Flow & Error Control

CST 05202: BASICS OF DATA COMMUNICATION NETWORKS

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Data link layer in OSI model: Part II

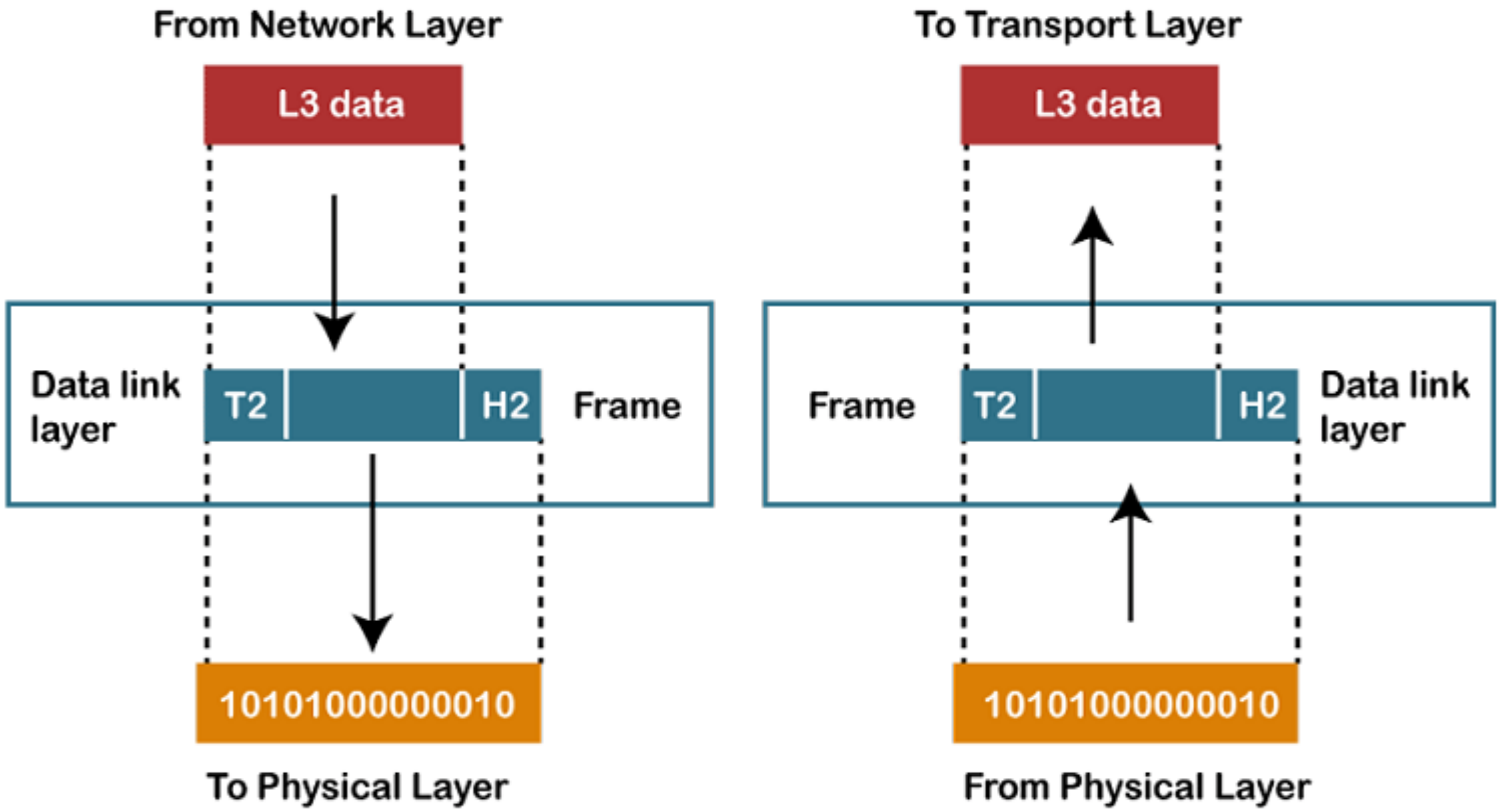
The data link layer is responsible for moving **data frames** from one hop (node) to the next (Hope to hope delivery). Data Link Layer is responsible for reliable point-to-point data transfer over a physical medium.

- This layer is responsible for the error-free transfer of data frames.
- It defines the format of the data on the network.
- It provides a reliable and efficient communication between two or more devices.
- It is mainly responsible for the unique identification of each device that resides on a local network.

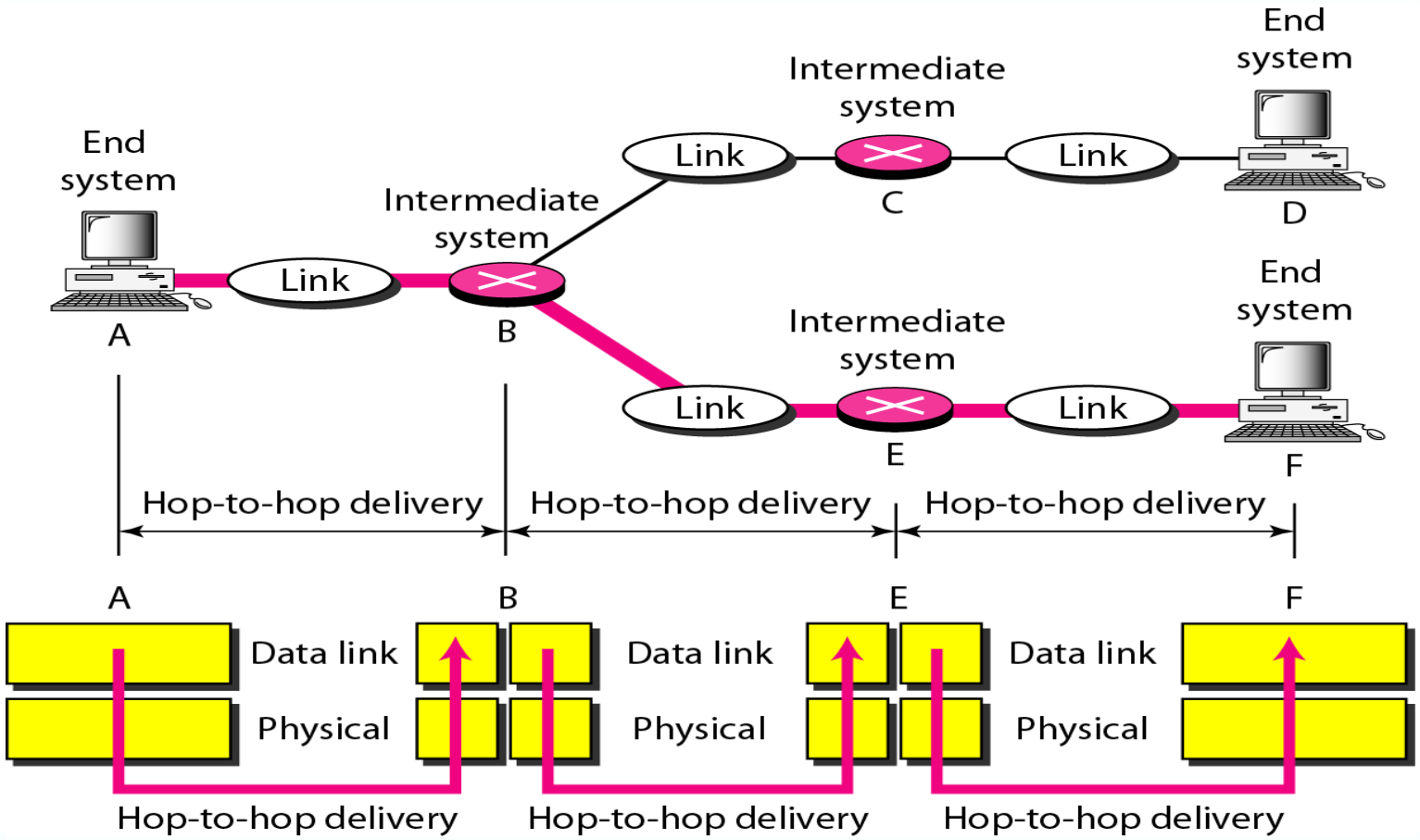
It contains two sub-layers:

- **Logical Link Control (LLC) Layer**
  - It is responsible for transferring the **packets** to the Network layer of the receiver that is receiving.
  - It identifies the address of the network layer protocol from the header.
  - It also provides flow control.
- **Media Access Control (MAC) Layer**
  - A Media access control layer is a link between the Logical Link Control layer and the network's physical layer. It is used for transferring the frame over the network.

