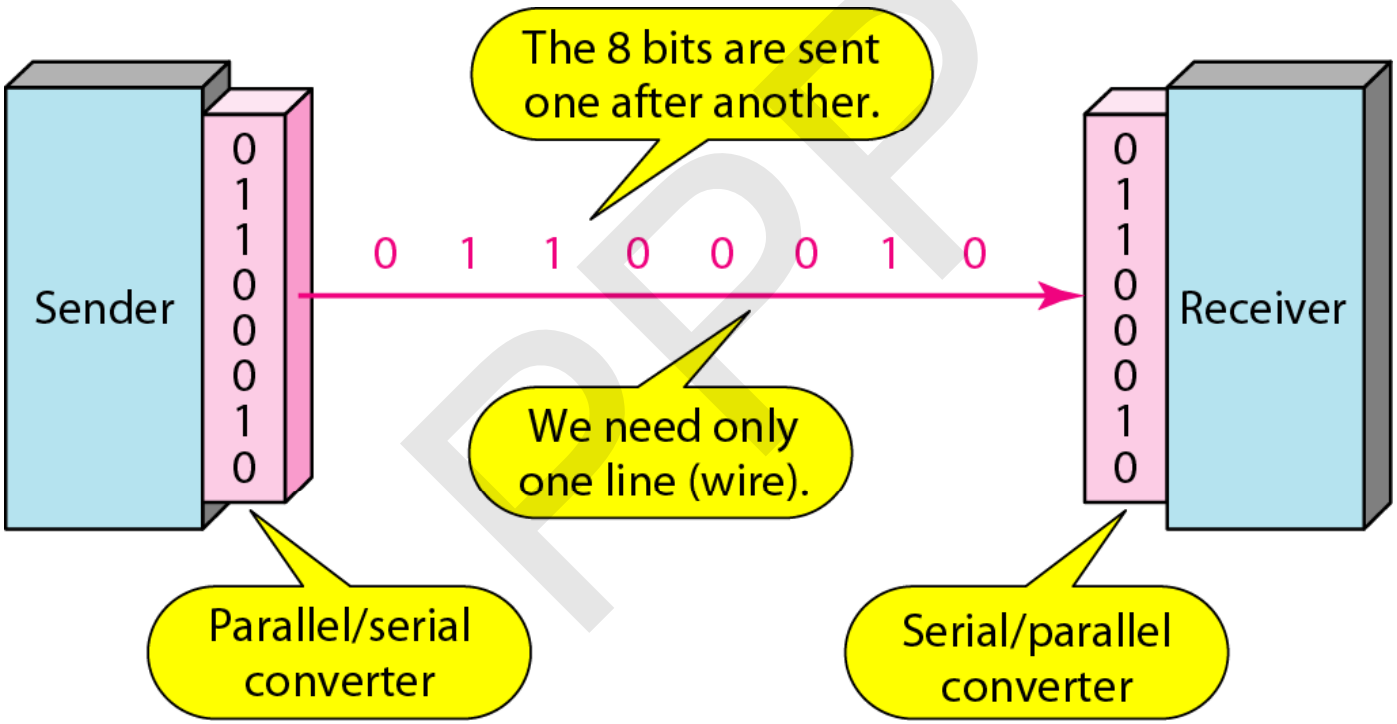
PPP

Parallel transmission



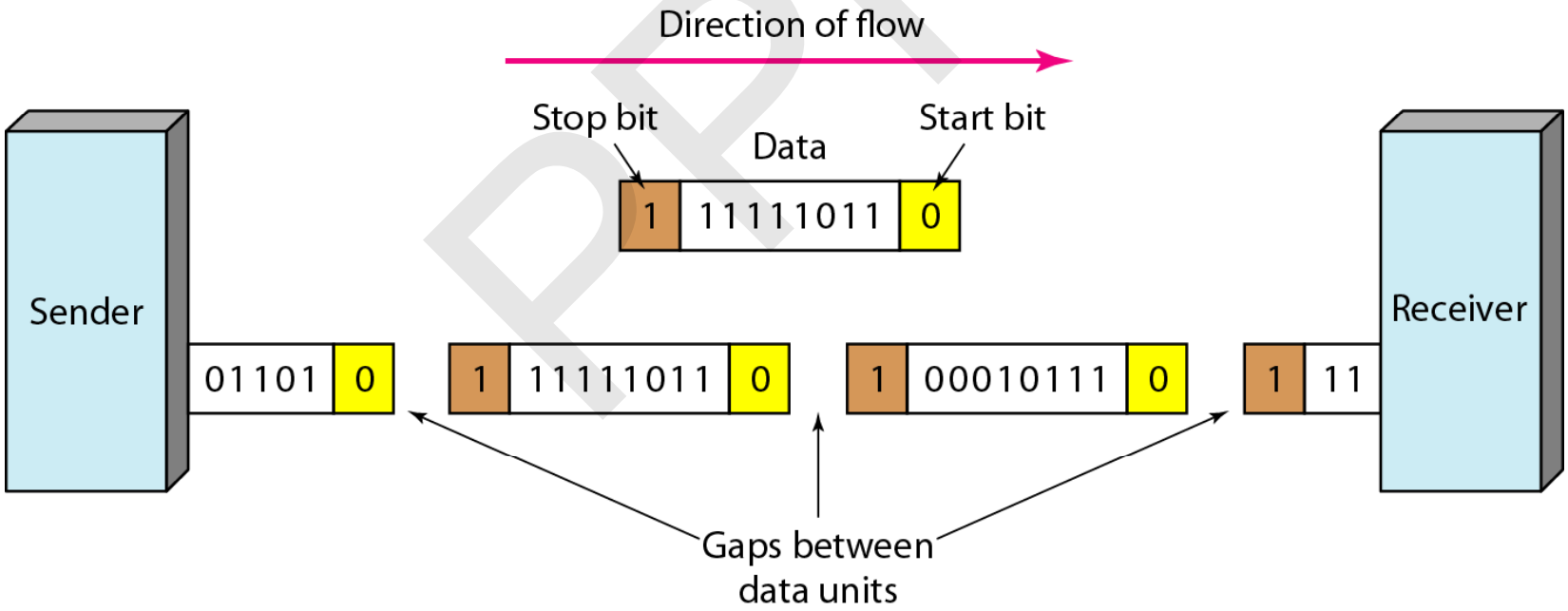
PPP

Serial transmission



Asynchronous transmission

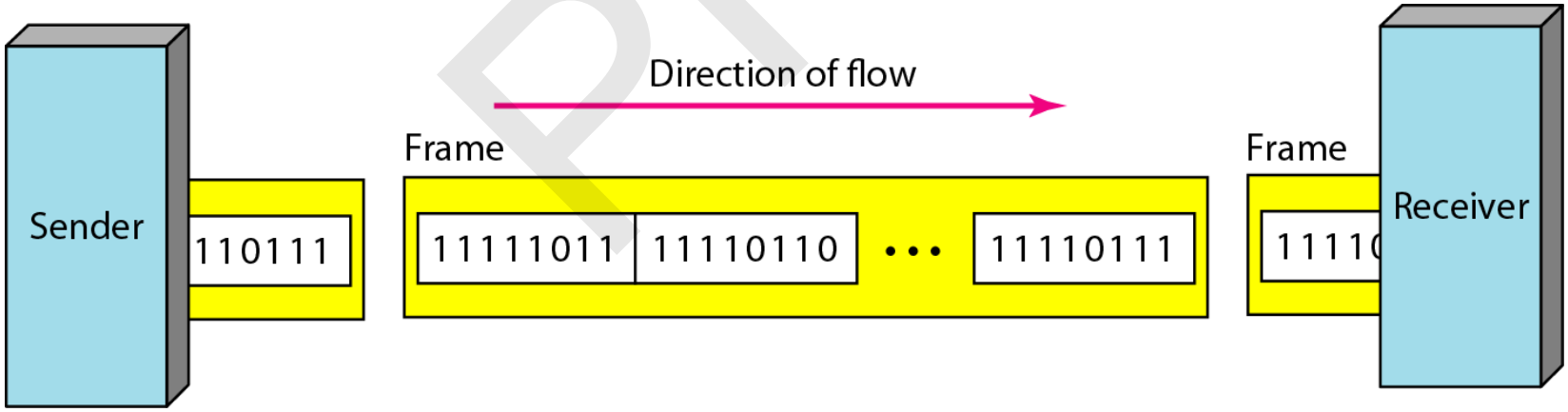
We send 1 start bit (0) at the beginning and 1 or more stop bits (1s) at the end of each byte.
There may be a gap between each byte.



It is “asynchronous at the byte level,” bits are still synchronized; their durations are the same.

Synchronous transmission

We send bits one after another without
start or stop bits or gaps.
It is the responsibility of the receiver to group the bits.



