IT200- Computer Communication and Networking

(4-0-0) 4

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Evaluation Process

- End Semester - 25 Marks
- Mid Semester - 15 Marks
- Course Project - 30 marks (NS-3 Implementation)
  - Mid Sem Evaluation - 10 Marks
  - End Sem Evaluation – 20 marks
- Quizzes - 20
  - Online Quiz. Two quizzes of 10 marks each.
- Assignment - 10
  - Four assignments of 2.5 marks each.
  - Theory Assignment or Lab Assignment
  - If it is a theory assignment, plagiarism check should result in less than 25%. Otherwise it may result in excluding such assignments for the evaluation.

Course Content

Theory Session

- Evolution of Data Communication and Networks, different generations of computer network, different mediums for internetworking, different networking devices and their roles,
- Transmission Fundamentals: Signaling Schemes, Encoding and Modulation
- Data Transmission over Networks – Switching Techniques, Layered Architecture of Computer Networks, OSI & TCP/IP Architectures and Layers with protocols.
- Data Link Control and Protocols, Error Detection and Correction
- Internetworking & Routing, Transport Layer Protocols

New Additions

- Evolution of 5G and its fundamentals.

Course Content (Contd.)

Lab Session

- TCP/IP Level Programming, Routing Algorithms, Exercises comprising simulation of various protocols.
    - Socket programming
    - NS-3 programming

- Text Books
    - “Computer Networks”, Andrew S. Tanenbaum and David J Wetherall, 5th Edition, Pearson, 2013.
    - “Data Communications and Networking”, Behrouz A. Forouzan, 4th Edition, McGraw Hill, 2017.

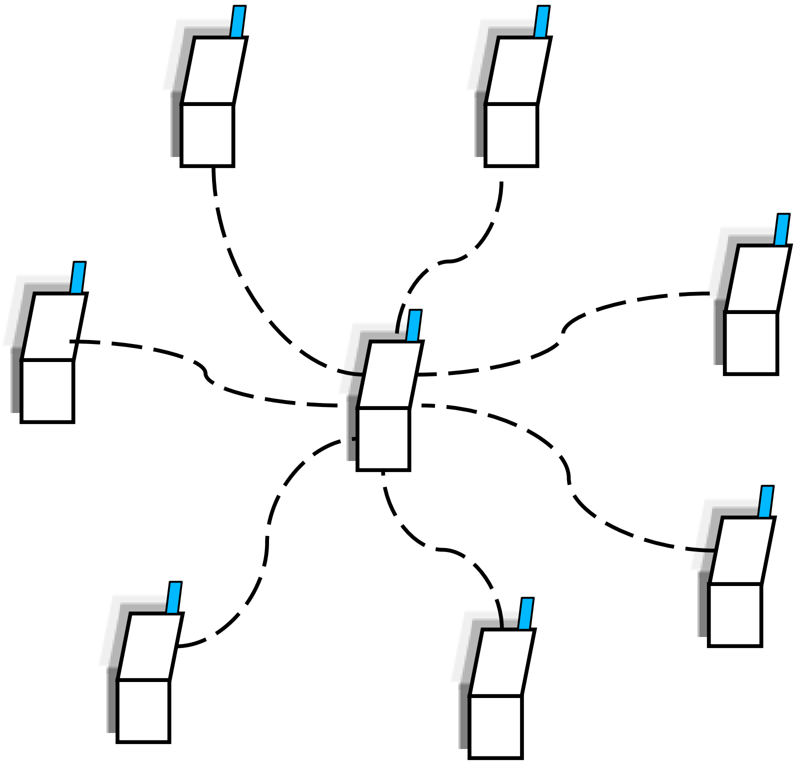
Computer Networks (CN)

- **L**arge number of separate but interconnected computers - *computer networks*.
- **T**wo computers are said to be interconnected if they are able to exchange information.
- **A**utonomous and Heterogeneous.
- **C**opper wire, fiber optics, microwaves, infrared and communication satellites.
- **N**etworks come in many sizes, shapes and forms
  - **I**nternet

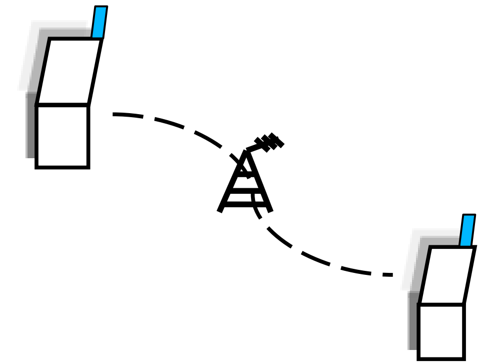
History of CN

- **5**00 BC, Darius – I, King of Persia
  - **L**ine of Shouting Men on Tall Structures
  - **R**hythmic Drums, Trumpets
  - **T**all Structures – Tower and Shouting Men **-** Antennas
- Norman , 1970 **-** ALOHAnet
  - Universities of Hawaiian islands
- PRNET – **P**acket **R**adio **Net**work (DARPA)
  - First Wireless Network
- **S**URAN – Survivable Radio Network
- **I**ETF – Internet Engineering Task Force

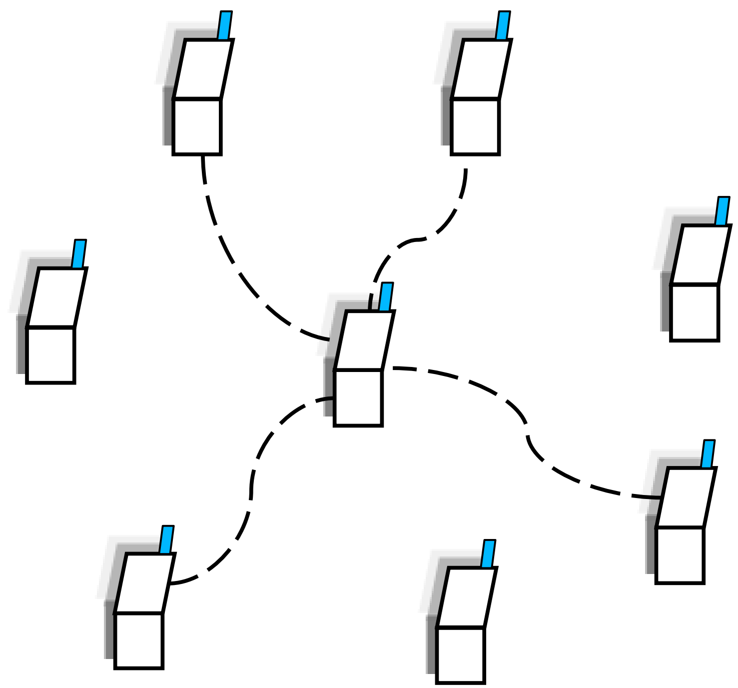
- Birds-of-a-Feather (BoF) – IETF Discussion form for improving Quality of Service.
- Different Generations of Computer Networks (1G, 2G, 3G, 4G, and 5G and Beyond)
- **T**ransmission Methods:
    - **P**oint-to-point (unicast) (1 : 1)
    - **B**roadcast (1 : N)
    - **M**ulticast (1 : *n*)



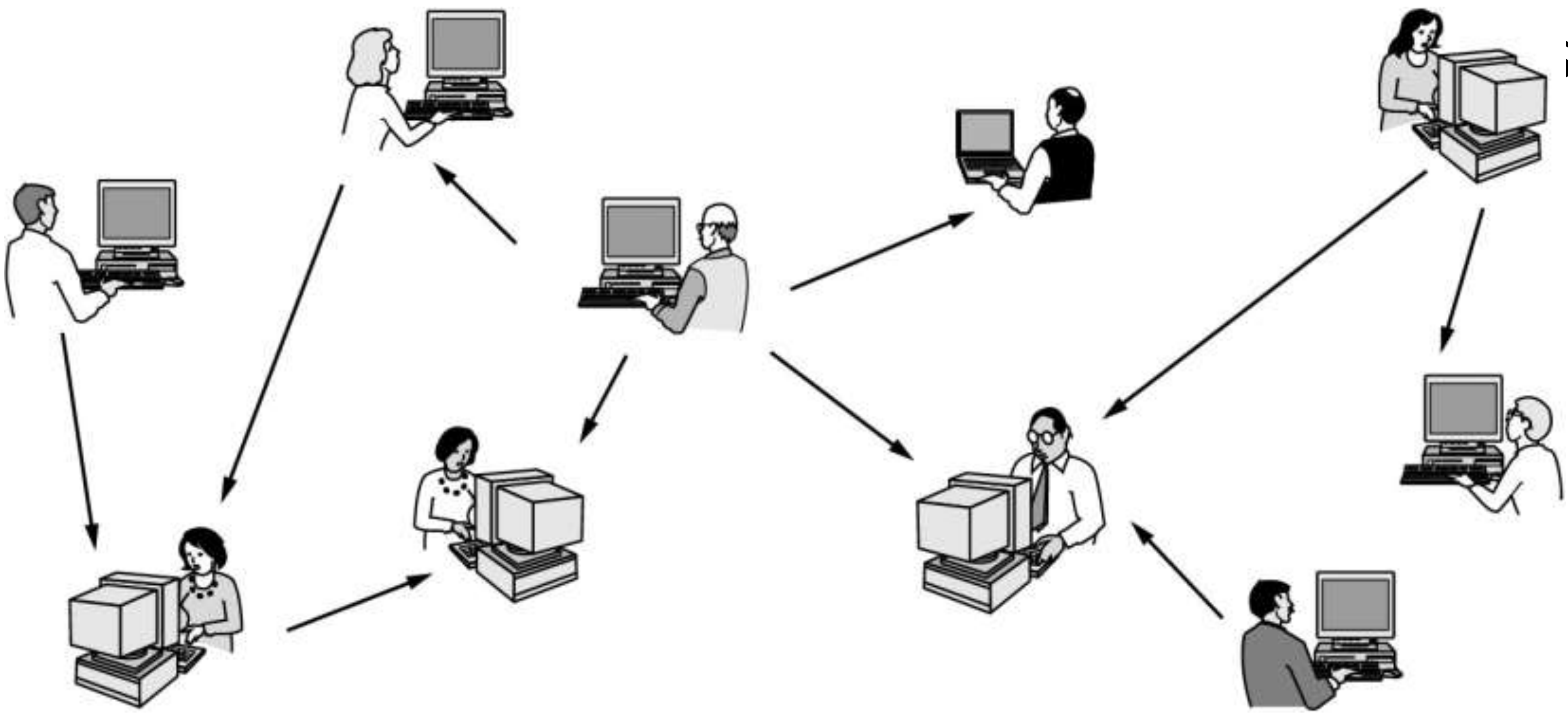
Broadcast (1 : N)

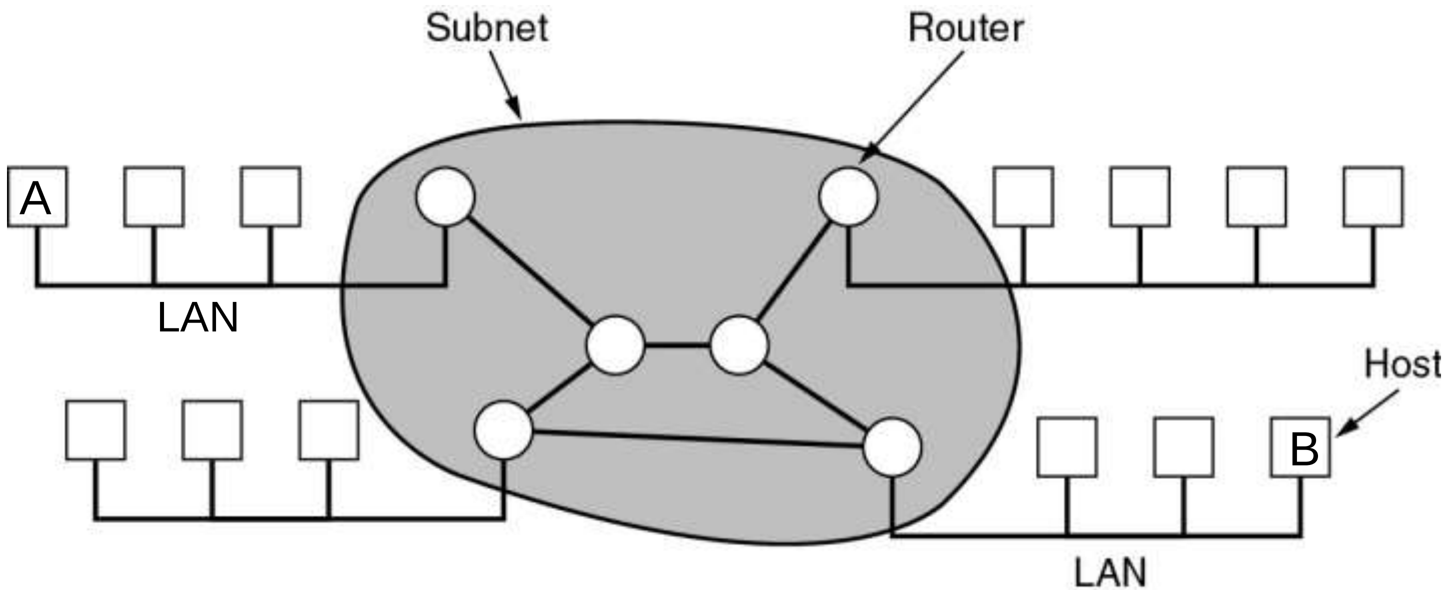


Point-to-point (unicast)



Multicast (1 : *n*)




Subnet
Router
A
LAN
Host
B
LAN

Next Session

- Different types of Computer Network
- Different Devices in Computer Network.

Thank You.

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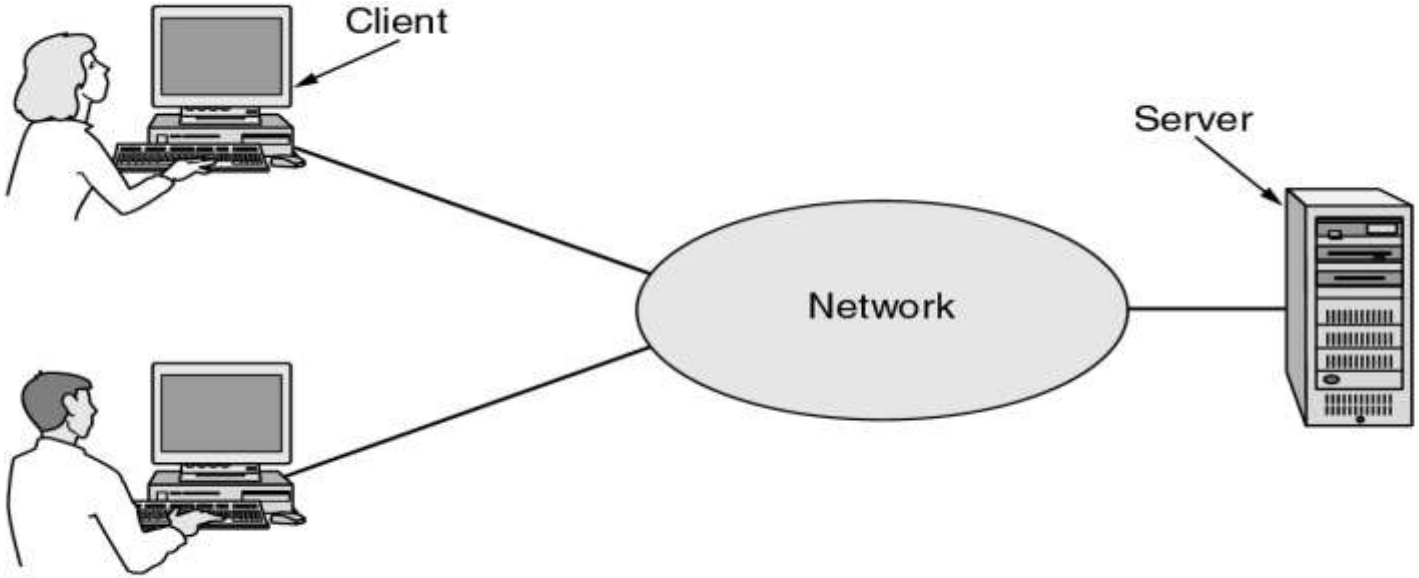
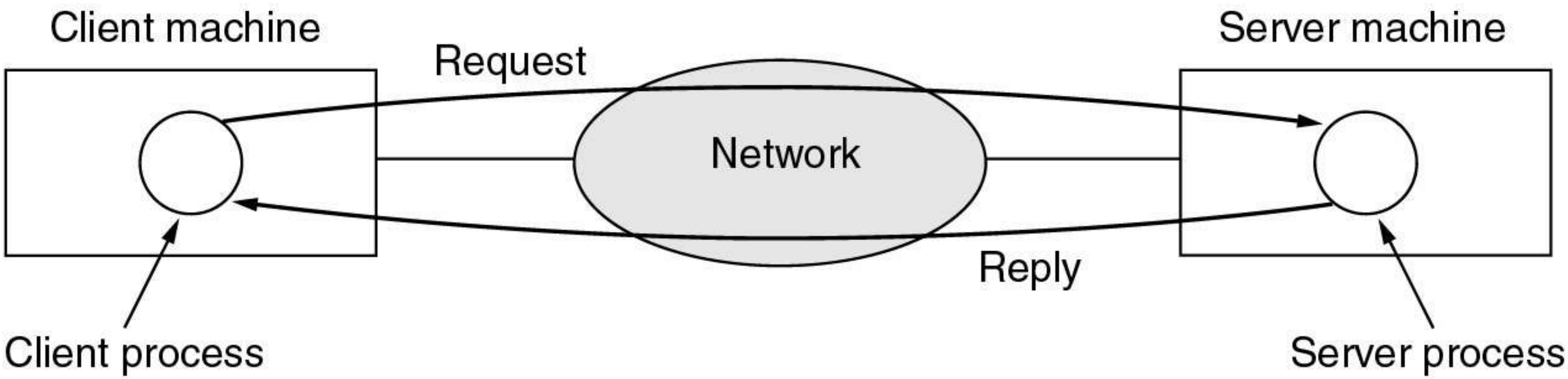


A network with two clients and one server.



The client-server model involves requests and replies.

Image Source : Tanenbaum Textbook.

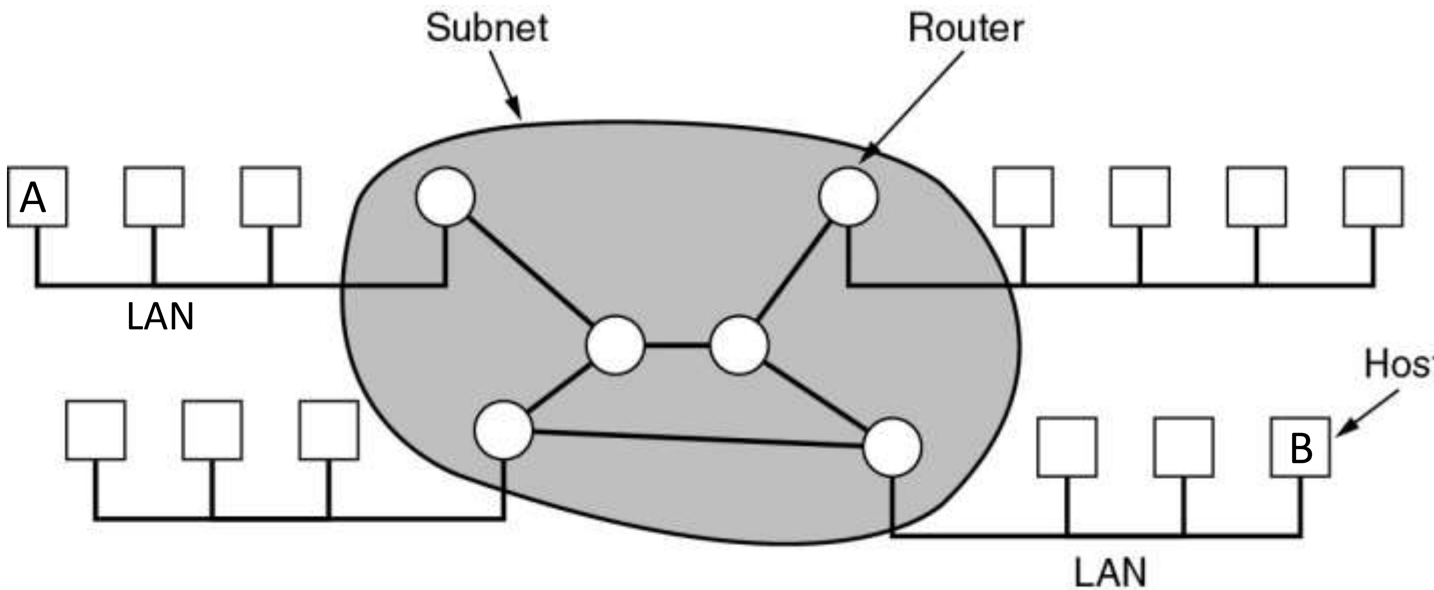
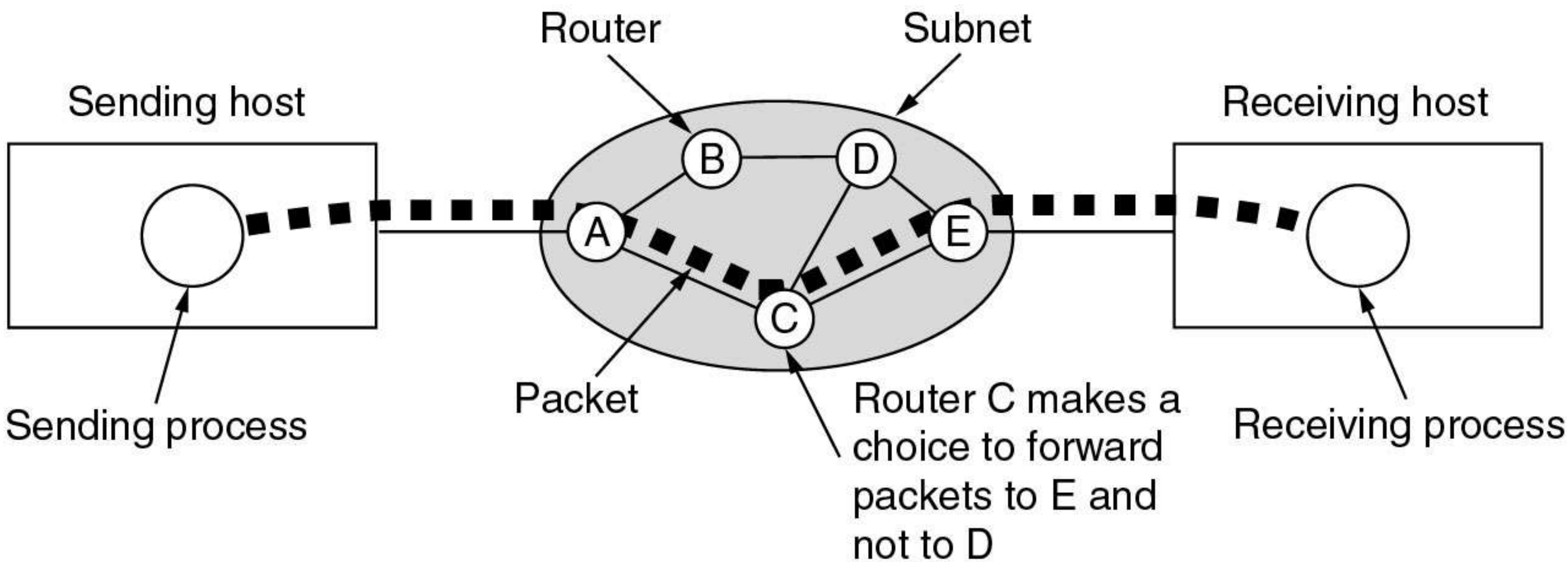


Image Source : Tanenbaum Textbook.



• **O**ften multiple routes/paths, of different lengths are possible hence finding good ones is important in point-to-point networks.

Image Source : Tanenbaum Textbook.

Types of Network

- Based on Communication mode
    - Point to Point , Broadcast and Multicast
- Based on the Scale

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	
100 m	Building	Local area network
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Image Source : Tanenbaum Textbook.

Protocol Stack

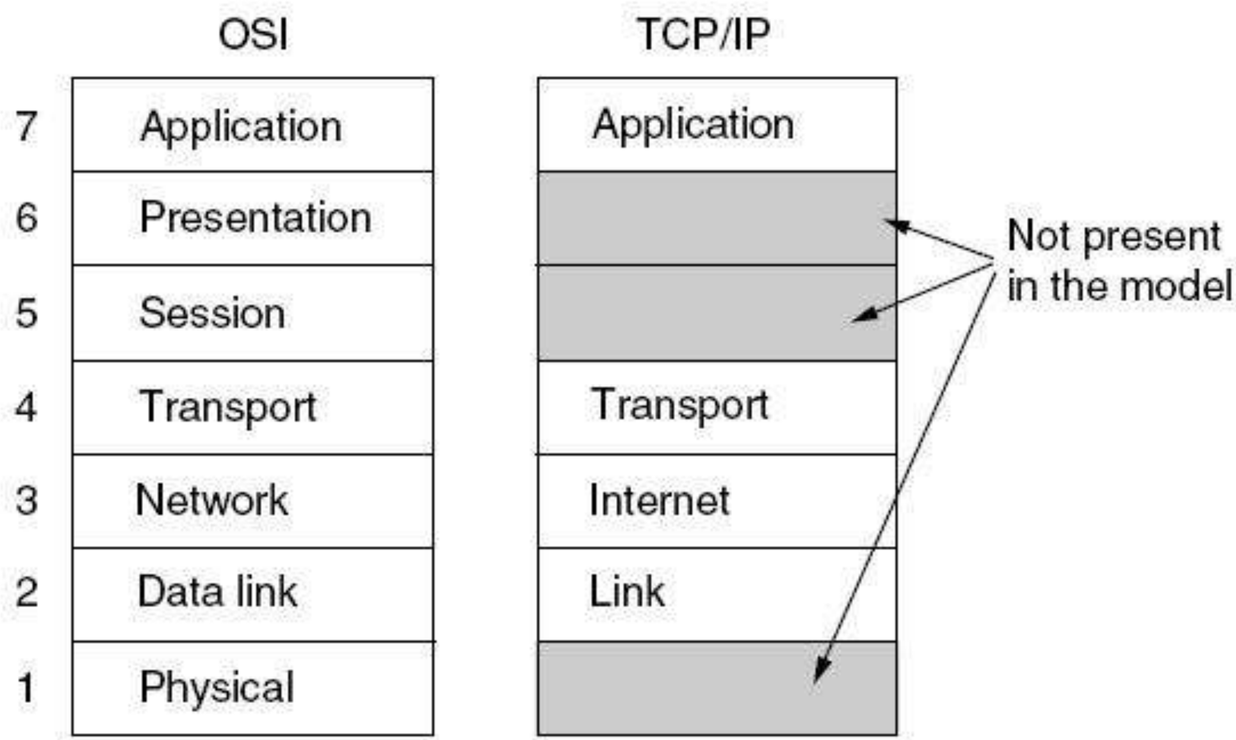


Figure 1-21. The TCP/IP reference model.

Open System Interconnection

Transmission Control Protocol/Internet Protocol

Image Source : Tanenbaum Textbook.

Types of Network

- Wired Network
- Wireless Network

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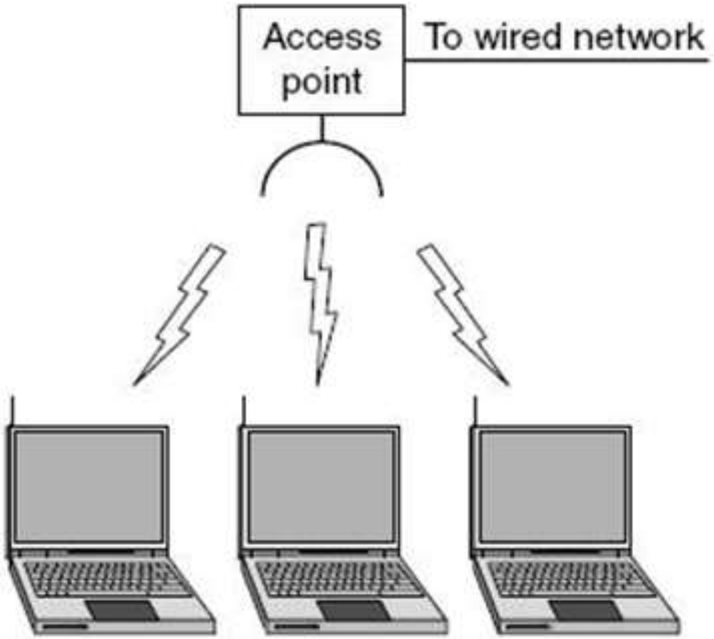
Previous Session

- Behind the system, Process
- Shortest Path
- OSI and TCP/IP Protocol stack

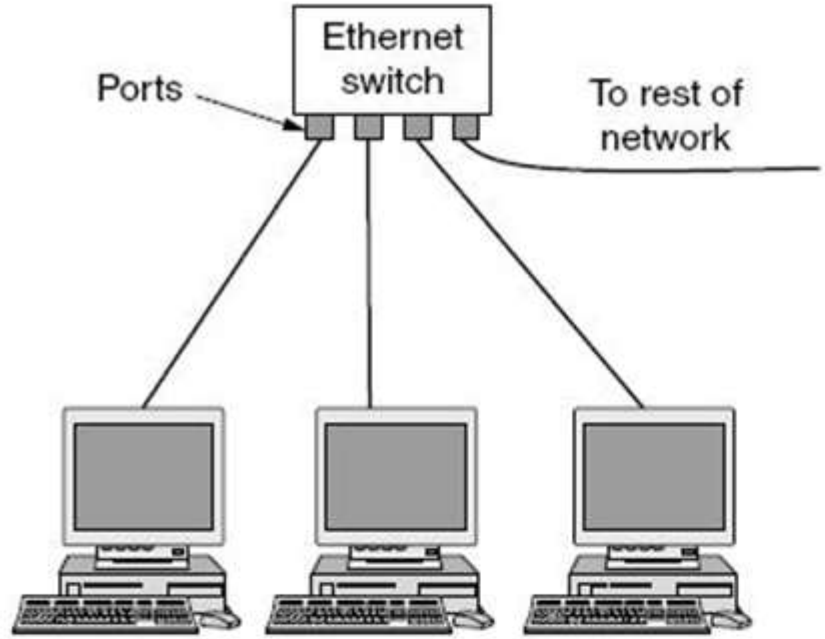
Contents

- Wired and Wireless Networks
- Network Topology
- Local Area Networks – Detailed Discussion
- Communication Medium

Wired and Wireless Network



Wireless Network



Wired Network

5 – 52 ports.

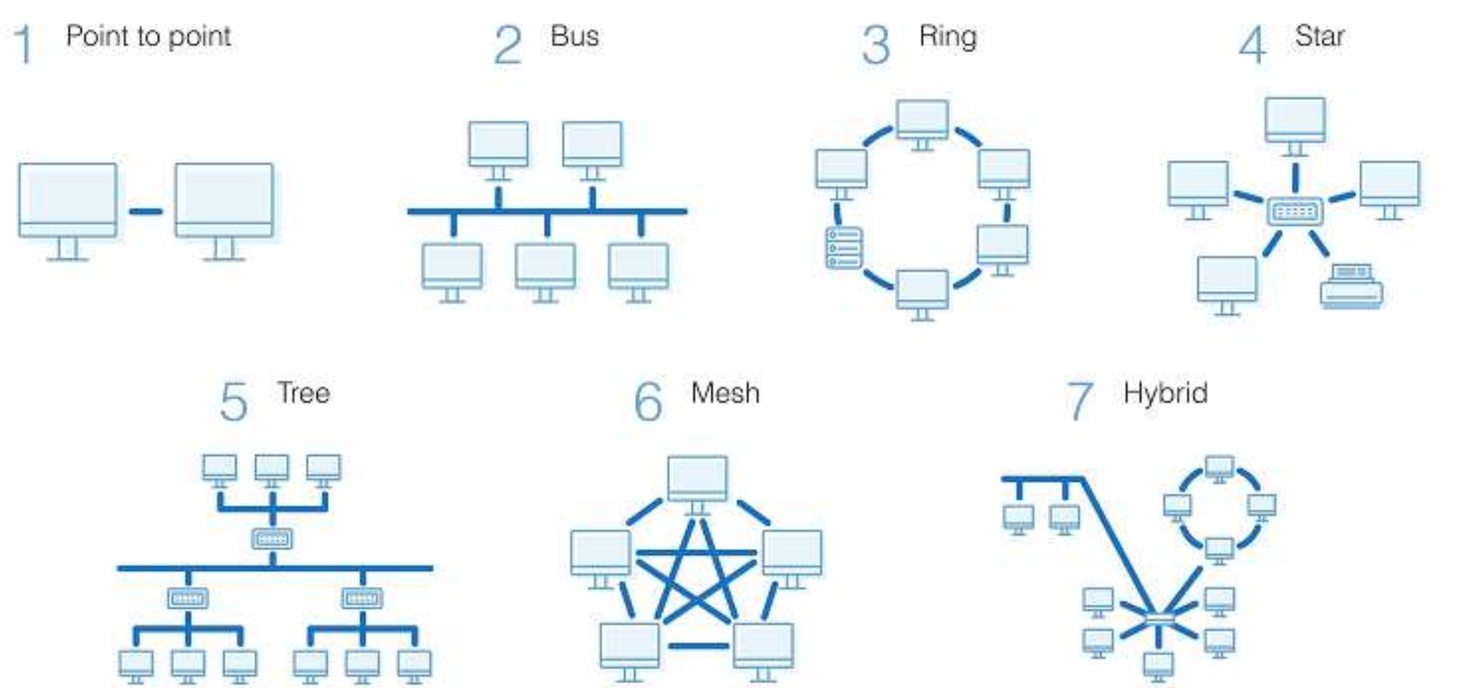
Based on the number of users, number of ports in the switch will be decided.