Data link layer cont…



Data link layer Hop to hop delivery



Data link layer functions

Framing: The data link layer translates the physical's raw bit stream into packets known as Frames. The Data link layer adds the header and trailer to the frame.

Physical Addressing: The Data link layer adds a header to the frame that contains a hardware destination address. The frame is transmitted to the destination address mentioned in the header.

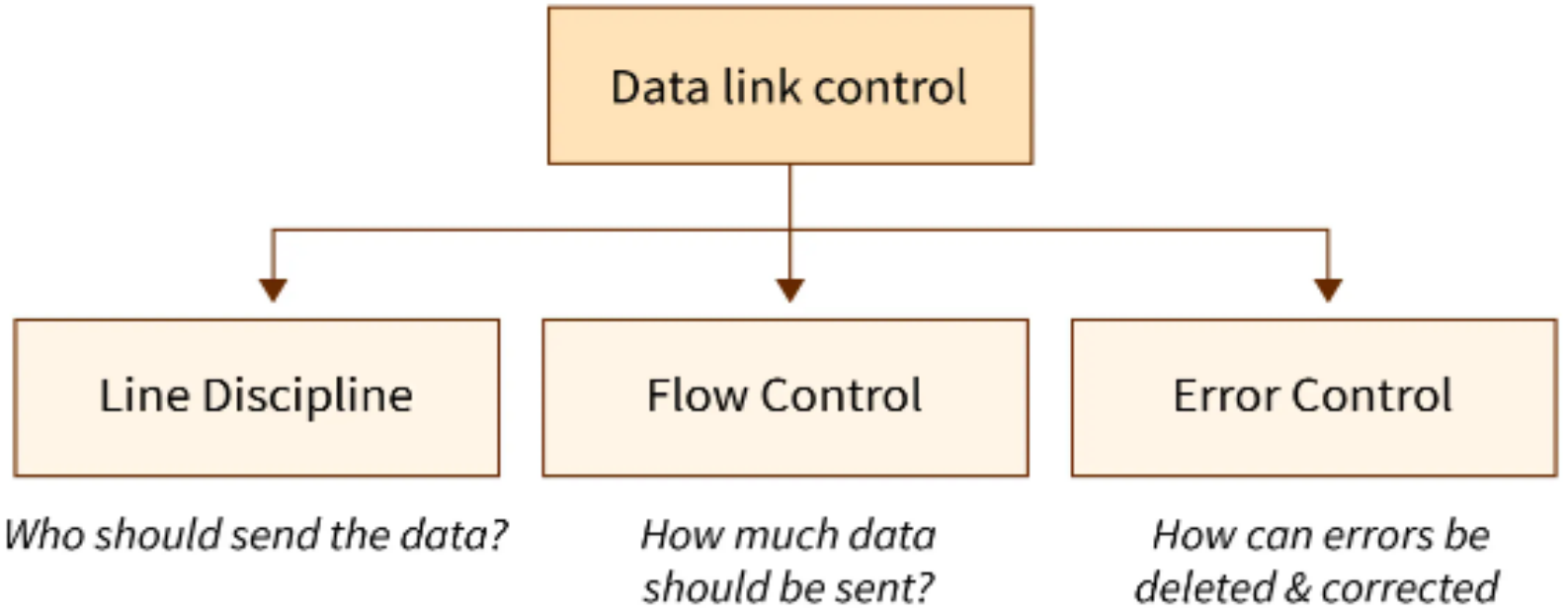
Flow Control: Flow control is the main functionality of the Data-link layer. It is the technique through which the constant data rate is maintained on both the sides so that no data get corrupted. It ensures that the transmitting station such as a server with higher processing speed does not exceed the receiving station, with lower processing speed.

Error Control: Error control is achieved by adding a calculated value CRC (Cyclic Redundancy Check) that is placed to the Data link layer's trailer which is added to the message frame before it is sent to the physical layer. If any error seems to occur, then the receiver sends the acknowledgment for the retransmission of the corrupted frames.

Access Control: When two or more devices are connected to the same communication channel, then the data link layer protocols are used to determine which device has control over the link at a given time.

Description of Functions of data link layer

1. Line Discipline (Access control)
2. Flow Control
3. Error Control.



Line Discipline

Line Discipline (Access Control)

Line discipline is the functionality used to establish coordination between link systems. It decides which device sends data and when.

Line Discipline can be achieved in two methods:

1. ENQ/ACK
2. Poll/select

Line Discipline: ENQ/ACK

ENQ/ACK stands for Enquiry/Acknowledgement is used when there is no wrong receiver available on the link and having a dedicated path between the two devices so that the device capable of receiving the transmission is the intended one.

- ENQ/ACK coordinates which device will start the transmission and whether the recipient is ready or not.

Working of ENQ/ACK:

The transmitter transmits the frame called an *Enquiry (ENQ)* asking whether the receiver is available to receive the data or not.

