

Data Link Layer | Neso Academy

 nesoacademy.org/cs/06-computer-networks/ppts/02-datalinklayer

CHAPTER - 2

Data Link Layer

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Data LinkLayerNeso AcademyCHAPTER - 2

OUTCOMES

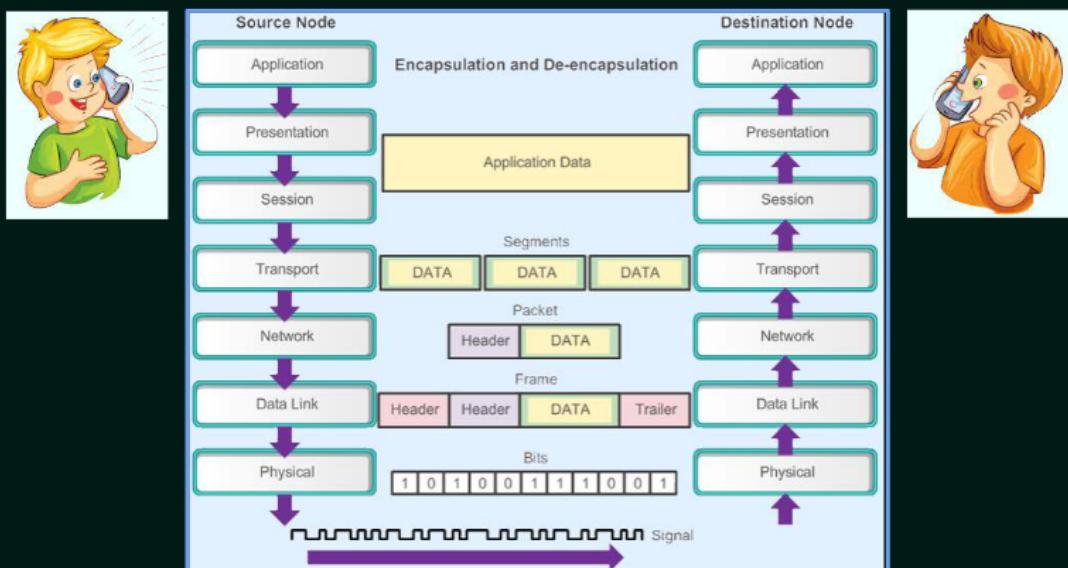
Upon the completion of this session, the learner will be able to

- ★ Understand the fundamental principles of physical layer.
- ★ Know about data and signals.

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Outcomes ★★ Neso Academy

FUNDAMENTAL PRINCIPLES OF PHYSICAL LAYER



Fundamental principles of physical layer Neso Academy

PHYSICAL LAYER – DATA AND SIGNALS

Data and Signals.

Source/Destination → Data → Signals.

Physical layer -Data and Signals Neso Academy

FUNDAMENTAL PRINCIPLES OF PHYSICAL LAYER

- ★ One of the major functions of the physical layer is to move data in the form of electromagnetic signals across a transmission medium.
- ★ The data usable to a person or an application are not in a form that can be transmitted over a network.
- ★ For example, an image must first be changed to a form that transmission media can accept.
- ★ To be transmitted, data must be transformed to electromagnetic signals.

Fundamental principles of physical Layer★★★Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand analog and digital signals.
- ★ Know various physical layer media.
- ★ Compare various physical media.

Outcomes★★★Neso Academy

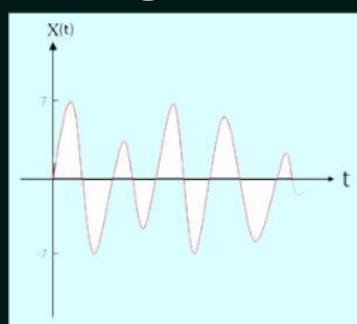
SIGNAL

- ★ It is a function that represents the variation of a physical quantity with respect to time.
- ★ Example: Variation in temperature of a city in one day i.e. 24 hours.
- ★ Analog Signal and Digital Signal.

Signal★★★Neso Academy

ANALOG SIGNAL

- ★ It is the signal that can take any value in the defined range.
- ★ All real-life signals are analog in nature.

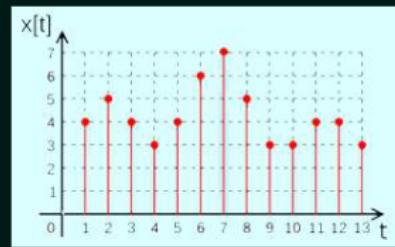


The signal $x(t)$ can take any value between -7 to +7.

Analog signal★★Neso Academy

DIGITAL SIGNAL

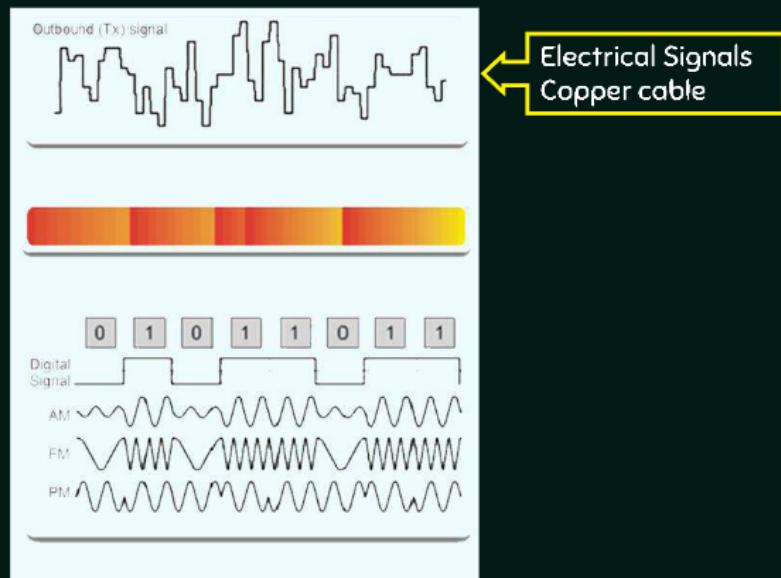
- ★ It is the signal that can take one of the finite values at any given time.
- ★ In case of digital signals, we discretize both time and magnitude.



The signal $x[t]$ can only take one value out of 0, 1, 2, 3, 4, 5, 6, and 7 for any discrete value of time.

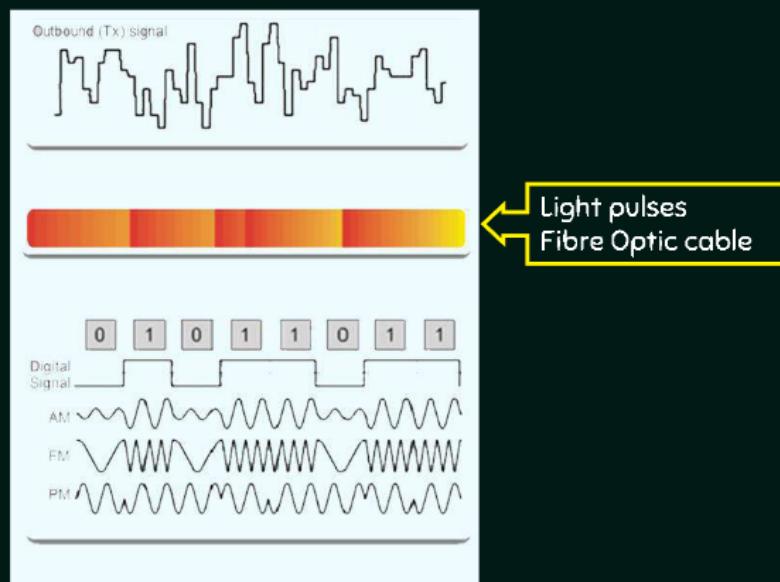
Digital signal ★★ Neso Academy

PHYSICAL LAYER MEDIA



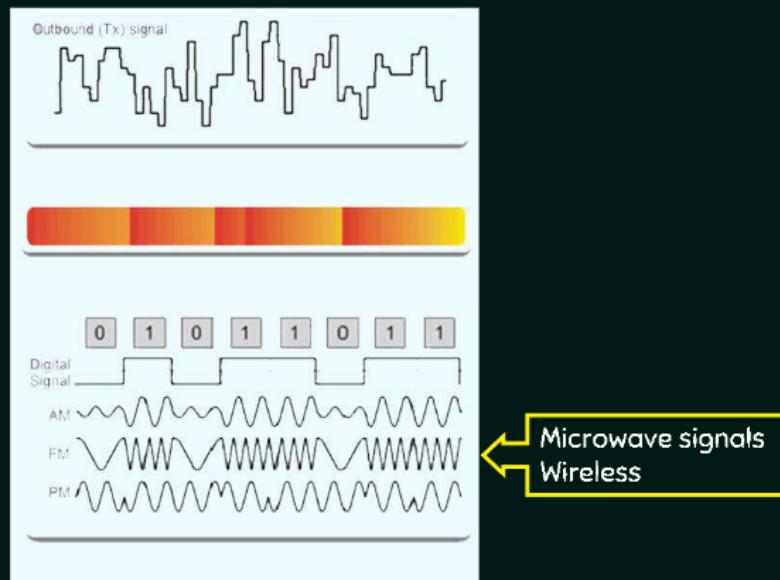
Physical Layer Media Neso Academy

PHYSICAL LAYER MEDIA



Physical Layer Media Neso Academy

PHYSICAL LAYER MEDIA



Physical Layer Media Neso Academy

COMPARISON OF VARIOUS PHYSICAL MEDIA

Media	Physical Components	Signal
Copper Cable (Wired)	<ul style="list-style-type: none">·UTP/STP·Coaxial·Connectors·NICs·Ports/Interfaces	Electromagnetic Signal
Fiber Optic Cable (Wired)	<ul style="list-style-type: none">·Single-mode Fiber·Multimode Fiber·Connectors·NICs and Interfaces·Lasers and LEDs	<ul style="list-style-type: none">·A light pulse equals 1.·No light pulse is 0.
Wireless Media	<ul style="list-style-type: none">·Access Points·NICs·Radio·Antennae	·Radio waves

Comparison of various physical media Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand wired and wireless media.
- ★ Understand UTP and STP.
- ★ Compare copper media and fiber optic media.
- ★ Know the popular wireless technologies.

Outcomes ★★★★ Neso Academy

WIRED MEDIA

- ★ Copper cable (Ethernet cable)
 - Unshielded Twisted Pair (UTP).
 - Shielded Twisted Pair (STP).
- ★ Copper coaxial cable.
- ★ Fiber optic cable.

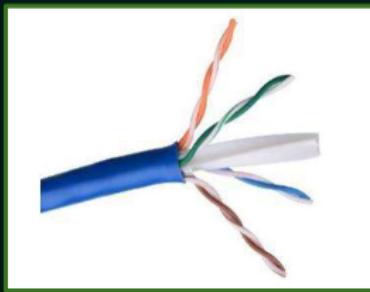
Wired media ★○○★★ Neso Academy

COPPER MEDIA – ETHERNET

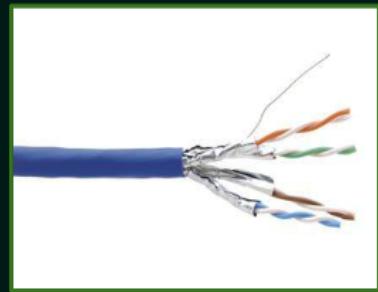


Copper media -Ethernet Neso Academy

COPPER MEDIA – ETHERNET



Unshielded Twisted Pair (UTP)
Ethernet Cable



Shielded Twisted Pair (STP)
Ethernet cable

Copper media -EthernetNeso Academy

CROSSTALK

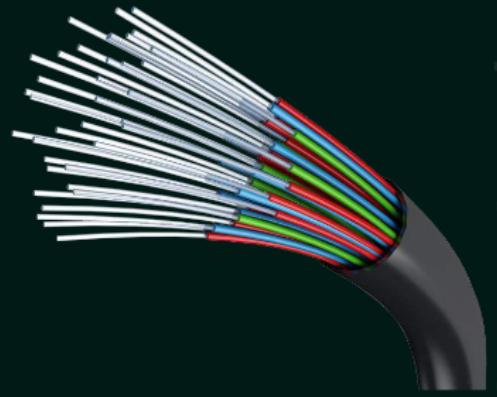
- ★ UTP cable does not use shielding to counter the effects of EMI and RFI.
- ★ The negative effect of crosstalk can be limited by varying the number of twists per wire pair.



Crosstalk★★Neso Academy

FIBER OPTIC MEDIA

- ★ Light waves.
- ★ High Speed transmission.



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Fiber optic media ★★ Neso Academy

COPPER VS FIBER OPTIC MEDIA

Implementation Points	Copper	Fiber Optic
Bondwidth Supported	10 Mbps – 10 Gbps	10 Mbps – 100 Gbps
Range	Relatively short (upto 100 meters)	Relatively High (upto 100,000 meters)
Immunity To EMI And RFI	Low	High (Completely immune)
Immunity To Electrical Hazards	Low	High (Completely immune)
Media And Connector Costs	Lowest	Highest
Installation Skills Required	Lowest	Highest
Safety	Lowest	Highest

Copper Vs Fiber Optic media Neso Academy

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WIRELESS MEDIA

Wireless media has the following areas of concern:

- ★ Coverage area
- ★ Interference
- ★ Security

Wireless media★★★Neso Academy

WIRELESS TECHNOLOGIES

	<ul style="list-style-type: none">• IEEE 802.11 standards• Commonly referred to as Wi-Fi.• Uses CSMA/CA• Variations include:<ul style="list-style-type: none">• 802.11a: 54 Mbps, 5 GHz• 802.11b: 11 Mbps, 2.4 GHz• 802.11g: 54 Mbps, 2.4 GHz• 802.11n: 600 Mbps, 2.4 and 5 GHz• 802.11ac: 1 Gbps, 5 GHz• 802.11ad: 7 Gbps, 2.4 GHz, 5 GHz, and 60 GHz
	<ul style="list-style-type: none">• IEEE 802.15 standard• Supports speeds up to 3 Mb/s• Provides device pairing over distances from 1 to 100 meters.
	<ul style="list-style-type: none">• IEEE 802.16 standard• Provides speeds up to 1 Gbps• Uses a point-to-multipoint topology to provide wireless broadband access.

Wireless technologiesNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

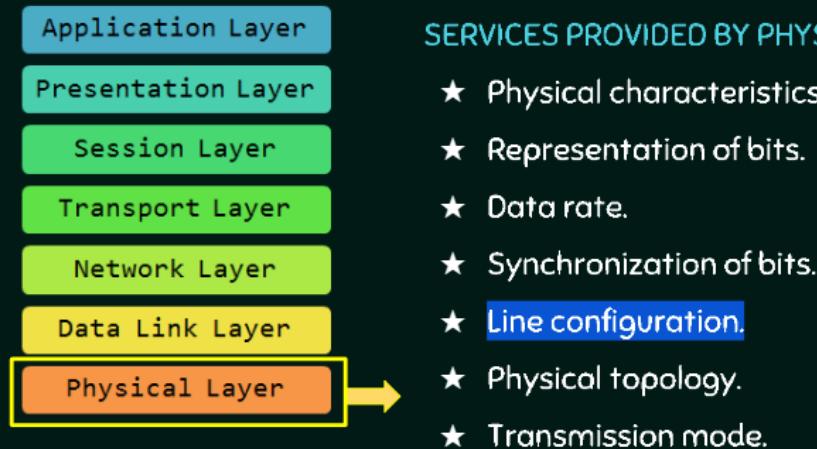
- ★ Recapture the services offered by physical layer of the OSI model.
- ★ Understand the line configuration.
- ★ Understand the types of line configuration.

Outcomes ★★★ Neso Academy

PHYSICAL LAYER

It is responsible for transmitting bits over a medium.

SERVICES PROVIDED BY PHYSICAL LAYER



- ★ Physical characteristics of the media.
- ★ Representation of bits.
- ★ Data rate.
- ★ Synchronization of bits.
- ★ Line configuration.
- ★ Physical topology.
- ★ Transmission mode.

Physical layer ★★★★★★★ Neso Academy

LINE CONFIGURATION

- ★ In a network, two or more nodes are connected by a communication link.
- ★ The communication link can be wired or wireless.
- ★ For visualization purpose, links are imagined as a line drawn between two points.
- ★ For communication to happen, two nodes must be connected to the same link at the same time.
- ★ This is called as line configuration or connection.

★★★★★Line configurationNeso Academy

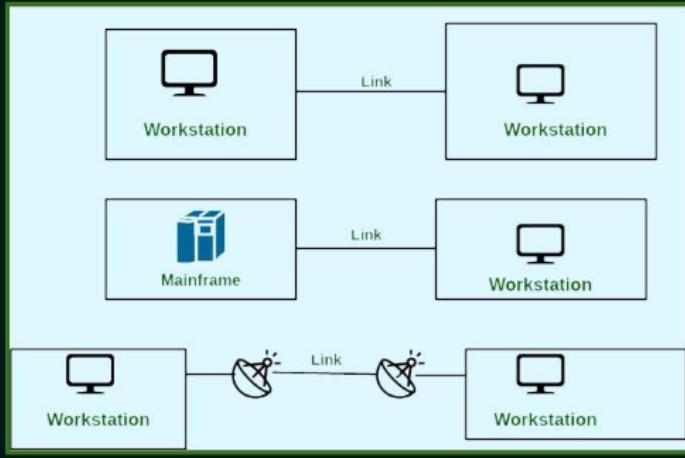
TYPES OF LINE CONFIGURATION

- ★ Point-to-Point Connection
- ★ Multipoint Connection

★★Types of line configurationNeso Academy

POINT-TO-POINT CONNECTION

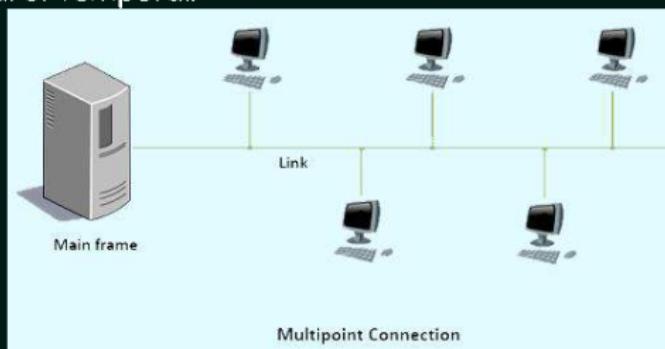
- ★ A point-to-point connection provides a dedicated link between two devices.
- ★ The entire capacity of the link is reserved for transmission between those two devices.



Point-to-point connection ★★ Neso Academy

MULTIPOINT CONNECTION

- ★ It is also called Multidrop configuration or Broadcast connection.
- ★ In this connection, two or more devices share a single link.
- ★ Since more than two devices share the link, the capacity of the channel is shared now.
- ★ It can be spatial or temporal.



Multipoint connection ★★★★ Neso Academy

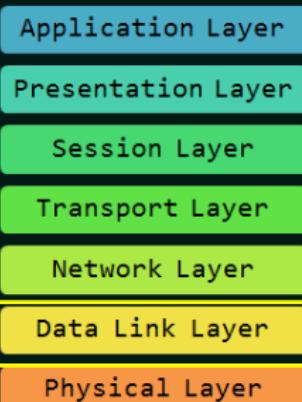
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various services offered by data link layer.
- ★ Understand the services offered by data link layer.

Outcomes ★★ Neso Academy

DATA LINK LAYER



It is responsible for moving data(frames) from one node to another node.

SERVICES PROVIDED BY DATA LINK LAYER

- ★ Framing.
- ★ Physical Addressing.
- ★ Flow Control.
- ★ Error Control.
- ★ Access Control.



Data Link Layer ★★★★ Neso Academy

FRAMING

- ★ The data link layer needs to pack bits into frames, so that each frame is distinguishable from another.
- ★ Our postal system practices a type of framing.
- ★ The simple act of inserting a letter into an envelope separates one piece of information from another; the envelope serves as the delimiter.



Framing ★★★ Neso Academy

PHYSICAL ADDRESSING

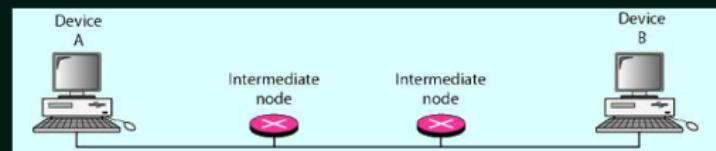
- ★ A Frame is the encapsulation of the header and trailer information with the packet.
- ★ In the header, the source and the destination MAC address are dealt.



Physical Addressing ★★★ Neso Academy

FLOW CONTROL

- ★ Flow Control is one of the duties of data link control sublayer.
- ★ The flow control in data link layer is end to end flow control.
- ★ Speed matching mechanism.
- ★ Flow control coordinates the amount of data that can be sent before receiving an acknowledgment.



Flow control★★★★Neso Academy

ACCESS CONTROL

- ★ Media Access control.



Access control★Neso Academy

ERROR CONTROL

- ★ Error Detection.
- ★ Error Correction.



Error control ★★ Neso Academy

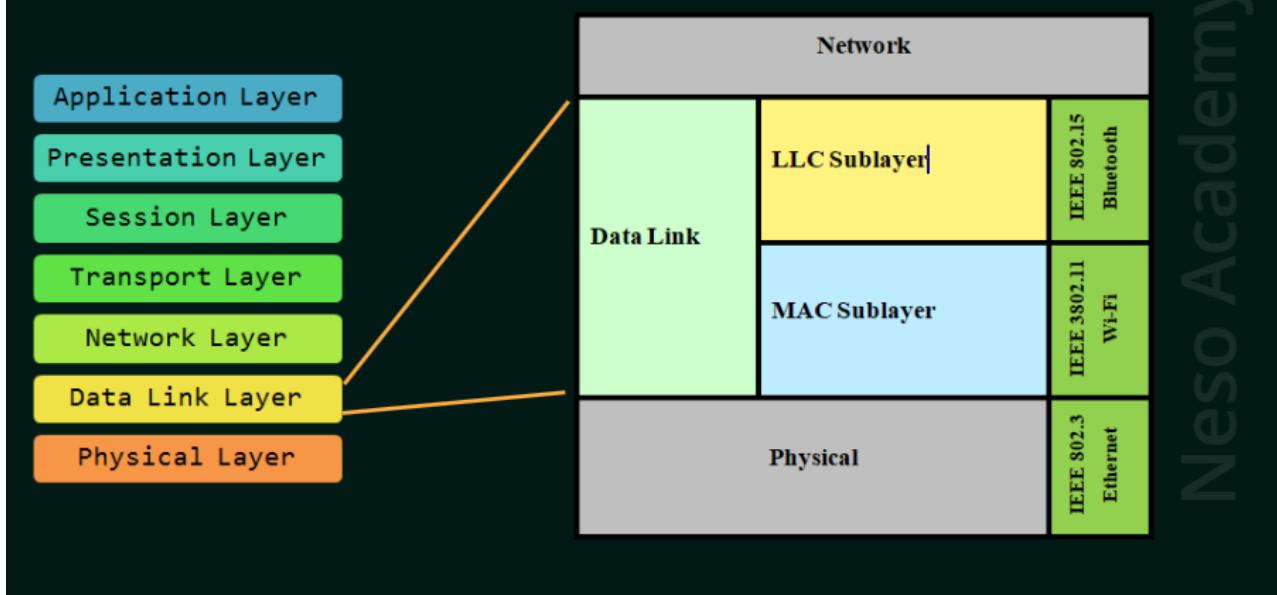
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the sublayers of data link layer.
- ★ Know the responsibilities of LLC or DLC.
- ★ Know the responsibilities of MAC sublayer.

Outcomes ★★ Neso Academy

DATA LINK LAYER



Data Link LayerNeso Academy

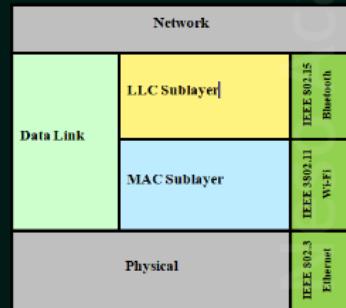
DATA LINK SUBLAYERS

Logical Link Control (LLC) or Data Link Control (DLC) Sublayer

- ★ Handles communication between upper and lower layers.
- ★ Takes the network protocol data and adds control information to help deliver the packet to the destination. (Flow control)

MAC Sublayer

- ★ Constitutes the lower sublayer of the data link layer.
- ★ Implemented by hardware, typically in the computer NIC.
- ★ Two primary responsibilities:
 - ★ Data encapsulation
 - ★ Media access control



Data Link sublayers★★★★★★Neso Academy

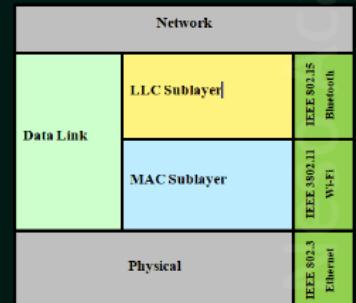
MAC SUBLAYER

Data encapsulation

- ★ Frame assembly before transmission and frame disassembly upon reception of a frame.
- ★ MAC layer adds a header and trailer to the network layer PDU.

Provides three primary functions:

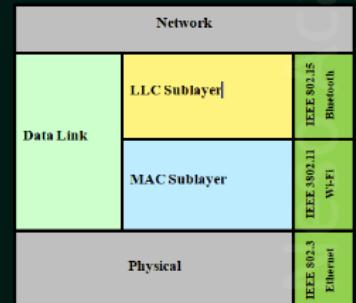
- ★ Framing.
- ★ Physical Addressing or MAC Addressing.
- ★ Error control.



MAC sublayer★★★★★Neso Academy

MAC SUBLAYER

- ★ Responsible for the placement of frames on the media and the removal of frames from the media
- ★ Communicates directly with the physical layer.



MAC sublayer★★Neso Academy

ACTIVITY TIME

Mention the sublayer that is responsible for the service shown in the table.

Service	Sublayer
Flow Control	LLC or DLC
Framing	
Physical Addressing	
Error Control	MAC
Access Control	

Activity Time Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand framing.
- ★ Understand framing errors.

Outcomes ★★ Neso Academy

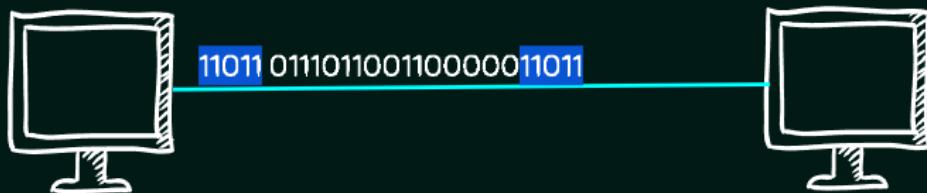
FRAMING



Bits flow between adaptors, frames between hosts

FramingNeso Academy

FRAMING



Let the start of frame and end of frame be 11011

FramingNeso Academy

FRAMING



Let the start of frame and end of frame be 11011

FramingNeso Academy

ANY PROBLEM HERE...



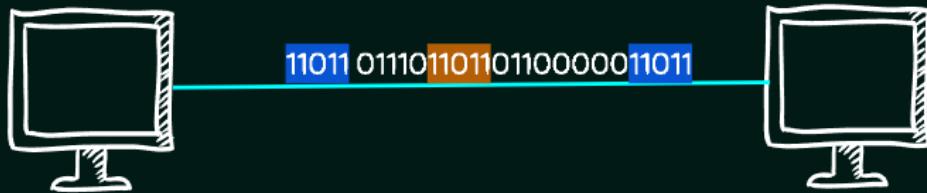
11011 01110110110110000011011



Let the start of frame and end of frame be 11011

Any problem here...Neso Academy

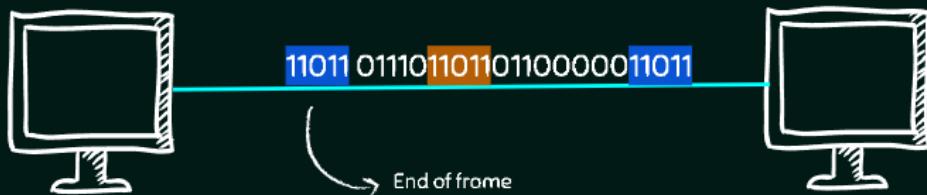
ANY PROBLEM HERE...



Let the start of frame and end of frame be 11011

Any problem here...Neso Academy

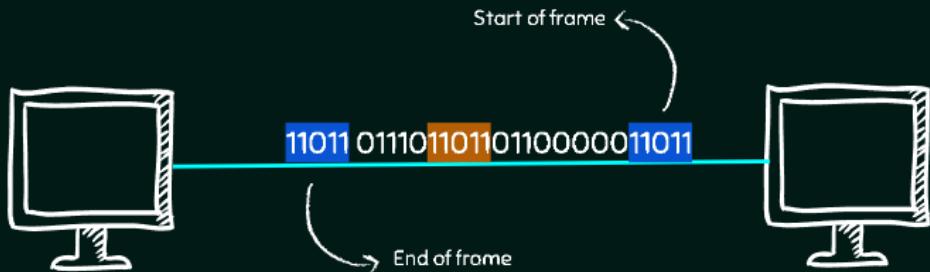
FRAMING ERROR



Let the start of frame and end of frame be 11011

Framing errorNeso Academy

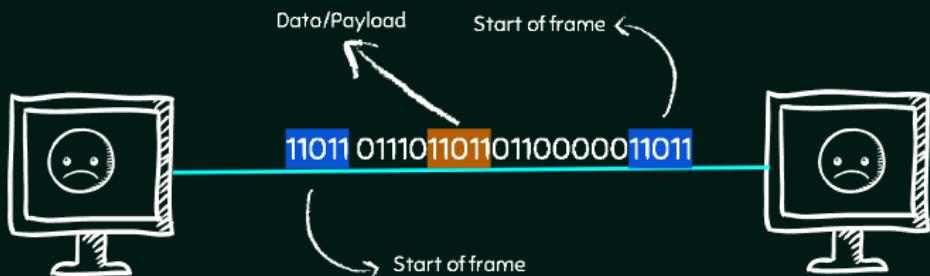
FRAMING ERROR



Let the start of frame and end of frame be 11011

Framing errorNeso Academy

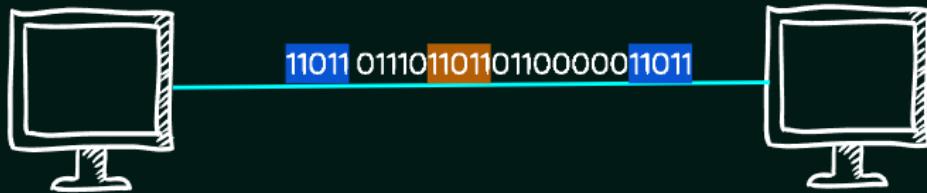
FRAMING ERROR



Let the start of frame and end of frame be 11011
Data = Start of Frame or End of Frame

Framing errorNeso Academy

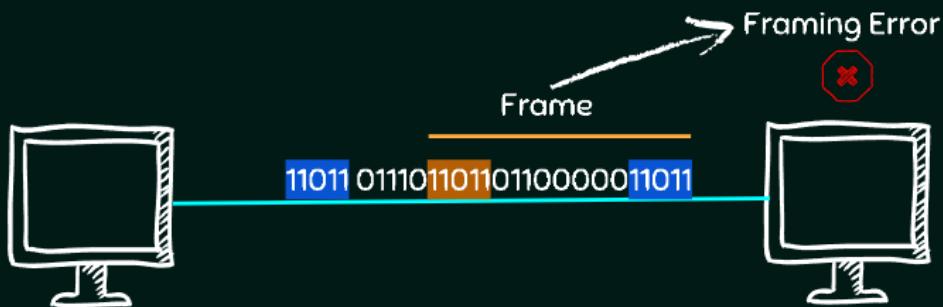
FRAMING ERROR



Let the start of frame and end of frame be 11011

Framing errorNeso Academy

FRAMING ERROR



Let the start of frame and end of frame be 11011

Framing errorNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the basics of framing.
- ★ Understand the types of framing.
- ★ Know various framing approaches.

Outcomes ★★★ Neso Academy

FRAMING

- ★ Framing in the data link layer separates a frame distinguishable from another frame.
- ★ Frame = Header + Network Layer PDU + Trailer.
- ★ In packet switched networks, the block of data called frames are exchanged between nodes, not bits streams.



Framing ★★★ Neso Academy

FRAMING

- ★ When node A wishes to transmit a frame to node B, it tells its adaptor to transmit a frame from the node's memory.
- ★ This results in a sequence of bits being sent over the link.
- ★ The adaptor on node B then collects together the sequence of bits arriving on the link and deposits the corresponding frame in B's memory.
- ★ Challenge: What set of bits constitute a frame?



Bits flow between adaptors, frames between hosts

Framing ★★★ Neso Academy

TYPES OF FRAMING

1. Fixed-size framing.

- ★ Here the size of the frame is fixed and so the frame length acts as delimiter of the frame.
- ★ Consequently, it does not require additional boundary bits to identify the start and end of the frame.

2. Variable-size framing.

- ★ Here, the size of each frame to be transmitted may be different.
- ★ So additional mechanisms are kept to mark the end of one frame and the beginning of the next frame.

Types of framing ★★★ Neso Academy

VARIOUS FRAMING APPROACHES



Various framing approachesNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know bit oriented approach and bit oriented protocols.
- ★ Know byte oriented approach and byte oriented protocols.
- ★ Know clock based framing.

Outcomes★★★Neso Academy

VARIOUS FRAMING APPROACHES



Various framing approaches Neso Academy

BIT ORIENTED APPROACH

- ★ It simply views the frame as a collection of bits.
- ★ These bits might come from
 - Some character set, such as ASCII

Bit oriented approach ★★○ Neso Academy

BIT ORIENTED APPROACH

- ★ It simply views the frame as a collection of bits.
- ★ In bit-oriented framing, data is transmitted as a sequence of bits that can be interpreted in the upper layers both as text as well as multimedia data.

Bit oriented approach ★★ Neso Academy

BIT ORIENTED PROTOCOL

- ★ HDLC <→ High-Level Data Link Control

Bit oriented protocol ★ Neso Academy

BYTE ORIENTED APPROACH

- ★ One of the oldest approaches to framing.
- ★ Here each frame is viewed as a collection of bytes (characters) rather than bits.
- ★ a.k.a Character Oriented Approach.

Byte oriented approach★★★Neso Academy

BYTE ORIENTED PROTOCOLS

- ★ BISYNC <-> Binary Synchronous Communication Protocol.
- ★ DDCMP <-> Digital Data Communication Message Protocol.
- ★ PPP <-> Point-to-Point Protocol

Byte oriented protocols★★★Neso Academy

CLOCK BASED FRAMING

- ★ The third approach to framing is the clock based framing.
- ★ Example: SONET <-> Synchronous Optical Network.

Clock based framing ★★Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand bit-oriented protocol.
- ★ Know the frame format of HDLC.
- ★ Know the types of HDLC frames.

Outcomes★★★Neso Academy

BIT ORIENTED APPROACH

- ★ It simply views the frame as a collection of bits.

Bit Oriented Protocol

HDLC <-> High-Level Data Link Control

Bit oriented approach ★ Neso Academy

HDLC

- ★ The Synchronous Data Link Control (SDLC) protocol developed by IBM is an example of a bit-oriented protocol.
- ★ SDLC was later standardized by the ISO as the High-Level Data Link Control (HDLC) protocol.
- ★ Bit Oriented Protocol.

HDLC ★★★ Neso Academy

HDLC – FRAME FORMAT

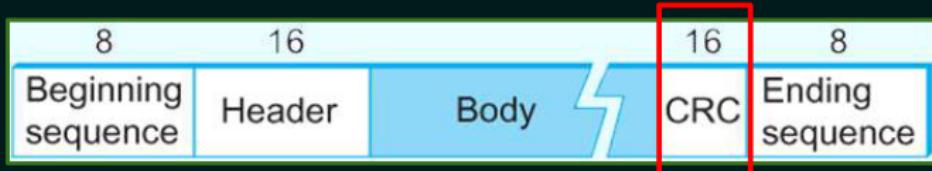
Beginning and Ending Sequences: 0111110

This sequence is also transmitted during any times that the link is idle so that the sender and receiver can keep their clocks synchronized.

Header: Address and Control Field.

Body: Payload (Variable size)

CRC: Cyclic Redundancy check – Error Detection



HDLC -Frame formatNeso Academy

TYPES OF HDLC FRAMES

The type of frame is determined by the control field.

I-Frame: Information Frame.

S-Frame: Supervisory Frame.

U-Frame: Un-numbered Frame.

I-Frame	1st bit is 0
S-Frame	1st two bits is 10
U-Frame	1st two bits is 11

Types of HDLC FramesNeso Academy

BIT ORIENTED APPROACH

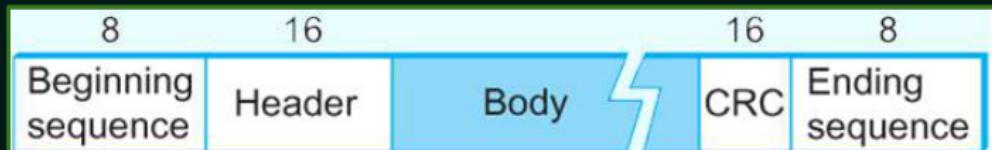
- ★ It simply views the frame as a collection of bits.

Bit Oriented Protocol

HDLC <→ High-Level Data Link Control

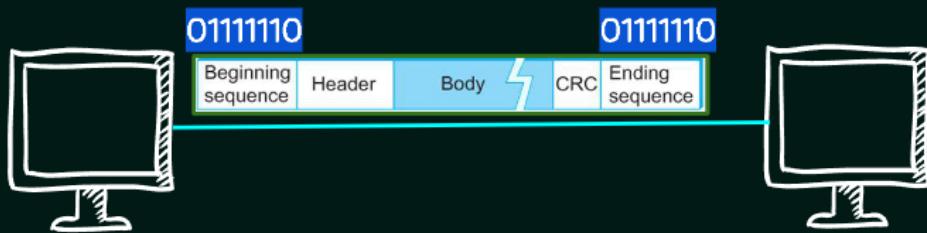
Bit oriented approach ★ Neso Academy

HDLC – FRAME FORMAT



HDLC -Frame format Neso Academy

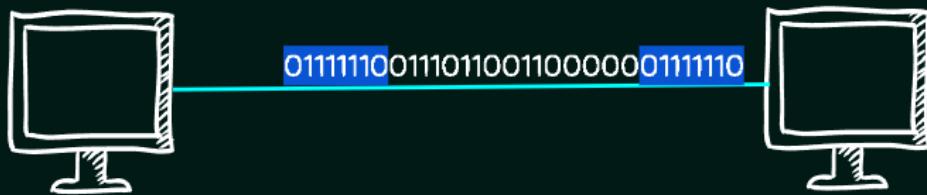
FRAMING



HDLC Protocol: Beginning and Ending Sequence is 01111110

FramingNeso Academy

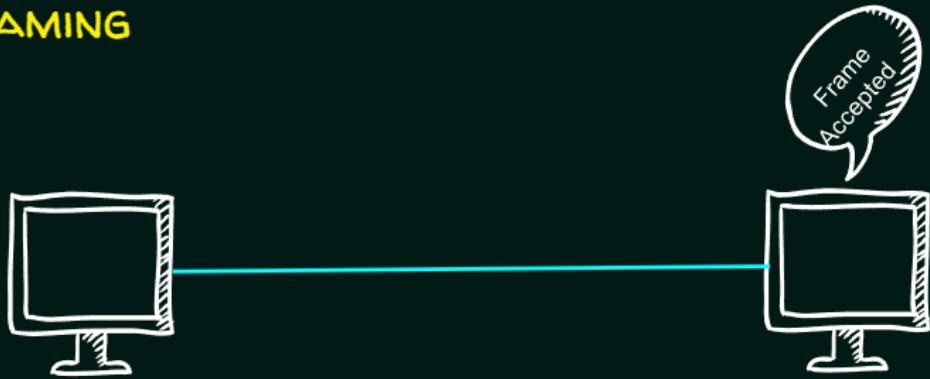
FRAMING



HDLC Protocol: Beginning and Ending Sequence is 01111110

FramingNeso Academy

FRAMING



HDLC Protocol: Beginning and Ending Sequence is **01111110**

FramingNeso Academy

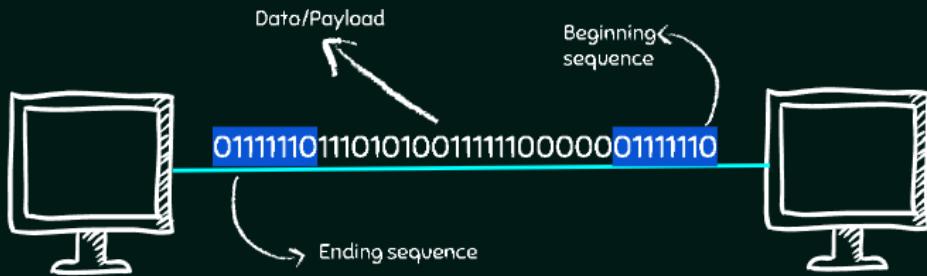
PROBLEM HERE...



