BCS502 – COMPUTER NETWORKS

Faculty:

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Course outline

Module 1:

Introduction: Data Communications, Networks, Network Types, Networks Models: Protocol Layering, TCP/IP Protocol suite, The OSI model, Introduction to Physical Layer: Transmission media, Guided Media, Unguided Media: Wireless. Switching: Packet Switching and its types.

Module 2:

Data Link Layer: Error Detection and Correction: Introduction, Block Coding, Cyclic Codes. Data link control: DLC Services: Framing, Flow Control, Error Control, Connectionless and Connection Oriented, Data link layer protocols, High Level Data Link Control. Media Access Control: Random Access, Controlled Access. Check Sum and Point to Point Protocol

Course outline

Module 3:

Network Layer: Network layer Services, Packet Switching, IPv4 Address, IPv4 Datagram, IPv6 Datagram, Introduction to Routing Algorithms, Unicast Routing Protocols: DVR, LSR, PVR, Unicast Routing protocols: RIP, OSPF, BGP, Multicasting Routing-MOSPF

Module 4:

Transport Layer: Introduction, Transport-Layer Protocols: Introduction, User Datagram Protocol, Transmission Control Protocol: services, features, segments, TCP connections, flow control, Error control, Congestion control.

Course outline

Module 5:

Application Layer: Introduction, Client-Server Programming, Standard ClientServer Protocols: World Wide Web and HTTP, FTP, Electronic Mail, Domain Name System (DNS), TELNET, Secure Shell (SSH).

Recommended Textbooks

1. **Data Communications and Networking**

   - Behrouz A. Forouzan

   Tata McGraw Hill,2013, 5th Edition

2. **Computer Networks**

   - Andrew S. Tanenbaum and David J. Wetherall.

   Pearson Education, 5th Edition.

Assessment details

- **Continuous Internal Evaluation (CIE) : 50% (50 marks)**
- **Theory part: 25 marks**
  - Two Internal assessments – 15 marks
  - Assignments and Quizzes – 10 marks
  - Should score a Minimum of 40% of the above maximum marks (10 marks out of 25)
- **Lab part: 25 marks**
  - Conduction of experiments and Record writing – 15 marks
  - Lab test – 10 marks
  - Should score a Minimum of 40% of the above maximum marks (10 marks out of 25)

Assessment details

- **Semester End Exam (SEE) : 50% (50 marks)**
  - Will have 5 either / or questions – One from each module, to be answered in 3 hours.
  - Minimum passing mark for the SEE is 40% of the maximum marks (20 marks)
- For an overall Pass grade, one must score a minimum of 40% of the CIE and SEE marks taken together.

Module 1

Introduction to Networks, & Physical layer

Main topics in Module 1

- Data Communications,
- Networks, and Network Types,
- Network Models: Protocol Layering
- The OSI model
- TCP/IP Protocol suite
- Introduction to Physical Layer: Transmission media, Guided Media, Unguided Media: Wireless.
- Switching: Packet Switching and its types.

Introduction to Computer Networks

- A computer network is an interconnection of autonomous computers.
- Benefits:
  - Resource sharing
    - Data sharing: Consistency, Easy updating, Saving of storage space
    - Software sharing: Saving of cost and storage space
    - Peripheral sharing: Saving of cost
  - Electronic communication: Fast, cheap, secure, convenient
  - Higher reliability and easy scalability compared to a single large computer
  - Cost-benefit ratio is better compared to a single large computer.

Separate network for Data communication ?

- We already have a very extensive telephone network for voice communication.
- Why can't it be used for data communication?
  - In fact, in the late 90's, it was used in the form of "dial-up" connections that offered a bandwidth (bit-rate) of 64kbps.
  - Later, DSL (Digital Subscriber Link) technology was used on the same infrastructure to offer a much higher data rate.

Voice communication vs Data communication

- Voice is analog, while data is primarily digital
- Voice is continuous, while data is usually discrete
- Latency has to be very low in Voice networks
- Zero tolerance for Jitter, in Voice networks
- Error control is very important in data communication
- Data communication has to be more secure
- Voice needs uniform bandwidth, while data has varying needs

Classification of Computer Networks

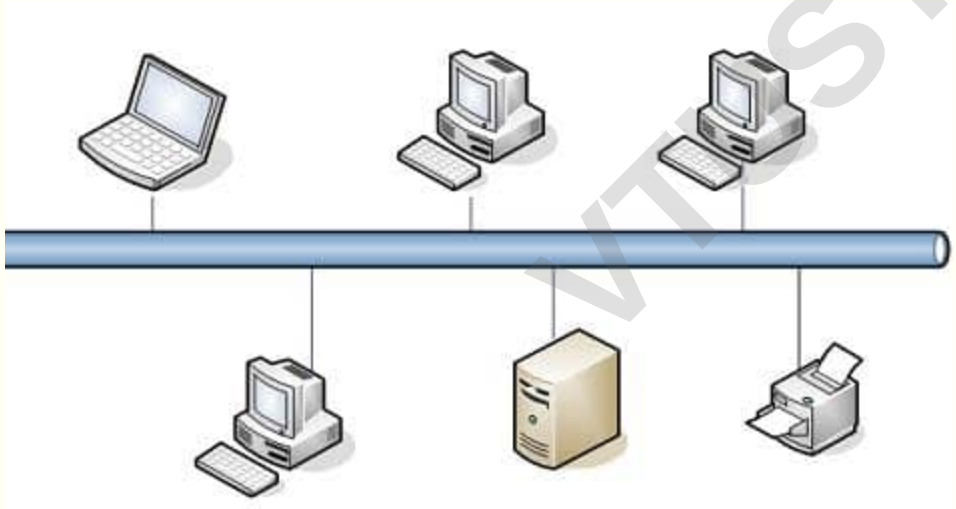
- Based on geographical area:
  - LAN: Local Area Network
  - MAN: Metropolitan Area Network
  - WAN: Wide Area Network
- Based on transmission technology:
  - Point-to-point Network
  - Broadcast Network
- Based on ownership:
  - Private Network
  - Public Network

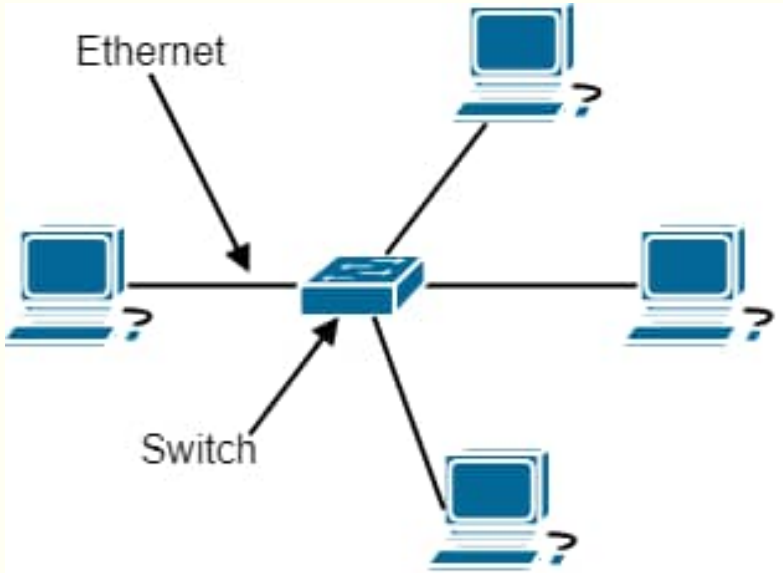
Local Area Network (LAN)

- LAN is a privately owned network that operates within a single building (office or factory) or a few nearby buildings (university campus).
- LANs connect many PCs and other peripherals (printers, etc) to exchange information between them.
- The interconnection can be using wired links or it can be wireless or even a combination of the two.
- Typically, wired LANs run at speeds of 100 Mbps to 1 Gbps, have a very low delay (milliseconds) and encounter very few transmission errors.

Local Area Network (LAN)

- The most popular LAN, popularly called Ethernet, is a wired LAN.
- While the older Bus-based topology enabled a Broadcast transmission, the newer version, Switched Ethernet, is based on many point-to-point links.





Local Area Network (LAN)

- Wireless LANs (WLAN) use an Access Point (Wireless Router) to transfer data packets between the devices and to the wired network.

Metropolitan Area Network (MAN)

- MAN is a privately owned network that operates within a single city.
- The current day MANs evolved from the Cable TV networks that were established in cities to overcome the poor over-the-air television reception.
- They used some unused part of the cable spectrum to provide 2-way internet service.
- Data Over Cable Service Interface Specifications (abbreviated as DOCSIS) is a globally-recognized telecommunications standard that enables high-bandwidth data transfer via existing coaxial cable systems.

Metropolitan Area Network (MAN)

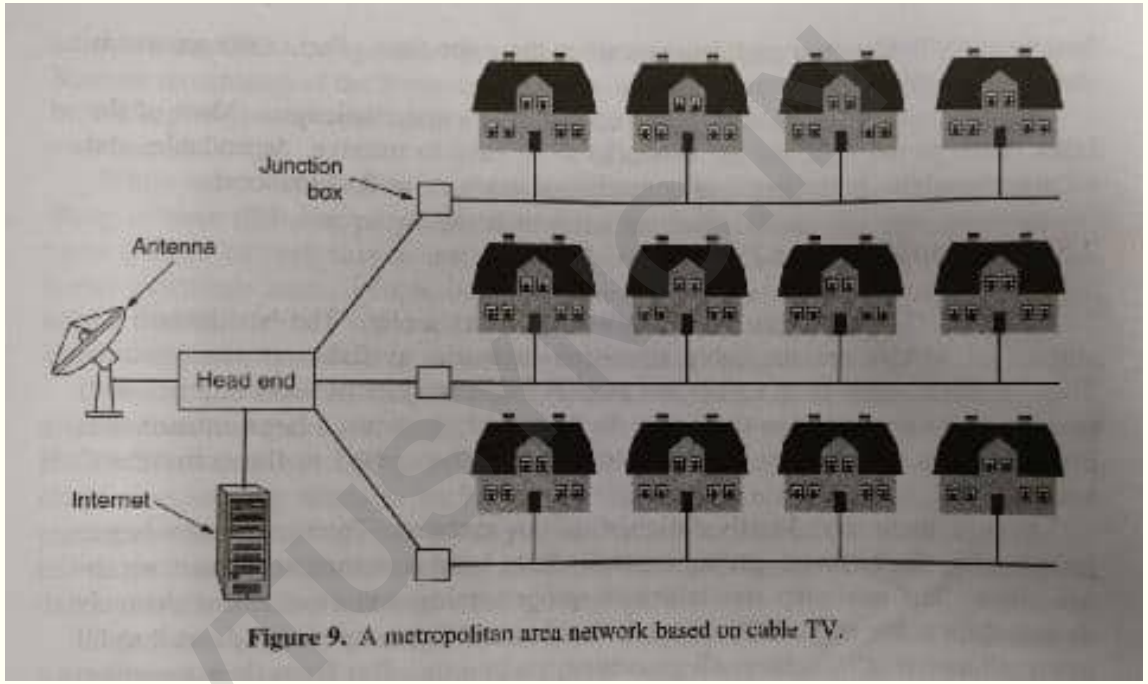


Figure 9. A metropolitan area network based on cable TV.