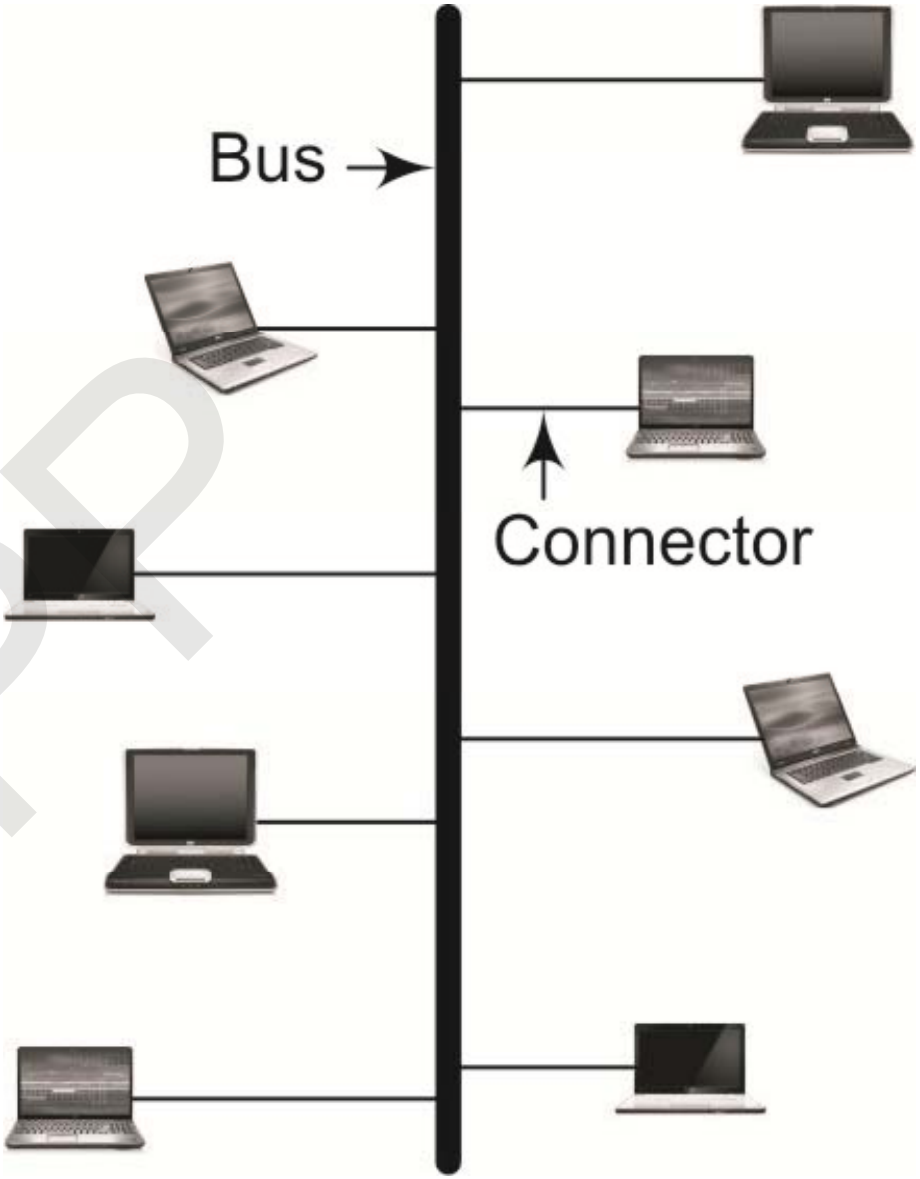
PPP

Asynchronous vs. Synchronous Transmission

Asynchronous Transmission	Synchronous Transmission
Start and Stop bits reduce efficiency	More efficient use of bandwidth
A character can be transmitted at random times	Characters buffered into blocks for transmission
Variable idle time between characters	No idle time between characters
Constant bit rate within a character. No limit on block length	Constant bit rate over a block. Blocks limited to a maximum size
Low speed communications (19.2 Kbits/s)	Higher speed communication (> =10 Mbits/s)
Synchronisation errors result in loss of only a single character	Synchronisation errors result in loss of a complete block

PPP

Ethernet First version



Topology: Bus
Cable: Co-axial
Speed: 2.94Mbps, 10 Mbps
Connector: Vampire Tape/T-connector
Transmission Type: Broadcasting
Transceiver: Carrier Sense
Frame Size: Min. 64 Bytes
Network Length: 2500 meter

DEC (Digital Equipment Corporation, Compaq , HP) 2.94 Mbps
DIX (Digital , Intel & Xerox) 10 Mbps Classic Ethernet