Differences

Parameter	Wired	Wireless
Communication Medium	Wired (Twisted Pair, Optical Fiber Etc.)	Wireless (Air)
Mobility	Limited	Higher
Interferences	Less	High
Delay	Low	High
Connection Type	Dedicated	Shared
Bandwidth / Speed	High	Low
Reliability	Much Reliable	Less Reliable
Standard	IEEE 802.3	IEEE 802.11
Security	High	Low
Cost (Installation/Maintenance)	High	Low

Network Topology

- Topology – Arrangements of the different networking devices and computers.
- Broadcast topology – Bus and Ring



Images from www.dnsstuff.com/what-is-network-topology

Local Area Networks (LANs)

- Two Types of LANs
  - Token Ring
  - Token Bus

- Token based
  - To Avoid Collision
  - Fairness
  - A user having token can transmit the data.
  - At any point of time, one user used to transmit the data.
  - Hence, the medium is not shared.

- Ethernet
  - Shared Medium
  - CSMA
    - CSMA/CD, CSMA/CA

Types of Ethernet

Name	IEEE Standard	Data Rate	Max. Distance
Ethernet	IEEE 802.3	10 Mbps	100 mtrs.
Fast Ethernet	IEEE 802.3u	100 Mbps	2000 mtrs
Gigabit Ethernet	IEEE 802.3z	1000 Mbps	5000 mtrs
10 Gigabit Ethernet	IEEE 802.3ae	10 Gbps	40 km

Wireless LAN

- Wireless Fidelity (WiFi)
- Radio Frequencies
  - Easy to generate
  - Penetrates
  - Propagates for longer distance.

WiFi Types

Type	Standards
Personal Area Network (PAN)	Bluetooth
LAN	IEEE 802.11 (WiFi)
MAN	IEEE 802.15 (WiMAX)
WAN	Cellular (LTE)

IEEE 802.11 Standards

Standard	Data Rate
IEEE 802.11 a	54 Mbps
IEEE 802.11 b	11 Mbps
IEEE 802.11 g	54 Mbps
IEEE 802.11 n	100 Mbps

IEEE 802.11d – Used for control information.

“Dude, my 802.11 is down”

- means WiFi is down….

“Dude, my 802.3 is down”

- means ….?

Wireless LAN

- Light Fidelity (WiFi)
- Uses light for data transmission.
  - Less Interferences.
  - Short Range

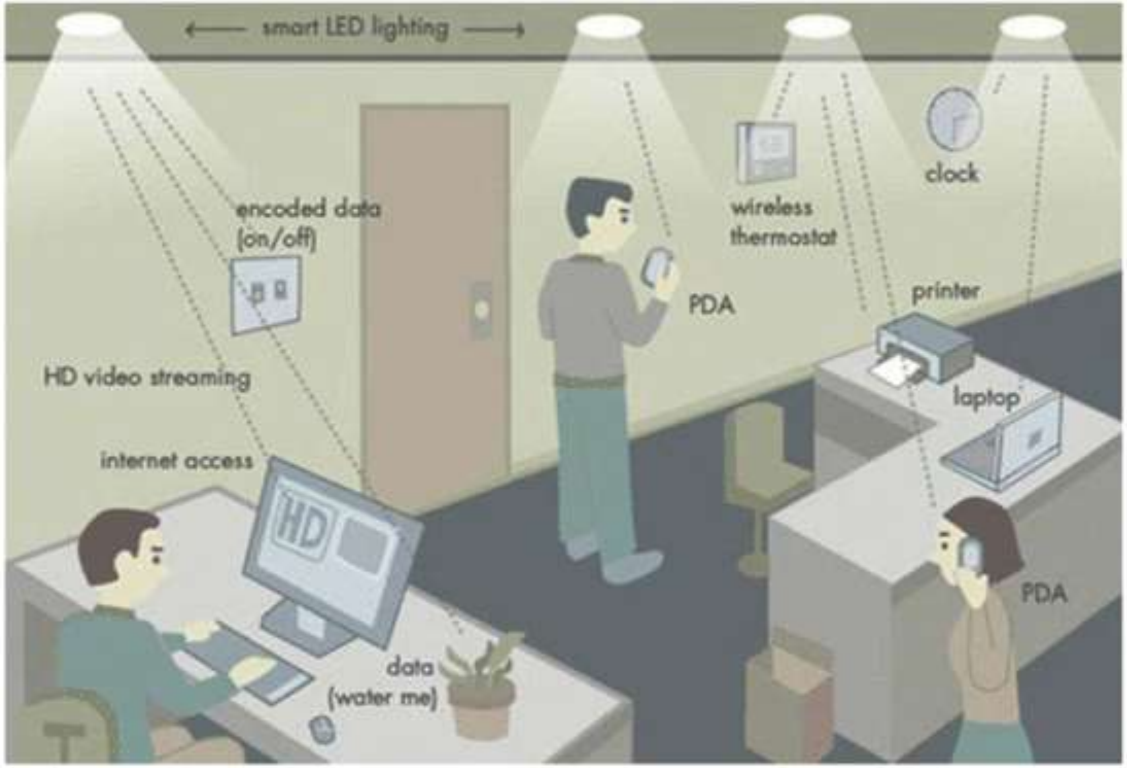
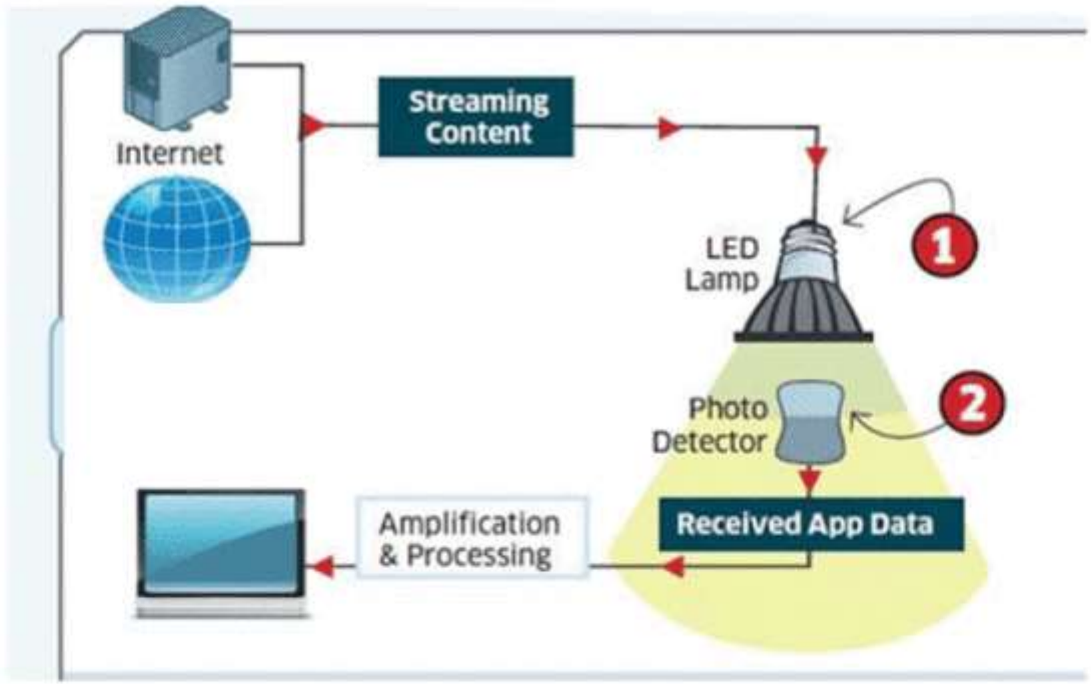


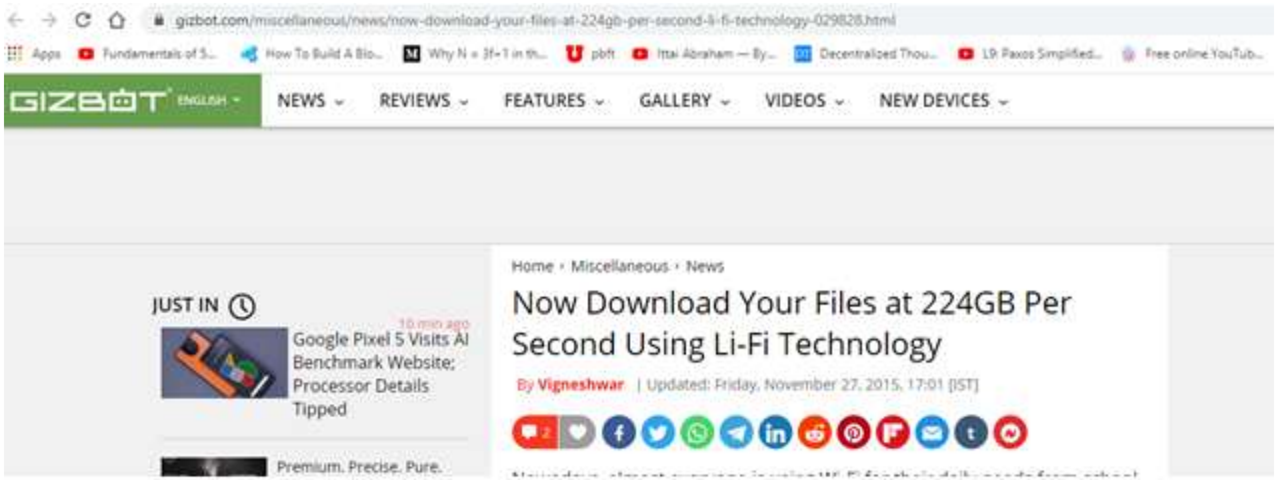
Image from V. Swetha and E. Annadevi, "Survey on Light-Fidelity," 2018 ICSSIT, doi: 10.1109/ICSSIT.2018.8748272.

LiFi Working Principle



Differences

Parameter	LiFi	WiFi
Operation	Light	Radio Waves
Interferences	Less	More
Applications	Operation Theaters	General Applications
Data Transfer	1 Gbps	100-150 Mbps
Density	Works in High dense environment	Works in low dense Environment
Distance	10 Meters	32 Meters
System Component	Lamp Driver, LED Bulb, Photo detector	Router, WAP


gizbot.com/miscellaneous/news/now-download-your-files-at-224gb-per-second-li-fi-technology-029828.html

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JUST IN

10 min ago
Google Pixel 5 Visits AI Benchmark Website; Processor Details Tipped

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Now Download Your Files at 224GB Per Second Using Li-Fi Technology

By Vigneshwar | Updated: Friday, November 27, 2015, 17:01 [IST]

- Network Media – Communication medium/channels for interconnecting the systems.
- Network Media includes
  - Coaxial Cables
  - Twisted Pair
  - Optical Fiber
  - Radio Frequencies

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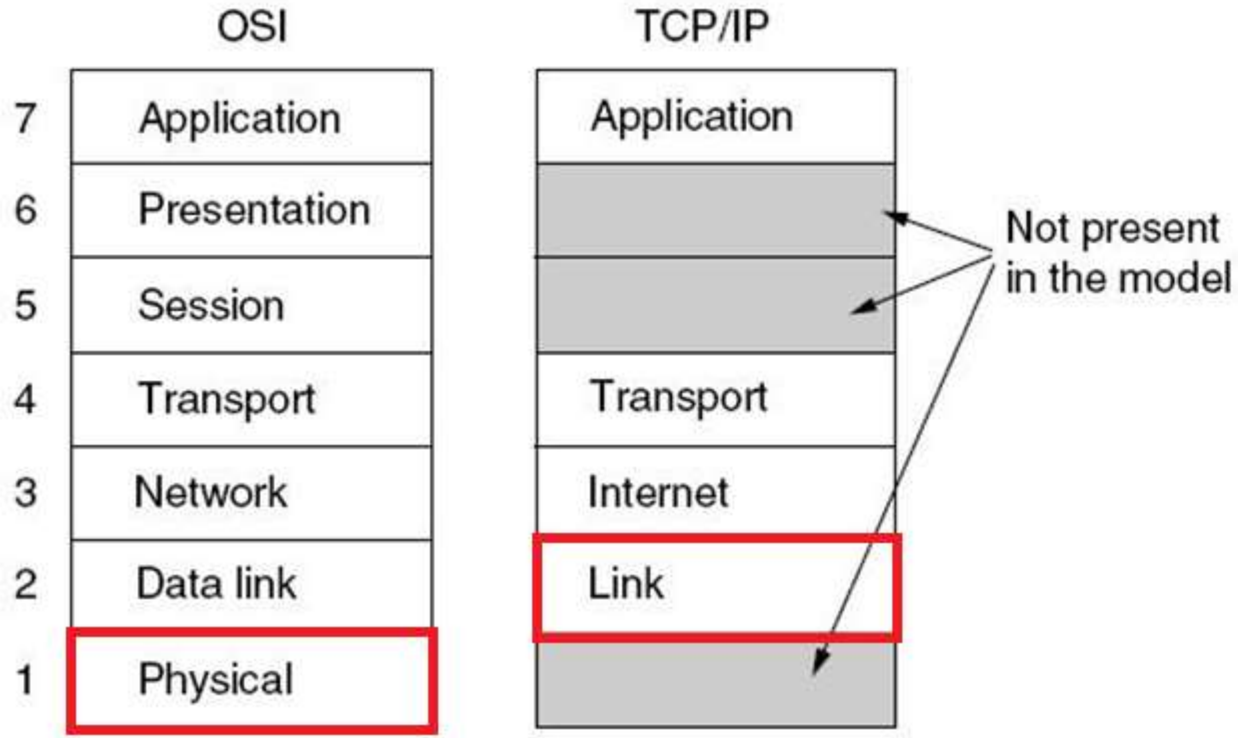
Previous Session

- Types of LANs
  - Token Bus, Token Ring and Ethernet
- Types of Ethernet (IEEE 802.3)
  - Ethernet
  - Fast Ethernet
  - Gigabit Ethernet
  - 10 Gigabit Ethernet
- Wireless LANs
  - WiFi
    - IEEE 802.11a, b , g , n
  - LiFi

Contents



Physical Layer Devices : Cables, Repeaters, Hubs

Types of Communication Medium

- Guided
  - Twisted pair
  - Coaxial Cable
  - Fiber Optics
- Unguided
  - Radio Waves
    - Cellular Communication
    - Satellite Communication

LAN cable picture source: Internet

Twisted Pair

- Two separate insulated copper wires are twisted together - pair or strand
- Consists of one or more strands in a wire.
- Why twisting ?
  - Two parallel wire constitutes a fine antenna
  - Parallel wires cancels exterior interferences.
- Signals with varying voltages representing 0’s and 1’s.
- Most commonly used cable for LANs.
- Most commonly used in telephone system.
  - If 4 strands (two pairs) wire is used, two seperate phone lines it carries.
- Twists per meter
  - More Twisting results in less cross talks- interferences.
  - More Twists gives better results with better signal propagation.

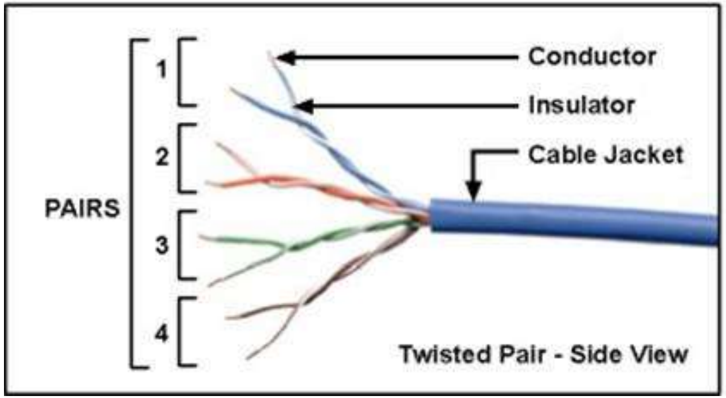
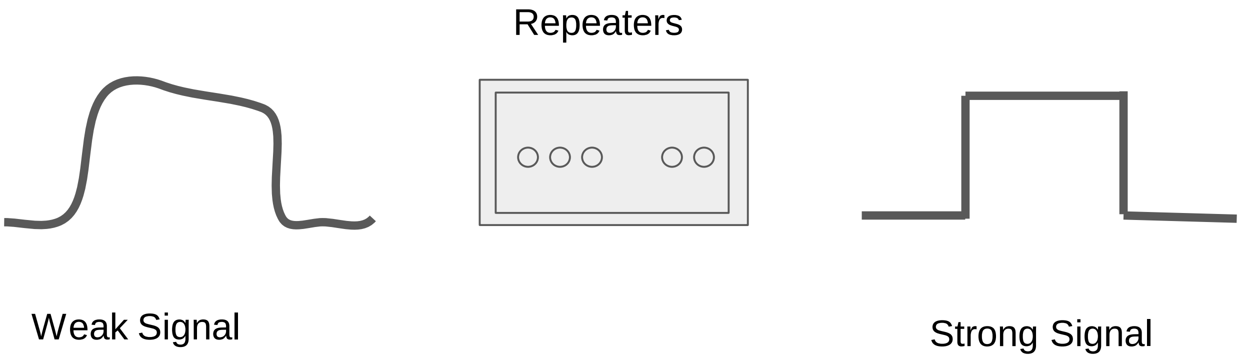


Image source: medium.com

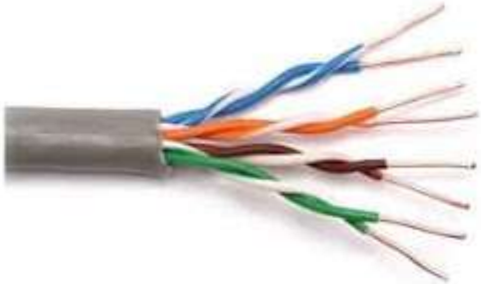
- Both analog and digital signals can be transmitted.
- For longer distance repeaters are required.
    - Repeaters will regenerate the signals.



Types of Twisted Pair Cables

- Shielded Twisted Pair (STP)
  - Additional metallic shielding around each pair of wires.
  - Less susceptible to EMI
  - But, expensive, difficult to maintain
  - Much Thicker, not flexible.

- Unshielded Twisted Pair (UTP)
  - No Shielding.



UTP Cable

STP Cable

Image source: Internet

Category	Speed (Mbps)	Common use
Cat 1	< 1	Analog voice
Cat 2	4	ARCNET
Cat 3	10	10baseT Ethernet
Cat 4	16	Token Ring
Cat 5	100	100baseT Ethernet
Cat 5e	1000	1000baseT Ethernet
Cat 6	1000	1000baseT Ethernet

Attached Resource Computer NETwork (ARCNET)

Ethernet - Cat 5 and above

Table Reference: CISSP Study Guide Book, 2015 Edition, Elsevier, Edts: Eric C, Seth M, Joshua M

UTPs are widely used cables in the LANs.

Color Code of Twisted Pair Cables

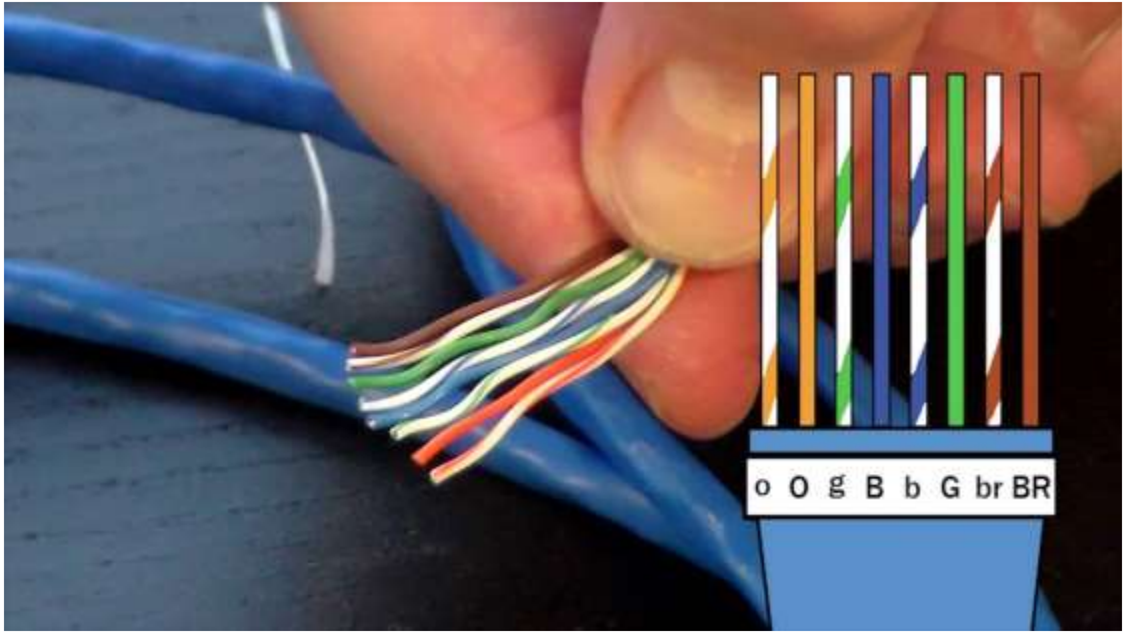


Image source: Youtube.video still

Grey cables - Ethernet connections,

Green cables - Crossover ethernet connections.

Yellow cables - POE (power over ethernet),

Blue cables - Terminal server connections.

At both ends of the cable the color combination should be same in cable.

Networking Devices

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Last Session

- Communication Medium - Guided, Unguided
- Twisted Pair, wires twisted to attain good performance.
- STP, UTP
- Repeaters
- Categories - Cat 1 to Cat 6
- Color Combination in LAN Cable , Orange, Green, Blue, Brown
    - Combination of white the O, G, B, B Colors

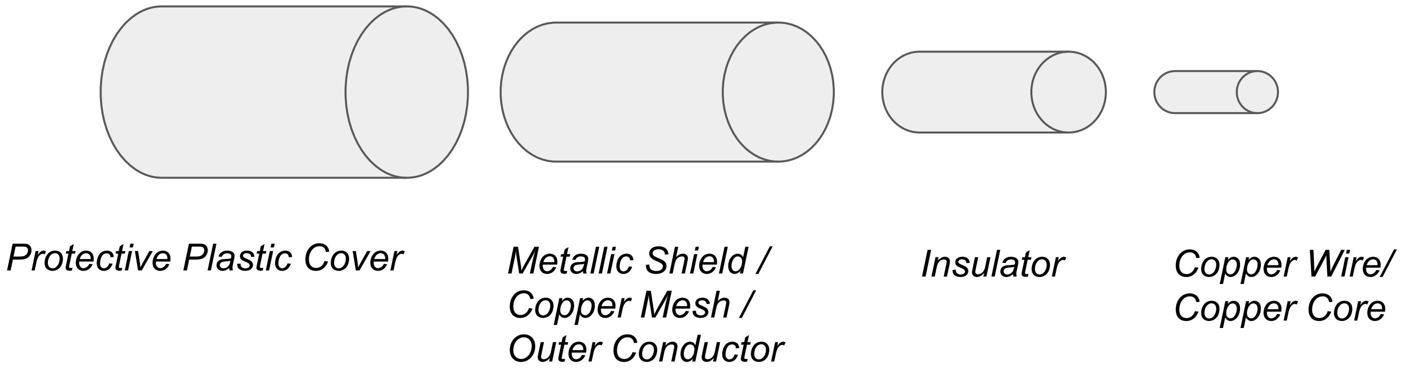
Today’s Session

- Coaxial Cable
- Optical Fiber

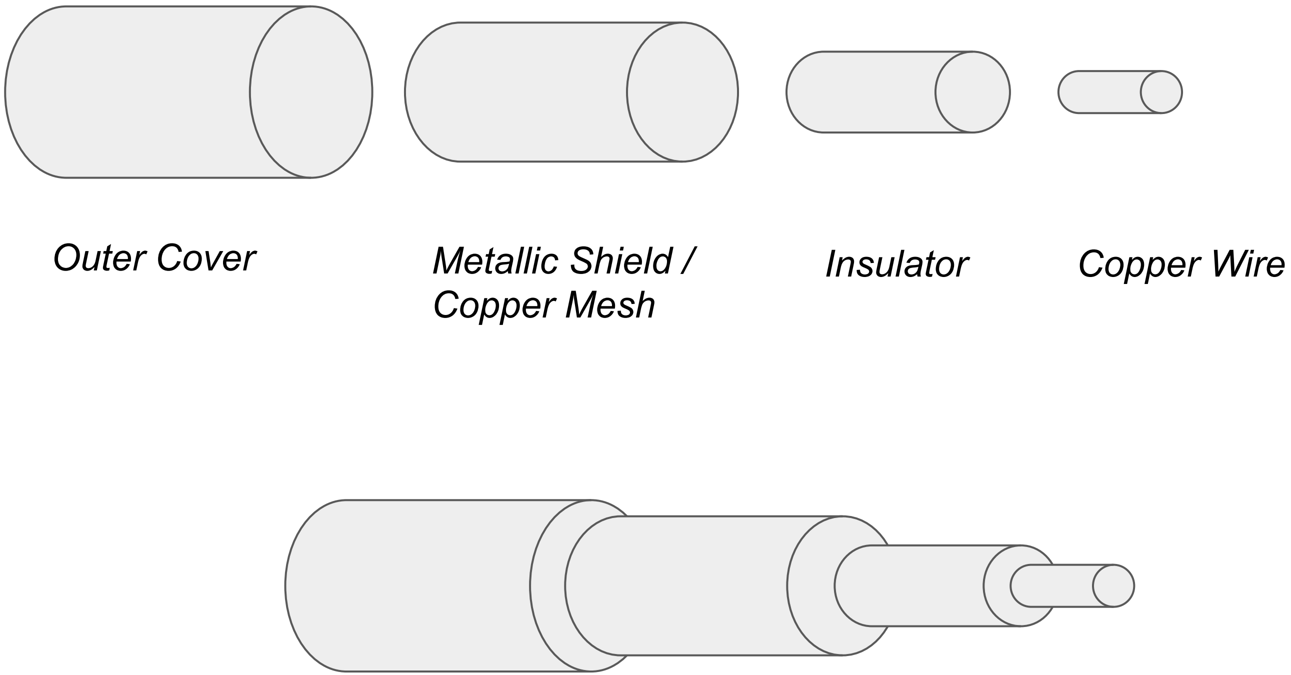
Coaxial Cable (Coax)

- Has Better Shielding
- Greater Bandwidth
- Can span longer distance at higher speed.

Coax Closer Look



Coax Closer Look



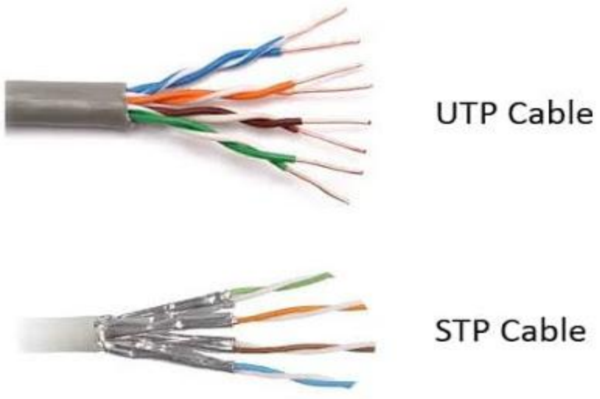
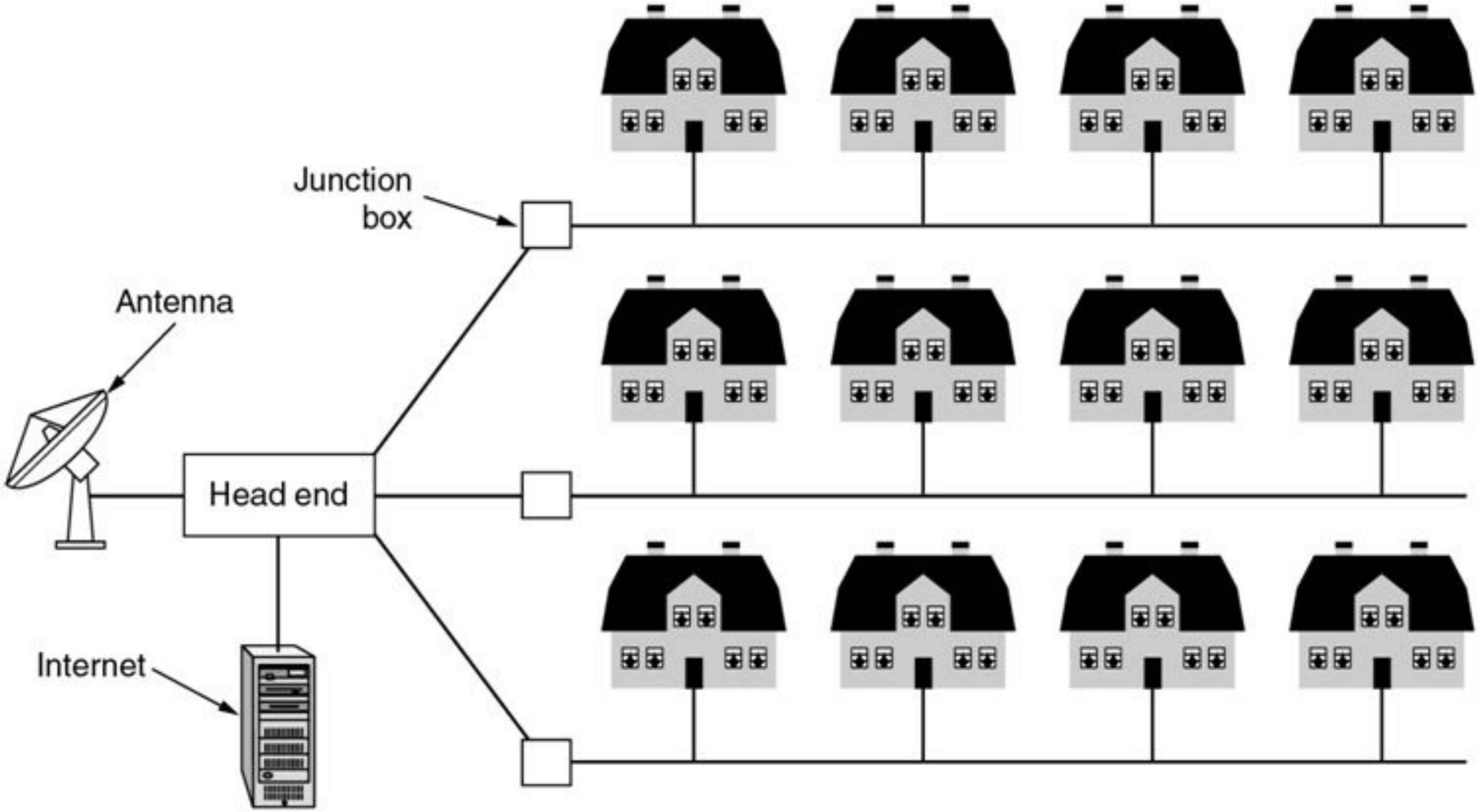


Image Source : dreamstime.com

Difference between Coax and Twisted Pair

Coax	Twisted Pair
Has Better Shielding	Shielding is Less
High Bandwidth	Less Bandwidth
Has high Propagation	Has Less Propagation
Expensive when compared to Twisted Pair	Thinner and Less Expensive
Less Cross Talk when compared to Twisted Pair	Handles cross talk reasonably.
Cable TV, MAN	LAN



Metropolitan Area Network (MAN)

Power Lines as Data Lines

Power lines as low rate data transfer

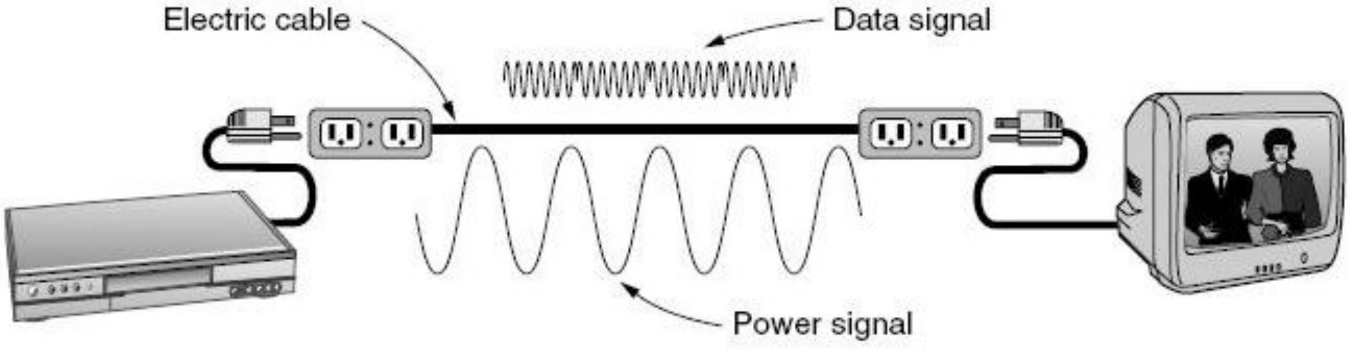


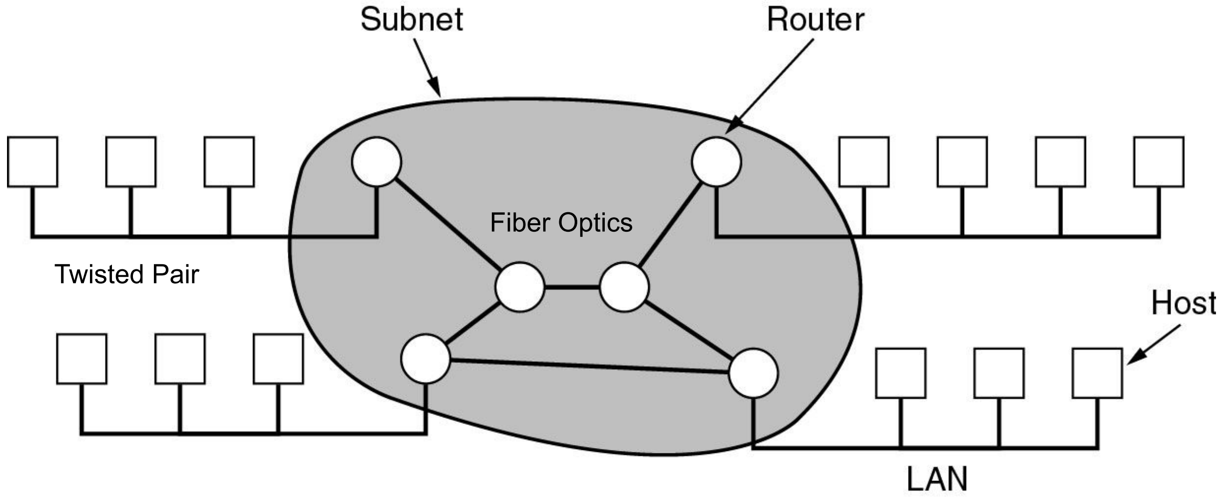
Figure 2-5. A network that uses household electrical wiring.