- WiMAX or Worldwide Interoperability for Microwave Access, is another MAN technology aimed at providing wireless data over longer distances (compared to WiFi) in a variety of ways.

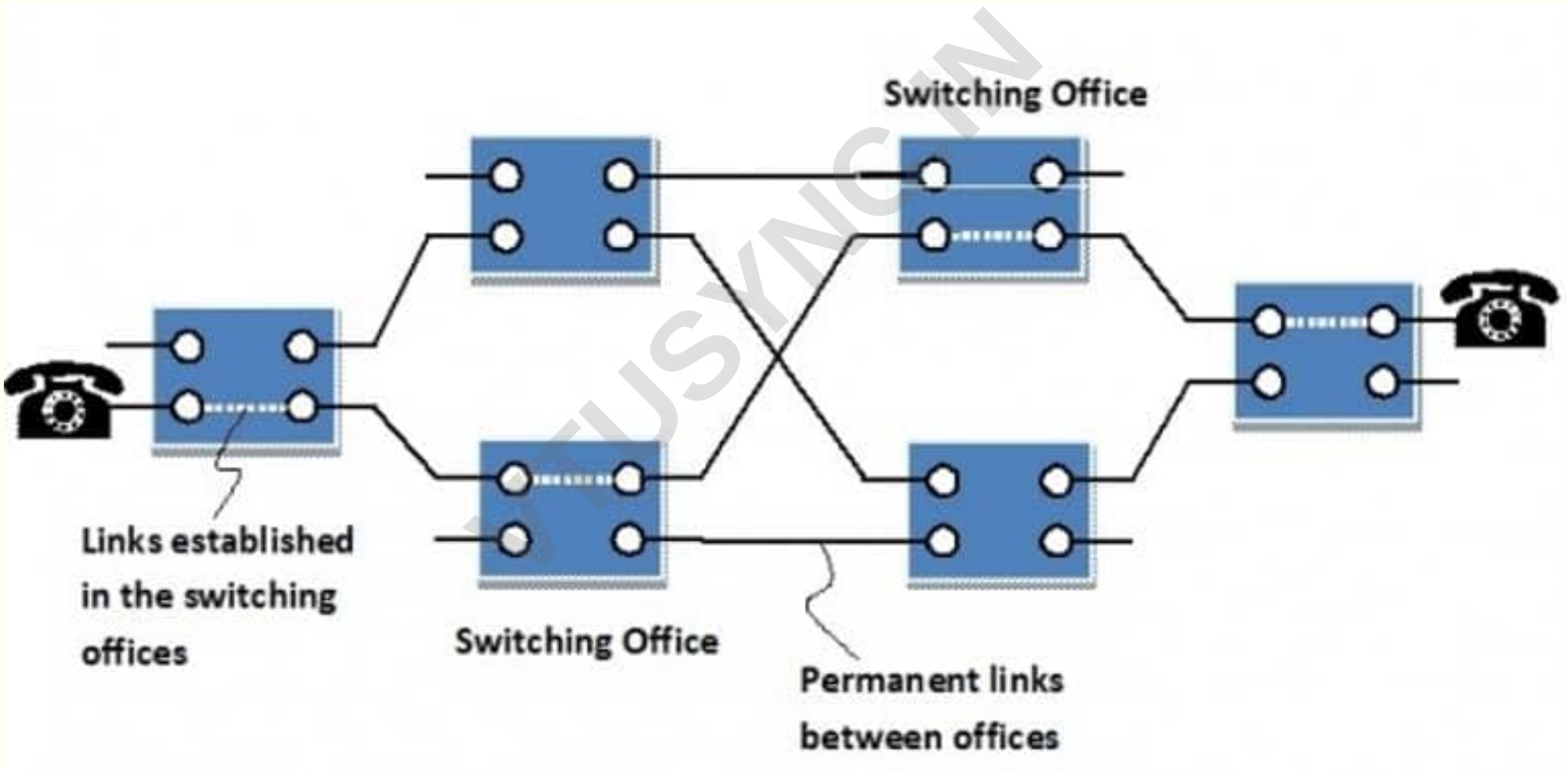
Wide Area Network (WAN)

- A WAN spans a large geographical are, often a country or a continent.
- The Internet is the interconnection of many WANs (who wish to be a part of it)
- The communication links and the switches (routers) that enable communication between the end devices (called 'hosts') together make up what is termed as sub-net.
- The transmission of messages is in the form of packets, using packet switching.
  - Voice messages are typically sent using Circuit switching.

Circuit switching

- A end-to-end connection is established before the message is transmitted.
- This is dedicated till the communication is disconnected (like a voice call).
- Results in low latency and zero jitter.
- Drawbacks:
  - Set-up time (to establish the connection);
  - A huge wastage of Bandwidth when the data transfer is 'bursty' (as it usually is).

Circuit switching



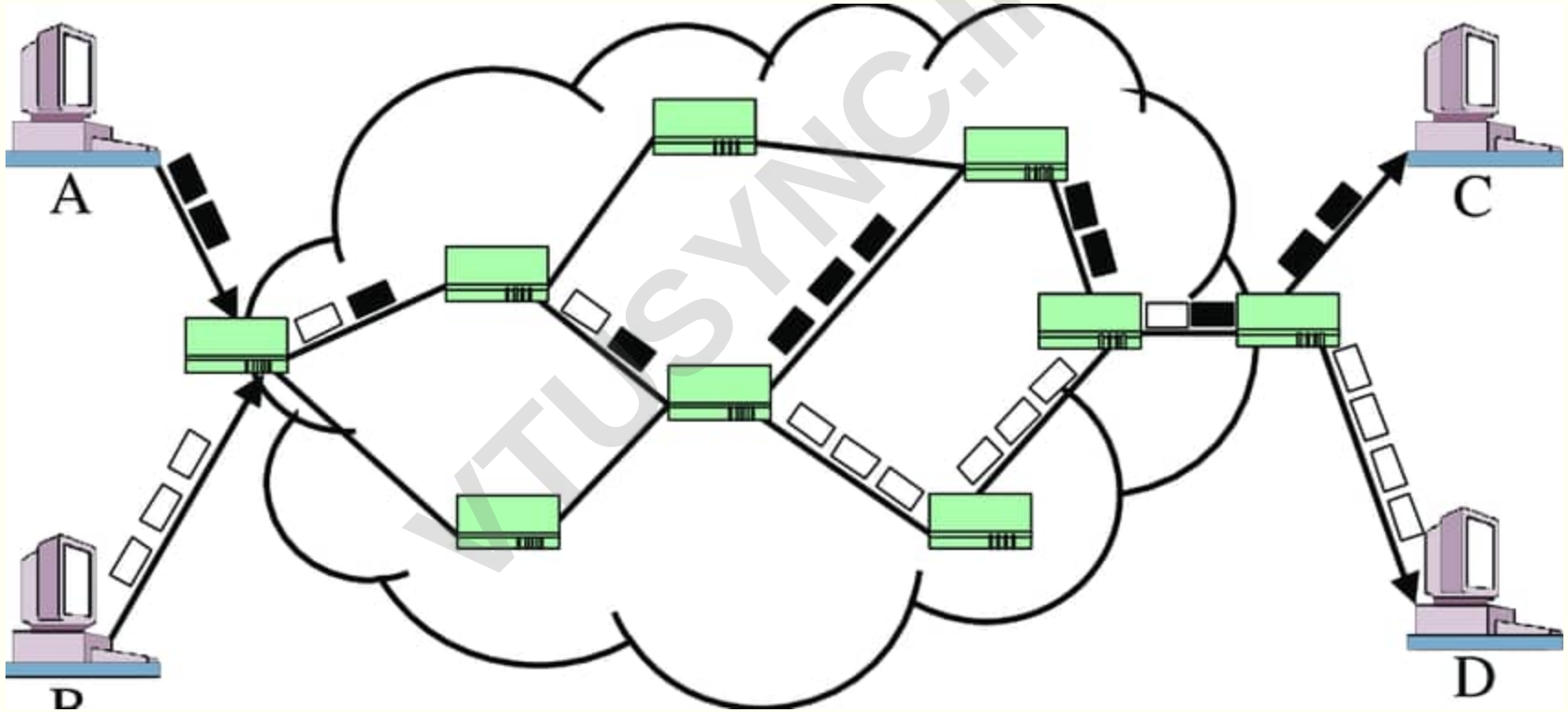
Packet switching

- There is no dedicated, end-to-end connection.
- The message is divided into small ‘packets’.
- Each packet has information of the message to which it belongs, as well as the destination address.
- They are received, processed and forwarded by routers in the network.
- At each router, an incoming packet is stored in a buffer (queue), processed (destination address is seen and analysed) and forwarded on the link that is seen as part of the best route to the destination.

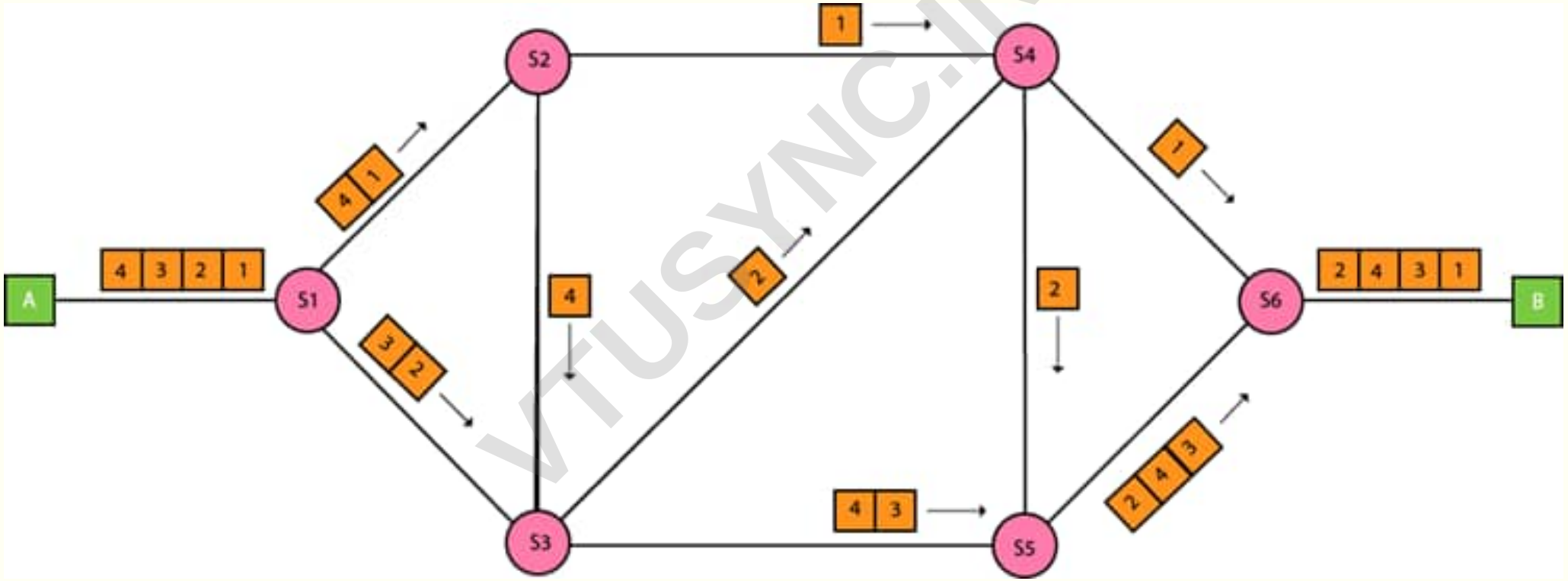
Packet switching

- Advantages:
  - Since the bandwidth of a link is not dedicated (but shared with packets from other hosts), the utilisation of the bandwidth is much higher.
  - No set-up time.
- Drawbacks:
  - Higher latency (due to waiting time at each of the routers).
  - Since different packets of the same message may take different routes, they may not all take the same time to reach the destination (Jitter).
  - Packets may not reach the destination in the proper sequence.