PPP

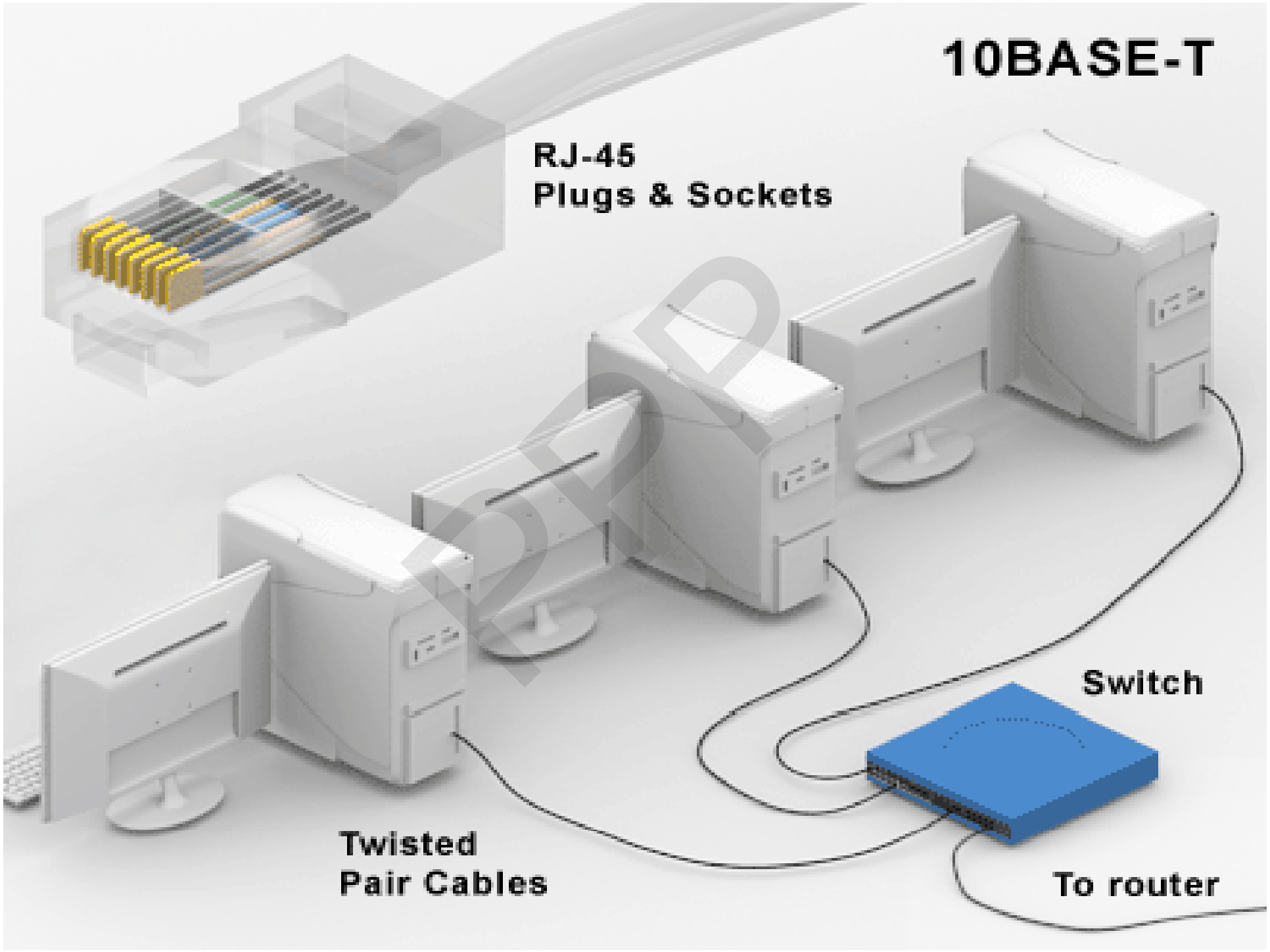
- Two standards, DIX and 802.3 (IEEE)
- Initially Bus and Hubs were used
- Later switches took over