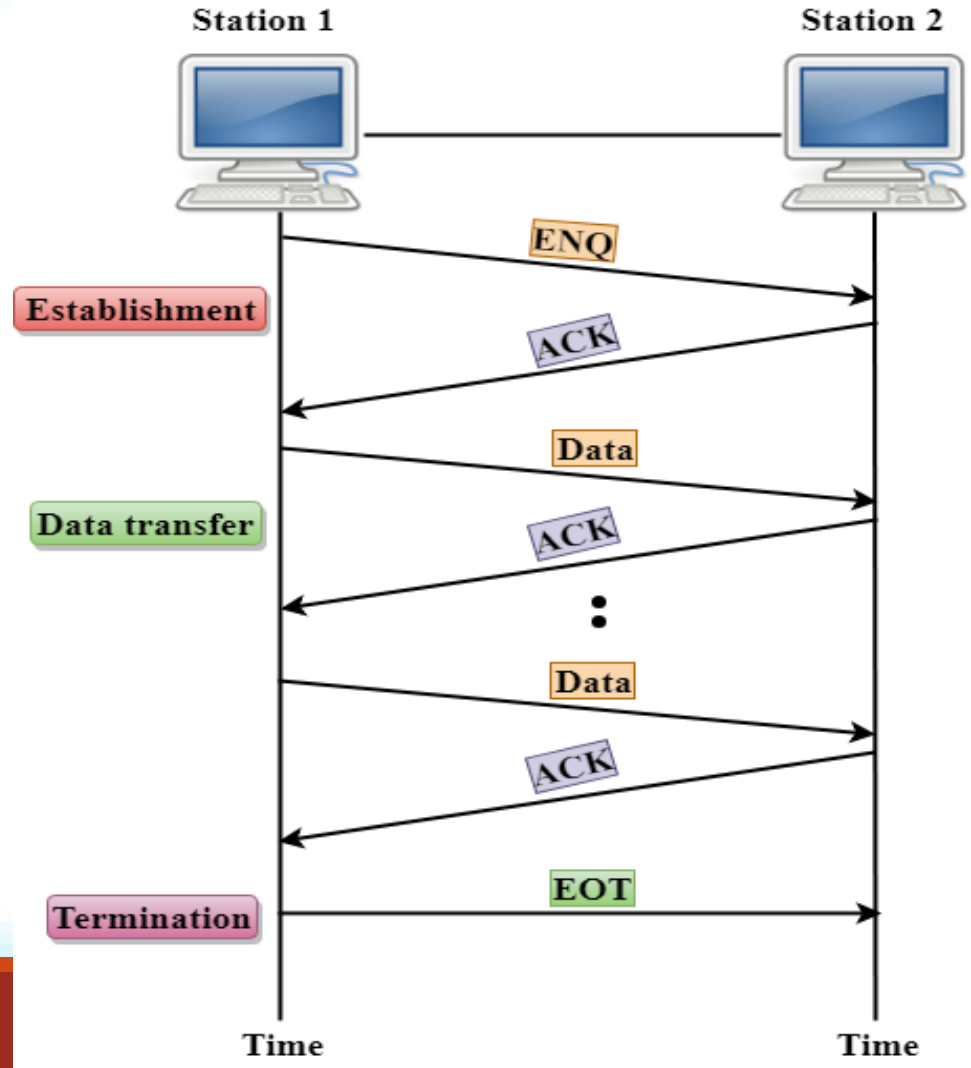
The receiver responses either with the positive acknowledgement(ACK) or with the negative acknowledgement(NACK) where positive acknowledgement means that the receiver is ready to receive the transmission and negative acknowledgement means that the receiver is unable to accept the transmission.

END/ACK: responses of the receiver

If the response to the ENQ is positive, the sender will transmit its data, and once all of its data has been transmitted, the device finishes its transmission with an EOT (END-of-Transmission) frame.

If the response to the ENQ is negative, then the sender disconnects and restarts the transmission at another time.

If the response is neither negative nor positive, the sender assumes that the ENQ frame was lost during the transmission and makes three attempts to establish a link before giving up.



Line Discipline: Poll/Select

The Poll/Select method of line discipline works with those topologies where one device is designated as a primary station, and other devices are secondary stations.

Working of Poll/Select

In this, the primary device and multiple secondary devices consist of a single transmission line, and all the exchanges are made through the primary device even though the destination is a secondary device.

The primary device has control over the communication link, and the secondary device follows the instructions of the primary device.

The primary device determines which device is allowed to use the communication channel. Therefore, we can say that it is an initiator of the session.

If the primary device wants to receive the data from the secondary device, it asks the secondary device that they anything to send**, this process is known as polling.**

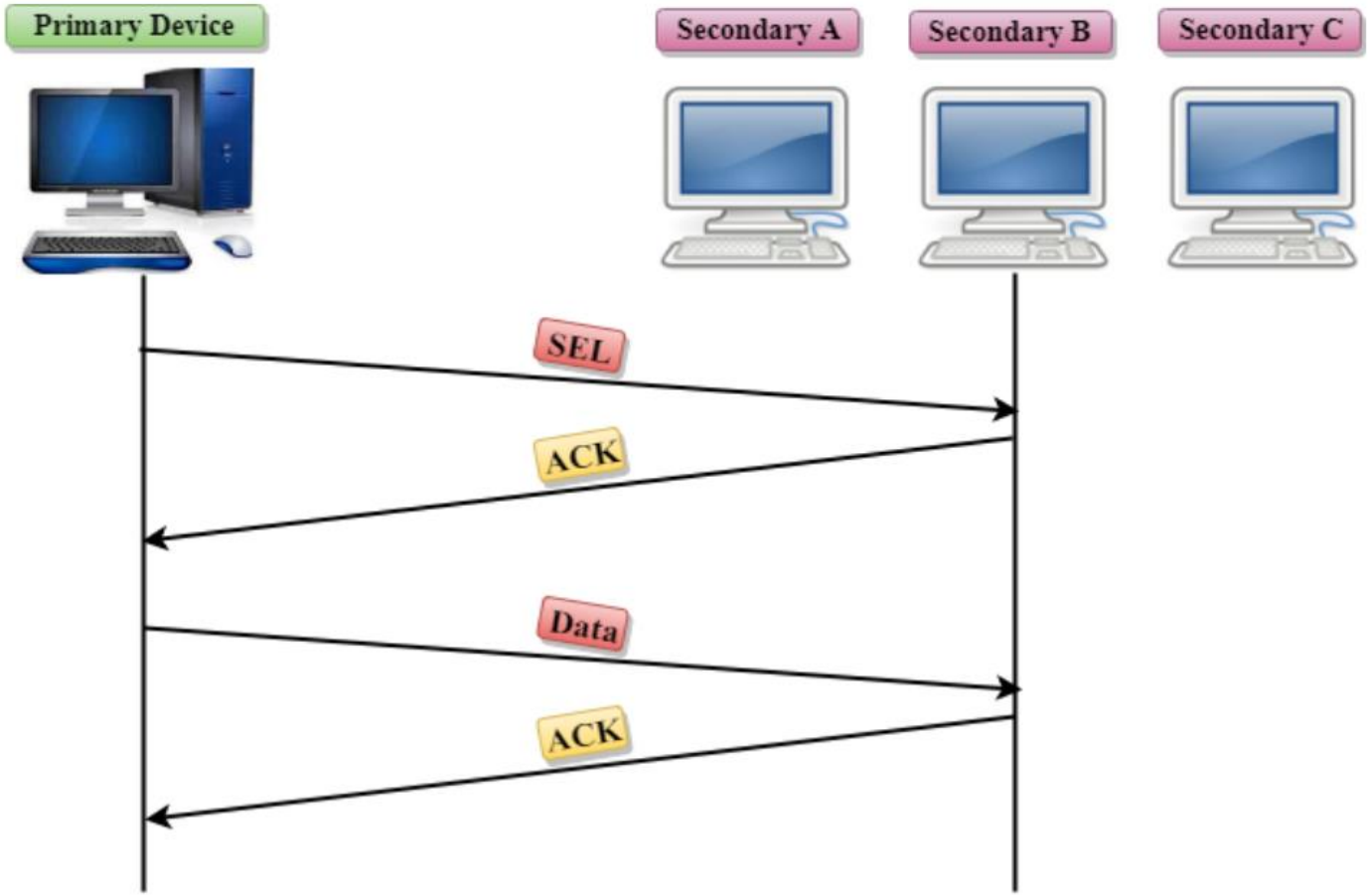
If the primary device wants to send some data to the secondary device, then it tells the target secondary to get ready to receive the data, **this process is known as selecting.**

Line Discipline: Select mode

The select mode is used when the primary device has something to send.

- When the primary device wants to send some data, then it alerts the secondary device for the upcoming transmission by transmitting a Select (SEL) frame, one field of the frame includes the address of the intended secondary device.
- When the secondary device receives the SEL frame, it sends an acknowledgement that indicates the secondary ready status.
- If the secondary device is ready to accept the data, then the primary device sends two or more data frames to the intended secondary device.
- Once the data has been transmitted, the secondary sends an acknowledgement specifies that the data has been received.

