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Unit -2 Data Link Layer

II	**Link layer:** Framing, Error Detection and Correction, Flow control (Elementary Data Link Protocols, Sliding Window protocols). Medium Access Control and Local Area Networks: Channel allocation, Multiple access protocols, LAN standards, Link layer switches & bridges (learning bridge and spanning tree algorithms).

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❖ Introduction to Data Link layer :

☞ The **Data Link Layer** is the **2nd layer** in the **OSI Model**.

Its job is to **ensure error-free and orderly delivery of data** from one computer to another **within the same network**.

💡 Think of It Like This:

Imagine you're **sending a letter** by post 📪.

- You put your **letter in an envelope**.
- You write the **receiver's address**.
- The **postman** makes sure it goes to the right person and **doesn't get lost**.

The **Data Link Layer is like that postman**:

- It wraps the message into a **frame** (envelope).
- It adds the **MAC address** (receiver's address).
- It checks if the message gets delivered **without errors**.

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Functions of Data Link Layer (Easy Words):

Function	Simple Explanation
Framing	Breaks data into chunks (frames) for sending.
Error Detection & Correction	Makes sure the data is not damaged.
Flow Control	Sends data at a speed the receiver can handle.
MAC (Media Access Control)	Helps devices take turns to send data.
Physical Addressing	Adds sender and receiver **MAC address** to the frame.

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Example:

Imagine 3 computers are connected in a LAN (Local Area Network):

- **You (Computer A)** want to send a file to **Computer B**.
- Data Link Layer **adds Computer B's MAC address** to the frame.
- It checks for **errors** and sends it.
- If there's any problem, it **asks to resend**.

Now let discuss exactly what is Framing →

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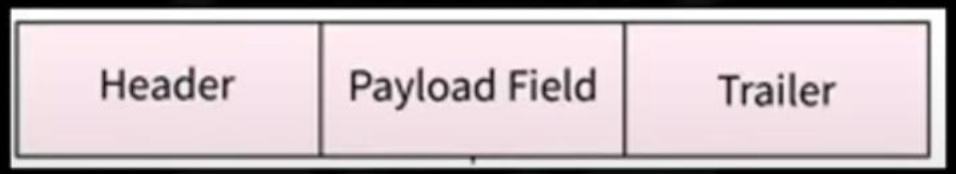
❖ What is Framing?

☞ **Framing** is a method used in the **Data Link Layer** of the OSI model to **divide the full message (data) into smaller, manageable units called frames.**

Each **frame** carries:

- A **piece of the original data**
- **Address information** (who is sending and who should receive)
- **Error checking bits** (to detect if anything got changed during transmission)



Frames

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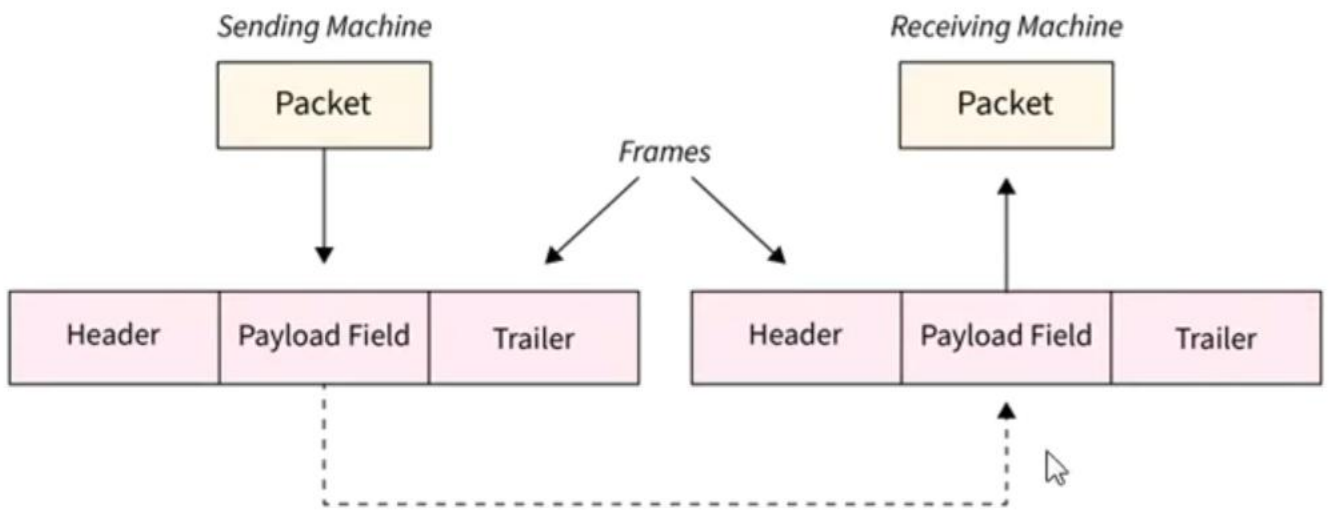

From Sending Machine to Receiving Machine using Frames
Let's Breakdown above diagram to clear understanding→

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🎯 1. What is a Packet?