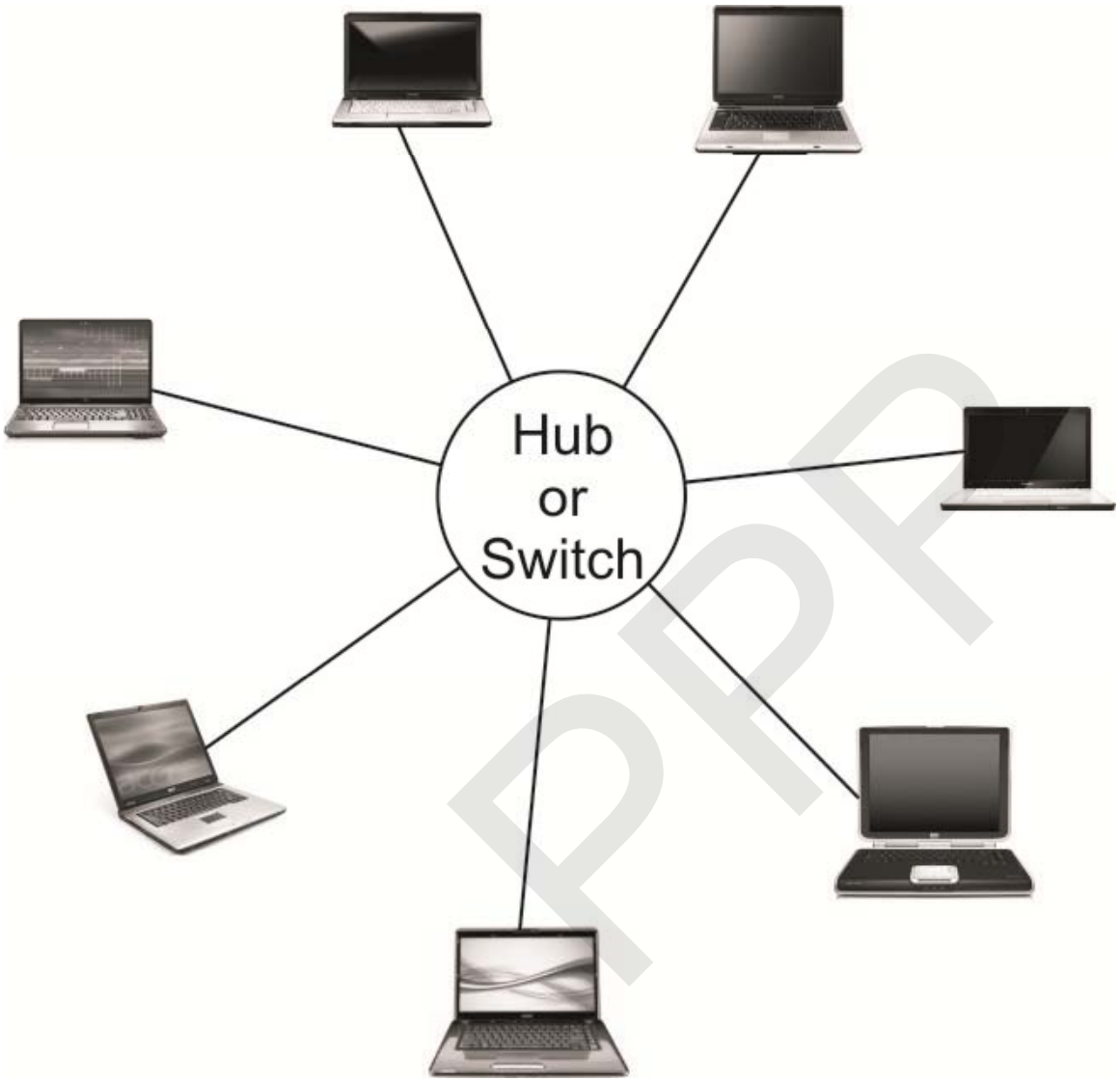
- Problems to use co-axial cable in bus topology
  - A machine cannot be added or removed without affecting others.
  - Reduce the overall capacity for a single user.
  - Maintenance is difficult. (Difficult to detect faulty node)
- Advantages of Cat-3 UTP cables
  - A machine can be added or replaced or removed without affecting others.
  - A node can have 10 Mbps bandwidth because of switch.
  - Maintenance is easy. (Easy to detect a faulty node).

PPP

Name	Type	Length (Max)	Advantage
10Base5	Thick coax	500 m	Good interconnection option.
10Base2	Thin coax	200 m	Flexible and easy to maneuver. It can bend easily than the thicker cable.
10BaseT	UTP (cat-3)	100 m	Best for Star topology.
10BaseF	Fiber optics	2 km	Best option for interconnection. Best noise immunity.