Line Discipline: Select mode



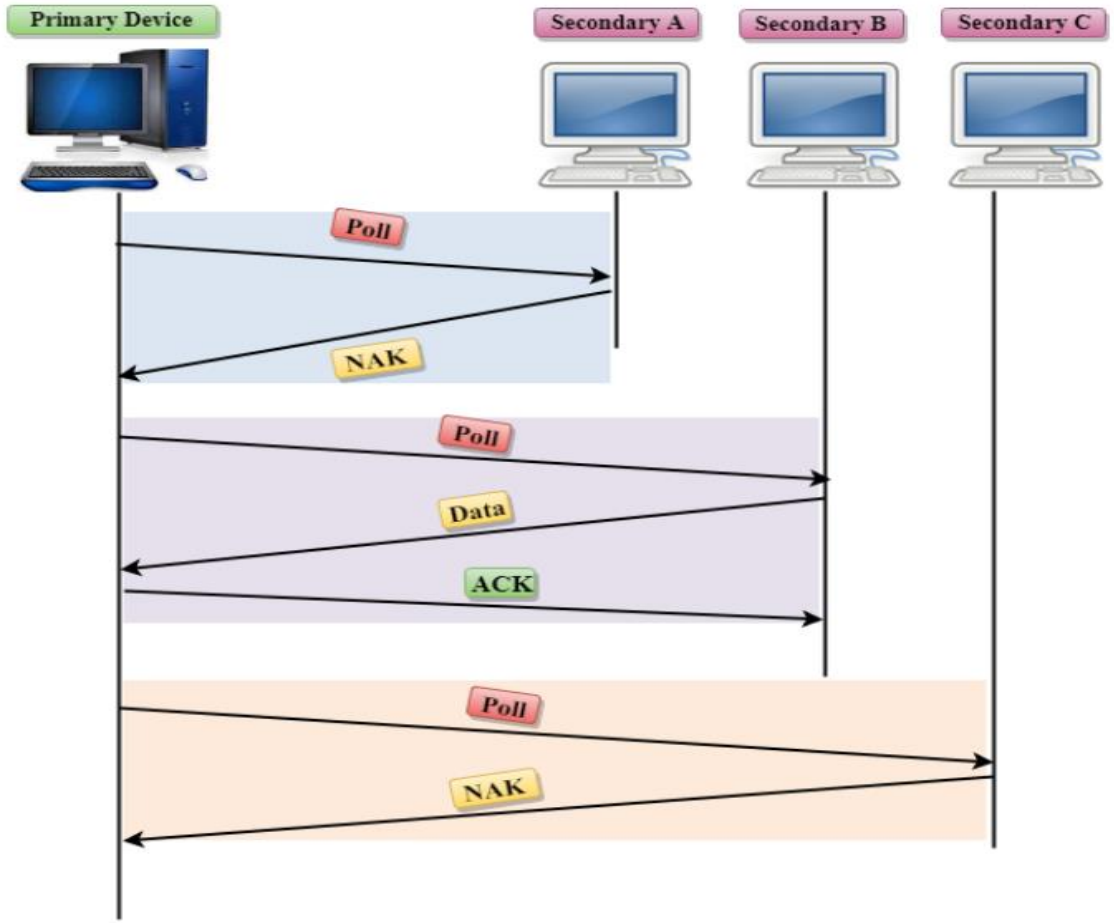
Line Discipline: Poll mode

The Poll mode is used when the primary device wants to receive some data from the secondary device.

When a primary device wants to receive the data, then it asks each device whether it has anything to send.

- Firstly, the primary asks (poll) the first secondary device, if it responds with the NACK (Negative Acknowledgement) means that it has nothing to send.
- Now, it approaches the second secondary device, it responds with the ACK means that it has the data to send.
- The secondary device can send more than one frame one after another or sometimes it may be required to send ACK before sending each one, depending on the type of the protocol being used.

Line Discipline: Poll mode



Flow Control

Flow Control: Introduction

Another important issue for the data link layer is dealing with the situation which occurs when the sender transmits frames faster than the receiver can accept or process them.

- If the sender is working on a fast machine and the receiver is working on a slow machine this situation may occur in the network.
- In this process of transmission, some of the frames might be lost as they were not processed by the receiver due to it's low speed, while the sender might have through the transmission to be completely error free.

To prevent this situation during transmission, a method is introduced called the Flow Control.

Flow Control Definition

Flow control is an essential function that coordinates the amount of data the sender can send before waiting for acknowledgment from the receiver.

- Flow control means using some feedback mechanism by which, the sender can be aware of when to the send next frame, and not at the usual speed of the sender.
- If the frame is accepted /processed by the receiver then only with the sender send the next frame.
- It may be said that the speed of the sender and the receiver should be compatible with each other, so that the receiver will receive or process all frames sent by the sender as every receiver has a limited block of memory called the buffer, reserved for storing incoming frames.

Flow Control: Methods to control the flow of data

There are several methods available for deciding when a sender should send one frame or the next frame. Flow control ensures that the speed of sending the frame, by the sender, and the speed of processing the received frame by the receiver are compatible.

There are two basic methods for flow control:

1. Stop-and-wait
2. Sliding window.

We shall start with the assumption that the transmission is error free and that we have an ideal channel.

Flow Control: Stop-and-wait method

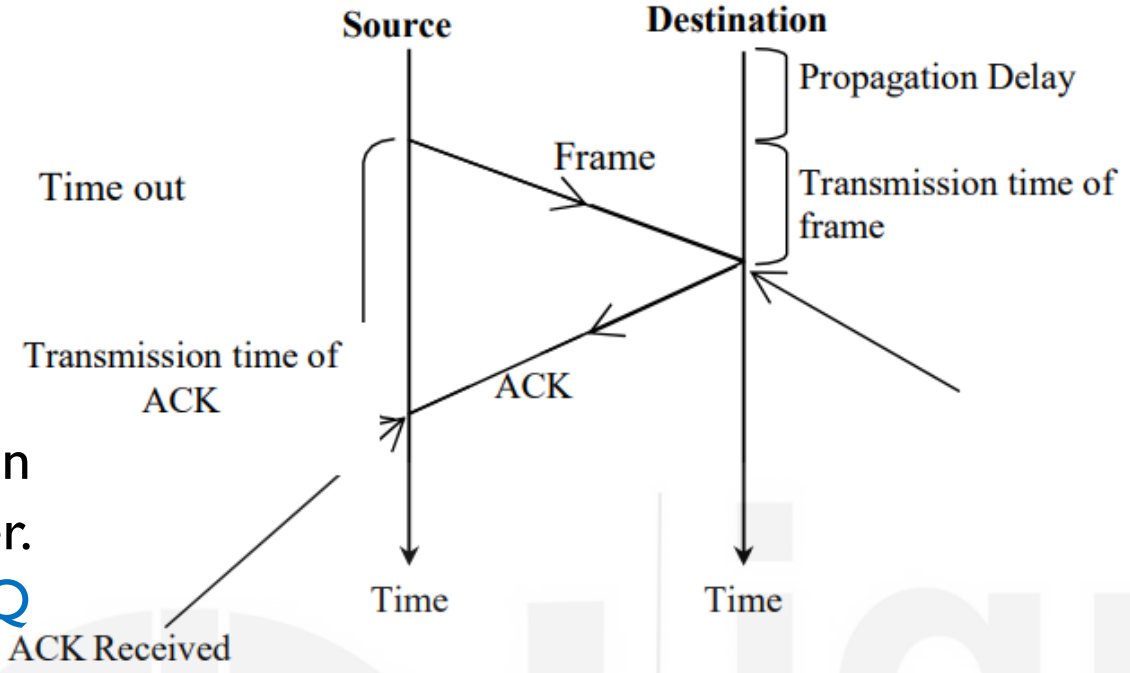
Stop-and-Wait Flow Control is the simplest form of flow control:

- In the Stop-and-wait method, the sender waits for an acknowledgement after every frame it sends.
- When acknowledgement is received, then only next frame is sent.
- The process of alternately sending and waiting of a frame continues until the sender transmits the EOT (End of transmission) frame.