HDLC Protocol: Beginning and Ending Sequence is **01111110**

Problem here...Neso Academy

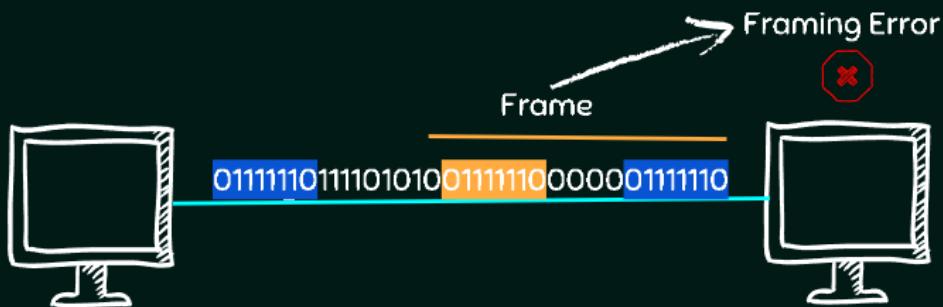
PROBLEM HERE...



HDLC Protocol: Beginning and Ending Sequence is 01111110

Problem here...Neso Academy

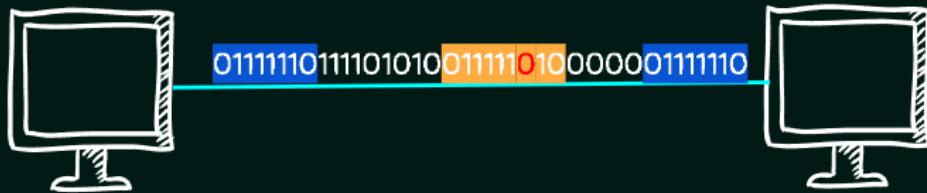
PROBLEM



HDLC Protocol: Beginning and Ending Sequence is 01111110

ProblemNeso Academy

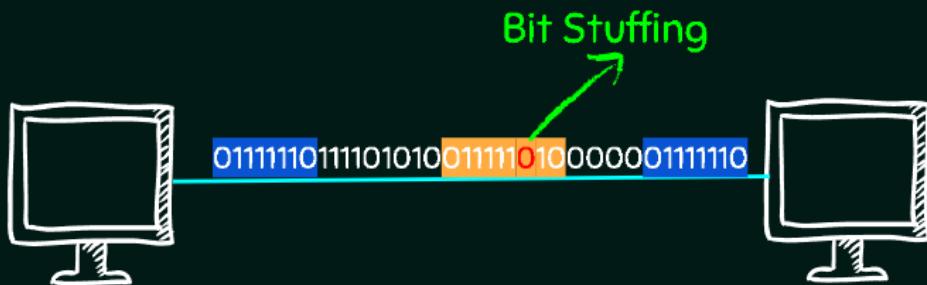
SOLUTION



HDLC Protocol: Beginning and Ending Sequence is 01111110

SolutionNeso Academy

BIT STUFFING



HDLC Protocol: Beginning and Ending Sequence is 01111110

Bit stuffingNeso Academy

HOMEWORK!

Correct? or Incorrect?

Bit sequence without stuffing: 110101111010111110101111110

Bit sequence with bit stuffing: 110101111001011110101011110110

Homework!Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand byte-oriented approach
- ★ Know the byte-oriented protocol.
- ★ Know the frame format of BISYNC.
- ★ Understand character stuffing in BISYNC.

Outcomes★★★★Neso Academy

BYTE ORIENTED APPROACH

- ★ It simply views the frame as a collection of bytes or characters.

Byte Oriented Protocols

BISYNC<-> Binary Synchronous Communication Protocol

PPP <-> Point-to-Point Protocol

DDCMP <-> Digital Data Communication Message Protocol.

Byte oriented approach★Neso Academy

BiSYNC

- ★ It is a sentinel approach.
- ★ Developed by IBM.
- ★ Also preferred as BSC.
- ★ It is a byte-oriented protocol.

BiSynC★★★★Neso Academy

BISYNC – FRAME FORMAT

Frames transmitted beginning with leftmost field.

- ★ Beginning of a frame is denoted by sending a special SYN (synchronize) character.
- ★ Data portion of the frame is contained between special sentinel character STX (start of text) and ETX (end of text).
- ★ SOH: Start of Header.
- ★ DLE: Data Link Escape.
- ★ CRC: Cyclic Redundancy Check.

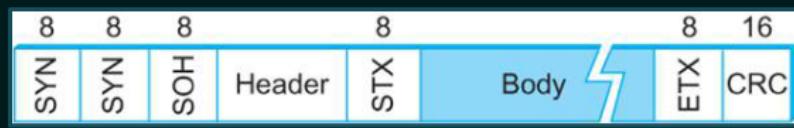


BISYNC -Frame format★★★★★Neso Academy

CHARACTER STUFFING

Byte stuffing or Character stuffing is the process of adding one extra byte whenever there is a flag or escape character in the text.

This is done by DLE in BISYNC protocol.



Character stuffingNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the byte-oriented protocol.
- ★ Know the frame format of PPP.
- ★ Understand character stuffing or byte stuffing in PPP.

Outcomes ★★★ Neso Academy

BYTE ORIENTED APPROACH

- ★ It simply views the frame as a collection of bits.

Byte Oriented Protocols

BISYNC<-> Binary Synchronous Communication Protocol

PPP <-> Point-to-Point Protocol

DDCMP <-> Digital Data Communication Message Protocol.

Byte oriented approach ★ Neso Academy

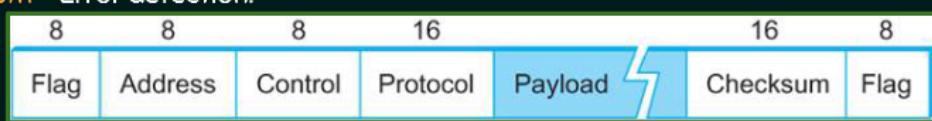
PPP

- ★ PPP is a data link layer protocol.
- ★ PPP is a WAN protocol and which is commonly run over Internet links.
- ★ It is widely used in broadband communications having heavy loads and high speeds.
- ★ It is used to transmit multiprotocol data between two directly connected (point-to-point) computers.

PPP★★★★Neso Academy

PPP – FRAME FORMAT

- ★ **Flag** – 1 byte that marks the beginning and the end of the frame. The bit pattern of the flag is 0111110.
- ★ **Address** – 1 byte which is set to 1111111 in case of broadcast.
- ★ **Control** – 1 byte set to a constant value of 11000000.
- ★ **Protocol** – 1 or 2 bytes that define the type of data contained in the payload field.
- ★ **Payload** – This carries the data from the network layer. The maximum length of the payload field is 1500 bytes. However, this may be negotiated between the endpoints of communication.
- ★ **Checksum** – Error detection.



PPP -Frame format★★★★★Neso Academy

CHARACTER STUFFING

Byte stuffing or Character stuffing is the process of adding one extra byte whenever there is a flag sequence appear in the payload.



Character stuffing Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand DDCMP frame format.
- ★ Understand the framing error in DDCMP.

Outcomes ★★ Neso Academy

BYTE ORIENTED APPROACH

- ★ It simply views the frame as a collection of bytes or characters.

Byte Oriented Protocols

BISYNC<-> Binary Synchronous Communication Protocol

PPP <-> Point-to-Point Protocol

DDCMP <-> Digital Data Communication Message Protocol.

Byte oriented approach★Neso Academy

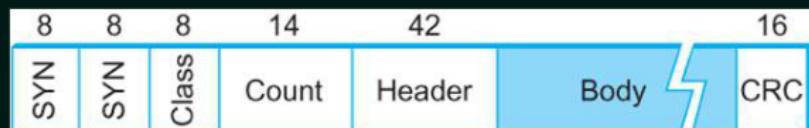
DDCMP

- ★ Byte-oriented communication protocol.
- ★ Devised by Digital Equipment Corporation.
- ★ It is a byte-counting approach.
- ★ Count field in the frame format.
- ★ **Count:** How many bytes are contained in the frame body?

DDCMP★★★★★Neso Academy

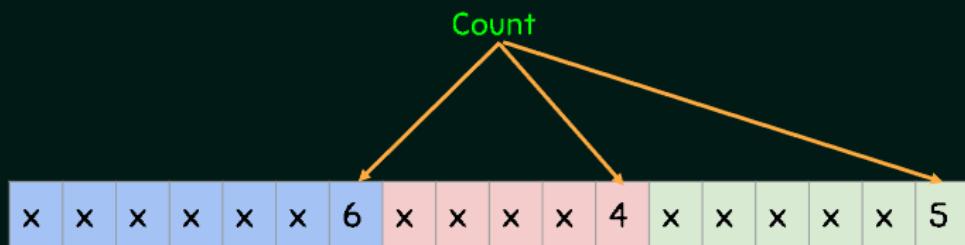
DANGER WITH THE COUNT FIELD

One danger with this approach is that if transmission error could corrupt the count field then the end of the frame would not be correctly detected by the receiver.



Danger with the count fieldNeso Academy

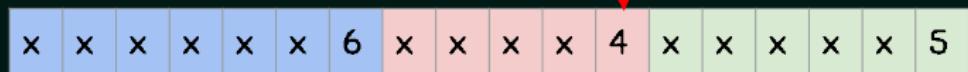
DANGER WITH THE COUNT FIELD



Danger with the count fieldNeso Academy

DANGER WITH THE COUNT FIELD

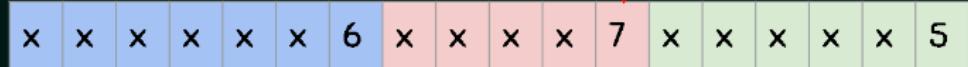
Transmission Error



Danger with the count field Neso Academy

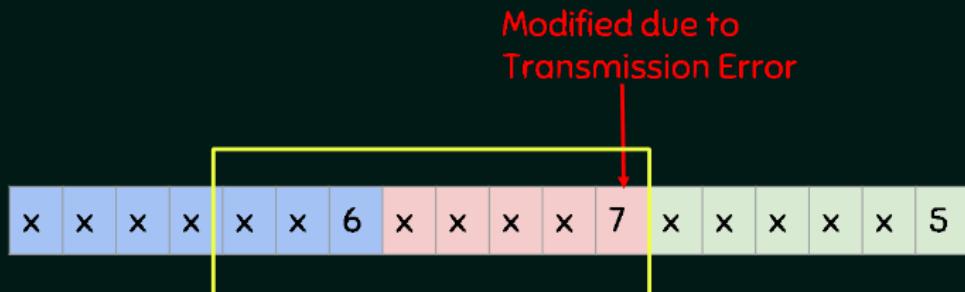
DANGER WITH THE COUNT FIELD

Modified due to
Transmission Error



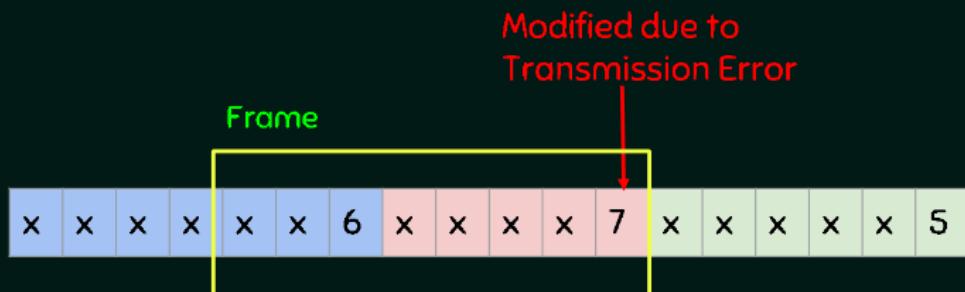
Danger with the count field Neso Academy

DANGER WITH THE COUNT FIELD



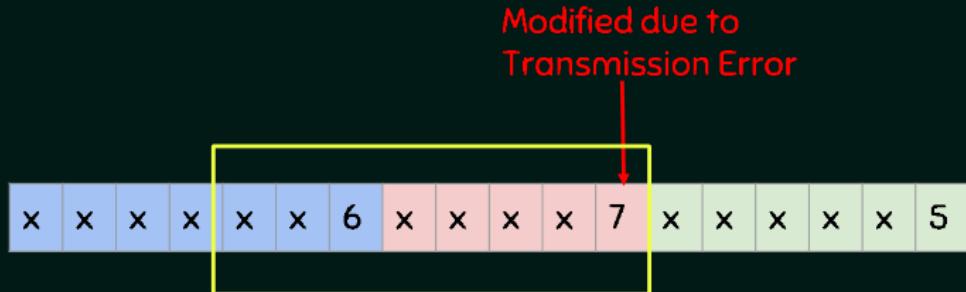
Danger with the count field Neso Academy

DANGER WITH THE COUNT FIELD



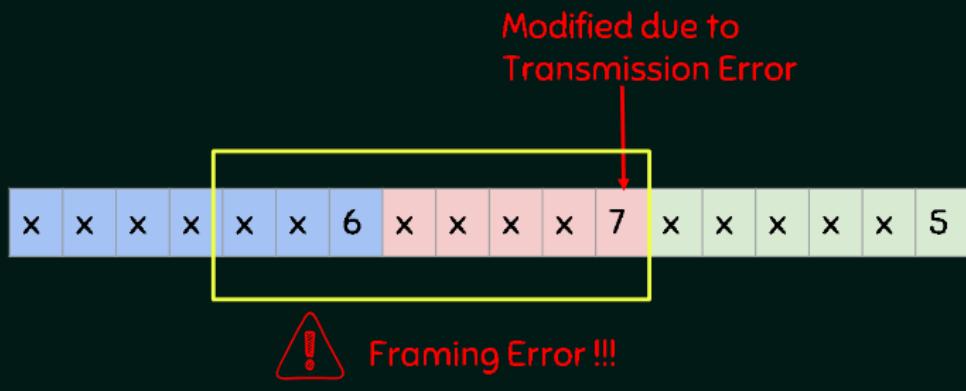
Danger with the count field Neso Academy

DANGER WITH THE COUNT FIELD



Danger with the count field Neso Academy

DANGER WITH THE COUNT FIELD



Danger with the count field Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand transmission errors.
- ★ Know the types of errors.
- ★ Understand error detection and error correction.
- ★ Know the various error detection techniques.

Outcomes ★★★★ Neso Academy

ERROR

- ★ Data are transmitted in the network.
- ★ The data can be corrupted during transmission.
- ★ Transmission error.
- ★ For reliable communication, errors must be detected and corrected.
- ★ Error detection and correction are implemented either at the data link layer or the transport layer of the OSI model.

Error ★★★★★ Neso Academy

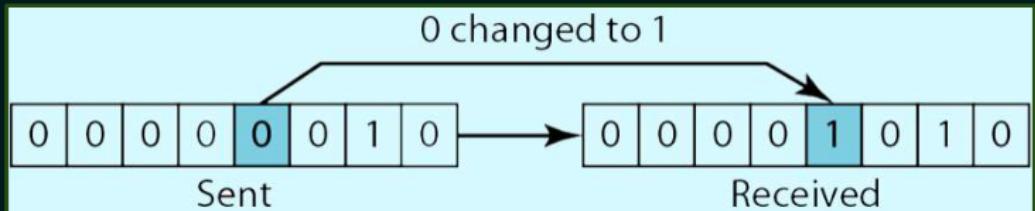
TYPES OF ERROR

1. Bit Error.
2. Burst Error.

Types of errorNeso Academy

BIT ERROR

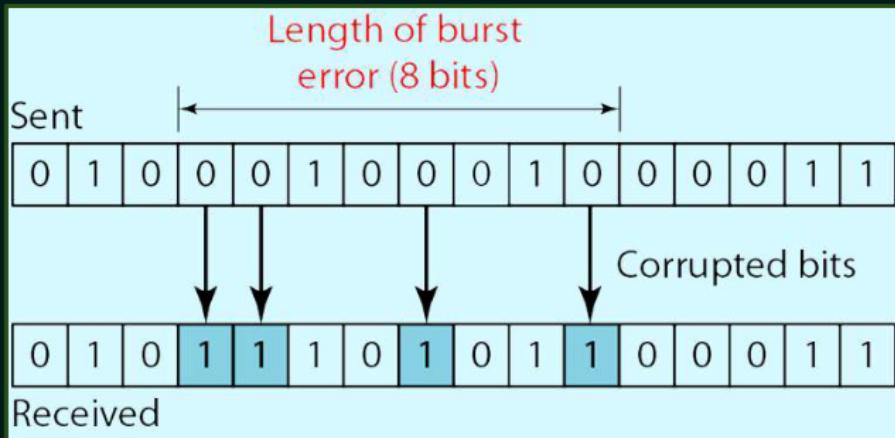
- ★ a.k.a single bit error.
- ★ In a single bit error, only 1 bit in the data unit has been changed.



★★Bit errorNeso Academy

BURST ERROR

- ★ In burst error, 2 or more bits in the data unit have changed.



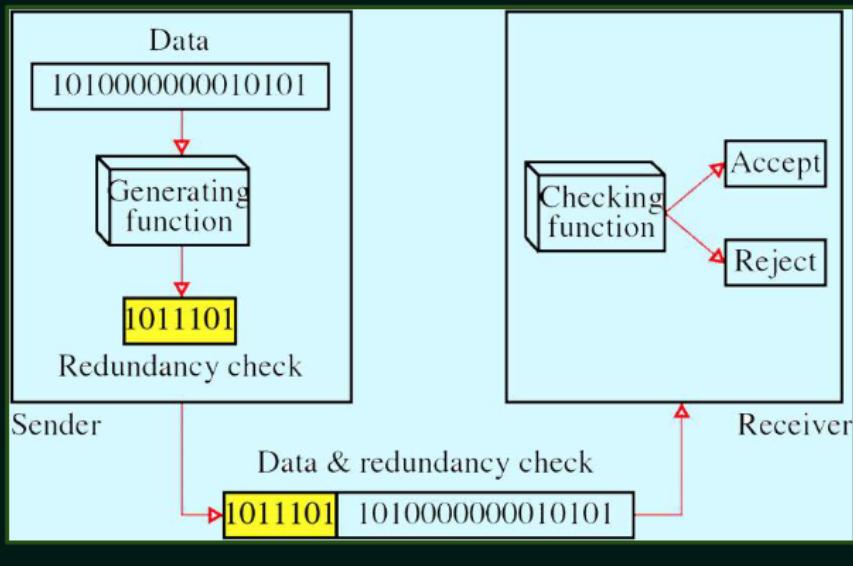
★ Burst error Neso Academy

HOW TO DETECT THE ERRORS?

- ★ Error detection means to decide whether the received data is correct or not without having a copy of the original message.
- ★ To detect or correct errors, we need to send some extra bits with the data.
- ★ The extra bits are called as redundant bits.

How to detect the errors? ★★★ Neso Academy

REDUNDANCY



RedundancyNeso Academy

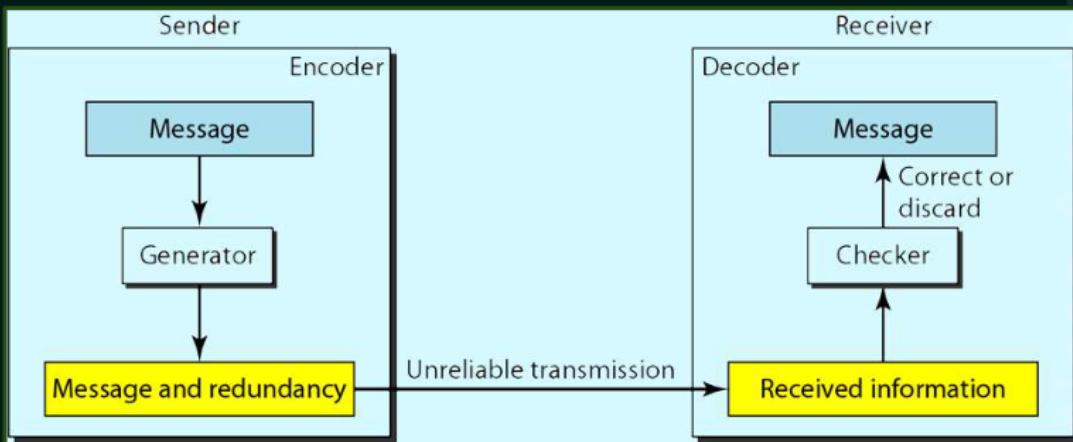
ERROR CORRECTION

It can be handled in two ways:

- 1) Receiver can have the sender retransmit the entire data unit.
- 2) The receiver can use an error-correcting code, which automatically corrects certain errors.

Error correctionNeso Academy

ERROR DETECTION/CORRECTION



Error detection/correctionNeso Academy

ERROR DETECTION TECHNIQUES

Four types of redundancy checks are used in data communications. They are:

1. Vertical Redundancy Check (VRC)
2. Longitudinal Redundancy Check (LRC)
3. Checksum
4. Cyclic Redundancy Check (CRC)

Error detection techniquesNeso Academy

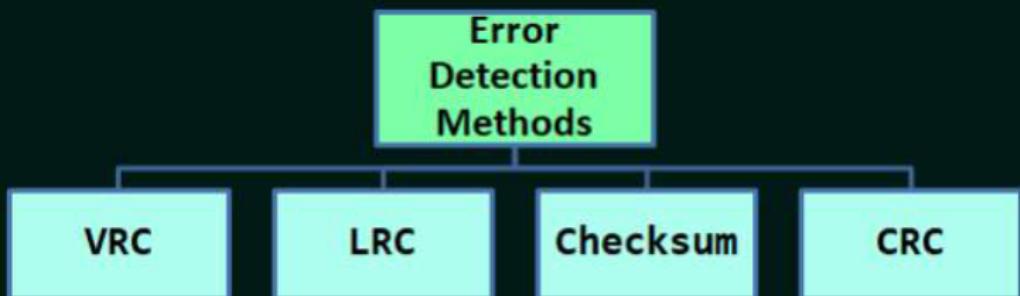
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the types of error detection..
- ★ Understand VRC and its performance.
- ★ Understand LRC and its performance.

Outcomes ★★★ Neso Academy

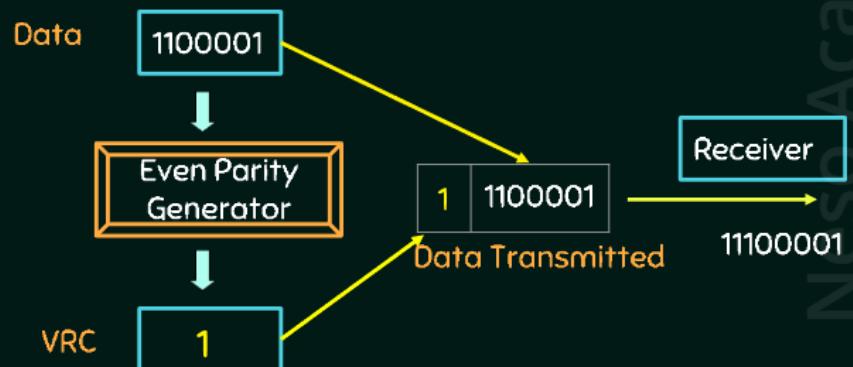
ERROR DETECTION



Error detection Neso Academy

VRC

- ★ Vertical Redundancy check.
- ★ It is also called as parity check.



VRC★★Neso Academy

PERFORMANCE OF VRC

- ★ It can detect single bit error.
- ★ It can detect burst error only if the number of errors is odd.

Sender: 11100001 → Transmission Error 10100001 → Receiver rejects this data.

Sender: 11100001 → Transmission Error 10100101 → Receiver accepts this data.

Performance of VRC★★Neso Academy

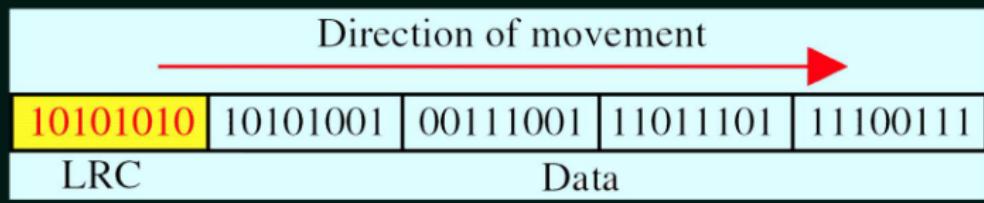
LRC

- ★ Longitudinal Redundancy Check.
- ★ A block of bits is organized in rows and columns.
- ★ a.k.a Two Dimensional parity.
- ★ The parity bit is calculated for each column and sent along with the data.
- ★ The block of parity acts as the redundant bits.

LRC★★★★★Neso Academy

LRC

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



LRCNeso Academy

PERFORMANCE OF VRC

- ★ LCR increases the likelihood of detecting burst errors.
- ★ If two bits in one data units are damaged and two bits in exactly the same positions in another data unit are also damaged, the LRC checker will not detect an error.

Performance of VRC ★★ Neso Academy

HOME WORK – ANSWERS

1. Append the parity bit after each block shown below using VRC.

1110110 1101111 1110010

Home work -Answers Neso Academy

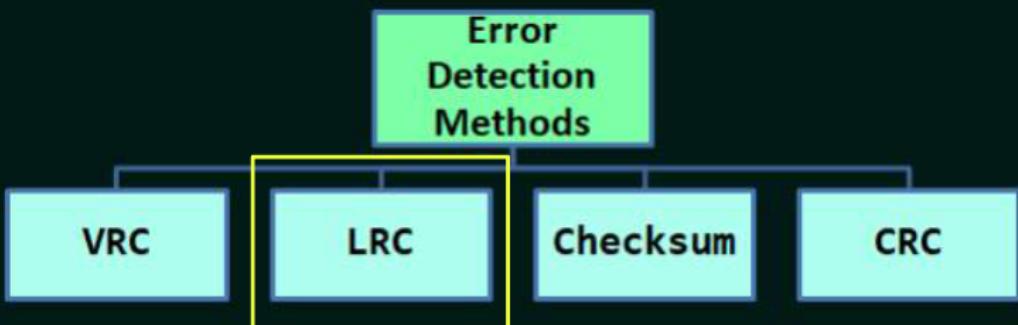
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the types of error detection.
- ★ Understand LRC and its performance.

Outcomes ★ Neso Academy

ERROR DETECTION



Error detection Neso Academy

LRC

- ★ Longitudinal Redundancy Check.
- ★ In LRC, a block of bits is organized in rows and columns.
- ★ a.k.a Two Dimensional parity.
- ★ The parity bit is calculated for each column and sent along with the data.
- ★ The block of parity acts as the redundant bits.

LRC ★★★★ Neso Academy

LRC – EXAMPLE

Find the LRC for the data blocks 11100111 11011101 00111001 10101001 and determine the data that is transmitted?

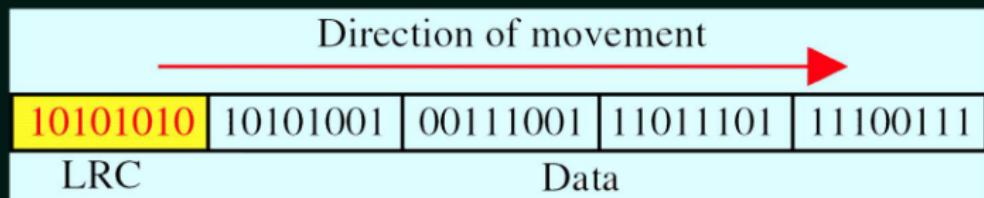
Odd no. of 1's	1
Even no. of 1's	0

1	1	1	0	0	1	1	1
1	1	0	1	1	1	0	1
0	0	1	1	1	0	0	1
1	0	1	0	1	0	0	1
LRC →							
1	0	1	0	1	0	1	0

LRC -ExampleNeso Academy

LRC – EXAMPLE

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



LRC -ExampleNeso Academy

PERFORMANCE OF LRC

- ★ LCR increases the likelihood of detecting burst errors.
- ★ If two bits in one data units are damaged and two bits in exactly the same positions in another data unit are also damaged, the LRC checker will not detect an error.

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

Performance of LRC★★Neso Academy

HOMEWORK

Find the LRC for the data blocks 01110111 10101001 01101001 10101010 and determine the data that is transmitted.

Homework★Neso Academy

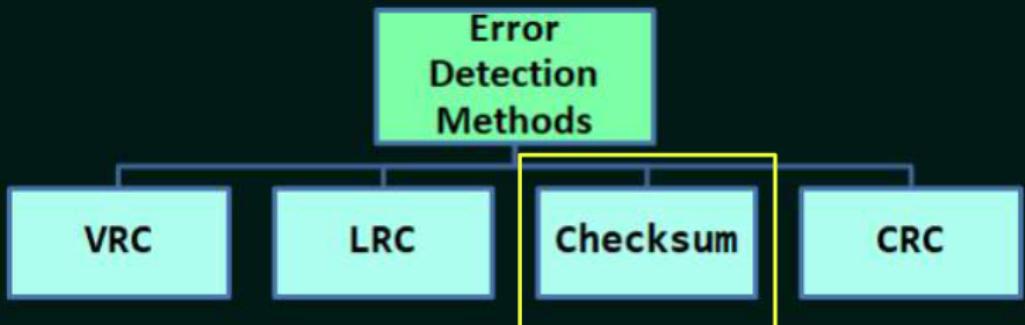
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand checksum and its performance.

Outcomes★Neso Academy

ERROR DETECTION



Neso Academy

Error detectionNeso Academy

CHECKSUM

$\text{Checksum} = \text{Check} + \text{sum.}$

Sender side – Checksum Creation.

Receiver side – Checksum Validation.

Neso Academy

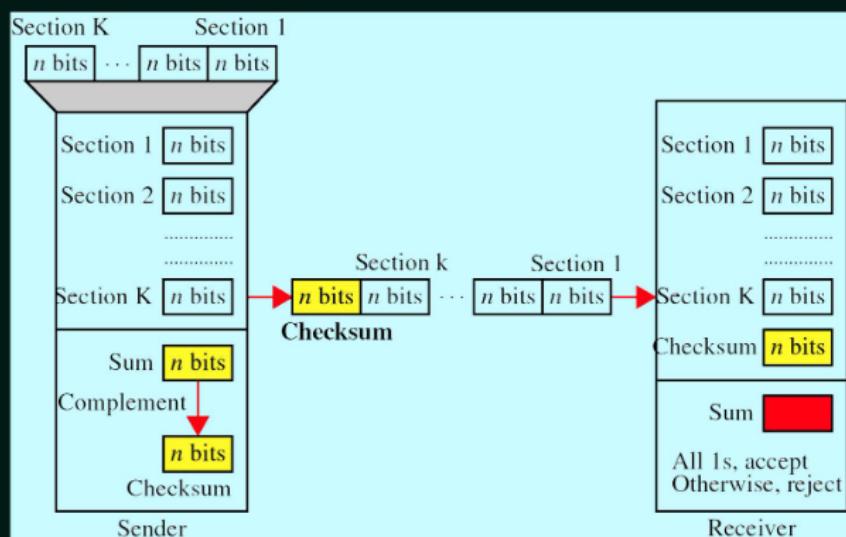
ChecksumNeso Academy

CHECKSUM – OPERATION AT SENDER SIDE

1. Break the original message in to 'k' number of blocks with 'n' bits in each block.
2. Sum all the 'k' data blocks.
3. Add the carry to the sum, if any.
4. Do 1's complement to the sum = Checksum.

Checksum -Operation at sender side Neso Academy

CHECKSUM



Checksum Neso Academy

CHECKSUM – EXAMPLE

Consider the data unit to be transmitted is:

1001100111000100010010010000100

10011001	11100010	00100100	10000100
----------	----------	----------	----------

Checksum -ExampleNeso Academy

CHECKSUM – EXAMPLE

	10011001	11100010	00100100	10000100				
Carry	1	1	1	1	1			
Sender	1	0	0	0	0	1	0	0
	0	0	1	0	0	1	0	0
	1	1	1	0	0	0	1	0
	1	0	0	1	1	0	0	1
	0	0	1	0	0	0	1	1
							1	0
	0	0	1	0	0	1	0	1
1's Complement	1	1	0	1	1	0	1	0

Checksum -ExampleNeso Academy

CHECKSUM – EXAMPLE

10011001	11100010	00100100	10000100
Carry	1	1	1
	1	0	0
	0	0	1
	1	1	1
	1	0	0
	0	0	1
	1	1	0
	1	0	0
	0	0	1
CHECKSUM	1	1	0
	0	0	1
	1	0	0
	0	1	0
	1	0	1

CHECKSUM – EXAMPLE

10011001	11100010	00100100	10000100
Carry	1	1	1
	1	0	0
	0	0	1
	1	1	1
	1	0	0
	0	0	1
	1	1	0
	1	0	1
	0	0	0
	0	1	0
	0	0	1
CHECKSUM	1	1	0

Checksum -ExampleNeso Academy

CHECKSUM – EXAMPLE

11011010	10011001	11100010	00100100	10000100				
Carry	1	1	1	1	1			
	1	0	0	0	0	1	0	0
	0	0	1	0	0	1	0	0
Sender	1	1	1	0	0	0	1	0
	1	0	0	1	1	0	0	1
	0	0	1	0	0	0	1	1
							1	0
CHECKSUM	1	1	0	1	1	0	1	0

Checksum -ExampleNeso Academy

CHECKSUM – EXAMPLE

11011010 10011001 11100010 00100100 10000100



Neso Academy

Checksum -ExampleNeso Academy

CHECKSUM – OPERATION AT RECEIVER SIDE

- ★ Collect all the data blocks including the checksum.
 - ★ Sum all the data blocks and checksum
 - ★ If the result is all 1's, ACCEPT; Else, REJECT.

Checksum -Operation at receiver side ★★★ Neso Academy

CHECKSUM – EXAMPLE

Checksum -Example1101101111111Neso Academy

PERFORMANCE OF CHECKSUM

- ★ The checksum detects all errors involving an odd number of bits.
- ★ It detects most errors involving an even number of bits.
- ★ If one or more bits of a segment are damaged and the corresponding bit or bits of opposite value in a second segment are also damaged, the sums of those columns will not change and the receiver will not detect the error(s).

Performance of checksum ★★★ Neso Academy

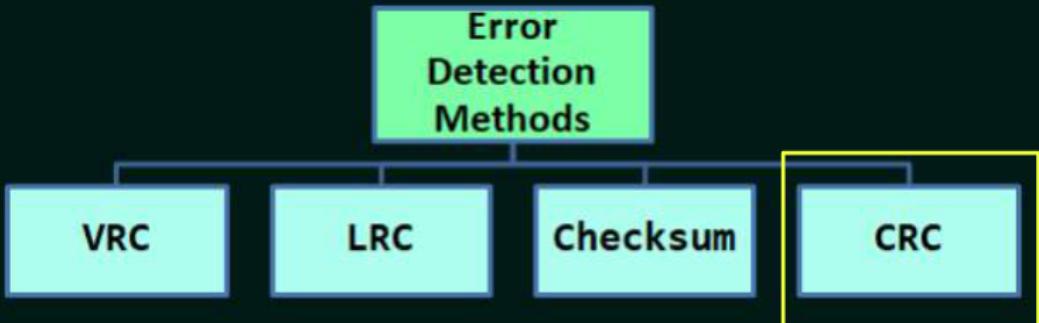
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the types of error detection.
- ★ Understand how to generate CRC.

★★ Outcomes Neso Academy

ERROR DETECTION



Error detectionNeso Academy

CRC GENERATION AT SENDER SIDE

1. Find the length of the divisor 'L'.
2. Append 'L-1' bits to the original message.
3. Perform binary division operation.
4. Remainder of the division = CRC.

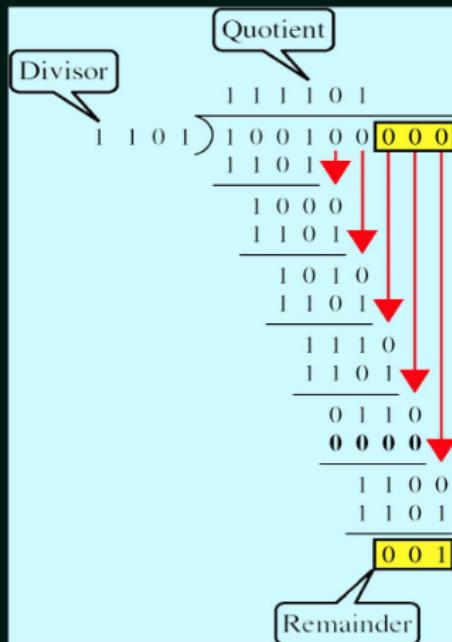
Note:

The CRC must be of L-1 bits.

A	B	A \oplus B
0	0	0
0	1	1
1	0	1
1	1	0

CRC Generation at sender sideNeso Academy

CRC



CRC: 001

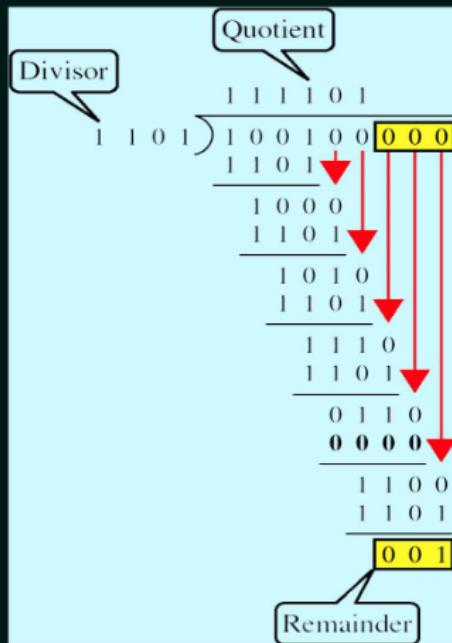
Data Transmitted: 100100001



Neso Academy

CRCNeso Academy

CRC



CRC: 001

Data Transmitted: 100100001



Neso Academy

CRCNeso Academy

HOMEWORK

Find the CRC for 1110010101 with the divisor x^3+x^2+1 ?

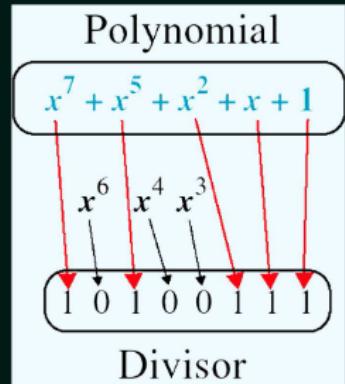
Hint:

HomeworkNeso Academy

HOMEWORK

Find the CRC for 1110010101 with the divisor x^3+x^2+1 ?

Hint:



HomeworkNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand how to detect error using CRC technique.

★OutcomesNeso Academy

CRC

Find the CRC for the data block 100100 with the divisor 1101?

CRCNeso Academy

CRC

$$\begin{array}{r} 1 \ 1 \ 1 \ 1 \ 0 \ 1 \\ 1 \ 1 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 1 \\ \hline 1 \ 1 \ 0 \ 1 \\ 1 \ 0 \ 0 \ 0 \\ \hline 1 \ 1 \ 0 \ 1 \\ 1 \ 0 \ 1 \ 0 \\ \hline 1 \ 1 \ 0 \ 1 \\ 1 \ 1 \ 1 \ 0 \\ \hline 1 \ 1 \ 0 \ 1 \\ 0 \ 1 \ 1 \ 0 \ 1 \\ \hline 1 \ 1 \ 0 \ 1 \\ 0 \ 0 \ 0 \end{array}$$



Data Accepted

CRCNeso Academy

HOMEWORK

Suppose we want to transmit the message 11001001 and protect it from errors using the CRC polynomial x^3+1 . Use polynomial long division to determine the message that should be transmitted. Corrupt the left-most third bit of the transmitted message and show that the error is detected by the receiver using CRC technique.

HomeworkNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Generate CRC code.
- ★ Determine the message to be transmitted.

★★OutcomesNeso Academy

QUESTION

The message 11001001 is to be transmitted using CRC polynomial x^3+1 to protect it from errors. The message that should be transmitted is:

[GATE CS 2007]

- A. 11001001000
- B. 11001001011
- C. 11001010
- D. 110010010011

QuestionNeso Academy

CRC GENERATION AT SENDER SIDE

1. Find the length of the divisor 'L'.
2. Append 'L-1' bits to the original message.
3. Perform binary division operation.
4. Remainder of the division = CRC.
5. Message to be transmitted = Message + CRC

Note:

The CRC must be of L-1 bits.

A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

CRC Generation at sender sideNeso Academy

CRC GENERATION AT SENDER SIDE

1. The length of the divisor is 4. ($x^3+1 = 1x^3+0x^2+0x^1+1$) = 1001
2. Append '4-1' bits to the original message. (3 bits are appended)
3. Perform binary division operation.
4. Remainder of the division = CRC.
5. Message to be transmitted = Message + CRC

Note:

The CRC must be of L-1 i.e 4-1=3 bits.