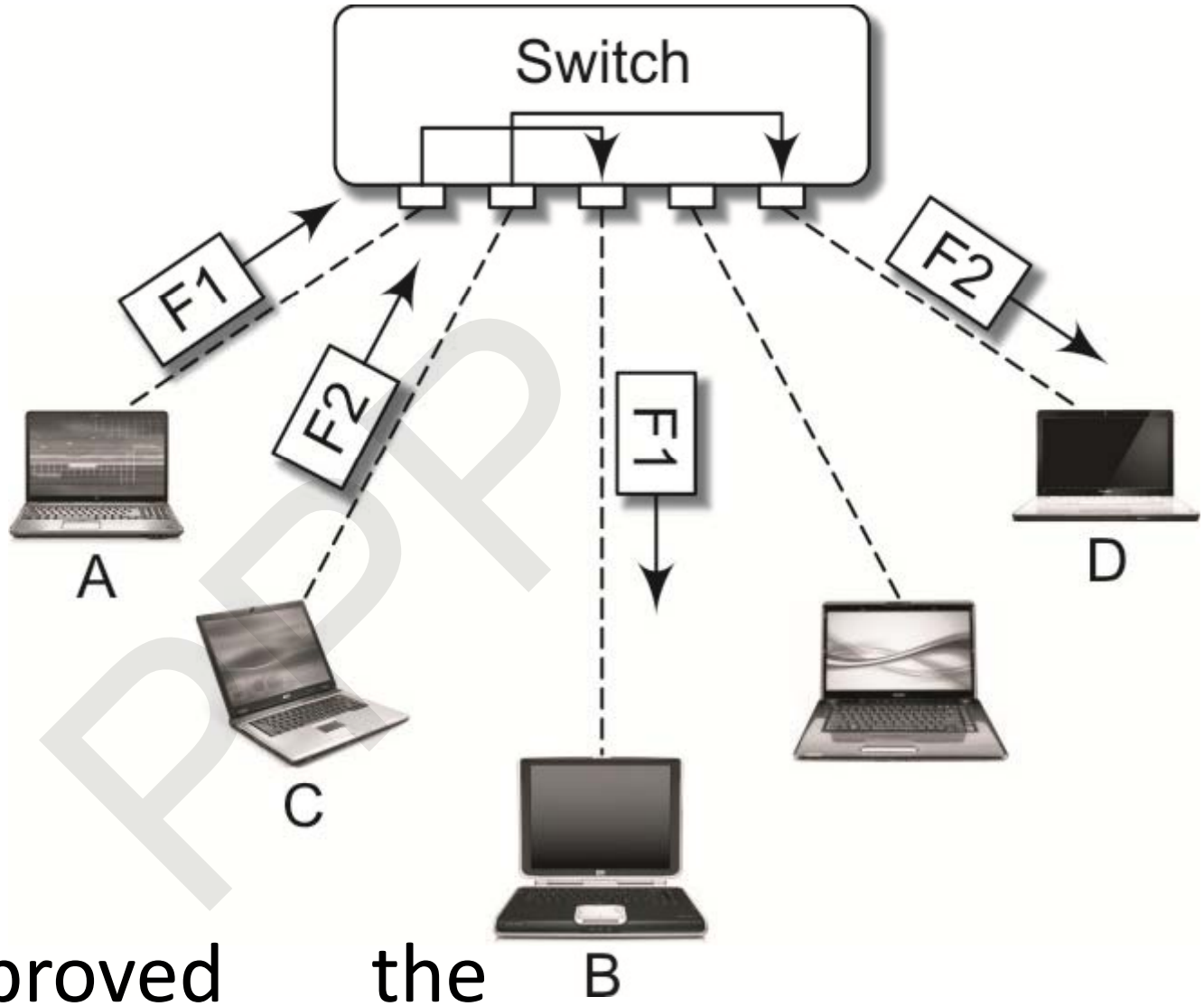
PPP


10BASE-T
RJ-45
Plugs & Sockets
Switch
Twisted
Pair Cables
To router

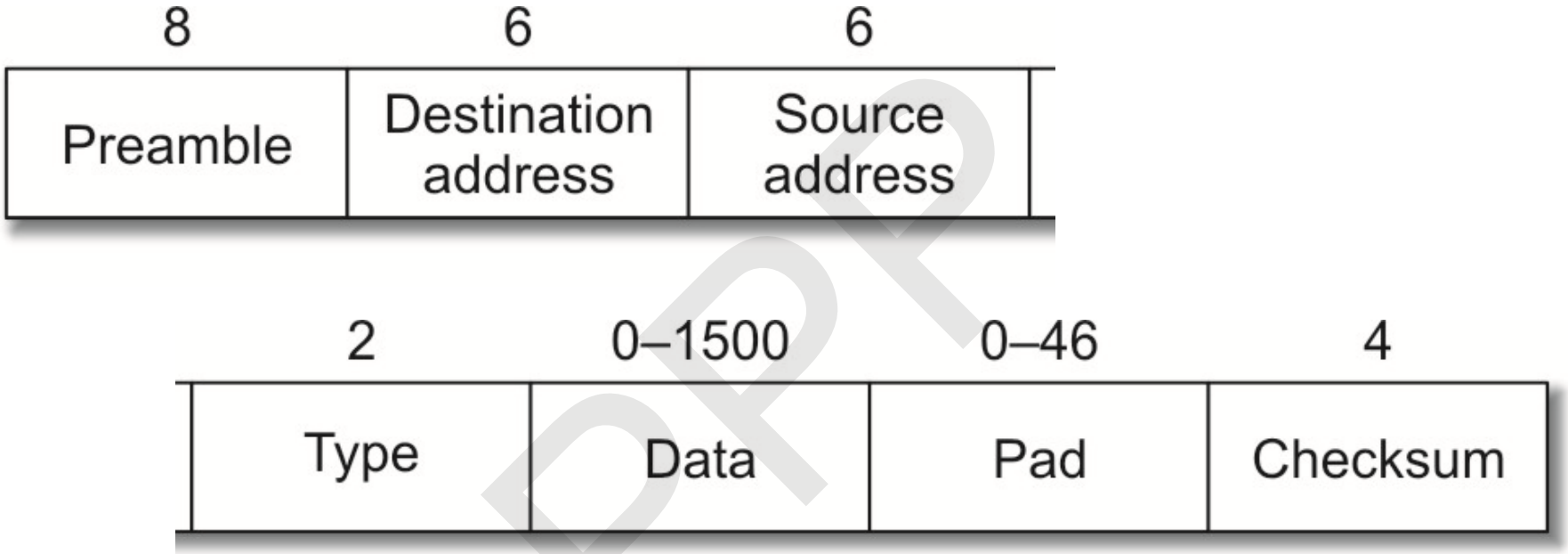


Star Topology