Stop-and-wait: Operations Steps

1) Sender: Transmits a single frame at a time.
2) Receiver: Transmits acknowledgement (ACK) as it receives a frame.
3) If Sender receives ACK within time out.
4) Go to step 1.

*** If a frame or ACK is lost during transmission then it has to be transmitted again by the sender. This retransmission process is known as ARQ (automatic repeat request)



Stop-and-wait: Advantage & Disadvantage

Advantage:

- The Stop-and-wait method is simple as each frame is checked and acknowledged before the next frame is sent.

Disadvantage:

- The problem with stop and wait is that only one frame can be transmitted at a time and that often leads to inefficient transmission channel till we get the acknowledgement the sender can not transmit any new packet. During this time both the sender and the channel are unutilized.

**To deal with this problem, there is another flow control method i.e., sliding window

Flow Control: Sliding window

The Sliding Window is a method of flow control in which a sender can transmit the several frames before getting an acknowledgement.

- In Sliding Window Control, multiple frames can be sent one after the another due to which capacity of the communication channel can be utilized efficiently.
- A single ACK acknowledge multiple frames.
- Sliding Window refers to imaginary boxes at both the sender and receiver end.
- The window can hold the frames at either end, and it provides the upper limit on the number of frames that can be transmitted before the acknowledgement.
- Frames can be acknowledged even when the window is not completely filled.

Flow Control: Sliding window

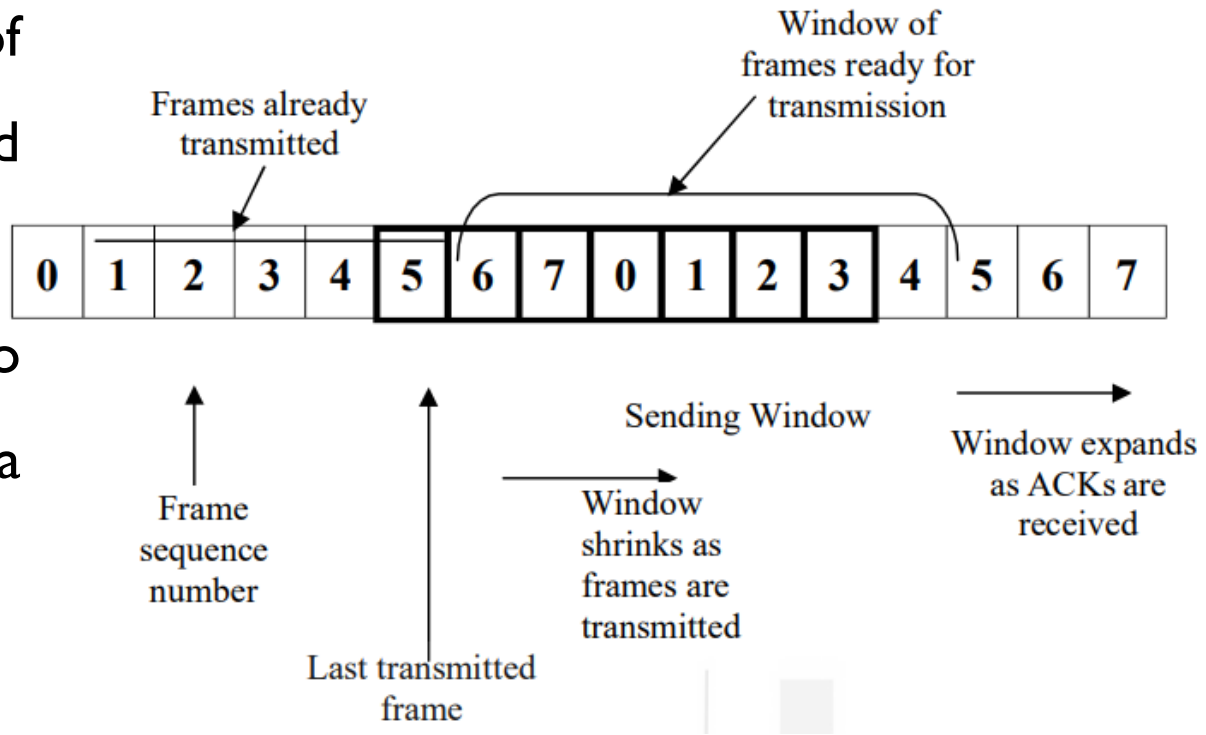
- The window has a specific size in which they are numbered as *modulo-n* means that they are numbered from 0 to n-1. For example, if n = 8, the frames are numbered from 0,1,2,3,4,5,6,7,0,1,2,3,4,5,6,7,0,1.....
- The size of the window is represented as n-1. Therefore, maximum n-1 frames can be sent before acknowledgement.
- When the receiver sends the ACK, it includes the number of the next frame that it wants to receive. For example, to acknowledge the string of frames ending with frame number 4, the receiver will send the ACK containing the number 5. When the sender sees the ACK with the number 5, it got to know that the frames from 0 through 4 have been received.

Sliding window: Operations

Sending Window:

In this mechanism we maintain two types of windows (buffer) sending window and receiving windows.

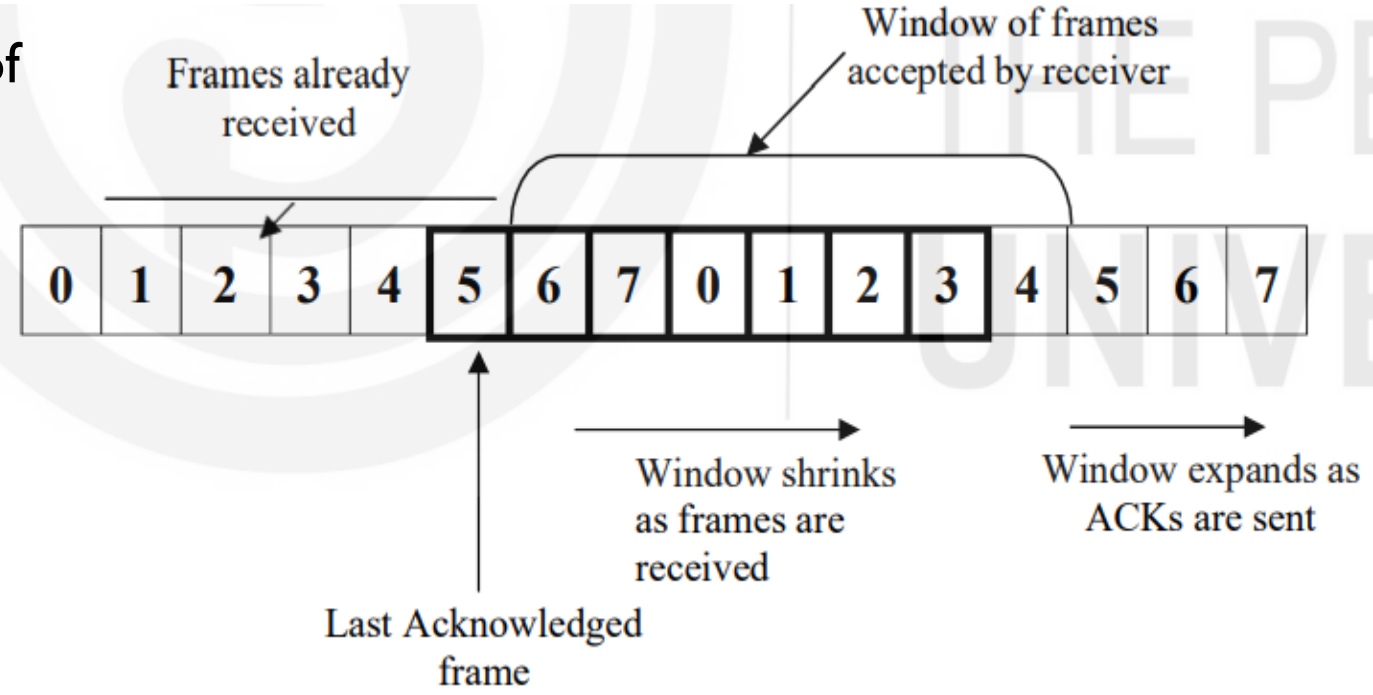
- At any instant, the sender is permitted to send frames with sequence numbers in a certain range (3-bit sending window)