A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

CRC Generation at sender sideNeso Academy

CRC GENERATION



CRC GenerationNeso Academy

MESSAGE TO BE TRANSMITTED

Message to be transmitted = Original Message + CRC

Message to be transmitted = $11001001\text{ }011$

Message to be transmittedNeso Academy

QUESTION

The message 11001001 is to be transmitted using CRC polynomial x^3+1 to protect it from errors. The message that should be transmitted is:

[GATE CS 2007]

- A. 11001001000
- B. 11001001011
- C. 11001010
- D. 110010010011

QuestionNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the importance of network performance.
- ★ Understand bandwidth.
- ★ Understand throughput.
- ★ Know latency (delay) and its components.

Outcomes★★★★Neso Academy

NETWORK PERFORMANCE

One important issue in networking is the performance of the network – how good is it?

Network performance is measured in following fundamental ways

- ★ Bandwidth
- ★ Throughput
- ★ Latency (Delay)

Network Performance ★★★ Neso Academy

BANDWIDTH AND THROUGHPUT – ANALOGY



Bandwidth and Throughput -Analogy Neso Academy

DERIVATIONS FROM ANALOGY

The bandwidth is 1000 cars per minute.

The throughput is 100 cars per minute.

Derivations from analogyNeso Academy

BANDWIDTH

Informal: Maximum amount of data that can be transmitted per second.

Formal: The bandwidth of a network is given by the number of bits that can be transmitted over the network in a certain period of time.

Bandwidth in bps

Bandwidth = Capability.

Example: Gigabit Ethernet can provide a bandwidth of 1 Gbps.

Bandwidth in Hertz

A range of frequencies used to transmit signals which is measured in hertz.

BandwidthNeso Academy

THROUGHPUT

Informal: Actual amount of data that passes through the medium.

Formal: The throughput is a measure of how fast we can actually send data through a network.

Although bandwidth in bits per second and throughput seem the same, they are different.

A link may have a bandwidth of 'B' bps, but we can only send 'T' bps through this link with $T < B$ always.

ThroughputNeso Academy

THROUGHPUT

We may have a link with a bandwidth of 1 Mbps, but the devices connected to the end of the link may handle only 200 kbps. This means that we cannot send more than 200 kbps through this link.

ThroughputNeso Academy

LATENCY (DELAY)

The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

Latency (Delay)Neso Academy

COMPONENTS OF LATENCY (DELAY)

Latency is made of four components:

1. Transmission delay.
2. Propagation delay.
3. Queueing delay.
4. Processing delay.

Latency = Transmission delay + Propagation delay + Queuing delay + Processing delay.

Components of latency (delay)Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the various components of latency.

Outcomes ★ Neso Academy

LATENCY (DELAY)

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Latency (Delay) Neso Academy

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Components of latency (delay) Neso Academy

TRANSMISSION DELAY

Time it takes to place the complete data packet on the transmission medium.



Transmission delay Neso Academy

TRANSMISSION DELAY

Time it takes to place the complete data packet on the transmission medium.

$$\text{Transmission Time} = \frac{\text{Message size}}{\text{Bandwidth}}$$

Transmission delayNeso Academy

PROPAGATION DELAY

Time it takes for a bit to go from device A to device B.

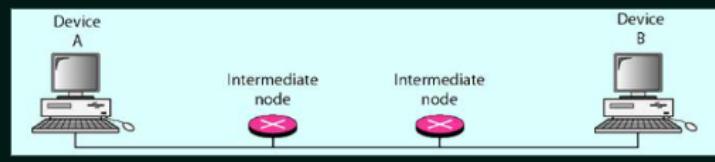
The propagation time is calculated by dividing the distance by the propagation speed.

$$\text{Propagation Time} = \frac{\text{Distance}}{\text{Propagation speed}}$$

Propagation delayNeso Academy

QUEUING DELAY

- ★ The third component in latency is the queuing time, the time needed for each intermediate or end device to hold the message before it can be processed.
- ★ The queuing time is not a fixed factor; it changes with the load imposed on the network.
- ★ When there is heavy traffic on the network, the queuing time increases.



Queuing delay★★★Neso Academy

PROCESSING DELAY

- ★ How much time the node takes to process the message?



Processing Delay★Neso Academy

OUTCOMES

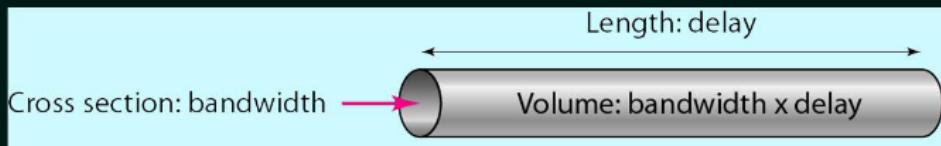
Upon the completion of this session, the learner will be able to

- ★ Understand bandwidth-delay product.

Outcomes ★ Neso Academy

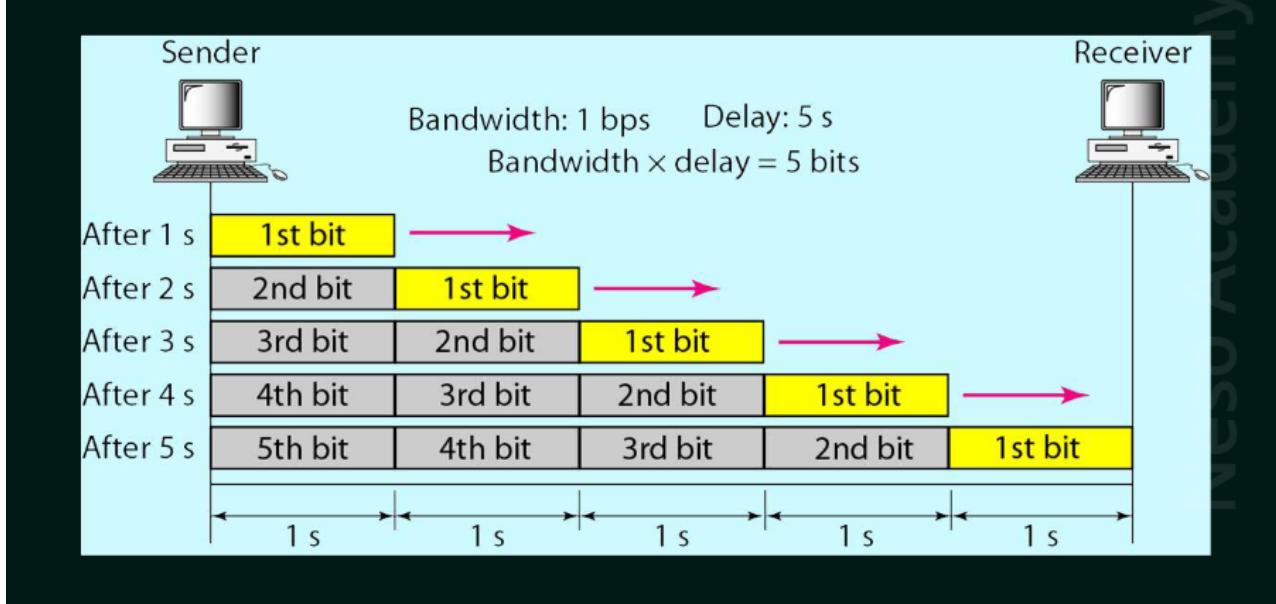
BANDWIDTH-DELAY PRODUCT

The bandwidth-delay product defines the number of bits that can fill the link.



Bandwidth-Delay product Neso Academy

BANDWIDTH-DELAY PRODUCT – EXAMPLE



Bandwidth-Delay product -ExampleNeso Academy

BANDWIDTH-DELAY PRODUCT – SOLVED EXAMPLE

Consider that the link capacity of a channel is 512 Kbps and round-trip delay time is 1000ms.

Solution:

$$\begin{aligned}\text{The bandwidth delay product} &= 512 \text{ Kbps} \times 1000 \text{ ms} \\ &= 512 \times 1000 \text{ bits/sec} \times 1000 \times 10^{-3} \text{ sec} \\ &= 512,000 \text{ bits} \\ &= 64,000 \text{ bytes} \\ &= 62.5 \text{ KB}\end{aligned}$$

Bandwidth-Delay product -Solved ExampleNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Calculate propagation time.

Outcomes ★ Neso Academy

QUESTION

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4×10^8 m/s in cable.

Given

Distance = 12000 Km

Propagation speed = 2.4×10^8 m/s

To Find

Propagation Time

Question Neso Academy

SOLUTION

$$\text{Propagation Time} = \frac{\text{Distance}}{\text{Propagation speed}}$$

$$\text{Propagation Time} = \frac{12000 \times 1000}{2.4 \times 10^8} \text{ sec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \text{ sec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \times \frac{10^{-3}}{10^{-3}} \text{ sec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \times \frac{1}{10^{-3}} \text{ millisec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \times \frac{10^3}{1} \text{ millisec}$$

$$\text{Propagation Time} = \frac{50 \times 100 \times 1000}{10^8} \times \frac{10^3}{1} \text{ millisec}$$

Propagation Time = 50 millisec OR 50 ms

SolutionNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Recall propagation time.
- ★ Understand RTT.
- ★ Calculate RTT.

Outcomes★★★Neso Academy

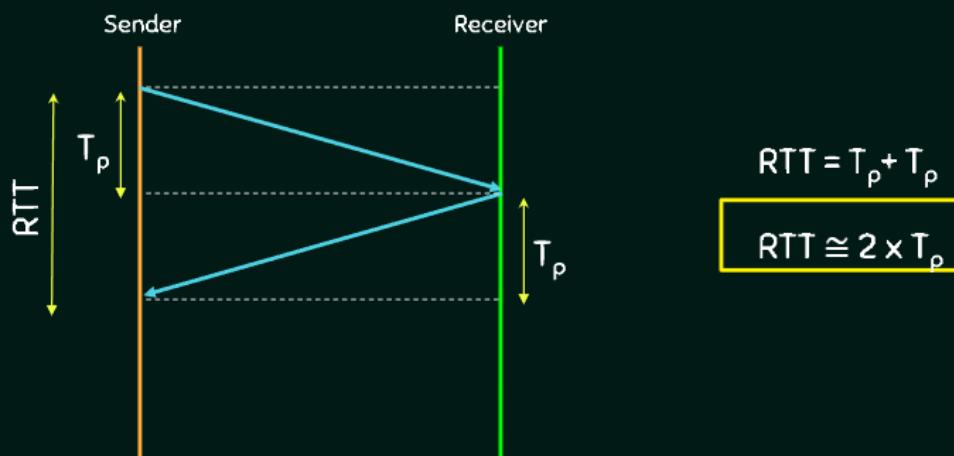
ROUND TRIP TIME (RTT)

- ★ a.k.a Round Trip Delay Time (RTD).
- ★ It is the length of time it takes for a signal to be sent plus the length of time it takes for an acknowledgement of that signal to be received.
- ★ This time therefore consists of the propagation times between the two point of signal.
- ★ If T_p is the Propagation time, then

$$RTT = 2 \times T_p$$

Round Trip Time (RTT) ★★★★ Neso Academy

ROUND TRIP TIME (RTT)



Round Trip Time (RTT) ≈ Neso Academy

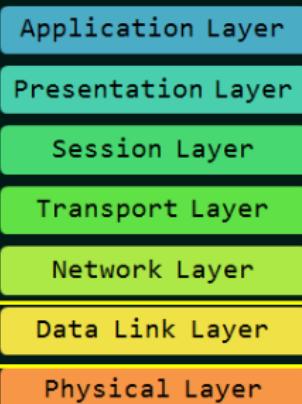
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Recall link layer services.
- ★ Understand flow control.
- ★ Know the flow control protocols.

Outcomes ★★★ Neso Academy

LINK LAYER SERVICES



It is responsible for moving data(frames) from one node to another node.

SERVICES PROVIDED BY DATA LINK LAYER

- ★ Framing.
- ★ Error Control.
- ★ **Flow Control.**
- ★ Physical Addressing.
- ★ Access Control.



Link layer services ★★★★★ Neso Academy

FLOW CONTROL

- ★ Speed matching mechanism.
- ★ Flow control coordinates the amount of data that can be sent before receiving an acknowledgment.
- ★ Flow control is a set of procedures that tells the sender how much data it can transmit before it must wait for an acknowledgement from the receiver.
- ★ Receiver has a limited speed at which it can process incoming data and a limited amount of memory in which to store incoming data.
- ★ Receiver must inform the sender before the limits are reached and request that the transmitter to send fewer frames or stop temporarily.

Flow control ★★★★★ Neso Academy

FLOW CONTROL – PROTOCOLS



Flow control -Protocols ★★★★★ Neso Academy

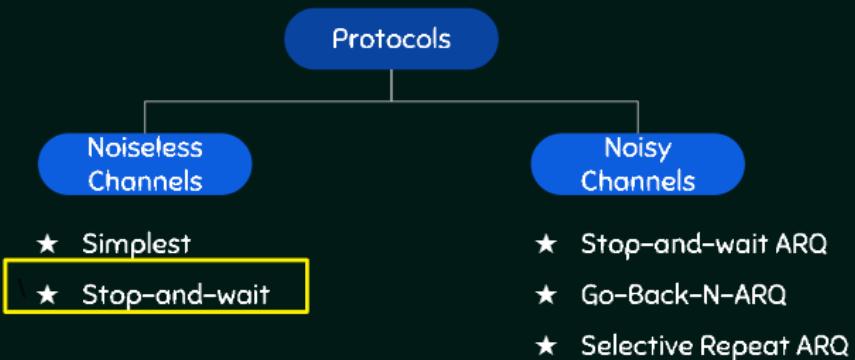
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the working of simple stop-and-wait protocol.
- ★ Understand the problems with simple stop-and-wait protocol.

Outcomes ★★ Neso Academy

FLOW CONTROL



Flow control ★★★★★ Neso Academy

STOP-AND-WAIT PROTOCOL

- ★ Stop - and - Wait protocol is data link layer protocol for transmission of frames over noiseless channels.
- ★ It provides unidirectional data transmission with flow control facilities but without error control facilities.
- ★ The idea of stop-and-wait protocol is straightforward.
- ★ After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.

Stop-and-Wait Protocol ★★★ Neso Academy

PRIMITIVES OF STOP-AND-WAIT PROTOCOL

Sender side

Rule 1 : Send one data packet at a time.

Rule 2 : Send the next packet only after receiving ACK for the previous.

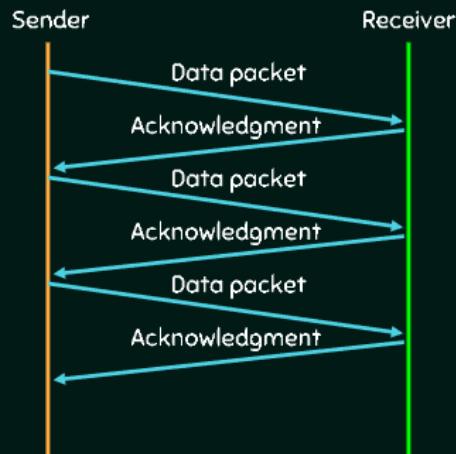
Receiver side

Rule 1 : Receive and consume data packet.

Rule 2 : After consuming packet, ACK need to be sent (Flow Control).

Primitives of Stop-and-Wait Protocol Neso Academy

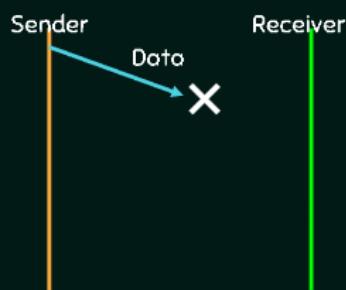
STOP-AND-WAIT PROTOCOL



Stop-and-Wait Protocol Neso Academy

PROBLEMS OF STOP-AND-WAIT PROTOCOL

1. Problems due to lost data.
 - ★ Sender waits for ack for an infinite amount of time.
 - ★ Receiver waits for data an infinite amount of time.

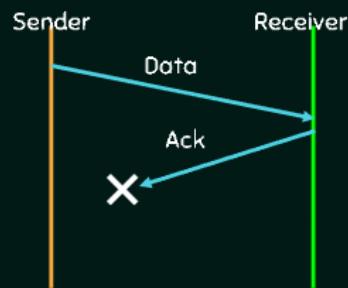


Problems of Stop-and-Wait Protocol ❌ ★★ Neso Academy

PROBLEMS OF STOP-AND-WAIT PROTOCOL

2. Problems due to lost ACK.

- ★ Sender waits for an infinite amount of time for ack.

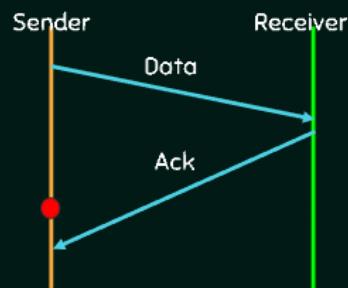


Problems of Stop-and-Wait Protocol  ★ Neso Academy

PROBLEMS OF STOP-AND-WAIT PROTOCOL

3. Problems due to delayed ACK/data.

- ★ After timeout on sender side, a delayed ack might be wrongly considered as ack of some other data packet.



Problems of Stop-and-Wait Protocol ★ Neso Academy

PROBLEMS OF STOP-AND-WAIT PROTOCOL

1. Problems due to lost data.

Sender waits for ack for an infinite amount of time.

Receiver waits for data an infinite amount of time.

1. Problems due to lost ACK.

Sender waits for an infinite amount of time for ack.

1. Problems due to delayed ACK/data.

After timeout on sender side, a delayed ack might be wrongly considered as ack of some other data packet.

Problems of Stop-and-Wait Protocol Neso Academy

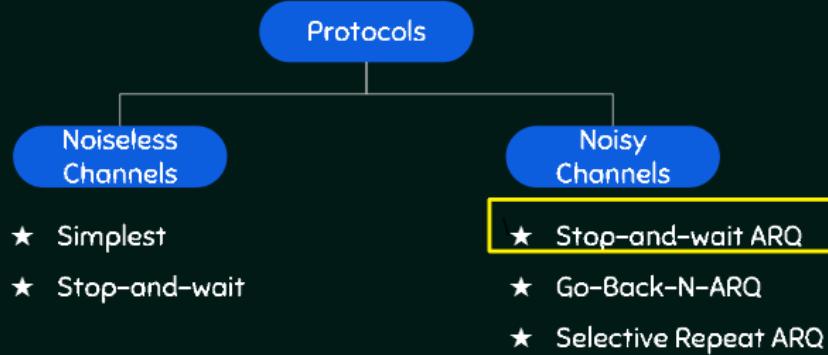
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the working of stop-and-wait ARQ protocol.

Outcomes ★ Neso Academy

FLOW CONTROL



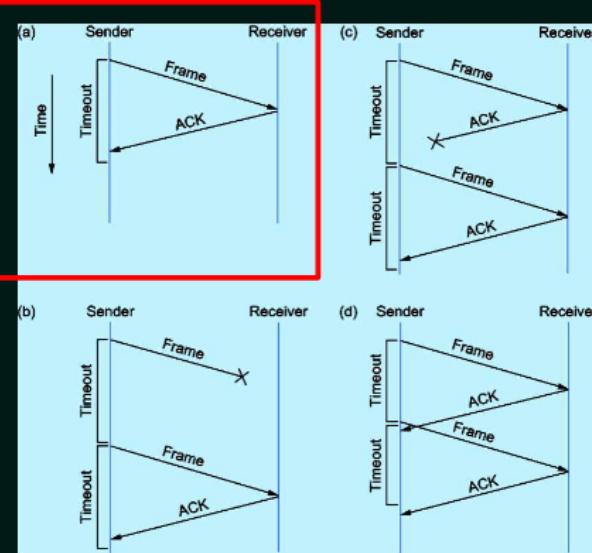
Flow control ★★★★\Neso Academy

STOP-AND-WAIT ARQ PROTOCOL

- ★ Idea of stop-and-wait protocol is straightforward.
- ★ After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.
- ★ If the acknowledgement does not arrive after a certain period of time, the sender times out and retransmits the original frame.
- ★ Stop-and-Wait ARQ = Stop-and-Wait + Timeout Timer + Sequence number

Stop-and-Wait ARQ Protocol ★★★★\Neso Academy

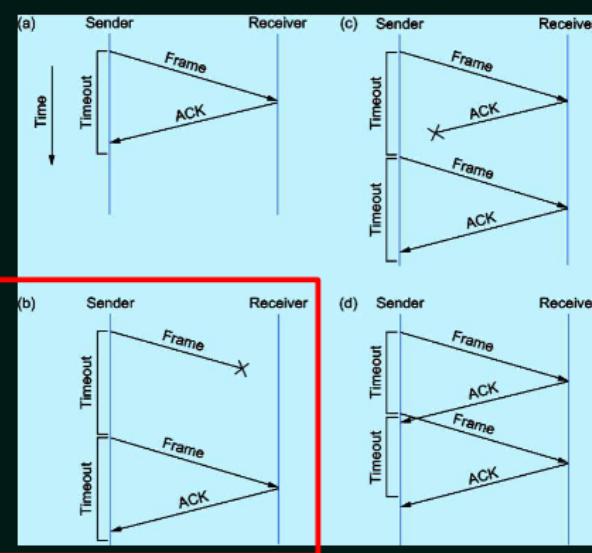
STOP-AND-WAIT ARQ PROTOCOL



(a) The ACK is received before the timer expires;

Stop-and-Wait ARQ Protocol Neso Academy

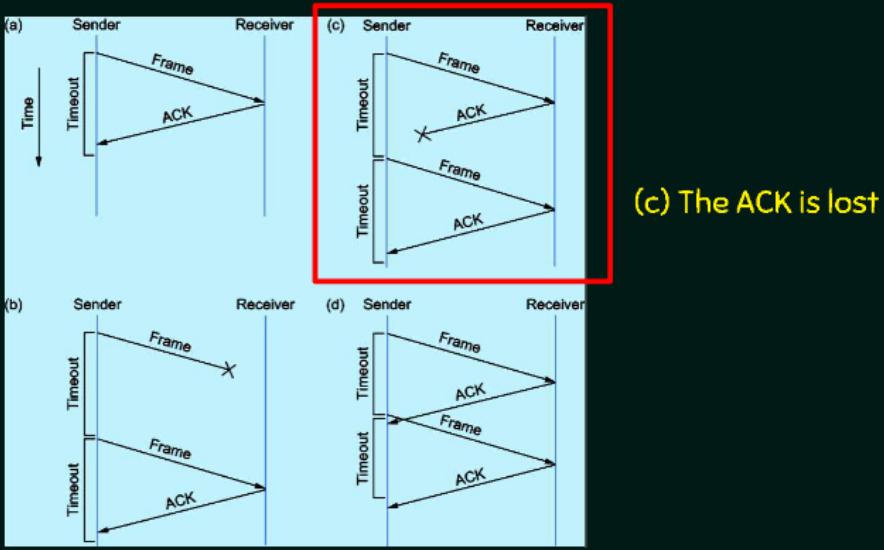
STOP-AND-WAIT ARQ PROTOCOL



(b) The original frame is lost

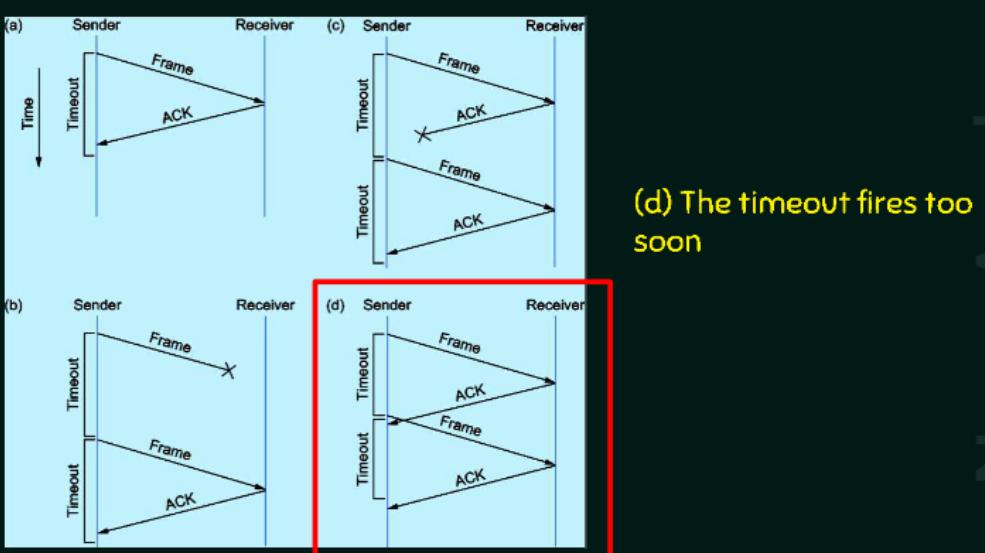
Stop-and-Wait ARQ Protocol Neso Academy

STOP-AND-WAIT ARQ PROTOCOL



Stop-and-Wait ARQ Protocol Neso Academy

STOP-AND-WAIT ARQ PROTOCOL



Stop-and-Wait ARQ Protocol Neso Academy

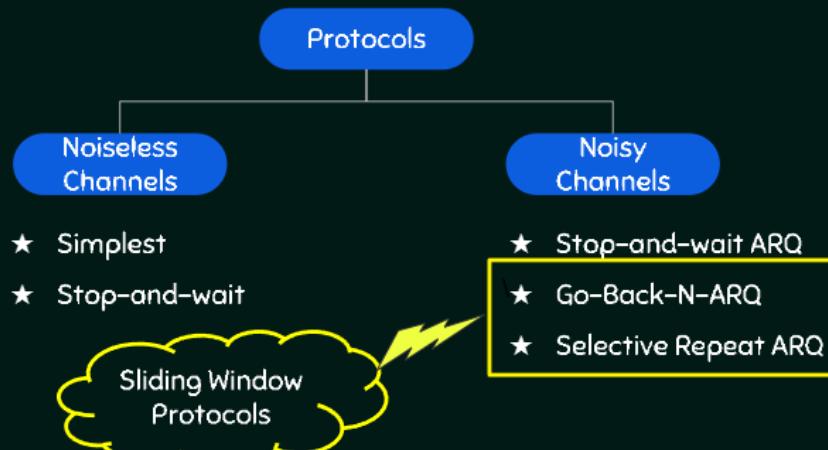
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the drawbacks of stop-and-wait ARQ protocol.
- ★ Know the need for sliding window protocol.
- ★ Understand the working of sliding window protocol.

Outcomes ★★★ Neso Academy

FLOW CONTROL



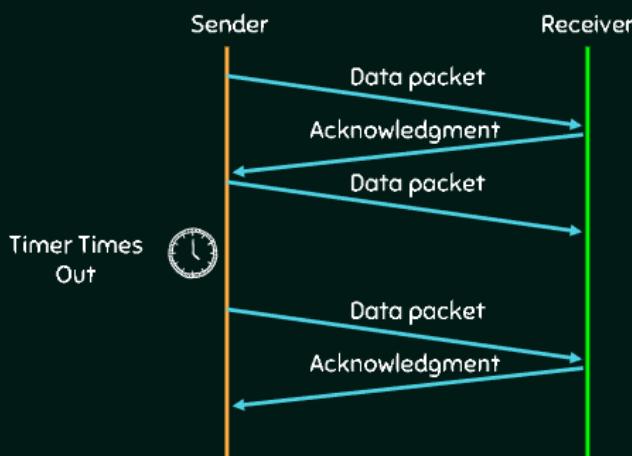
Flow control ★★★★★ Neso Academy

STOP-AND-WAIT ARQ PROTOCOL

- ★ Idea of stop-and-wait ARQ protocol is simple.
- ★ After transmitting one frame, the sender waits for an acknowledgement before transmitting the next frame.
- ★ If the acknowledgement does not arrive after a certain period of time, the sender times out and retransmits the original frame.

Stop-and-Wait ARQ Protocol ★★★ Neso Academy

STOP-AND-WAIT ARQ PROTOCOL



Stop-and-Wait ARQ Protocol Neso Academy

STOP-AND-WAIT ARQ – DRAWBACKS

- ★ One frame at a time.
- ★ Poor utilization of bandwidth.
- ★ Poor Performance

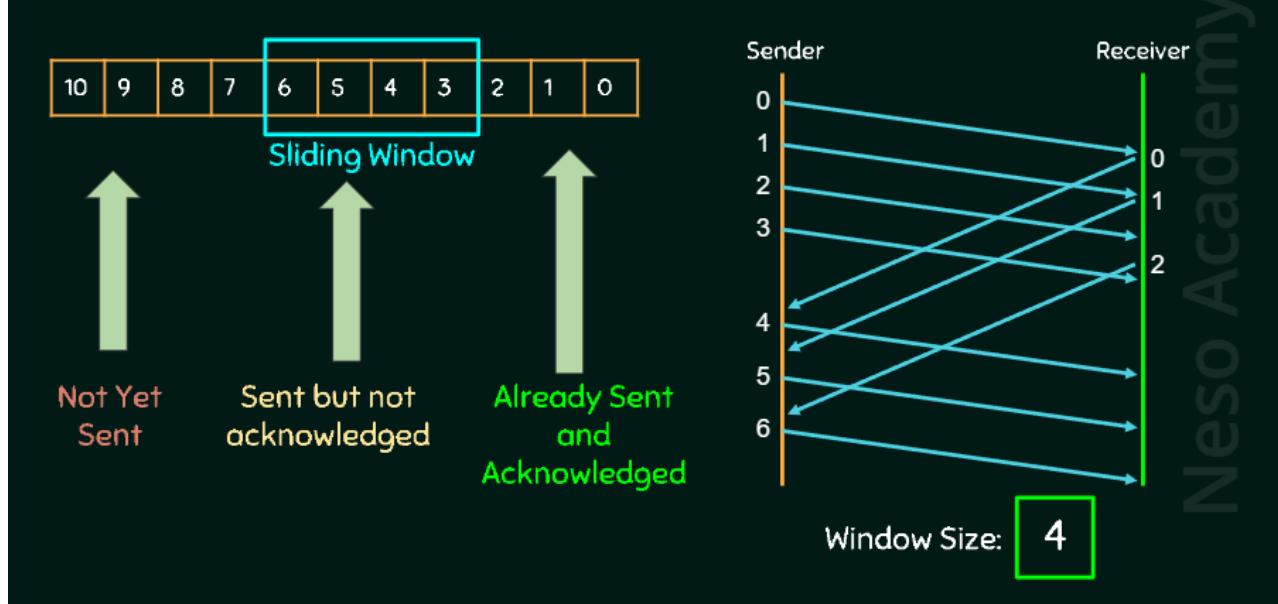
Stop-and-Wait ARQ -Drawbacks★★★Neso Academy

SLIDING WINDOW PROTOCOL

- ★ Send multiple frames at a time.
- ★ Number of frames to be sent is based on Window size.
- ★ Each frame is numbered → Sequence number.

Sliding window protocol★★★Neso Academy

WORKING OF SLIDING WINDOW PROTOCOL



Working of sliding window protocol0132041526Neso Academy

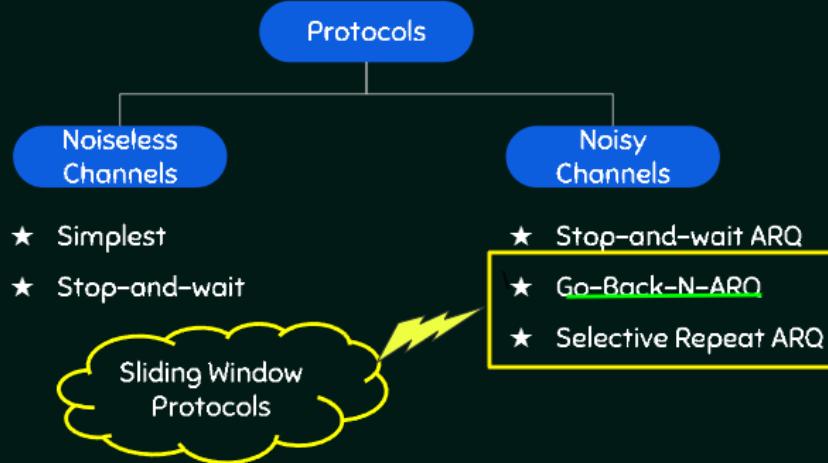
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the working of Go-back-N ARQ.

Outcomes★Neso Academy

SLIDING WINDOW PROTOCOLS



Sliding window protocols ★★★★★ | Neso Academy

Go-BACK-N ARQ

'N' is the sender window size.

Go-Back-N ARQ Neso Academy

Go-BACK-N ARQ

- ★ Go – Back – N ARQ uses the concept of protocol pipelining i.e. the sender can send multiple frames before receiving the acknowledgment for the first frame.
- ★ There are finite number of frames and the frames are numbered in a sequential manner.
- ★ The number of frames that can be sent depends on the window size of the sender.
- ★ If the acknowledgment of a frame is not received within an agreed upon time period, all frames in the current window are transmitted.
- ★ The size of the sending window determines the sequence number of the outbound frames.

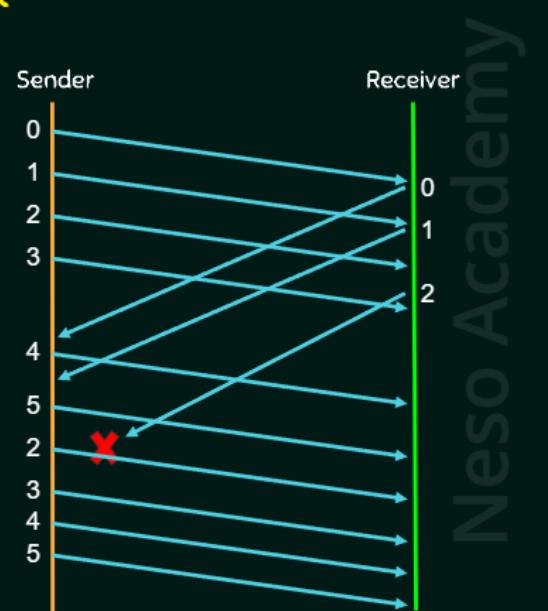
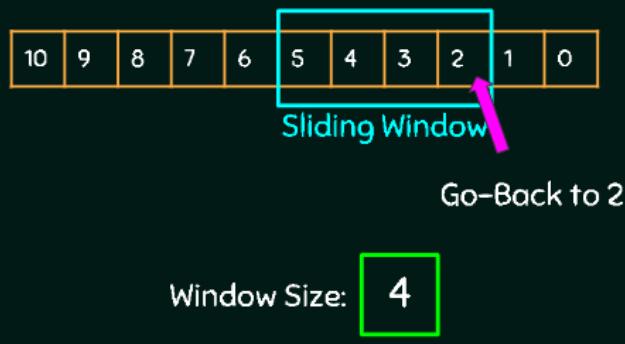
Go-Back-N ARQ★★★★★Neso Academy

Go-BACK-N ARQ

- ★ N – Sender's Window Size.
- ★ For example, if the sending window size is 4 (2^2), then the sequence numbers will be 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, and so on.
- ★ The number of bits in the sequence number is 2 to generate the binary sequence 00, 01, 10, 11.

Go-Back-N ARQ★★★Neso Academy

WORKING OF Go-BACK-N ARQ



Working of Go-Back-N ARQ0132041523245Neso Academy

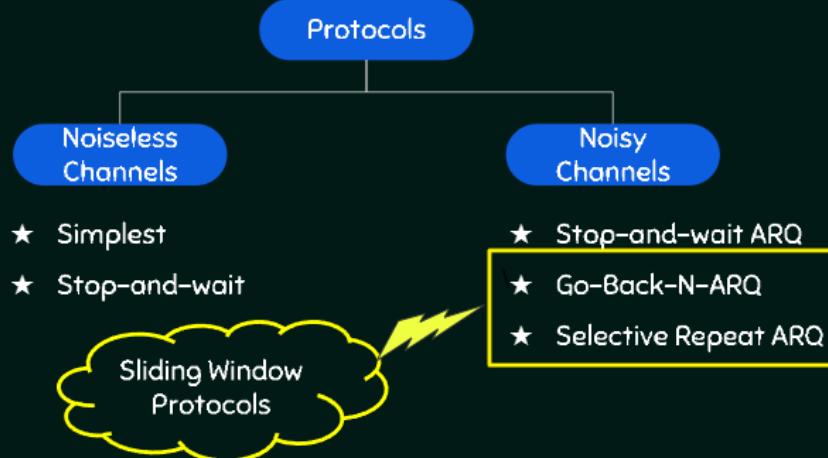
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Calculate the sender and receiver's window size for 100% efficiency. (GATE)
- ★ Know the importance of sequence numbers.
- ★ Find the minimum number of bits required to represent sequence numbers. (GATE)

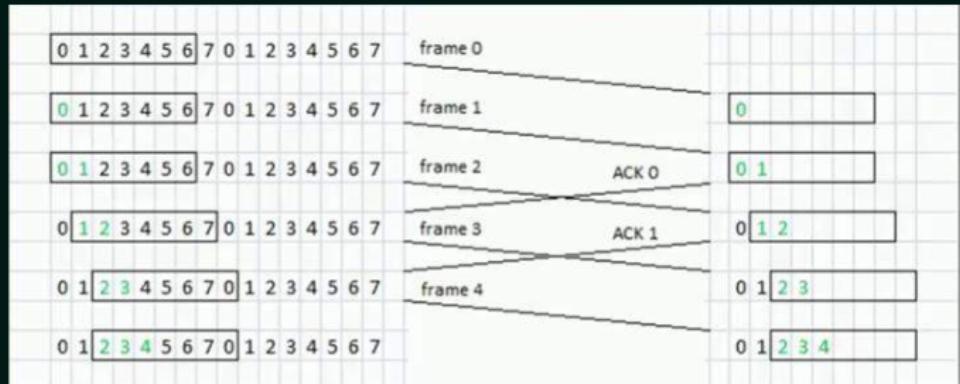
Outcomes★★★Neso Academy

SLIDING WINDOW PROTOCOLS



Sliding window protocols ★★★★★ | Neso Academy

Sliding Window Protocol



Sliding Window Protocol | Neso Academy

Window Size for 100% Efficiency

$$\text{Window Size } (W_s) = 1 + \frac{2T_p}{T_t}$$

Where

T_p - Propagation Time

T_t - Transmission Time

Window Size for 100% Efficiency Where
 T_p -Propagation Time T_t -Transmission Time Neso
Academy

Minimum number of bits in Sequence Number

$$\text{Min. No. of bits req} = \text{Ceil} \left(\log_2 \left(1 + \frac{2T_p}{T_t} \right) \right)$$

Where

T_p - Propagation Time

T_t - Transmission Time

Minimum number of bits in Sequence Number Where
 T_p -Propagation Time T_t -Transmission Time Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the working of Go-back-N ARQ by solving a problem asked in GATE CS 2006.

Outcomes★Neso Academy

QUESTION

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. All packets are ready and immediately available for transmission. If every 5th packet that A transmits gets lost (but no ACKs from B ever get lost), then what is the number of packets that A will transmit for sending the message to B? [GATE CS 2006]

- (A) 12
- (B) 14
- (C) 16
- (D) 18

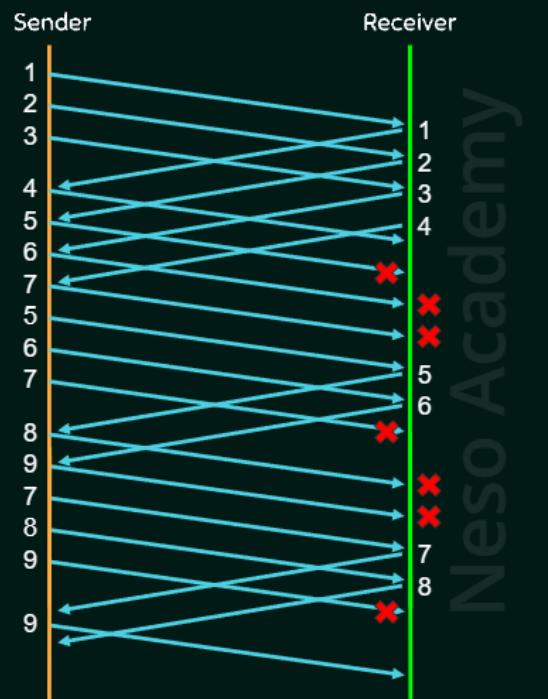
QuestionNeso Academy

SOLUTION



Window Size: 3

No. of packets transmitted by A (sender) 16



123142536475765869789789SolutionNeso Academy

QUESTION

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. All packets are ready and immediately available for transmission. If every 5th packet that A transmits gets lost (but no ACKs from B ever get lost), then what is the number of packets that A will transmit for sending the message to B?