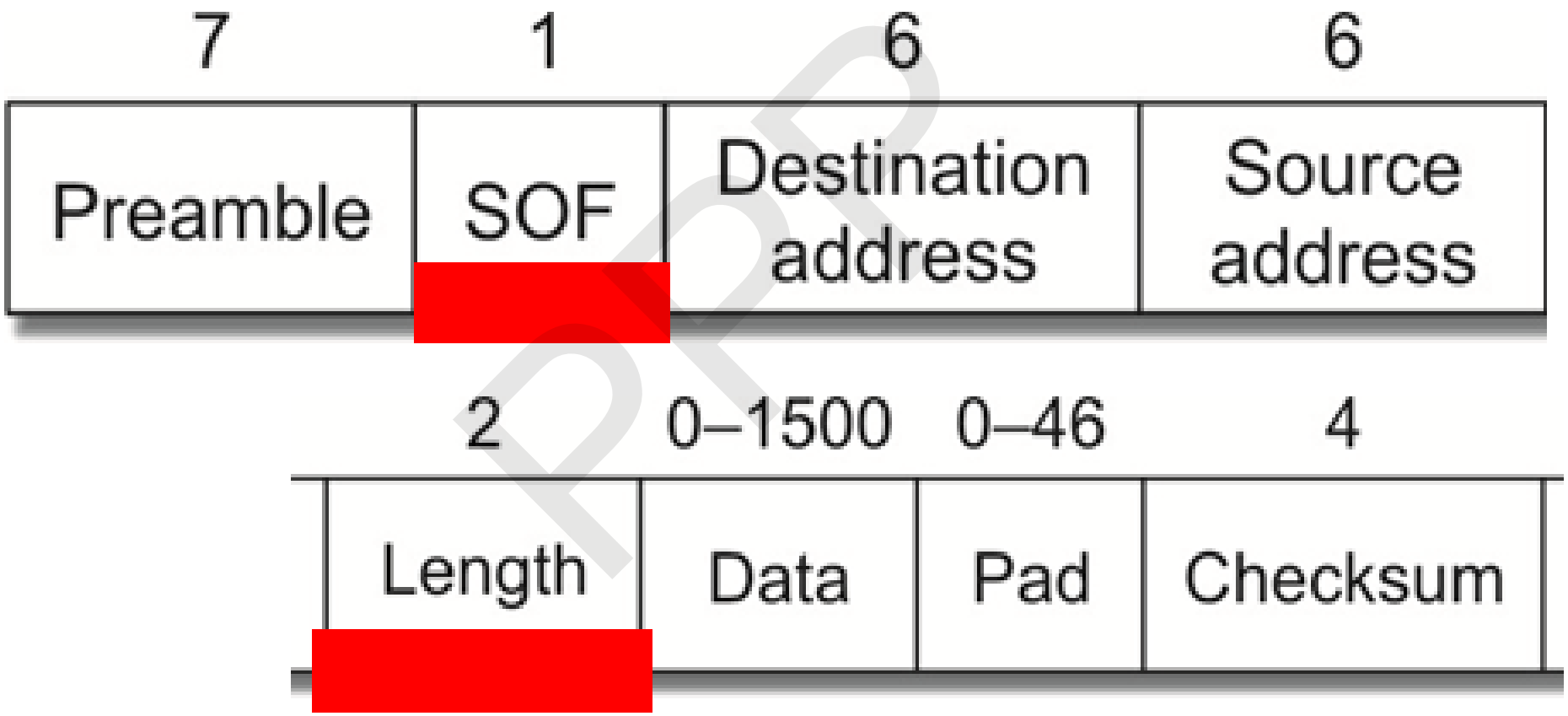
PPP



Switch improved the performance by reducing collision domain


8
6
6
Preamble
Destination address
Source address
2
0–1500
0–46
4
Type
Data
Pad
Checksum