Sliding window: Operations

Receiving Window:

The receiver maintains a receiving window depending on the sequence numbers of frames that are accepted.



Sliding window: Functions

Functioning of Sliding Window Flow control is achieved as the receiver can control the size of the sending window by limiting the size of the sending window.

Similarly, data flow from the sender to the receiver can be limited, and that too can controls the size of receiving window

Error Control

Error Control: Introduction

- In case of lost or corrupted frames, the receiver does not receive the correct data-frame and sender is ignorant about the loss. Data link layer follows a technique to detect transit errors and take necessary actions, which is retransmission of frames whenever error is detected or frame is lost. The process is called **Automatic Repeat Request (ARQ).**

Error control in data link layer *is the process of detecting and correcting data frames that have been corrupted or lost during transmission.*

Error Control: Introduction cont…

Data-link layer uses error control techniques to ensure that frames, i.e. bit streams of data, are transmitted from the source to the destination with a certain extent of accuracy. A reliable system should have methods to detect and correct the errors.

What is Errors?

When bits are transmitted over the computer network, they are subject to get corrupted due to interference and network problems. The corrupted bits leads to spurious data being received by the destination and are called errors.

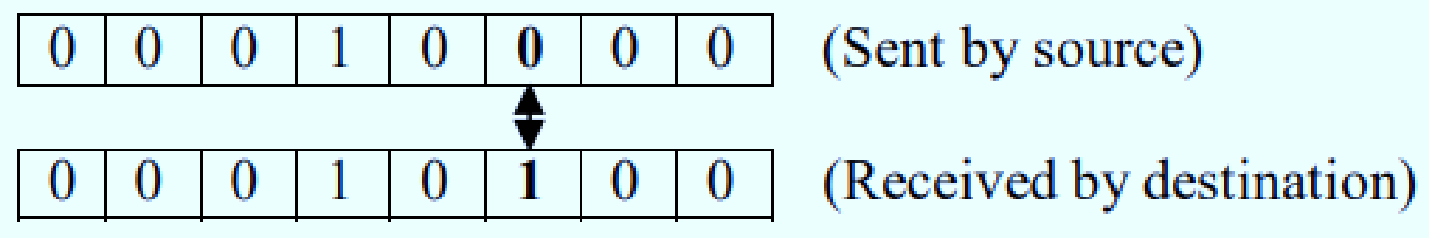
Types of Errors

Several types of error may occur during transmission

1) Single bit error
2) Burst error
3) Lost message (frame)

Types of Errors: Single Bit error

Single bit error means that only one bit is changed in the data during transmission from the source to the destination node i.e., either 0 is changed to 1 or 1 Is changed to 0

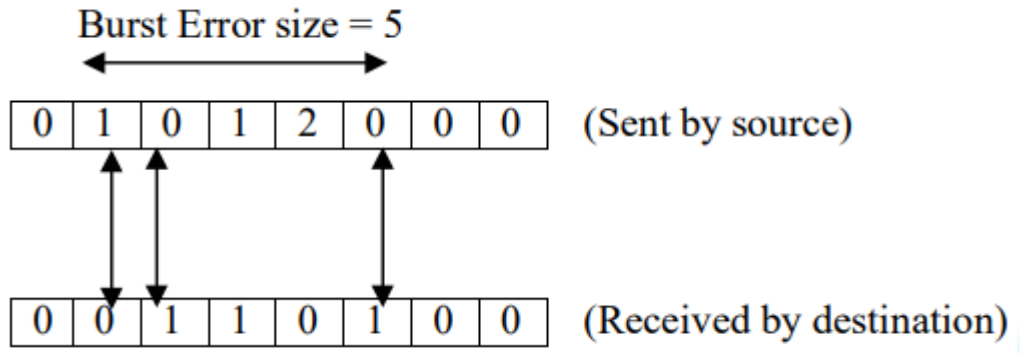


In the above figure, the message which is sent is corrupted as single-bit, i.e., 0 bit is changed to 1.

Types of Errors: Burst Error

Burst error means that 2 or more bits of data are altered during transmission from the source to the destination node. But, it is not necessary that error will appear in consecutive bits. Size of burst error is from the first corrupted bit to the last corrupted bit

- The duration of noise in Burst Error is more than the duration of noise in Single-Bit.
- The number of affected bits depends on the duration of the noise and data rate.



Types of Errors: Lost Message (Frame)

The sender has sent the frame but that is not received properly, this is known as loss of frame during transmission.

To deal with this type of error, a retransmission of the sent frame is required by the sender.

Error Control: Phases

- Detection of Error: Transmission error, if any, is detected by either the sender or the receiver.
- Acknowledgment: acknowledgment may be positive or negative.
  - Positive ACK − On receiving a correct frame, the receiver sends a positive acknowledge.
  - Negative ACK − On receiving a damaged frame or a duplicate frame, the receiver sends a negative acknowledgment back to the sender.
- Retransmission: The sender maintains a clock and sets a timeout period. If an acknowledgment of a data-frame previously transmitted does not arrive before the timeout, or a negative acknowledgment is received, the sender retransmits the frame.

Error Control: Technique



Error Control Technique: Stop and Wait ARQ

This protocol involves the following transitions −

- A timeout counter is maintained by the sender, which is started when a frame is sent.
- If the sender receives acknowledgment of the sent frame within time, the sender is confirmed about successful delivery of the frame. It then transmits the next frame in queue.
- If the sender does not receive the acknowledgment within time, the sender assumes that either the frame or its acknowledgment is lost in transit. It then retransmits the frame.
- If the sender receives a negative acknowledgment, the sender retransmits the frame.

Error Control Technique: Sliding Window ARQ

Sliding Window ARQ is a technique used for continuous transmission error control.

Three Features used for retransmission:

1. In this case, the sender keeps the copies of all the transmitted frames until they have been acknowledged.
    - Suppose the frames from 0 through 4 have been transmitted, and the last acknowledgement was for frame 2, the sender has to keep the copies of frames 3 and 4 until they receive correctly.

Error Control Technique: Sliding Window ARQ

2. The receiver can send either NAK or ACK depending on the conditions.
    - The NAK frame tells the sender that the data have been received damaged. Since the sliding window is a continuous transmission mechanism, both ACK and NAK must be numbered for the identification of a frame.
    - The ACK frame consists of a number that represents the next frame which the receiver expects to receive.
    - The NAK frame consists of a number that represents the damaged frame.