- (A) 12
- (B) 14
- (C) 16 ✓
- (D) 18

No. of packets transmitted by A (sender) 16

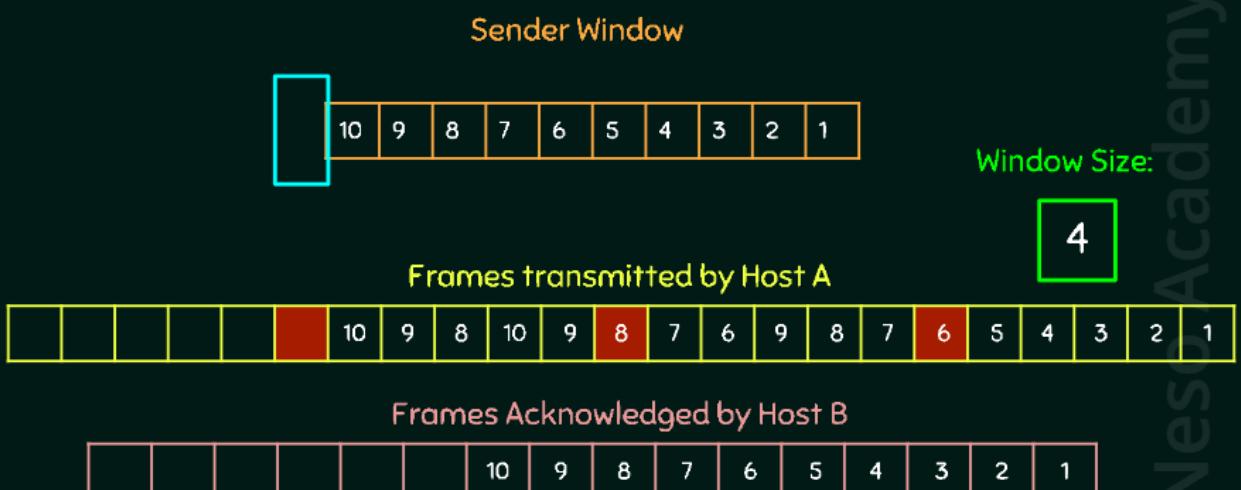
Question ✓ Neso Academy

QUESTION

Host A wants to send 10 frames to Host B. The hosts agreed to go with Go-Back-4. How many number of frames are transmitted by Host A if every 6th frame that is transmitted by host A is either corrupted or lost?

QuestionNeso Academy

SOLUTION



SolutionNeso Academy

QUESTION

Host A wants to send 10 frames to Host B. The hosts agreed to go with Go-Back-4. How many number of frames are transmitted by Host A if every 6th frame that is transmitted by host A is either corrupted or lost?

ANSWER

Number of frames transmitted by Host A: **17**

QuestionAnswer Neso Academy

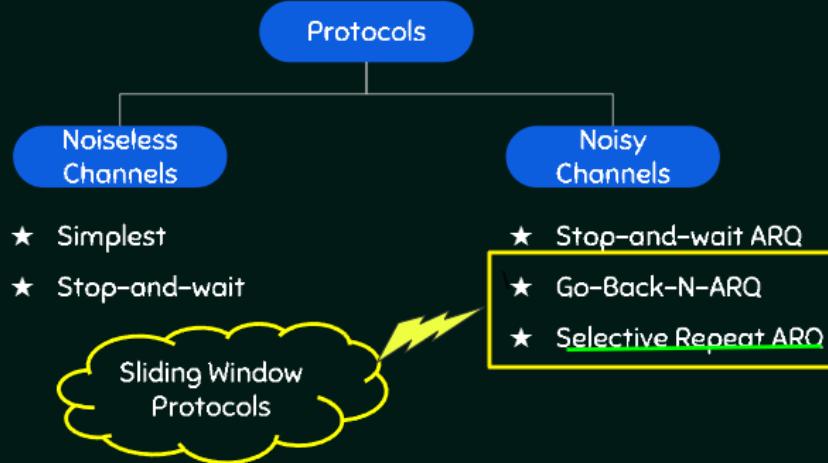
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the working of Selective Repeat ARQ.

Outcomes★Neso Academy

SLIDING WINDOW PROTOCOLS



Sliding window protocols ★★★★★ | Neso Academy

SELECTIVE REPEAT ARQ

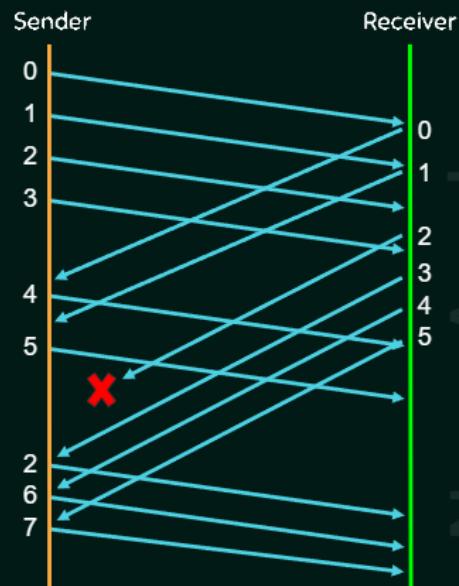
- ★ In Selective Repeat ARQ, only the erroneous or lost frames are retransmitted, while correct frames are received and buffered.
- ★ The receiver while keeping track of sequence numbers, buffers the frames in memory and sends NACK for only frame which is missing or damaged.
- ★ The sender will send/retransmit packet for which NACK is received.

Selective Repeat ARQ ★★★ Neso Academy

WORKING OF SELECTIVE REPEAT



Window Size: 4

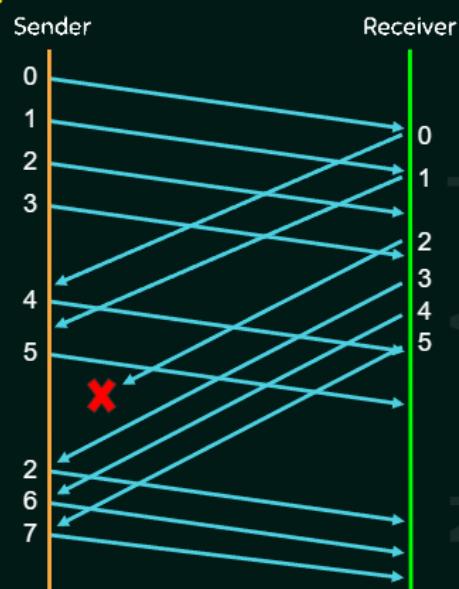


Working of Selective Repeat013204152326475Neso Academy

WORKING OF SELECTIVE REPEAT

In SR Protocol, only the required frame is retransmitted and not the entire window.

Window Size: 4



Working of Selective Repeat013204152326475Neso Academy

SOLUTION

In SR protocol, suppose frames through 0 to 4 have been transmitted. Now, imagine that 0 times out, 5 (a new frame) is transmitted, 1 times out, 2 times out and 6 (another new frame) is transmitted. At this point, what will be the outstanding packets in sender's window?

- a. 341526
- b. 3405126✓
- c. 0123456
- d. 654321
- e. None of the above

Sender's Window

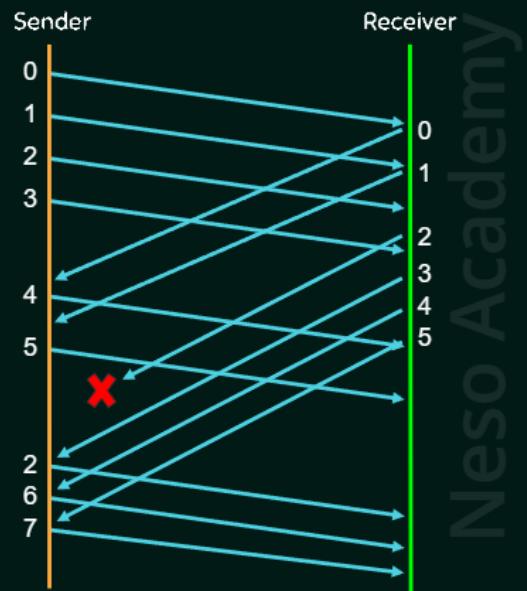


Solution✓Neso Academy

WORKING OF SELECTIVE REPEAT

In SR Protocol, only the required frame is retransmitted and not the entire window.

Window Size: 4



Working of Selective Repeat013204152326475Neso Academy

QUESTION

Host A wants to send 10 frames to Host B. The hosts agreed to go with SR ARQ. How many number of frames are transmitted by Host A if every 6th frame that is transmitted by host A is either corrupted or lost? Also compare the number of transmissions of SR ARQ with Go-Back-4 ARQ.

QuestionNeso Academy

SOLUTION

Number of transmission with Go-Back-4 ARQ: [17](#)

Refer previous lecture titled: [Go-Back-N ARQ \(Solved Problem 2\)](#)

SolutionNeso Academy

SOLUTION

10	9	8	7	6	5	4	3	2	1
----	---	---	---	---	---	---	---	---	---

Frames transmitted by Host A



Number of frames transmitted by Host A: **11**

SolutionNeso Academy

QUESTION

Host A wants to send 10 frames to Host B. The hosts agreed to go with SR ARQ. How many number of frames are transmitted by Host A if every 6th frame that is transmitted by host A is either corrupted or lost? Also compare the number of transmissions of SR ARQ with Go-Back-4 ARQ.

ANSWER

Go-Back-N: Number of frames transmitted by Host A: **17**

Selective Repeat: Number of frames transmitted by Host A: **11**

QuestionAnswer Neso Academy

QUESTION

Station A uses 32 byte packets to transmit message to Station B using a sliding window protocol. The round trip delay between A and B is 80 milliseconds and the bottleneck bandwidth on the path between A and B is 128 kbps. What is the optimal window size that A should use?

[GATE CS 2006]

- (A) 20
- (B) 40
- (C) 160
- (D) 320

QuestionNeso Academy

SOLUTION

Refer Previous Lecture titled [Bandwidth – Delay Product](#)

Refer Previous Lecture titled [Sliding Window Protocol](#)

SolutionNeso Academy

SOLUTION

Station A uses 32 byte packets to transmit message to Station B using a sliding window protocol. The round trip delay between A and B is 80 milliseconds and the bottleneck bandwidth on the path between A and B is 128 kbps. What is the optimal window size that A should use?

Given Data

Delay = 80 milliseconds

Bandwidth = 128 kbps

Packet Size = 32 bytes

SolutionNeso Academy

SOLUTION

$$\text{Bandwidth - Delay Product} = \text{Bandwidth} \times \text{Delay}$$

$$\text{Bandwidth - Delay Product} = 128 \text{ kbps} \times 80 \text{ milliseconds}$$

$$\text{Bandwidth - Delay Product} = 128 \times 1024 \times 80 \text{ milliseconds}$$

$$\text{Bandwidth - Delay Product} = 128 \times 1024 \times 80 \times 10^{-3} \text{ bits}$$

$$\text{Bandwidth - Delay Product} = \frac{128 \times 1024 \times 80 \times 10^{-3}}{8} \text{ bytes}$$

$$\text{Optimal Window Size} = \frac{128 \times 1024 \times 80 \times 10^{-3}}{8 \times 32} \text{ bytes}$$

$$\text{Optimal Window Size} = 40$$

SolutionNeso Academy

SOLUTION

Station A uses 32 byte packets to transmit message to Station B using a sliding window protocol. The round trip delay between A and B is 80 milliseconds and the bottleneck bandwidth on the path between A and B is 128 kbps. What is the optimal window size that A should use?

- (A) 20
- (B) 40 ✓
- (C) 160
- (D) 320

Solution ✓ Neso Academy

QUESTION

The distance between two stations M and N is L kilometres. All frames are K bits long. The propagation time per kilometer is t seconds. Let R bits/second be the channel capacity. Assuming the processing delay is negligible, the minimum number of bits for the sequence number field in a frame for maximum utilization, when the sliding window protocol is used, is:

[GATE CS 2007]

- A. $\log_2 \left(\frac{2LtR+2K}{K} \right)$
- B. $\log_2 \left(\frac{2LtR}{K} \right)$
- C. $\log_2 \left(\frac{2LtR+K}{K} \right)$
- D. $\log_2 \left(\frac{2LtR+K}{2K} \right)$

QuestionNeso Academy

SOLUTION

Let Propagation Delay = L_t sec

Round Trip Time = $2 \times$ Propagation Delay

Round Trip Time = $2 \times L_t$ sec

Round Trip Time = $2 L_t$ sec

No. of bits transmitted in round trip = $2 L_t R$ bits.

SolutionNeso Academy

SOLUTION

$$\text{No. of frames} = \left(\frac{2L_t R}{K} \right)$$

Let the bits in the sequence numbers be b .

$$2^b = \left(\frac{2L_t R}{K} \right)$$

Take log on both sides, we get

$$b = \log \left(\frac{2L_t R}{K} \right)$$

SolutionNeso Academy

QUESTION

The distance between two stations M and N is L kilometres. All frames are K bits long. The propagation time per kilometer is t seconds. Let R bits/second be the channel capacity. Assuming the processing delay is negligible, the minimum number of bits for the sequence number field in a frame for maximum utilization, when the sliding window protocol is used, is:

[GATE CS 2007]

- A. $\log_2 \left(\frac{2LtR+2K}{K} \right)$
- C. $\log_2 \left(\frac{2LtR+K}{K} \right)$
- B. $\log_2 \left(\frac{2LtR}{K} \right) \checkmark$
- D. $\log_2 \left(\frac{2LtR+K}{2K} \right)$

Question★Neso Academy

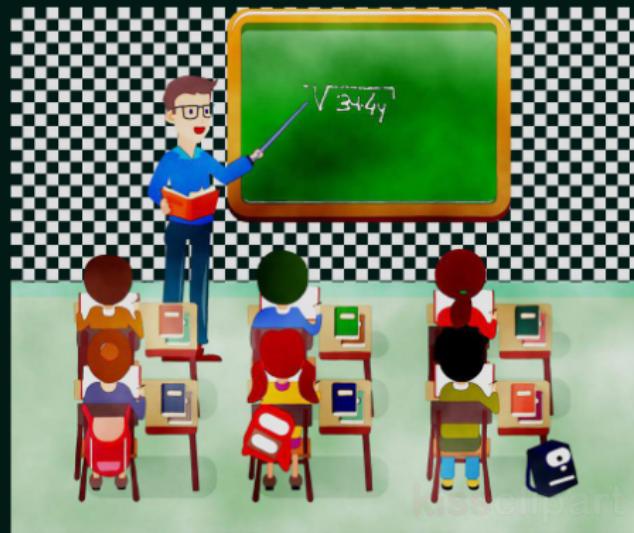
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.

Outcomes★Neso Academy

ANALOGY !



Analogy !Neso Academy

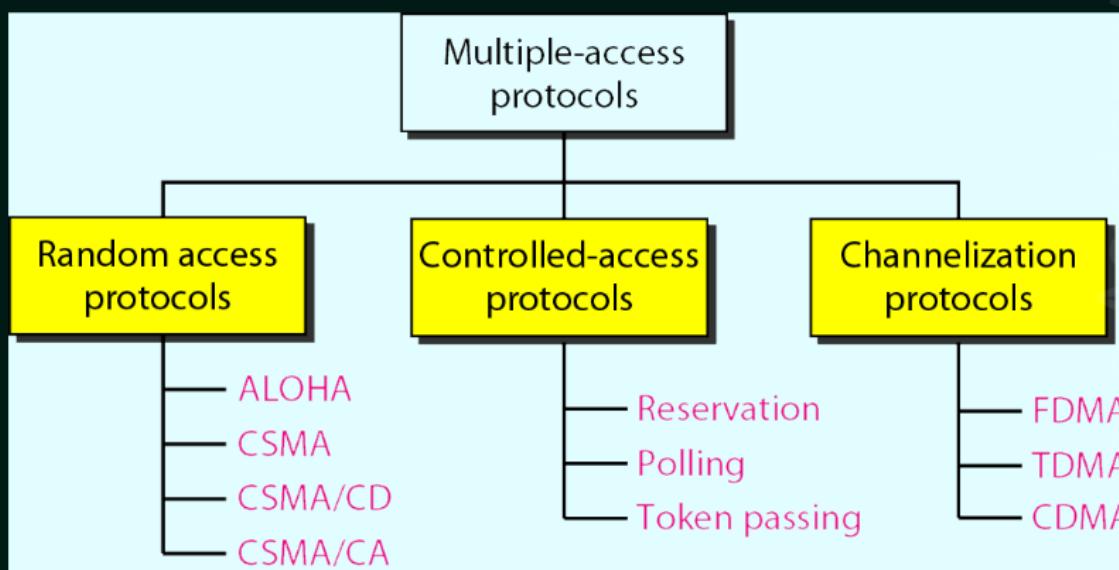
WHY MULTIPLE ACCESS PROTOCOLS?

If there is a dedicated link between the sender and the receiver then data link control layer is sufficient, however if there is no dedicated link present then multiple stations can access the channel simultaneously.

Hence multiple access protocols are required to decrease collision and avoid crosstalk.

Why Multiple Access Protocols?Neso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access Protocols Neso Academy

RANDOM ACCESS PROTOCOLS

- ★ In this, all stations have same superiority that is no station has more priority than another station. Any station can send data depending on medium's state(idle or busy).
- ★ In a Random access method, each station has the right to the medium without being controlled by any other station.
- ★ If more than one station tries to send, there is an access conflict (COLLISION) and the frames will be either destroyed or modified.

Random Access Protocols ★★★ Neso Academy

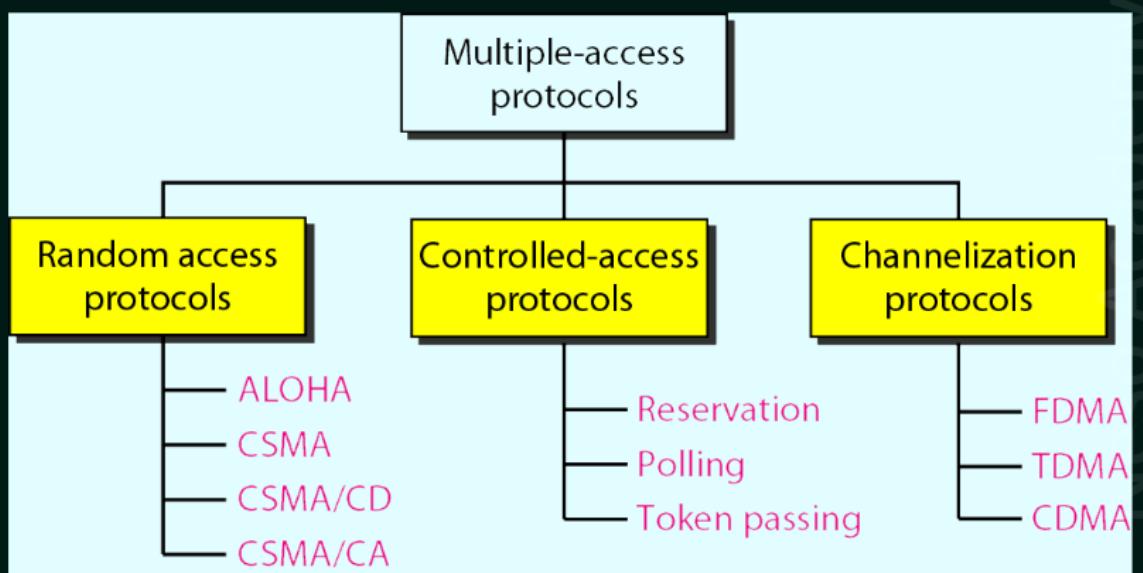
RANDOM ACCESS PROTOCOLS

To avoid access conflict, each station follows a procedure.

- ★ When can the station access the medium ?
- ★ What can the station do if the medium is busy ?
- ★ How can the station determine the success or failure of the transmission ?
- ★ What can the station do if there is an access conflict ?

Random Access Protocols ★★★ Neso Academy

RANDOM ACCESS PROTOCOLS



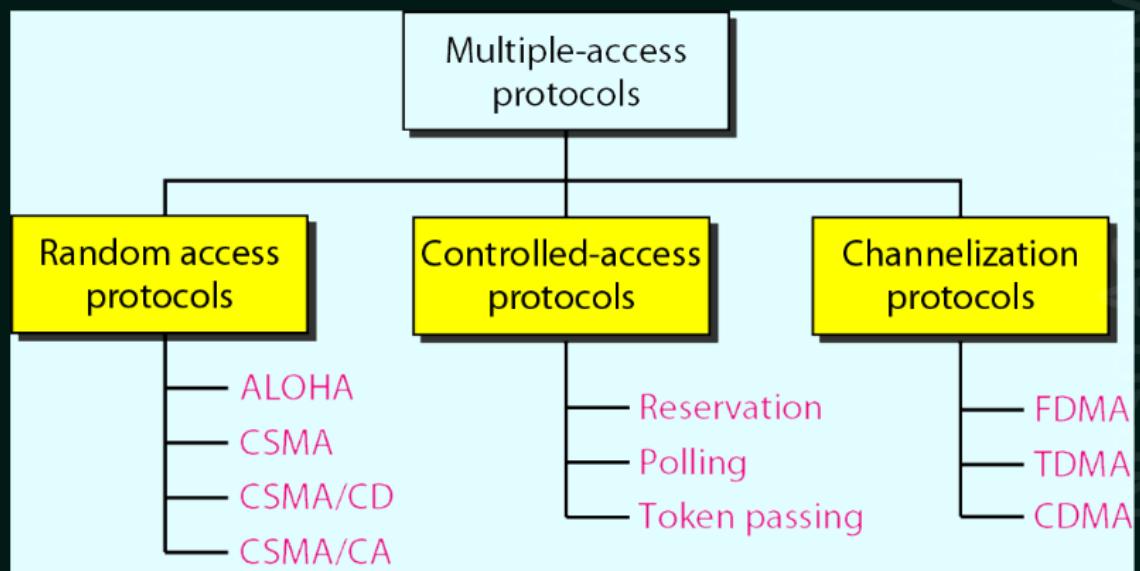
Random Access Protocols Neso Academy

CONTROLLED ACCESS PROTOCOLS

- ★ In controlled access, the stations consult one another to find which station has the right to send.
- ★ A station cannot send unless it has been authorized by other stations.

Controlled Access Protocols ★★ Neso Academy

CONTROLLED ACCESS PROTOCOLS



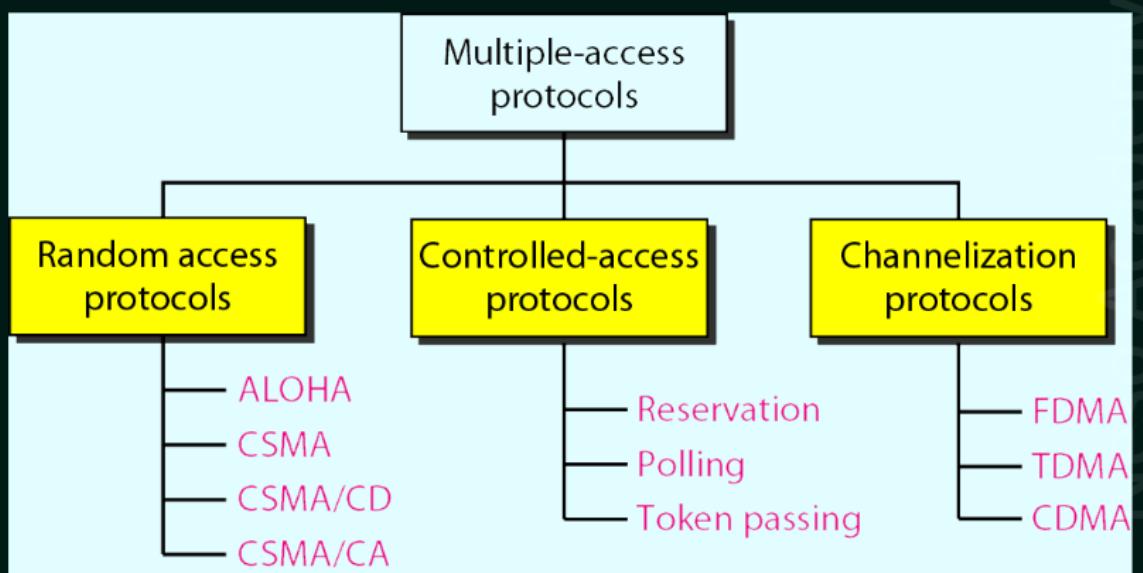
Controlled Access Protocols Neso Academy

CHANNELIZATION PROTOCOLS

Channelization is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations.

Channelization ProtocolsNeso Academy

CHANNELIZATION PROTOCOLS



Channelization ProtocolsNeso Academy

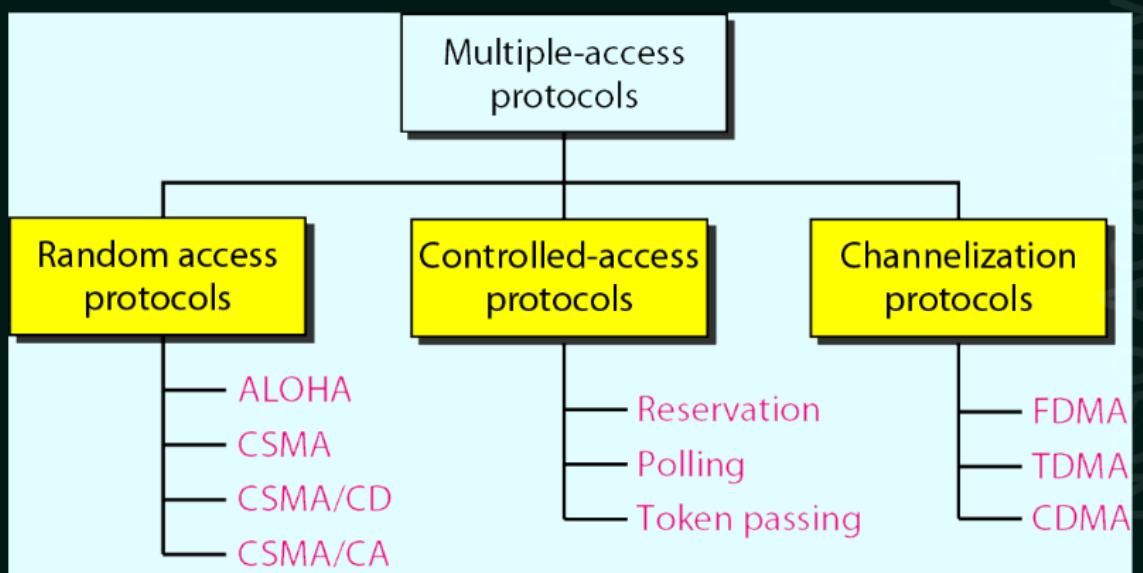
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.
- ★ Understand collision.
- ★ Understand Pure Aloha.

Outcomes ★★★ Neso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access Protocols Neso Academy

ALOHA

- ★ Aloha is a random access protocol.
- ★ It was actually designed for WLAN but it is also applicable for shared medium.
- ★ In this, multiple stations can transmit data at the same time and can hence lead to **collision** and data being garbled.

ALOHA★★★Neso Academy

COLLISION



CollisionA-FrameB-FrameNeso Academy

COLLISION



CollisionA-FrameB-FrameCOLLISIONFrames lost / CorruptedNeso Academy

ALOHA

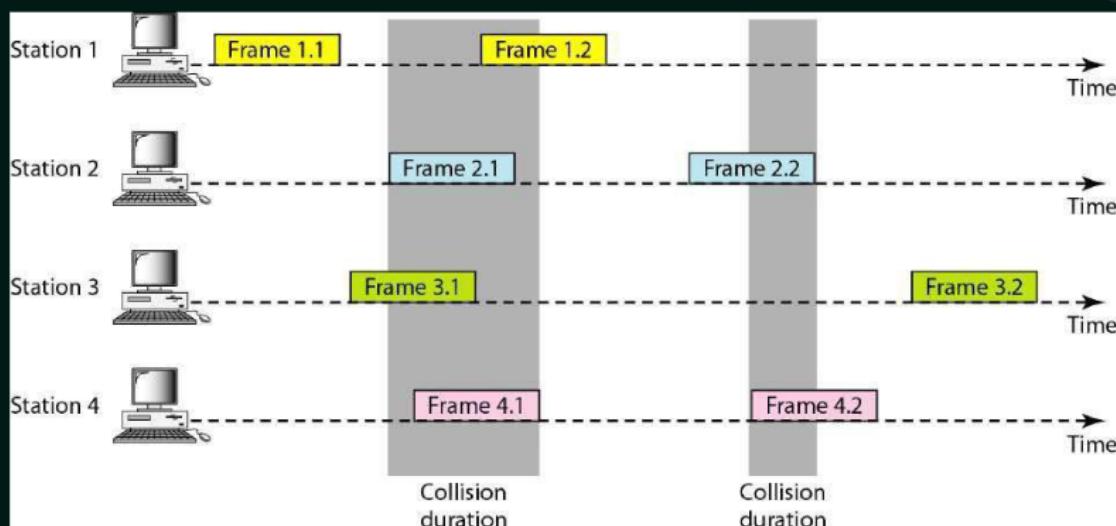
- ★ Aloha is a random access protocol.
- ★ It was actually designed for WLAN but it is also applicable for shared medium.
- ★ In this, multiple stations can transmit data at the same time and can hence lead to collision and data being garbled.

Types:

- ★ Pure Aloha
- ★ Slotted Aloha

ALOHA★★★★★Neso Academy

PURE ALOHA



Pure alohaNeso Academy

PURE ALOHA

- ★ Pure ALOHA allows stations to transmit whenever they have data to be sent.
- ★ When a station sends data it waits for an acknowledgement.
- ★ If the acknowledgement doesn't come within the allotted time then the station waits for a random amount of time called back-off time (T_b) and re-sends the data.
- ★ Since different stations wait for different amount of time, the probability of further collision decreases.
- ★ The throughput of pure aloha is maximized when frames are of uniform length.

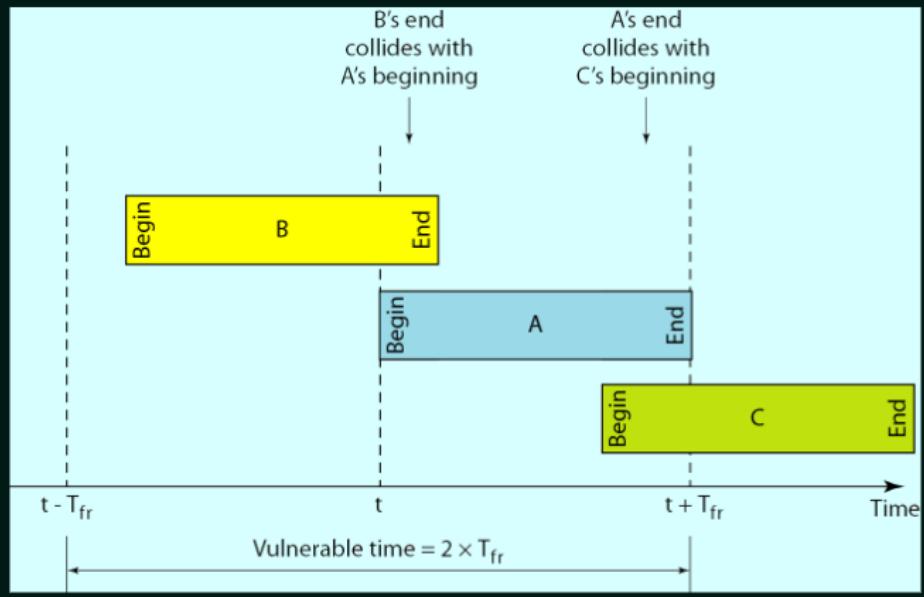
Pure aloha★★★★★Neso Academy

PURE ALOHA

- ★ Whenever two frames try to occupy the channel at the same time, there will be a collision and both will be garbled.
- ★ If the first bit of a new frame overlaps with just the last bit of a frame almost finished, both frames will be totally destroyed and both will have to be retransmitted later.

Pure aloha★★Neso Academy

PURE ALOHA



Pure alohaNeso Academy

PURE ALOHA

- ★ Whenever two frames try to occupy the channel at the same time, there will be a collision and both will be garbled.
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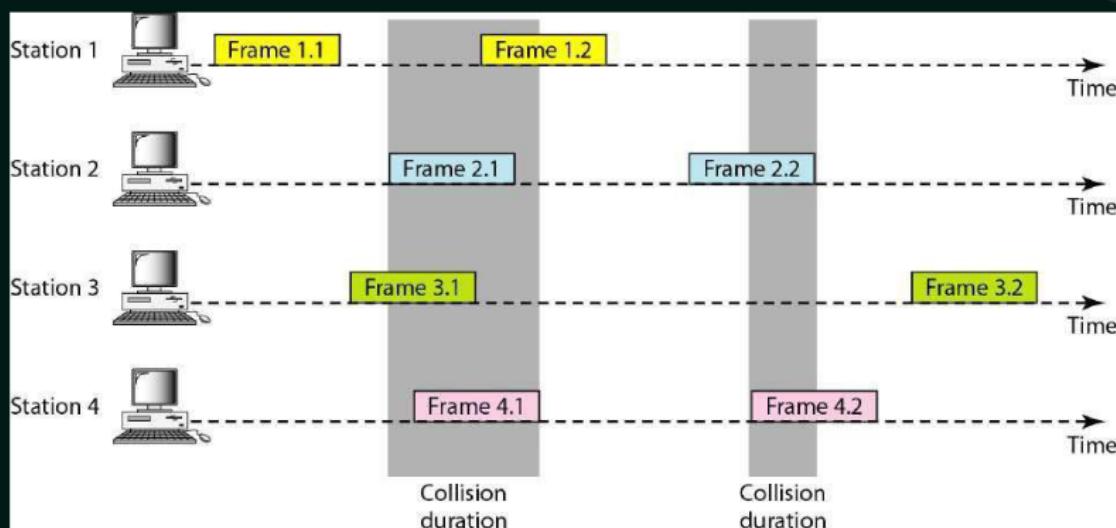
$$\text{Vulnerable Time} = 2 * T_{fr}$$

Throughput = $G \times e^{-2G}$; Where G is the number of stations wish to transmit in the same time.

Maximum throughput = 0.184 for G=0.5 ($\frac{1}{2}$)

Pure aloha★★Neso Academy

PURE ALOHA



Pure alohaNeso Academy

QUESTION

There are n stations in a slotted LAN. Each station attempts to transmit with a probability ρ in each time slot. What is the probability that ONLY one station transmits in a given time slot?

[GATE CS 2007]

- A. $n\rho(1-\rho)^{n-1}$
- B. $(1-\rho)^{n-1}$
- C. $\rho(1-\rho)^{n-1}$
- D. $1-(1-\rho)^{n-1}$

QuestionNeso Academy

QUESTION

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4×10^8 m/s in cable.

Given

Distance = 12000 Km

Propagation speed = 2.4×10^8 m/s

To Find

Propagation Time

QuestionNeso Academy

SOLUTION

$$\text{Propagation Time} = \frac{\text{Distance}}{\text{Propagation speed}}$$

$$\text{Propagation Time} = \frac{12000 \times 1000}{2.4 \times 10^8} \text{ sec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \text{ sec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \times \frac{10^{-3}}{10^{-3}} \text{ sec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \times \frac{1}{10^{-3}} \text{ millisec}$$

$$\text{Propagation Time} = \frac{5000 \times 1000}{10^8} \times \frac{10^3}{1} \text{ millisec}$$

$$\text{Propagation Time} = \frac{50 \times 100 \times 1000}{10^8} \times \frac{10^3}{1} \text{ millisec}$$

Propagation Time = 50 millisec OR 50 ms

SolutionNeso Academy

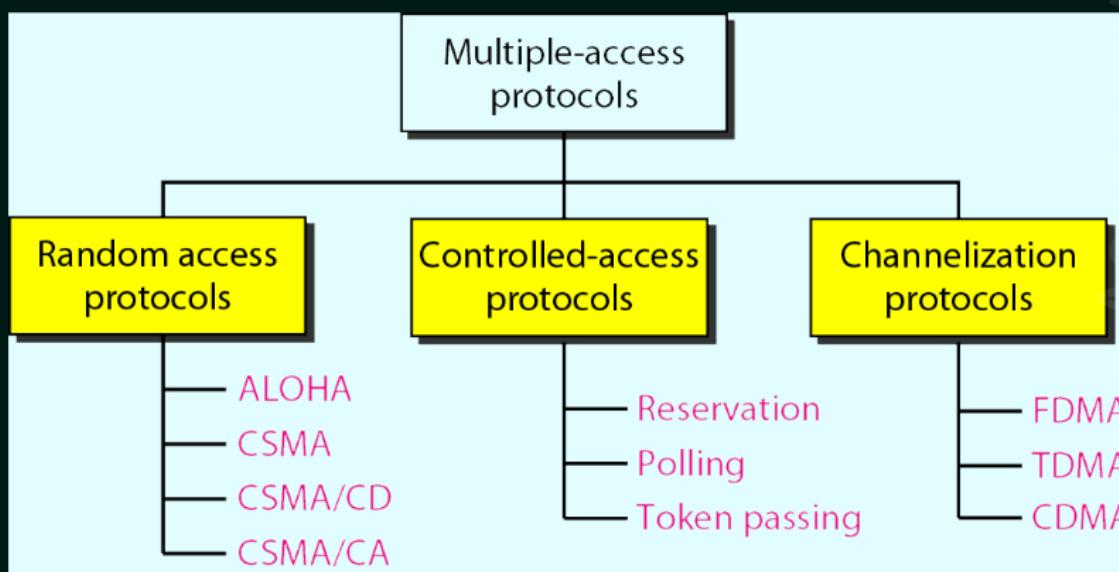
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand Slotted Aloha.
- ★ Compare Pure Aloha and Slotted Aloha.

★★OutcomesNeso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access ProtocolsNeso Academy

ALOHA

- ★ Aloha is a random access protocol.
- ★ It was actually designed for WLAN but it is also applicable for shared medium.
- ★ In this, multiple stations can transmit data at the same time and can hence lead to collision and data being garbled.

Types:

★ Pure Aloha

★ Slotted Aloha

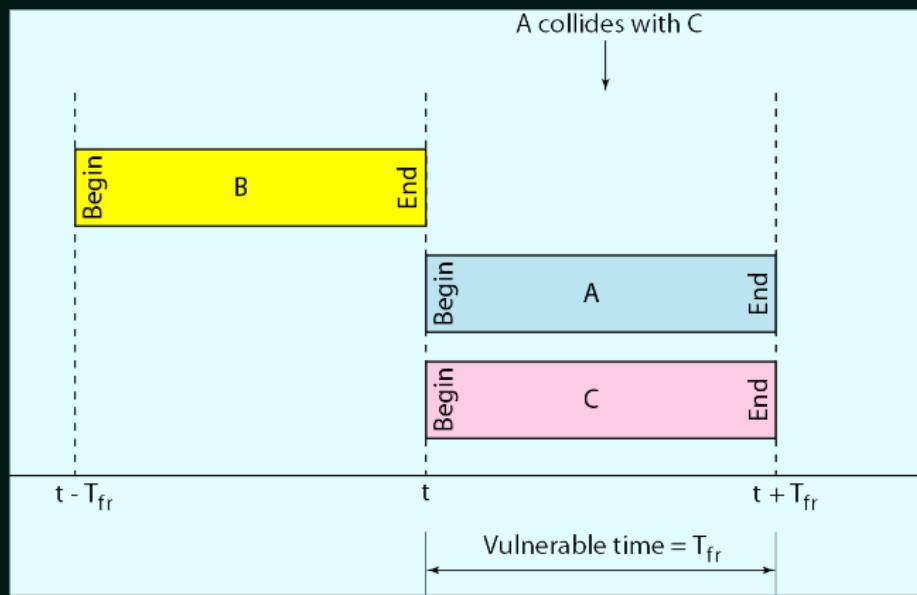
ALOHA★★★★★Neso Academy

SLOTTED ALOHA

- ★ It was developed just to improve the efficiency of pure aloha as the chances for collision in pure aloha are high.
- ★ The time of the shared channel is divided into discrete time intervals called slots.
- ★ Sending of data is allowed only at the beginning of these slots.