Optical Fiber

- During 2000, communication links increased from 45 Mbps to 100 Gbps
- At the same time the error rate (Bit Error Rate, BER) went from 10^{-5} per bit to almost zero
    - BER of 10^{-5}, 1 out of every 100,000 bits transmitted exhibits an error.
- The achievable bandwidth with fiber optics is in excess of 50,000 Gbps (50 Tbps) and we are nowhere near reaching these limits
- Backhaul Network

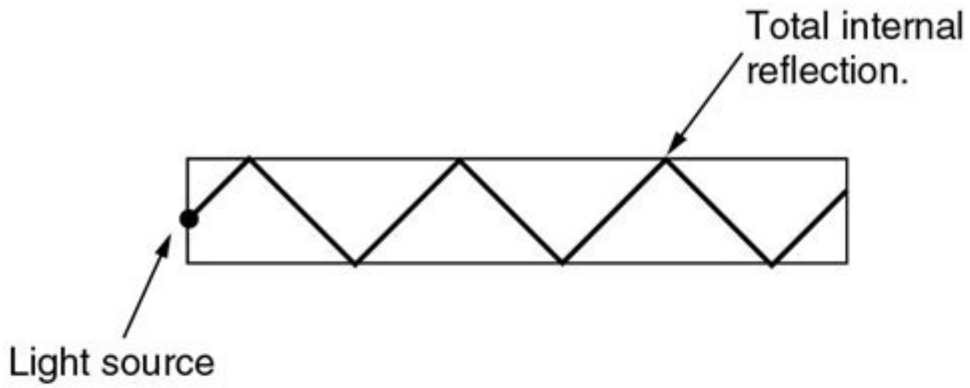
Fiber Optics (Contd)

- Used for long haul transmission in network backbones, high speed LAN’s and high speed internet access such as **FttH**(Fibre to the Home).



- An optical transmission system has three key components:
    - Light source
    - Transmission Medium
    - Detector
- A pulse of light indicates a 1 bit and the absence of light indicates a 0 bit.
- The transmission medium is an ultra-thin fiber of glass.
- The detector generates an electrical pulse when light falls on it.
- Optical fibers are made of glass
    - Thanks to Egyptians

- Light pulses spreads out in length as they propagate. This spreading is called **chromatic dispersion**.
- These pulses are called **solitons**.
- Increase the distance between them to avoid overlapping
- It is possible to send pulses for thousands of kilometers



- Multimode Fibre
- Single-mode Fibre. Expensive and used for longer distances. Can transmit data at 100 Gbps for 100 km without amplification

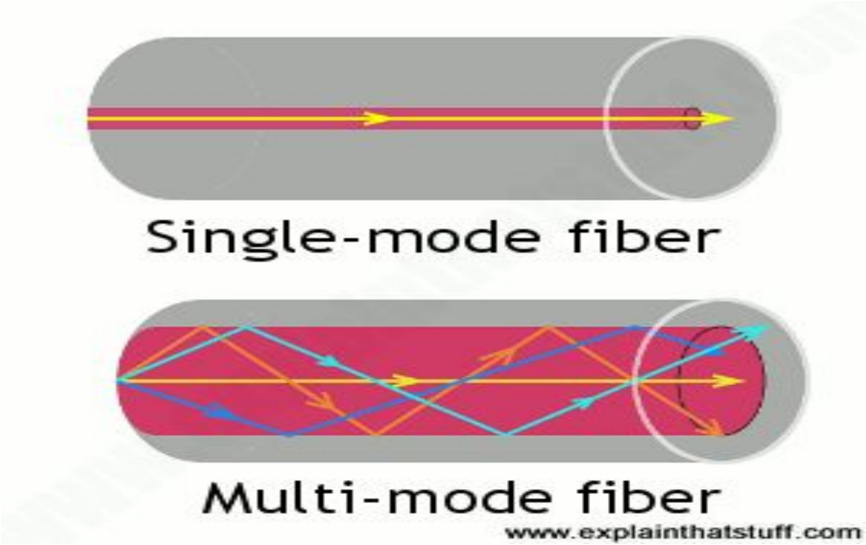
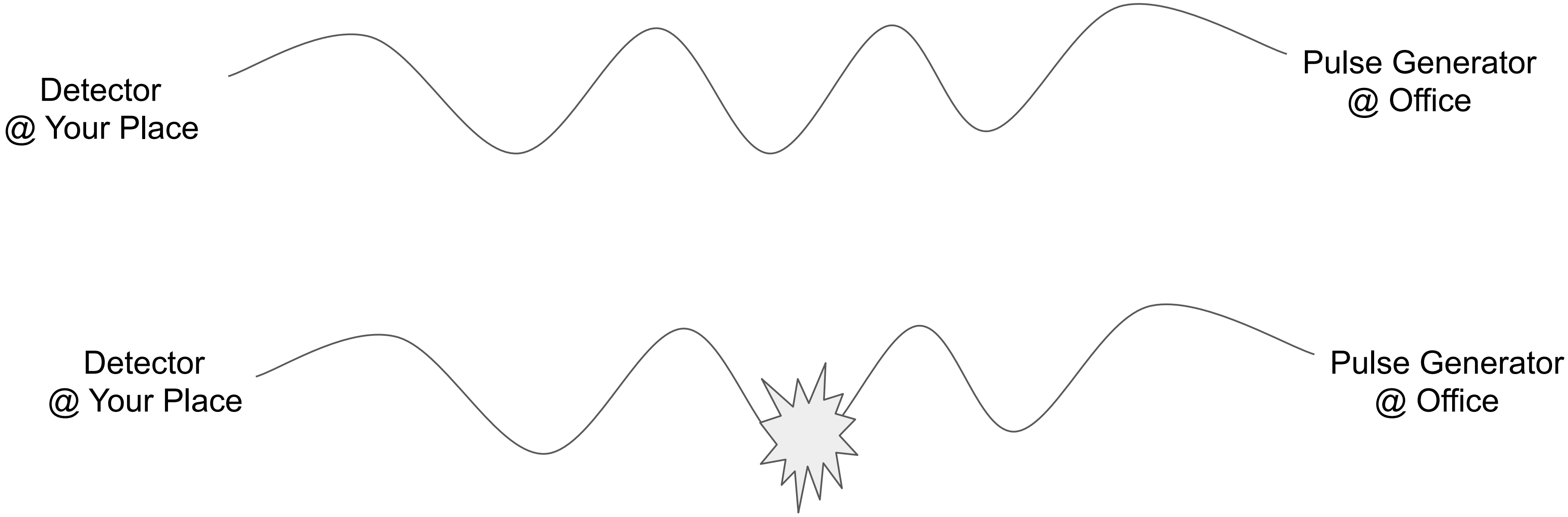


Image Source: Explainthatstuff.com

Checking Fiber Optic Cable



Next Session

OSI Protocol stack - Functionalities of each layer

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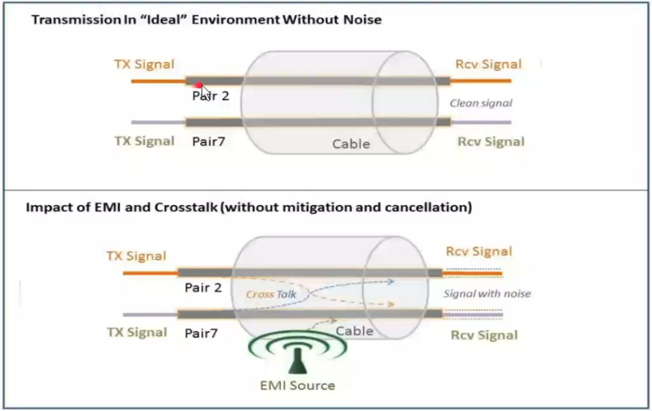
Last Session

- Coax - high bandwidth, less cross talk, Better Shielding
- Basically used for Cable TV, MAN
- Optical Fiber - much better features when compared to all other communication medium
- Uses glass medium for communication
  - Thanks to Egyptians for the Glass Invention.
- Good Bandwidth, Good Propagation, Less Cross Talk
- Used for Backhaul Network.

- What is Cross Talk ?
    - Signal Transmitted in one channel disturbs the signals transmitted on another channel.
    - Basically due to EMI.
    - Can be Intentional or Unintentional.



EMI Sources: Another Signal, Cell Phones, High Power Lines

Image Source: http://actelis.com/technology-2/copper-broadband-technologies/cross-talk/

Communication Medium - All Together

Twisted Pair - LAN

Coax - Cable TV, WAN

Optical Fiber - WAN and Internet, High Speed LAN (Some Times)

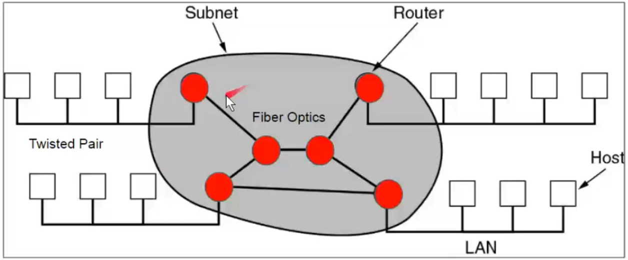
Networking Devices

- Routers
- Bridges
- Switches
- Repeaters
- NIC/Ethernet Card
- Hub
- Gateways

Routers

- Receives and Forwards data packets between the computer networks.
- Traffic Direction.
- Finds the best path to reach the destination network.
- Routers are connected to the modem, switches.
- Router Types
    - Wired Router, Wireless Router, Core Router.
- The speed of the internet also depends on the router.

Image Source: *amazon.com and linuxsys.xom*


Subnet
Router
Fiber Optics
Twisted Pair
Host
LAN

Modem

- Modem has only two ports
    - One for router and one for the device.
- Modem in turn is connected to router for the internet.

IT200 OSI Layers....pptx

Show all

+77 GG CR EA T AK TK R AN D NB

AYUSH DINESHBHAI MANGUKIA

Niraj Nandish

akshayjain.191it102

KIRAN M

Switches

- Creates a network
- Connects all other devices in a network (Systems, Printers, Scanners)
- Has got direct access to individual system
    - Unlike, routers where it connects networks, not systems.
- Transmission - Unicast, Multicast and Broadcast.
- Hence, called as Intelligent Device.
- It can also act as repeaters, sometimes.
- Operates in Data link layer (in OSI Protocol stack)
- Supports Packet Filtering (Static Filtering).
    - Can control outgoing and incoming packets.
- Store and Forward, Security (little bit)

Image Source: *linuxhint.com*

Hubs

- Just like Switch
  - Creates a network
  - Has got direct access to individual system
- But,
  - Less intelligent
  - Transmission - Only broadcasting
  - Operates in Physical Layer.
  - No Packet Filtering.

Bridges

- Aggregates multiple network segments.
- Works at Network Level.
    - Unlike switch, hub which operates at system level.

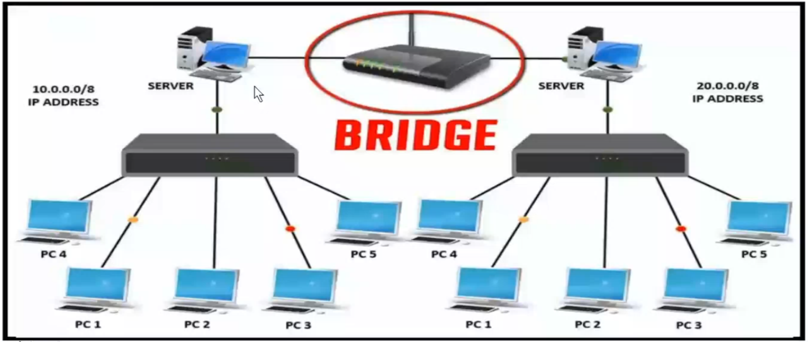


Image Source: *internet*

Gateways

- Acts as a “Gate”, Stop Point
    - Firewall, Server, Proxyserver
- Allows packets to travel across the network.
- Traffic Controller - used by ISP

Router Vs Gateways

- Gateways - Regulates Traffic between dissimilar networks
- Router - Regulates Traffic between similar networks
- Dissimilar Networks - which use different protocols.

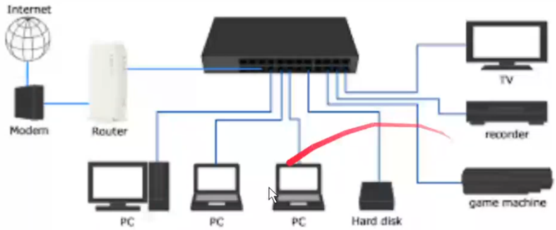


Image Source: *internet*

NIC / Ethernet Card

- Network Interface Controller
  - Connects system to the internet through cable.
- Can I have multiple NIC cards in my system ?
  - YES. Mostly for the Servers.
  - Can Handle More Traffic.

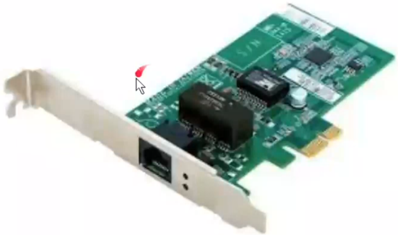


Image Source: *internet*

OSI Protocol Stack Pros and Cons

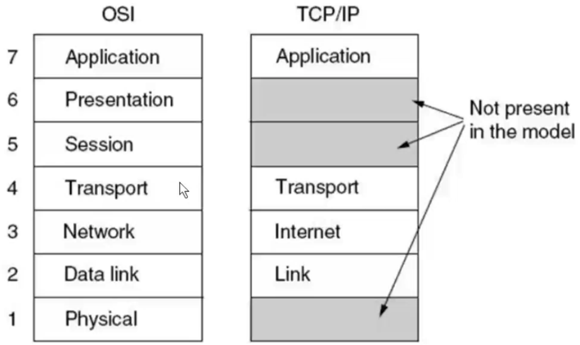


Figure 1-21. The TCP/IP reference model.

IT200 OSI Layers....pptx

Show all

+72 GG CR EA T AK TK AP NR D MA

AYUSH DINESHBHAI MANGUKIA Niraj Nandish R Rishit KM KIRAN M

OSI Layers

Dr. Kiran M
Assistant Professor
NITK

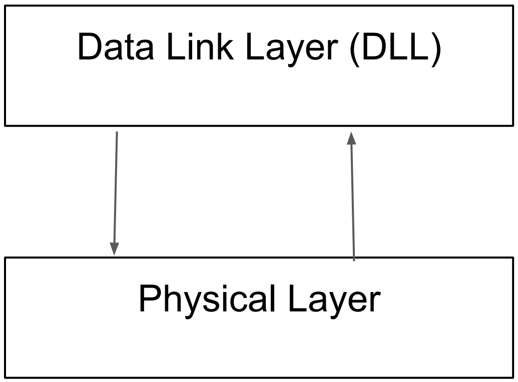
Last Session

- Networking Devices
  - Router , Modem , Bridge
  - Switch, Hub
  - NIC card.

- Live streaming of sports is done by switch or hubs ?
    - Its is a client server architecture. You will be the client and Star Sports, for ex., will be the server.
    - Switch.
    - Just like requesting required files to send from the server. It is a unicasting.
    - Netflix, Amazon works in client server architecture.
- FM
    - Broadcasting
    - The signals will be spread in 360 degrees around.
    - You can tune up your device to receive the signals.

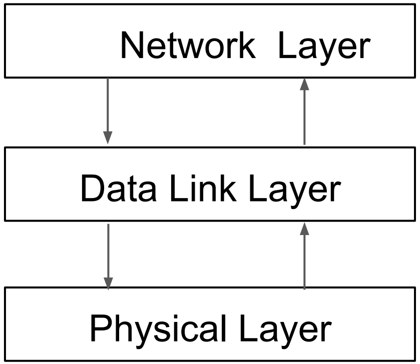
Physical Layer

- Layer 1 - Lowest Layer
- Actual Physical Connection and Transmission of bits between the systems.
- Deals with bits (0’s and 1’s), the smallest part of the information.
- Communication Devices -Twisted Pair or Optical Fiber
- Receives data from DLL (@sender node), sends data to DLL (@receiving node)
- Networking Devices - Hubs, Repeaters



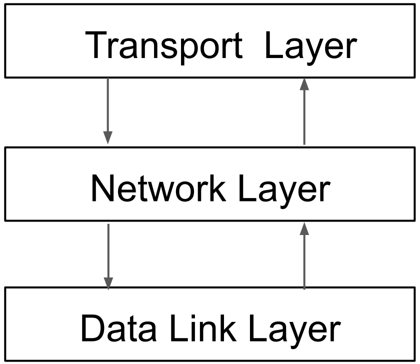
Data Link Layer (DLL)

- Makes sure the data transfer is error free
  - Error Detection and Correction
- DLL has to find the destination system in the network.
- Deals with MAC address (48 bit address specific to system)
- Access Control - Channel access
- Two sub layers
  - Logical Link Control
  - Media Access Control
- Networking Devices - Switch, NIC card



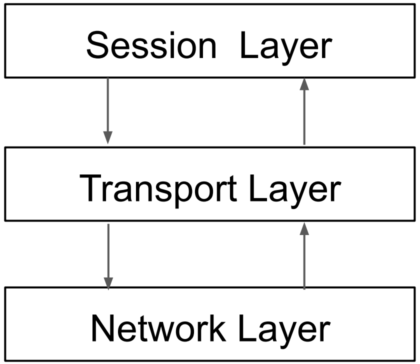
Network Layer

- Routes packet between the networks.
    - Packet is the chunk of the information provided by the user @ Application Layer.
- Finding the optimal path for routing packets is the key.
- If path breaks up, should reinitiate the new path.
- Networking Devices - Routers and Gateways.



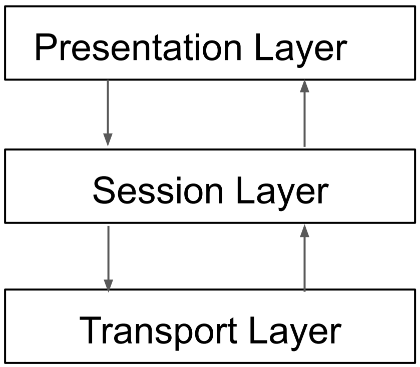
Transport Layer

- Traffic Control.
- Decides packet/sec based on the network condition.
- Firewalls.



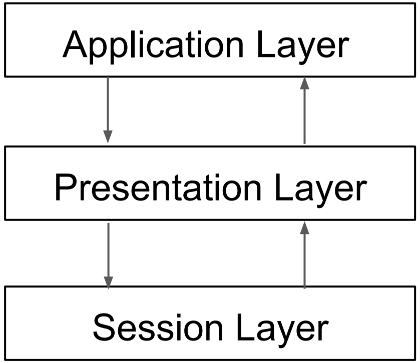
Session Layer

- Responsible for establishing end-to-end session and managing the session



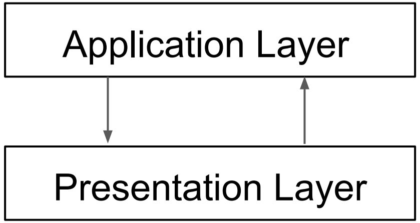
Presentation Layer

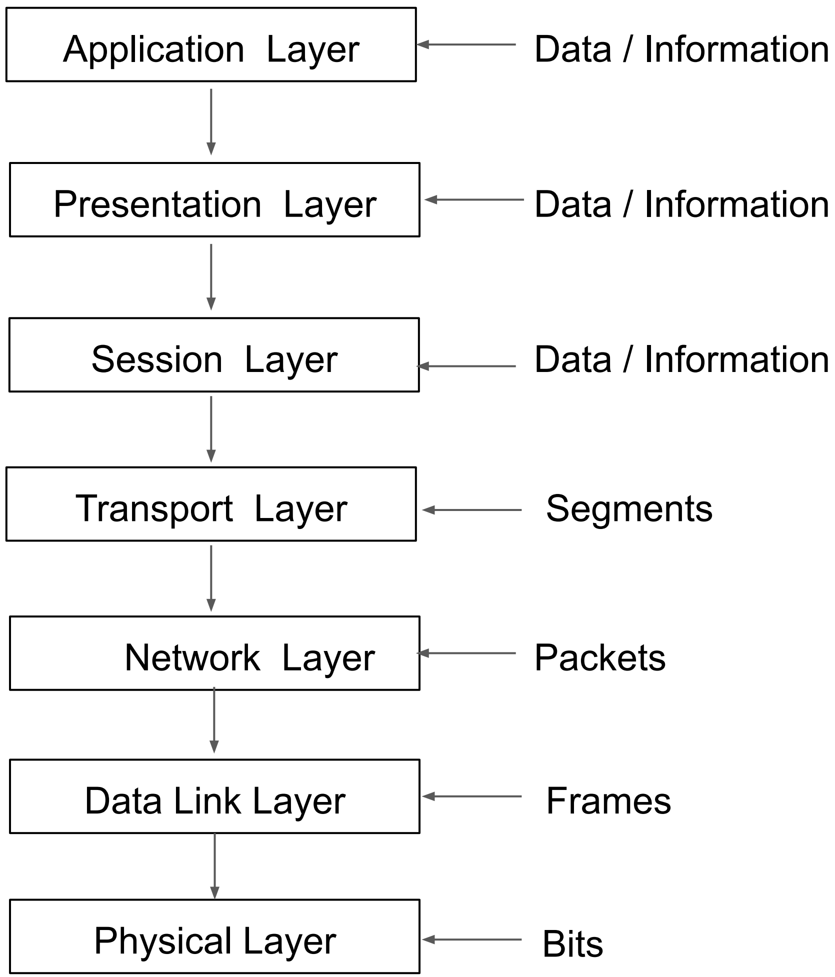
- Encryption, Compression, Data Conversion.
- Security.

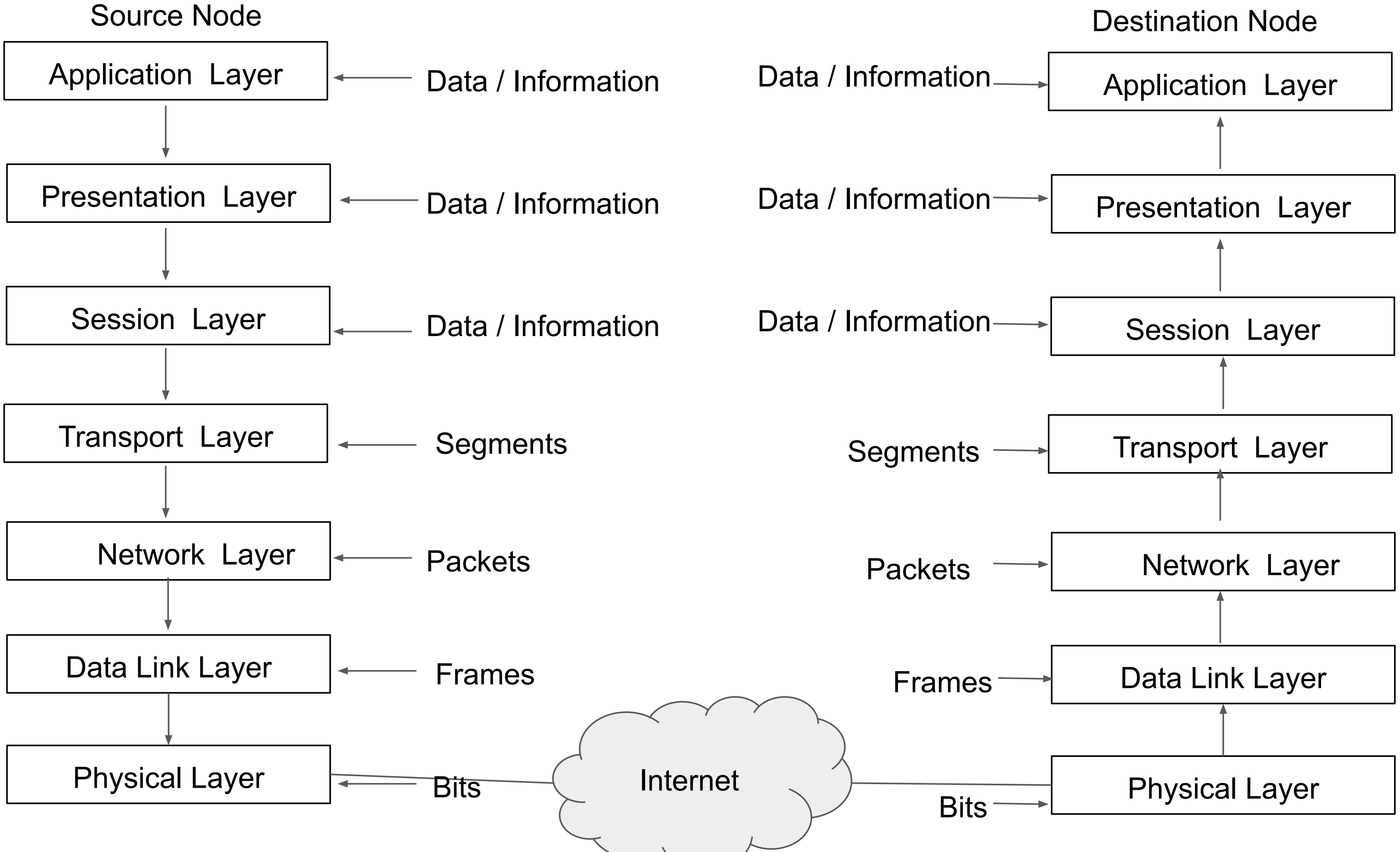


Application Layer

- User Interaction
- File Sharing, E mail, all internet activities performed by user.




Application Layer
Data / Information
Presentation Layer
Data / Information
Session Layer
Data / Information
Transport Layer
Segments
Network Layer
Packets
Data Link Layer
Frames
Physical Layer
Bits


Source Node
Destination Node
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Data / Information
Data / Information
Data / Information
Segments
Packets
Frames
Bits
Internet
Data / Information
Data / Information
Data / Information
Segments
Packets
Frames
Bits
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

OSI Drawbacks

- No Interoperability
  - Each layer can only communicate with its immediate lower and upper layer.
- Not Practical
- First Model was developed, then protocols
- Stringent
- Cross Layer Design.
  - No Restrictions on layer interoperability.

Case 1:

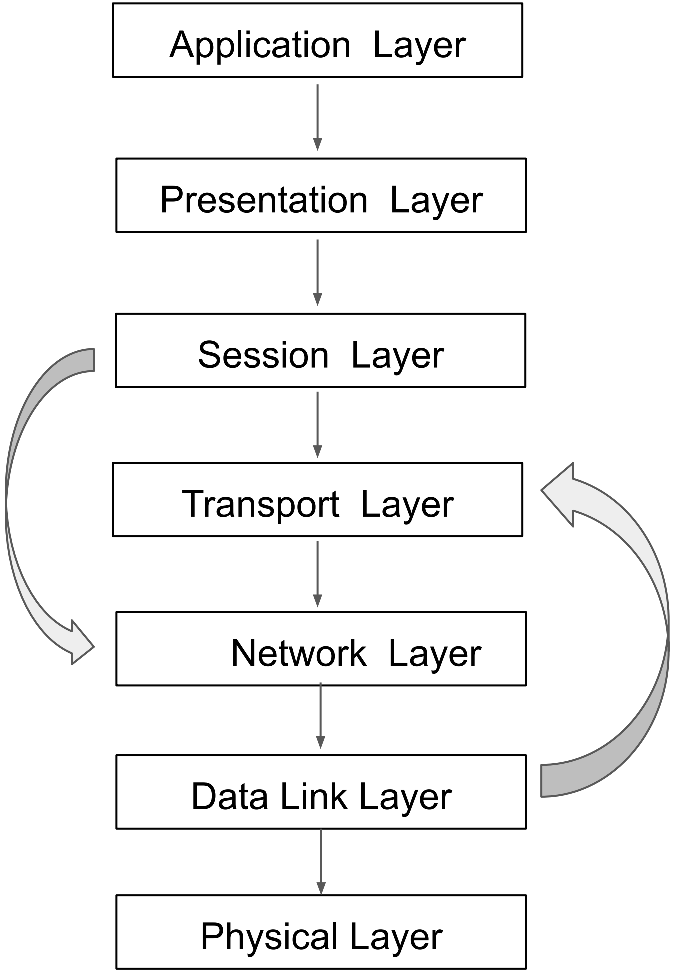
Session: Is it session failure ?

Network : Nop, Im finding the best path, wait for while.

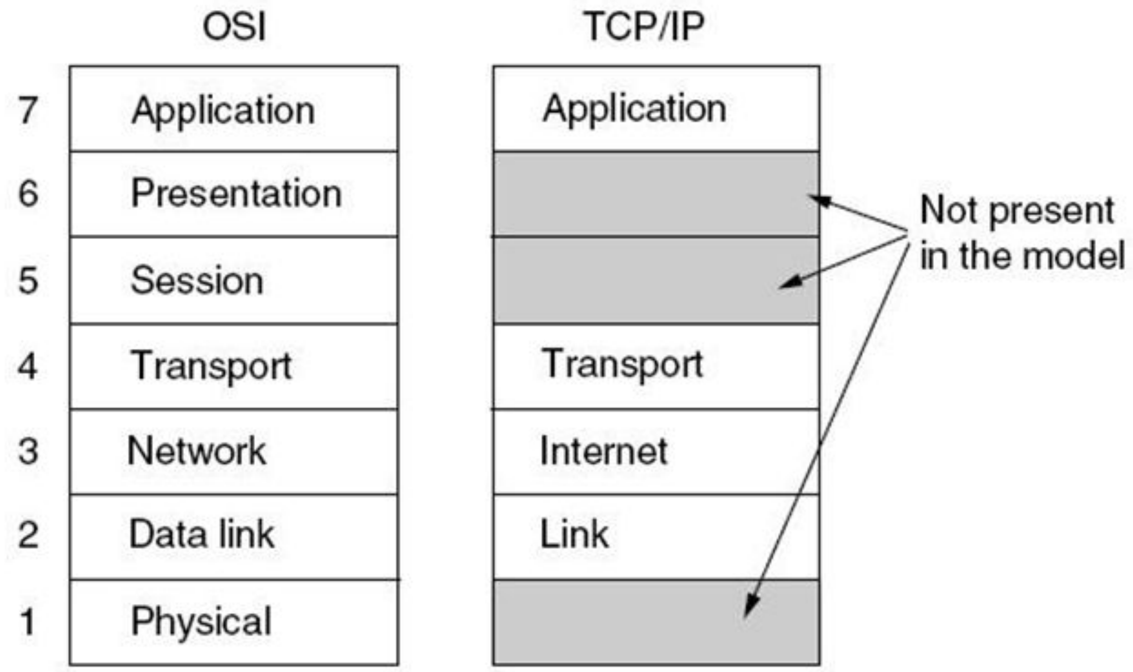
Case 2:

Transport: Network is bad, shall I reduce the data rate ?

Data Link: Network is quite good, the target system is taking a while to respond. Wait for my call.



TCP/IP Protocol Stack



Next Session

Error Detection and Correction.

Line Coding

Dr. Kiran M
Assistant Professor
NITK

Previous Session

- NS-3
- Layer Functionalities
- Physical Layer - Data Transmission
- DLL - Access Control
- Network Layer (Routing Layer) - Finding the best path
- Transport Layer - Traffic Control
- Session Layer - Session Control
- Presentation Layer - Presenting data to the user
- Application Layer - User Layer.

Q) Data is transferred from Transport to Network at source node. Transport layer tells the speed: packets/sec with which transmission takes place.

How can it decide the speed before network layer decides resourceful path to send the packets.

- Transport Layer initially starts with a default rate, minimum (n packet/sec).
- After observing the network condition (resources available), it increases and decreases the data rate.

Questions

Q) Can One Website have two different IP address ?