Error Control Technique: Sliding Window ARQ

3. The sliding window ARQ is equipped with the timer to handle the lost acknowledgements.

- Suppose then n-1 frames have been sent before receiving any acknowledgement. The sender waits for the acknowledgement, so it starts the timer and waits before sending any more.
- If the allotted time runs out, the sender retransmits one or all the frames depending upon the protocol used.

Sliding Window ARQ Error Control : Protocols

1) Go-Back-n ARQ:

In Go-Back-N ARQ protocol, if one frame is lost or damaged, then it retransmits all the frames after which it does not receive the positive ACK.

Three possibilities can occur for retransmission:

1. Damaged Frame: When the frame is damaged, then the receiver sends a NAK frame.

2. Lost Data Frame: In Sliding window protocols, data frames are sent sequentially. If any of the frames is lost, then the next frame arrive at the receiver is out of sequence.

- The receiver checks the sequence number of each of the frame, discovers the frame that has been skipped, and returns the NAK for the missing frame.
- The sending device retransmits the frame indicated by NAK as well as the frames transmitted after the lost frame.

Sliding Window ARQ Error Control : Protocols

1) Go-Back-n ARQ cont…

Three possibilities can occur for retransmission:

3. *Lost Acknowledgement:* The sender can send as many frames as the windows allow before waiting for any acknowledgement.

- Once the limit of the window is reached, the sender has no more frames to send; it must wait for the acknowledgement.
- If the acknowledgement is lost, then the sender could wait forever. To avoid such situation, the sender is equipped with the timer that starts counting whenever the window capacity is reached.
- If the acknowledgement has not been received within the time limit, then the sender retransmits the frame since the last ACK.

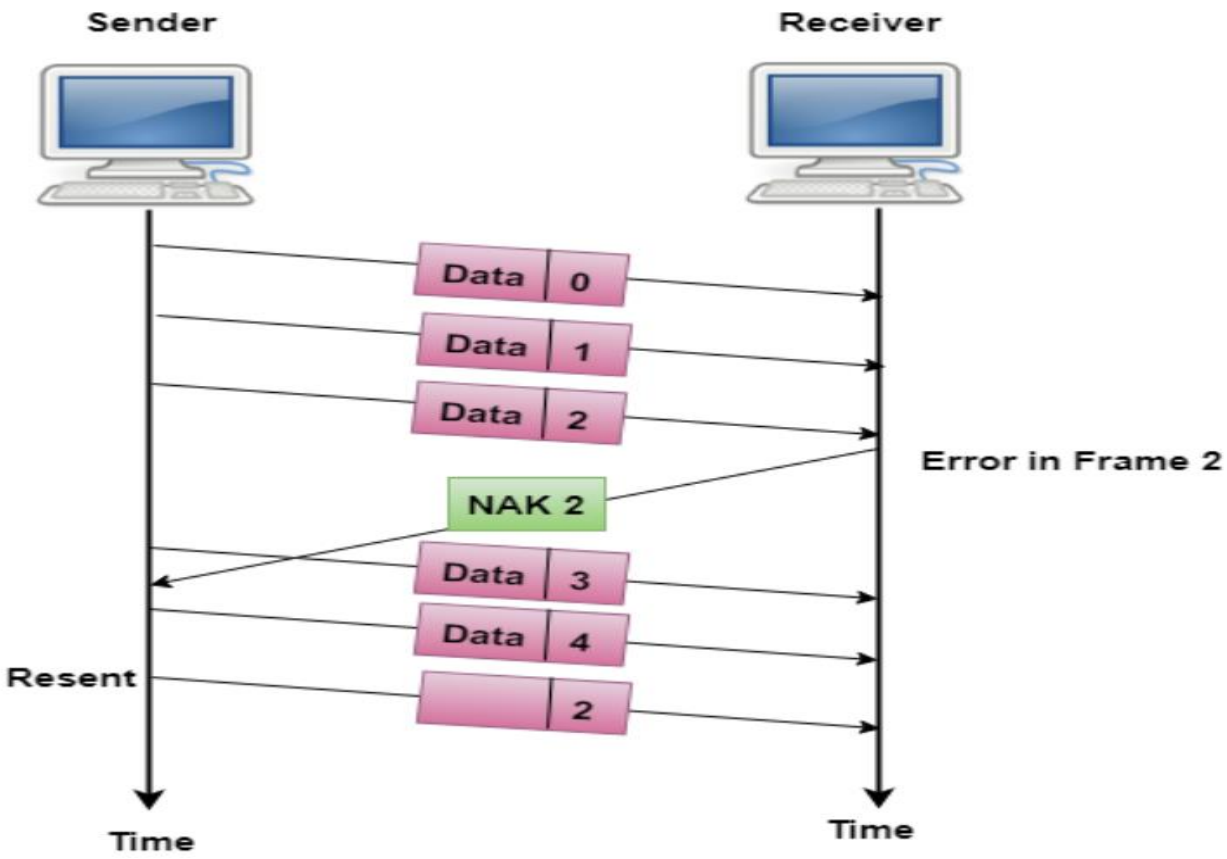
Sliding Window ARQ Error Control : Protocols

2) Selective-Reject ARQ:

Selective-Reject ARQ technique is more efficient than Go-Back-n ARQ.

- In this technique, only those frames are retransmitted for which negative acknowledgement (NAK) has been received.
- The receiver storage buffer keeps all the damaged frames on hold until the frame in error is correctly received.
- The receiver must have an appropriate logic for reinserting the frames in a correct order.
- The sender must consist of a searching mechanism that selects only the requested frame for retransmission.

Sliding Window ARQ Error Control : Protocols



Errors Control Categories

Error control is done in two techniques:

Error detection – Error detection involves checking whether any error has occurred or not. The number of error bits and the type of error does not matter.

Error correction – Error correction involves ascertaining the exact number of bits that has been corrupted and the location of the corrupted bits.

Error Detection

Error Detection: Introduction

Due to some factors if, the data gets corrupted, we need to correct it using various techniques. So, we require error detection methods first to detect the errors in the data before correcting it.

There are three main techniques for detecting errors in frames:

1. Parity Check
2. Checksum
3. Cyclic Redundancy Check (CRC).

Error Detection Technique: Parity Check

The parity check is done by adding an extra bit, called parity bit to the data to make a number of 1s either even in case of even parity or odd in case of odd parity.

While creating a frame, the sender counts the number of 1s in it and adds the parity bit in the following way:

- In case of even parity: If a number of 1s is even then parity bit value is 0. If the number of 1s is odd then parity bit value is 1.
- In case of odd parity: If a number of 1s is odd then parity bit value is 0. If a number of 1s is even then parity bit value is 1.
- On receiving a frame, the receiver counts the number of 1s in it. In case of even parity check, if the count of 1s is even, the frame is accepted, otherwise, it is rejected. A similar rule is adopted for odd parity check.

Parity Check: Single Parity Check

Single Parity (similarity) checking is the simple mechanism and inexpensive to detect the errors.

In this technique, a redundant bit is also known as a parity bit which is attached at the end of the data unit.

If the number of 1s bits is odd, then parity bit 1 is appended and if the number of 1s bits is even, then parity bit 0 is appended at the end of the data unit.

At the receiving end, the parity bit is calculated from the received data bits and compared with the received parity bit.

This technique generates the total number of 1s even, so it is known as even-parity checking.