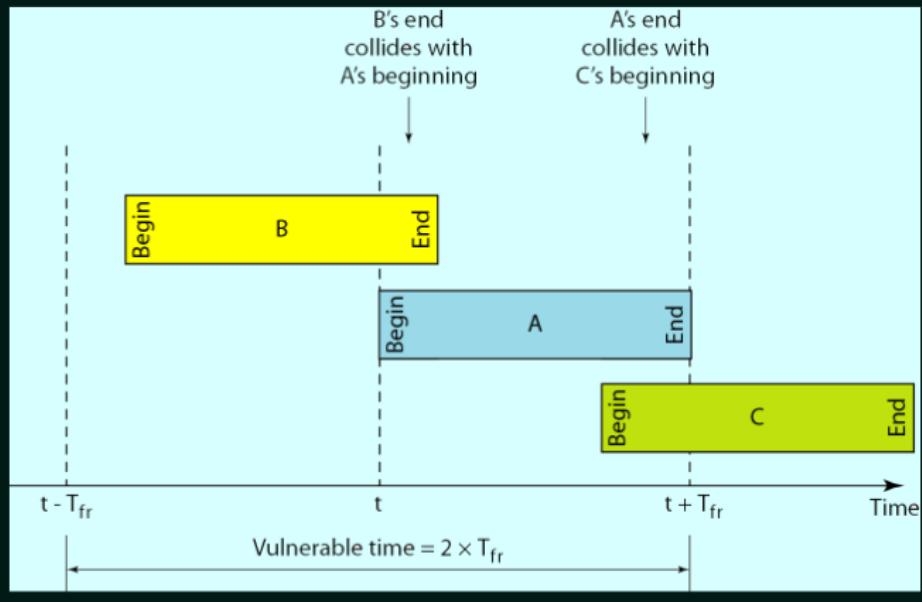
Slotted aloha★★★Neso Academy

SLOTTED ALOHA



Slotted alohaNeso Academy

PURE ALOHA



Pure aloha Neso Academy

SLOTTED ALOHA

- ★ It was developed just to improve the efficiency of pure aloha as the chances for collision in pure aloha are high.
- ★ The time of the shared channel is divided into discrete time intervals called slots.
- ★ Sending of data is allowed only at the beginning of these slots.
- ★ If a station misses out the allowed time, it must wait for the next slot. This reduces the probability of collision.

Slotted aloha ★★★★ Neso Academy

SLOTTED ALOHA

Vulnerable Time = Frame Transmission Time.

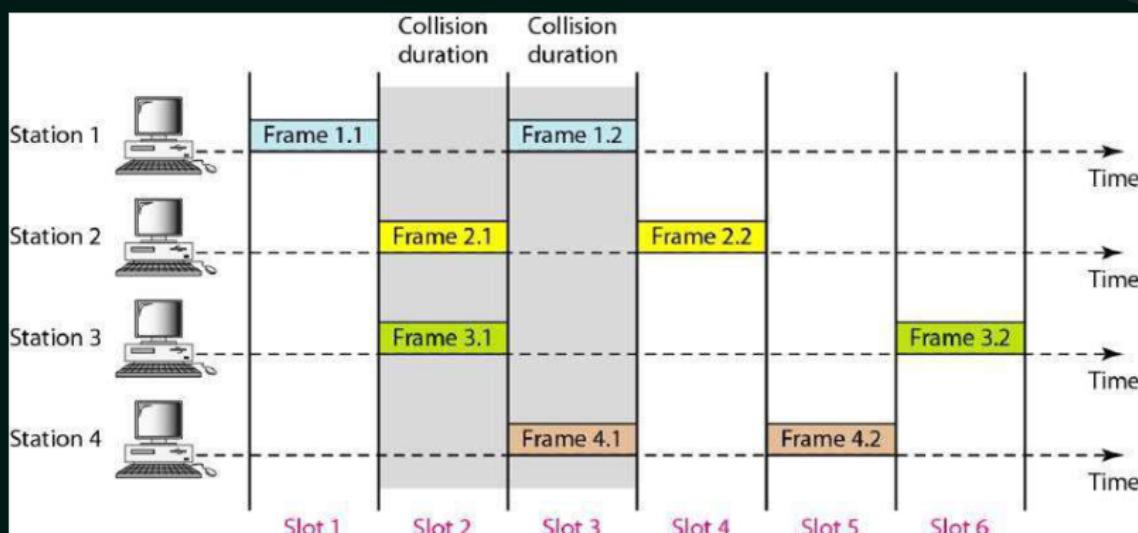
Throughput = $G \times e^{-G}$; Where G is the number of stations wish to transmit in the same time.

Maximum throughput = 0.368 for G=1.

Neso Academy

Slotted alohaNeso Academy

SLOTTED ALOHA



Slotted alohaNeso Academy

PURE ALOHA VS SLOTTED ALOHA

Pure Aloha	Slotted Aloha
Any station can transmit the data at any time.	Any station can transmit the data at the beginning of any time slot.
The time is continuous and not globally synchronized.	The time is discrete and globally synchronized.
Vulnerable time in which collision may occur $= 2 \times T_{Fr}$	Vulnerable time in which collision may occur $= T_{Fr}$
Probability of successful transmission of data packet $= G \times e^{-2G}$	Probability of successful transmission of data packet $= G \times e^{-G}$
Maximum efficiency = 18.4% (Occurs at $G = 1/2$)	Maximum efficiency = 36.8% (Occurs at $G = 1$)
Main advantage: Simplicity in implementation.	Main advantage: It reduces the number of collisions to half and doubles the efficiency of pure aloha.

Pure aloha vs Slotted alohaNeso Academy

OUTCOMES

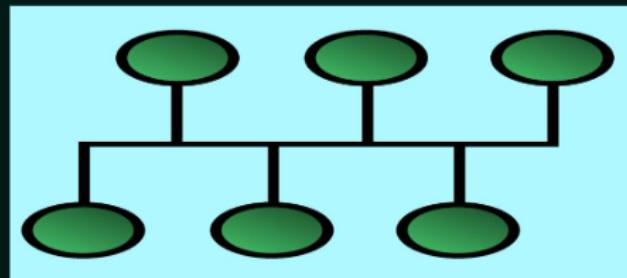
Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.
- ★ Understand CSMA protocol.
- ★ Types of CSMA.
- ★ Understand the behaviour of three persistent methods.

Outcomes★★★★Neso Academy

CSMA PROTOCOL

- ★ Carrier Sense Protocol.
- ★ To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed.
- ★ Principle of CSMA: “sense before transmit” or “listen before talk.”



CSMA protocol★★★Neso Academy

CSMA PROTOCOL

- ★ Carrier Sense Protocol.
- ★ To minimize the chance of collision and, therefore, increase the performance, the CSMA method was developed.
- ★ Principle of CSMA: “sense before transmit” or “listen before talk.”
- ★ Carrier busy = Transmission is taking place.
- ★ Carrier idle = No transmission currently taking place.
- ★ The possibility of collision still exists because of propagation delay; a station may sense the medium and find it idle, only because the first bit sent by another station has not yet been received.

CSMA protocol★★★★★Neso Academy

TYPES OF CSMA

1. 1-Persistent CSMA
2. P-Persistent CSMA
3. Non-Persistent CSMA
4. 0-Persistent CSMA

CSMA/CD (CSMA with Collision Detection)

CSMA/CA (CSMA with Collision Avoidance)

Types of CSMA Neso Academy

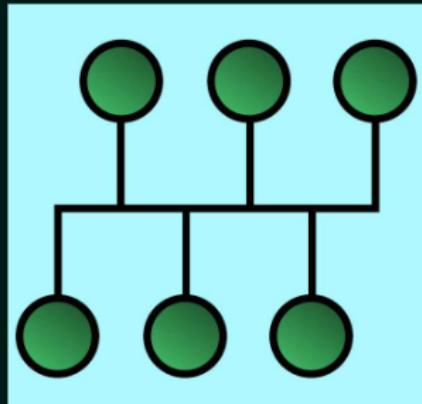
1-PERSISTENT CSMA

- ★ Before sending the data, the station first listens to the channel to see if anyone else is transmitting the data at that moment.
- ★ If the channel is idle, the station transmits a frame.
- ★ If busy, then it senses the transmission medium continuously until it becomes idle.
- ★ Since the station transmits the frame with the probability of 1 when the carrier or channel is idle, this scheme of CSMA is called as 1-Persistent CSMA.
- ★ The propagation delay has an important effect on the performance of the protocol.
- ★ There is a small chance that just after a station begins sending, another station will become ready to send and sense the channel.

1-Persistent CSMA ★★★★★ Neso Academy

1-PERSISTENT CSMA

- ★ The longer the propagation delay, the more important this effect becomes, and the worse the performance of the protocol.
- ★ Even if the propagation delay is zero, there will still be collisions.



1-Persistent CSMA ★★ Neso Academy

NON-PERSISTENT CSMA

- ★ Before sending, a station senses the channel. If no one else is sending, the station begins doing so itself.
- ★ However, if the channel is already in use, the station does not continually sense it for the purpose of seizing it immediately upon detecting the end of the previous transmission.
- ★ Instead, it waits a random period of time and then repeats the algorithm. Consequently, this algorithm leads to better channel utilization but longer delays than 1-persistent CSMA.

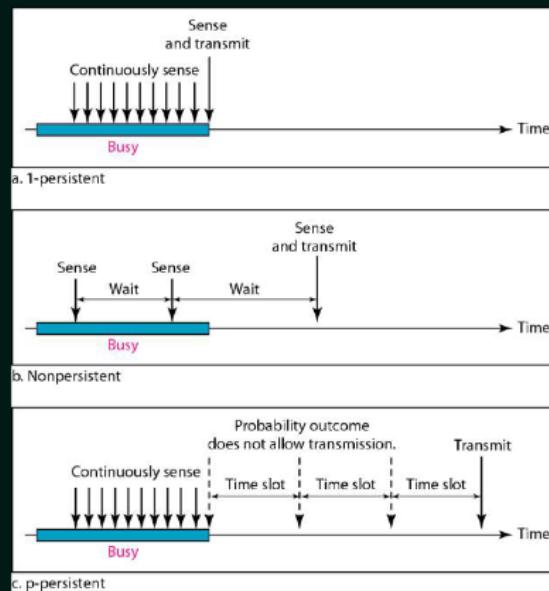
Non-Persistent CSMA ★★★ Neso Academy

P-PERSISTENT CSMA

- ★ It applies to slotted channels.
- ★ When a station becomes ready to send, it senses the channel.
- ★ If it is idle, it transmits with a probability P.
- ★ With a probability Q=1-P, it defers until the next slot.
- ★ If that slot is also idle, it either transmits or defers again, with probabilities P and Q.
- ★ This process is repeated until either the frame has been transmitted or another station has begun transmitting.
- ★ In the latter case, the unlucky station acts as if there had been a collision (i.e., it waits a random time and starts again).
- ★ If the station initially senses the channel busy, it waits until the next slot and applies the above algorithm.

P-Persistent CSMA★★★★★★★★Neso Academy

BEHAVIOUR OF THREE PERSISTENT METHODS



Behaviour of three persistent methodsNeso Academy

O-PERSISTENT CSMA

- ★ Each node is assigned a transmission order by a supervisory node.

O-Persistent CSMA ★ Neso Academy

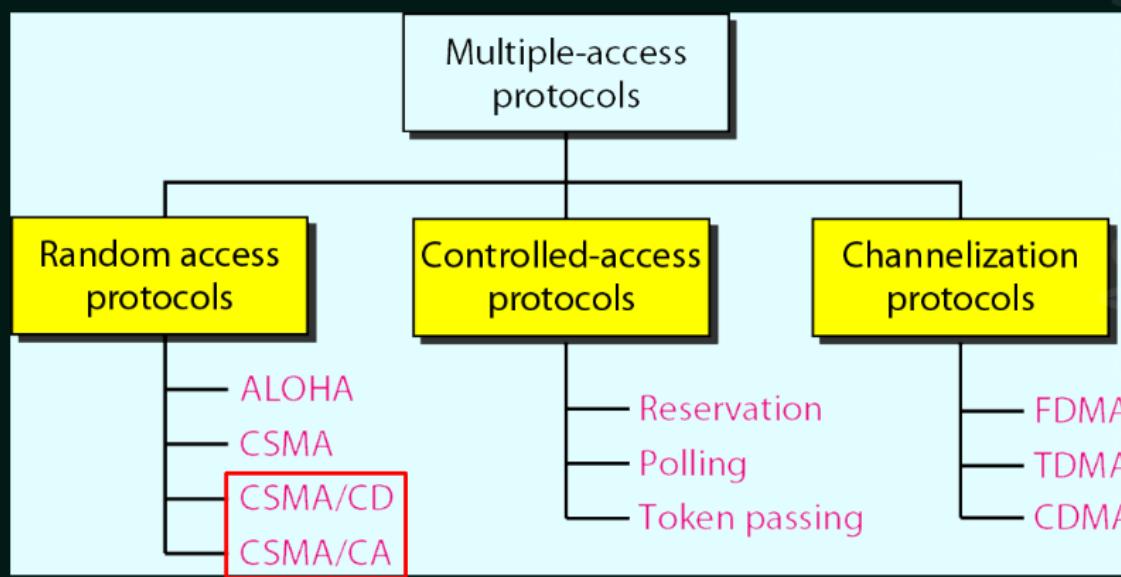
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.
- ★ Understand CSMA/CD.
- ★ Understand CSMA/CA.

Outcomes ★★★ Neso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access Protocols Neso Academy

CSMA PROTOCOL

- ★ Principle of CSMA: “sense before transmit” or “listen before talk.”
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CSMA protocol ★★★ Neso Academy

TYPES OF CSMA

1. 1-Persistent CSMA
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4. O-Persistent CSMA

CSMA/CD (CSMA with Collision Detection)

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Types of CSMA Neso Academy

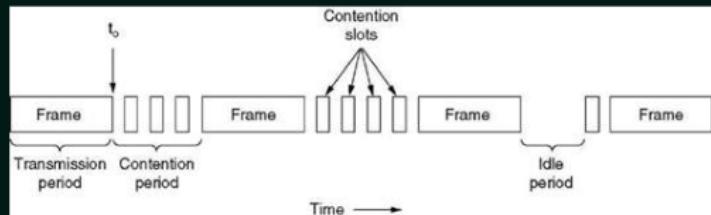
CSMA/CD

- ★ If two stations sense the channel to be idle and begin transmitting simultaneously, they will both detect the collision almost immediately.
- ★ Rather than finish transmitting their frames, which are irretrievably garbled anyway, they should abruptly stop transmitting as soon as the collision is detected.
- ★ Quickly terminating damaged frames saves time and bandwidth.
- ★ This protocol, known as CSMA/CD (CSMA with Collision Detection) is widely used on LANs in the MAC sublayer.
- ★ Access method used by Ethernet: CSMA/CD.

CSMA/CD ★★★★★ Neso Academy

CSMA/CD

- ★ At the point marked t_0 , a station has finished transmitting its frame.

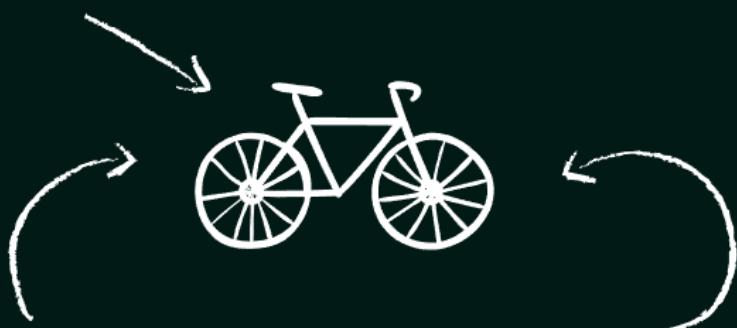


CSMA/CD★Neso Academy

CSMA/CD

- ★ At the point marked t_0 , a station has finished transmitting its frame.
- ★ Any other station having a frame to send may now attempt to do so. If two or more stations decide to transmit simultaneously, there will be a collision.
- ★ Collisions can be detected by looking at the power or pulse width of the received signal and comparing it to the transmitted signal.
- ★ After a station detects a collision, it aborts its transmission, waits a random period of time, and then tries again, assuming that no other station has started transmitting in the meantime.
- ★ Therefore, model for CSMA/CD will consist of alternating contention and transmission periods, with idle periods occurring when all stations are quiet.

CSMA/CD★★★★★Neso Academy



IMPORTANT CONCEPT

CSMA/CD – For GATE aspirants

Important concept Neso Academy

CSMA/CD – FOR GATE ASPIRANTS

$$\text{Efficiency} = \frac{1}{1 + 6.44 \times a}$$

$$a = \frac{T_p}{T_t}$$

- ★ If distance increases, efficiency of CSMA decreases.
- ★ CSMA is not suitable for long distance networks like WAN; but works optimally for LAN.
- ★ If length of packet is bigger, the efficiency of CSMA also increases; but maximum limit for length is 1500 Bytes.
- ★ Transmission Time \geq Round Trip Time of 1 bit
- ★ Transmission Time $\geq 2 * \text{Propagation Time}$

CSMA/CD -For GATE aspirants★★★★★Neso Academy

CSMA/CA

- ★ Carrier-sense multiple access with collision avoidance (CSMA/CA) is a network multiple access method in which carrier sensing is used, but nodes attempt to avoid collisions by beginning transmission only after the channel is sensed to be "idle".
- ★ It is particularly important for wireless networks, where the collision detection of the alternative CSMA/CD is not possible due to wireless transmitters desensing their receivers during packet transmission.
- ★ CSMA/CA is unreliable due to the hidden node problem and exposed terminal problem.
- ★ Solution: RTS/CTS exchange.
- ★ CSMA/CA is a protocol that operates in the Data Link Layer (Layer 2) of the OSI model.

CSMA/CA★★★★★Neso Academy

CSMA/CA

- ★ The Access method used by IEEE 802.11 Wi-Fi is CSMA/CA.

CSMA/CA★Neso Academy

HOMEWORK!

Find the correct box.

Multiple Access Method used by

Ethernet : CSMA/CA

Wi-Fi : CSMA/CD

Multiple Access Method used by

Ethernet : CSMA/CD

Wi-Fi : CSMA/CA

Please post your answer in the comments section

Homework!Neso Academy

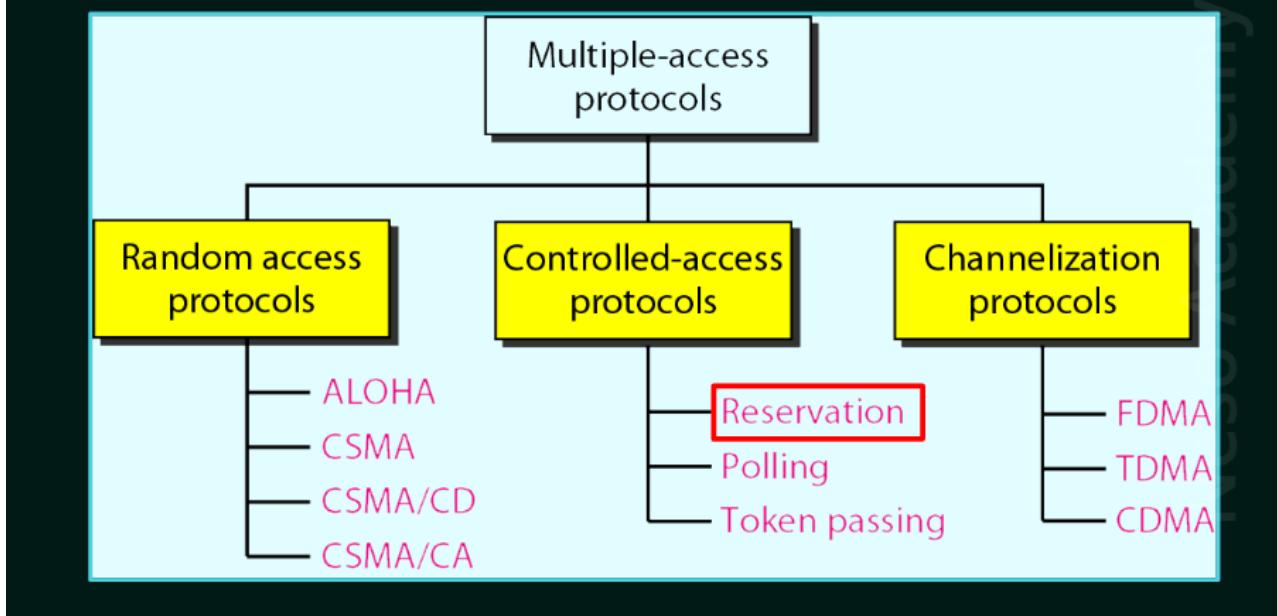
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.
- ★ Understand the Controlled Access Protocols – Reservation.

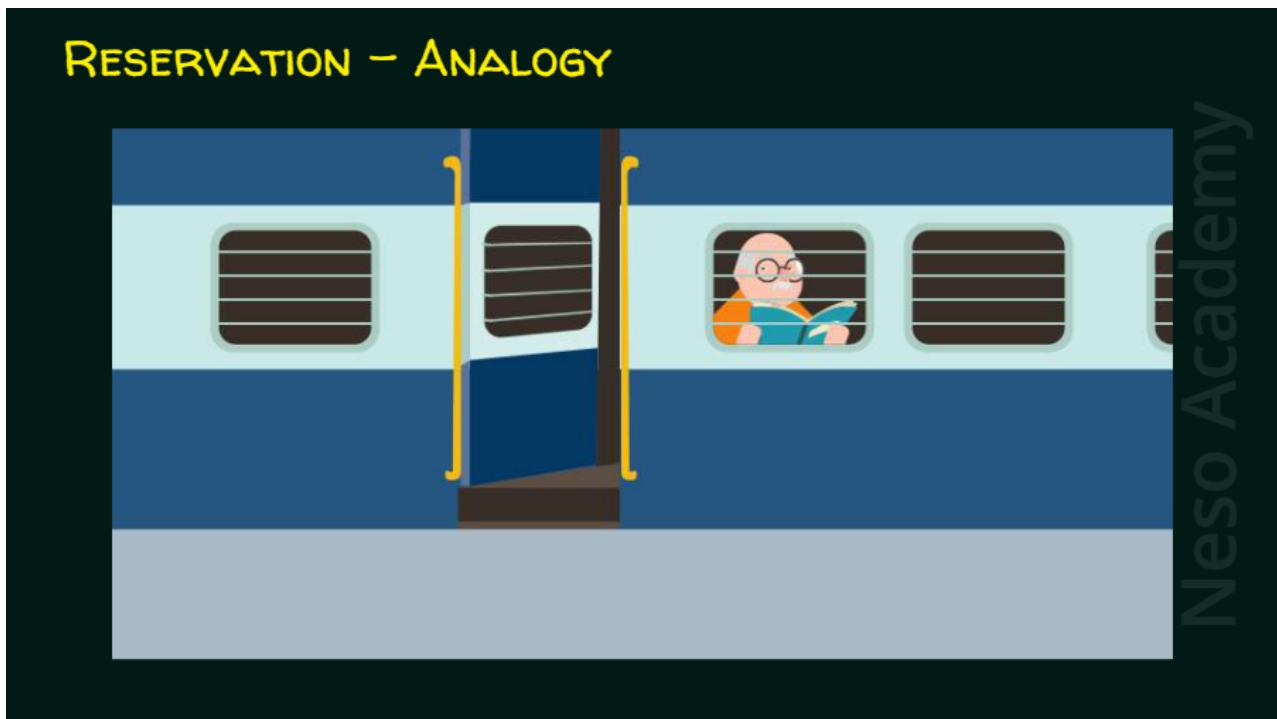
Outcomes ★★ Neso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access ProtocolsNeso Academy

RESERVATION – ANALOGY



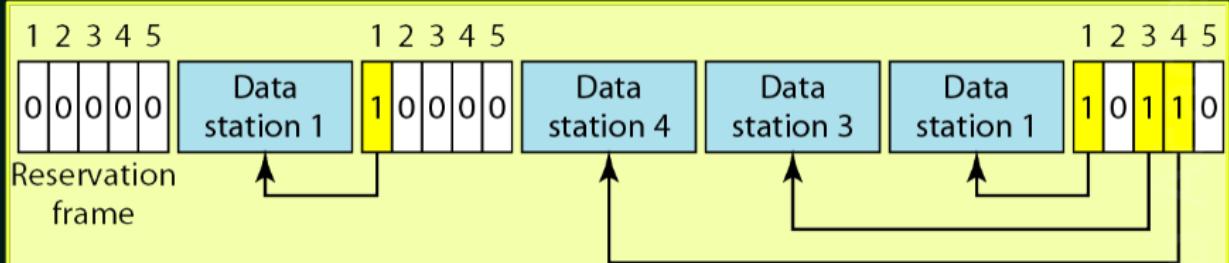
Reservation -AnalogyNeso Academy

RESERVATION

- ★ A station need to make a reservation before sending data.
- ★ In each interval, a reservation frame precedes the data frames sent in that interval.
- ★ If there are N stations in the system, there are exactly N reservation minislots in the reservation frame.
- ★ Each minislot belongs to a station.
- ★ When a station needs to send a data frame, it makes a reservation in its own minislot.
- ★ The stations that have made reservations can send their data frames after the reservation frame.

Reservation★★★★★Neso Academy

RESERVATION



ReservationNeso Academy

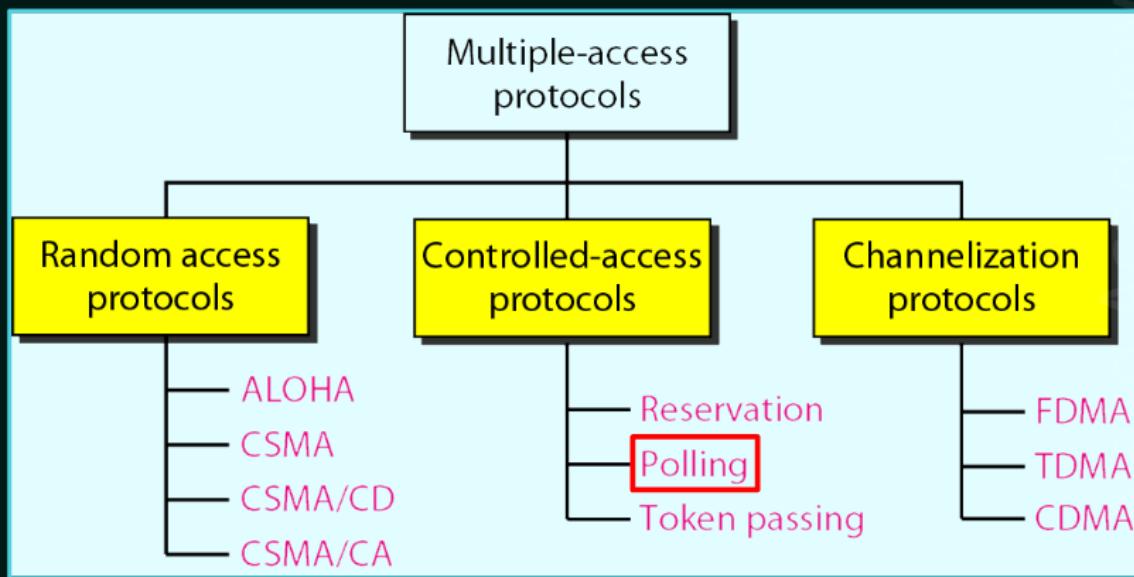
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.
- ★ Understand the Controlled Access Protocol – Polling.
- ★ Know the efficiency of polling.

Outcomes ★★★ Neso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access Protocols Neso Academy

POLLING -ANALOGY!



Polling -Analogy! Neso Academy

POLLING

- ★ The polling protocol requires one of the nodes to be designated as a Master node (Primary station).
- ★ The master node polls each of the nodes in a round-robin fashion.
- ★ In particular, the master node first sends a message to node 1, saying that it (node 1) can transmit up to some maximum number of frames.
- ★ After node 1 transmits some frames, the master node tells node 2 it (node 2) can transmit up to the maximum number of frames.
- ★ The master node can determine when a node has finished sending its frames by observing the lack of a signal on the channel.

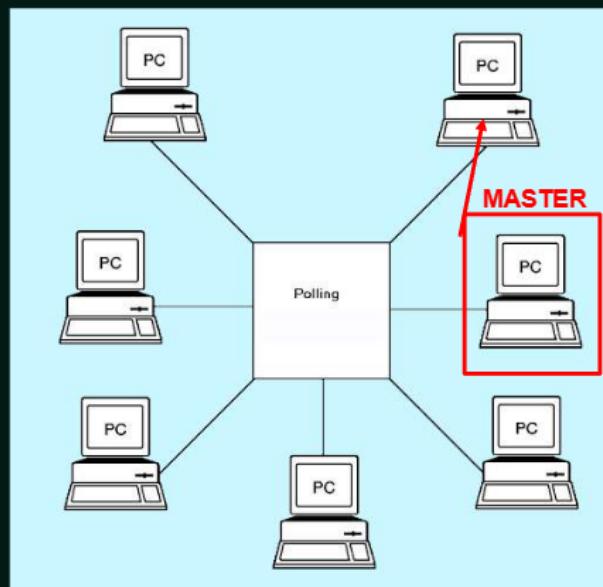
Polling★★★★★Neso Academy

POLLING

- ★ The procedure continues in this manner, with the master node polling each of the nodes in a cyclic manner.
- ★ The polling protocol eliminates the collision.
- ★ This allows polling to achieve a much higher efficiency.
- ★ The first drawback is that the protocol introduces a polling delay—the amount of time required to notify a node that it can transmit.
- ★ The second drawback, which is potentially more serious, is that if the master node fails, the entire channel becomes inoperative.

Polling★★★★★Neso Academy

POLLING



PollingMASTERNeso Academy

POLLING – FUNCTIONS

- ★ **Poll function** : If the primary wants to receive data, it asks the secondaries if they have anything to send.
- ★ **Select function** : If the primary wants to send data, it tells the secondary to get ready to receive.

Polling -Functions★★Neso Academy

EFFICIENCY OF POLLING

Let T_{poll} be the time for polling and T_t be the time required for transmission of data. Then,

$$\text{Efficiency} = \frac{T_t}{T_t + T_{poll}}$$

Efficiency of PollingNeso Academy

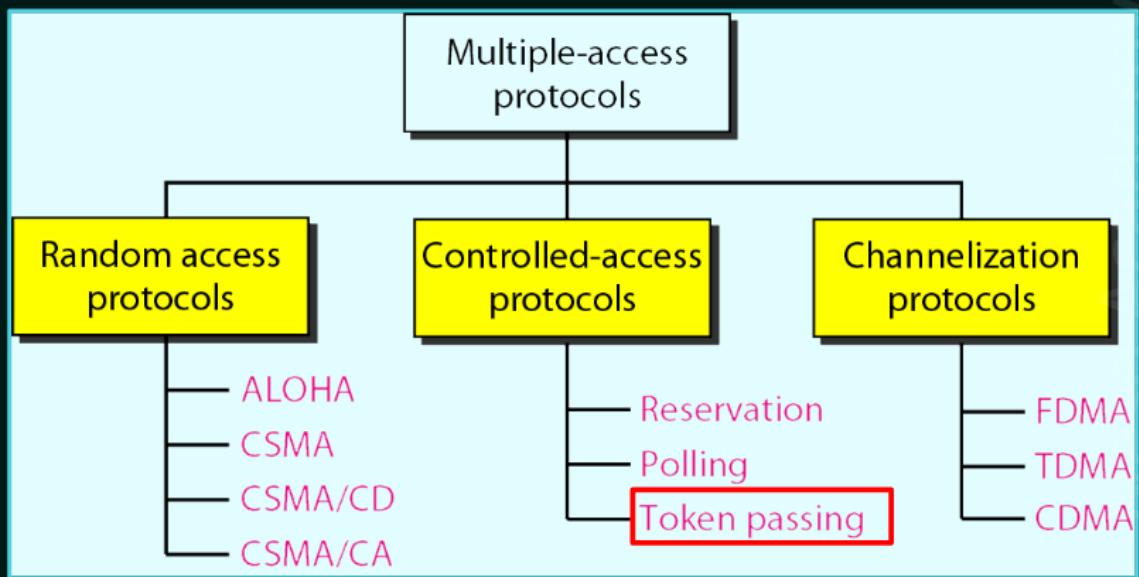
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various multiple access protocols.
- ★ Understand the Controlled Access Protocol – Token Passing.
- ★ Know the performance of Token Passing.

Outcomes ★★★ Neso Academy

MULTIPLE ACCESS PROTOCOLS



Multiple Access Protocols Neso Academy

TOKEN PASSING

- ★ A station is authorized to send data when it receives a special frame called a token.
- ★ Here there is no master node.
- ★ A small, special-purpose frame known as a token is exchanged among the nodes in some fixed order.
- ★ When a node receives a token, it holds onto the token only if it has some frames to transmit; otherwise, it immediately forwards the token to the next node.

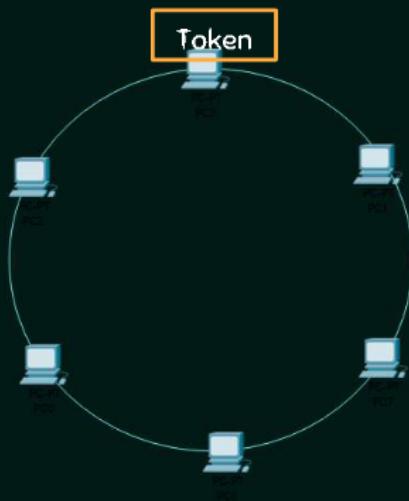
Token passing★★★Neso Academy

TOKEN PASSING

- ★ If a node does have frames to transmit when it receives the token, it sends up to a maximum number of frames and then forwards the token to the next node.
- ★ Token passing is decentralized and highly efficient. But it has problems as well.
- ★ For example, the failure of one node can crash the entire channel. Or if a node accidentally neglects to release the token, then some recovery procedure must be invoked to get the token back in circulation.

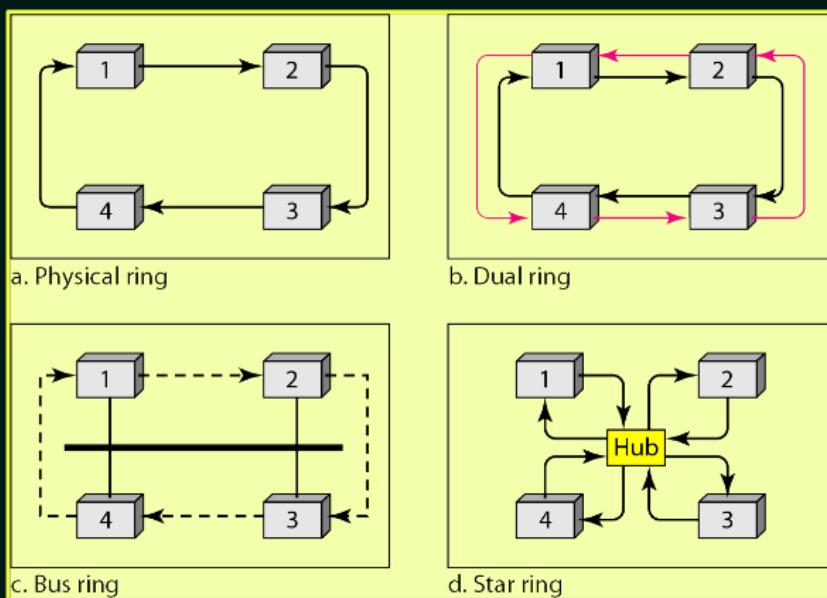
Token passing★★★Neso Academy

TOKEN PASSING



Token PassingNeso Academy

TOKEN PASSING



Token passingNeso Academy

PERFORMANCE OF TOKEN PASSING

$$S = \frac{1}{1 + \alpha/N} \quad ; \text{for } \alpha < 1$$

$$S = \frac{1}{\alpha(1 + 1/N)} \quad ; \text{for } \alpha > 1$$

$$\alpha = \frac{T_p}{T_t}$$

S = Throughput

N = number of stations

T_p = Propagation delay

T_t = Transmission delay

Performance of Token passing Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the Ethernet protocol.
- ★ Know the evolution of Ethernet.
- ★ Understand the frame format of Ethernet.
- ★ Know the minimum and maximum length of Ethernet frames.
- ★ Understand the Ethernet address.

Outcomes ★★★★★ Neso Academy

ETHERNET

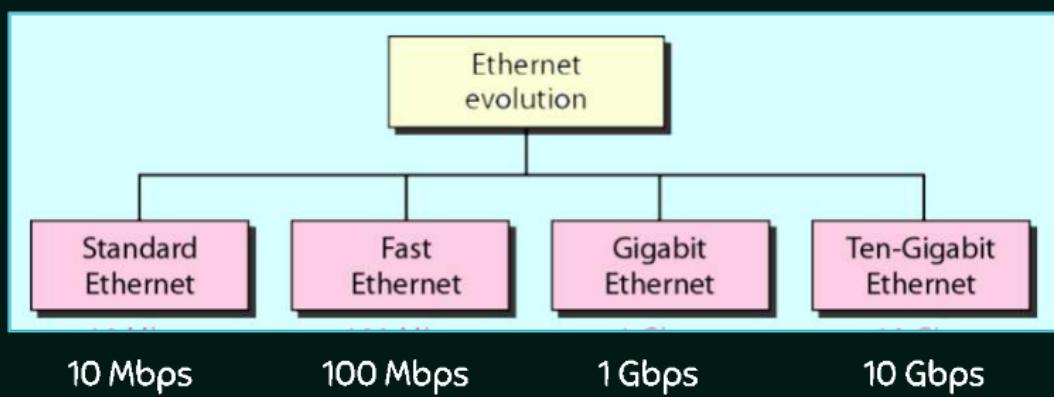
- ★ One of the most widely used Wired LAN technologies.
- ★ Operates in the data link layer and the physical layer.
- ★ Family of networking technologies that are defined in the IEEE 802.2 and 802.3 standards.
- ★ Supports data bandwidths of 10, 100, 1000, 10,000, 40,000, and 100,000 Mbps (100 Gbps).

Ethernet Standards

- ★ Define Layer 2 protocols and Layer 1 technologies
- ★ Two separate sublayers of the data link layer to operate – Logical link control (LLC) and the MAC sublayers.

Ethernet★★★★★Neso Academy

EVOLUTION OF ETHERNET

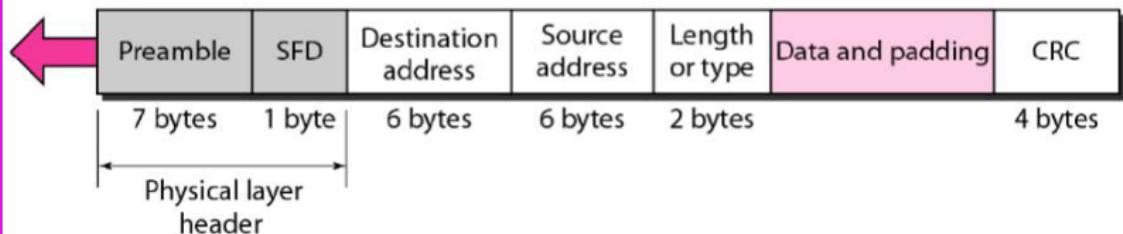


Evolution of ethernetNeso Academy

ETHERNET FRAME FORMAT

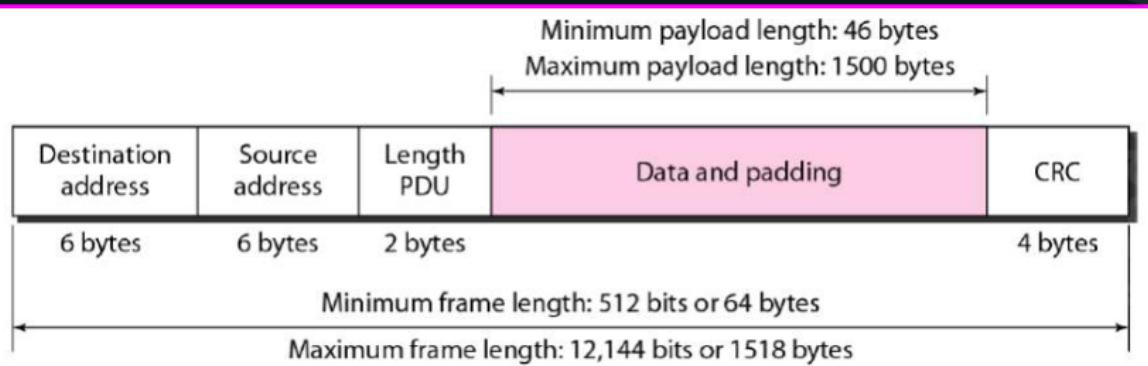
Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)



Ethernet frame formatNeso Academy

ETHERNET FRAME – MIN AND MAX LENGTH



Frame length:

Minimum: 64 bytes (512 bits)

Maximum: 1518 bytes (12,144 bits)

Ethernet frame -Min and Max LengthNeso Academy

ETHERNET ADDRESS

Example - 06:01:02:01:2C:4B

06:01:02:01:2C:4B \Leftrightarrow 6 bytes \Leftrightarrow 12 hex digits \Leftrightarrow 48 bits



The least significant bit of the first byte defines the type of address.

If the bit is 0, the address is unicast; otherwise, it is multicast.