- YES.
- Amazon.com have different IP addresses.

tools.tracemyip.org/search--isp/amazon.com

https://tools.tracemyip.org/search--isp/amazon.com

Amazon.com IP Addresses | Records 1 to 50

ID	IP Address	Organization	Country	State	City	Timezone
1	54.88.253.19	Amazon.com	United States	Virginia	Ashburn	America/New_York
2	52.68.62.185	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
3	176.34.232.247	Amazon.com	Ireland	Leinster	Dublin	Europe/Dublin
4	54.88.253.120	Amazon.com	United States	Virginia	Ashburn	America/New_York
5	54.88.253.142	Amazon.com	United States	Virginia	Ashburn	America/New_York
6	52.220.52.184	Amazon.com	Singapore	- - -	Singapore	Asia/Singapore
7	23.21.145.172	Amazon.com	United States	Virginia	Ashburn	America/New_York
8	52.86.200.84	Amazon.com	United States	Virginia	Ashburn	America/New_York
9	3.8.177.195	Amazon.com	United Kingdom	England	London	Europe/London
10	52.68.62.173	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
11	52.68.62.247	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
12	52.6.227.194	Amazon.com	United States	- - -	- - -	America/Chicago
13	52.26.153.90	Amazon.com	United States	California	Redwood City	America/Los_Angeles
14	54.88.253.95	Amazon.com	United States	Virginia	Ashburn	America/New_York
15	52.68.62.219	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
16	35.175.190.117	Amazon.com	United States	- - -	- - -	America/Chicago
17	54.88.253.121	Amazon.com	United States	Virginia	Ashburn	America/New_York
18	52.35.96.206	Amazon.com	United States	Colorado	Rockvale	America/Denver
19	52.35.96.130	Amazon.com	United States	Colorado	Rockvale	America/Denver
20	52.6.227.99	Amazon.com	United States	- - -	- - -	America/Chicago
21	52.68.62.226	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
22	63.35.99.198	Amazon.com	Ireland	Leinster	Dublin	Europe/Dublin
23	52.68.62.145	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo

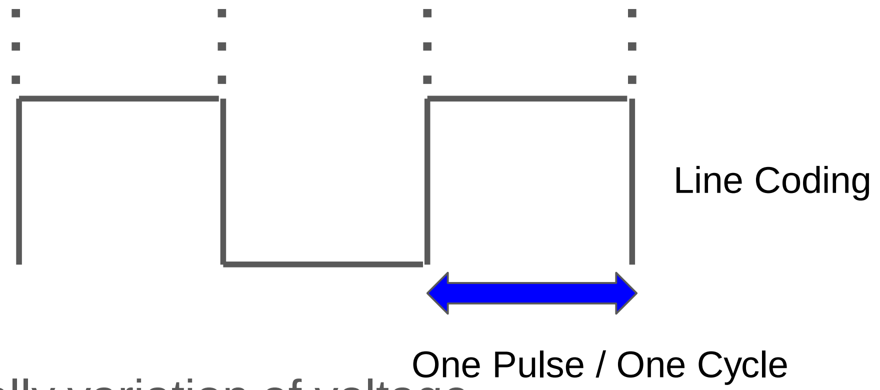
22	63.35.99.198	Amazon.com	Ireland	Leinster	Dublin	Europe/Dublin
23	52.68.62.145	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
24	13.233.132.106	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
25	54.88.253.20	Amazon.com	United States	Virginia	Ashburn	America/New_York
26	52.35.96.230	Amazon.com	United States	Colorado	Rockvale	America/Denver
27	13.233.142.223	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
28	52.6.227.252	Amazon.com	United States	---	---	America/Chicago
29	99.79.134.9	Amazon.com	Canada	Quebec	Montreal	America/Toronto
30	52.29.222.93	Amazon.com	Germany	Hesse	Frankfurt Am Main	Europe/Berlin
31	52.35.96.85	Amazon.com	United States	Colorado	Rockvale	America/Denver
32	34.192.14.72	Amazon.com	United States	Kansas	Leavenworth	America/Chicago
33	13.233.195.90	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
34	13.233.195.200	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
35	34.193.95.102	Amazon.com	United States	Minnesota	Minneapolis	America/Chicago
36	34.238.98.14	Amazon.com	United States	---	---	America/Chicago
37	54.88.253.8	Amazon.com	United States	Virginia	Ashburn	America/New_York
38	54.88.253.251	Amazon.com	United States	Virginia	Ashburn	America/New_York
39	52.68.62.154	Amazon.com	Japan	Tokyo	Tokyo	Asia/Tokyo
40	35.174.119.107	Amazon.com	United States	---	---	America/Chicago
41	13.239.42.148	Amazon.com	Australia	New South Wales	Sydney	Australia/Sydney
42	13.233.195.199	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
43	13.233.195.183	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
44	13.233.195.141	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
45	13.233.195.166	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
46	13.233.195.217	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
47	13.233.195.220	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata
48	13.233.195.181	Amazon.com	India	Maharashtra	Mumbai	Asia/Kolkata

Today’s Session

- Line Coding.
    - How data is transmitted in the physical layer ?

Line Coding

- Converts Digital Data into Digital signals.

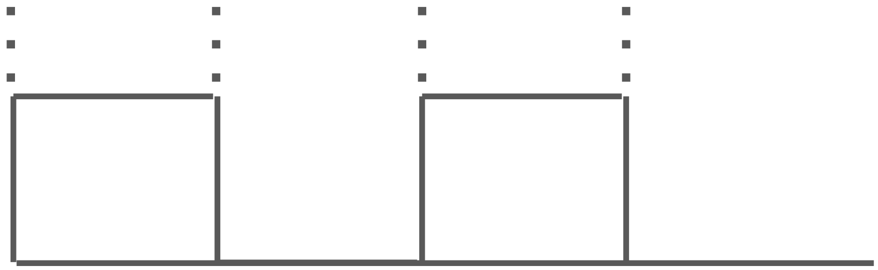


- Basically variation of voltage.
- At the sender end, data is converted in to digital signals - Encoding.
- At the receiver end, digital signals are converted in to digital data - Decoding.
- Directly transmitted in Communication channels (TP, Coax…).
- Uniploar, Polar, Biploar,

Unipolar

NRZ (Non Return to Zero)

- Positive Voltage - Bit 1, No Voltage - Bit 0.
- Voltage will not come to zero in the middle of the cycle/bit,
    - Hence, Non Return to Zero. (NRZ)



Unipolar

NRZ (Non Return to Zero)

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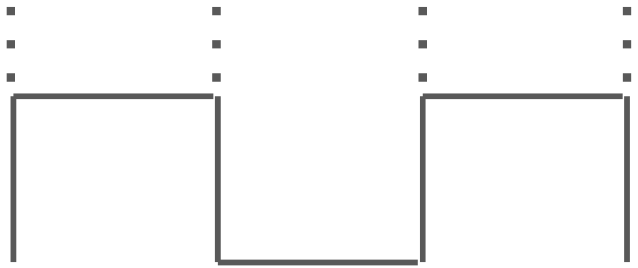


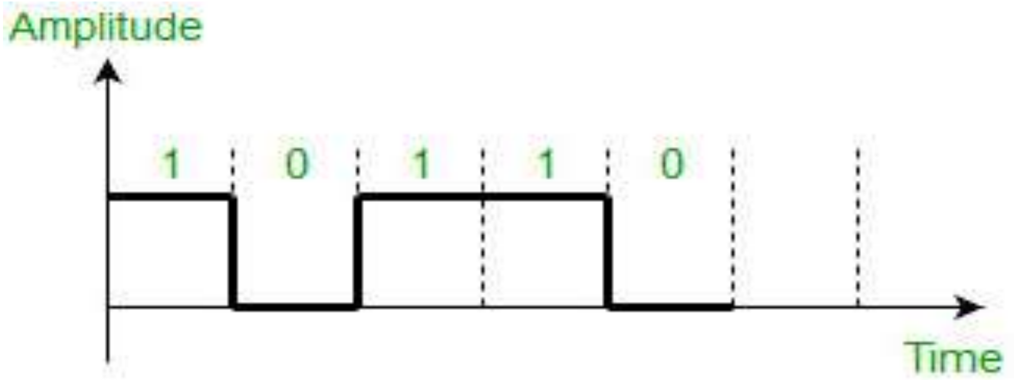


Image Source: https://www.geeksforgeeks.org/difference-between-unipolar-polar-and-bipolar-line-coding-schemes/

Advantages Disadvantages

- It is simple
- Lesser bandwidth is required.

Disadvantages

- No Error Correction
- Synchronization problem for the long series of 1’s or 0’s.

Unipolar

RZ (Return to Zero)

- Positive Voltage - Bit 1, No Voltage - Bit 0.
- For half of the bit duration, voltage will be high, then returns to zero.
- For remaining half of the bit, voltage will be zero.
- Voltage will come to zero in the middle of the bit,
    - Hence, Return to Zero.(RZ)

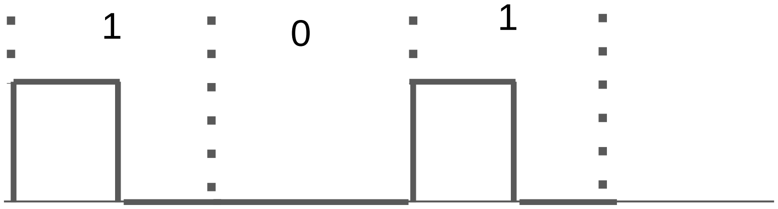


Image Source: https://www.geeksforgeeks.org/difference-between-unipolar-polar-and-bipolar-line-coding-schemes/

Advantages Disadvantages

- It is simple
- Only half bandwidth is used.

Disadvantages

- No Error Correction
- Synchronization problem for the long series of 1’s or 0’s.

Polar

- Use both levels of Voltages.
- Use both side of the x axis.
- NRZ and RZ

Polar NRZ

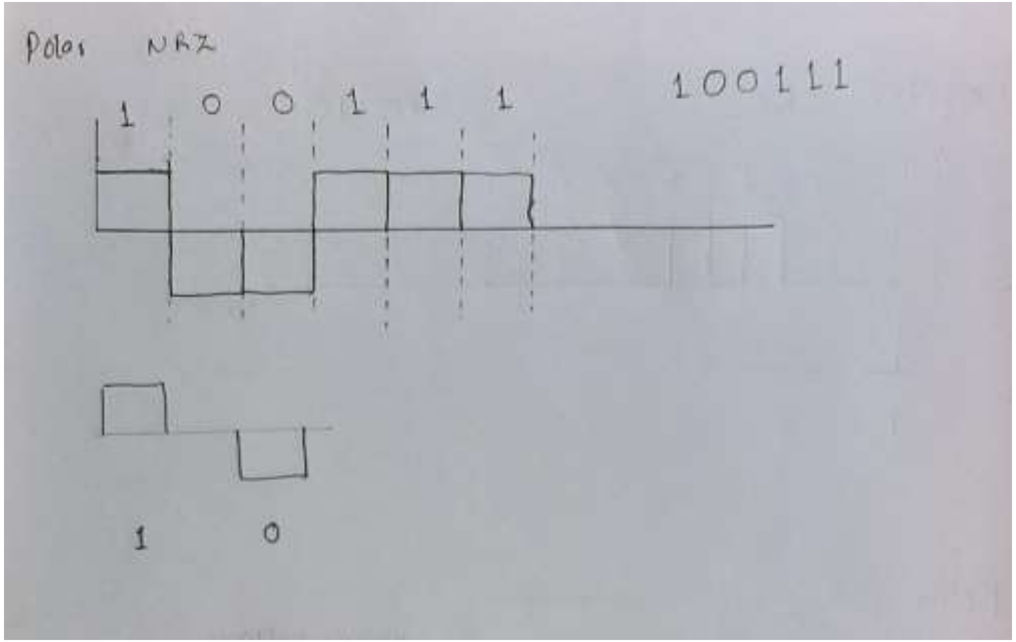
Complete Cycle will be used.

+ve Voltage - 1 bit

-ve Voltage - 0 bit

Complete one cycle will be used

for both 1 and 0.



Advantages Disadvantages

- It is simple

Disadvantages

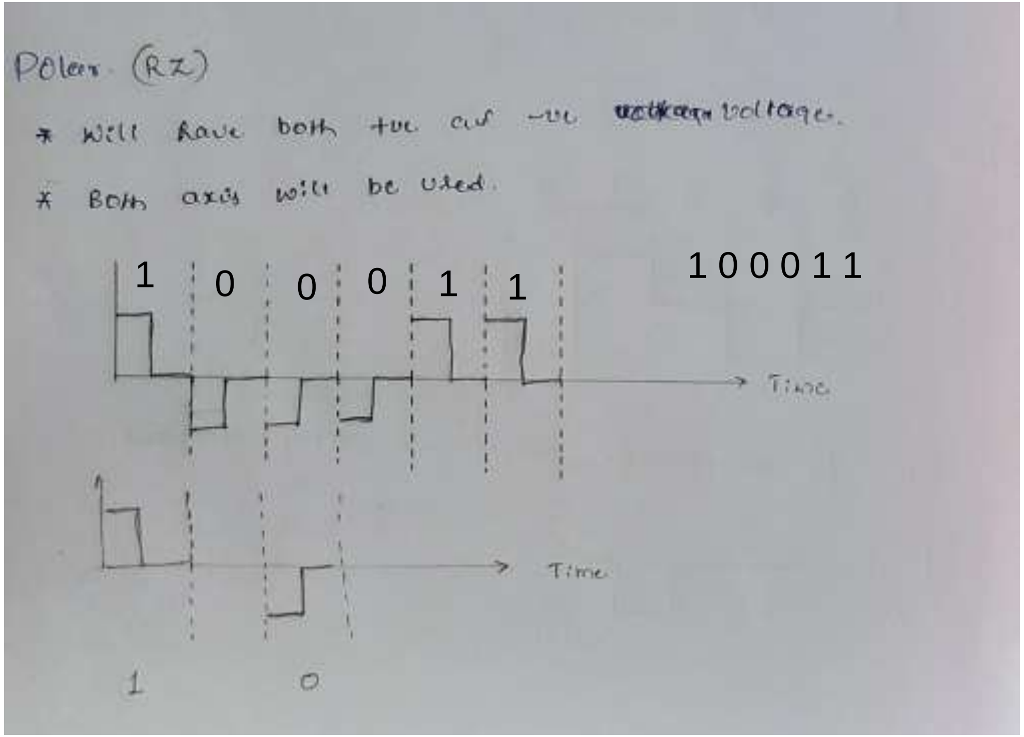
- No Error Correction
- Occupies twice the bandwidth when compared to unipolar
    - For both one and zero voltage should be there, either +ve or -ve.
- Synchronization problem for the long series of 1’s or 0’s.

Polar RZ

Returns to zero in the middle of the bit.

Half of the +ve voltage in a bit = 1

Half of the -ve voltage in a bit = 0



Advantages Disadvantages

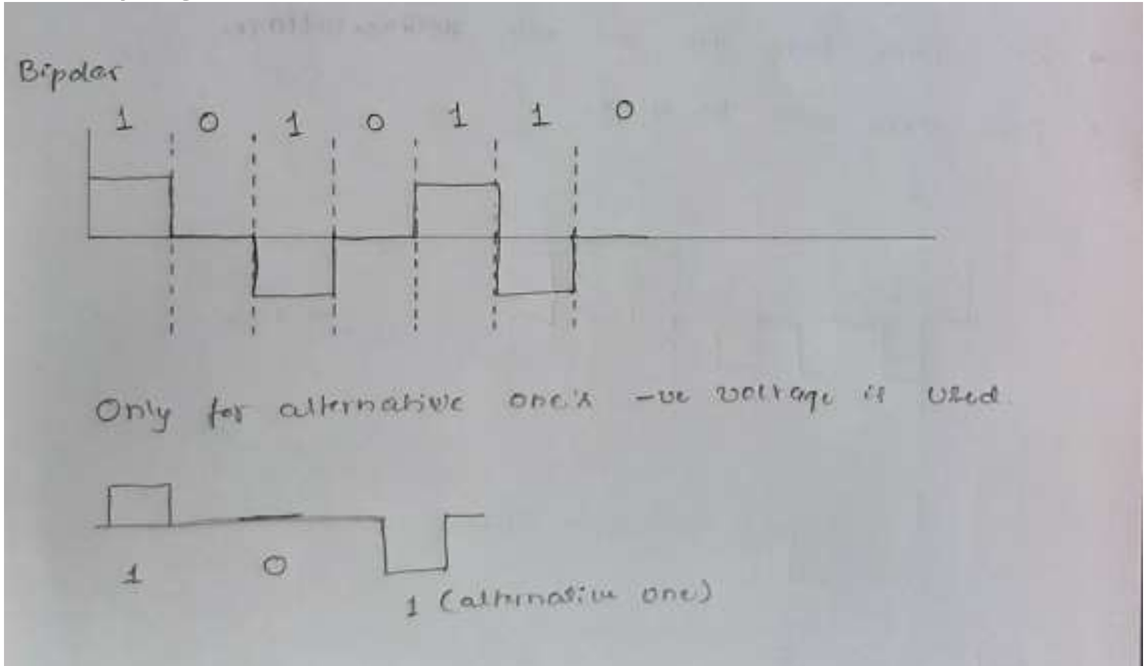
- It is simple

Disadvantages

- No Error Correction
- Occupies twice the bandwidth when compared to unipolar
  - For both one and zero voltage should be there, either +ve or -ve.
- Synchronization problem for the long series of 1’s or 0’s.

Bipolar

- As same as Unipolar
- But, Alternative ones will be inverted.
- It has three types of voltages, +ve, -Ve and 0.
  - Such a signal is called as duo binary signal.



Advantages Disadvantages

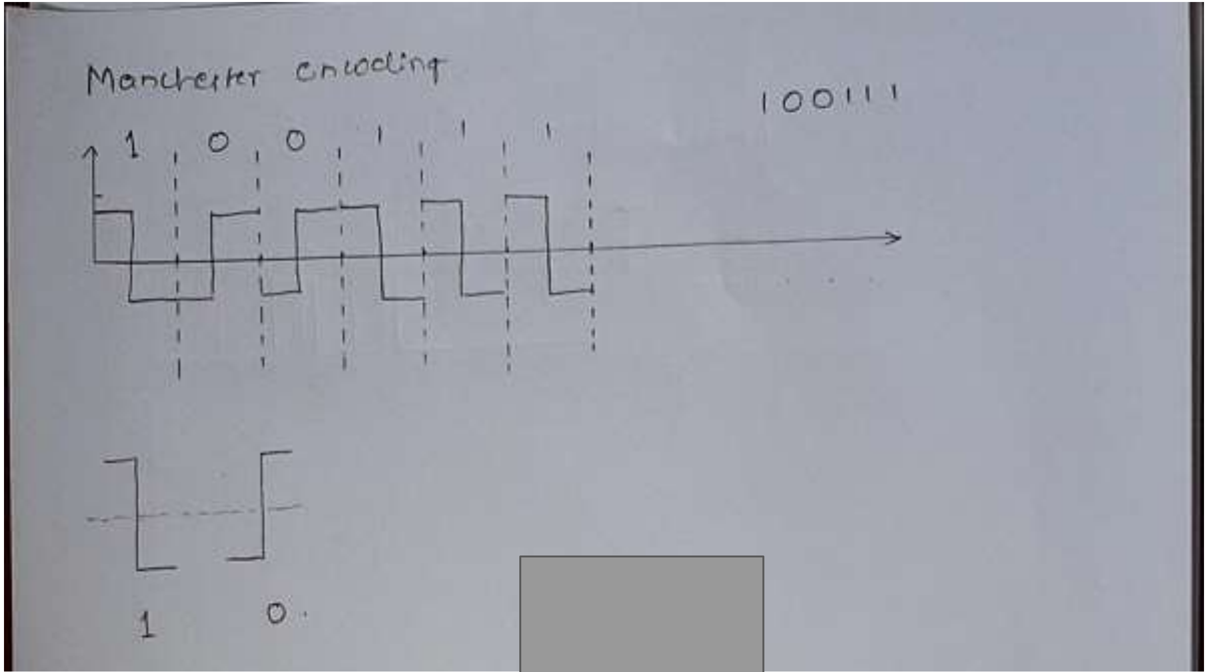
- It is simple
- Single Bit error correction is possible.

Disadvantages

- Occupies twice the bandwidth when compared to unipolar
    - For both one and zero voltage should be there, either +ve or -ve.
- But, some times may save bandwidth, if you have a sequence of zeros.
- Synchronization problem for the long series of 1’s or 0’s.

Manchester Coding

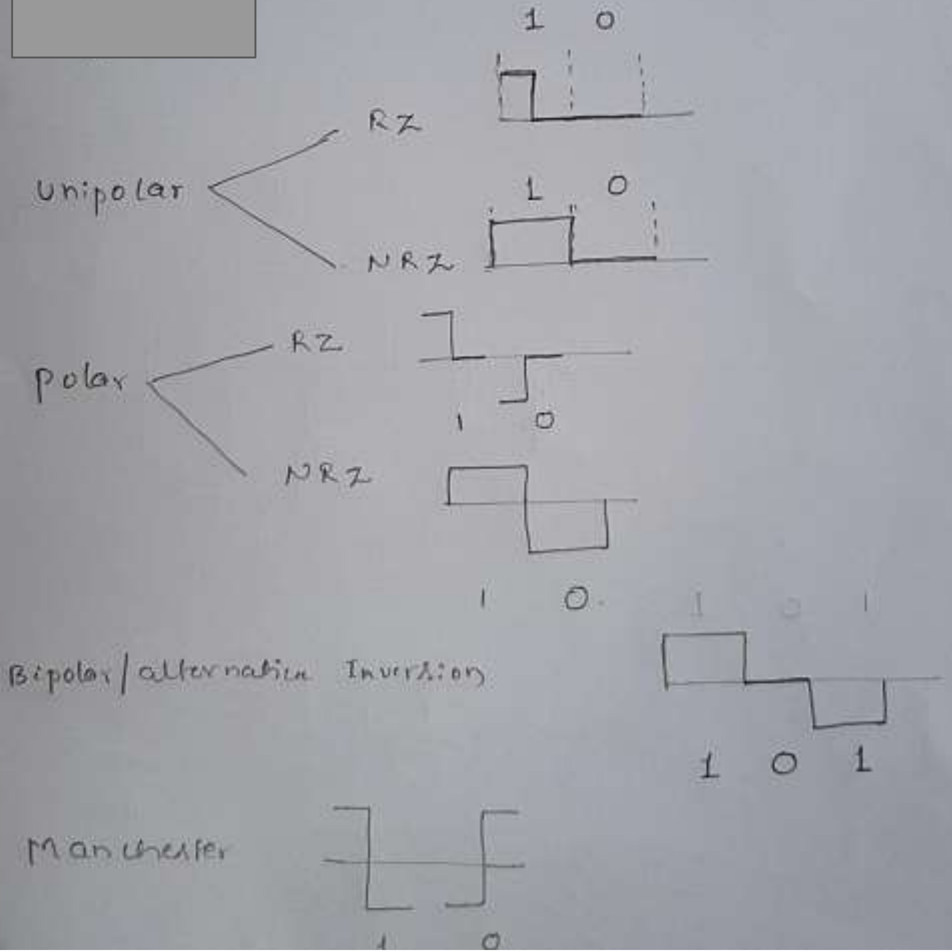
- Currently used line coding.
- Uses both +ve and -ve voltage for representing 0's and 1's.



Advantages

Though bandwidth utilization is high, Multiple Error Detection and correction is possible.

Synchronous, No Confusion.

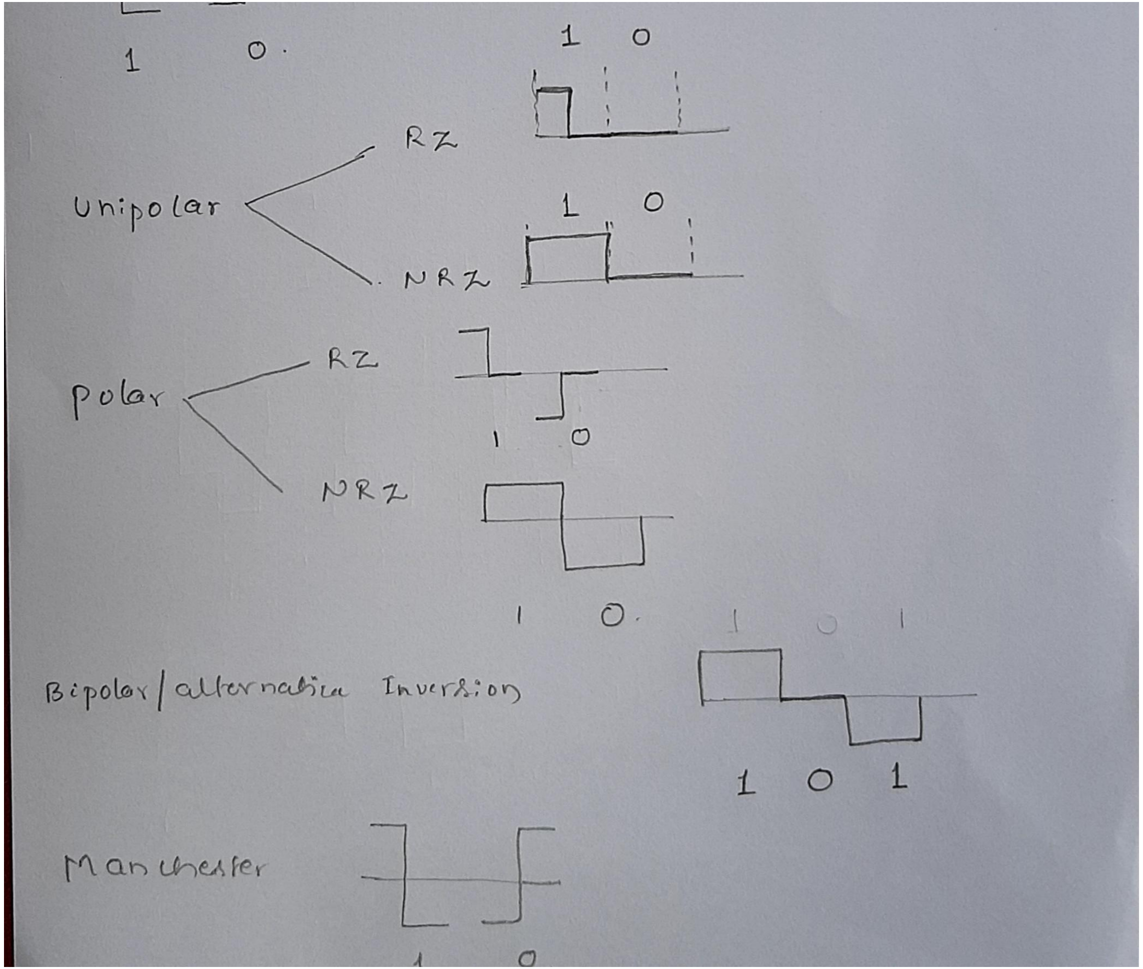


1 0
RZ
Unipolar
1 0
NRZ
RZ
polar
1 0
NRZ
1 0.
1 0 1
Bipolar/alternation Inversion
1 0 1
Manchester
1 0

Multiplexing and Switching

Dr. Kiran M
IT Dept. , NITK, Surathkal

Previous Session



Today’s Session

- Multiplexing
- Switching

Multiplexing Schemes

- The networking devices, cables are very costly.
- It should be used in an efficient manner.
- If we allocate entire available resources for a a single user for a single call/session - It will not workout.
- Hence, Multiplexing.
- Giving service to the multiple user parallelly / at the same time.
- Two types basically,
    - Frequency Division Multiplexing.
    - Time Division Multiplexing.

Frequency Division Multiplexing (FDM)

- Frequency - No.of waves
- The Frequency spectrum is divided into bands
- Multiple user can opt for the different bands and they can use it simultaneously.
- The user will get the complete access to the their band. - No sharing.
- Ex. Radio
  - FM radio works in different bands
  - Exclusive channels and will be active all the time.

Wavelength Division Multiplexing (WDM)

- Variation of FDM.
- Wavelength is the parameter.
- Used in optical fiber, multimode fiber.

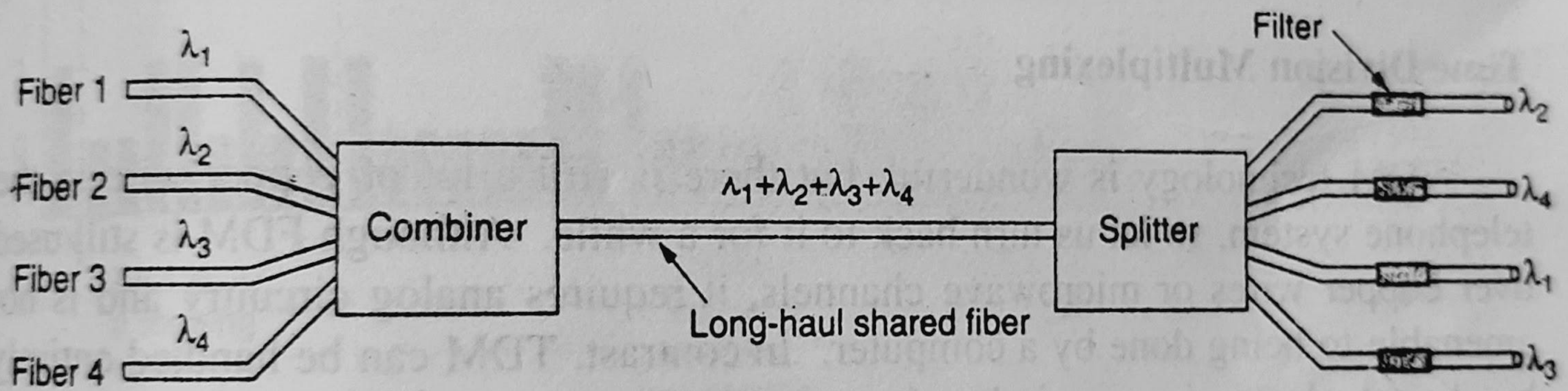


Figure 2-32. Wavelength division multiplexing.

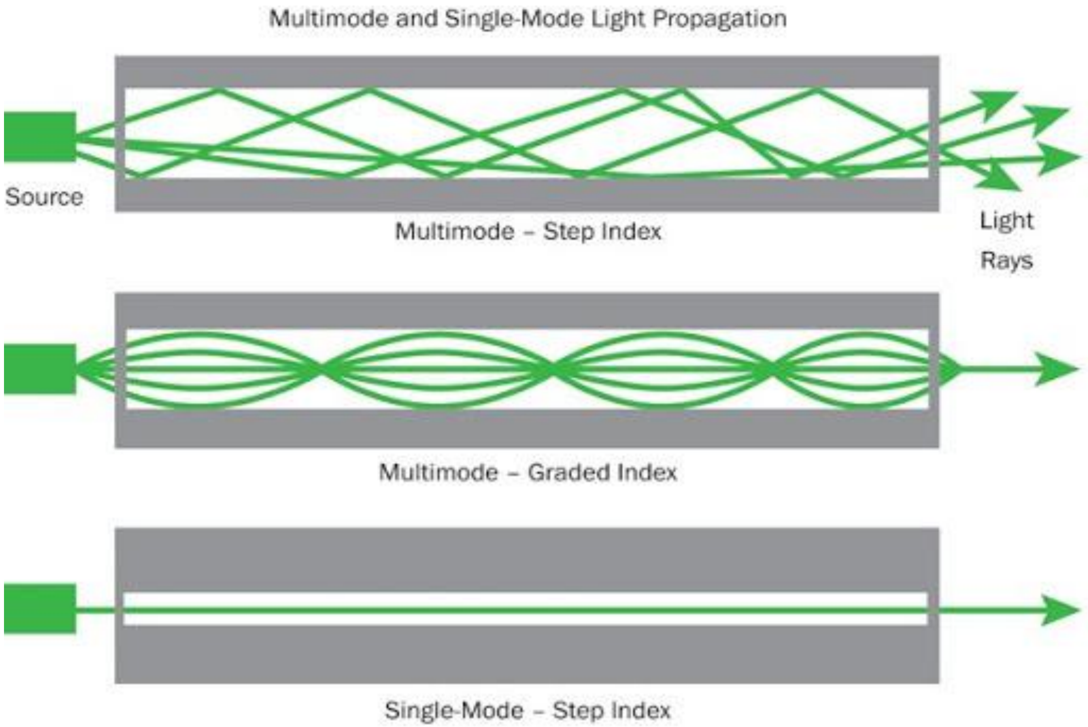


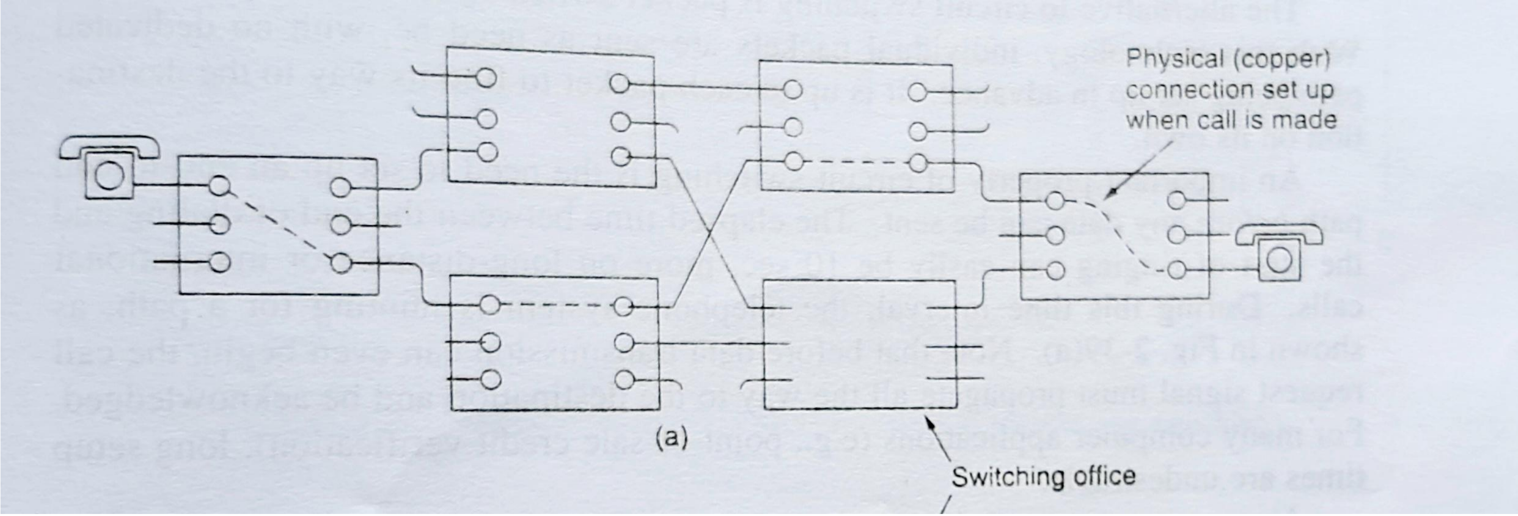
Image Source: Internet

Time Division Multiplexing (TDM)

- Time is divided into slots.
- Each user will get a slot.
- Users have to transmit in their time slot/turn only.
- Very rarely used.
- FDM and WDM - mostly used.

Switching

- Mobile Switching Centers (MSC), Switching offices, Switching centers.
- All back-haul cables will lead to MSC.
- From MSC, the end points are reached.
- Many cables - how to manage ?