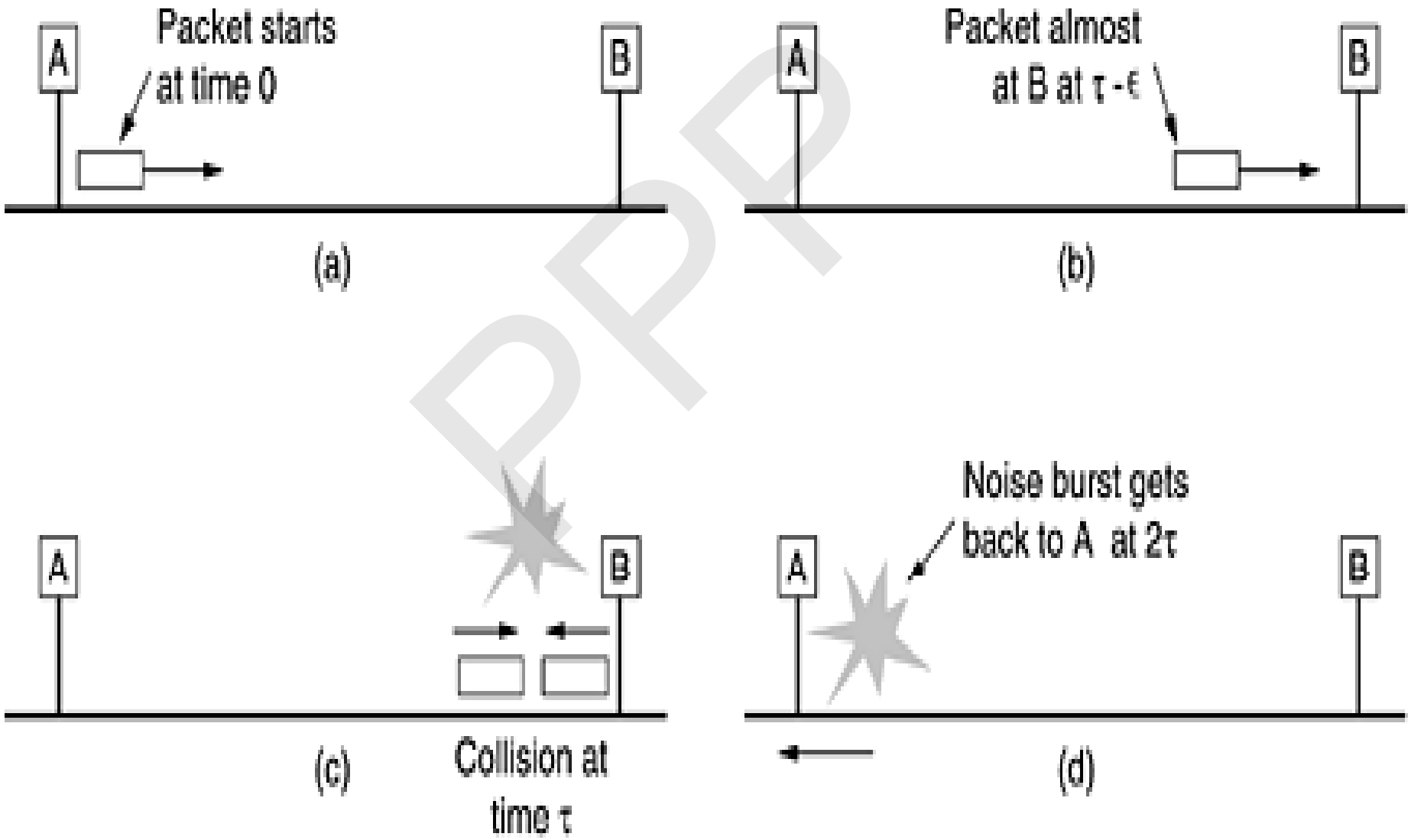
PPP


7
1
6
6
Preamble
SOF
Destination address
Source address
2
0–1500
0–46
4
Length
Data
Pad
Checksum

7	1	6	6
10101010 repeated seven times	10101010 in DIX and 10101011 in 802.3	A group address begins with 1. An individual address begins with 0 A broadcast address contains all 1s	Source Addres is the sender's unicast addres

2	0-1500	0-46	4
Type in DIX and Length in Ethernet 802.3	Data contains IPv4 or IPv6 or ICMP or IGMP packet in case of Internet	Pad to add bytes when the frame is shorter than 64 bytes	Checksum in CRC

PPP


A
Packet starts
at time 0
B
(a)
A
Packet almost
at B at τ - ϵ
B
(b)
A
B
(c)
Collision at
time τ
A
Noise burst gets
back to A at 2τ
B
(d)

PPP

Why is the minimum size of the frame 64 bytes?

10 Mbps LAN , 2500 m , 4 repeaters

Round-trip Time 2τ = 50 μsec or slot time = 50 μsec

Sec	**No. of bits transferred**
1	**$10 * 10^6$**
$50 * 10^{-6}$	**?**

500 bits = Approx(512 bits) = 64 bytes

PPP