If all bits are 1, then it is broadcast address

Ethernet addressNeso Academy

HEXADECIMAL TO BINARY

1 Hexadecimal digit = 4 binary bits.

Hex: 0-9,A,B,C,D,E,F

Binary: 0,1

Hexadecimal to Binary

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Conversion:

8	4	2	1
2^3	2^2	2^1	2^0

Hexadecimal to BinaryNeso Academy

HEXADECIMAL TO BINARY – EXAMPLE

Convert $5B_{16}$ to binary.

Hexadecimal to Binary

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

$$5B_{16} = 0101\ 1011_2$$

	8	4	2	1
	2^3	2^2	2^1	2^0
5	0	1	0	1
B	1	0	1	1

Hexadecimal to Binary -ExampleNeso Academy

QUESTION 1

What is the hexadecimal equivalent of the following Ethernet address?

01011010 00010001 01010101 00011000 10101010 00001111

SOLUTION

01011010 = 5A

00010001 = 11

01010101 = 55

00011000 = 18

10101010 = AA

00001111 = OF

Hexadecimal to Binary

Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

8	4	2	1	
0	0	0	0	0
1	1	1	1	F

Question 1Neso Academy

QUESTION 1

What is the hexadecimal equivalent of the following Ethernet address?

01011010 00010001 01010101 00011000 10101010 00001111

SOLUTION

01011010 = 5A

00010001 = 11

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Hexadecimal to Binary																
Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

The Answer is: 5A 11 55 18 AA OF

Question 1Neso Academy

QUESTION 2

Define the type of the following destination addresses:

- (A) 4A:30:10:21:10:1A (B) 47:20:1B:2E:08:EE (C) FF:FF:FF:FF:FF:FF

SOLUTION

(A) 4A

Neso Academy

Question 2Neso Academy

QUESTION 2

Define the type of the following destination addresses:

- (A) 4A:30:10:21:10:1A (B) 47:20:1B:2E:08:EE (C)FF:FF:FF:FF:FF:FF

SOLUTION

(A) 4A \Leftrightarrow 0100 1010 \Leftrightarrow 0100 1010 \Leftrightarrow Unicast Address.

(B) 47 \Leftrightarrow 0100 0111 \Leftrightarrow 0100 0111 \Leftrightarrow Multicast Address.

(C) All digits are 'F' so it is a Broadcast Address.

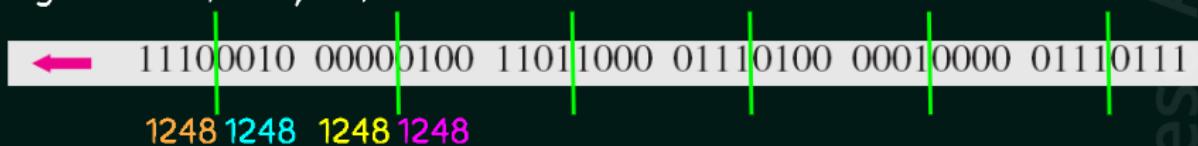
Question 2 \Leftrightarrow Neso Academy

QUESTION 3

Show how the address 47:20:1B:2E:08:EE is sent out on line.

SOLUTION

The address is sent left-to-right, byte by byte; for each byte, it is sent right-to-left, bit by bit, as shown below:



Question 3 Neso Academy

QUESTION 4

The address 43:7B:6C:DE:10:00 has been shown as the source address in an Ethernet frame. The receiver has discarded the frame. Why?

ANSWER:

The first byte in binary is 01000011.

The least significant bit is 1.

This means that the pattern defines a multicast address.

A multicast address can be a destination address, but not a source address.

Therefore, the receiver knows that there is an error, and discards the packet.

Question 4Neso Academy

QUESTION 1

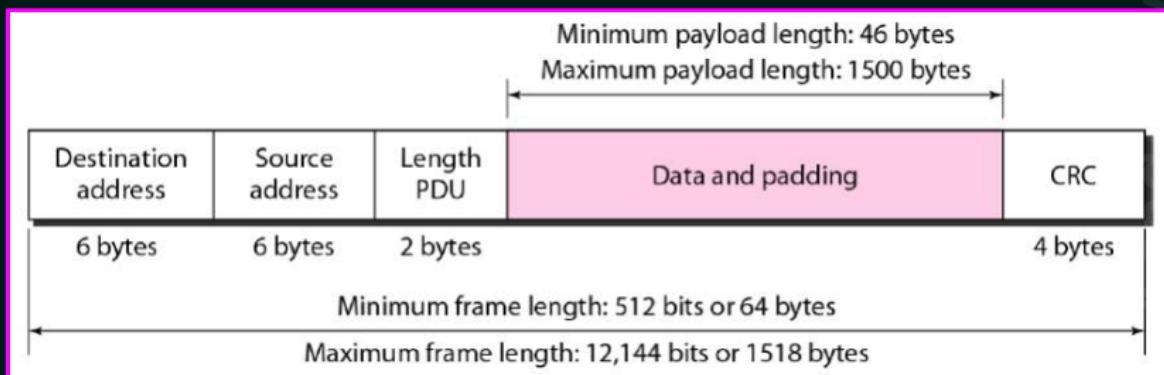
An Ethernet MAC sublayer receives 42 bytes of data from the upper layer.

How many bytes of padding must be added to the data?

ANSWER:

Question 1Neso Academy

ETHERNET FRAME – MIN AND MAX LENGTH



Frame length:

Minimum: 64 bytes (512 bits)

Maximum: 1518 bytes (12,144 bits)

Ethernet frame -Min and Max LengthNeso Academy

QUESTION 1

An Ethernet MAC sublayer receives 42 bytes of data from the upper layer.

How many bytes of padding must be added to the data?

ANSWER:

The minimum data size (Payload) in Ethernet is 46 bytes.

Therefore, we need to add 4 bytes of padding to the data so as to make the minimum data size of 46 bytes.

Question 1Neso Academy

QUESTION 2

An Ethernet MAC sublayer receives 1510 bytes of data from the upper layer. Can the data be encapsulated in one frame? If not, how many frames need to be sent? What is the size of the data in each frame?

ANSWER:

The maximum data size in the Standard Ethernet is 1500 bytes. The data of 1510 bytes, therefore, must be split between two frames. The standard dictates that the first frame must carry the maximum possible number of bytes (1500); the second frame then needs to carry only 10 bytes of data (it requires padding). The following shows the breakdown:

Data size for the first frame: 1500 bytes

Data size for the second frame: 46 bytes (with padding)

Question 2≤Neso Academy

QUESTION 3

What is the ratio of useful data to the entire packet for the smallest Ethernet frame? What is the ratio for the largest frame?

ANSWER:

The smallest Ethernet frame is 64 bytes and carries 46 bytes of data (and possible padding).

The largest Ethernet frame is 1518 bytes and carries 1500 bytes of data. The ratio is (data size) / (frame size) in percent.

We can then answer the question as follows:

Smallest Frame: Frame size = 64 & Data size = 46 Ratio \leq 71.875%

Largest Frame: Frame size = 1518 & Data size = 1500 Ratio = 98.814%

Question 3≤Neso Academy

QUESTION 4

The data rate of 10Base5 is 10 Mbps. How long does it take to create the smallest frame? Show the calculation.

ANSWER:

The smallest frame is 64 bytes or 512 bits. With a data rate of 10 Mbps, we have

$$\text{Transmission Delay} = \frac{\text{Message Size}}{\text{Bandwidth}}$$

$$\text{Transmission Delay} = \frac{512 \text{ bits}}{10 \text{ Mbps}}$$

$$\text{Transmission Delay} = \frac{512 \text{ bits}}{10 \times 1000 \times 1000 \text{ bps}}$$

$$\text{Transmission Delay} = 51.2 \mu \text{s}$$

Question 4Neso Academy

HOMEWORK!

Choose the correct pair from the following <address-size> pairs.

IPv4 – 32 bits			
IPv6 – 128 bits			
MAC – 40 bits	MAC – 48 bits	MAC – 48 bits	MAC – 46 bits
Port – 16 bits	Port – 32 bits	Port – 16 bits	Port – 16 bits
A	B	C	D

Homework!Neso Academy

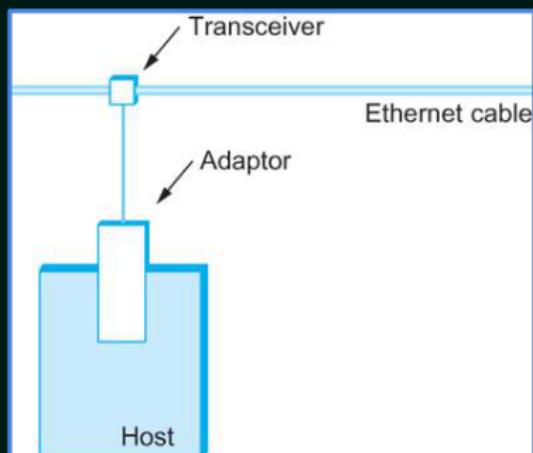
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the Ethernet Transmitter Algorithm.
- ★ Understand Runt Frames.
- ★ Know about Exponential backoff.

Outcomes ★★★ Neso Academy

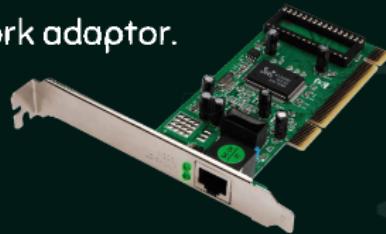
ETHERNET ADAPTOR



Ethernet Adaptor Neso Academy

ACCESS PROTOCOL FOR ETHERNET

The algorithm is commonly called Ethernet's Media Access Control (MAC) which is implemented in Hardware on the network adaptor.



Access Method of Ethernet: CSMA/CD

Encoding method: Manchester Encoding Technique for converting data bits into signals.

Access Protocol for EthernetNeso Academy

ETHERNET TRANSMITTER ALGORITHM

- ★ When the adaptor has a frame to send and the line is idle, it transmits the frame immediately.
- ★ The upper bound of 1500 bytes in the message means that the adaptor can occupy the line for a fixed length of time.
- ★ When the adaptor has a frame to send and the line is busy, it waits for the line to go idle and then transmits immediately.
- ★ The Ethernet is said to be CSMA 1-persistent protocol because an adaptor with a frame to send transmits with probability 1 whenever a busy line goes idle.

Ethernet Transmitter Algorithm★★★★Neso Academy

ETHERNET TRANSMITTER ALGORITHM

- ★ Since there is no centralized control it is possible for two (or more) adaptors to begin transmitting at the same time, either because both found the line to be idle, or, both had been waiting for a busy line to become idle.
- ★ When this happens, the two (or more) frames are said to be collide on the network.

Ethernet Transmitter Algorithm ★★ Neso Academy

ETHERNET TRANSMITTER ALGORITHM

- ★ Since Ethernet supports collision detection, each sender is able to determine that a collision is in progress.
- ★ At the moment an adaptor detects that its frame is colliding with another, it first makes sure to transmit a 32-bit jamming sequence and then stops transmission.
- ★ Thus, a transmitter will minimally send 96 bits in the case of collision 64-bit preamble + 32-bit jamming sequence.

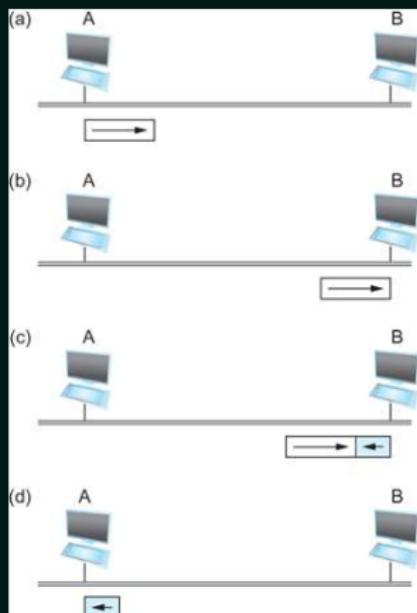
Ethernet Transmitter Algorithm ★★★ Neso Academy

RUNT FRAMES

- ★ A runt frame is an Ethernet frame that is less than the IEEE 802.3's minimum length of 64 bytes.
- ★ Runt frames are most commonly caused by collisions.
- ★ Other possible causes are a malfunctioning network card, buffer underrun, duplex mismatch or software issues.

Runt Frames★★★Neso Academy

ETHERNET TRANSMITTER ALGORITHM



Worst-case scenario:

- A sends a frame at time t .
- A's frame arrives at B at time $t + d$.
- B begins transmitting at time $t + d$ and collides with A's frame.
- B's runt (32-bit) frame arrives at A at time $t + 2d$.**

Ethernet Transmitter AlgorithmNeso Academy

EXPONENTIAL BACKOFF

- ★ Once an adaptor has detected a collision, and stopped its transmission, it waits a certain amount of time and tries again.
- ★ Each time the adaptor tries to transmit but fails, it doubles the amount of time it waits before trying again.
- ★ This strategy of doubling the delay interval between each retransmission attempt is known as **Exponential Backoff**.

Exponential Backoff★★★Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the pros of Ethernet.
- ★ Know the cons of Ethernet.
- ★ Know various categories of Ethernet cables.

★★★OutcomesNeso Academy

ETHERNET – PROS

- ★ Ethernet is the most widely used wired LAN technology.
- ★ Ethernet is relatively inexpensive.
- ★ In Ethernet, all the nodes have the same privileges. It does not follow client-server architecture.
- ★ Maintenance and administration are simple.
- ★ The cable used to connect systems in ethernet is robust to noise.
- ★ As it is robust to the noise, the quality of the data transfer does not degrade. The data transfer quality is good.
- ★ With latest versions such as gigabit ethernet, the transfer speeds in Gbps have become possible.

★★★★★Ethernet -ProsNeso Academy

ETHERNET – CONS

- ★ Under heavy loads, too much of the network's capacity is wasted by collisions.
- ★ It does not hold good for real-time applications and interactive applications.
- ★ As the network cannot set priority for the packets, it is not suitable for a client-server architecture.
- ★ For interactive applications, dummy data have to be fed to make the frame size 46B which is mandatory.
- ★ After receiving a packet, the receiver doesn't send any acknowledgement.

Ethernet -Cons★★★★★Neso Academy

ETHERNET CATS

CATEGORY	SHIELDING	MAX TRANSMISSION SPEED (AT 100 METERS)
Cat 3	Unshielded	10 Mbps
Cat 5	Unshielded	10/100 Mbps
Cat 5e	Unshielded	1000 Mbps / 1 Gbps
Cat 6	Shielded or Unshielded	1000 Mbps / 1 Gbps
Cat 6a	Shielded	10000 Mbps / 10 Gbps
Cat 7	Shielded	10000 Mbps / 10 Gbps
Cat 8	Shielded	Up to 40 Gbps

Ethernet catsNeso Academy

QUESTION

In an Ethernet local area network, which one of the following statements is TRUE ? [GATE CS 2016]

- (A) A station stops to sense the channel once it starts transmitting a frame. ✗
- (B) The purpose of the jamming signal is to pad the frames that are smaller than the minimum frame size. ✗
- (C) A station continues to transmit the packet even after the collision is detected. ✗
- (D) The exponential backoff mechanism reduces the probability of collision on retransmissions. ✓

✓ QuestionNeso Academy

QUESTION

Determine the maximum length of the cable (in km) for transmitting data at a rate of 500 Mbps in an Ethernet LAN with frames of size 10,000 bits. Assume the signal speed in the cable to be 2,00,000 km/s.

[GATE CS 2013]

- (A) 1
- (B) 2
- (C) 2.5
- (D) 5

QuestionNeso Academy

SOLUTION

Given Data:

Rate of transmission = 500 Mbps

Size = 10^4 bits

Signal speed = 2×10^5 km/sec

Solution:

Transmission time \geq round trip time of 1 bit

Transmission time $\geq 2 \times$ propagation time

Solution \geq Neso Academy

SOLUTION

Transmission time $\geq 2 \times$ propagation time

$$\text{Transmission time} = \frac{\text{Message Size}}{\text{Bandwidth}}$$

$$\text{Propagation time} = \frac{\text{Length}}{\text{Propagation Speed}}$$

$$\frac{\text{Message Size}}{\text{Bandwidth}} = \frac{2 \times \text{Length}}{\text{Propagation Speed}}$$

$$\frac{10^4 \text{ bits}}{500 \text{ Mbps}} \geq \frac{2 \times \text{Length}}{2 \times 10^5 \text{ Km/sec}}$$

SolutionNeso Academy

SOLUTION

$$\frac{10^4 \text{ bits}}{500 \text{ Mbps}} \geq \frac{2 \times L}{2 \times 10^5 \text{ Km/sec}}$$

$$\frac{10^4 \text{ bits}}{500 \text{ Mbps}} \geq \frac{L}{10^5 \text{ Km/sec}}$$

$$\frac{10^4 \text{ bits} \times 10^5 \text{ Km/sec}}{500 \text{ Mbps}} \geq L$$

$$\frac{10^4 \text{ bits} \times 10^5 \text{ Km/sec}}{500 \text{ Mbps}} \geq L$$

$$\frac{10^4 \text{ bits} \times 10^5 \text{ Km/sec}}{500 \times 10^6 \text{ bps}} \geq L$$

$$\frac{10^4 \text{ bits} \times 10^5 \text{ Km/sec}}{500 \times 10^6 \text{ bps}} \geq L$$

$$\frac{10^4 \text{ Km/sec}}{500 \times 10} \geq L$$

$$2 \text{ Km} \geq L$$

Solution≥Neso Academy

QUESTION

Determine the maximum length of the cable (in km) for transmitting data at a rate of 500 Mbps in an Ethernet LAN with frames of size 10,000 bits. Assume the signal speed in the cable to be 2,00,000 km/s.

[GATE CS 2013]

- (A) 1
- (B) 2 ✓
- (C) 2.5
- (D) 5

Question ✓ Neso Academy

QUESTION

A network with CSMA/CD protocol in the MAC layer is running at 1 Gbps over a 1 km cable with no repeaters. The signal speed in the cable is 2×10^8 m/sec. The minimum frame size for this network should be

[GATE CS 2005]

- (A) 10000 bits
- (B) 10000 bytes
- (C) 5000 bits
- (D) 5000 bytes

Question Neso Academy

SOLUTION

Given Data:

Rate of transmission = 1 Gbps

Length = 1 Km

Signal speed = 2×10^8 m/sec

Solution:

Transmission time \geq round trip time of 1 bit

Transmission time $\geq 2 \times$ propagation time

Solution \geq Neso Academy

SOLUTION

Transmission time $\geq 2 \times$ propagation time

$$\text{Transmission time} = \frac{\text{Message Size}}{\text{Bandwidth}}$$

$$\text{Propagation time} = \frac{\text{Length}}{\text{Propagation Speed}}$$

$$\frac{\text{Message Size}}{\text{Bandwidth}} \geq \frac{2 \times \text{Length}}{\text{Propagation Speed}}$$

$$\frac{\text{Message Size}}{1 \text{ Gbps}} \geq \frac{2 \times 1 \text{ Km}}{2 \times 10^8 \text{ m/sec}}$$

Solution Neso Academy

SOLUTION

$$\text{Message Size} \geq \frac{2 \times 1 \text{ Km} \times 10^9 \text{ bps}}{2 \times 10^8 \text{ m/sec}}$$

$$\text{Message Size} \geq \frac{2 \times 1 \times 10^3 \text{ m} \times 10^9 \text{ bps}}{2 \times 10^8 \text{ m/sec}}$$

$$\text{Message Size} \geq \frac{2 \times 1 \times 10^3 \times 10^9 \text{ bits}}{2 \times 10^8}$$

$$\text{Message Size} \geq 10^4 \text{ bits}$$

$$\boxed{\text{Message Size} \geq 10000 \text{ bits}}$$

Neso Academy

SolutionNeso Academy

QUESTION

A network with CSMA/CD protocol in the MAC layer is running at 1 Gbps over a 1 km cable with no repeaters. The signal speed in the cable is 2×10^8 m/sec. The minimum frame size for this network should be

[GATE CS 2005]

- (A) 10000 bits ✓
- (B) 10000 bytes
- (C) 5000 bits
- (D) 5000 bytes

Neso Academy

Question ✓ Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know about IEEE 802.11 Wi-Fi.
- ★ Know the access method of Wi-Fi.
- ★ See Wi-Fi adaptors.
- ★ Understand the modes of Wi-Fi.
- ★ Know different Wi-Fi protocols.

★★★★★ Outcomes Neso Academy

ANALOGY



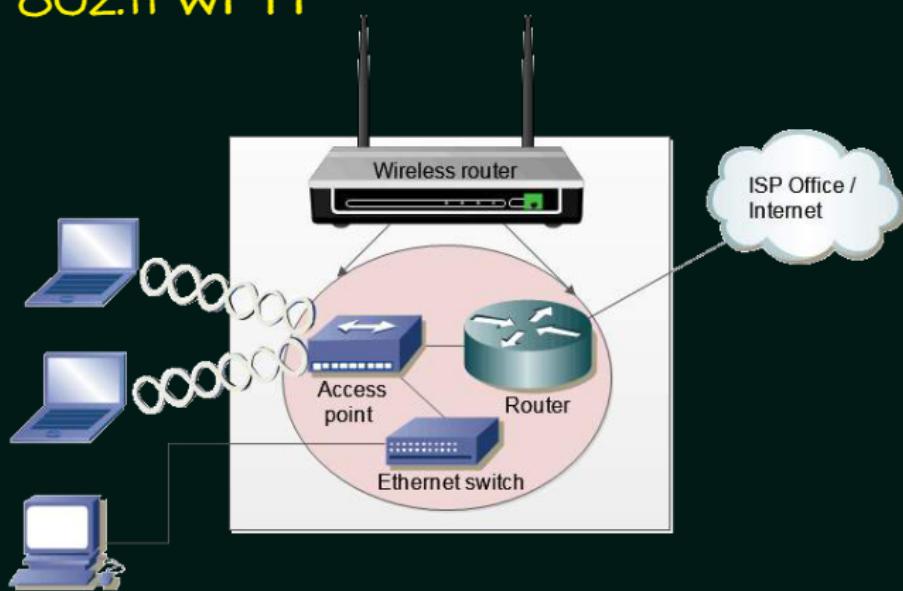
Analogy Neso Academy

IEEE 802.11 Wi-Fi

- ★ Also known as Wireless Fidelity (Wi-Fi).
- ★ Like its Ethernet and token ring siblings, 802.11 is designed for use in a limited geographical area (homes, office buildings, campuses).
- ★ Primary challenge is to mediate access to a shared communication medium – in this case, signals propagating through space.
- ★ 802.11 supports additional features:
 - power management and
 - security mechanisms

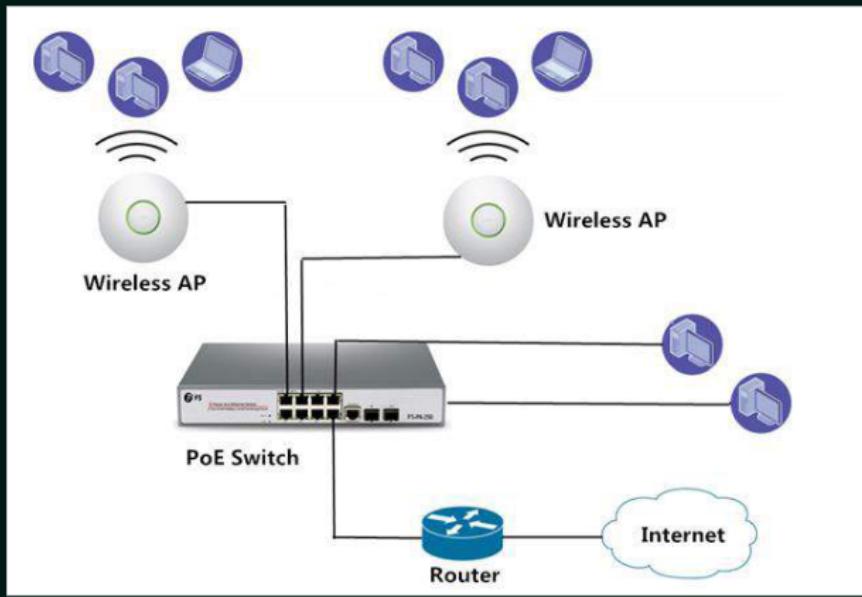
IEEE 802.11 Wi-Fi ★★★★○ Neso Academy

IEEE 802.11 Wi-Fi



IEEE 802.11 Wi-Fi Neso Academy

IEEE 802.11 Wi-Fi



Neso Academy

IEEE 802.11 Wi-Fi Neso Academy

IEEE 802.11 Wi-Fi

- ★ 802.11 uses 5 GHz Radio Band (High Frequency) which has 23 overlapping channels rather than the 2.4 GHz frequency band which has only three non-overlapping channels.

Access Method of IEEE 802.11 Wi-Fi: CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)

Neso Academy

IEEE 802.11 Wi-Fi ★Neso Academy

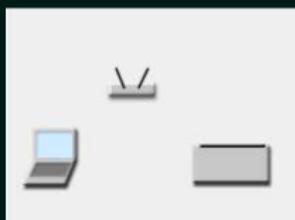
Wi-Fi ADAPTOR



Wi-Fi Adaptor Neso Academy

MODES OF Wi-Fi

- ★ Infrastructure mode



- ★ Ad hoc and Wi-Fi Direct

This wireless ad hoc network mode has proven popular with multiplayer handheld game consoles, such as the Nintendo DS, PlayStation Portable, digital cameras, and other consumer electronics devices.

Modes of Wi-Fi ★★ Neso Academy

DIFFERENT WI-FI PROTOCOLS

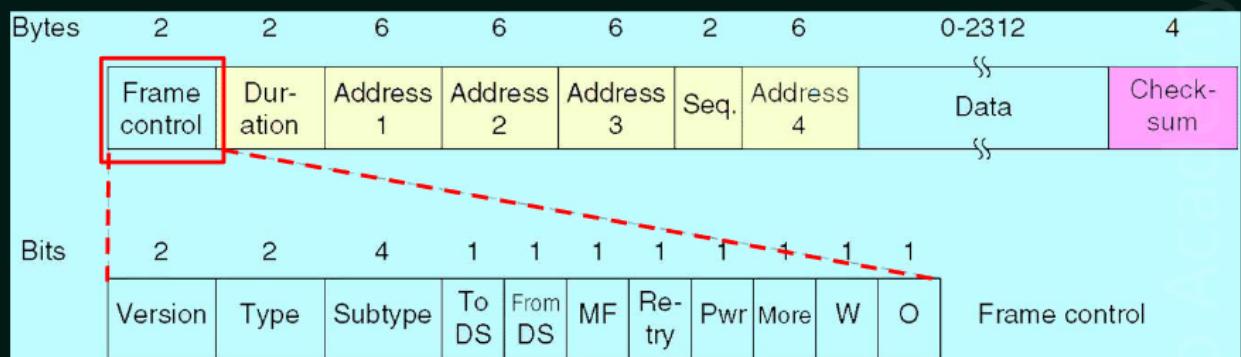
Protocol	Frequency	Channel Width	Maximum data rate (theoretical)
802.11ax	2.4 or 5GHz	20, 40, 80, 160MHz	2.4 Gbps
802.11ac wave2	5 GHz	20, 40, 80, 160MHz	1.73 Gbps
802.11ac wave1	5 GHz	20, 40, 80MHz	866.7 Mbps
802.11n	2.4 or 5 GHz	20, 40MHz	450 Mbps
802.11g	2.4 GHz	20 MHz	54 Mbps
802.11a	5 GHz	20 MHz	54 Mbps
802.11b	2.4 GHz	20 MHz	11 Mbps
Legacy 802.11	2.4 GHz	20 MHz	2 Mbps



Neso Academy

Different Wi-Fi protocols Neso Academy

IEEE 802.11 WI-FI FRAME FORMAT

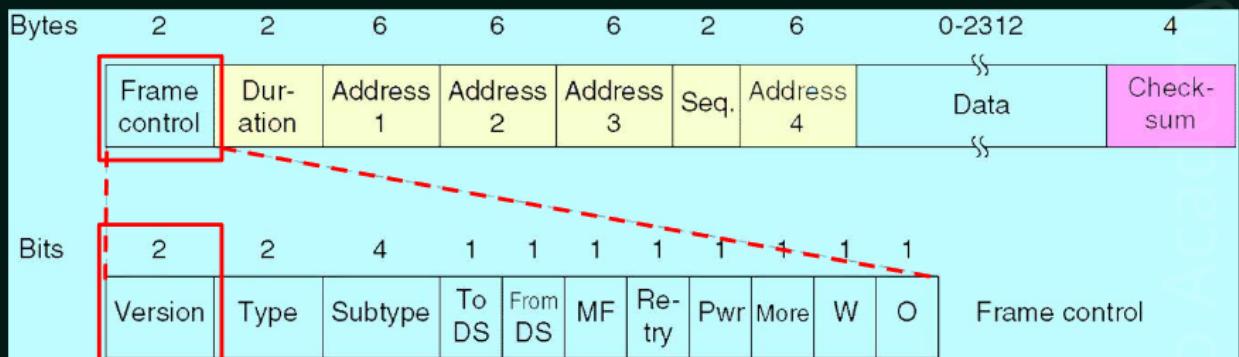


Frame Control:

- ★ It is a 2 bytes starting field composed of 11 subfields. It contains control information of the frame.
- ★ It has 11 subfields.

IEEE 802.11 Wi-Fi Frame Format ★★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

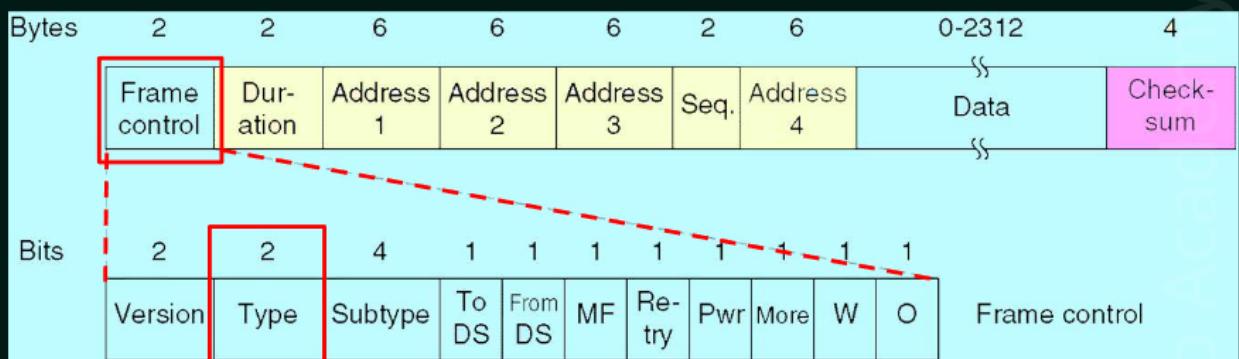


Protocol Version:

- ★ The first sub-field is a two – bit field set to 00. It has been included to allow future versions of IEEE 802.11 to operate simultaneously.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

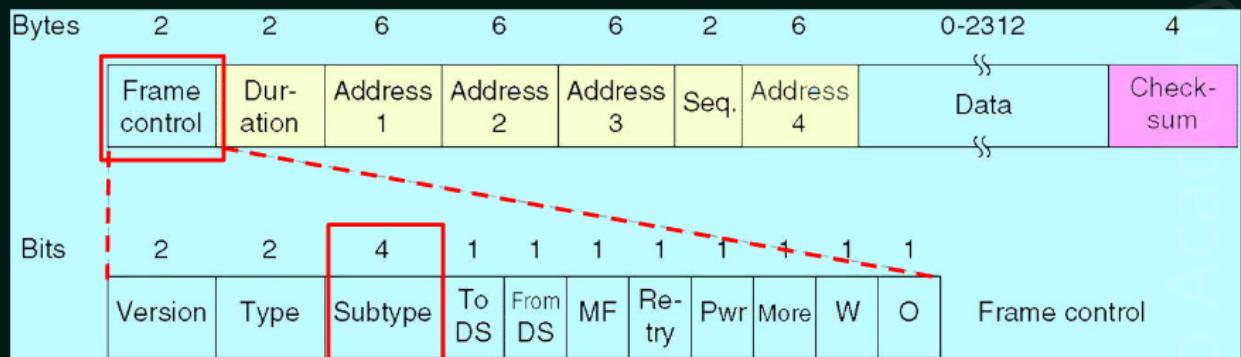


Type:

- ★ It is a two-bit subfield that specifies whether the frame is a data frame, control frame or a management frame.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

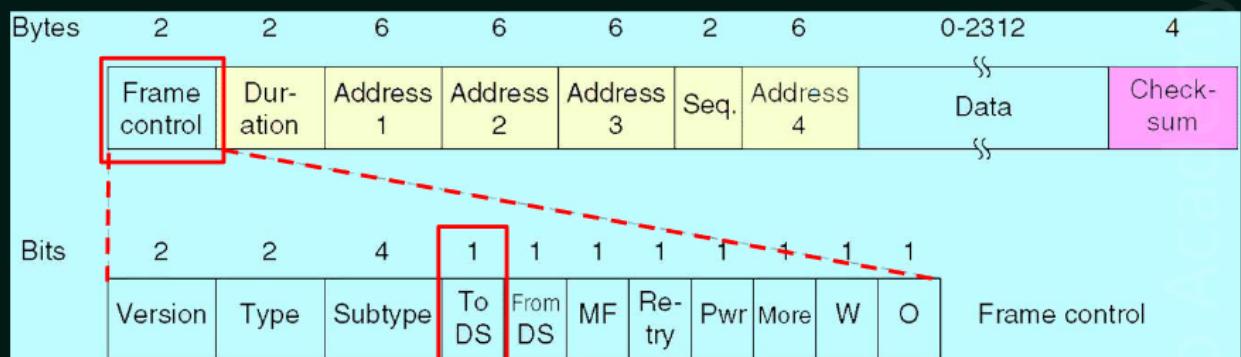


Subtype:

- ★ It is a four - bit subfield states whether the field is a Request to Send (RTS) or a Clear to Send (CTS) control frame. For a regular data frame, the value is set to 0000.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

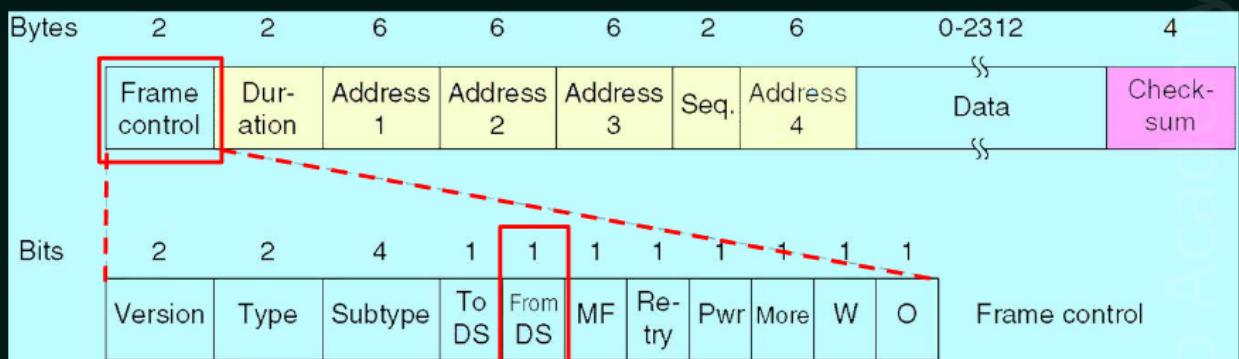


To DS:

- ★ A single bit subfield indicating whether the frame is going to the access point (AC), which coordinates the communications in centralised wireless systems.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

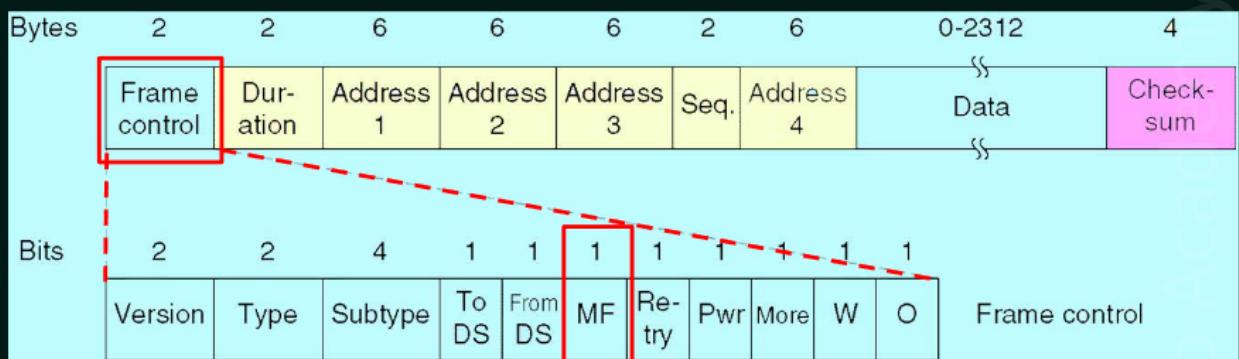


From DS:

- ★ A single bit subfield indicating whether the frame is coming from the Access point.

IEEE 802.11 Wi-Fi Frame Format ★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

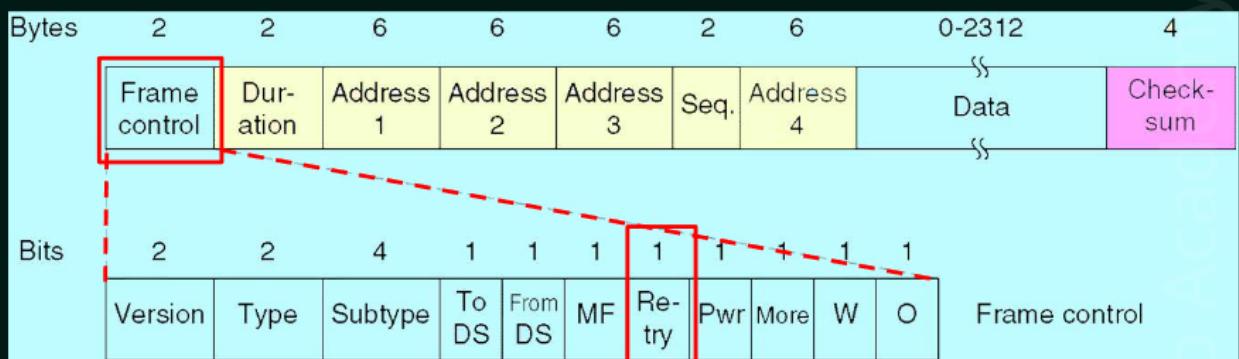


More Fragments:

- ★ A single bit subfield which when set to 1 indicates that more fragments would follow.

IEEE 802.11 Wi-Fi Frame Format ★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

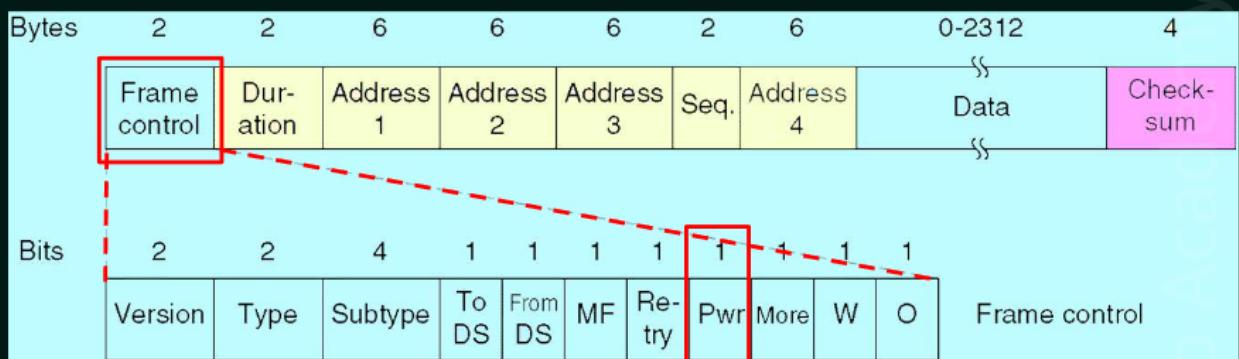


Retry:

- ★ A single bit subfield which when set to 1 specifies a retransmission of a previous frame.

IEEE 802.11 Wi-Fi Frame Format ★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

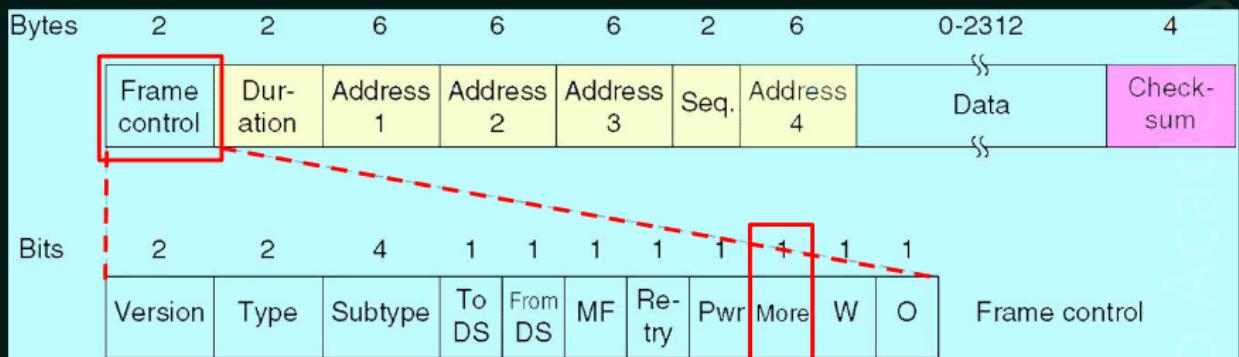


Power Management:

- ★ A single bit subfield indicating that the sender is adopting power-save mode.