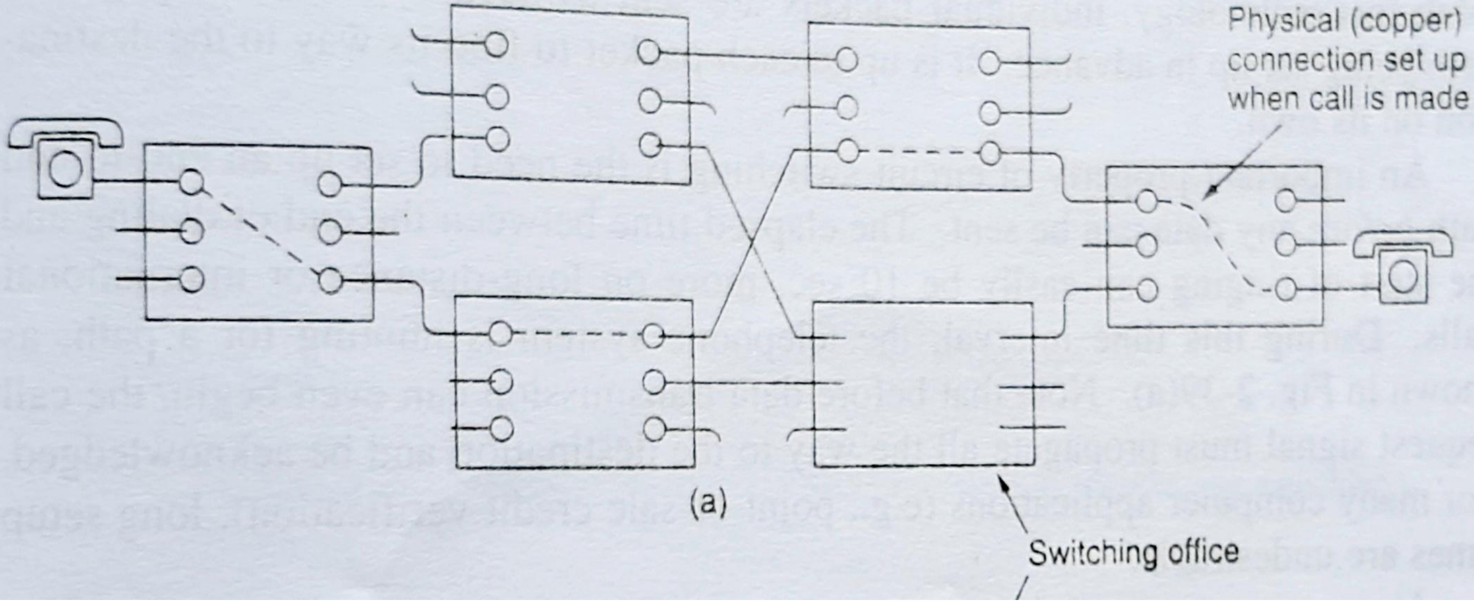


Switching Types

- Circuit Switching
- Message Switching
- Packet Swithcing

Circuit Switching

- Used for Telephone system
- Physical dedicated path between the end users.
- Established in advance.
- It was done manually in the early days.
    - Trunc calls in the old movies.
- Now it is auto switching


Physical (copper) connection set up when call is made
Switching office
(a)

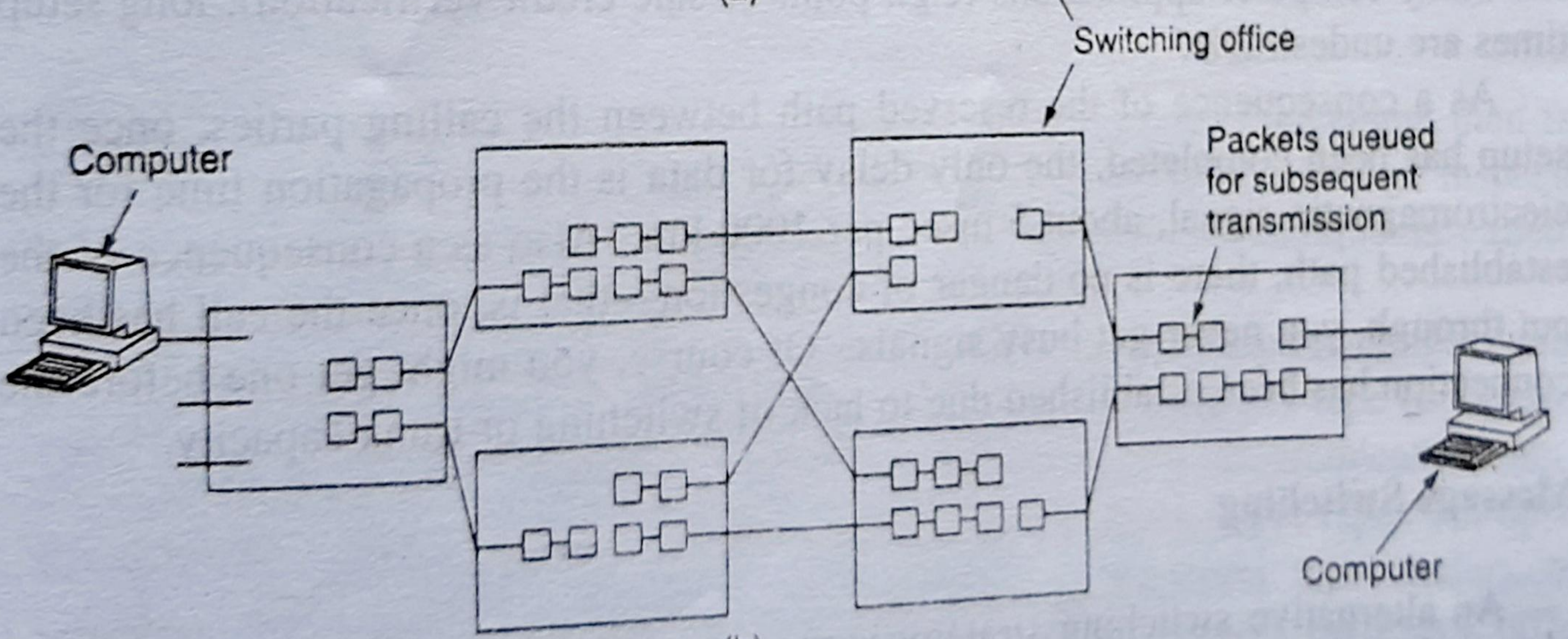
Drawbacks

- No fault tolerance
- If a switch goes down in between the call, then all the calls handled by that switch goes down.

Message Switching

- Basically used for internet.
- No physical, dedicated path in advance.
- Message will be in terms of blocks.
- Complete block will be received entirely in router/switching office.
- Error Checking is done.
- Hence, Store and Forward.
- Each message will find its own path to reach the destination.

(a)


Switching office
Computer
Packets queued
for subsequent
transmission
Computer

(b)

Drawbacks

- No limit on block size
- Since Store and Forward, enough router should have enough resource.
  - hard disk for storing big blocks
- Monopoly.
  - Traffic will be blocked.
- Hence, not good for interactive traffic / live traffic.

Packet Switching

- Like message switching
- Small sized Packets, routers can store in its buffer.
- No dedicated path.
- Each packet will find its own path to reach the destination.
- No monopoly
- Store and Forward, Error Detection
- Interactive traffic - Well Suited.
- Fault Tolerant.
- Packet switching (for Internet) and Circuit Switching (for Telephone) are most widely used.

Item	Circuit switched	Packet switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
Time of possible congestion	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

Thank You

Data Link Layer - Layer 2

Dr. Kiran M
IT, NITK

Previous Session

- Multiplexing
  - FDM , WDM
  - TDM
- Switching
  - Circuit Switching
  - Message Switching
  - Packet Switching

Physical Layer

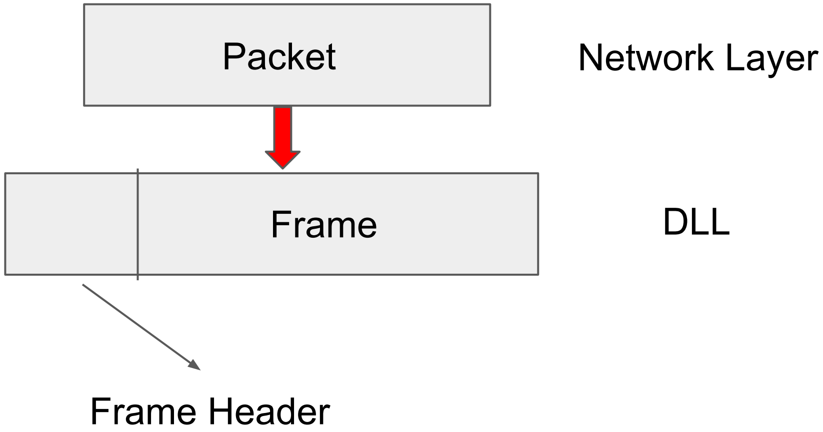
- OSI Layer Functionalities
- Networking Devices- Switch, Router, Hub, Bridge, NIC
- Line Coding - Unipolar, Polar, Bipolar, Manchester
- Multiplexing Schemes - FDM, WDM and TDM
- Switching - Message, Circuit and Packet

Data Link Layer (DLL) - Layer 2

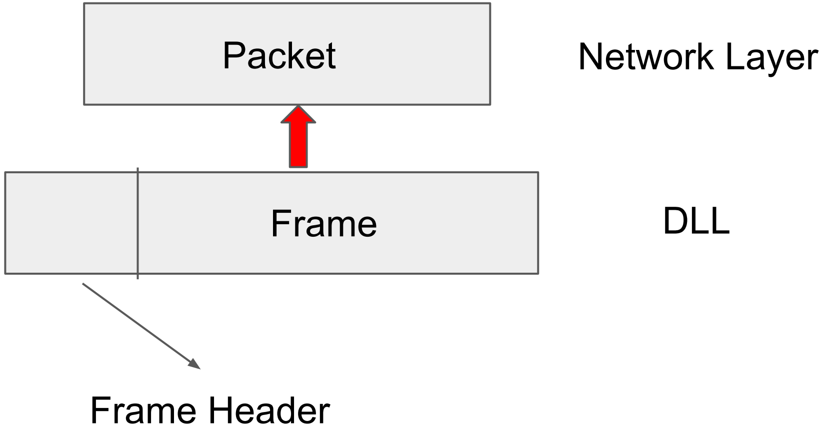
- Machine A puts bits into Channel - Machine B takes off those bits.
- Occasionally, bits might be erroneous.
    - Channel, Interferences, Intruder.
- DLL Responsibilities
    - Error Control (Handling Transmission Errors)
        - Error Detection and Correction
    - Flow Control.
        - Regulating the flow of data.

Frames at DLL

MTU 1500



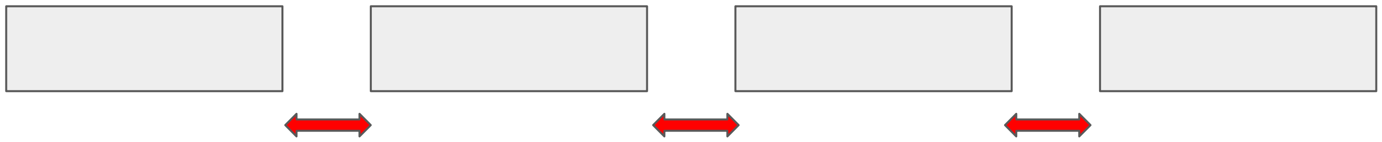
@ Sender Node



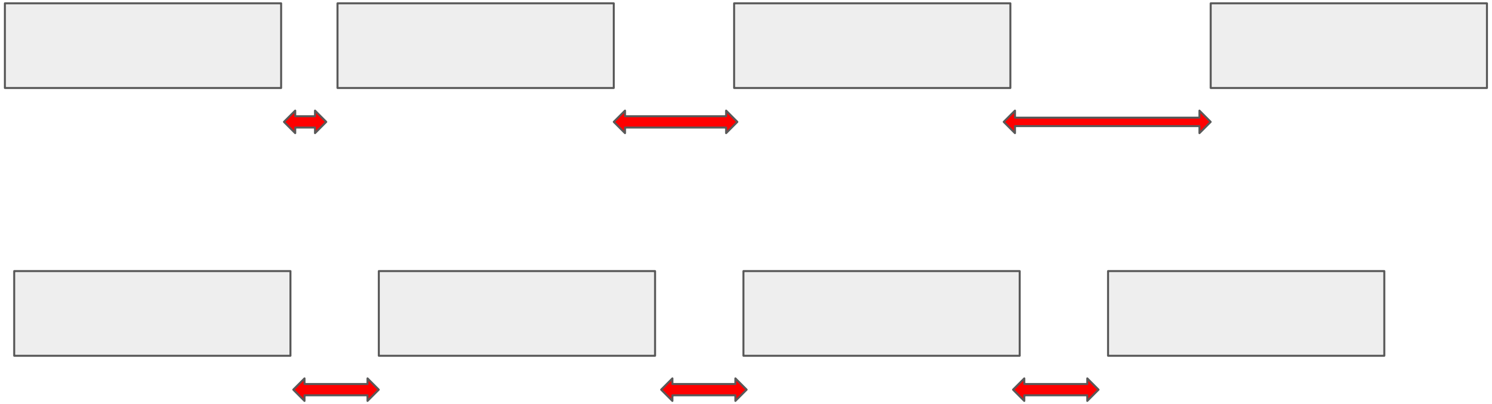
@ Receiver Node

Responsibilities of DLL (Contd.)

- Breaking frames in to bits.
- Continuous frames should be separated.
  - Like space between the words.
- Time Gap between the frames.



But, no guarantee of time in network - best effort service.

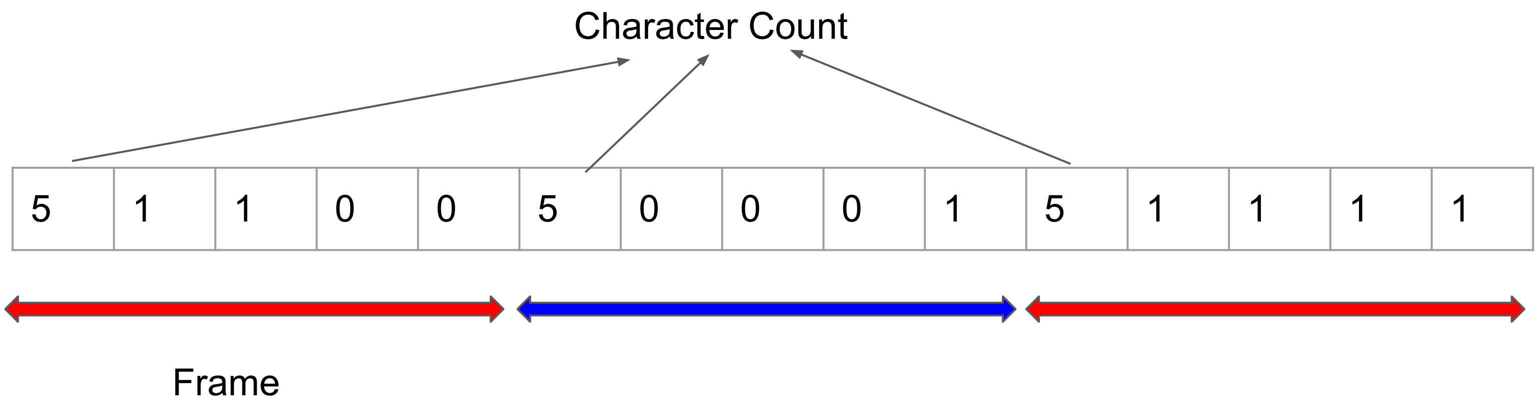


Like space between the words.

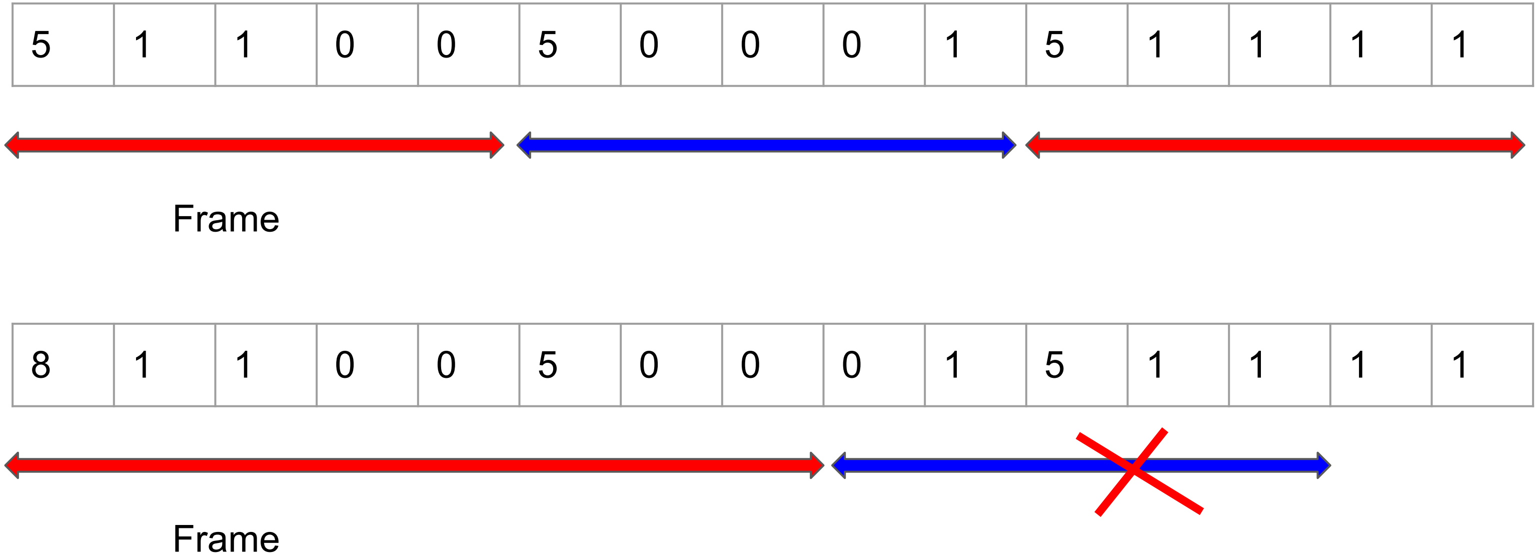
Likespace   between   the   words

Character Count

- Character count in the frame herder.
- It is the very first framing method used.
- Easy to differentiate between the frames.



- Character Count Bit Error



FLG byte

- The second method used for differentiating the continuous frames.
- FLG byte is used as a delimiter.

FLG	Frame	FLG

0 0 1	0 0 0 1 0 0 0 1 0 1 0 1 0 1 0 1 0 1 0	0 0 1

0 0 1	0 0 0 1 0 0 0 1 0 1 0 1 0 1 0 1 0 1 0	0 0 1

Accidental FLG in the data

Byte Stuffing

- When FLG byte itself is a data bit.
- ESC bits as byte stuffing/ Character stuffing.

FLG	ESC FLG	FLG

0 0 1	0 10 0 0 1 0 10 0 0 1 0 1 0 1 0 1 0 1 0 1 0	0 0 1

Accidental FLG in the data

FLG	ESC ESC FLG	FLG

Error Detection and Correction

- Error Detection - Hamming Code
- R. W Hamming
- 7 Bit Hamming - Most Normally Used
- Data Bit + Parity bit
  - 4 Data Bit + 3 Parity Bit = 7 Bits

D4	D3	D2	P3	D1	P2	P1
7	6	5	4	3	2	1

- Parity Bits - 2^n

-	-	-	2^2	-	2^1	2^0
D4	D3	D2	P3	D1	P2	P1
7	6	5	4	3	2	1

2^3	-	-	-	2^2	-	2^1	2^0
D5	D4	D3	D2	P3	D1	P2	P1
8	7	6	5	4	3	2	1

Error Detection

- Even Parity
- Odd Parity

Parity and Data Bits

P1 - D3 D5 D7

P2 - D3 D6 D7

P4 - D5 D6 D7

Next Session

Error Detection and Correction

Hamming Code

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Previous Session

- DLL Functionalities
    - Transmission error detection and correction.
- Flow Control
- The frames @ DLL - 1500 bytes.
- “From” and “To” - Network Layer
- Time gap between the frames,
- Character Count,
- FLG byte and ESC byte
- Error Detection and Correction - Hamming Codes

Error

- Transmitted data can be corrupted during the transmission.
    - EMI, Cross Talks,
- Single, Multiple , Burst
- Error Detection and Correction
    - A method of checking the received bits for the errors and correcting it.
    - At the receiving end,
    - At the sender side, precautionary measures will be taken.

Error Detection and Correction

- Single Bit Error Detection and Correction.
- Hamming Code - Data Bit + Parity bit
    - 4 Data Bit + 3 Parity Bit = 7 Bits

D7	D6	D5	P4	D3	P2	P1
7	6	5	4	3	2	1

- @ Sender Side - Data Bits + Parity Bits
- @ Receiver Side - Data Bits + Parity Bits are used for error detection/correction.

- Parity Bits - 2^n

7 Bit Hamming Code

-	-	-	2^2	-	2^1	2^0
D7	D6	D5	P3	D3	P2	P1
7	6	5	4	3	2	1

8 Bit Hamming Code

2^3	-	-	-	2^2	-	2^1	2^0
P4	D7	D6	D5	P3	D4	P2	P1
8	7	6	5	4	3	2	1

7 Bit Hamming Code

Parity Bit and Associated Data Bits

P1 - D3 D5 D7 (1 ~~2~~ 3 ~~4~~ 5 ~~6~~ 7 ...)

P2 - D3 D6 D7 (2 3 ~~4~~ ~~5~~ 6 7 ...)

P4 - D5 D6 D7 (4 5 6 7 ~~8~~ ~~9~~ ~~10~~ ~~11~~...)

Actual Data = 1 0 1 1

D7	D6	D5	P4	D3	P2	P1
1	0	1		1		

P1 - D3 D5 D7 = 1 1 1 P1 = 1 (1 1 1 1)

P2 - D3 D6 D7

P4 - D5 D6 D7

Even Parity Bit.

- No. of 1's = even

Actual Data = 1 0 1 1

D7	D6	D5	P4	D3	P2	P1
1	0	1		1		1

P1 - D3 D5 D7 = 1 1 1 P1 = 1 (1 1 1 1)

P2 - D3 D6 D7

P4 - D5 D6 D7

Actual Data = 1 0 1 1

D7	D6	D5	P4	D3	P2	P1
1	0	1		1		1

P1 - D3 D5 D7 = 1 1 1 P1 = 1 (1 1 1 1)

P2 - D3 D6 D7 = 1 0 1 P2 = 0 (1 0 1 0)

P4 - D5 D6 D7

Actual Data = 1 0 1 1

D7	D6	D5	P4	D3	P2	P1
1	0	1		1	0	1

P1 - D3 D5 D7 = 1 1 1 P1 = 1 (1 1 1 1)

P2 - D3 D6 D7 = 1 0 1 P2 = 0 (1 0 1 0)

P4 - D5 D6 D7

Actual Data = 1 0 1 1

D7	D6	D5	P4	D3	P2	P1
1	0	1	0	1	0	1

P1 - D3 D5 D7 = 1 1 1 P1 = 1 (1 1 1 1)

P2 - D3 D6 D7 = 1 0 1 P2 = 0 (1 0 1 0)

P4 - D5 D6 D7 = 1 0 1 P3 = 0 (1 0 1 0)

Tx = 1 0 1 0 1 0 1

Tx = 1 0 1 0 1 0 1

Rx = 1 0 1 0 1 0 1

D7	D6	D5	P4	D3	P2	P1
1	0	1	0	1	0	1

No. of 1’s

P1 D3 D5 D7 = 1 1 1 1 - even

P2 D3 D6 D7 = 1 0 1 0

P4 D5 D6 D7 = 1 0 1 0

Rx = 0 1 0 0 1 1 0

D7	D6	D5	P4	D3	P2	P1
0	1	0	0	1	1	0

P1 D3 D5 D7 = 0 1 0 0

P2 D3 D6 D7

P4 D5 D6 D7

Rx = 0 1 0 0 1 1 0

D7	D6	D5	P4	D3	P2	P1
0	1	0	0	1	1	0

P1 D3 D5 D7 = 0 1 0 0 ✗

P2 D3 D6 D7 = 1 1 1 0 ✗

P4 D5 D6 D7

Rx = 0 1 0 0 1 1 0

D7	D6	D5	P4	D3	P2	P1
0	1	0	0	1	1	0

P1 D3 D5 D7 = 0 1 0 0 ✗

P2 D3 D6 D7 = 1 1 1 0 ✗

P4 D5 D6 D7 = 0 0 1 0 ✗

Rx = 0 1 0 0 1 1 0

D7	D6	D5	P4	D3	P2	P1
0	1	0	0	1	1	0

P1 D3 D5 D7 = 0 1 0 0

P2 D3 D6 D7 = 1 1 1 0

P4 D5 D6 D7 = 0 0 1 0

P4	P2	P1
1	1	1

4 + 2 + 1 = 7th Bit Error

Rx= 0 1 0 0 1 1 0 - Erroneous.

D7	D6	D5	P4	D3	P2	P1
~~0~~ 1	1	0	0	1	1	0

P1 D3 D5 D7 = 0 1 0 0 ✗

P2 D3 D6 D7 = 1 1 1 0 ✗

P4 D5 D6 D7 = 0 0 1 0 ✗

P4	P2	P1
1	1	1

4 + 2 + 1 = 7th Bit Error

Single Bit Error Detection-Correction

Corrected Bit Stream = 1 1 0 0 1 1 0

Rx= 0 1 0 0 1 1 0 - Erroneous.

D7	D6	D5	P4	D3	P2	P1
~~0~~ 1	1	0	0	1	1	0

Data Bit Error, there can be parity bit error

$Rx = 1\ 1\ 0\ 1\ 1\ 1\ 0$

D7	D6	D5	P4	D3	P2	P1
1	1	0	1	1	1	0

P1 D3 D5 D7 = 0 1 0 1 ✓

P2 D3 D6 D7

P4 D5 D6 D7

Rx = 1 1 0 1 1 1 0

D7	D6	D5	P4	D3	P2	P1
1	1	0	1	1	1	0

P1 D3 D5 D7 = 0 1 0 1 ✓

P2 D3 D6 D7 = 1 1 1 1 ✓

P4 D5 D6 D7

Rx = 1 1 0 1 1 1 0

D7	D6	D5	P4	D3	P2	P1
1	1	0	1	1	1	0

P1 D3 D5 D7 = 0 1 0 1 ✓

P2 D3 D6 D7 = 1 1 1 1 ✓

P4 D5 D6 D7 = 1 0 1 1 ✗

Rx = 1 1 0 1 1 1 0

D7	D6	D5	P4	D3	P2	P1
1	1	0	1	1	1	0

P1 D3 D5 D7 = 0 1 0 1 ✓

P2 D3 D6 D7 = 1 1 1 1 ✓

P4 D5 D6 D7 = 1 0 1 1 ✗

P4	P2	P1
1	0	0

4 + 0 + 0 = 4th Bit Error

Single Bit Error Detection-Correction

Rx = 1 1 0 1 1 1 0

D7	D6	D5	P4	D3	P2	P1
1	1	0	~~1~~ 0	1	1	0

P1 D3 D5 D7 = 0 1 0 1 ✓

P2 D3 D6 D7 = 1 1 1 1 ✓

P4 D5 D6 D7 = 1 0 1 1 ✗

P4	P2	P1
1	0	0

4 + 0 + 0 = 4th Bit Error

Single Bit Error Detection-Correction

Corrected Bit Stream = 1 1 0 0 1 1 0

Odd Parity

- No. of 1s should be Odd in the parity and data bits combination.
- Rest of the procedures are same.

Checksum - Only Error Detection

- Data bits are divided into *m* segments, each with *n* bits.
- @ Sender End:
  - Each segments are added using 1s complement
  - Sum is complemented - checksum.
  - The checksum is also sent along with the segments.
- @ Receiving End:
  - All received segments are added using 1's complement.
  - Then the sum is complemented.
  - If result is zero, segments received are non erroneous. Else… discarded.

$\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\boxed{4}$

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

m = 4 and n = 8

							1		
	1	0	1	1	0	0	0	1	$\boxed{1}$
+	1	0	1	0	1	0	1	1	$\boxed{2}$

							0

$\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\boxed{4}$

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

						1	1	
	1	0	1	1	0	0	0	1
+	1	0	1	0	1	0	1	1
							0	0

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

						1	1	
	1	0	1	1	0	0	0	1
+	1	0	1	0	1	0	1	1
						1	0	0

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

		1				1	1	
	1	0	1	1	0	0	0	1
+	1	0	1	0	1	0	1	1
			0	1	1	1	0	0

$\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\boxed{4}$

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

		1				1	1	
	1	0	1	1	0	0	0	1
+	1	0	1	0	1	0	1	1
$\boxed{1}$	0	1	0	1	1	1	0	0

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

		1				1	1	
	1	0	1	1	0	0	0	1
+	1	0	1	0	1	0	1	1

1	0	1	0	1	1	1	0	0
								1
	0	1	0	1	1	1	0	1

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

	0	1	0	1	1	1	0	1	
+	0	0	1	1	0	1	0	1	3
	?	?	?	?	?	?	?	?	

Hamming Code
&
Cyclic Redundancy Check (CRC)

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Checksum - Only Error Detection

- Data bits are divided into *m* segments, each with *n* bits.
- @ Sender End:
    - Each segments are added using 1s complement
    - Sum is complemented - checksum.
    - The checksum is also sent along with the segments.
- @ Receiving End:
    - All received segments are added using 1’s complement.
    - Then the sum is complemented.
    - If result is zero, segments received are non erroneous. Else… discarded.

1	2	3	4
1 0 1 1 0 0 0 1 ,	1 0 1 0 1 0 1 1 ,	0 0 1 1 0 1 0 1 ,	1 0 1 0 0 0 1

		1				1	1		
	1	0 1	1	1	0	0 1	0 1	1	1
+	1	0	1	0	1	0	1	1	2
1	0	1	0	1	1	1	0	0	

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 0, Carry 1

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

		1				1	1	
	1	0	1	1	0	0	0	1
+	1	0	1	0	1	0	1	1
1	0	1	0	1	1	1	0	0
								1
	0	1	0	1	1	1	0	1

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 0, Carry 1

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 1

	0	1	0	1	1	1	0	1
+	0	0	1	1	0	1	0	1

3

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 0, Carry 1

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 0 1

+ +

1 | 2 | 3 | 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 0 1

+ + +

Final Result = 0 0 1 1 0 1 0 0

$\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\boxed{4}$

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 0 1

$\boxed{+}$ $\boxed{+}$ $\boxed{+}$

Final Result = 0 0 1 1 0 1 0 0

Complement = 1 1 0 0 1 0 1 1

1 2 3 4

1 0 1 1 0 0 0 1 , 1 0 1 0 1 0 1 1 , 0 0 1 1 0 1 0 1 , 1 0 1 0 0 0 0 1

\+ \+ \+

= 0 0 1 1 0 1 0 0

1 1 0 0 1 0 1 1 Complement

10110001 , 10101011 , 00110101 , 10100001, 11001011

@ Sender Side = Data Bits + Checksum

10110001 , 10101011 , 00110101 , 10100001, 11001011

\+ \+ \+ \+

Result = 1 1 1 1 1 1 1 1 → Complement 0 0 0 0 0 0 0 0

All zeros indicates no transmission errors. Otherwise, the received bits are erroneous.

Only error detection, no correction

Cyclic Redundancy Check (CRC)

- Only Error Detection
- Most Commonly used.
- m = data bits , r = redundancy bits $m + r$
- Polynomial - for finding the r bits.
- Divisor - highest degree of the polynomial
- Dividend - $m + r$ bits

Finding Redundant bits and Divisor

$$x^4 + x^3 + 1$$

Highest Degree will be *r* bits

$$1 * x^4 + 1 * x^3 + 1 * x^0$$

$$x^4 + x^3 + x^2 + x^1 + x^0$$

1 1 0 0 1 - Divisor

- **Redundant Bits = Total Bits in the divisor - 1**

= 5 - 1 = 4

Data Bits + 0 0 0 0

In some cases, directly divisor will be given.

Find the redundant bits from the divisor.

Ex. Divisor - 1 1 0 0 1

Total Bits = 5 - 1

= 4 i.e, 0 0 0 0

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 0 0 0 (

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 0 0 0 (

1 1 0 0 1

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 0 0 0 (

1 1 0 0 1

0 1 1 0 0

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 0 0 0

1 1 0 0 1

0 1 1 0 0 0

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 0 0 0 (

1	1	0	0	1							
0	1	1	0	0	0						
	1	1	0	0	1						
	0	0	0	0	1						

1	1	0	0	1	)	1	0	1	0	1	0	1	0	0	0	0	0	(
						1	1	0	0	1								
						0	1	1	0	0	0							
							1	1	0	0	1							
							0	0	0	0	1	1	0	0	0			

1 1 0 0 1)	1	0	1	0	1	0	1	0	0	0	0	0 (
	1	1	0	0	1							
	0	1	1	0	0	0						
		1	1	0	0	1						
		0	0	0	0	1	1	0	0	0		
						1	1	0	0	1		
						0	0	0	0	1		

```
1 1 0 0 1 ) 1 0 1 0 1 0 1 0 0 0 0 0 (
            1 1 0 0 1
            ---------------------------
            0 1 1 0 0 0
              1 1 0 0 1
            ---------------------------
              0 0 0 0 1 1 0 0 0
                      1 1 0 0 1
            ---------------------------
                      0 0 0 0 1 0 0
```

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 0 0 0

1 1 0 0 1

0 1 1 0 0 0

1 1 0 0 1

0 0 0 0 1 1 0 0 0

1 1 0 0 1

0 0 0 $\boxed{0\ 1\ 0\ 0}$

r bits - should be appended in the data bits.

Data Bits + r Bits	1	0	1	0	1	0	1	0	0	1	0	0

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 1 0 0 (

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 1 0 0

1 1 0 0 1

$$
\begin{array}{ccccc|cccccccccccc}
1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\
 & & & & & 1 & 1 & 0 & 0 & 1 & & & & & & & \\
\cline{6-10}
 & & & & & 0 & 1 & 1 & 0 & 0 & & & & & & &
\end{array}
$$

1	1	0	0	1	)	1	0	1	0	1	0	1	0	0	1	0	0	(
						1	1	0	0	1								
						0	1	1	0	0	0							

1 1 0 0 1) 1 0 1 0 1 0 1 0 0 1 0 0

1 1 0 0 1

0 1 1 0 0 0

1 1 0 0 1

0 0 0 0 1

1	1	0	0	1	)	1	0	1	0	1	0	1	0	0	1	0	0
						1	1	0	0	1							
						0	1	1	0	0	0						
							1	1	0	0	1						
							0	0	0	0	1	1	0	0	1		

1	1	0	0	1	)	1	0	1	0	1	0	1	0	0	1	0	0
						1	1	0	0	1							
						0	1	1	0	0	0						
							1	1	0	0	1						
							0	0	0	0	1	1	0	0	1		
											1	1	0	0	1		
											0	0	0	0	0		

$$
\begin{array}{r|cccccccccccc}
11001 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\
 & 1 & 1 & 0 & 0 & 1 & & & & & & & \\
\hline
 & 0 & 1 & 1 & 0 & 0 & 0 & & & & & & \\
 & & 1 & 1 & 0 & 0 & 1 & & & & & & \\
\hline
 & & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & & \\
 & & & & & & 1 & 1 & 0 & 0 & 1 & & \\
\hline
 & & & & & & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{array}
$$

1	1	0	0	1	)	1	0	1	0	1	0	1	0	0	1	0	0
						1	1	0	0	1							
						0	1	1	0	0	0						
							1	1	0	0	1						
							0	0	0	0	1	1	0	0	1		
											1	1	0	0	1		
											0	0	0	0	0	0	0

Home Work

Data Bits	1	0	1	0	1	0	1	0	1	0
Divisor	1	1	0	0	1					

What is r ?