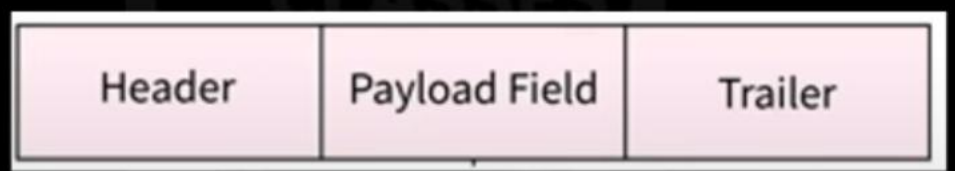
At the start, the **sending machine** (your computer or any device) has **data** to send. This data is packaged into a **packet** by the **Network Layer**.

👉 **Example:** You're sending a message "HELLO" to a friend.

🎁 2. What Happens in the Data Link Layer?

The **Data Link Layer** takes that packet and wraps it into a **frame**.

Look at the structure of the frame in your diagram:



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➤ Header (Start of the Frame)

❑ **Contains control information:**

- **Source MAC address** (who sent it)
- **Destination MAC address** (who should receive it)
- Frame type, sequence number, etc.

✓ Helps the receiver know **where the data is from and where it's going**.

Payload Field (Main Data)

- This is the actual **data (message)** you're trying to send.
- Also called the **packet from network layer**.
- Example: The word "HELLO"

✓ It's the **real content** of the message.

Trailer (End of the Frame)

- Contains **error checking** info like **CRC** or **checksum**.
- Helps detect if the data was **changed or corrupted** during transmission.

✓ Ensures **data integrity**.

→□ 3. Frames Travel Across the Network

Now the **entire frame** (Header + Payload + Trailer) is sent over the network.
Multiple such frames can be sent if the original data is large.

←? 4. Receiving Machine

The **receiving device** gets these frames. It does three main things:

1.Reads Header: To know if the message is for it.

2.Checks Trailer: Verifies if data is safe (no corruption).

3.Extracts Payload: Sends the actual message to the **Network Layer** above it.

Once all frames are received and reassembled, your friend finally gets the message "HELLO".

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📌 Why is Framing Needed?

Let's understand this with real-life situations.

🛍️ Real-Life Example:

You want to send a **big book** by courier to your friend.

- If you send it all in one box, it's too heavy, may get lost or damaged.
- So you break it into **smaller parcels (frames)**.

You **label each parcel** with:

- Your friend's address (destination)
- Part number (1 of 5, 2 of 5...)
- A note inside to confirm content

This way: ✓ The courier (network) can handle it easily

✓ If one parcel is damaged, only that one is resent

✓ Your friend can **reassemble** the book in correct order

That's what **framing** does with **digital data**.

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❖ **Types of Framing :**

1. Character Count Framing

The **first field** of the frame tells the **number of characters (bytes)** in that frame.

🔧 **Example:**

[06][D][A][T][A][1][2]

Here, 06 means the frame has 6 characters.

✓ **Advantage:**

- Simple and easy to understand.

✗ **Disadvantage:**

- If the count is corrupted during transmission, **entire frame becomes useless**.

2. Character/Byte Stuffing:

It means inserting a special byte called **ESC (Escape character)** before any accidental FLAG that appears in the **data**.

✓ **Why?**

To make sure the receiver knows: "Hey, this is not a real FLAG, it's just part of the data."

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Let's understand with an example

Data : [41 7D 42 7E 50 70 46] , Here FLAG = 7E and ESC=7D.

Now,

[7E 41 7D 42 7E 50 70 46 7E]

FLAG FLAG

Final Frame : [7E 41 7D 7D 42 7D 7E 50 70 46 7E]

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💻 3. Bit Stuffing

Used in **bit-oriented protocols**.

A special pattern like **01111110** is used to indicate frame boundaries.

If 5 continuous 1's appear in data, a 0 is **"stuffed"** after them to avoid confusion.

Example:

Data: 011111 → Stuff a 0 → 0111110

Final frame:

[01111110]Data with bit stuffing[01111110]

✓ Advantage:

- Works with all types of data (text, images, files).
- Very reliable for **bit-level communication**.

✗ Disadvantage:

- Adds **extra bits**, increasing the frame size.

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What is an Error in Networking?

In computer networks, an **error** happens when the data sent from the **sender** gets **changed or corrupted** while reaching the **receiver**.