Packet switching – Hosts sharing the bandwidth



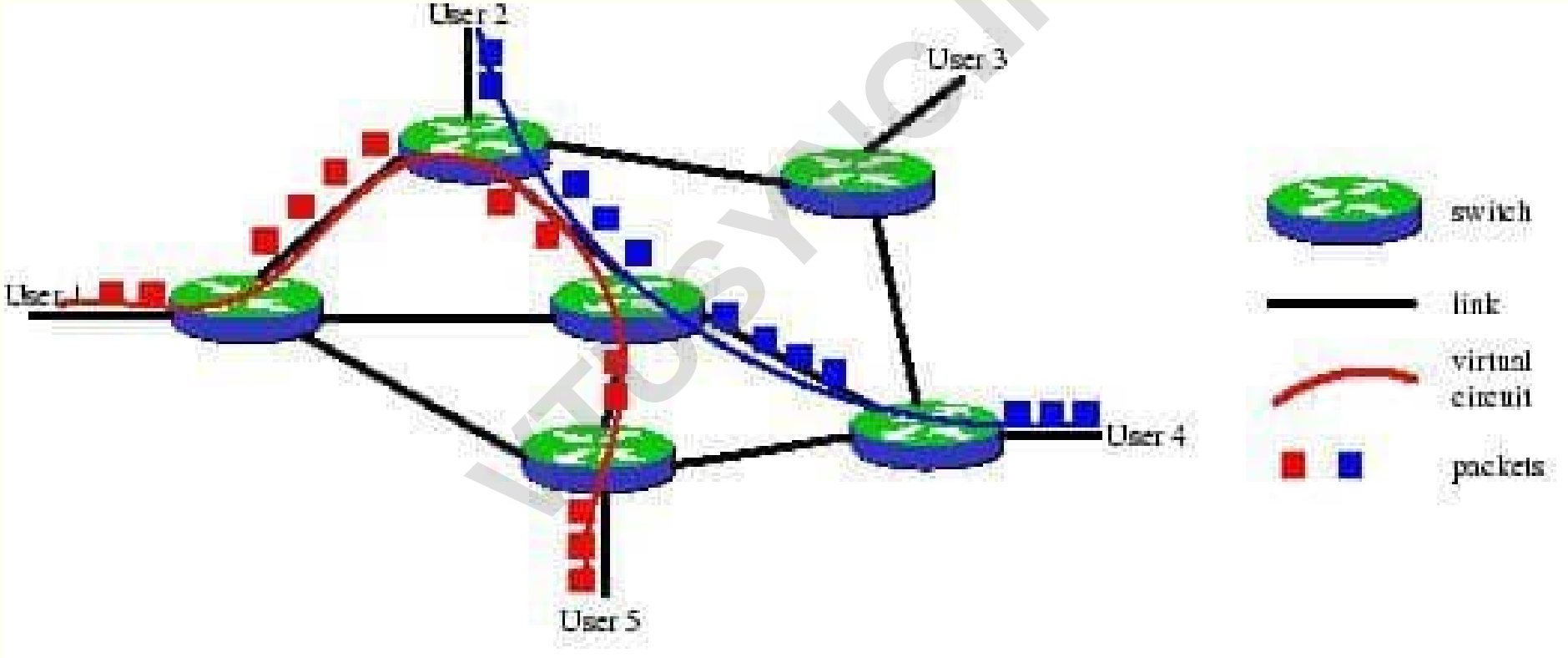
Packet switching – Packets not arriving in sequence



Virtual Circuit (VC) Packet switching

- The Datagram Packet Switching explained earlier is used on most WANs, including the Internet.
- In another method, called Virtual Circuit Packet Switching, all the packets of a message take the same route (called the Virtual Circuit or VC).
- This route is decided before the first packet is transmitted and the routing information conveyed to the routers (they are called Switches in this case) along the route.
- Each router (switch) examines the VCI (VC identifier – a globally unique number) in the packet and forwards it on the appropriate link.

Virtual Circuit (VC) Packet switching



Virtual Circuit (VC) Packet switching

- Here, packets will always arrive at the destination in proper sequence.
- However, some time has to be spent in the beginning to establish the VC and perform the 'handshake' with the receiver (informing about the transfer of message packets with a particular VCI).
- In a variation called Permanent Virtual Circuit (PVC) Packet Switching, the VC need not be identified for each message between A and B. It is fixed forever, unless changed.
- This is used, for example, to connect 2 offices with a lot of continuous data flow between them.

Virtual Circuit (VC) Packet switching

- As part of the deal with the network operator, a certain QoS is ensured.
- QoS parameters generally include a minimum Bandwidth and an average Bandwidth, along with an average transmission time.
- VC networks are relatively costly to implement.

Network Reference models

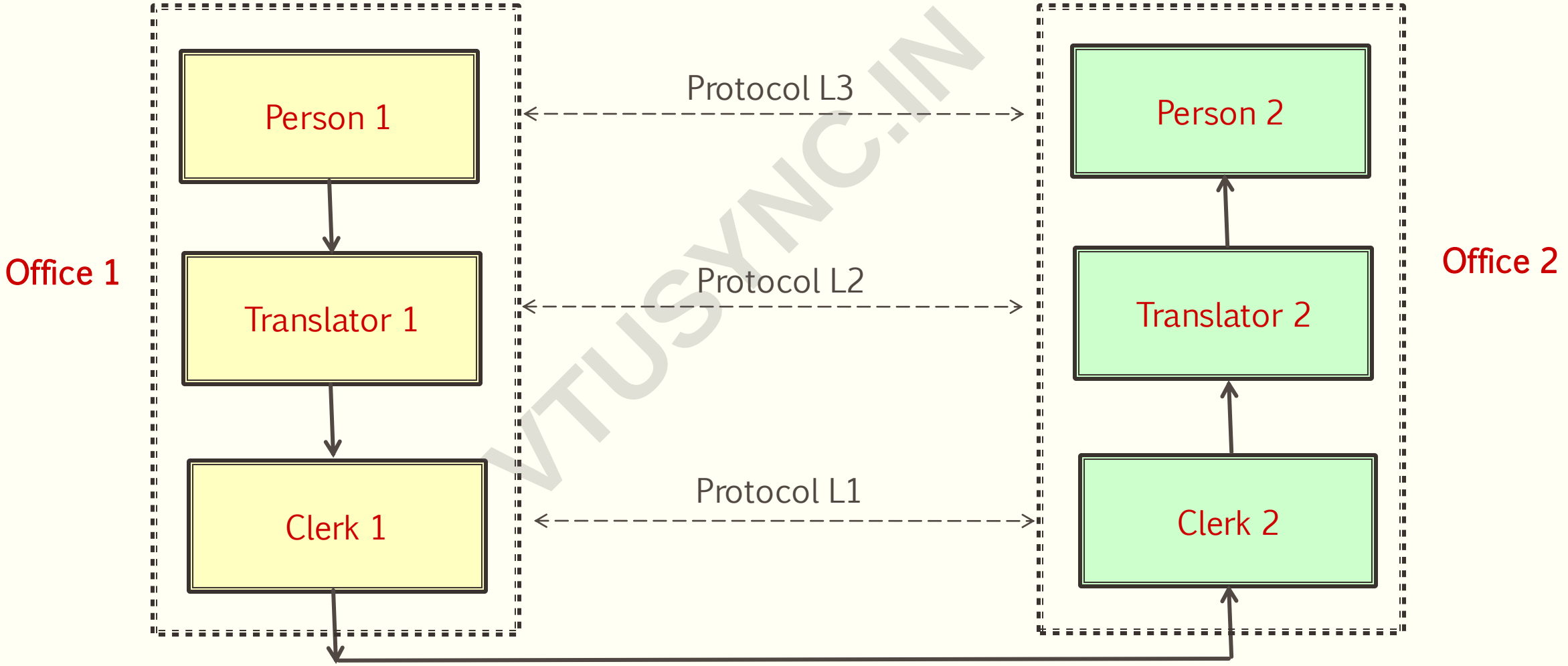
OSI Reference model

- The OSI (Open Systems Interconnection) model, created in 1984 by ISO, is a reference framework for the design of networks.
- The task of transmitting data between computers is divided among seven ‘layers’.
- While the hosts have all the 7 layers implemented in them, other devices may have less than 7 layers.
- The model adopts a Hierarchical format.

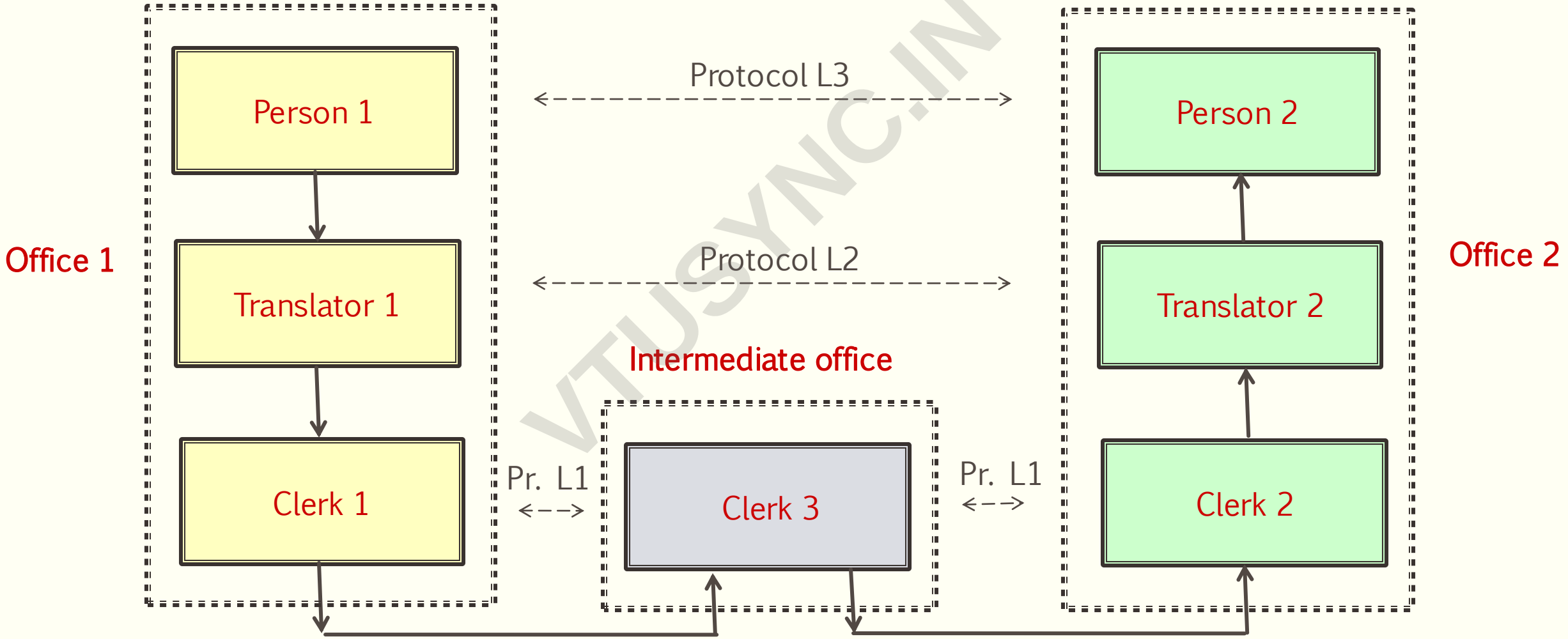
OSI Reference model

- Main characteristics:
  - Each layer has a well-defined function to accomplish.
  - Each layer is implemented with a combination of hardware and software.
  - A lower layer provides a service to the one above it (in the hierarchy).
  - Each layer has it's own Protocol, that is transparent to the layers above it.
  - The OSI Reference Model only provides a framework and does not define the actual implementation or the protocols to be used.