What is D + r ?

What is the Tx @ sender ?

What is the Rx @ the receiver ?

Check whether the receive has received the data with errors.

TDM Efficiency Calculation

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TDM

Time is divided in to slots.

Transmission has to be done in the particular slot only.

Should not interfere in other slots.

Slot Time (Cycle Time) = $t_t + t_p$

t_t Data transmission time, the amount of time taken by the router to forward.

T_p Propagation Time, the amount of time taken by the signal to reach next point.

$$\eta = \frac{\text{Useful Time}}{\text{Cycle Time}}$$

$$\eta = \frac{\text{USEFUL TIME}}{\text{CYCLE TIME}} = \frac{T_t}{T_t + T_p}$$

$$\eta = \frac{\text{USEFUL TIME}}{\text{CYCLE TIME}} = \frac{T_t}{T_t + T_p}$$

Divide by T_t

$$= \frac{T_t / T_t}{T_t/T_t + T_p/T_t}$$

$$\eta = \frac{\text{USEFUL TIME}}{\text{CYCLE TIME}} = \frac{T_t}{T_t + T_p}$$ Divide by T_t

$$= \frac{\cancel{T_t / T_t}}{\cancel{T_t / T_t} + T_p / T_t}$$

$$= \frac{1}{1 + \alpha}$$ where $\alpha = T_p / T_t$

Efficiency of TDM $\eta = \frac{1}{1+\alpha}$, $\alpha = T_p / T_t$

Find the Efficiency of a TDM : $T_P = T_t = 1$ ms

$$\eta = \frac{1}{1 + T_p/T_t} = \frac{1}{1 + 1/1} =$$

$$\eta = \frac{1}{1 + T_p/T_t} = \frac{1}{1 + 1/1} = \frac{1}{1+1} = 1/2$$

Efficiency is only 50 % !!

If Available Bandwidth is 4 Mbps then,

$$= 4 * (1 / 2)$$

$$= 2$$

Effective Bandwidth is only 2Mbps !!

If each node requires 2 Kbps, then how many systems can be connected to the above network ?

$N = 2\ \text{Kbps}$

$N * 2\text{Kbps} = 2\ \text{Mbps}$

$$N = \frac{2\ \text{Mbps}}{2\ \text{Kbps}}$$

N = 2 Kbps

N * 2Kbps = 2 Mbps

$$N = \frac{2 \text{ Mbps}}{2 \text{ Kbps}} \qquad \frac{2\ 000\ 000}{2\ 000} \qquad = 1000$$

1000 Systems can be connected to the above system

1. Find the Efficiency of a TDM where its T_P = 1 ms T_t= 3 ms
2. If the Bandwidth is 3 Mbps, then find the effective Bandwidth
3. How many systems can be connected to the above system each with 1 Kbps.
4. How many systems can be connected to the above system each with 1.2 Kbps.

Flow Control

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IT Dept., NITK

Previous Session

- Checksum
- CRC
- Homework - All bits are received without any errors at the received end.
    - Both for CRC and Checksum

Transmission Modes in CN

- Simplex, Half Duplex, Full Duplex
- Simplex - Unidirectional Communication
  - One Way Communication
  - Sender can only send the data.
  - Ex - System to Printer
- Half Duplex - Bidirectional, One at a time.
  - Sender/Receiver can send and receive the data,
  - But, not at the same time.
  - Ex - Walkie - Talkie

- Full Duplex - Bidirectional Communication.
    - Sender/Receiver can send and receive data simultaneously.
    - Ex - Telephone

Frames Structure

Address	Control	Payload (Packet from Routing Layer)

- Address @ LAN level.
    - MAC (Medium Access Control) Address

MAC Address

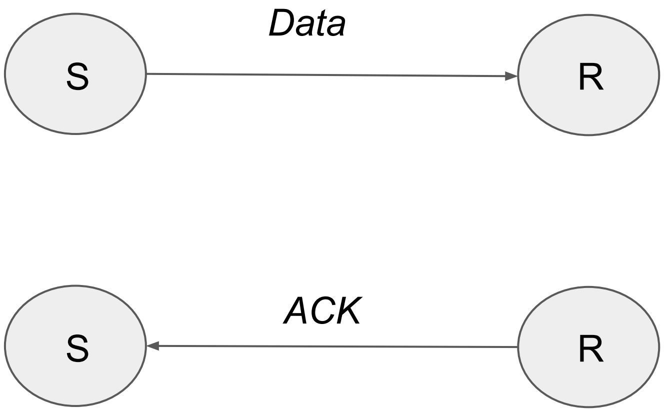
- Physical Address comes with NIC card - unique.
- Used to identify individual system in the LAN.
- Who will provide this ?
  - Companies - Card Manufacturers.
- 6 bytes (48 bits) hexadecimal values.
- Windows - ipconfig /all
  - Physical Address
- Linux - ifconfig
  - HWaddr

Frames - Control Field and Info field

- *kind, seq , ack*
- *Info - Payload, contains packet received from Network Layer.*
- *kind - type of frame*
  - *Data or control frame.*
- *seq - sequence number of the frames.*
  - *For re-arranging the frames at the destination*
  - *For giving acknowledgement*
- *ack - acknowledgement (control frame)*
  - *For each successfully received data packet,receiver will send the ack.*

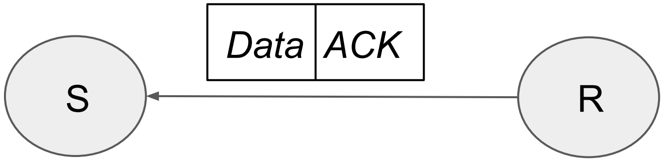
ACK

For each data frame received successfully, receiver will send a control frame (ACK) to sender.



Half-duplex communication

ACK will get a free ride along with Data



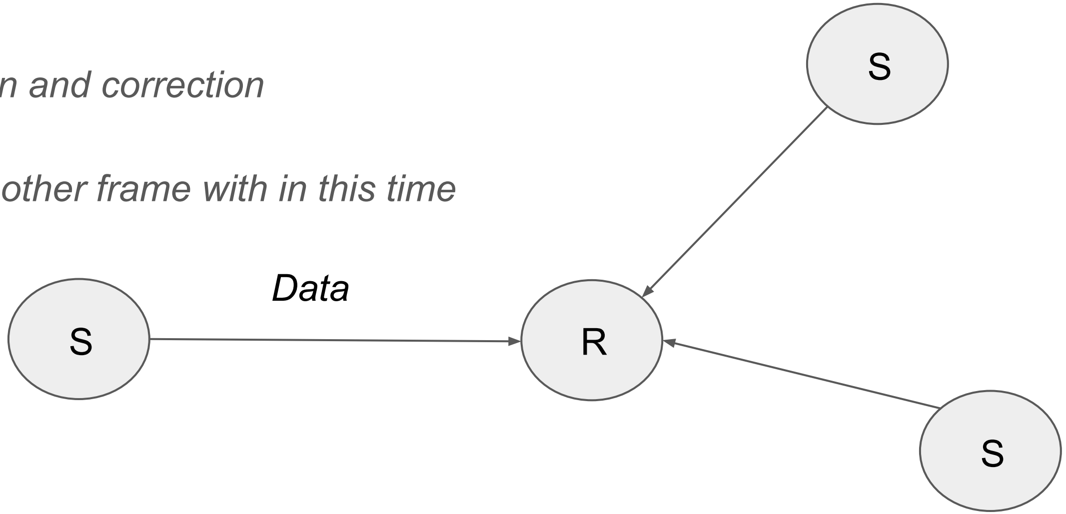
Full-duplex communication

Flow Control Methods

- Synchronizing the fast sender with slow receiver.
- Different flow controls methods:
  - Stop- and-Wait protocol
  - Sliding Window Protocol
  - Selective Repeat

Stop and Wait Protocol

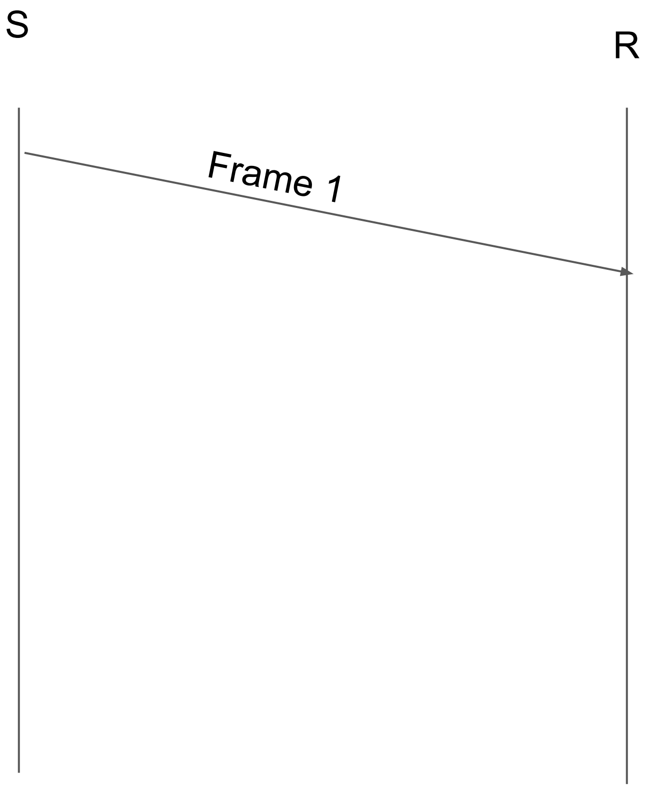
- Time required @ DLL
  - Receiving time *from_phy_layer*
  - *Processing time - error detection and correction*
  - Sending time *to_network_layer*
  - *Δ t - sender should not send another frame with in this time*

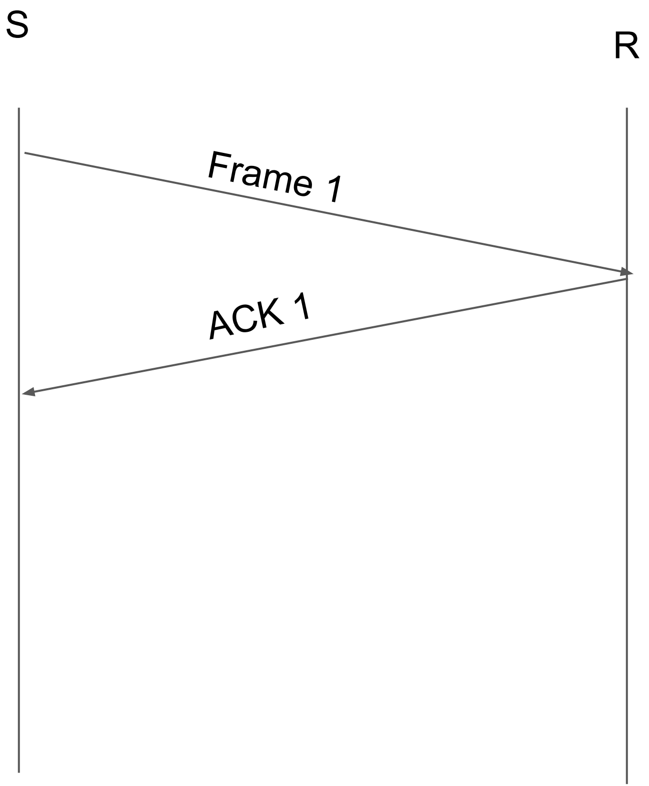


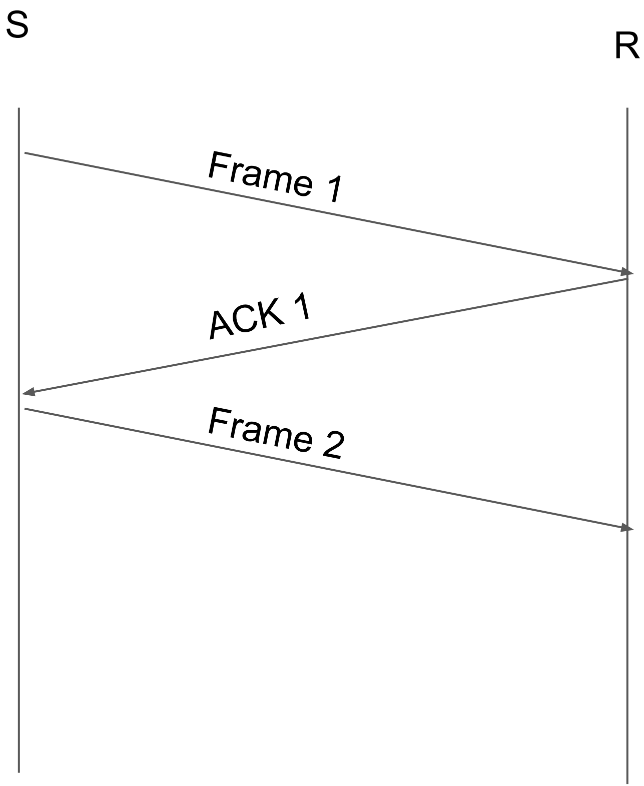
- *Calculating the worst case scenario of a receiver/ network and adjusting the sender.*
  - *Too conservative, wasting the resources.*

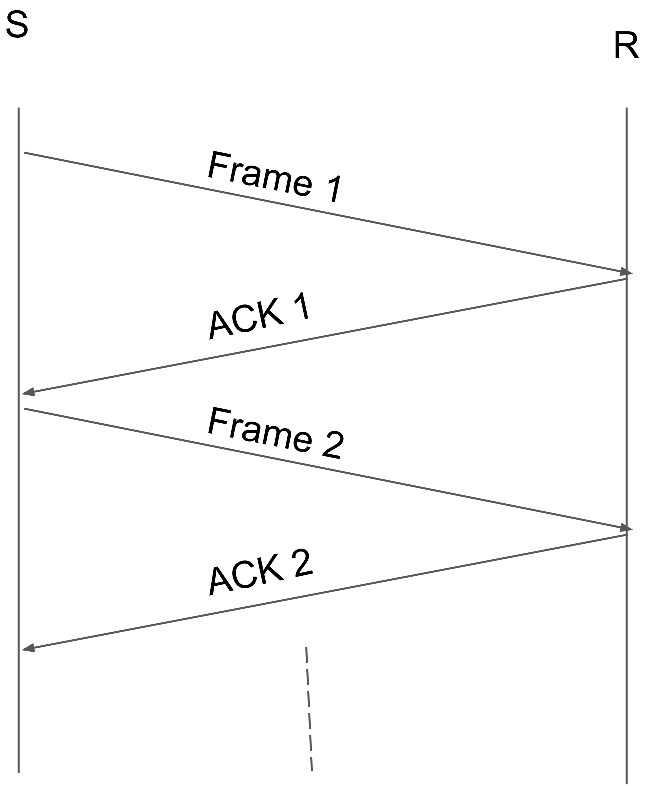
Best Way..

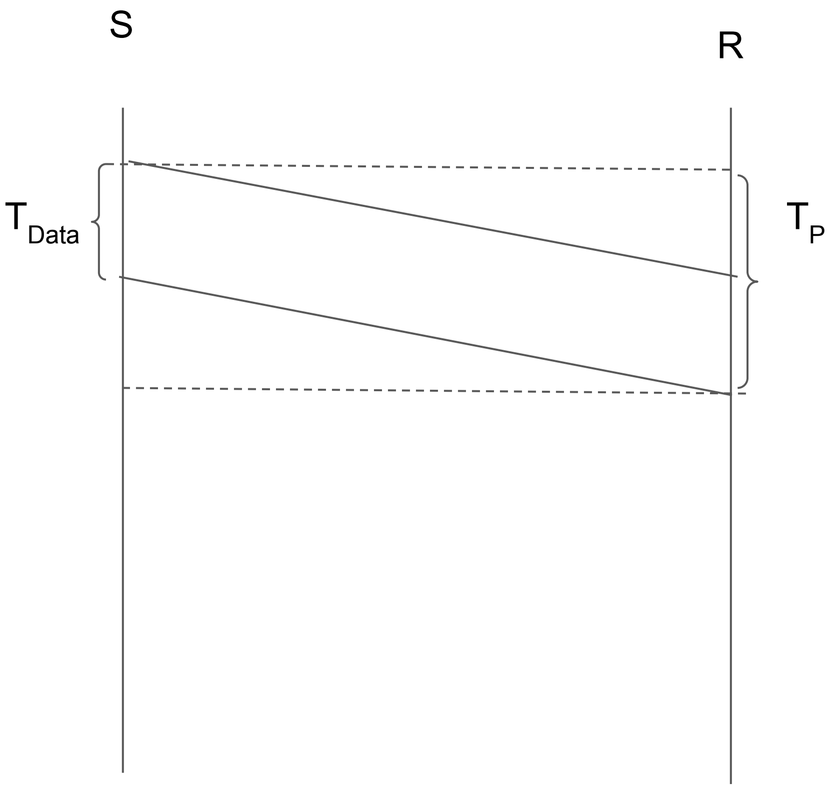
- Receiver Feedback to the sender.
  - After sending the packet to network layer, the receiver will send ACK to sender.
- ACK - Dummy frame with the seq no of the frame received.
- After sending a frame, source will wait for the ACK.
  - ACK will give permission to sender to send the next frame.
- Stop and Wait for the ACK - Stop and Wait Protocol

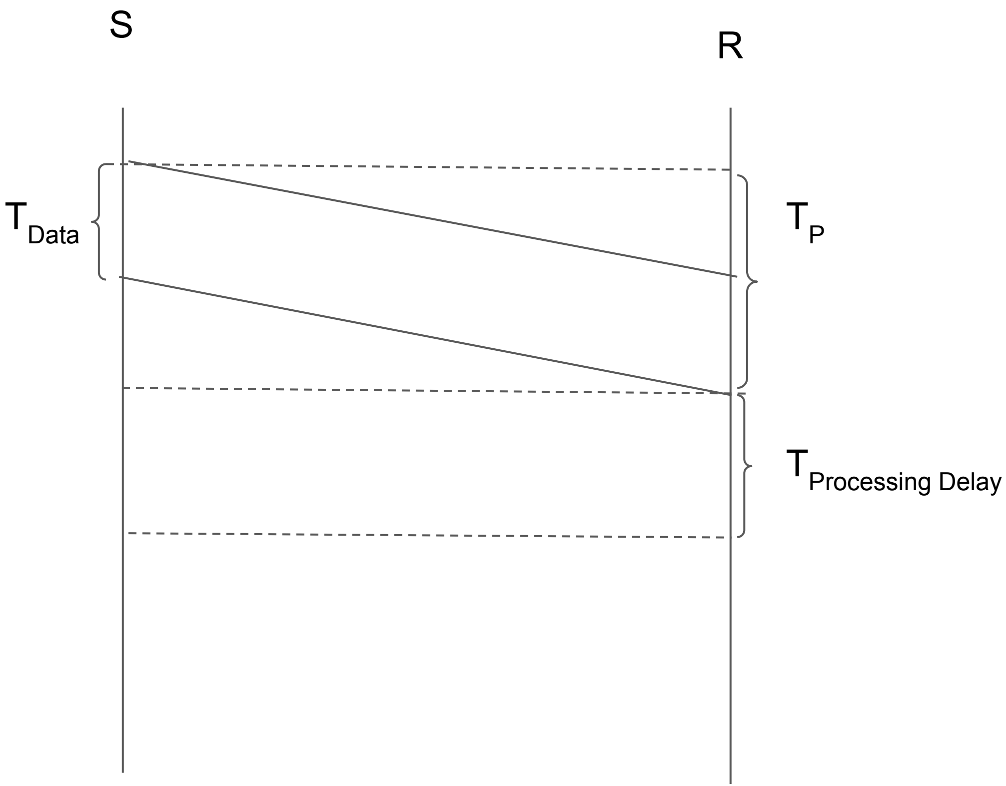

S
R
Frame 1

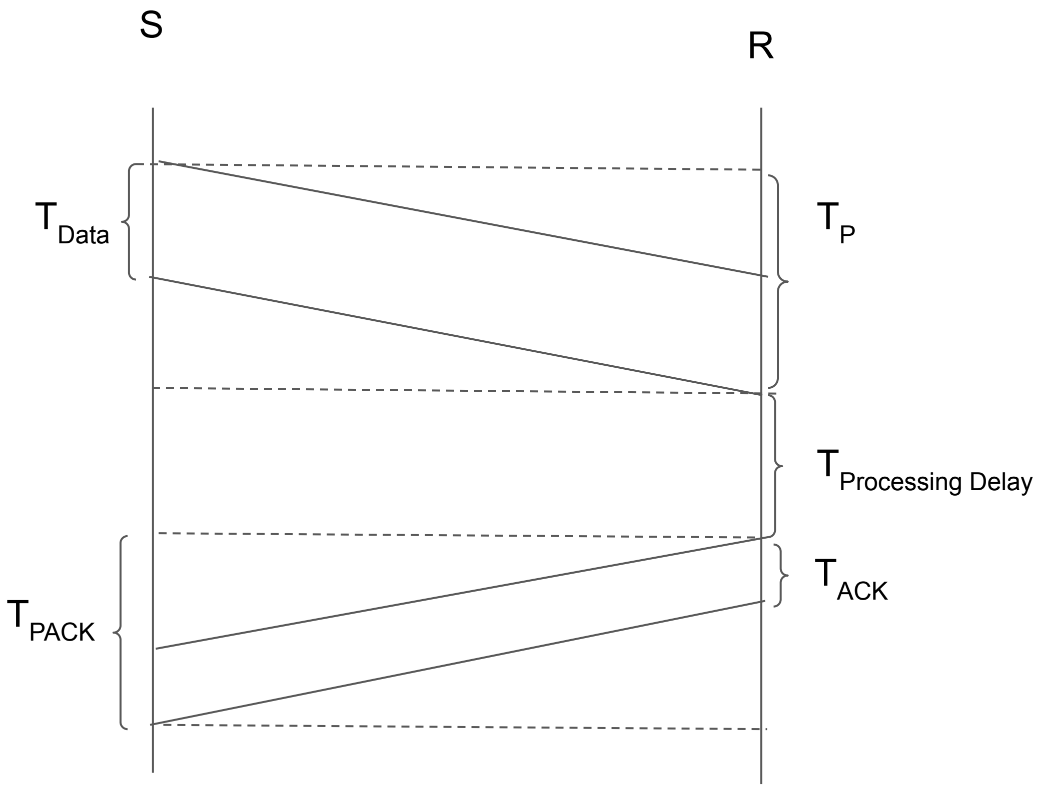

S
R
Frame 1
ACK 1


S
R
Frame 1
ACK 1
Frame 2


S
R
Frame 1
ACK 1
Frame 2
ACK 2


S
R
T_{Data}
T_P


S
R
T_{Data}
T_P
$T_{Processing\ Delay}$



Cycle Time = Tdata + Tpdata + Tqdelay + Tprocessing_delay + Tack + Tpack

Cycle Time

Don’t know   Don’t know

Cycle Time = Tdata + Tpdata + ~~Tqdelay~~ + ~~Tprocessing_delay~~ + Tack + Tpack

= Tdata + Tpdata + ~~Tack~~ + Tpack

Very Small - hardly 40 bytes,
1500 frame bytes

= Tdata + Tpdata + Tpack

$$\boxed{\text{Cycle Time} = T_t + 2\,T_p}$$

Efficiency

$$\eta = \frac{\text{Useful Time}}{\text{Cycle Time}} = \frac{Tt}{Tt + 2\,Tp}$$

Divide by Tt both sides

$$= \frac{Tt\,/\,Tt}{Tt\,/\,Tt + 2\,(Tp/Tt)}$$

$\alpha = Tp\,/\,Tt$

$$= \frac{\cancel{Tt\,/\,Tt}}{\cancel{Tt\,/\,Tt} + 2\,(Tp/Tt)} = \frac{1}{1 + 2\,\alpha}$$

Example

Tt = Tp = 1ms

$$\eta = \frac{1}{1 + 2\,(Tp / Tt)} = \frac{1}{1 + 2\,(1/1)} = \frac{1}{3}$$

Available Bandwidth = 4 Mbps

Effective Bandwidth = ?

(⅓) of 4 Mbps = 1.33 Mpbs

Home Work

Given

T_t = 2ms T_p = 1ms

Available B/W = 3 Mbps

Find out the Efficiency and Effective B/W

Flow Control
Sliding Window Protocol

Dr. Kiran M
IT Dept, NITK

Previous Session

- Simplex, Half Duplex, Full Duplex
- Frame Structure
  - Header
    - Address
    - kind, seq, ack
  - Info - payload
- DLL @ LAN , contains MAC address
  - 6 byte address, Unique, Manufacturer will give.
- Flow Control - Selective Repeat

Home Work

Given

Tt = 2ms Tp = 1ms

Available B/W = 3 Mbps

Find out the Efficiency and Effective B/W

ANS:

η = 0.75   Effective Bandwidth = 2.25 Mbps

@ 1Kbps = 2250 systems @ 1.2 Kbps = 1875 Systems.

Sliding Window Protocol

- Sending Window and Receiving Window.
- Sender and Receiver maintains sequence numbers to be sent/ to be received.
- *Seq* plays the important role.
- Sender and Receiver will have a window
  - Window size will be defined.
  - Fixed
  - Grow and Shrink over the time (some times)

- Once the frames are sent, it is vulnerable for the attack and transmission errors.
- The sender has to buffer the sent frames for the possible re-transmission.
    - If window size is n, then buffer size should be of at least n.
- The sender’s window seq no. represents frames sent but Ack is not yet received.
- Once the Ack is received, the sender’s window will be advanced.

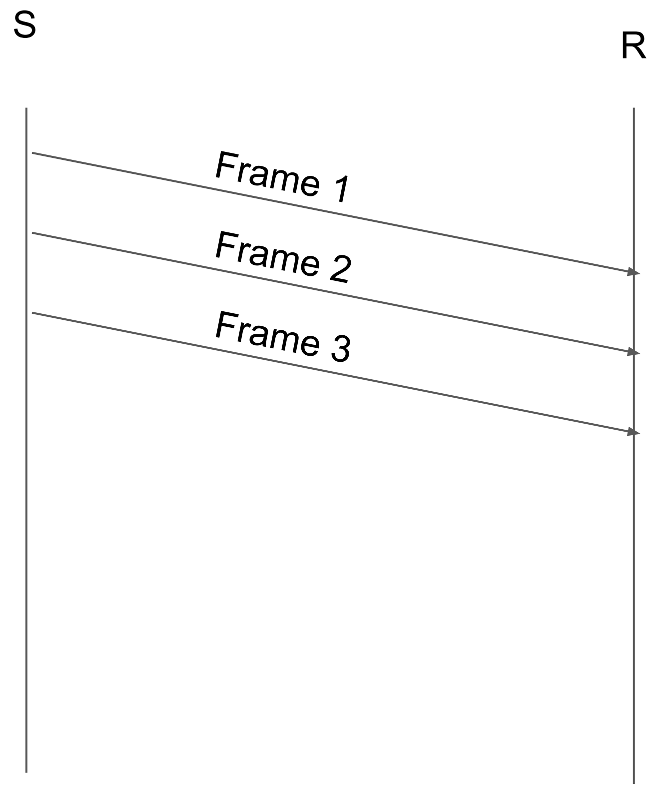
Sliding Window Protocol

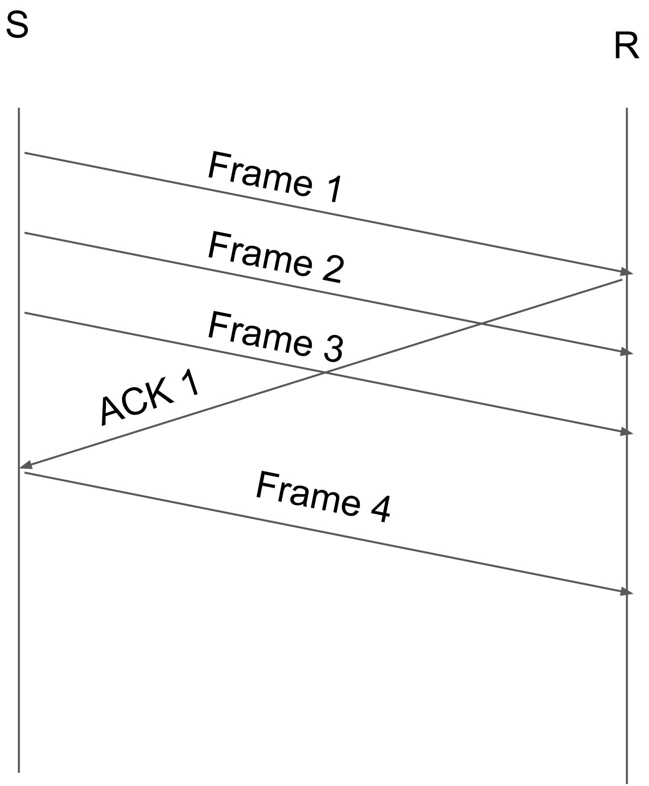
- One Bit (Similar to Stop and Wait)
- Go-Back-N
- Selective Repeat

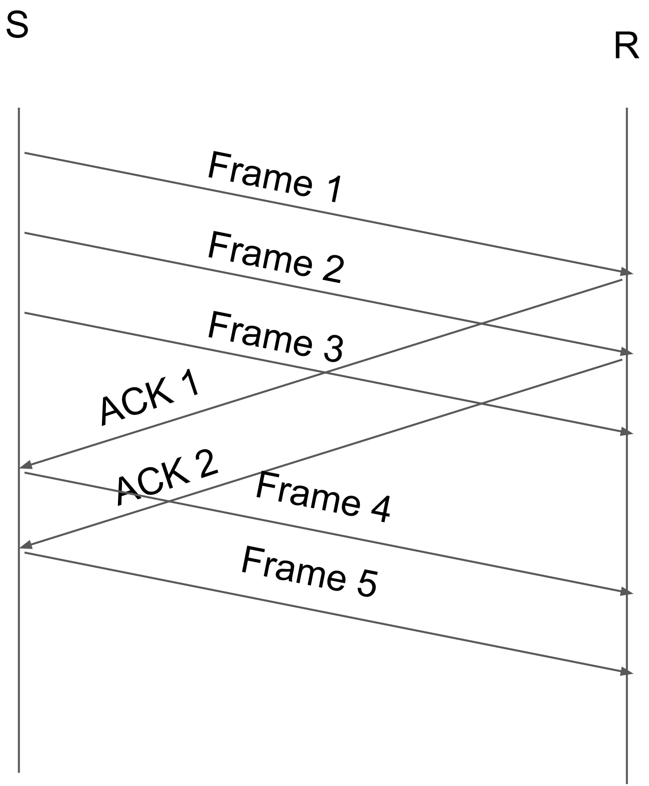
- Efficiency, Complexity and Buffer requirements
- Freedom to the DLL about the frame order of transmission and reception.

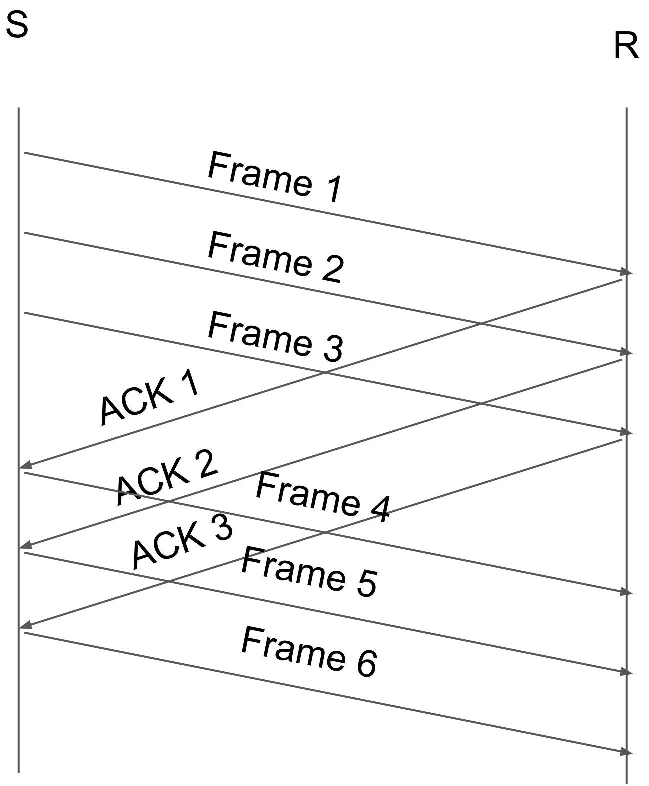
Go Back N

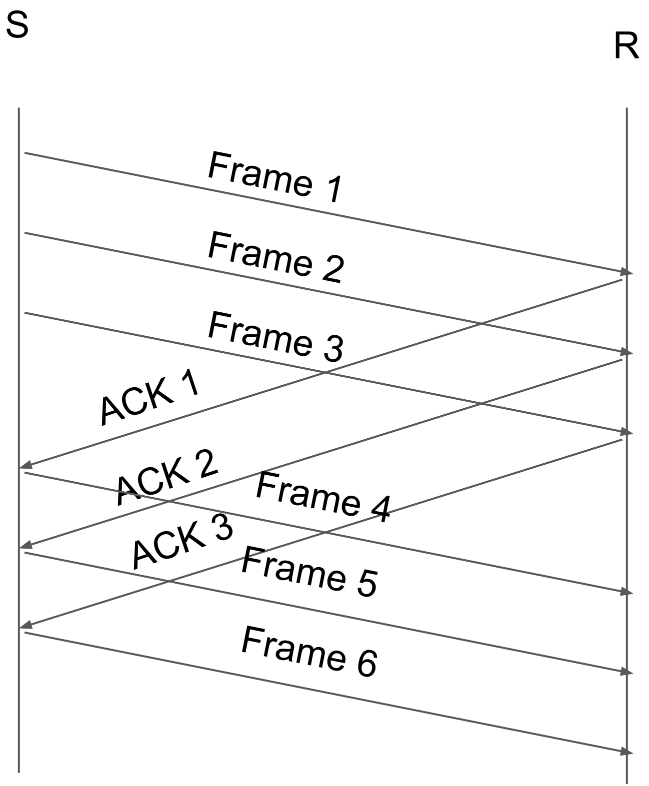
- Multiple Frames can be sent.
- Receiver Window Size is one.
- Sender Window Size = 3 (i.e N = 3)
  - GB3
- Receive accepts only inorder frames.