This can be due to:

- Noise in the communication medium
- Weak signals
- Hardware issues

Example:

Suppose a sender sends this binary data:

10110011

But the receiver gets:

10010011

☞ One bit changed! This is called a **bit error**.

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Types of Errors :

There are **two main types** of errors in networking:

1. Single-bit Error

- **Definition**: Only **one bit** of the data is changed.
- **Cause**: Usually due to a small noise or glitch.

📌 **Example**: Sent: 10110011
Received: 10100011
Only the **3rd bit** changed.
✓ Easy to detect and correct.

2. Burst Error

- **Definition**: **Two or more bits** in a data unit are changed.
- Can be consecutive or within a short group of bits.

📌 **Example**: Sent: 10110011
Received: 10001011
Here, **multiple bits** are incorrect.
✗ Harder to detect and correct than single-bit errors.

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Error Detection :

1. Single Parity Check
2. Two Dimensional Parity Check
3. Checksum
4. Cyclic redundancy check

Error Correction :

1. Hamming Code
2. Binary Convolution
3. Reed Solomon
4. Low desigty parity check

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1. Single Parity Check?

Single Parity Check is an error detection method. It helps us find out if an error happened while sending data from one computer to another.

It adds one extra bit, called the parity bit, to the original data. This bit tells whether the number of 1s in the data is even or odd.

✓ Two Types of Parity(Two Rules)

i. Even Parity:

In Even Parity, We count the number of 1's in original data if count is odd then we add parity bit 1 to make even number of 1's otherwise add 0.

i. Odd Parity:

In Even Parity, We count the number of 1's in original data if count is odd then we add parity bit 0 to make odd number of 1's otherwise add 1.

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🔢 Example of Even Parity (Working)

Sender

Suppose we want to send this **4-bit data**:

- **Data: 1011**

Count the number of 1s:

- **1 + 0 + 1 + 1 = 3 (odd number)**

To make it **even**, we add a **parity bit = 1**

So, the data becomes:

Sent Data: 1011 1 (parity bit is 1)

Receiver

What does the receiver do?

Receiver receives: 10111

- It again counts the number of 1s:

1 + 0 + 1 + 1 + 1 = 4 (even)

✔ So, data is **correct** (no error).

✖ What if there's an error?

Let's say one bit changed due to noise:

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Sent: 1 0 111

Received: 1 1 111

Now, count 1s:

1 + 1 + 1 + 1 + 1 = 5 (odd)

❌ So, error is **detected**.

⚠Important Note:

Single parity can **only detect odd number of errors** (like 1, 3, 5 errors).

It **cannot detect** if **two bits(Even Bits)** are wrong this is the major disadvantages of this methods.

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2. Two-Dimensional Parity Check?

Two-dimensional parity is an **advanced version of single parity check**.

It adds **parity bits in both row-wise and column-wise direction** (just like a table or grid of data).

Example:

Let's say we want to send this 3x3 data (just 0s and 1s):

	C1	C2	C3
R1	1	0	1
R2	1	1	0
R3	0	0	1

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Now, Add Row parity(RP) & Column Parity (CP)

	C1	C2	C3	RP
R1	1	0	1	0
R2	1	1	0	0
R3	0	0	1	1
CP	0	1	0	

Now send the full matrix with **row and column parity bits**.(Data Sent)

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❌ What if an Error Happens?

Suppose one bit changes during transmission, like:

- R2 C2 = 1 becomes 0

Now the receiver will check:

- Row 2 parity is **wrong**
- Column 2 parity is **wrong**

So, error is in **Row 2, Column 2**

→ easy to find and correct it!

✔

🎯 Advantages:

- Better than single parity
- Can **detect AND correct** single-bit errors
- Can **detect many types of multiple-bit errors**

⚠Limitation:

- It can't detect **all** multi-bit errors
- It uses **extra bits**, so a little more space is needed

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3.Checksum

Checksum is a method used to **detect errors** in data during transmission (like sending data from sender to receiver).

If the data changes even a little, the summary (checksum) will also change.

?? Basic Steps:

- **Divide data into equal-size blocks** (usually in 8 bits or 16 bits).
- **Add all the blocks together** using binary addition.
- **Take the 1's complement** of the result (flip all 0s to 1s and 1s to 0s).
- That result is called the **checksum**.
- Sender sends both **data + checksum**.
- Receiver adds all data blocks + checksum.
- If the result is **all 1s**, the data is correct. Otherwise, error detected!