IEEE 802.11 Wi-Fi Frame Format ★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

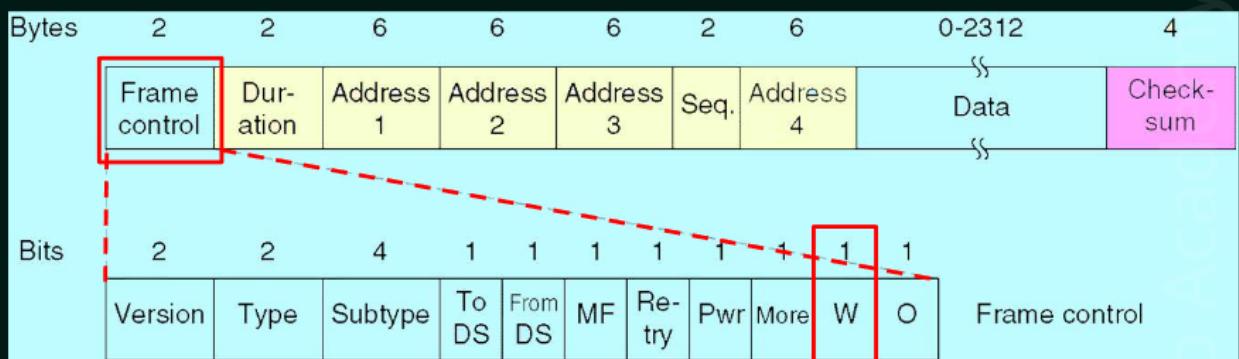


More Data:

- ★ A single bit subfield showing that sender has further data frames for the receiver.

IEEE 802.11 Wi-Fi Frame Format ★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

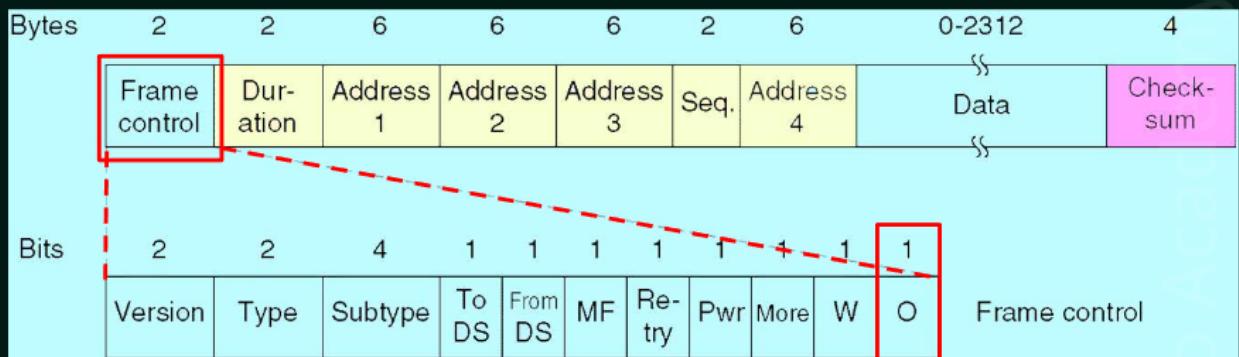


WEP:

- ★ A single bit subfield indicating that this is an encrypted frame.

IEEE 802.11 Wi-Fi Frame Format ★ Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

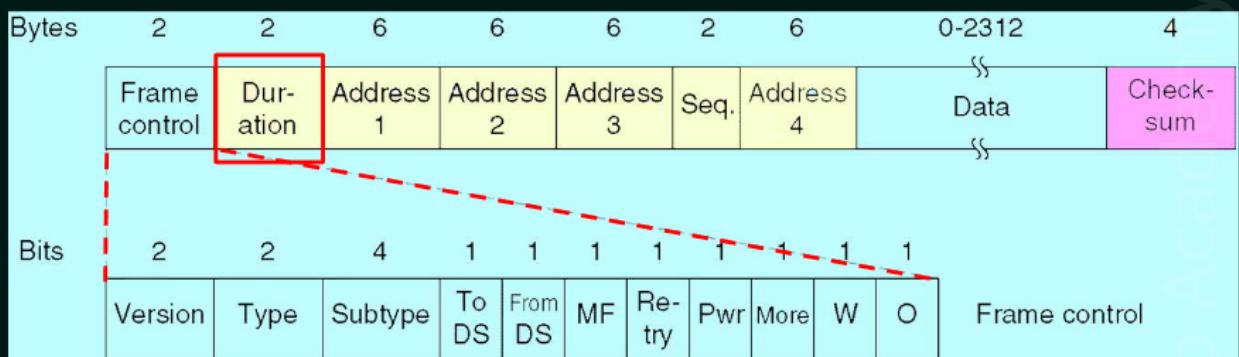


Order:

- ★ The last subfield, of one – bit, informs the receiver that to the higher layers the frames should be in an ordered sequence.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

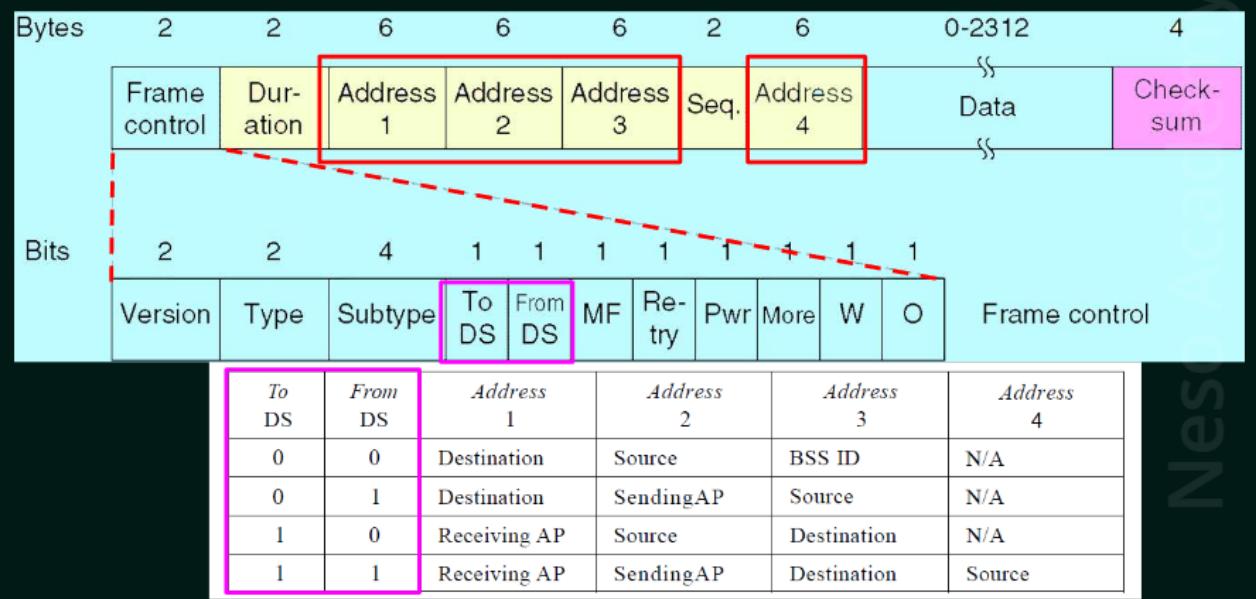


Duration:

- ★ It is a 2-byte field that specifies the time period for which the frame and its acknowledgement occupy the channel.

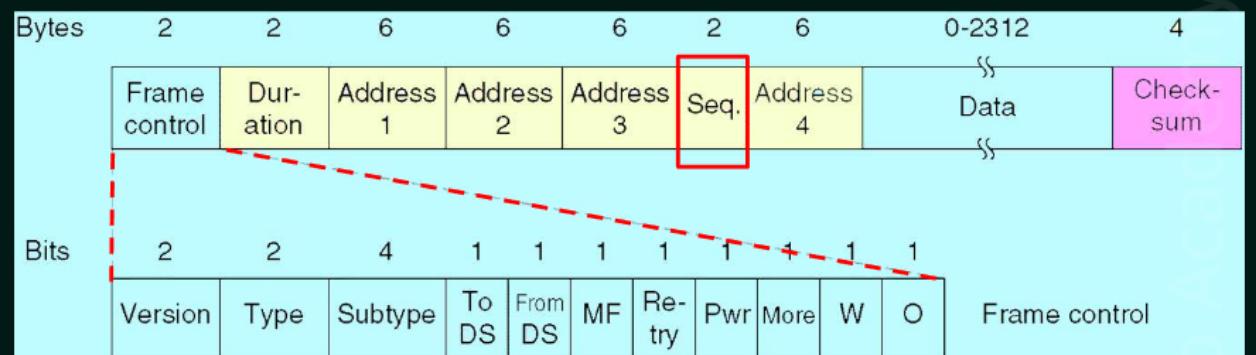
IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT



IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

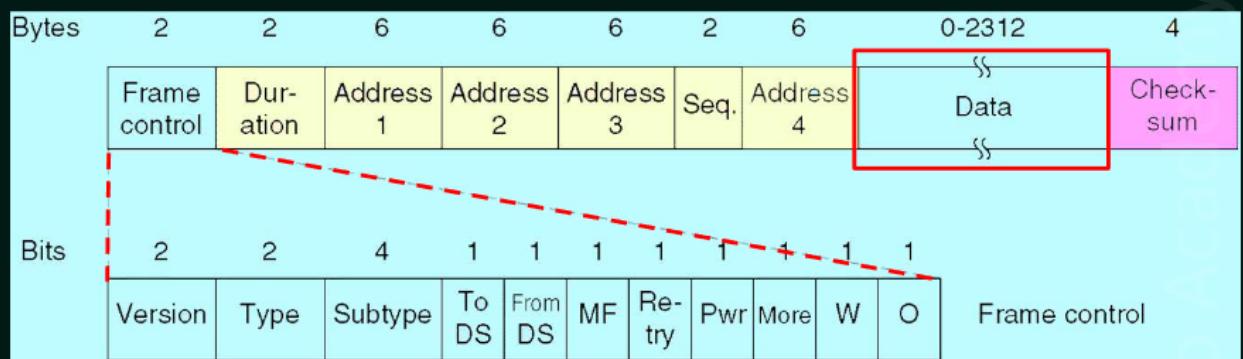


Sequence:

- ★ It a 2 bytes field that stores the frame numbers. It detects duplicate frames and determines the order of frames for higher layers. Among the 16 bits, the first 4 bits provides identification to the fragment and the rest 12 bits contain the sequence number that increments with each transmission.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT

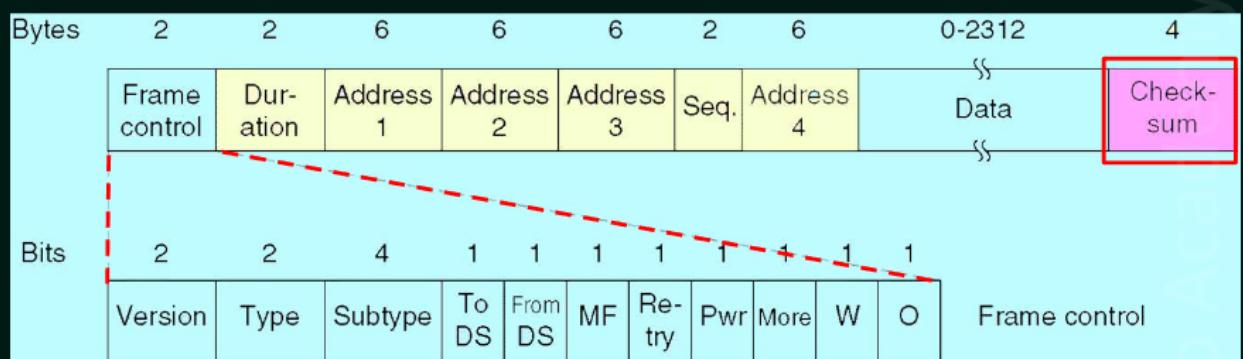


Data:

- ★ This is a variable sized field that carries the payload from the upper layers. The maximum size of data field is 2312 bytes.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

IEEE 802.11 Wi-Fi FRAME FORMAT



Checksum:

- ★ It is a 4-byte field for error detection purpose.

IEEE 802.11 Wi-Fi Frame Format★Neso Academy

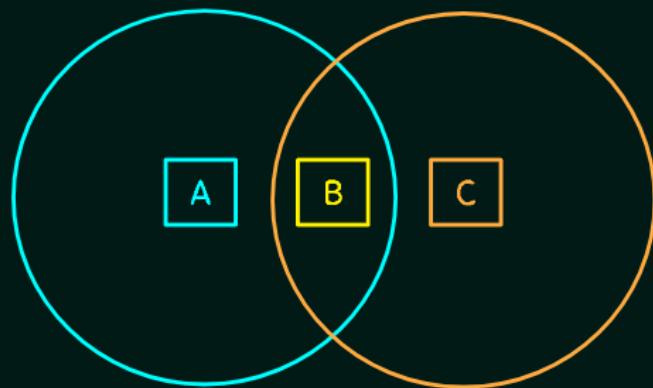
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the hidden terminal problem.
- ★ Know the solution for hidden terminal problem.

★★OutcomesNeso Academy

HIDDEN TERMINAL PROBLEM



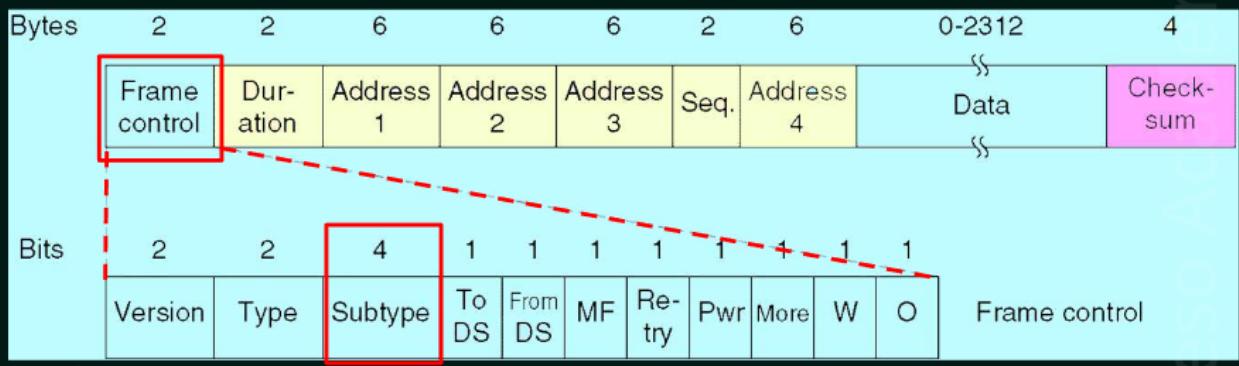
Suppose both A and C want to communicate with B and so they each send it a frame.

- ★ A and C are unaware of each other since their signals do not carry that far.
- ★ These two frames collide with each other at B (But unlike an Ethernet, neither A nor C is aware of this collision).
- ★ A and C are said to be hidden nodes with respect to each other.

Hidden Terminal Problem★★★Neso Academy

HIDDEN TERMINAL PROBLEM – SOLUTION

Multiple Access Collision Avoidance (MACA) Algorithm – RTS and CTS frames



Subtype:

- ★ It is a four – bit subfield states whether the field is a Request to Send (RTS) or a Clear to Send (CTS) control frame. For a regular data frame, the value is set to 0000.

Hidden Terminal Problem -Solution★Neso Academy

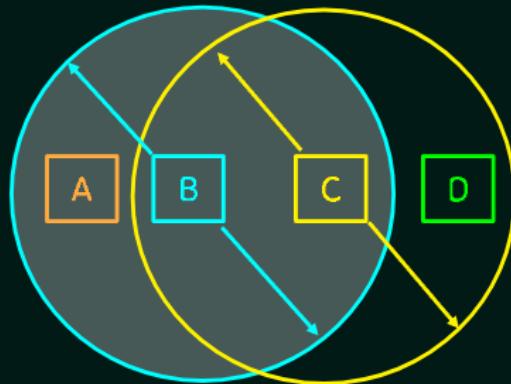
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the exposed terminal problem.
- ★ Know the solution for exposed terminal problem.

★★OutcomesNeso Academy

EXPOSED TERMINAL PROBLEM



Suppose B is sending to A. Node C is aware of this communication because it hears B's transmission.

- ★ It would be a mistake for C to conclude that it cannot transmit to anyone just because it can hear B's transmission.
- ★ Suppose C wants to transmit to node D.
- ★ This is not a problem since C's transmission to D will not interfere with A's ability to receive from B.

Exposed Terminal Problem ★★★ Neso Academy

EXPOSED TERMINAL PROBLEM – SOLUTION

Multiple Access Collision Avoidance (MACA) Algorithm – RTS and CTS frames

Bytes	2	2	6	6	6	2	6	0-2312	4
Bits	Frame control	Dur- ation	Address 1	Address 2	Address 3	Seq.	Address 4	Data	Check- sum
Bits	2	2	4	1	1	1	1	1	1
Subtype:									Frame control
Version Type Subtype To DS From DS MF Retry Pwr More W O									Frame control

- ★ It is a four-bit subfield states whether the field is a Request to Send (RTS) or a Clear to Send (CTS) control frame. For a regular data frame, the value is set to 0000.

Exposed Terminal Problem -Solution ★ Neso Academy

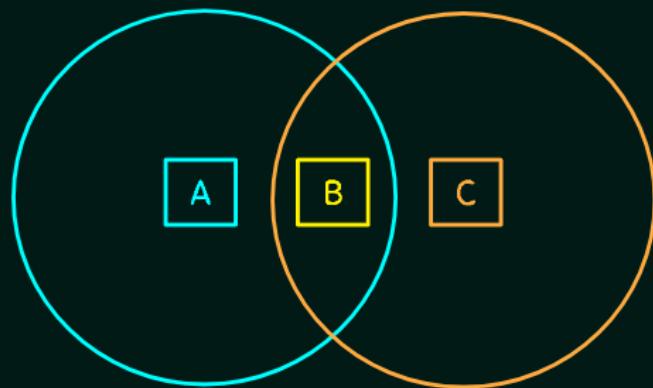
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Recall hidden terminal and exposed terminal problem.
- ★ Understand the MACA algorithm.

★★OutcomesNeso Academy

HIDDEN TERMINAL PROBLEM

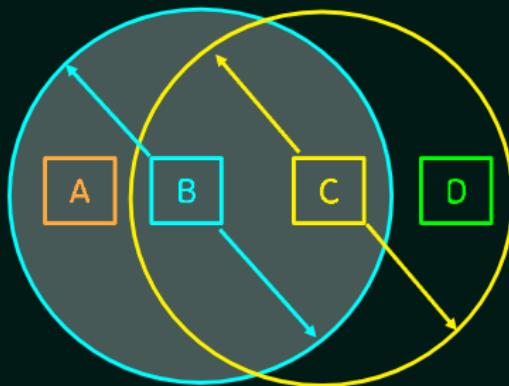


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Hidden Terminal Problem★★★Neso Academy

EXPOSED TERMINAL PROBLEM



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Exposed Terminal Problem ★★★ Neso Academy

IEEE 802.11 – COLLISION AVOIDANCE

- ★ 802.11 addresses these two problems with an algorithm called Multiple Access with Collision Avoidance (MACA).

Key Idea

- ★ Sender and receiver exchange control frames with each other before the sender actually transmits any data.
- ★ This exchange informs all nearby nodes that a transmission is about to begin.
- ★ Sender transmits a **Request to Send (RTS)** frame to the receiver.
 - The RTS frame includes a field that indicates how long the sender wants to hold the medium. Length of the data frame to be transmitted.
- ★ Receiver replies with a **Clear to Send (CTS)** frame
 - This frame echoes this length field back to the sender

IEEE 802.11 -Collision Avoidance ★★★★○★○ Neso Academy

IEEE 802.11 – COLLISION AVOIDANCE

- ★ Any node that sees the CTS frame knows that
 - it is close to the receiver, therefore
 - cannot transmit for the period of time it takes to send a frame of the specified length
- ★ Any node that sees the RTS frame but not the CTS frame
 - is not close enough to the receiver to interfere with it, and
 - so is free to transmit

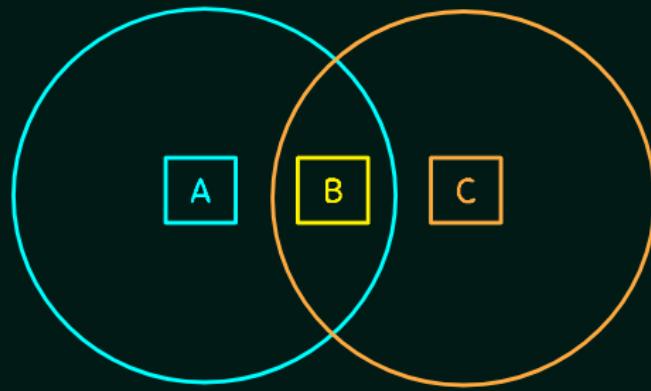
IEEE 802.11 -Collision Avoidance ★○○★○○Neso Academy

IEEE 802.11 – COLLISION AVOIDANCE

- ★ The idea of using ACK in MACA is Proposed in **MACAW: MACA for Wireless LANs**.
- ★ Receiver sends an ACK to the sender after successfully receiving a frame.
- ★ All nodes must wait for this ACK before trying to transmit.
- ★ If two or more nodes detect an idle link and try to transmit an RTS frame at the same time
 - ★ Their RTS frame will collide with each other
- ★ **802.11 does not support collision detection**
 - ★ So the senders realize the collision has happened when they do not receive the CTS frame after a period of time
 - ★ In this case, they each wait a random amount of time before trying again.
 - ★ The amount of time a given node delays is defined by the same **exponential backoff algorithm** used on the Ethernet.

IEEE 802.11 -Collision Avoidance ★★★★★★★★★Neso Academy

HIDDEN TERMINAL PROBLEM

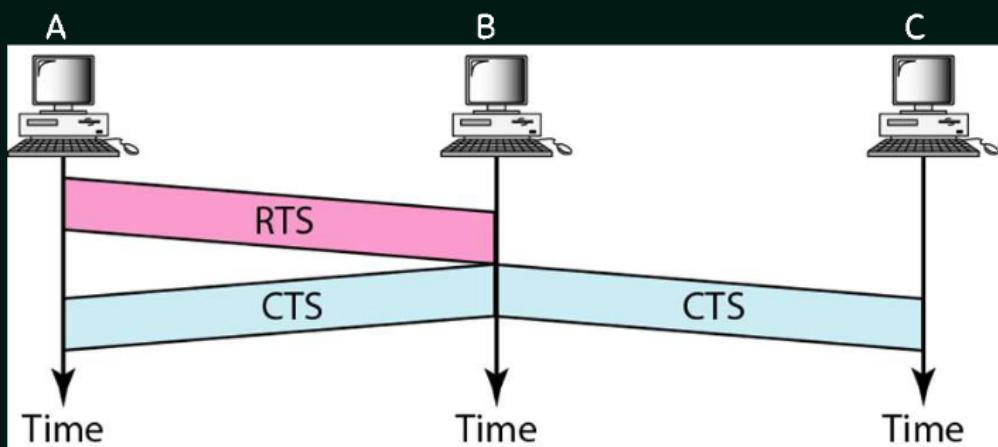


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Hidden Terminal Problem ★★★ Neso Academy

USE OF RTS/CTS HANDSHAKING



Station C doesn't hear RTS from A, but it does hear CTS from B, so it knows something is up.

Use of RTS/CTS handshaking Neso Academy

QUESTION

For the IEEE 802.11 MAC protocol for wireless communication, which of the following statements is/are TRUE?

- I. At least three non-overlapping channels are available for transmissions.
- II. The RTS-CTS mechanism is used for collision detection.
- III. Unicast frames are ACKed.

[GATE CS 2016]

- (A) All I, II, and III
- (B) I and III only ✓
- (C) II and III only
- (D) II only

Question ✓ Neso Academy

HOMEWORK

Which of the following statements is TRUE about CSMA/CD.

- (A) IEEE 802.11 wireless LAN runs CSMA/CD protocol
- (B) Ethernet is not based on CSMA/CD protocol
- (C) CSMA/CD is not suitable for a high propagation delay network like satellite network
- (D) There is no contention in a CSMA/CD network

[GATE CS 2005]

Homework Neso Academy

QUESTION

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[GATE CS 2005]

QuestionNeso Academy

ANSWER

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- (D) There is no contention in a CSMA/CD network.

[GATE CS 2016]

AnswerNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the basics of bluetooth.
- ★ Understand piconet and scatternet.
- ★ See the bluetooth adaptors.
- ★ Understand the pros and cons of bluetooth.
- ★ Know about bluesnarfing.

Outcomes ★★★★ Neso Academy



BLUETOOTH

- ★ Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using short-wavelength UHF radio waves in the ISM radio bands, from 2.400 to 2.485 GHz, and building personal area networks (PANs).
- ★ It was originally conceived as a wireless alternative to RS-232 data cables.
- ★ Bluetooth is a wireless technology named after Harald Bluetooth, based on an analogy that Bluetooth technology would unite devices the way Harald Bluetooth united the tribes of Denmark into a single kingdom.

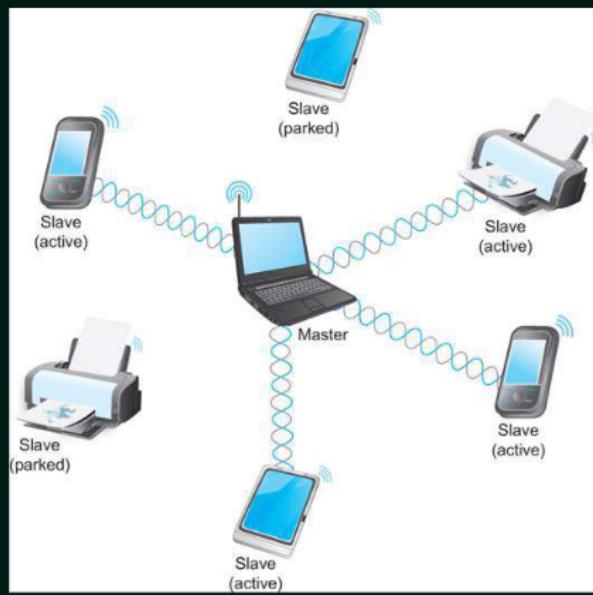
Bluetooth★★★Neso Academy

BLUETOOTH

- ★ Bluetooth is specified by an industry consortium called the Bluetooth Special Interest Group.
- ★ It specifies an entire suite of protocols, going beyond the link layer to define application protocols, which it calls profiles, for a range of applications.
 - There is a profile for synchronizing a PDA with personal computer.
 - Another profile gives a mobile computer access to a wired LAN.
- ★ The basic Bluetooth network configuration is called a **piconet**.

Bluetooth★★○○★Neso Academy

AN EXAMPLE BLUETOOTH PICONET



An example bluetooth piconet Neso Academy

BLUETOOTH

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- ★ The basic Bluetooth network configuration is called a **piconet**.
 - Consists of a master device and up to seven slave devices.
 - Any communication is between the master and a slave.
 - The slaves do not communicate directly with each other.

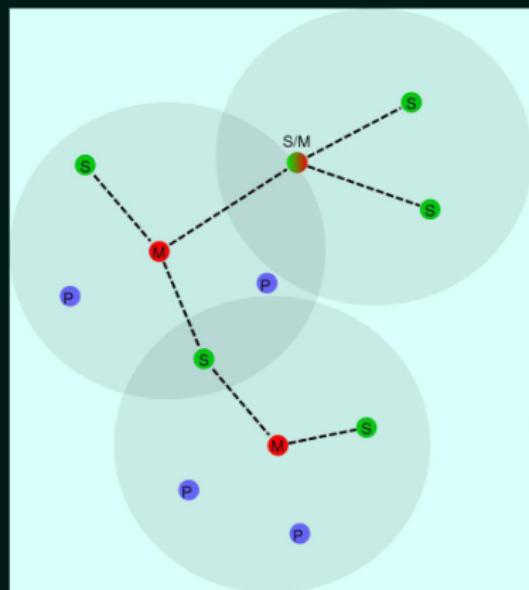
Bluetooth ★★★○○★★○○ Neso Academy

BLUETOOTH

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- ★ The basic Bluetooth network configuration is called a **piconet**.
 - Consists of a master device and up to seven slave devices.
 - Any communication is between the master and a slave.
 - The slaves do not communicate directly with each other.
 - A slave can be parked: set to an inactive, low-power state.

Bluetooth ★★★○○●○○○ Neso Academy

PICONET AND SCATTERNET



Piconet and Scatternet Neso Academy

BLUETOOTH DEVICES



Bluetooth Devices Neso Academy

PROS

- ★ Low cost.
- ★ Easy to use.
- ★ It can also penetrate through walls.
- ★ It creates an ad-hoc connection immediately without any wires.
- ★ It is used for voice and data transfer.

Pros ★★★★★ Neso Academy

CONS

- ★ It can be hacked and hence, less secure.
- ★ It has slow data transfer rate.
- ★ It has small range: 10 meters.

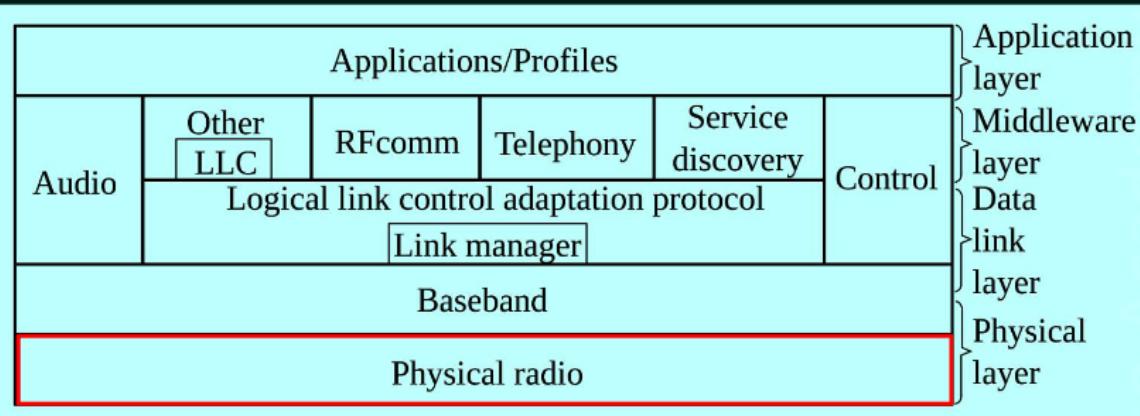
Cons★★★Neso Academy

BLUESNARFING

- ★ Bluesnarfing is the unauthorized access of information from a wireless device through a Bluetooth connection, often between phones, desktops, laptops, and PDAs.
- ★ This allows access to calendars, contact lists, emails and text messages, and on some phones, users can copy pictures and private videos.
- ★ Bluesnarfing is the theft of information from the target device.

Bluesnarfing★★★Neso Academy

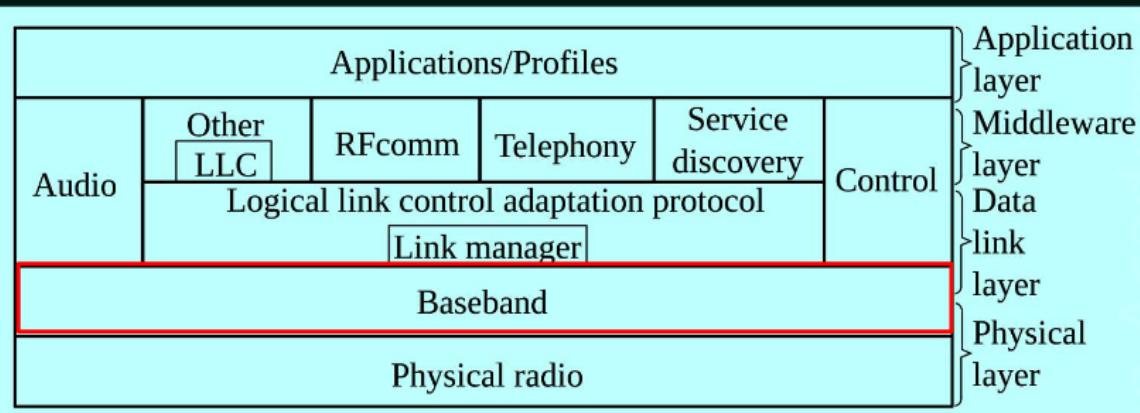
BLUETOOTH PROTOCOL STACK



Physical Radio (RF) layer: It performs modulation/demodulation of the data into RF signals. It defines the physical characteristics of bluetooth transceiver. It defines two types of physical link: connection-less and connection-oriented.

Bluetooth protocol stackNeso Academy

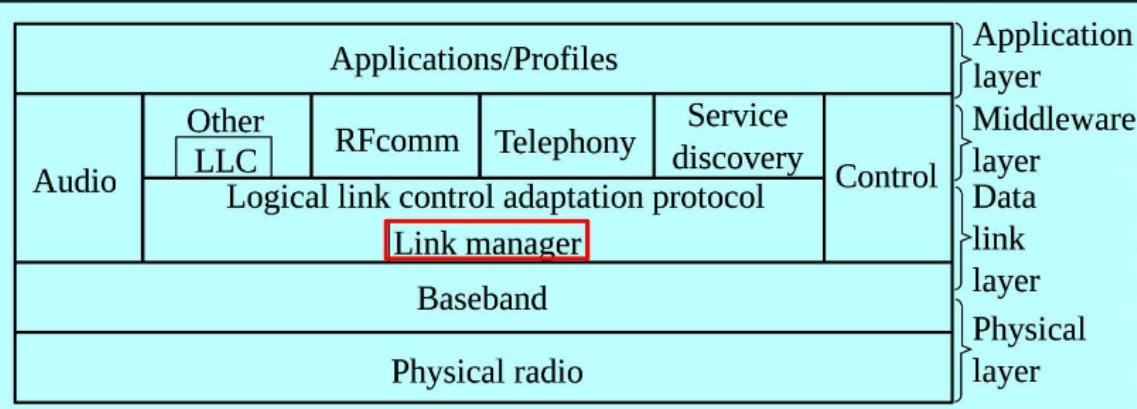
BLUETOOTH PROTOCOL STACK



Baseband Link layer: It performs the connection establishment within a piconet.

Bluetooth protocol stackNeso Academy

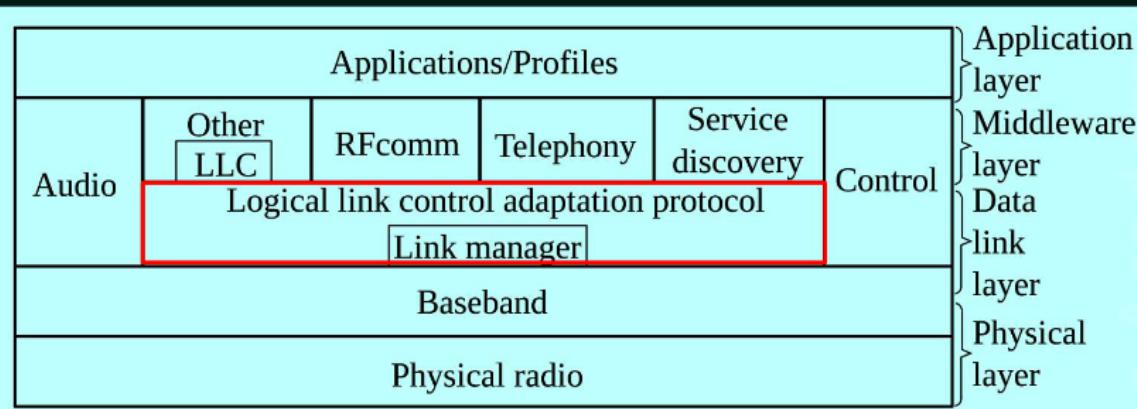
BLUETOOTH PROTOCOL STACK



Link Manager protocol layer: It performs the management of the already established links. It also includes authentication and encryption processes.

Bluetooth protocol stackNeso Academy

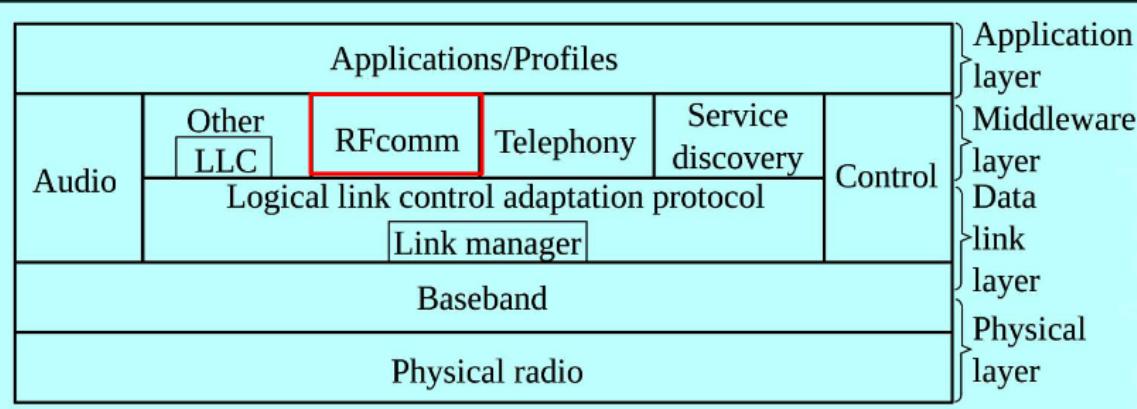
BLUETOOTH PROTOCOL STACK



Logical Link Control and Adaptation protocol layer: It is also known as the heart of the bluetooth protocol stack. It allows the communication between upper and lower layers of the bluetooth protocol stack. It packages the data packets received from upper layers into the form expected by lower layers. It also performs the segmentation and multiplexing.

Bluetooth protocol stackNeso Academy

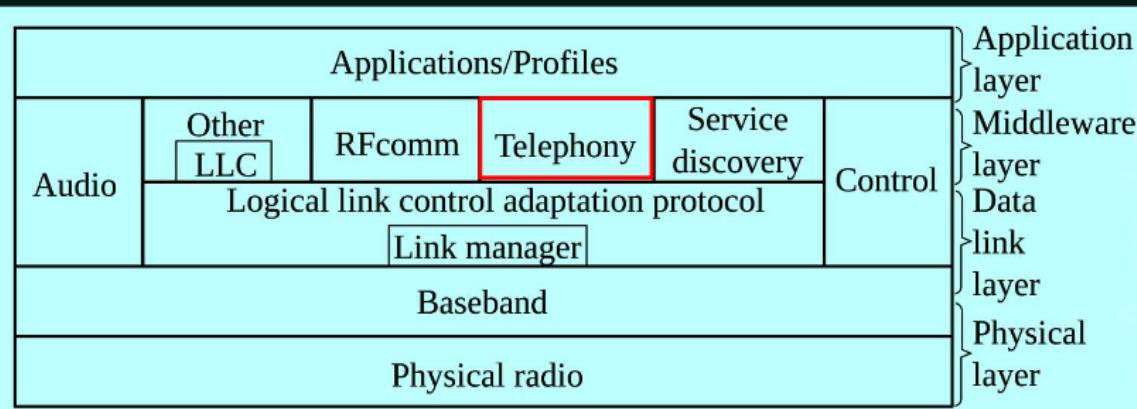
BLUETOOTH PROTOCOL STACK



RF comm layer: It is short for Radio Frontend Component. It provides serial interface with WAP and OBEX.