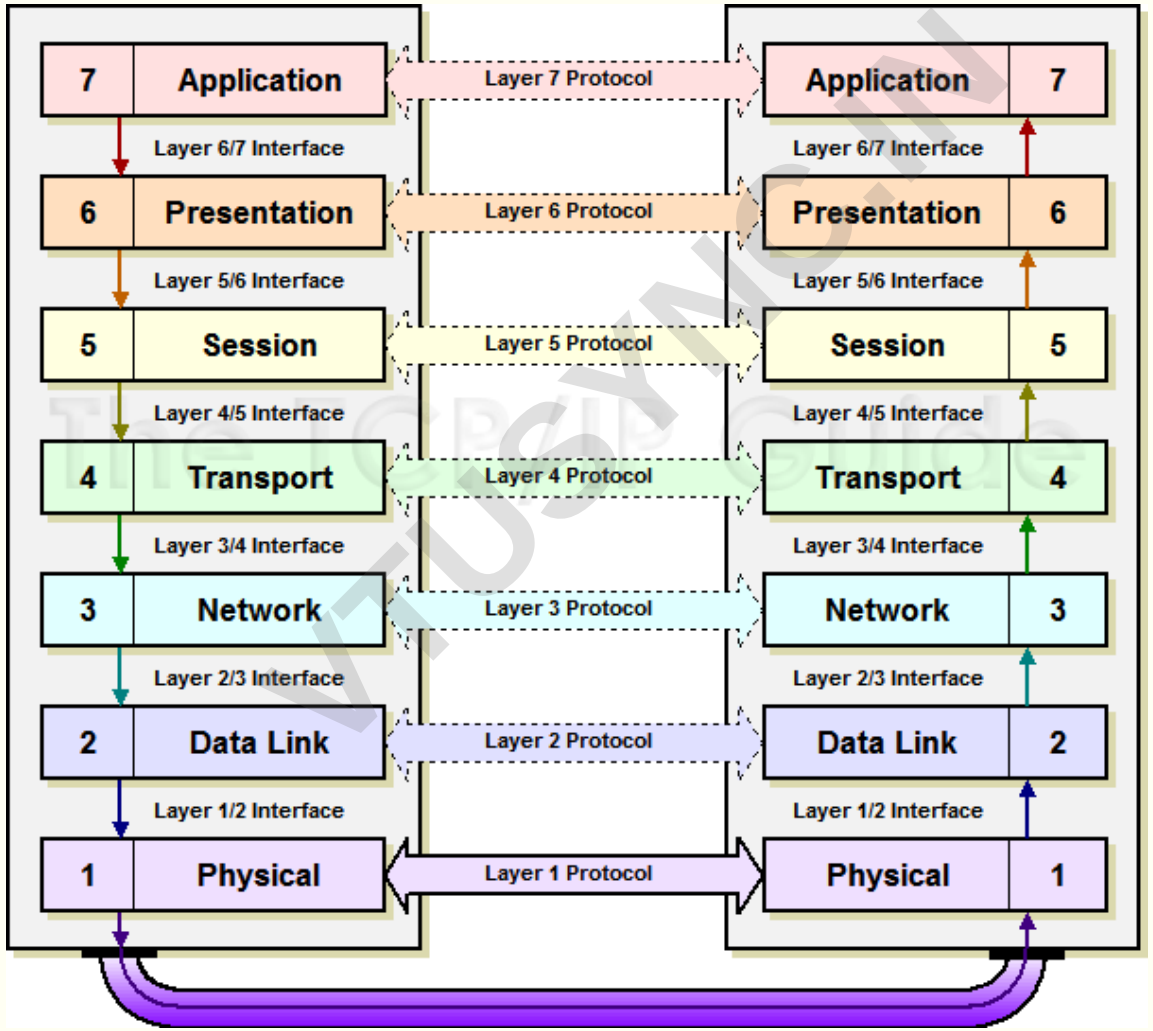
A communication model



A communication model



OSI Reference model



Application layer

- This layer provides the user interface by using various applications (Browsers, Messengers, etc)
- Functions:
  - File management by allowing users to access, retrieve and manage the files on a remote computer.
  - Allows users to send and receive emails.
  - Provides distributed database sources and global information about several objects.
- Protocols used: SMTP, POP3, FTP, HTTP, SNMP.

Presentation layer

- This layer is responsible for converting data into a format that is understood understood by the network components.
  - For example, translation of the characters using ASCII or EBCDIC.
- At the transmitter side, it encrypts the data, and decrypts it back into plain text on the receiver side.
  - Protocols used: RSA, AES, DES, etc
- It compresses data and reduces the number of bits needed for network transmission.
  - Protocols used: JPEG, MPEG, GIF, etc

Session layer

- **Functions of the Session Layer:**
- The layer takes care of the establishment, use, and termination of a connection.
- It adds checkpoints as synchronization points into the data for identifying the errors easily and thus avoiding data loss at the end points.
- It also decides whether the 2 systems interact with each other in half-duplex or full-duplex mode.

Transport layer

- It takes complete responsibility for the end-to-end delivery of the message.
- It accepts data and breaks it down into smaller units (called 'segments') while sending. It reassembles the segments on the receiving side.
- It follows a service point (Port) address to deliver the message to the correct process; Multiple processes could be running in the PC at the same time.
- It takes care of Flow Control and thus prevents a fast sender from swamping a slow receiver.
- This layer provides the reliable Connection-oriented service (TCP protocol) as well as the not-so-reliable Connectionless service (UDP protocol).

Network layer

- **Functions of the Network Layer:**
- **Routing:** The network layer protocols determine the 'best' route to take the packets (segment + network layer header) from source to destination.
  - These protocols work between 2 adjacent network devices like routers.
- **Congestion control:** To ensure a smooth and orderly flow of data across the network.
- **Logical Addressing:** The network layer defines and implements an addressing scheme (IPv4, IPv6) to uniquely identify every single device on the Internet.

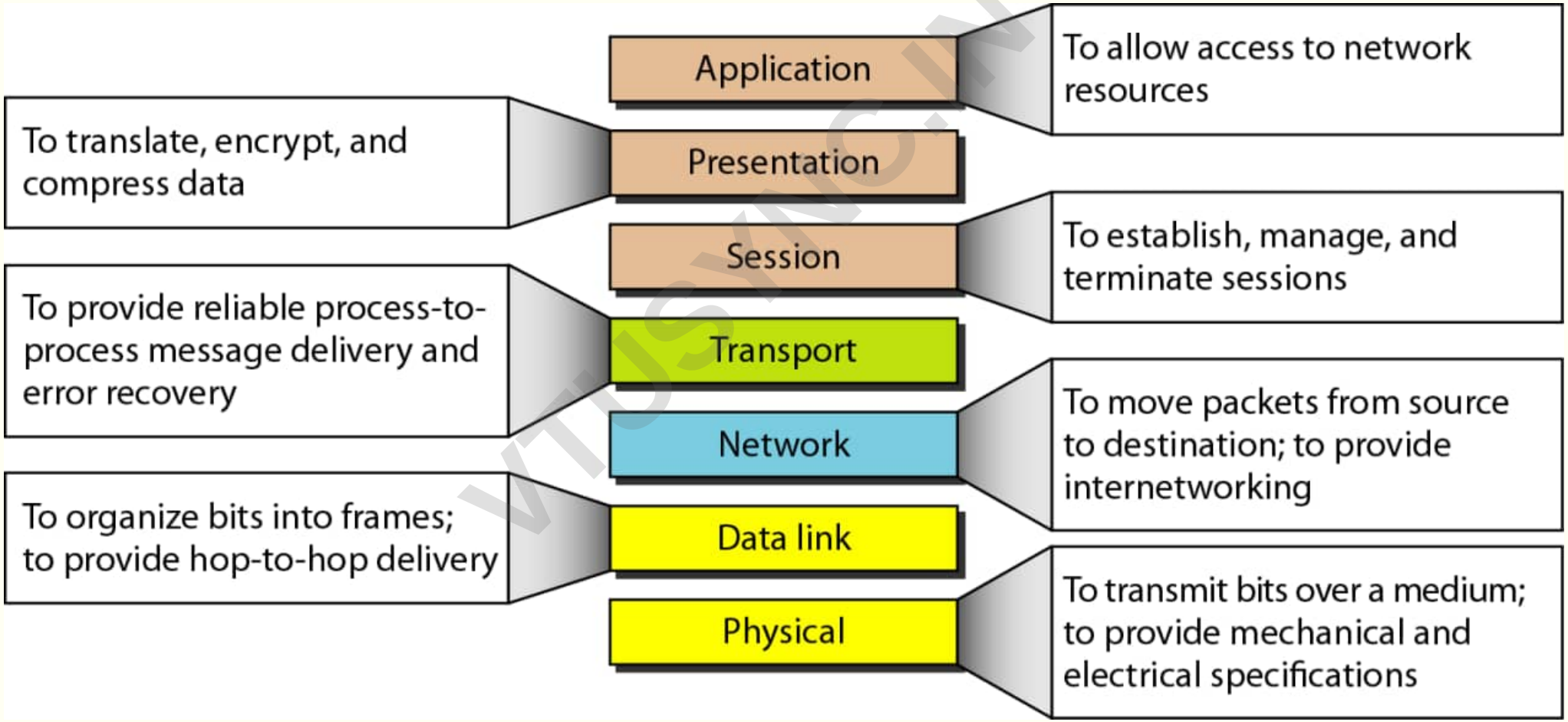
Data link layer

- It frames the data in a way that is meaningful to the receiver using special bit patterns.
- It adds physical (MAC) addresses of both sender and receiver in every frame.
- This layer controls error by using error-detection and error-correction codes.
- It controls the data flow over a link.
- When a single communication channel is shared by multiple devices, the MAC sub-layer of the data link layer helps to determine which device has control over the channel at a given time.