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Simple Example:

Let's take **3 blocks of 8-bit data**:

11001100 10101010 11110000 11000011

Data Block 1: 11001100
Data Block 2: 10101010
Data Block 3: 11110000
Data Block 4: 11000011

11001100
10101010 -> Block 1 Add

01110110
+1

01110111 (intermediate Sum)
11110000 -> Block 3 Add

01100111
+1

01101000 (intermediate Sum)
11000011

00101011
+1

00101100 -> Final Sum of all block
1's - >11010011 ->Know as Checksum

Receiver:
00101100
11010011

11111111

Now take 1's
00000000 (data is correct)

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⚠Limitations:

- Cannot detect all types of errors.
- Not useful for large or very sensitive data.
- Cannot correct errors — only **detects** them.

4. What is CRC (Cyclic Redundancy Check)?

CRC is an **error-detecting technique** used in data communication.
It helps check whether the data received is **correct or has any errors** during transmission.
When data is sent, a special **CRC code** is added to it. The receiver checks this code.
If it matches what is expected, the data is correct. If not, there was an error during transmission.

🎁 Real-life Example:

- Imagine you're sending a parcel and you seal it with a unique sticker (CRC code). If the receiver sees the seal is not matching or is broken, they know something is wrong.
- Similarly, in networks, CRC is that “sticker” added to the data to check its correctness.

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✓ **CRC generation**

- Find length of **Divisor (L)**
- Append (L-1) bits '0' to original msg
- Perform binary division operation
- Remainder of division = **CRC** ←
- Transmitted msg = msg bit + CRC ←

✓ **CRC is verified at Receiver end:**

- Received data is divided by **divisor**
- If no remainder, the data is correct and accepted.
- Otherwise data is rejected.

Now let understand with easy example ->

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Example –

Msg = 100100

Divisor = 1101

Solution →

- Find length of **Divisor (L)** = 4
- Append (L-1) bits '0' to original msg.
- L-1 = 3 (000) append in msg

→ Now **Msg Becomes 100100000**

Now Perform binary division operation

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Sender,

```
        1 1 1 1 0 1
1 1 0 1 ) 1 0 0 1 0 0 0 0 0
          XOR 1 1 0 1
          -----------
          X 1 0 0 0
          XOR 1 1 0 1
          -----------
          X 1 0 1 0
          XOR 1 1 0 1
          -----------
          X 1 1 1 0
          XOR 1 1 0 1
          -----------
          X 0 1 1 0
          XOR 0 0 0 0
          -----------
          X 1 1 0 0
          XOR 1 1 0 1
          -----------
          X 0 0 1   → CRC (L-1)
```

Transmitted msg = 10010001

Receiver,

```
        1 1 1 1 0
1 1 0 1 ) 1 0 0 1 0 0 0 0
          XOR 1 1 0 1
          -----------
          X 1 0 0 0
          XOR 1 1 0 1
          -----------
          X 1 0 1 0
          XOR 1 1 0 1
          -----------
          X 1 1 1 0
          XOR 1 1 0 1
          -----------
          X 0 1 1 0
          XOR 0 0 0 0
          -----------
          X 1 1 0 1
          XOR 1 1 0 1
          -----------
remainder → 0 0 0 0
```

data is Correct.

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💡 Advantages of CRC:

- Can detect most common errors
- More reliable than parity or simple checksums
- Widely used in network protocols and storage devices

⚠ Disadvantages:

- It can only **detect errors**, not fix them
- Slightly more complex than parity/checksum

Q. Find the CRC for data 1101011111 using the divisor $x^4 + x + 1$ (V.V.IMP)

Hint -

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

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

1 0 0 1 1(Now 10011 use previous step and find CRC)

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Error Correction :

1. **Backward Error Detection**
2. **Forward error detection**

❖ What is Hamming Code?

Hamming Code is an **error detection and correction technique** used in communication systems.

✓ It can:

- **Detect 1-bit and 2-bit errors**
- **Correct only 1-bit error**

It's better than CRC and Parity when you also want to **correct** the error (not just detect it).

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✓ Hamming Code Encoding:

- Calculation of redundant bit *(2^r > m + r + 1)*
- Positioning of redundant bit *(...2^3, 2^2 2^1, 2^0)*

Calculation of value at redundant bit:

i. P_1: 1, 3, 5, 7, ...
ii. P_2: 2-3, 6-7, 10-11, ...
iii. P_4: 4,-7, 12–15, 20–30, ...