Parity Check: Single Parity Check

Drawbacks Of Single Parity Checking

- It can only detect single-bit errors which are very rare.
- If two bits are interchanged, then it cannot detect the errors.

Parity Check: Two-Dimensional Parity Check

Performance can be improved by using **Two-Dimensional Parity Check** which organizes the data in the form of a table.

- Parity check bits are computed for each row, which is equivalent to the single-parity check.
- In Two-Dimensional Parity check, a block of bits is divided into rows, and the redundant row of bits is added to the whole block.
- At the receiving end, the parity bits are compared with the parity bits computed from the received data.

Parity Check: Two-Dimensional Parity Check

Drawbacks Of 2D Parity Check

- If two bits in one data unit are corrupted and two bits exactly the same position in another data unit are also corrupted, then 2D Parity checker will not be able to detect the error.
- This technique cannot be used to detect the 4-bit errors or more in some cases.

Error Detection Technique: Checksum

In this error detection scheme, the following procedure is applied:

i. Data is divided into fixed sized frames or segments.

ii. The sender adds the segments using 1's complement arithmetic to get the sum. It then complements the sum to get the checksum and sends it along with the data frames.

iii. The receiver adds the incoming segments along with the checksum using 1's complement arithmetic to get the sum and then complements it.

iv. If the result is zero, the received frames are accepted; otherwise, they are discarded

Error Detection Technique: Cyclic Redundancy Check (CRC)

Cyclic Redundancy Check (CRC) involves binary division of the data bits being sent by a predetermined divisor agreed upon by the communicating system. The divisor is generated using polynomials.

- Here, the sender performs binary division of the data segment by the divisor. It then appends the remainder called CRC bits to the end of the data segment. This makes the resulting data unit exactly divisible by the divisor.
- The receiver divides the incoming data unit by the divisor. If there is no remainder, the data unit is assumed to be correct and is accepted. Otherwise, it is understood that the data is corrupted and is therefore rejected.

Error Detection Technique: Cyclic Redundancy Check (CRC)

Following are the steps used in CRC for error detection:

- Firstly, In CRC technique, a string of n 0s is appended to the data unit, and this n number is less than the number of bits in a predetermined number, known as division which is n+1 bits.
- Secondly, the newly extended data is divided by a divisor using a process is known as binary division. The remainder generated from this division is known as CRC remainder.
- Thirdly, the CRC remainder replaces the appended 0s at the end of the original data. This newly generated unit is sent to the receiver.
- The receiver receives the data followed by the CRC remainder. The receiver will treat this whole unit as a single unit, and it is divided by the same divisor that was used to find the CRC remainder.

Error Detection Technique: Cyclic Redundancy Check (CRC) cont…

If the resultant of this division is zero which means that it has no error, and the data is accepted.

If the resultant of this division is not zero which means that the data consists of an error. Therefore, the data is discarded.

Error correction

Error Correction

Error correction techniques find out the exact number of bits that have been corrupted and as well as their locations.

Single additional bit can detect the error, but cannot correct it.

- For correcting the errors, one has to know the exact position of the error.
- For example, If we want to calculate a single-bit error, the error correction code will determine which one of seven bits is in error.
- To achieve this, we have to add some additional redundant bits.

Error Correction Technique

Backward Error Correction (Retransmission): If the receiver detects an error in the incoming frame, it requests the sender to retransmit the frame. Once the error is discovered, the receiver requests the sender to retransmit the entire data unit.

Forward Error Correction: If the receiver detects some error in the incoming frame, it executes error-correcting code that generates the actual frame. This saves bandwidth required for retransmission. It is inevitable in real-time systems. However, if there are too many errors, the frames need to be retransmitted.

Error Correction Codes

An **error correcting code (ECC)** is an encoding scheme that transmits messages as binary numbers, in such a way that the message can be recovered even if some bits are erroneously flipped.

They are used in practically all cases of message transmission, especially in data storage where ECCs defend against data corruption.

The four main error correction codes are

1. Hamming Codes:
2. Binary Convolution Code
3. Reed – Solomon Code
4. Repetition codes

Error Correction Codes: Repetition codes

This method of transmission results in the correct message despite two bits being incorrectly flipped.

An even simpler example of a repetition code is the **parity code**, in which each bit is transmitted twice:

Message	Encoding
0	00
1	11

- It can detect, but not correct, single-bit errors.
- The importance of this code lies in the concept of a **parity bit**, which is a bit added to make the number of 1s in each encoding even. By doing so, any message with an odd number of 1s can immediately be recognized as erroneous.

Error Correction Codes: Hamming codes

A more efficient encoding scheme is a Hamming code.

In a Hamming code, every possible message string is encoded as a certain binary number, with the set of numbers specifically chosen so that they are all significantly different in some sense; in other words, every pair of encoded messages are substantially different by some measure.

That measure is *Hamming distance*.

- The Hamming distance between 2 numbers is the number of bits they differ at. For example, 1101010 and 1111000 are a hamming distance of 2 apart:

  1101010

  1111000

- The key here is that if any pair of encodings are sufficiently far apart in terms of Hamming distance, errors can be detected and corrected by seeing which of the codewords is closest to the transmitted message.

Bandwidth & Data rate

Introduction

The terms "bandwidth" and "data rate" are frequently used interchangeably in the field of telecommunications, which can make things somewhat unclear at times.

Every connection to a network has a *data rate*, which is the speed at which bits are sent from one node to another, and a *bandwidth*, which is the maximum amount of bits that a link may send or receive in one second.

Both of these rates are measured in bits per second.

Bandwidth

In data communication, amount of information to be transmitted through channel is proportional to the bandwidth of the channel.

- Bandwidth (*The Width of the Band*) is a measure of the transmission capacity of a network over a specific period of time. It is the rate at which a link may send or receive bits per second.
- The amount of data that can be sent via a network is referred to as its bandwidth, and it is measured in bits per second.
- The amount of data that can be transmitted varies, which might reduce the effectiveness of a transmitter such as an Internet connection. To put it another way, *the bandwidth of a connection determines how quickly a device can download data from the Internet.*

Bandwidth as a Measure of Data Transfer

In this context, “bandwidth” is simply the rate at which your computer is successfully sending and receiving data, and this rate fluctuates because it is influenced by overall network conditions.

Data Rate

Data rate is used to measure how fast data is transferred from one point to another. It refers to the actual amount of data transferred.

- It refers to the maximum number of bits that can be sent over a network in one second.
- Data rate is measured in terms of the amount of data that is moved in a certain amount of time. To increase the quantity of data rate, increase the count by 8 and reduce the amount of bandwidth by that amount.
- Local area networks that use Ethernet can achieve data transfer speeds of up to 10 megabits per second.

Bandwidth & Data rate

Therefore, if you are given bandwidth of 5 MHz, the maximum amount of data that may be transferred to and from your device at one time will be 5 Mbps

The quantity of data that is moved from one device to another device and between peripheral devices like the computer is referred to as the data rate.

Bandwidth Vs. Data rate

Basis of Comparison	Bandwidth	Data Rate
Definition	Bandwidth is a measure of the transmission capacity of a network over a specific period of time. It is the rate at which a link may send or receive bits per second.	Data rate is used to measure how fast data is transferred from one point to another. It refers to the actual amount of data transferred.
Transmission	It refers to the fastest possible data transfer speed.	It refers to the real pace of data transfer.
Units	In most cases, it will be measured in bps, Mbps, or Gbps.	The standard unit of measurement is Mbps.
Dependent on	It is not dependent on the characteristics of either the transmitter or the receiver.	Data rate is dependent on the characteristics of the sender or the receiver.

Thank you!

For listen