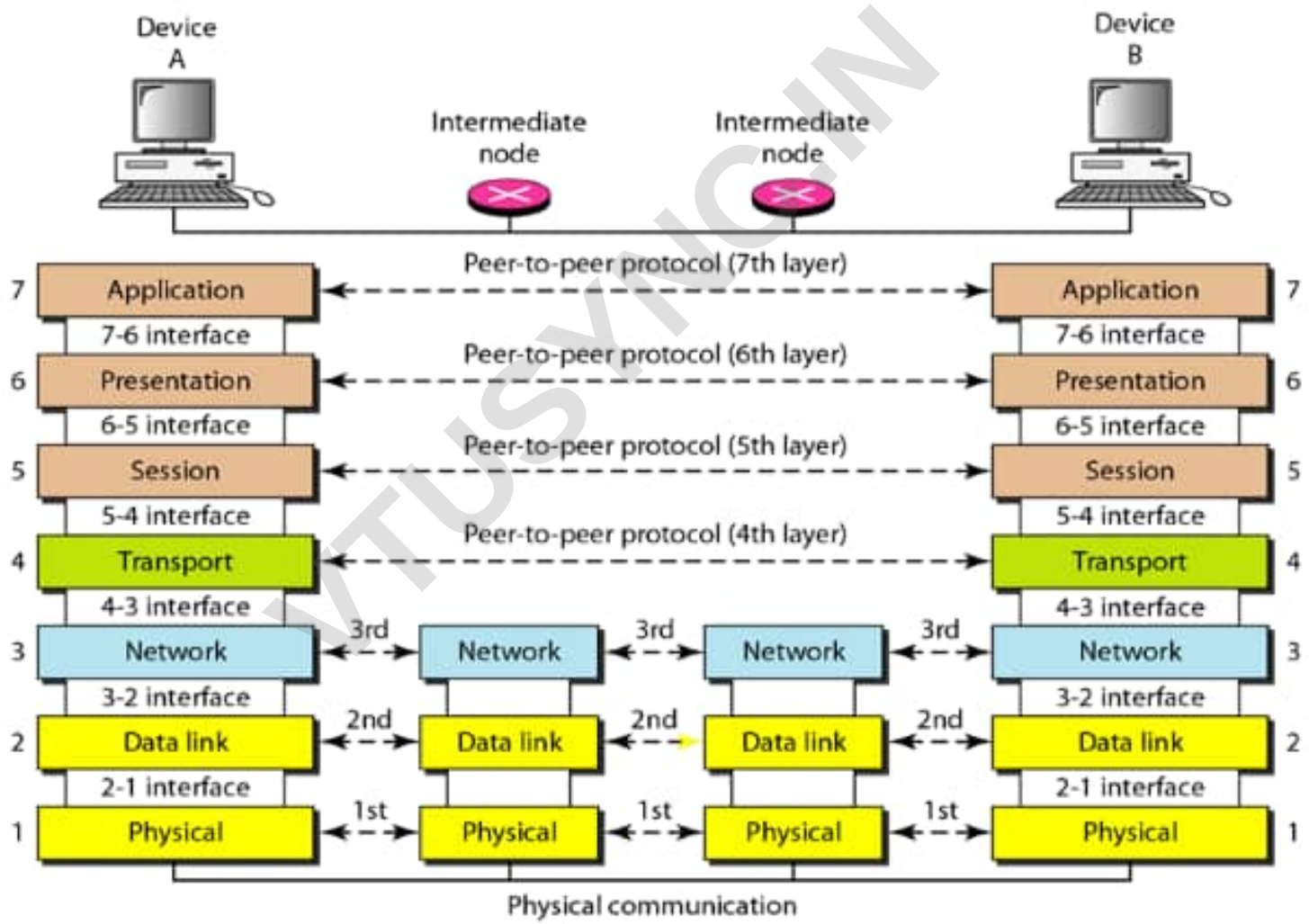
Physical layer

- It converts the bits into appropriate signals (electrical, optical, electromagnetic waves, etc) to be transmitted on the physical transmission medium.
- It enables bit synchronization using a clock to prevent loss of bits.
- It determines the transmission rate / bit rate (bits sent per second).
- It decides the ideal topology for interconnection of the nodes (Bus, Star, Mesh, etc)
- The physical layer consists of – Hub, Repeater, Modem, and Cables.

OSI Reference model



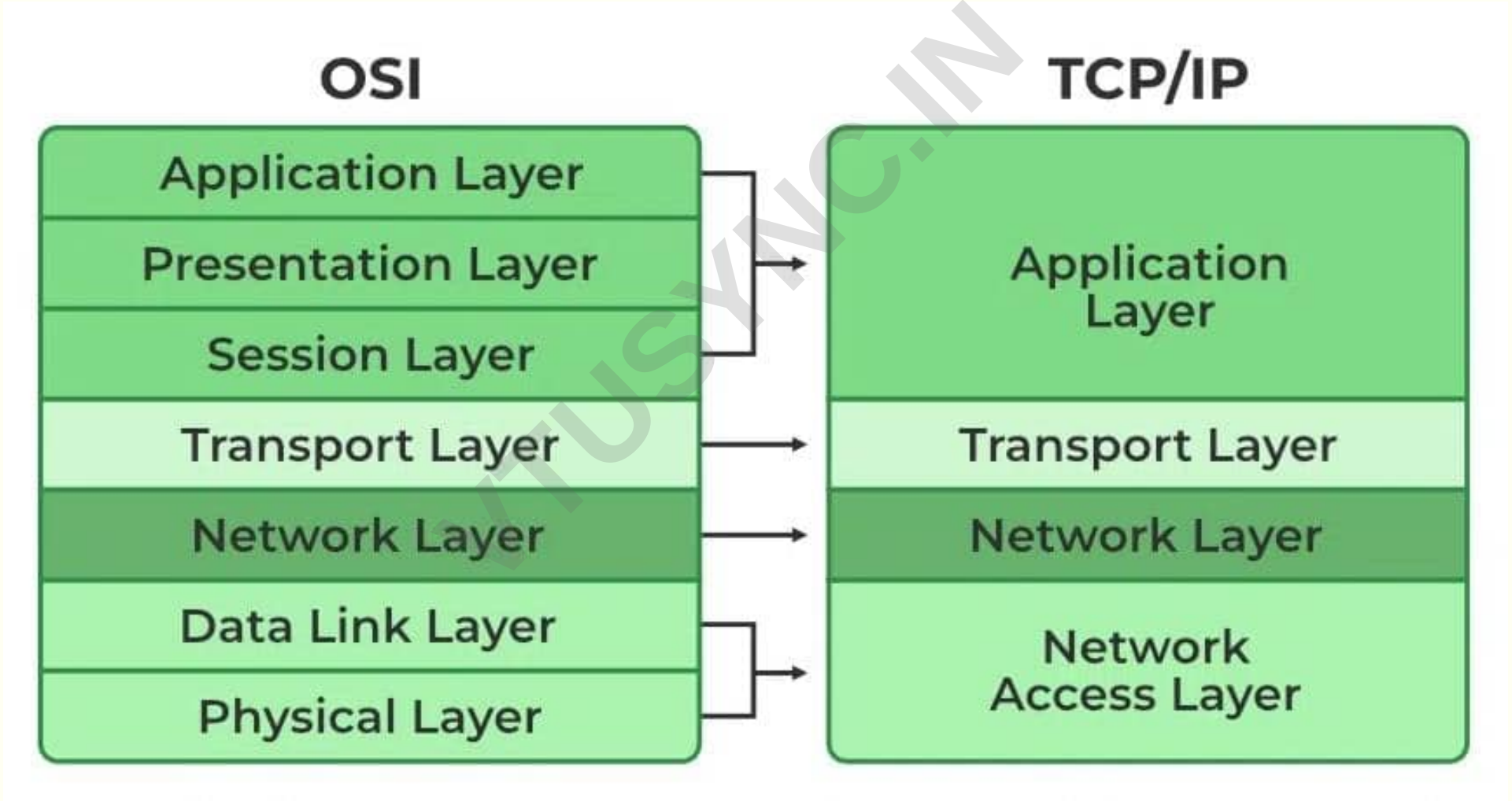
OSI Reference model



TCP/IP Reference model

- It defines just 4 layers, unlike the 7 layers of OSI model.
- This model, defined in the 1960's (much before the OSI model), is widely used (including on the Internet).
- The top 3 layers of the OSI Reference model are combined into one layer here.
- Similarly, the lowest 2 layers of the OSI model are combined into one layer.
- OSI model tried to segregate the various functions as minutely as possible; But in practice, there were a few ambiguities and overlaps between the functions of adjacent layers.

TCP/IP Reference model



Physical layer - Transmission media

Transmission media

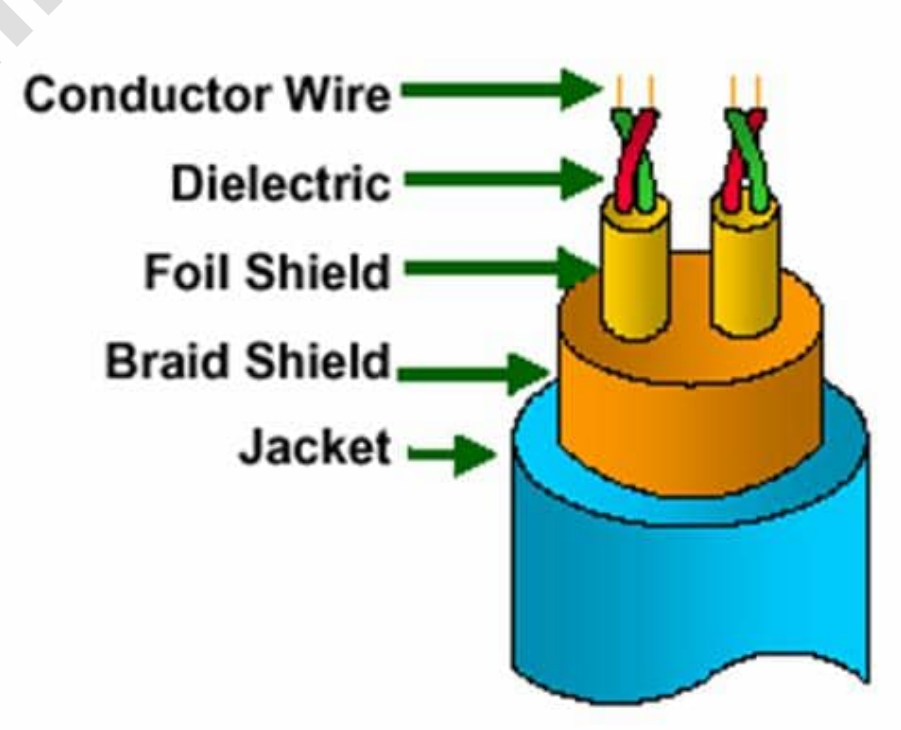
- The transmission medium carries the message from the transmitter to the receiver.
- Common transmission media:
  - Twisted wire pair (TWP)
  - Coaxial cable (Coax)
  - Optical fibre
  - Space (Wireless transmission)
- The transmission medium is also referred to as Communication Channel or Link.