❖ Hamming Code Decoding:

- Parity check in received message
- Error detecting and correcting

Now let's understand with an easy example →

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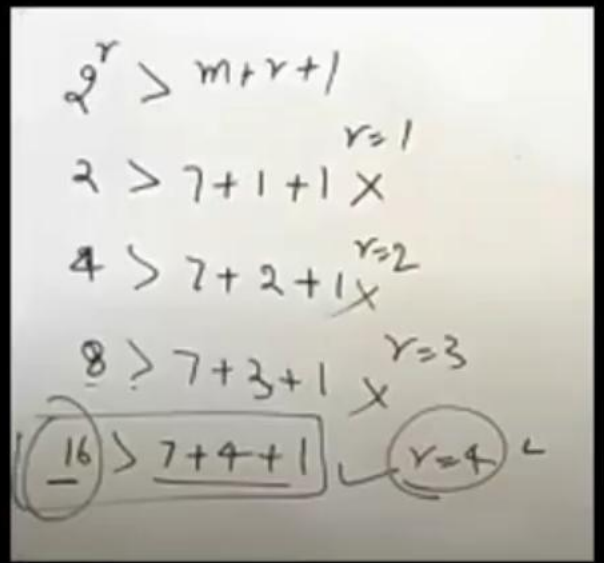
Example –

Msg – 1000001

M = 7

Solution :

1. Calculation of redundant bit *(2^r > m + r + 1)*



r = 4 (redundant bit)

Transmitted Msg = M + r

= 7 + 4 = 11 bit

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2. Positioning of redundant bit (...2^3, 2^2 2^1, 2^0)

Msg – 1000001

$2^0 = 1$

$2^1 = 2$

$2^2 = 4$

$2^3 = 8$

1	0	0	r	0	0	0	r	1	r	r

3. Calculation of value at redundant bit:

			p8				p4		p2	p1
1	0	0	r	0	0	0	r	1	r	r

P1 = r 1 0 0 0 1 = 0 (To make even 1's)

P2 = r 1 0 0 0 1 = 0 (To make even 1's)

P4 = r 0 0 0 = 0 (To make even 1's)

P8 = r 0 0 1 = 1 (To make even 1's)

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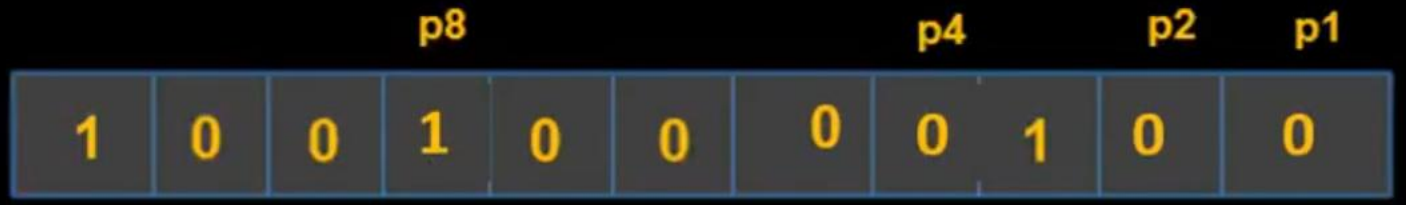

Transmitted msg : 10010000100

Hamming Code Decoding(Receiver end)

Received MSG = 10010000100

- Parity check in received message

P1 = 0 1 0 0 0 1 = 0 (To make even 1's)

P2 = 0 1 0 0 0 1 = 0 (To make even 1's)

P4 = 0 0 0 0 = 0 (To make even 1's)

P8 = 1 0 0 1 = 0 (To make even 1's)

Here, $(0)_{10}$ (no error)

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❖ **Error Control Mechanism (AKTU 2022-23)(V.IMP)**

isme kuch naya nahi hai bus whi Error detection + Error Correction likhna hai with their types yahi hai Error Control Mechanism.

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❖ Flow Control :

Flow control is a technique used in the **Data Link Layer** to make sure that:

☞ The **sender does not send data faster** than the receiver can process.

If the sender is very fast and the receiver is slow, then the receiver may **miss or lose data**. So flow control is important to **prevent data loss**.

❖ Simple Example:

Imagine you are filling a water bottle with a tap.

- If the tap is too fast and the bottle is small and slow to fill, the water will **overflow**.
- The same happens in networking — if sender sends too fast, the receiver **overflows**.