Bluetooth protocol stackNeso Academy

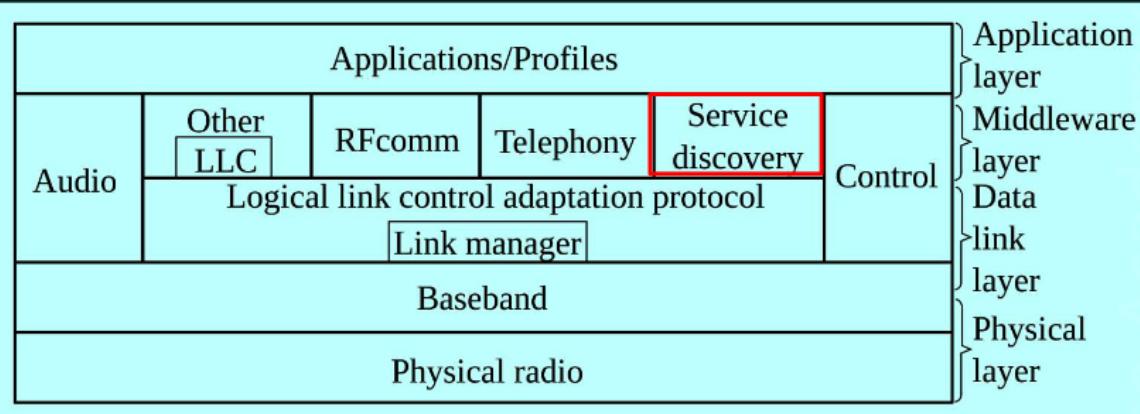
BLUETOOTH PROTOCOL STACK



TCS: It is short for Telephony Control Protocol. It provides telephony service.

Bluetooth protocol stackNeso Academy

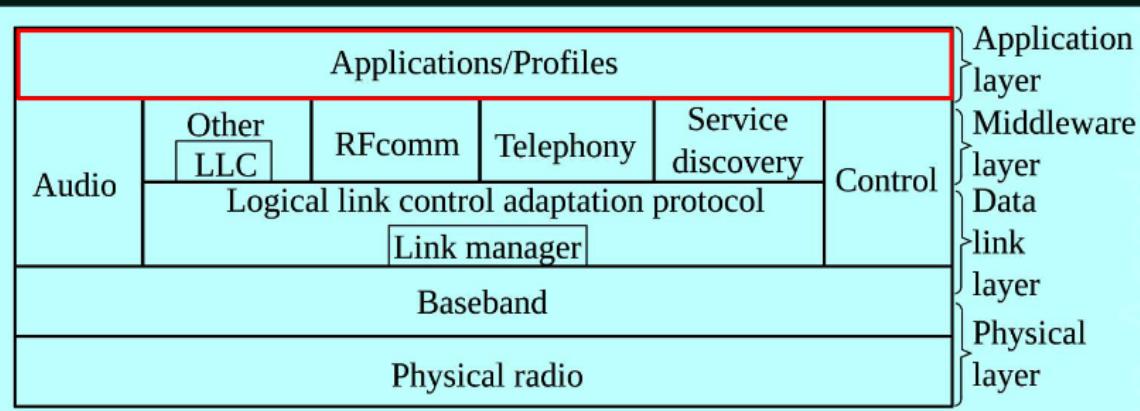
BLUETOOTH PROTOCOL STACK



SDP layer: It is short for Service Discovery Protocol. It allows to discover the services available on another bluetooth enabled device.

Bluetooth protocol stackNeso Academy

BLUETOOTH PROTOCOL STACK



Application layer: It enables the user to interact with the application.

Bluetooth protocol stackNeso Academy

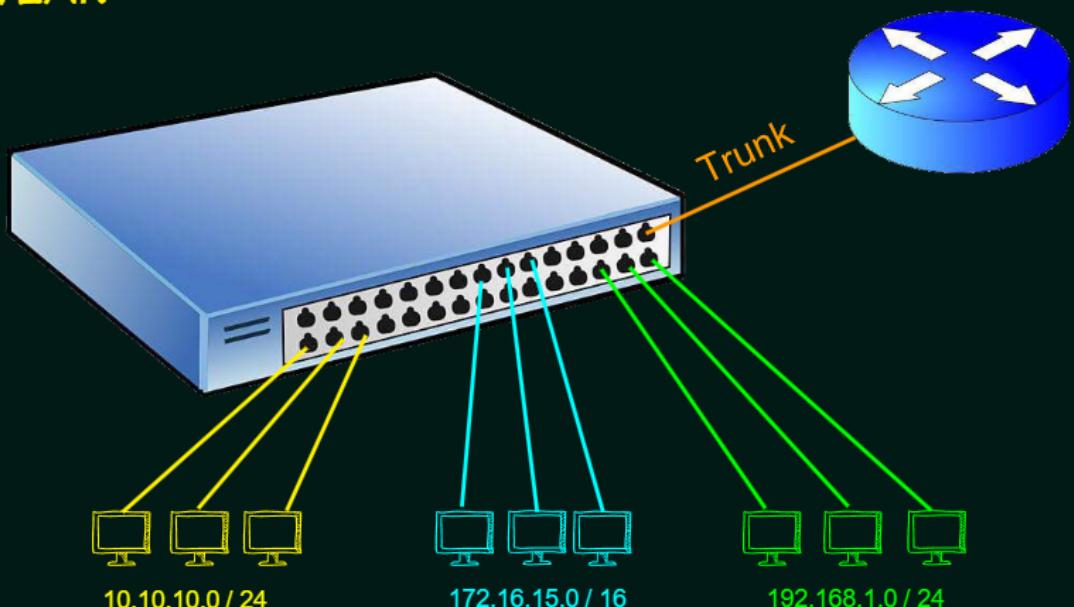
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the need for VLAN.
- ★ Working of VLAN.
- ★ Benefits of VLAN.
- ★ Types of VLAN.
- ★ VLAN Frame Tagging.

Outcomes ★★★★ Neso Academy

VLAN



10.10.10.0 / 24 192.168.1.0 / 24 172.16.15.0 / 16 VLAN Neso Academy

VLAN

- ★ A VLAN is a logical partition of a Layer 2 network.
- ★ Multiple partitions can be created, allowing for multiple VLANs to co-exist.
- ★ Each VLAN is a broadcast domain, usually with its own IP network.
- ★ VLANs are mutually isolated and packets can only pass between them via a router.
- ★ The partitioning of the Layer 2 network takes place inside a Layer 2 device, usually via a switch.
- ★ The hosts grouped within a VLAN are unaware of the VLAN's existence.

VLAN★★★★★Neso Academy

VLAN



VLANNeso Academy

BENEFITS OF VLAN

- ★ Security.
- ★ Cost reduction.
- ★ Better performance.
- ★ Shrink broadcast domains.
- ★ Improved IT staff efficiency.
- ★ Simpler project and application management.

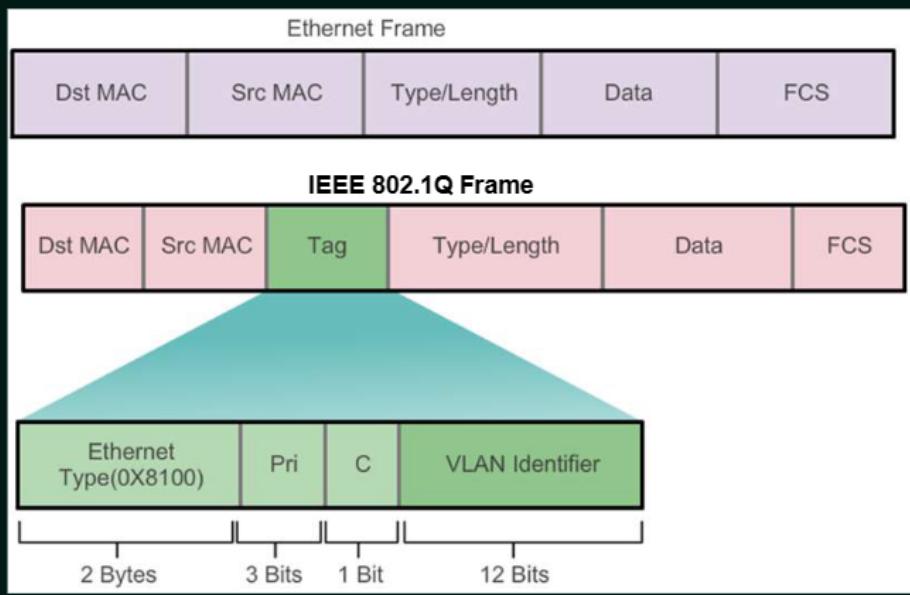
Benefits of VLAN★★★★★Neso Academy

TYPES OF VLAN

- ★ Data VLAN
- ★ Default VLAN
- ★ Native VLAN
- ★ Management VLAN
- ★ Voice VLAN

Types of VLAN★★★★★Neso Academy

VLAN FRAME TAGGING



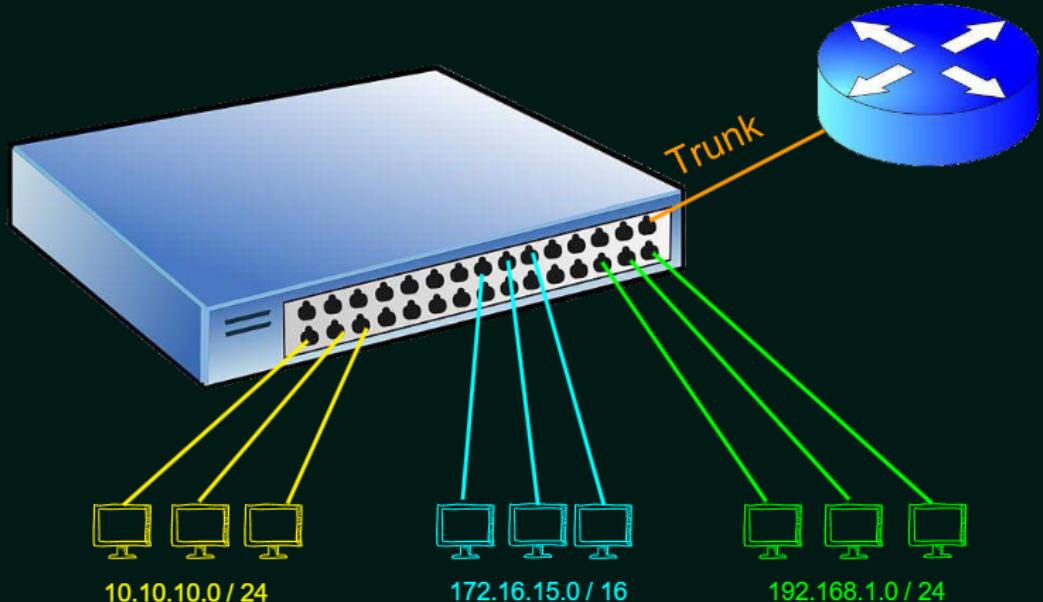
VLAN Frame Tagging|IEEE 802.1Q Frame|Neso Academy

VLAN FRAME TAGGING

- ★ Frame tagging is the process of adding a VLAN identification header to the frame.
- ★ It is used to properly transmit multiple VLAN frames through a trunk link.
- ★ Switches tag frames to identify the VLAN to that they belong. Different tagging protocols exist; IEEE 802.1Q is a very popular example.
- ★ The protocol defines the structure of the tagging header added to the frame.
- ★ Switches add VLAN tags to the frames before placing them into trunk links and remove the tags before forwarding frames through non-trunk ports.
- ★ When properly tagged, the frames can transverse any number of switches via trunk links and still be forwarded within the correct VLAN at the destination.

★★★★★VLAN Frame Tagging|Neso Academy

VLAN



10.10.10.0 / 24 192.168.1.0 / 24 172.16.15.0 / 16 VLAN Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the need for redundancy and how failure is handled.
- ★ Know about broadcast storm.
- ★ Understand Spanning Tree Protocol.
- ★ Understand various key concepts and terms in STP.

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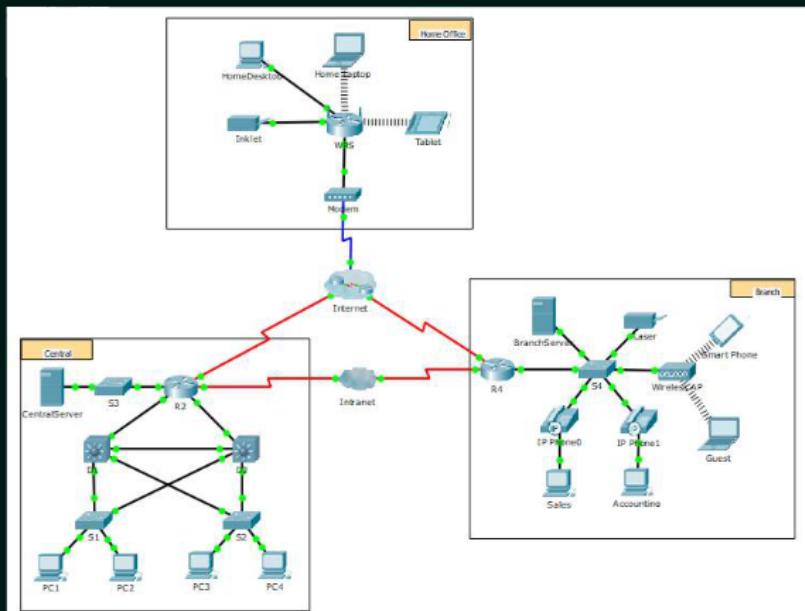
Outcomes ★★★★ Neso Academy

REDUNDANCY IS GOOD!

- ★ Enables users to access network resources, despite path disruption.
 - Improves reliability.
 - Improves availability.
- ★ In Technology, 2 is 1 and 1 is none. Single connection mean single point of failure.
 - Creating redundant links is very simple and is advisable.

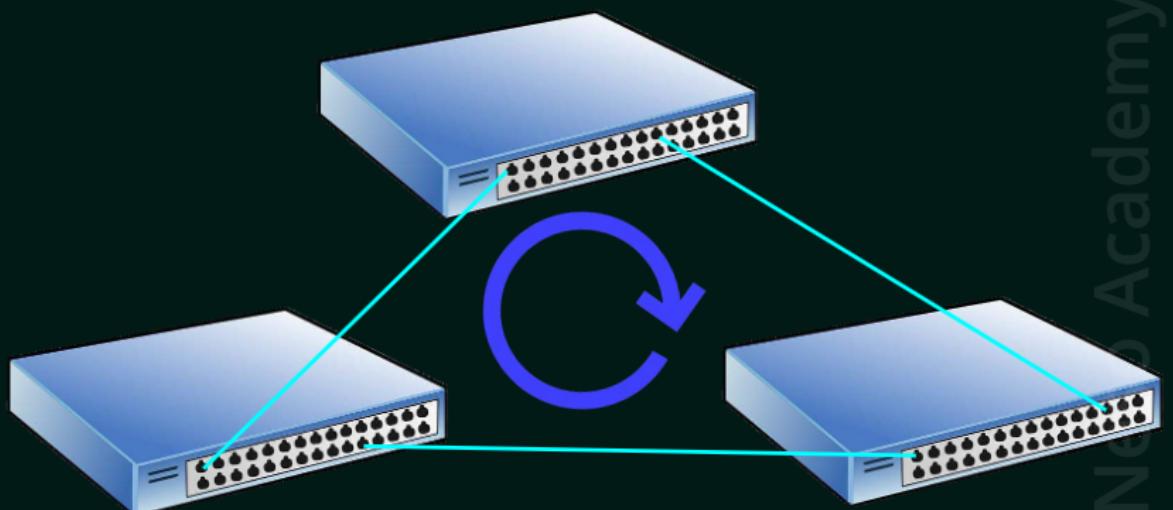
Redundancy is good!★○○★○Neso Academy

REDUNDANCY



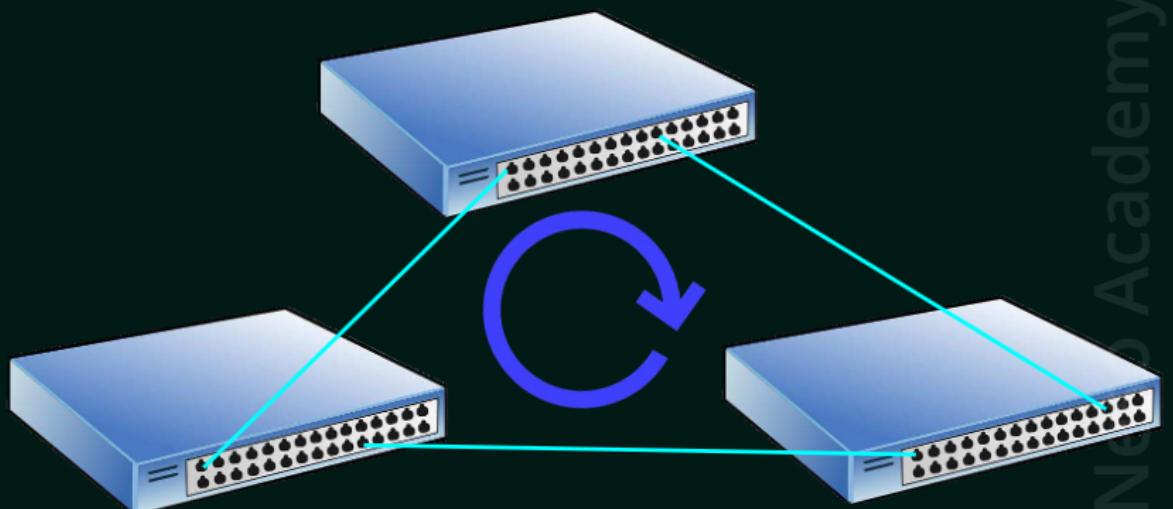
RedundancyNeso Academy

REDUNDANCY IS GOOD!



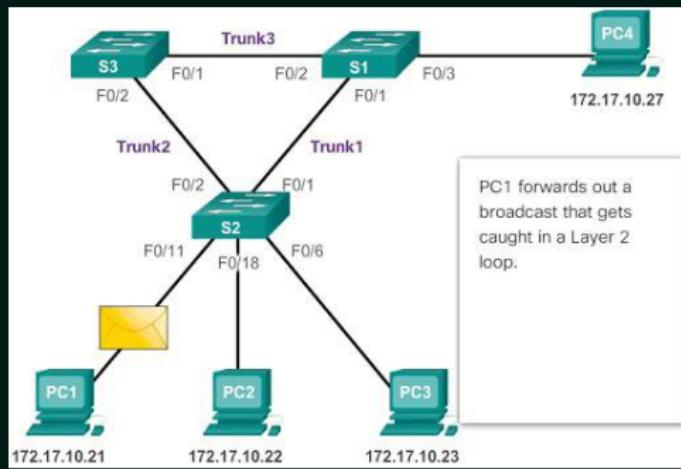
Redundancy is good!Neso Academy

BROADCAST STORM



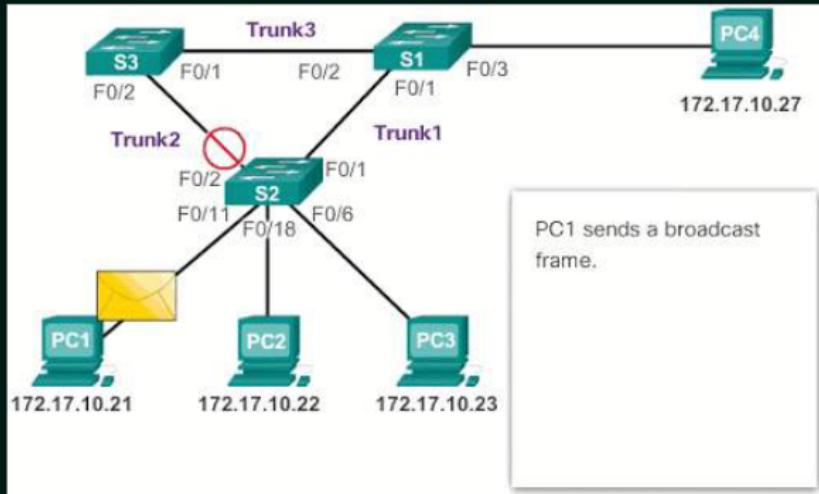
Broadcast stormNeso Academy

BROADCAST STORM



Broadcast stormNeso Academy

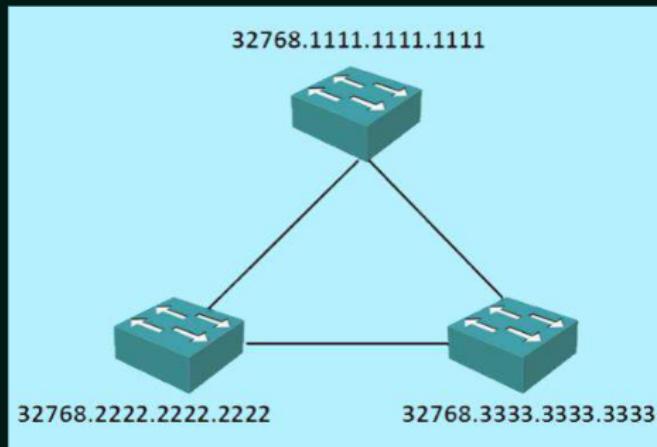
STP PREVENTS LOOPS



STP prevents loopsNeso Academy

KEY FACTS – STP

- ★ Original STP (802.1D) was created to prevent loops.
- ★ Switches send probes into the network to discover loops.



Key facts -STP★★Neso Academy

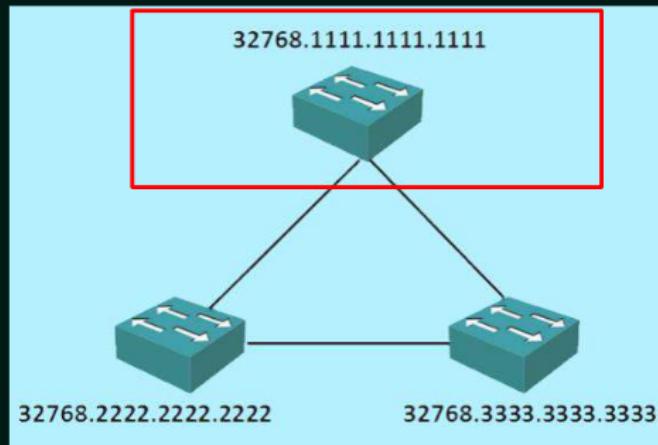
KEY FACTS – STP

- ★ Original STP (802.1D) was created to prevent loops.
- ★ Switches send probes into the network to discover loops.
- ★ These probes are called as BPDU.
- ★ BPDU = Bridge Protocol Data Unit.
- ★ BPDU will have specific information about the switch.
- ★ Switch multicasts BPDU probes (every 2 seconds) and if it receives its own BPDU back, it means there is a loop in the network.
- ★ Also the BPDU probes helps to elect the root bridge.
- ★ All switches will find the best way to reach the root bridge and the redundant links will be blocked. (Port cost)
- ★ This redundant links will be active only if the existing links or ports goes down.

Key facts -STP★★★★★★★★Neso Academy

ELECTION – Root BRIDGE

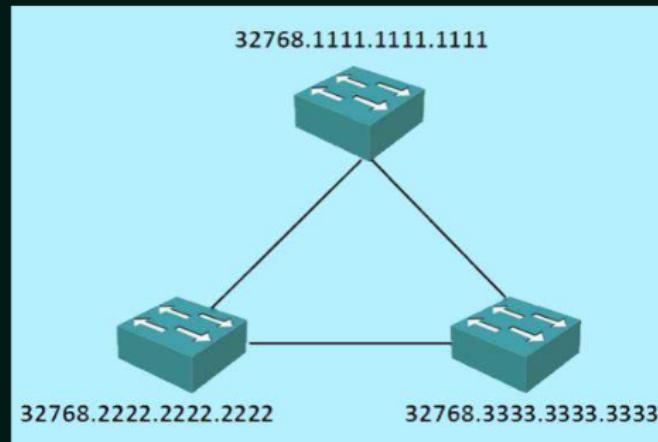
BPDU (Bridge ID)	
Bridge Priority	MAC Address of the switch



Election -Root BridgeBPDU (Bridge ID)Bridge PriorityMAC Address of the switchNeso Academy

ROOT BRIDGE

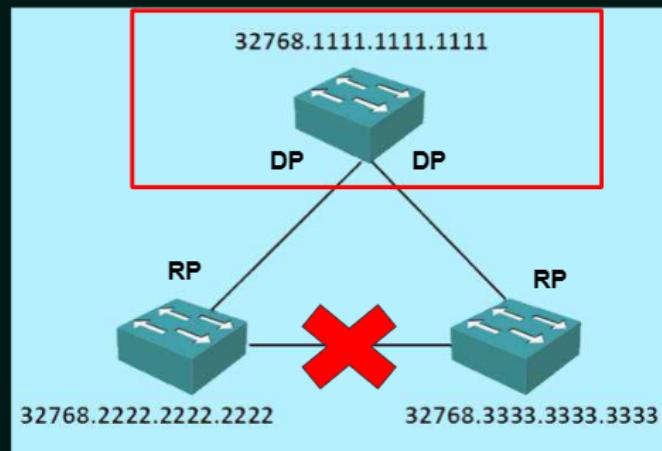
- ★ The Root Bridge will have the lowest bridge id.
- ★ If Tie, The bridge with the lowest MAC address will be the Root bridge.



Root bridge★★Neso Academy

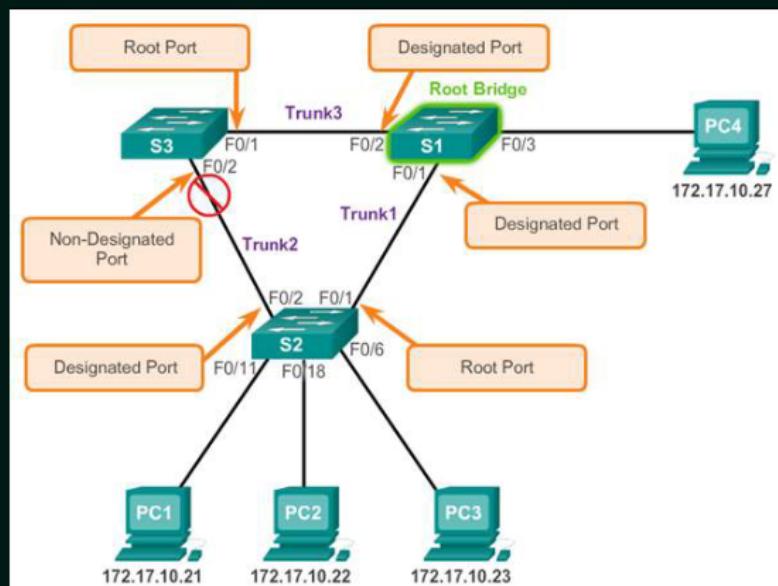
PORT ROLES

- ★ Root Port (Used to reach the root bridge)
- ★ Designated Port (Forwarding port; One per link)
- ★ Blocking/Non Designated Port. (Loops)



Port roles ★★★ RPDPRPDP Neso Academy

PORT ROLES AND PORT COST



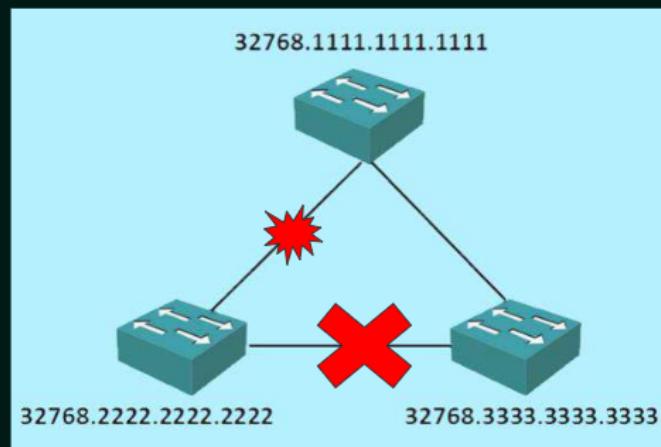
Port roles and Port cost Neso Academy

SPANNING TREE PROTOCOL

- ★ STP ensures that there is only one logical path between all destinations on the network by intentionally blocking redundant paths that could cause a loop.
- ★ A port is considered blocked when user data is prevented from entering or leaving that port. This does not include bridge protocol data unit (BPDU) frames that are used by STP to prevent loops.
- ★ The physical paths still exist to provide redundancy, but these paths are disabled to prevent the loops from occurring.
- ★ If the path is ever needed to compensate for a network cable or switch failure, STP recalculates the paths and unblocks the necessary ports to allow the redundant path to become active.

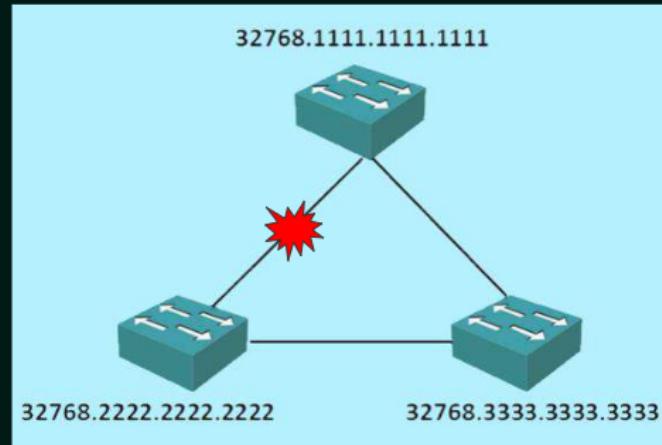
Spanning Tree Protocol★★★★Neso Academy

SPANNING TREE PROTOCOL



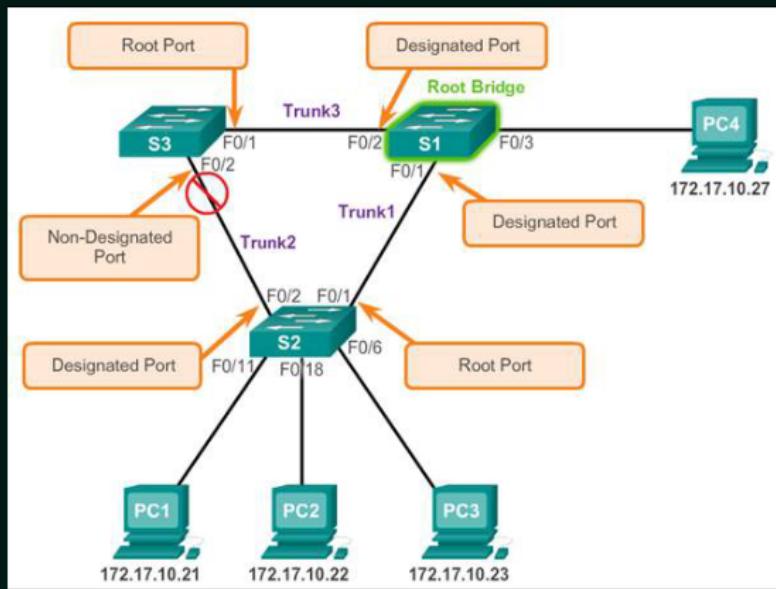
Spanning Tree ProtocolNeso Academy

SPANNING TREE PROTOCOL



Spanning Tree ProtocolNeso Academy

HOMEWORK!



Homework! Neso Academy

QUESTION

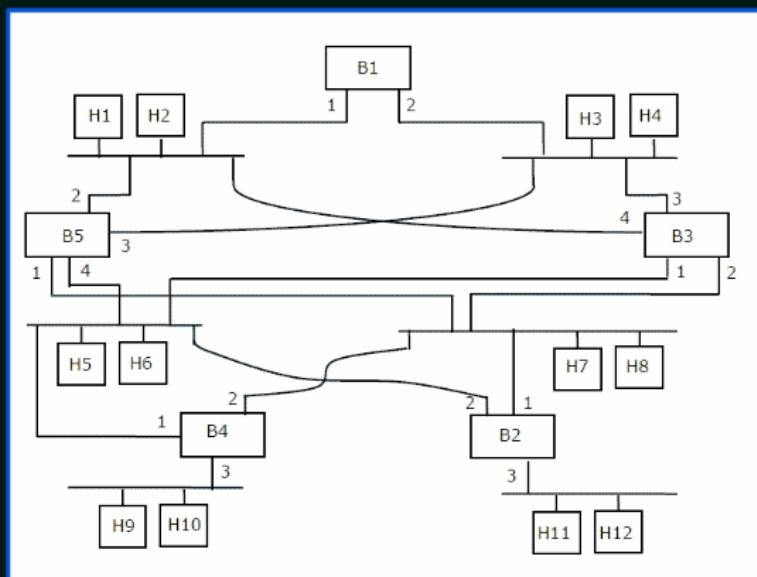
Consider the diagram shown below where a number of LANs are connected by (transparent) bridges. In order to avoid packets looping through circuits in the graph, the bridges organize themselves in a spanning tree. First, the root bridge is identified as the bridge with the least serial number. Next, the root sends out (one or more) data units to enable the setting up of the spanning tree of shortest paths from the root bridge to each bridge.

Each bridge identifies a port (the root port) through which it will forward frames to the root bridge. Port conflicts are always resolved in favour of the port with the lower index value. When there is a possibility of multiple bridges forwarding to the same LAN (but not through the root port), ties are broken as follows: bridges closest to the root get preference and between such bridges, the one with the lowest serial number is preferred.

[GATE CS 2006]

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QUESTION



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QUESTION

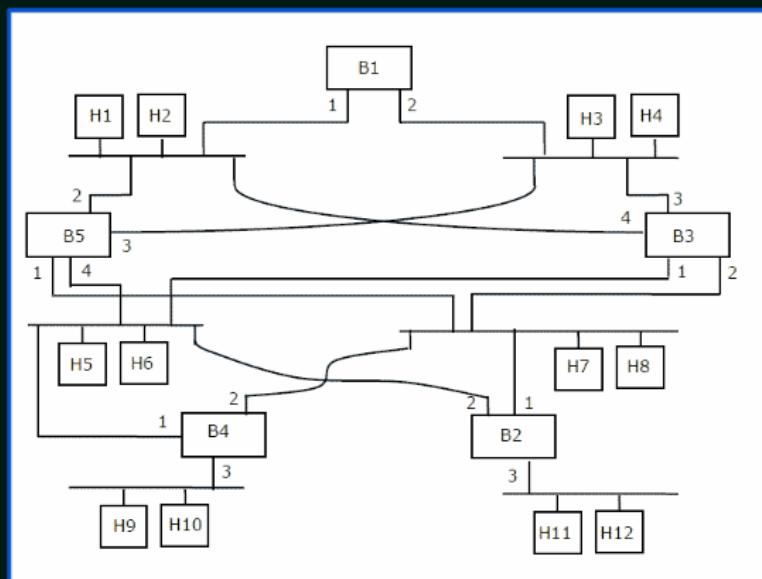
For the given connection of LANs by bridges, which one of the following choices represents the depth first traversal of the spanning tree of bridges?

[GATE CS 2006]

- (A) B1, B5, B3, B4, B2
- (B) B1, B3, B5, B2, B4
- (C) B1, B5, B2, B3, B4
- (D) B1, B3, B4, B5, B2

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QUESTION



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QUESTION

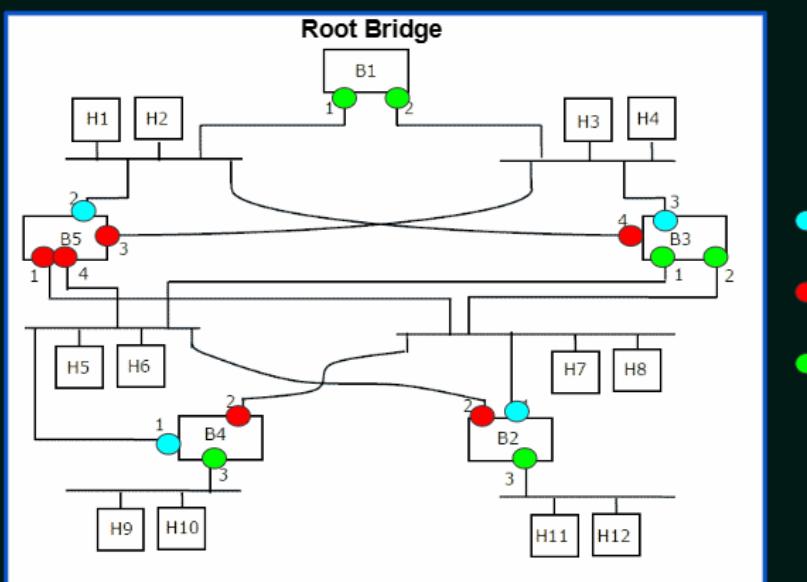
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[GATE CS 2006]

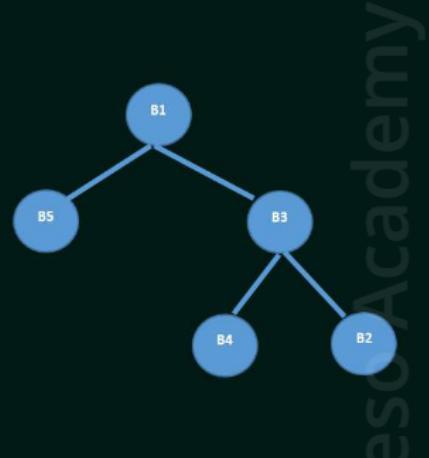
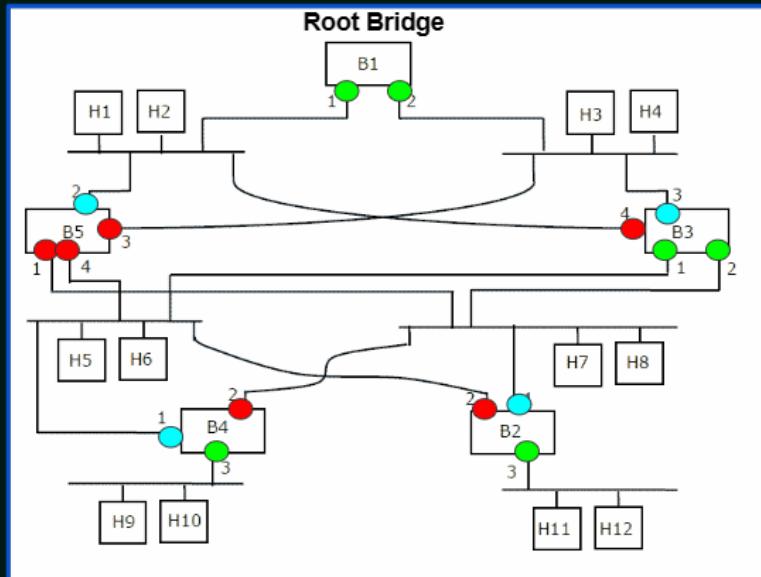
QuestionNeso Academy

QUESTION



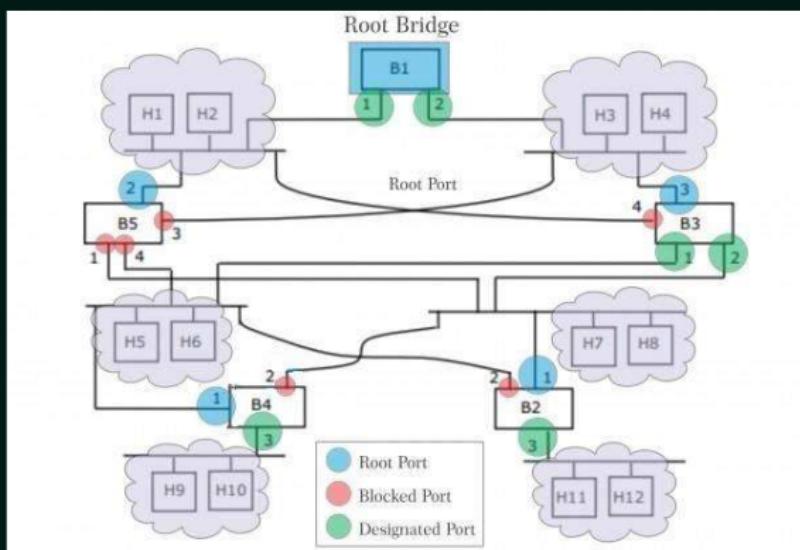
QuestionRoot BridgeRoot ProtBlocked PortDesignated PortNeso Academy

QUESTION



QuestionRoot BridgeNeso Academy

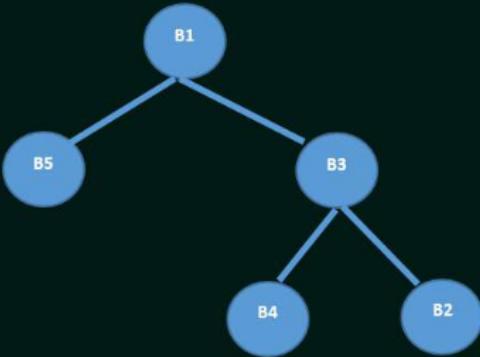
SOLUTION



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SOLUTION



B4 and B2 are connected through B3 (Not B5) because B3 has lower serial number than B5.

One DFS traversal of tree is: B1 – B5 – B3 – B4 – B2

SolutionNeso Academy

SOLUTION

For the given connection of LANs by bridges, which one of the following choices represents the depth first traversal of the spanning tree of bridges?

[GATE CS 2006]

- (A) B1, B5, B3, B4, B2 ✓
- (B) B1, B3, B5, B2, B4
- (C) B1, B5, B2, B3, B4
- (D) B1, B3, B4, B5, B2

✓ SolutionNeso Academy