Transmission media

- Wire pair
  - carries message in the form of an electrical signal.
- Coaxial cable
  - carries message in the form of an electrical signal.
- Space
  - The message travels through space as an electromagnetic signal.
- Optical fiber
  - The optical fiber carries the message as a light signal.
  - It has a very high bandwidth and very low error rate.

Twisted wire pair

- One of the oldest and least expensive media.
- Extensively used in the last-mile connectivity in landline telephone networks.
- Low bandwidth compared to Coax and fibre.
- Also used in LANs (to connect PCs to the Hub).



Coaxial cable

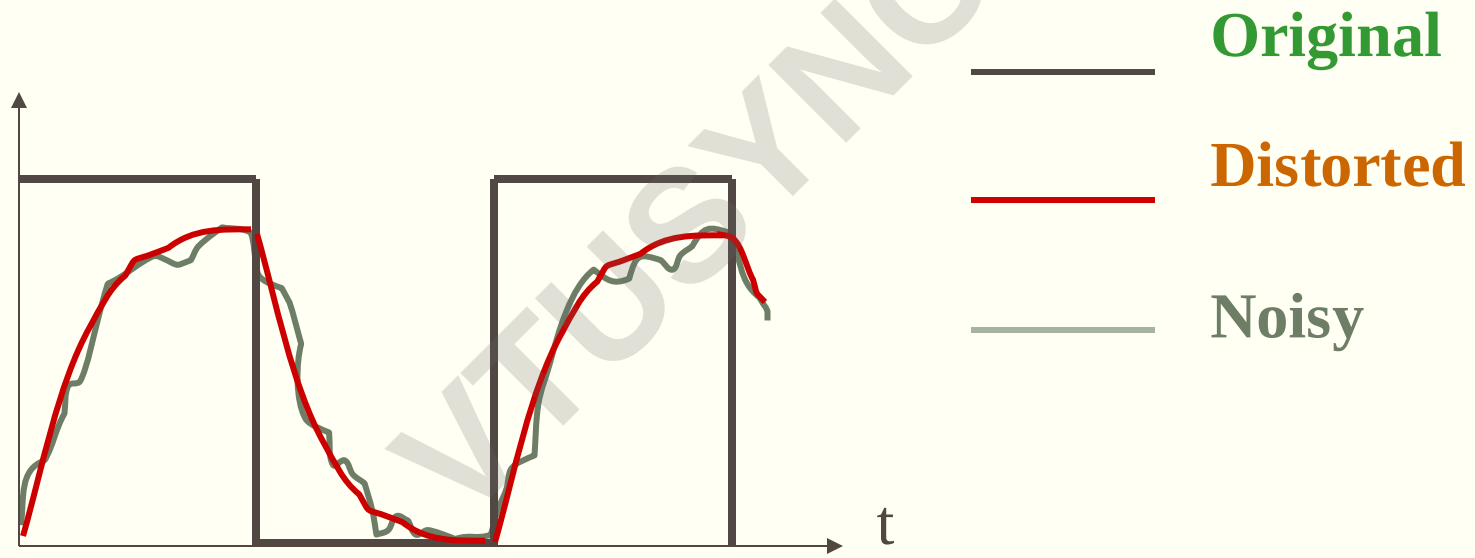
- Was widely used on the trunk routes in the telephone system.
- Much higher bandwidth and better noise immunity, compared to wire pairs.
- Also used in Cable TV networks, and as a Bus in the older Ethernet LANs.

Distortion, noise and errors on copper lines

- The electric signals sent on copper lines (wire pair and coax cables) suffer from:
  - Power loss (attenuation)
  - Distortion of the sharp pulses (representing the 1's and 0's)
  - Electrical Noise from the environment.
- Distortion in a signal is the change of the shape or some other characteristic of the waveform. It depends on the characteristics of the media.
- Noise is an external random (unpredictable) signal added to the original signal.

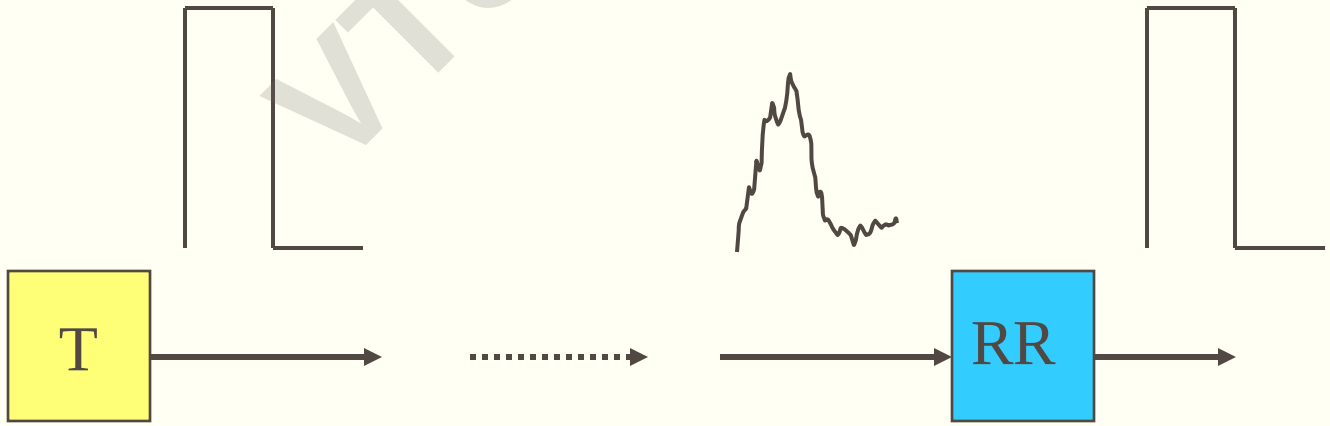
Distortion, noise and errors on copper lines

- All the 3 factors increase with the distance travelled.



Distortion, noise and errors on copper lines

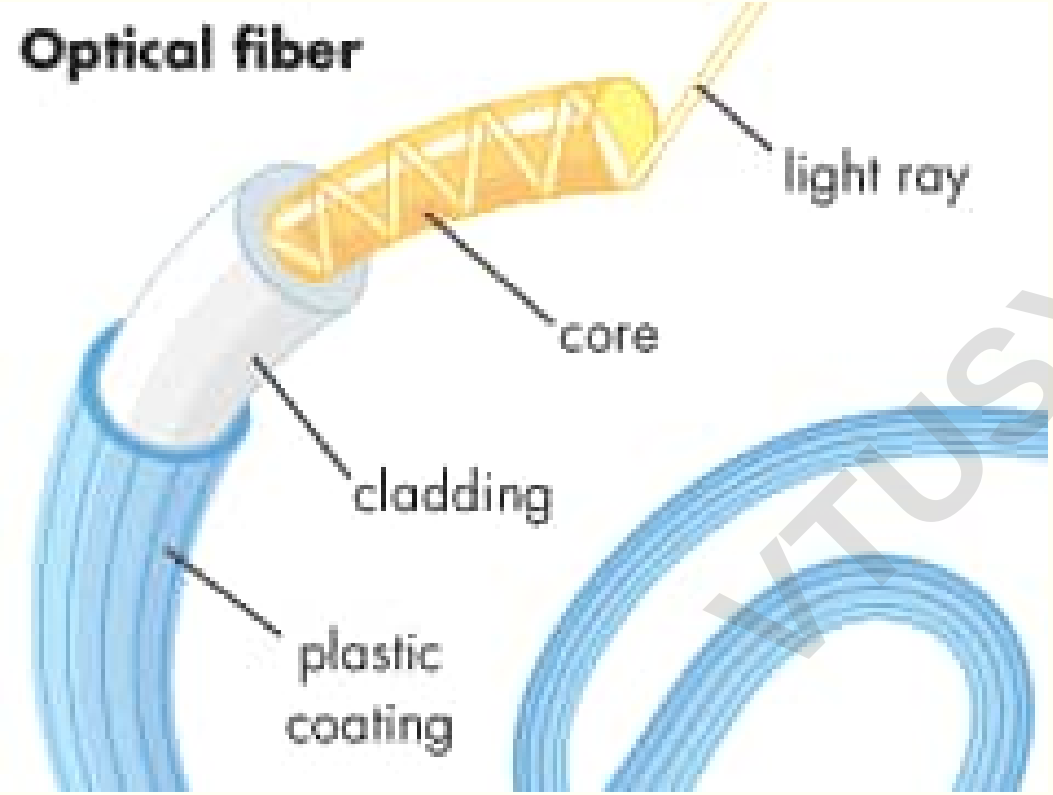
- The first 2 parameters can be dealt with by using Regenerative Repeaters
- Repeaters receive weak and noisy signals and retransmit strong and clean pulses.
- Transmission errors occur mainly because of impulsive noise (that cannot be predicted or controlled).

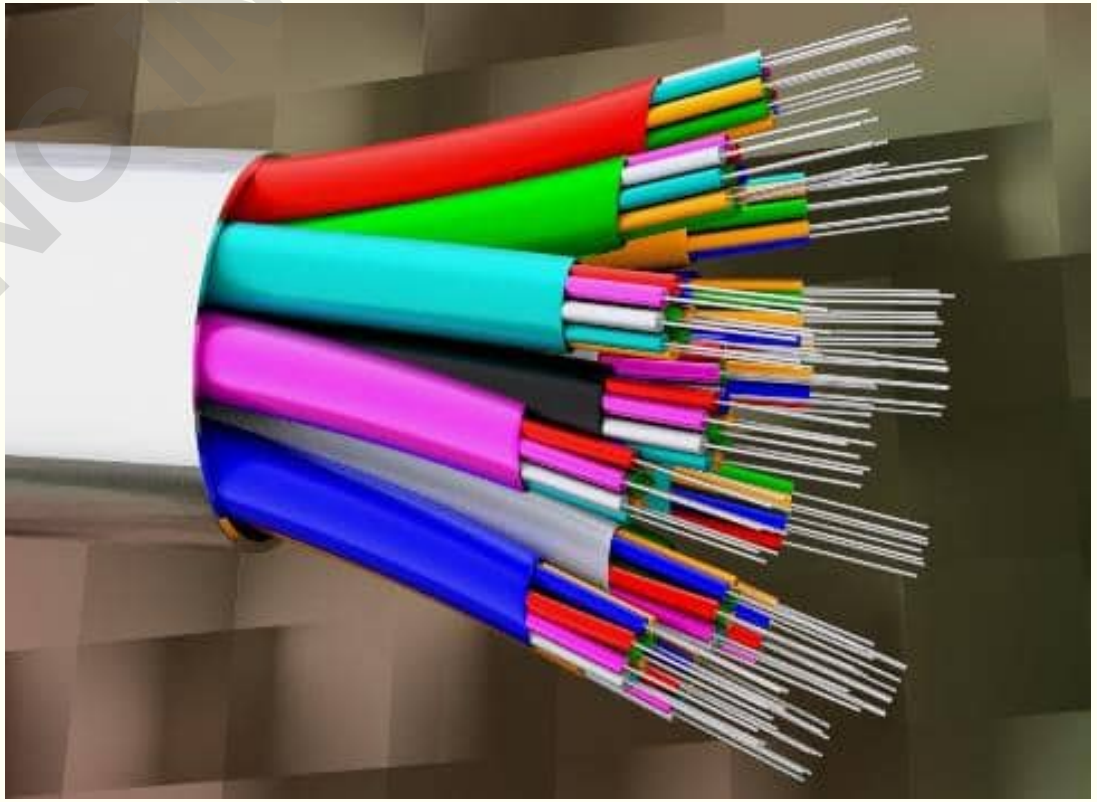


Optical fibre

- It consists of a transparent core and a cladding around the core.
- The refractive index of the cladding is higher than that of the core.
- The electrical signal is converted to a light signal by means of a specialised LED or Laser, and is then transmitted into the core of the fibre.
- The light signal propagates in the core due to "Total Internal Reflection", even around bends.
- They offer a high bandwidth and have a very low Error Rate (10^{-12} and 10^{-14})
- The power loss is also very low, thereby needing fewer 'regenerative repeaters' along the way.