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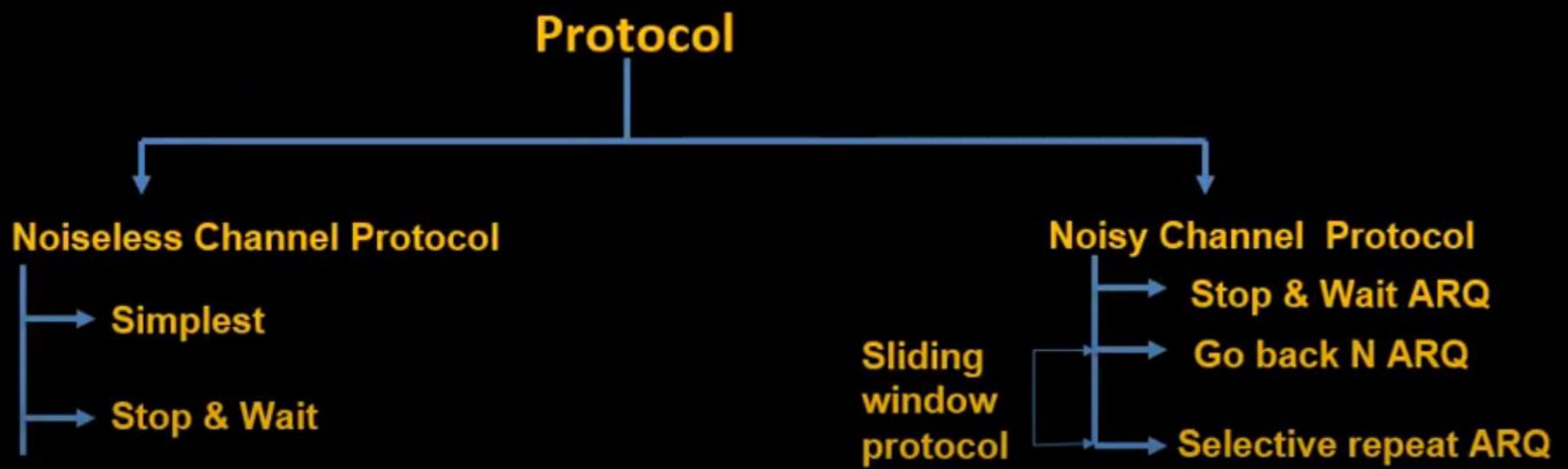
Why Flow Control is Needed?

- The **receiver has limited buffer (memory)**.
- If the sender keeps sending data without control, the receiver's memory may get full.
- This can cause **data loss** or **data to be overwritten**.



❖ Noiseless Channel Protocol :

Ideal channel, no Frame is lost, no duplicated or corrupted.

1. Simplest protocol :

- No Flow & error control.
- Unidirectional (Sender→ Receiver)
- No acknowledgement.

2. Stop & Wait Protocol – (AKTU 2021-22)

- The sender sends one data frame.
- Then waits for an acknowledgment (ACK) from the receiver.
- Only after getting ACK, it sends the next frame.

Pros:

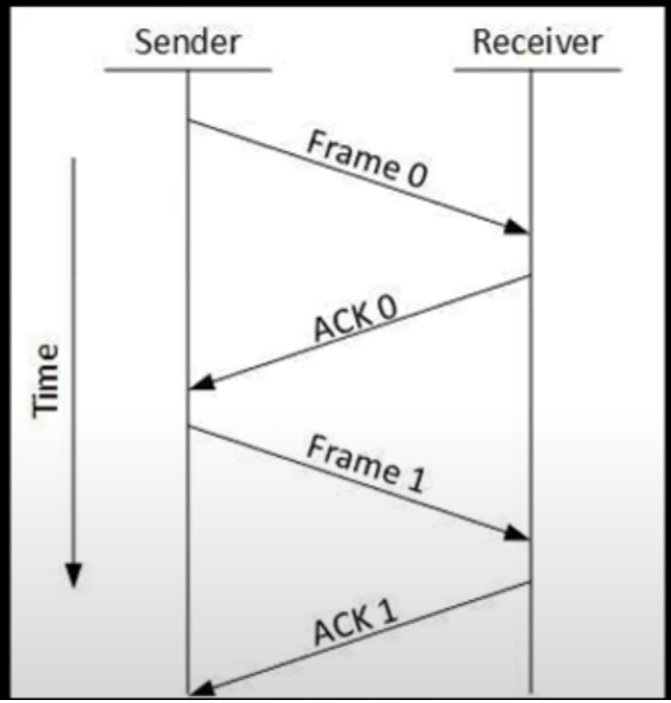
✓ Simple and easy to implement

✓ Reliable

Cons:

✓ Very slow

✓ Sender stays idle most of the time



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❖ Noisy Channel Protocol – (AKTU 2023-24)

1. Stop and Wait ARQ(Automatic Repeat Request) :

- **Stop-and-Wait ARQ** is an error-control method used in networking.
  It ensures the receiver gets each data frame correctly before sending the next one.
- **ARQ = Automatic Repeat Request**
  ☞ **Means:** If there's a problem (like no ACK or error), the sender **automatically repeats** the request (frame).
- If **ACK does not come in time**, sender will **timeout** and **resend** the frame.
- This method uses **timeout + sequence number** to handle errors and avoid confusion between old and new frames.

How it works (step by step):

1. **Sender sends one frame.**
2. **Sender waits for an Acknowledgment (ACK)** from the receiver.
3. If the **ACK is received**, the sender sends the next frame.
4. If the **ACK is not received within some time**, the sender assumes that the frame or ACK is lost.
5. The sender **resends** the same frame again.