S
R
Frame 1
Frame 2
Frame 3


S
R
Frame 1
Frame 2
Frame 3
ACK 1
Frame 4


S
R
Frame 1
Frame 2
Frame 3
ACK 1
ACK 2
Frame 4
Frame 5


S
R
Frame 1
Frame 2
Frame 3
ACK 1
ACK 2
Frame 4
ACK 3
Frame 5
Frame 6


S
R
Frame 1
Frame 2
Frame 3
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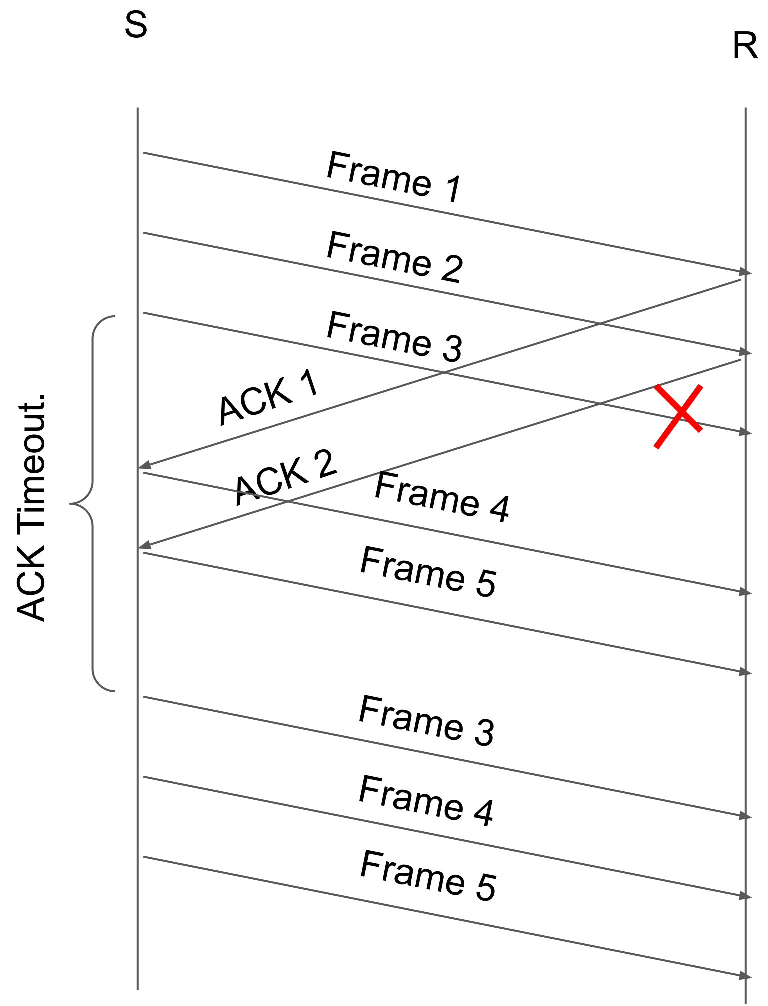
ACK 2
Frame 4
ACK 3
Frame 5
Frame 6



@ Sender Side

- Time out occurs @ sender side
- Latest Seq no is 5 @ sender side.
- Go Back N (N = 3)
- 5 , 4, 3
- Restart transmission from Seq no 3
- Entire window is retransmitted.

@ Receiver Side

- Out of order reception of frames,
    - After Frame 2 , Frame 4 is received.
- Drops all the received unorderred frames.

Efficiency of Go Back N

$$\eta = \frac{\text{Window Size}}{1 + 2\,(Tp / Tt)}$$

Tt = 1 ms , Tp = 32 ms , GB10 , BW = 4 Mbps

Find efficiency and throughput.

Tt = 1 ms , Tp = 32 ms , GB10 , BW = 4 Mbps

Find efficiency and throughput.

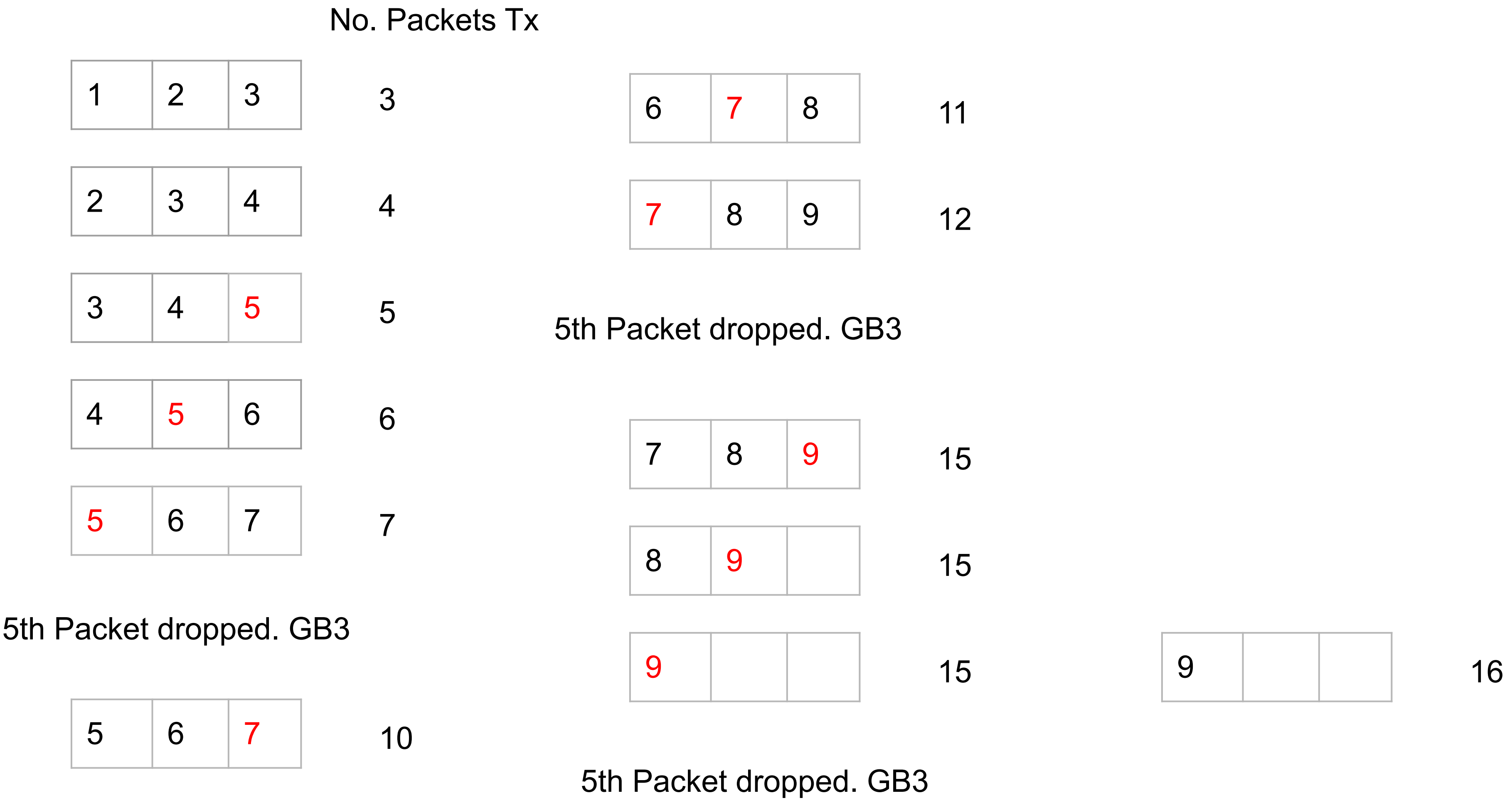
$$\eta = \frac{\text{Window Size}}{1 + 2\,(Tp / Tt)} = \frac{10}{1 + 2\,(32/1)} = \frac{10}{65} = 0.15$$

$$\text{Throughput} = \eta * BW$$

$$= 0.15 * 4 \text{ Mbps}$$

$$\cong 61 \text{ Kbps.}$$

Station A needs to send a message consisting of 9 packets to station B using a sliding window (window size 3) and go back n error control strategy. If every 5th packet that A transmits gets lost, then what is the number of packets that A will transmit for sending the message to B?


No. Packets Tx
1 2 3
3
2 3 4
4
3 4 5
5
4 5 6
6
5 6 7
7
5th Packet dropped. GB3
5 6 7
10
6 7 8
11
7 8 9
12
5th Packet dropped. GB3
7 8 9
15
8 9
15
9
15
9
16
5th Packet dropped. GB3

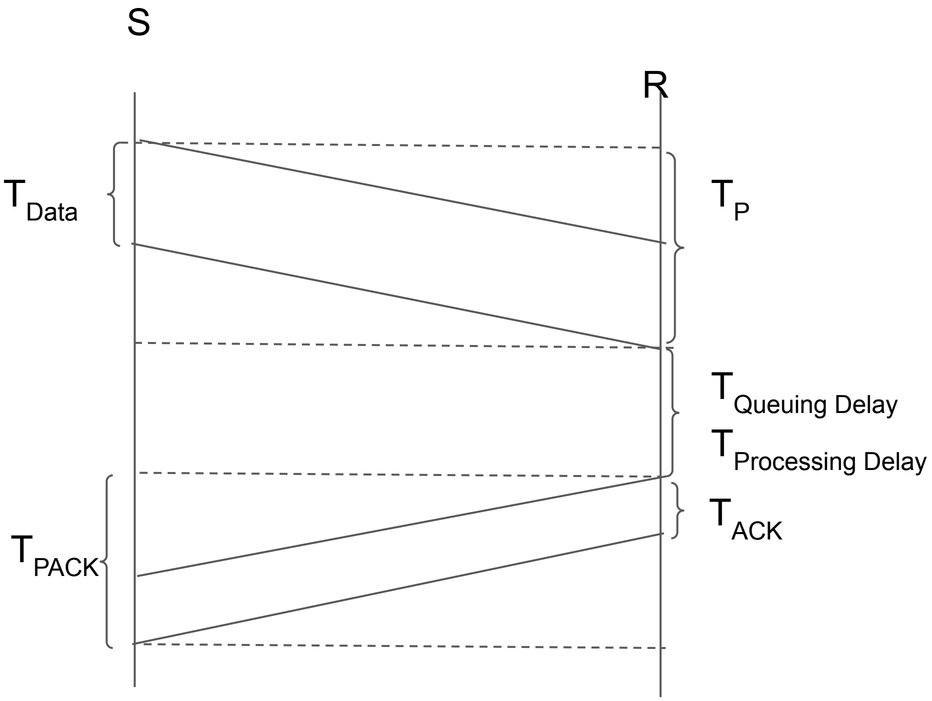
Flow Control
Selective Repeat Protocol

Dr. Kiran M,
IT Dept., NITK

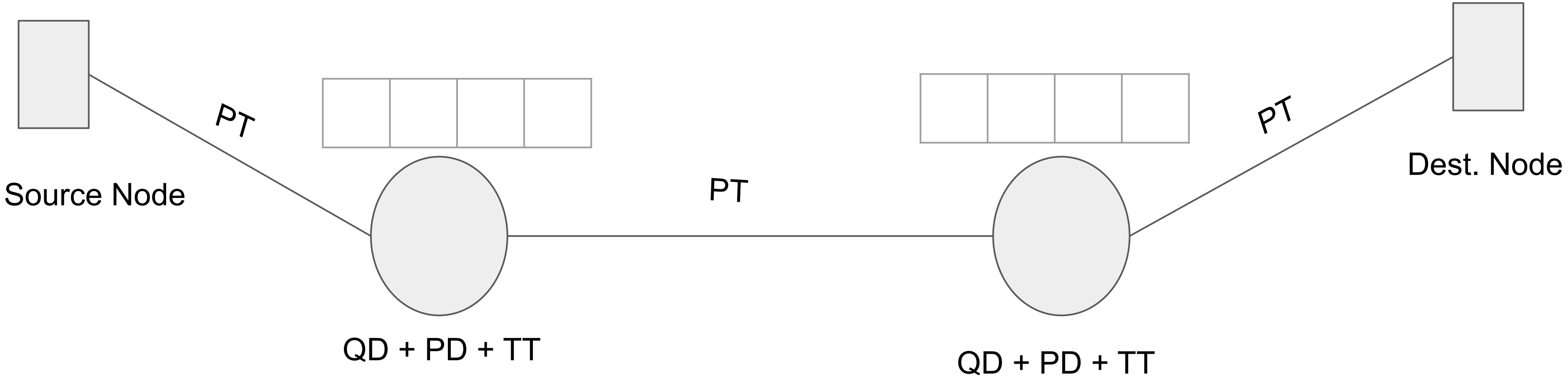
Previous Session

- Sliding Window Protocol
  - Go Back N
- Both sender and receiver will have a window.
- Window Size
  - @ Sender = N
  - @ Receiver = 1
- Receiver expects all frames in the order
  - Out of order frames will be dropped by the receiver.
- Efficiency and Total Number of transmissions required are detailed.

Q) While Tdata is going on, Tp is also going on, since both times are happening simultaneously (Tp includes Tdata), why should we sum it up ? It'll be like taking same time twice.



Cycle Time = Tdata + Tpdata + Tqdelay + Tprocessing_delay + Tack + Tpack



Propagation Time (PT) - The amount of time taken by a bit to travel from one router to next router.

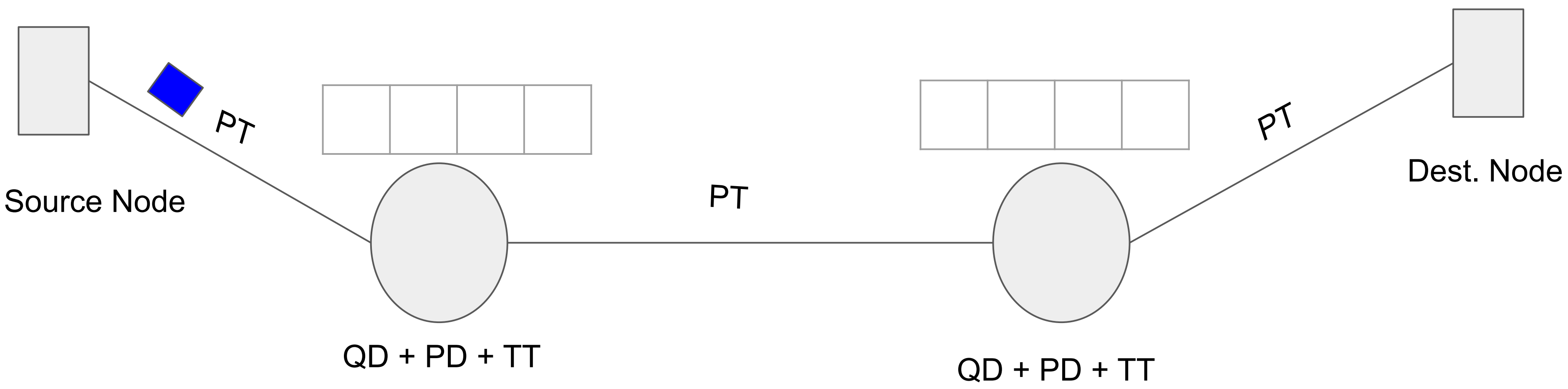
Transmission Time (TT)- The amount of time required by the router to push the frame/packet in to the channel

- Channel might be busy, Depends on different multiplexing schemes.

Processing Delay (PD) - The amount of time taken @ node/router for processing the frame/packet.

- Checking for source and destination address, Finding the best path, Error Checking, SINR

Queuing Delay (QD) - The delay experienced by the frame / packet in the queue of node/router.



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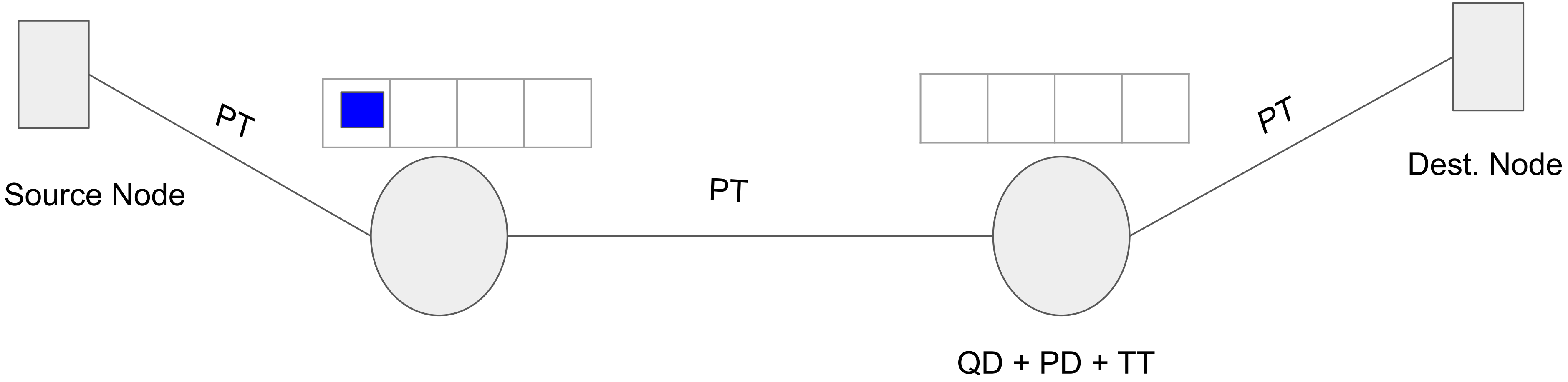

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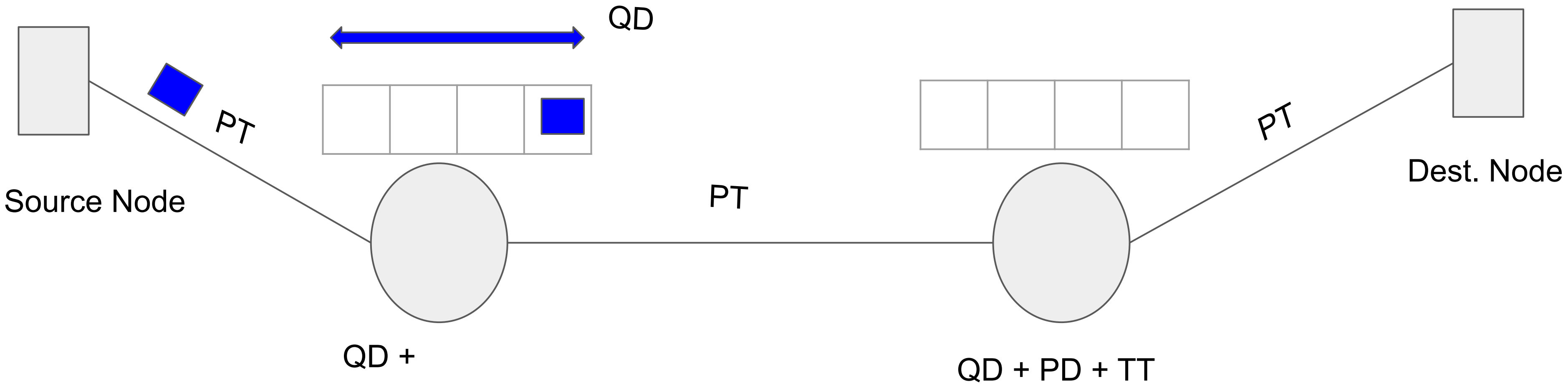

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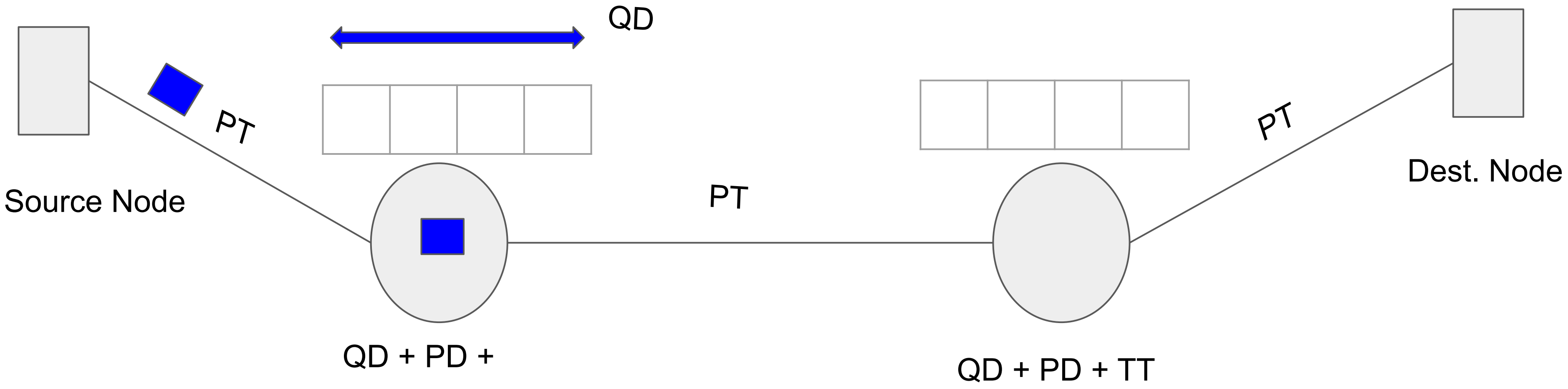

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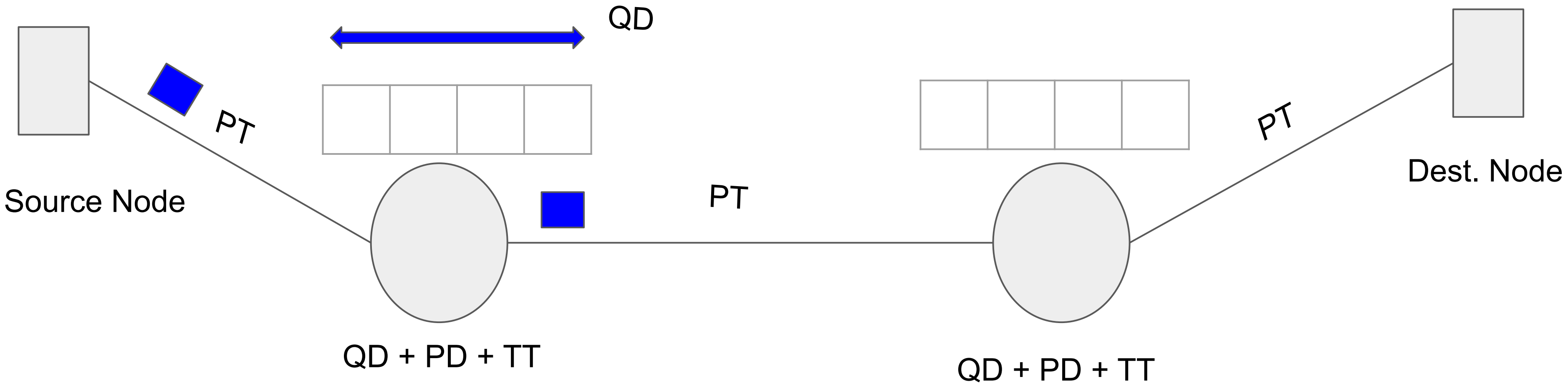

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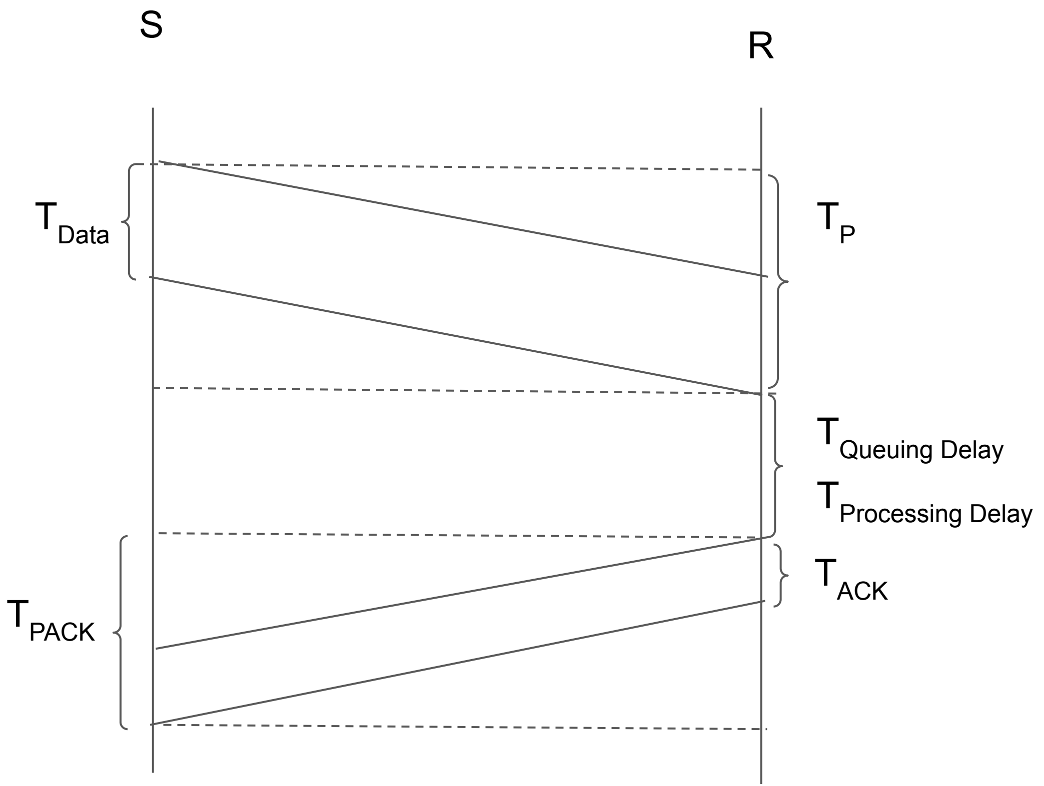
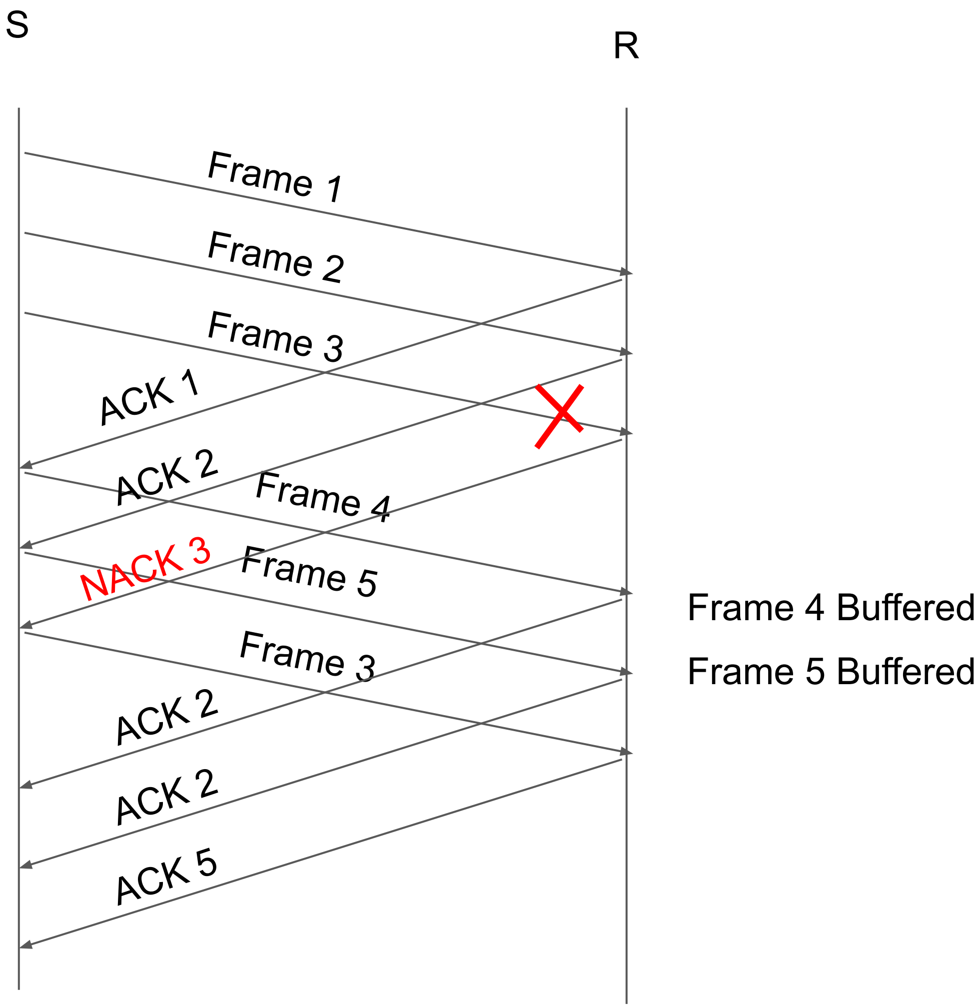


Cycle Time = Tdata + Tpdata + Tqdelay + Tprocessing_delay + Tack + Tpack

Selective Repeat Protocol

- Receiver will have a window size of N.
  - Unlike Go Back N where receiver window size is 1.
- Sender sends N frames according to the window size.
- Receiver will receive N frames and buffers for processing.
- Better than Go-Back-N
  - No. of retransmissions.
- Receiver is bit flexible. It can receive (buffers) out of order frames. It will reorder it later.
  - Unlike Go Back N where receiver will drop out of order frames.


S
R
Frame 1
Frame 2
Frame 3
ACK 1
ACK 2
Frame 4
NACK 3
Frame 5
Frame 4 Buffered
Frame 5 Buffered
Frame 3
ACK 2
ACK 2
ACK 5

Only one frame will be retransmitted.

Unlike Go Back N where the complete window will be retransmitted.

Automatic Repeat Request (ARQ)

All the methods studied before are called as ARQ’s

Stop and Wait.

Go-Back-N.

Selective Repeat.