Optical fibre





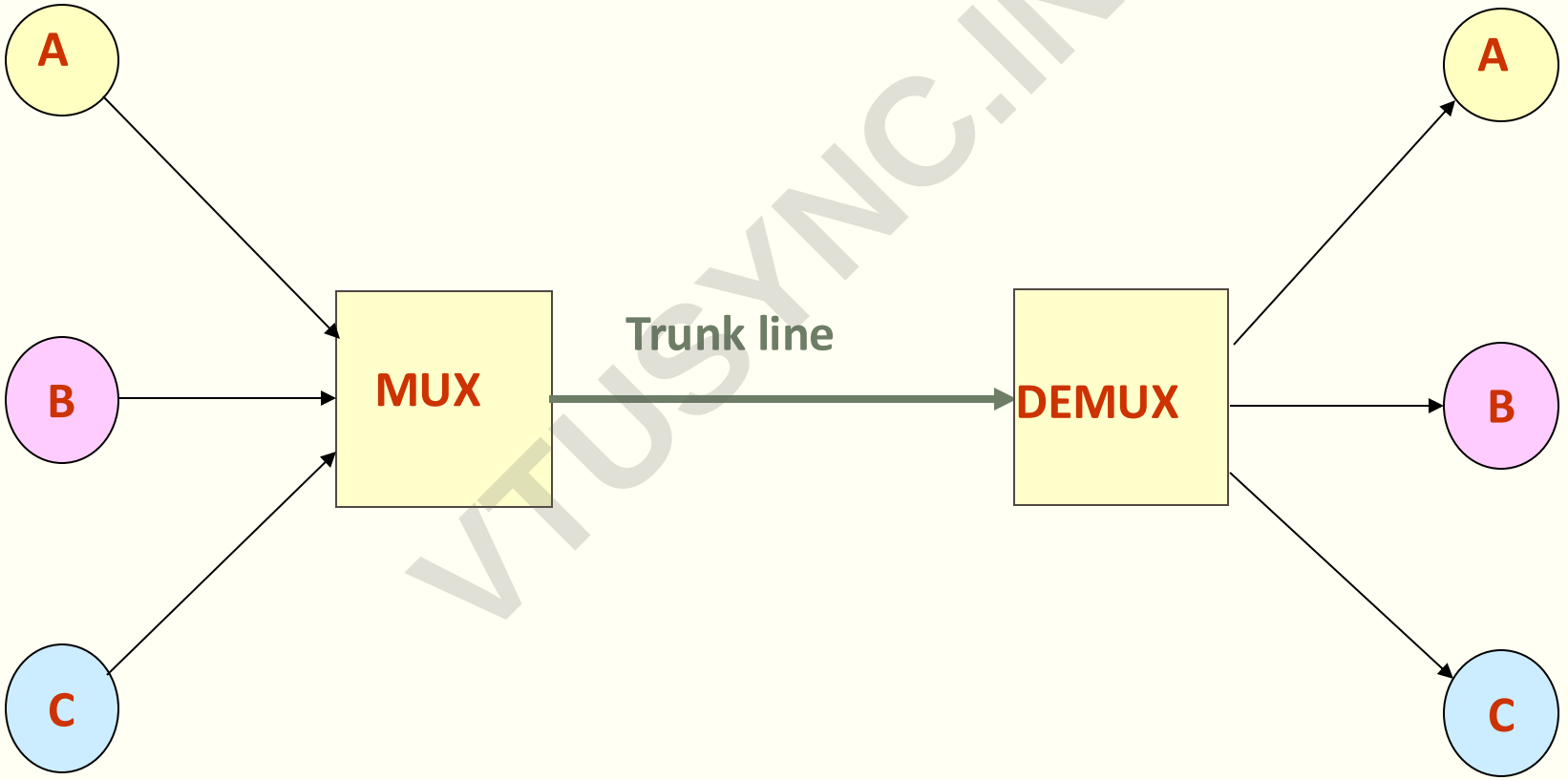
Wire-line versus Wireless transmission

Parameter	Wire-line	Wireless
Bandwidth	Virtually unlimited	Limited to spectrum
Error rate	Low to very low	High
Security	Highly secure	Less secure
Cost (media)	Low to medium	High Spectrum license fees
Cost (installation)	High	Very low
Reach	Limited	Virtually anywhere
Mobility to users	No	Possible

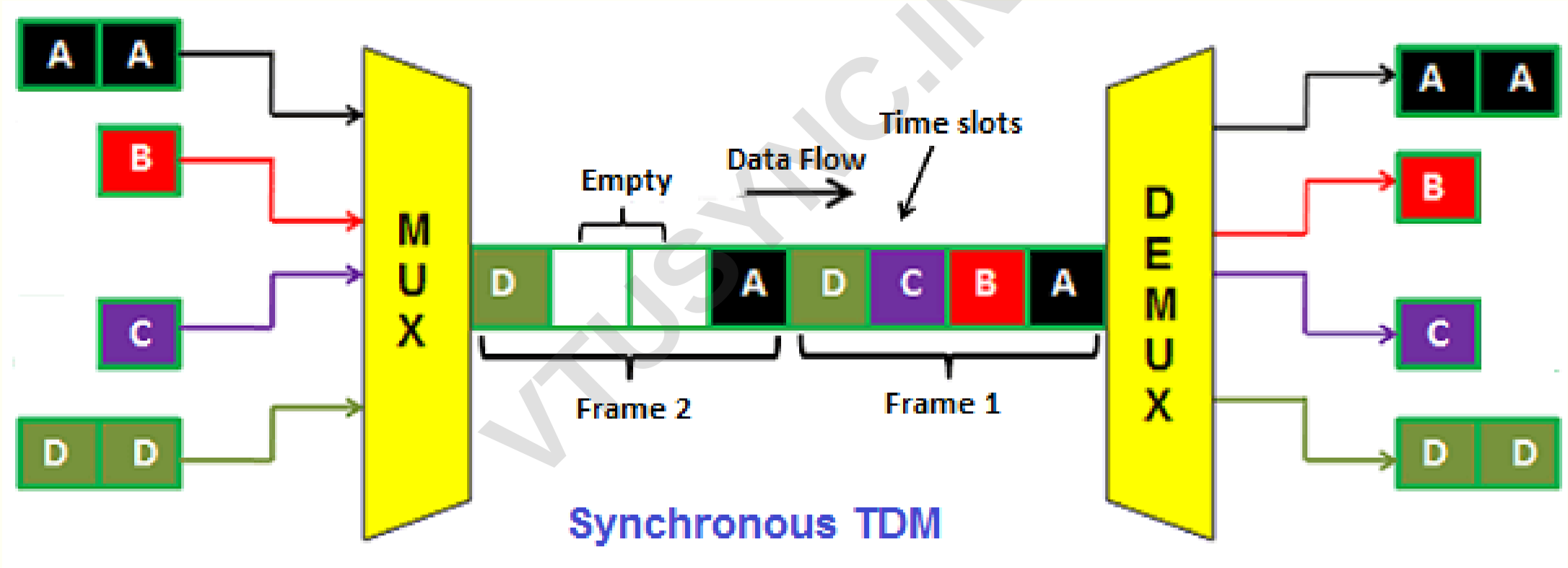
Multiplexing

- It involves combining many signals, arriving on as many connections, on to a single, larger capacity transmission line.
- It results in a huge cost saving and better utilization of the large bandwidth.
- Common types of multiplexing :
  - Time Division Multiplexing (TDM)
    - Different signals are transmitted in different time-slots
  - Frequency Division Multiplexing (FDM)
    - Different signals are transmitted using different frequencies
  - Wavelength Division Multiplexing (WDM)

Multiplexing



Time Division Multiplexing (TDM)



Space

- Transmitting antennas convert the electrical signal to an electromagnetic signal, of a particular assigned frequency, and is then radiated into space.
- The receiving antenna would convert the e.m. signal to an electrical one.
- Space (wireless) transmission is used in many applications:
  - Radio and TV broadcasts
  - Microwave transmission
  - Satellite communication
  - Cellular (phone) networks
  - Navigation (airplanes and ships), ….