This repeats until the frame is acknowledged correctly.

Real-Life Example (Easy):

🎾 Imagine you're throwing balls to your friend (one at a time).

- You throw one ball.
- You **wait for a thumbs-up (ACK)** from your friend.
- If you don't get the thumbs-up in time, you think the ball was missed.
- So, you throw that **same ball again** until you get a thumbs-up.

That's Stop-and-Wait ARQ.

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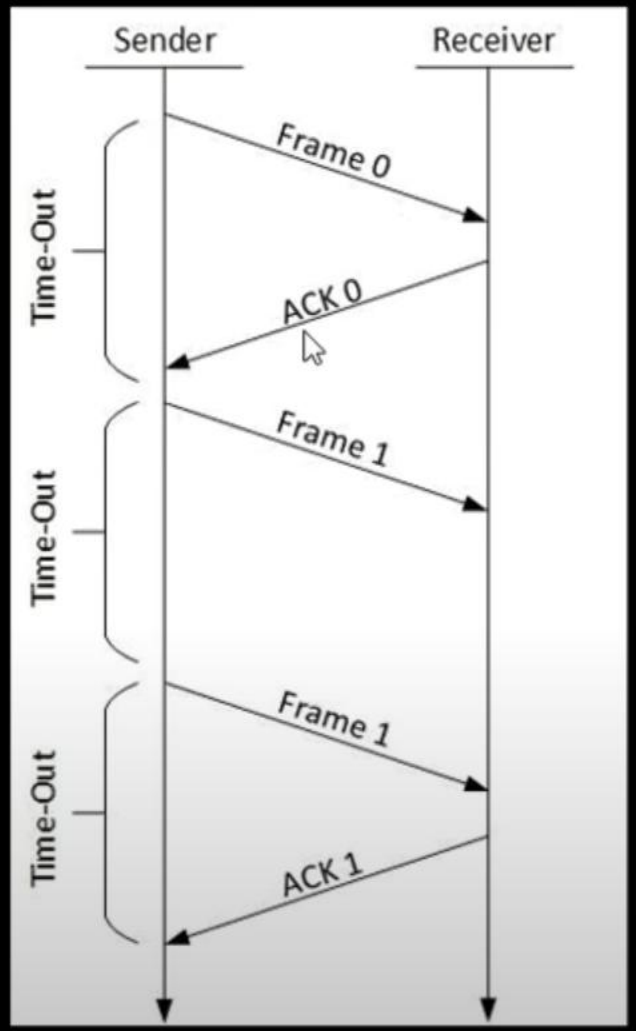
❖ **Advantages:**

✓ Simple to understand and use
✓ Reliable for error checking
✓ Ensures correct delivery

❖ **Disadvantages:**

✗ Slow (only one frame at a time)
✗ Wastes time waiting
✗ Not efficient for long-distance communication



❖ **Sliding Window Protocol :- Go Back –N ARQ Protocol , Selective Repeat protocol.**

2. Go Back –N ARQ Protocol – (AKTU 2022-23)

- Go-Back-N ARQ uses concept of pipeline i.e. sender send multiple frame before receiving Ack of first frame.
- The number of frame depends on size of window (N).
- If Ack not received of a frame within time timeout → all the frame in current window are retransmitted.
- The size of window determine the sequence number of frame.

The sender can send **multiple frames** continuously **without waiting** for ACK of each frame.

But... if **one frame fails**, the sender **goes back** and **resends that frame and all the next ones** (even if some were correct).

Eg – Number of frame 10 and window size is 2 then
If window size = 2, sender can send **2 frames at once**.
→ Sequence no is = 0,1 0,1 0,1 0,1 0,1

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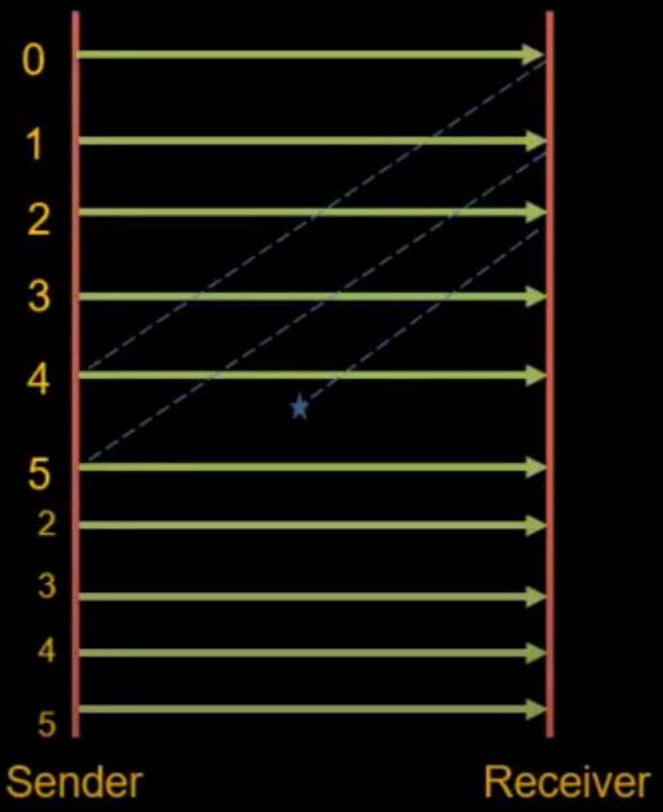
Exmple : Number of frame 11 and window size is 4 then
If window size = 4, sender can send 4 **frames at once**.
→ Sequence no is = 0,1,2,3