DLL - Layer 2

- Layer 2 Functionalities
- Frame Separation
  - Checksum, Hamming code, CRC
- Flow Control (ARQ)
  - Stop and Wait protocol
  - Go Back N
  - Selective Repeat

Network Layer

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IT Dept., NITK

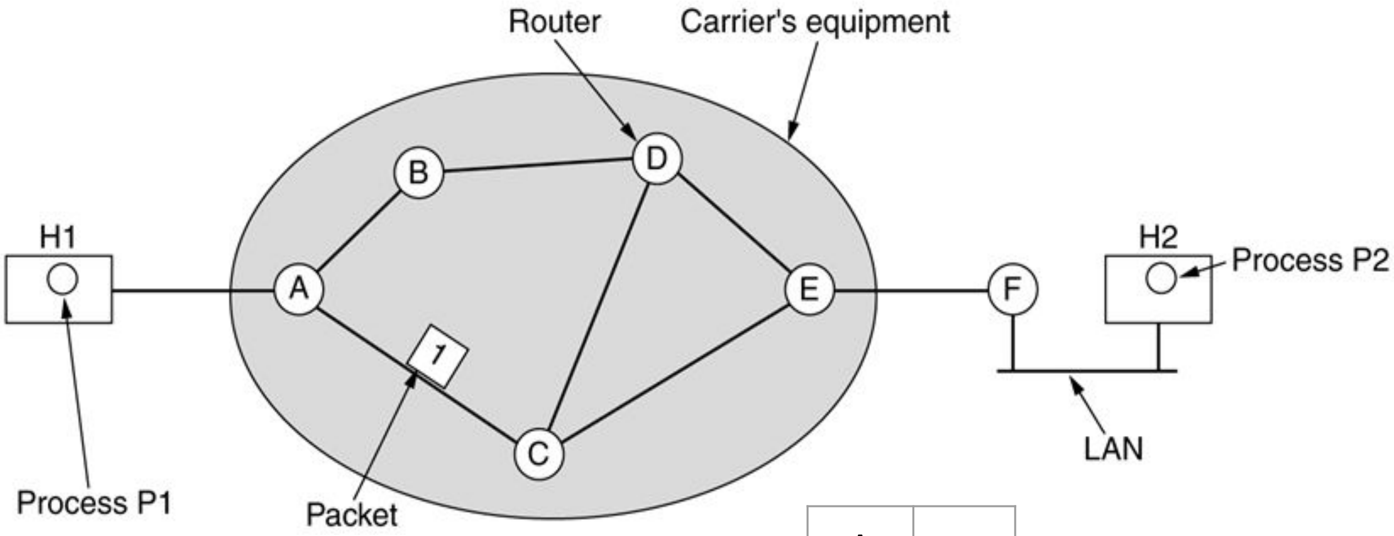
Two Types of Services

Connection Oriented Services

  Virtual Circuit

Connection Less Services

  Packet Switching

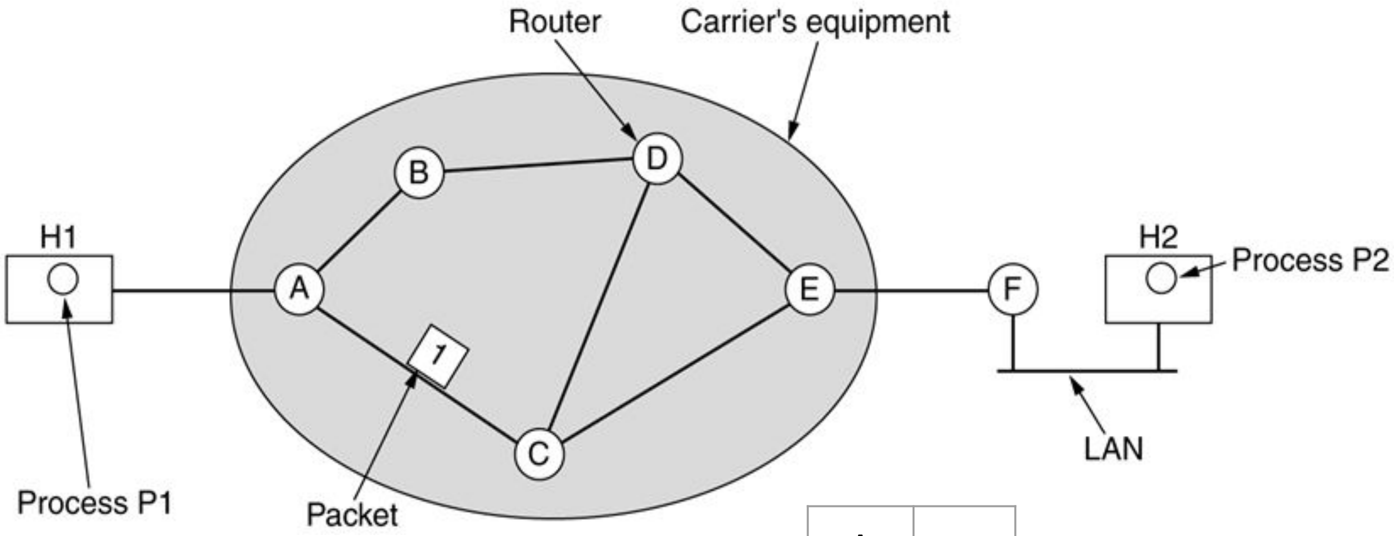


Routing Table Structure

To	Next Node

A’s Routing Table

A	--
B	
C	
D	
E	
F	



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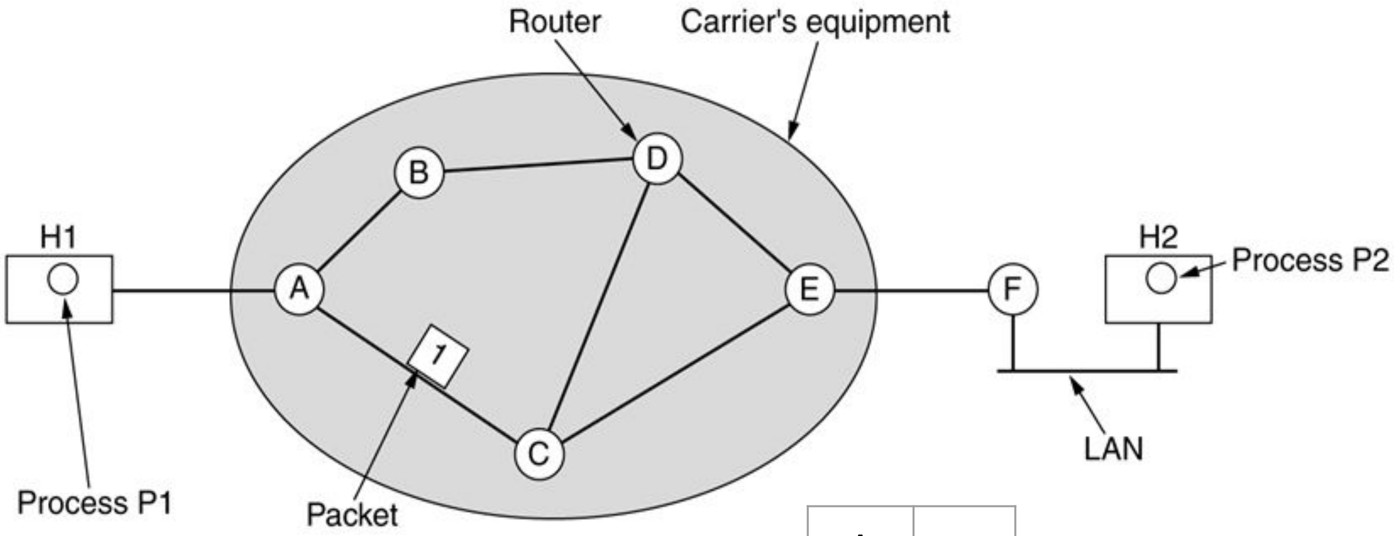

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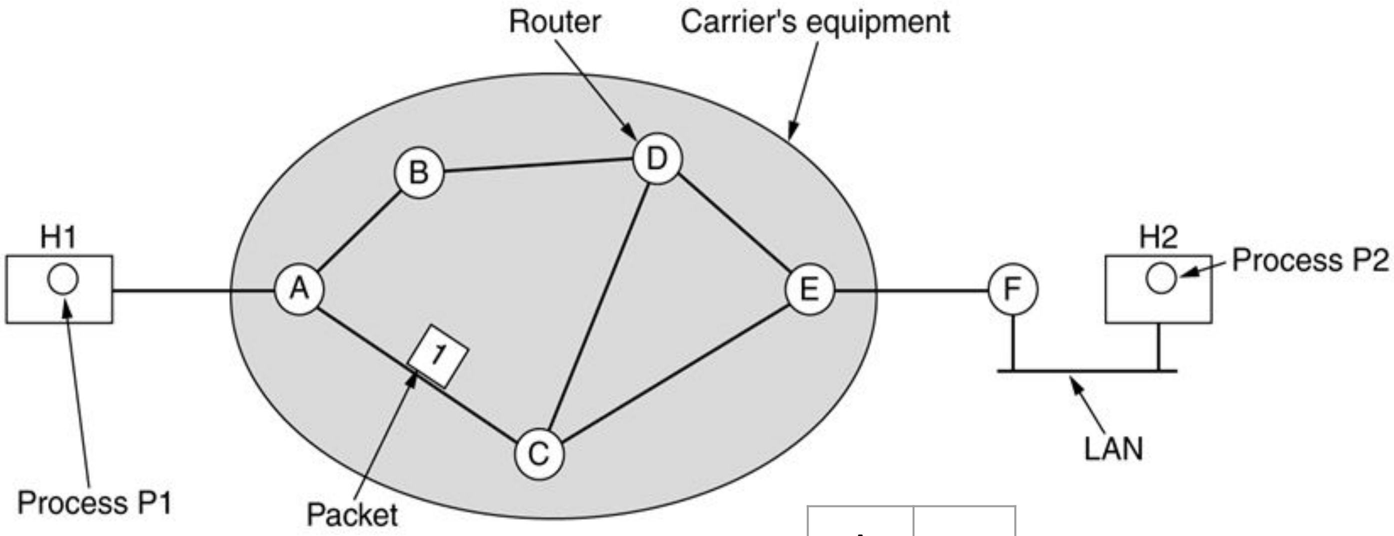
F	

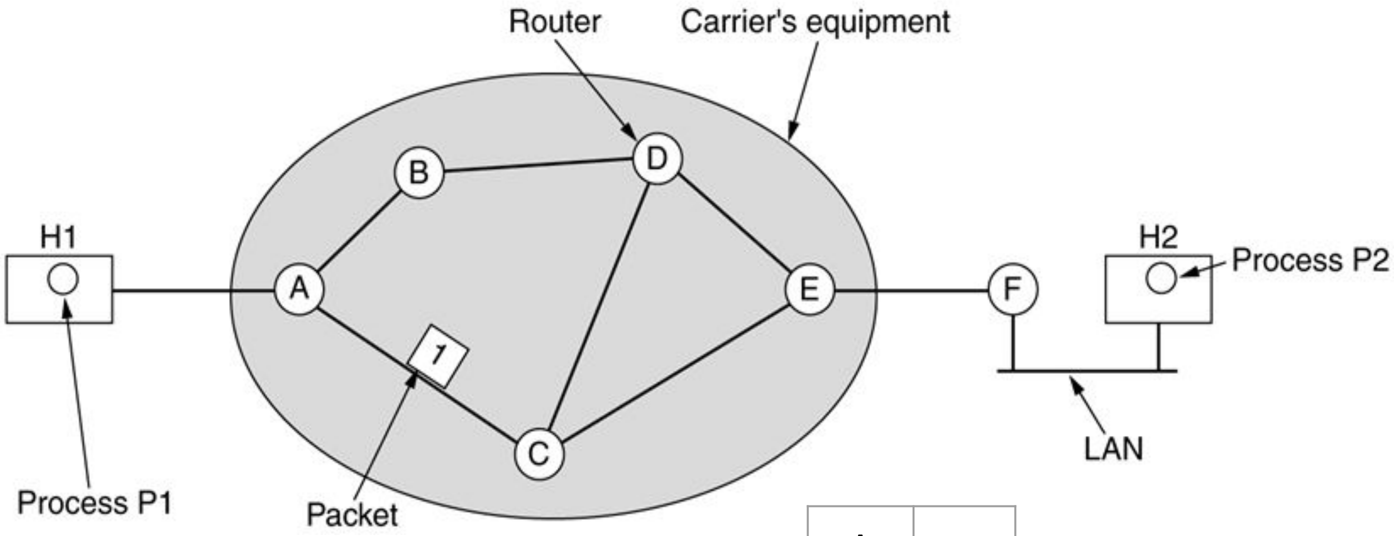


Routing Table Structure

To	Next Node

A's Routing Table

A	--
B	B
C	C
D	B/C
E	
F	

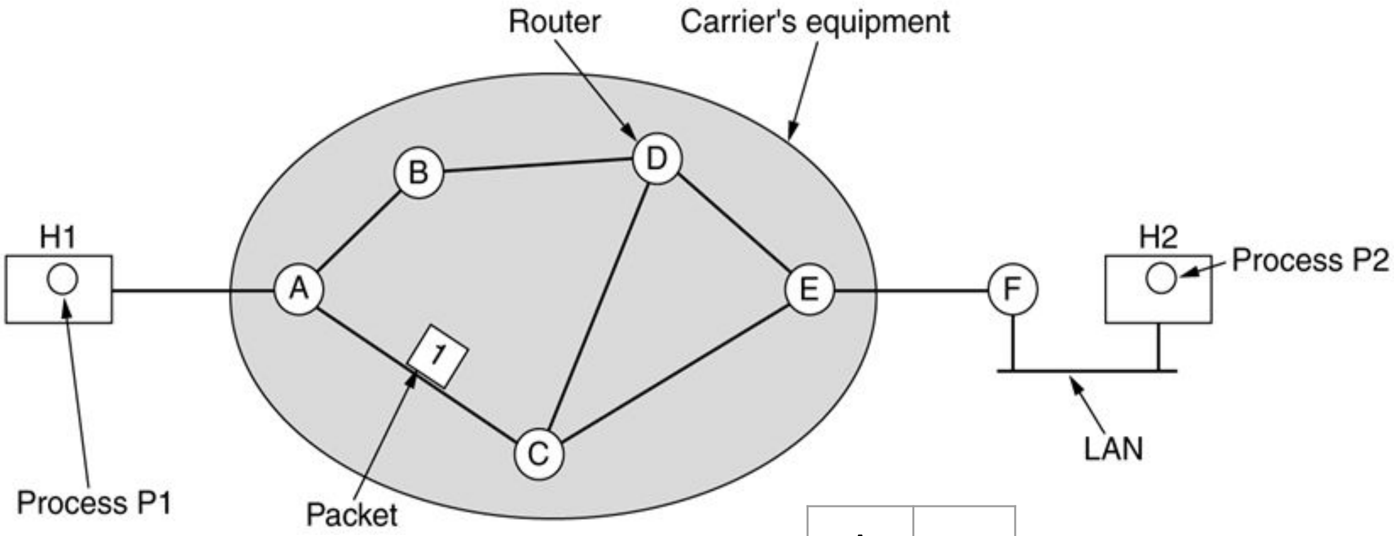


Routing Table Structure

To	Next Node

A's Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	

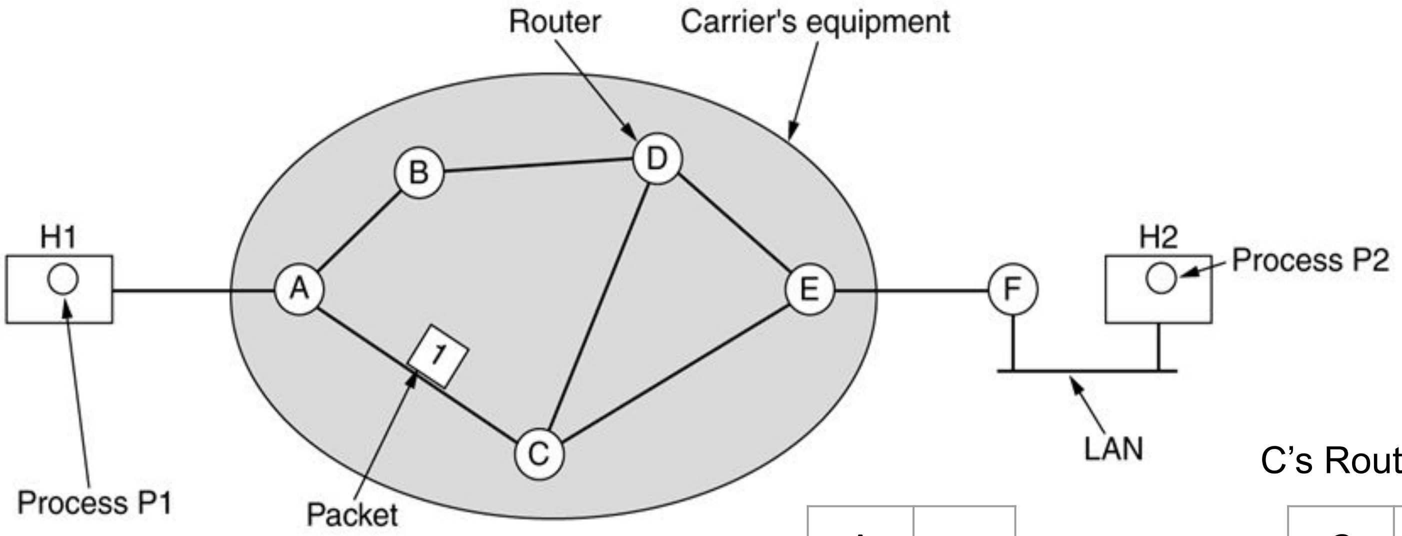


Routing Table Structure

To	Next Node

A’s Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C



Routing Table Structure

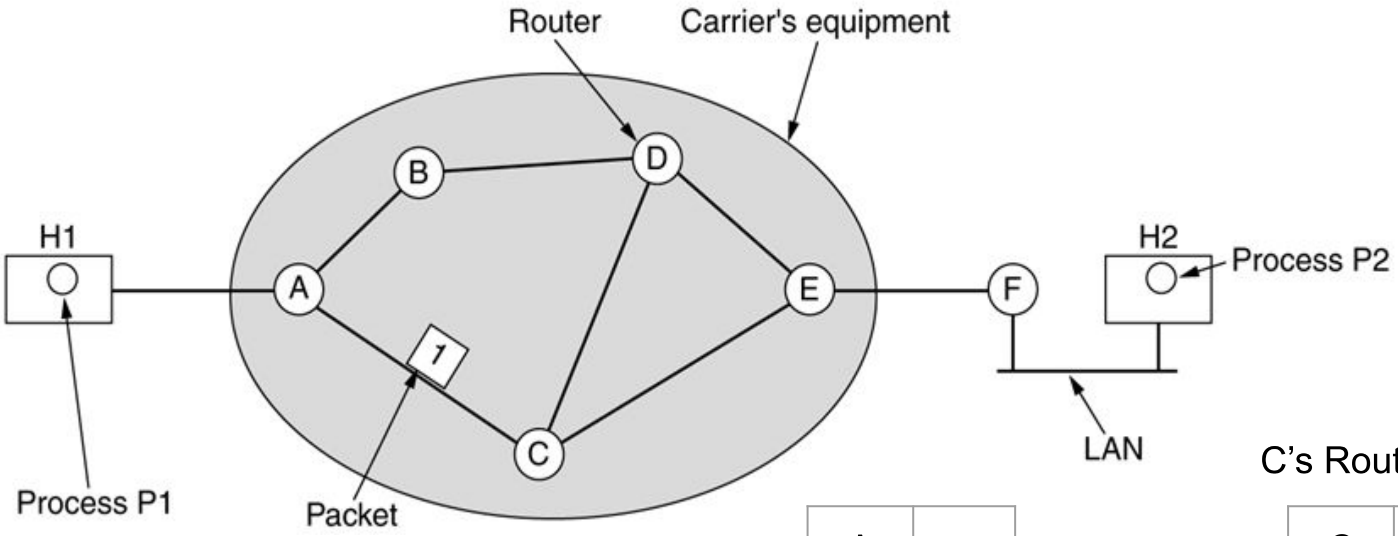
To	Next Node

A’s Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C

C’s Routing Table

C	--
A	
B	
D	
E	
F	



Routing Table Structure

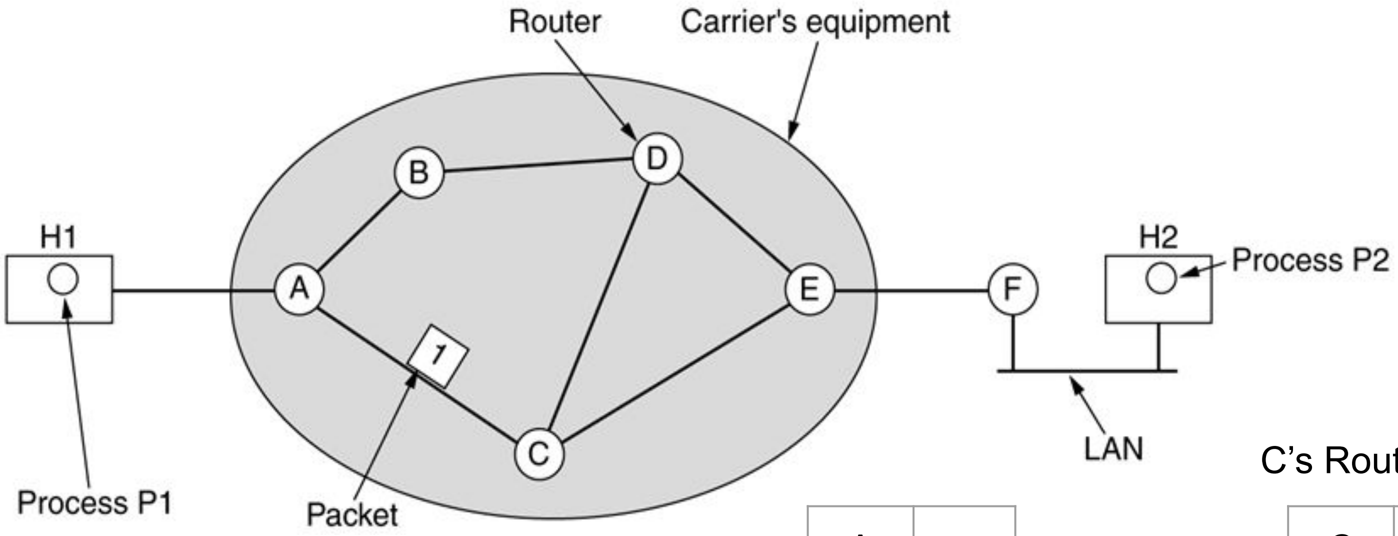
To	Next Node

A's Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C

C's Routing Table

C	--
A	A
B	
D	
E	
F	



Routing Table Structure

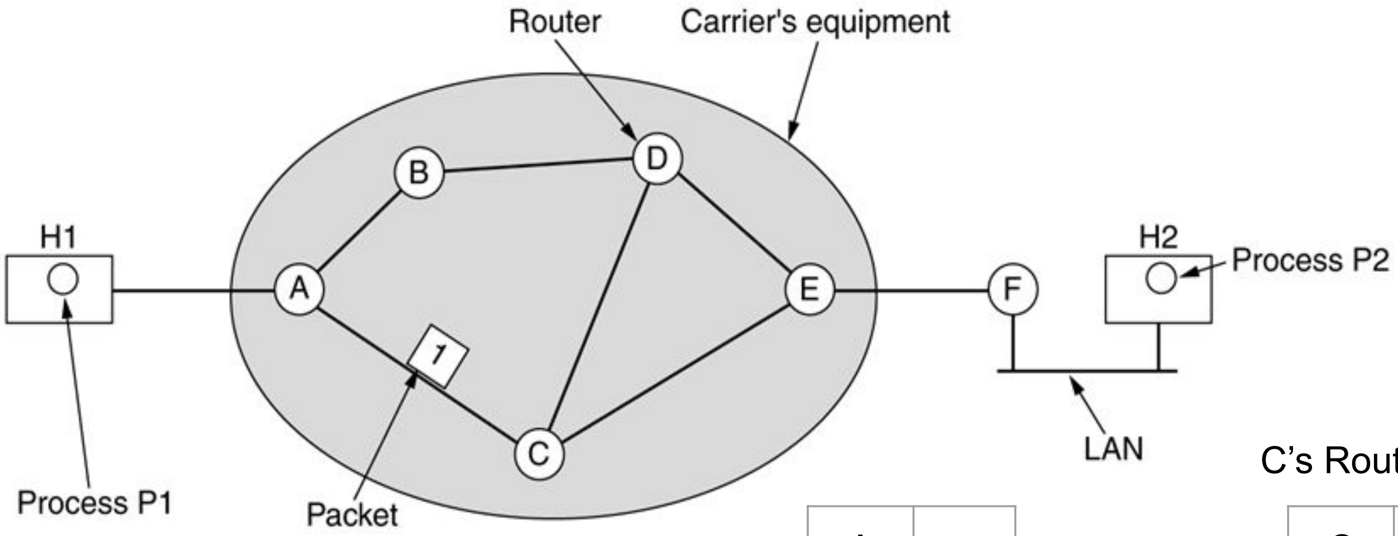
To	Next Node

A's Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C

C's Routing Table

C	--
A	A
B	A/D
D	
E	
F	



C’s Routing Table

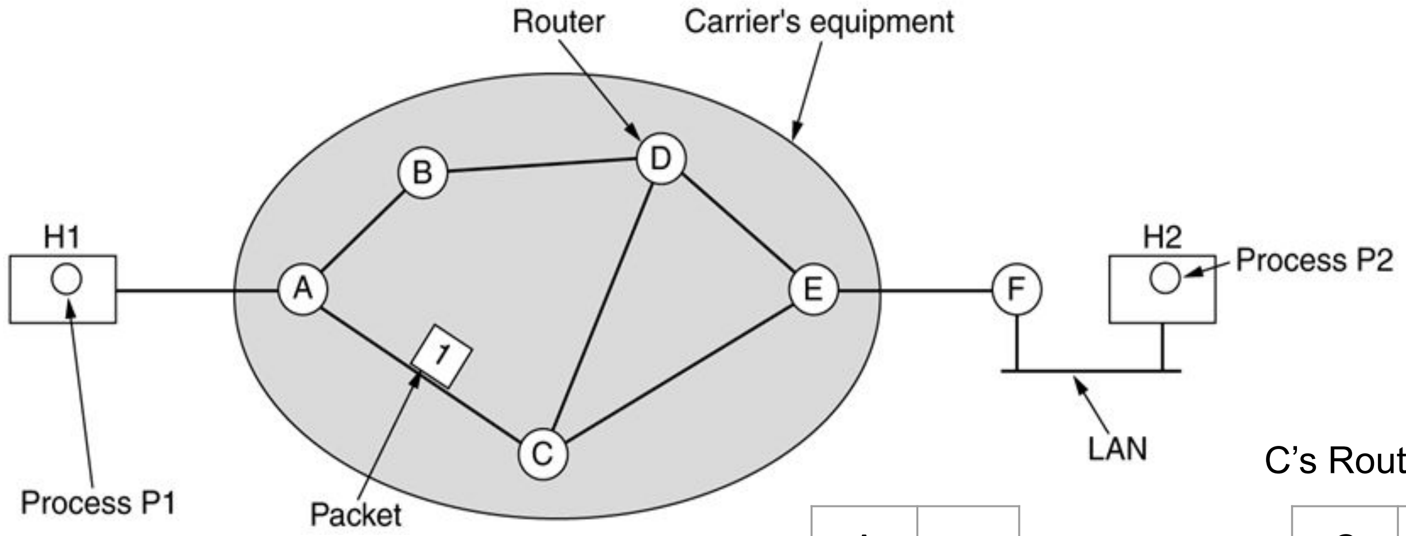
C	--
A	A
B	A/D
D	D
E	
F	

Routing Table Structure

To	Next Node

A’s Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C



C’s Routing Table

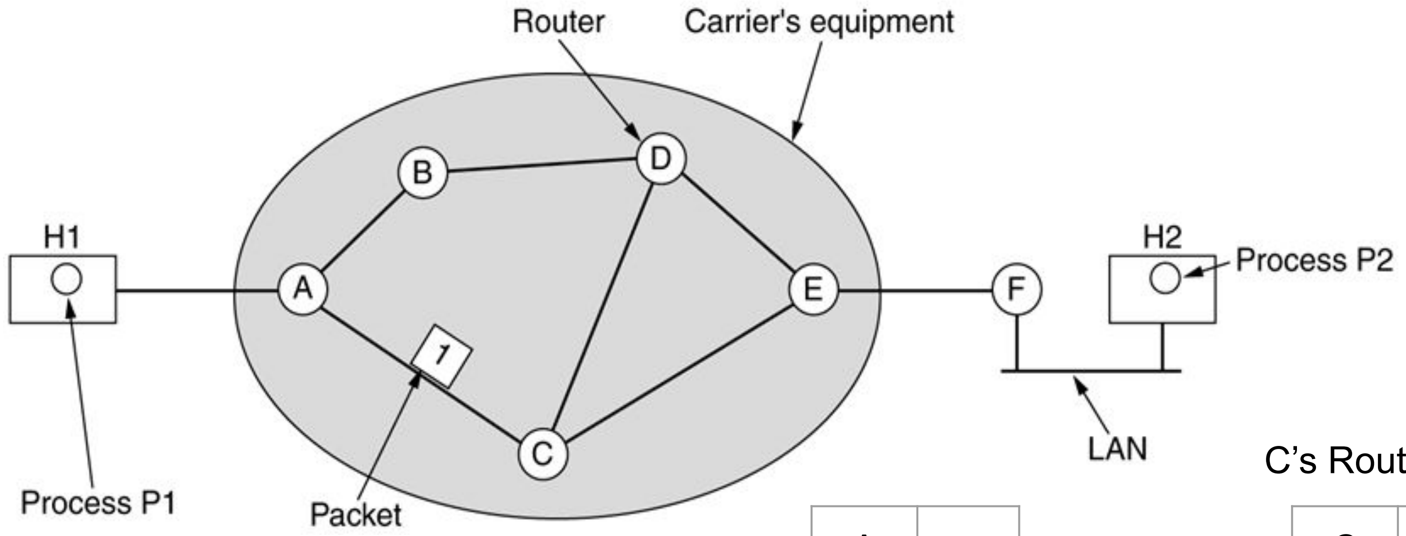
C	--
A	A
B	A/D
D	D
E	E
F	

Routing Table Structure

To	Next Node

A’s Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C



Routing Table Structure

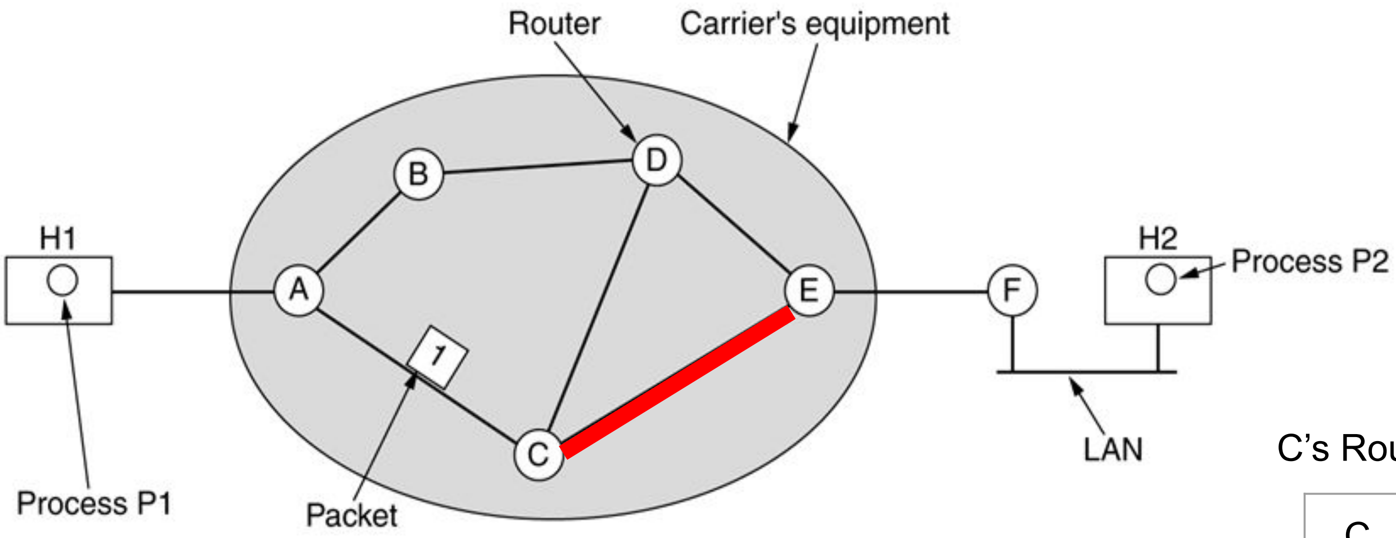
To	Next Node

A's Routing Table

A	--
B	B
C	C
D	B/C
E	C
F	C

C's Routing Table

C	--
A	A
B	A/D
D	D
E	E
F	E

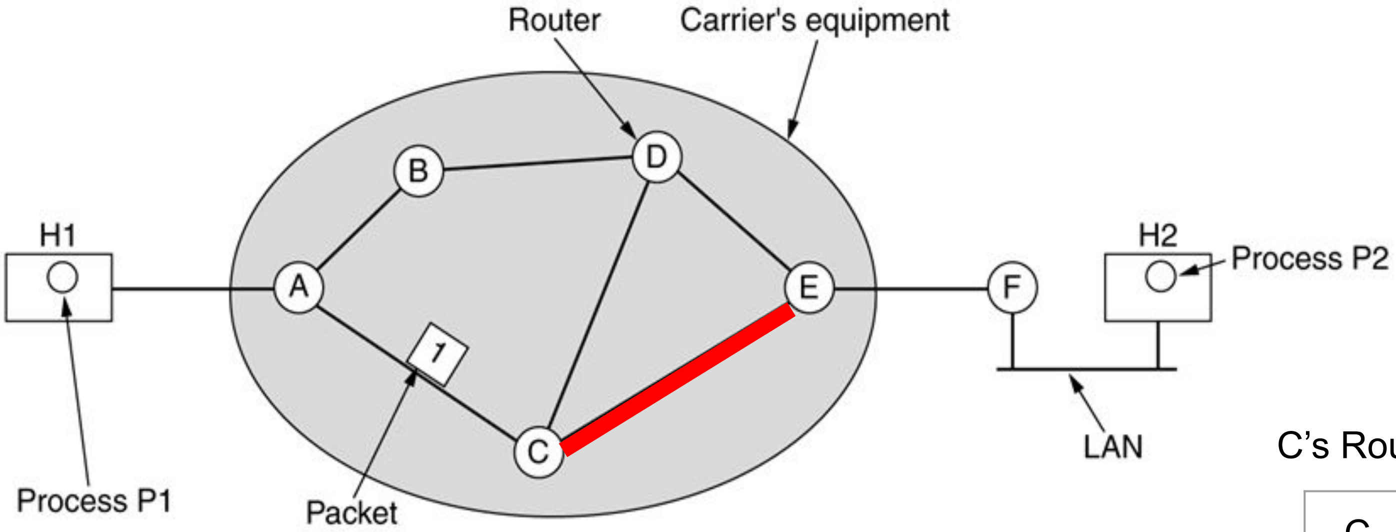


C’s Routing Table

C	--
A	A
B	A/D
D	D
E	E
F	E

Case B : C-E gets Congested @ time *t* + *n*

Update the routing table of C



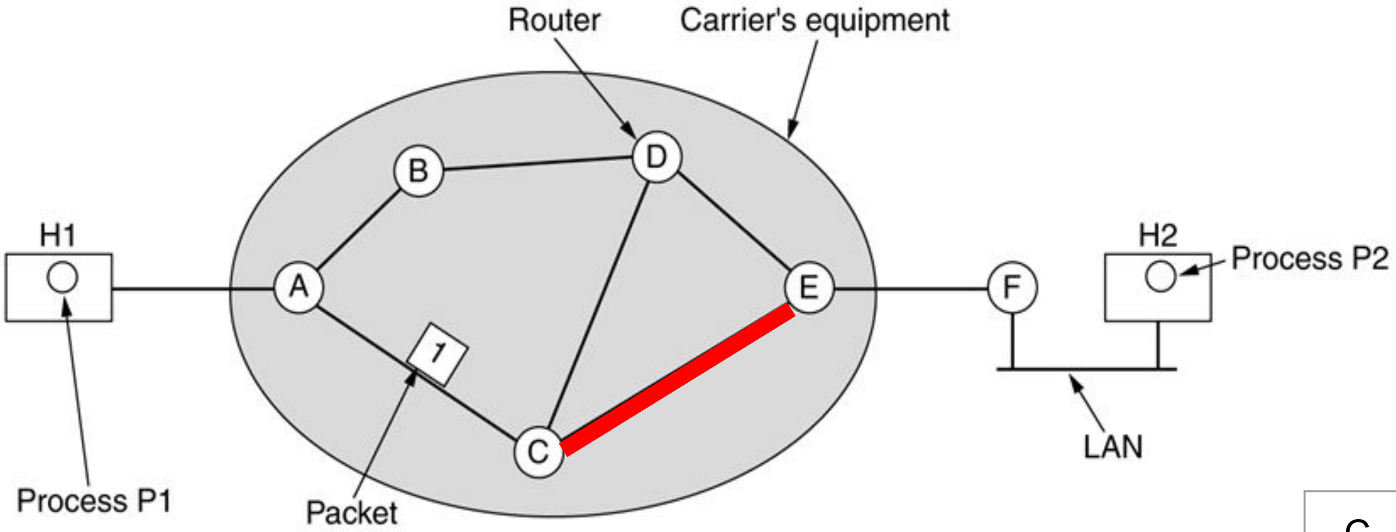
C’s Routing Table

Case B : C-E gets Congested @ time *t* + *n*

Update the routing table of C

C’s Updated Routing Table

C	--
A	A
B	A/D
D	D
E	D
F	



Case B : C-E gets Congested @ time $t + n$

Update the routing table of C

C's Updated Routing Table

C	--
A	A
B	A/D
D	D
E	D
F	D