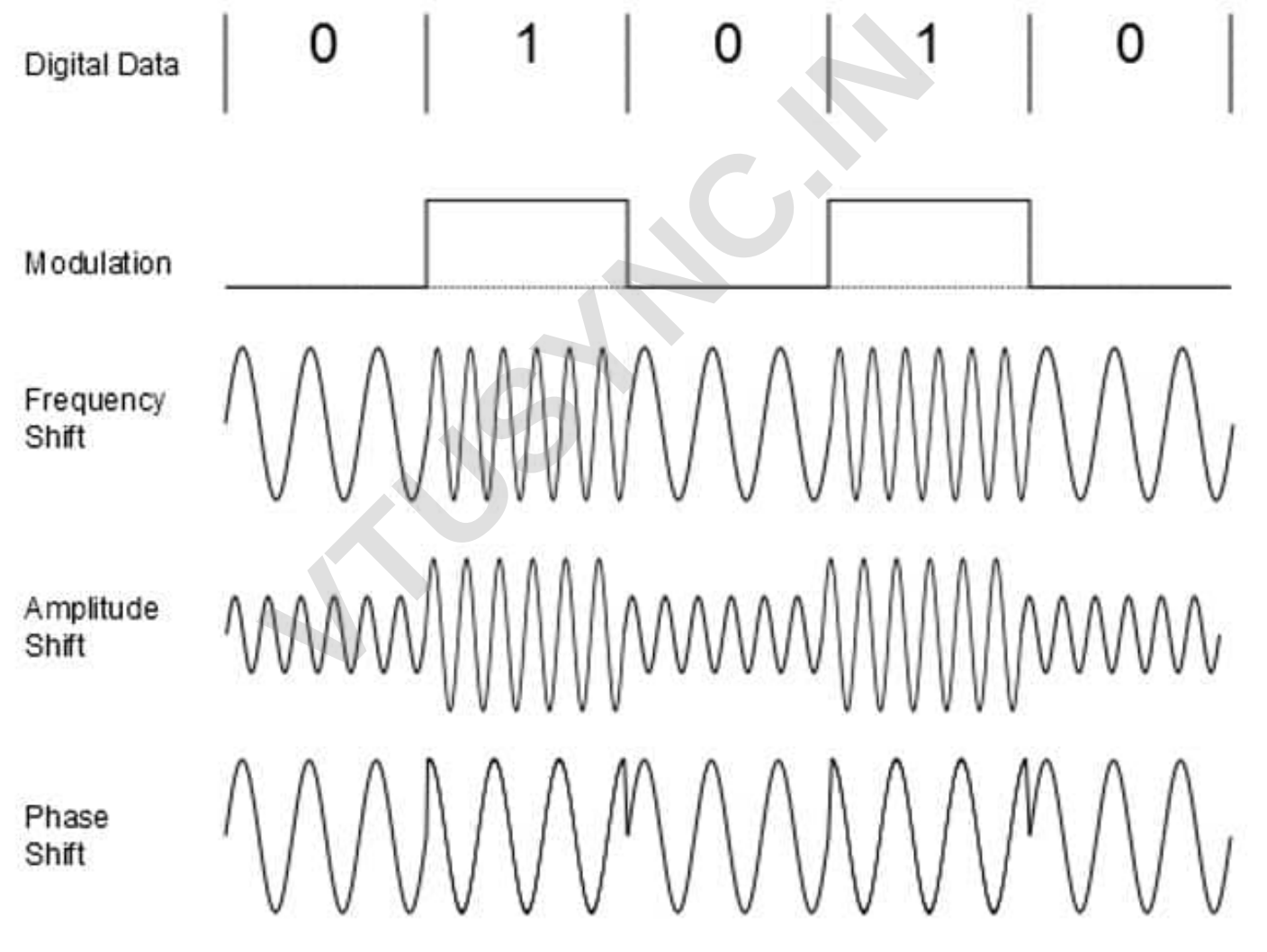
Modulation

- Modulation is the process of varying one or more properties of a periodic, high-frequency waveform, called the carrier signal, with a separate signal called the modulation signal that typically contains information to be transmitted.
- Modulation is done to make the digital signal suitable for long distance transmission on the media (both wireline and wireless)
- In the case of wireless transmission, this takes care of sending multiple messages in the same space, as well as to reduce the power loss.
- In the case of wireline transmission, modulation helps implement FDM.

Types of Modulation

- Analog modulation techniques (when the message is Analog):
  - Amplitude Modulation (AM)
  - Frequency Modulation (FM)
  - Phase Modulation (PM)
- Digital modulation techniques (when the message is Digital):
  - Amplitude Shift Keying (ASK)
  - Frequency Shift Keying (FSK)
  - Phase Shift Keying (PSK)

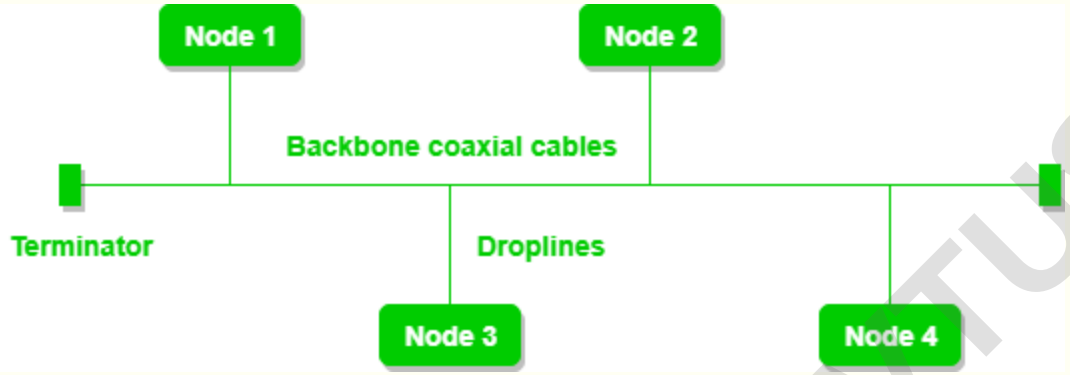
Digital Modulation techniques



Network topologies

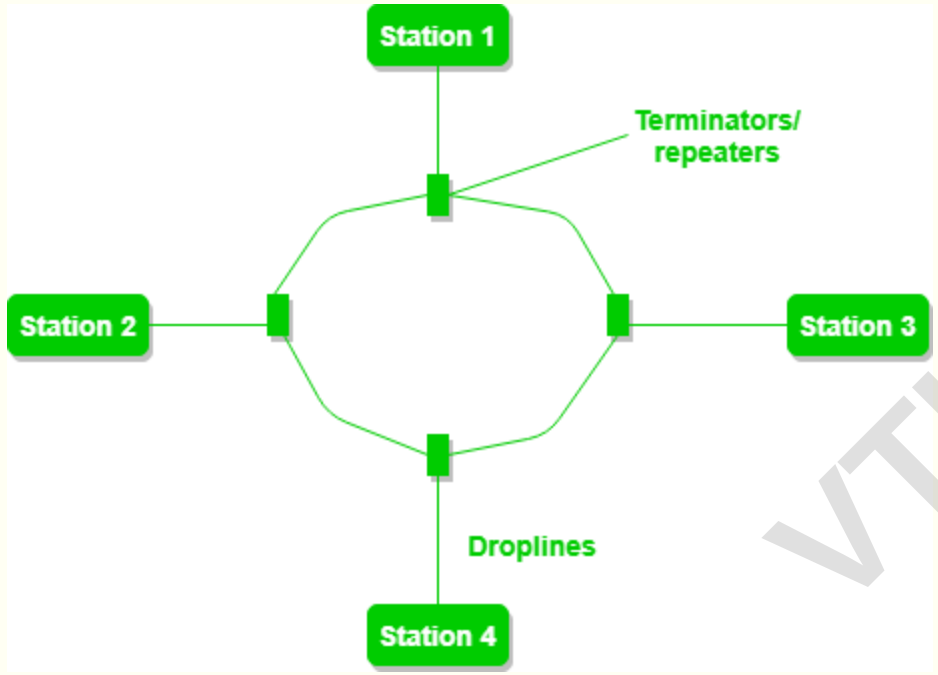
- Topology refers to the way the various devices are connected in a network.
- Common topologies are:
  - Bus topology;
  - Star topology;
  - Ring topology;
  - Mesh topology.
- While the first 3 are used in a LAN or MAN, the Mesh topology is used in the WAN.

Bus topology



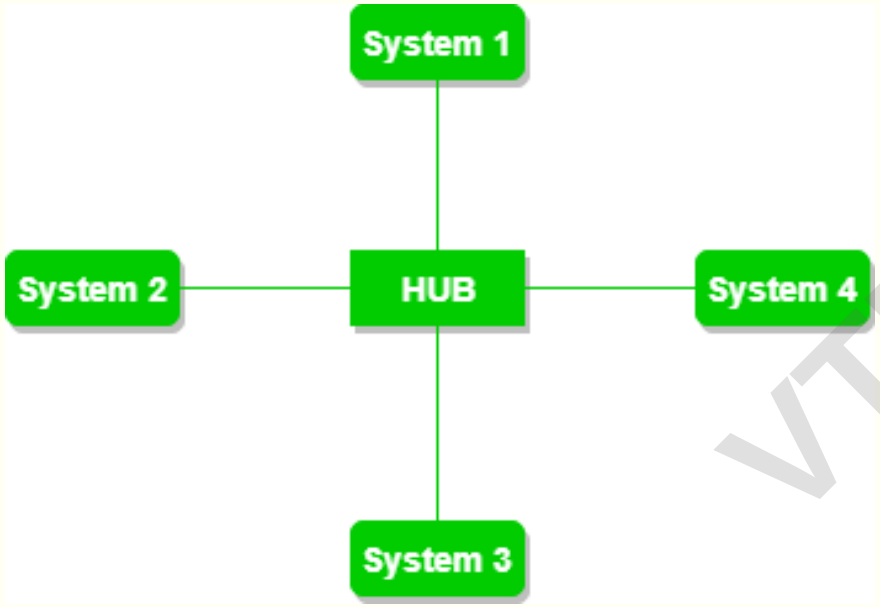
- Every network device is connected to a single, bi-directional cable
- It is a broadcast in nature.
- Not a robust topology because if the backbone (Bus) fails the network crashes.
- Various MAC (Media Access Control) protocols are followed to allow the devices to transmit on the Bus.

Ring topology



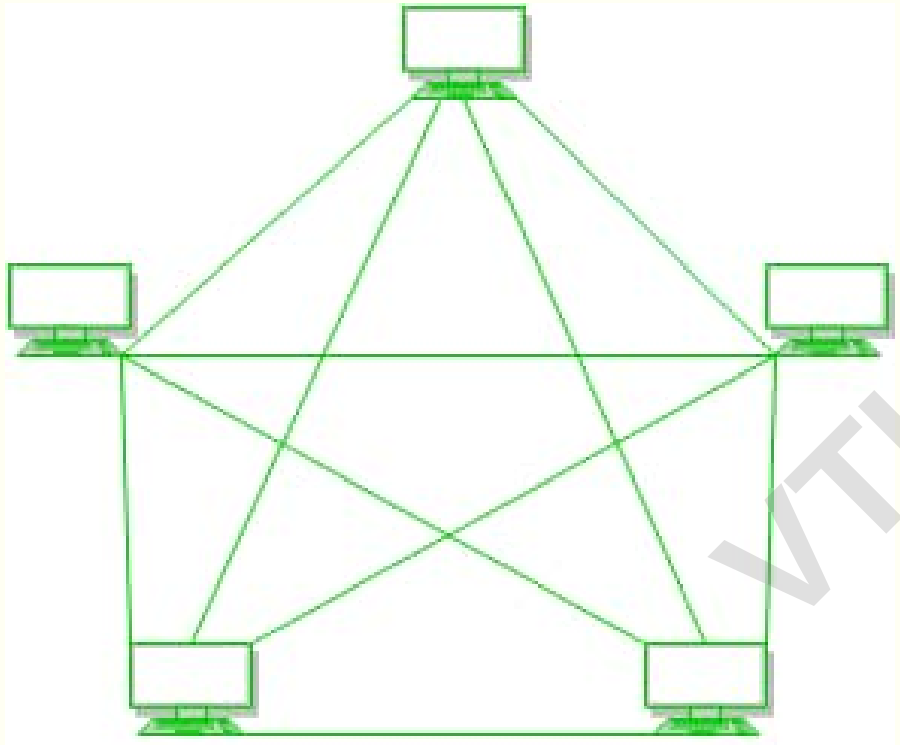
- It forms a ring connecting devices with exactly two neighbouring devices.
- A repeater is used at every node.
- The data flows in a fixed direction.
- The failure of a single node in the network can cause the entire network to fail.
- Various MAC protocols are followed to allow the devices to transmit on the Ring.

Star topology



- All the devices are connected to a single hub through a cable.
- This hub forwards the messages to the other nodes.
- It can be passive (broadcast) or active (with repeaters) in nature.
- If one link fails only that link will be affected. If the Hub fails, the network crashes.
- Easy to identify and isolate faults.

Mesh topology



- Every network device is connected to all the other devices directly.
- Internet backbone uses mesh topology, where various ISPs are connected to each other via dedicated channels.
- Very robust, since an alternate route can be found in case of a link failure.
  - Hence, also used in defence applications.
- Fast communication between the nodes.