10 9 8 7 6 5 4 3 2 1 0



✓ Advantages:

✓ Better than Stop-and-Wait (more efficient)

✓ Uses pipelining — multiple frames in transit

✗ Disadvantages:

✗ If one frame fails, many others may also be resent (even if correct)

✗ Wastes bandwidth

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3. Selective Repeat protocol – (AKTU 2022-23)

Selective Repeat ARQ is a method used in computer networks to **detect and correct errors** during data transmission.

It works by:

- Sending **multiple frames at once** (like a pipeline).
- But instead of resending **all frames** when an error happens (like Go-Back-N), it only **resends the frame that has an error**.

🎁 Example (Simple Story):

Imagine you're sending 5 boxes (frames) to your friend:

You send Box 1, 2, 3, 4, 5.

Your friend receives:

✓ Box 1 → OK

✗ Box 2 → Damaged

✓ Box 3 → OK

✓ Box 4 → OK

✓ Box 5 → OK

Now, instead of sending **Box 2 to 5 again**, you just **re-send Box 2 only**.

This saves **time and bandwidth**!

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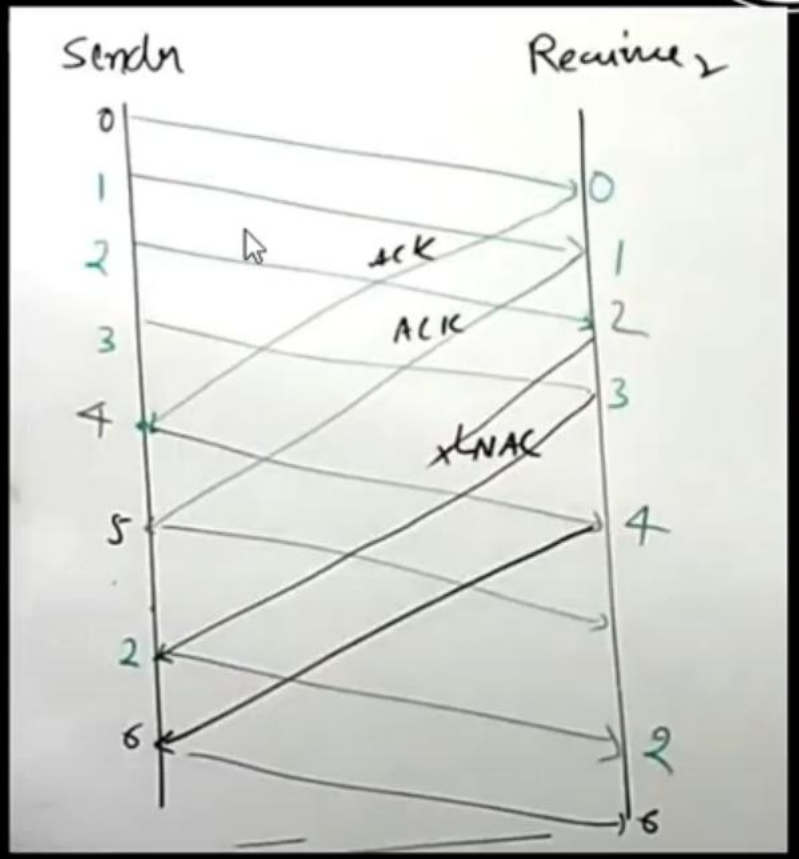
Example : Number of frame 11 and window size is 4 then

If window size = 4, sender can send 4 **frames at once**.

→ Sequence no is = 0,1,2,3

10 9 8 7 6 5 4 3 2 1 0



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Advantages:

- ✓ Saves bandwidth.
- ✓ More efficient than Go-Back-N.
- ✓ Faster transmission when errors are few.

✕ Disadvantages:

- ✕ More **complex** to implement.
- ✕ Requires more **memory/buffers** to handle out-of-order frames.

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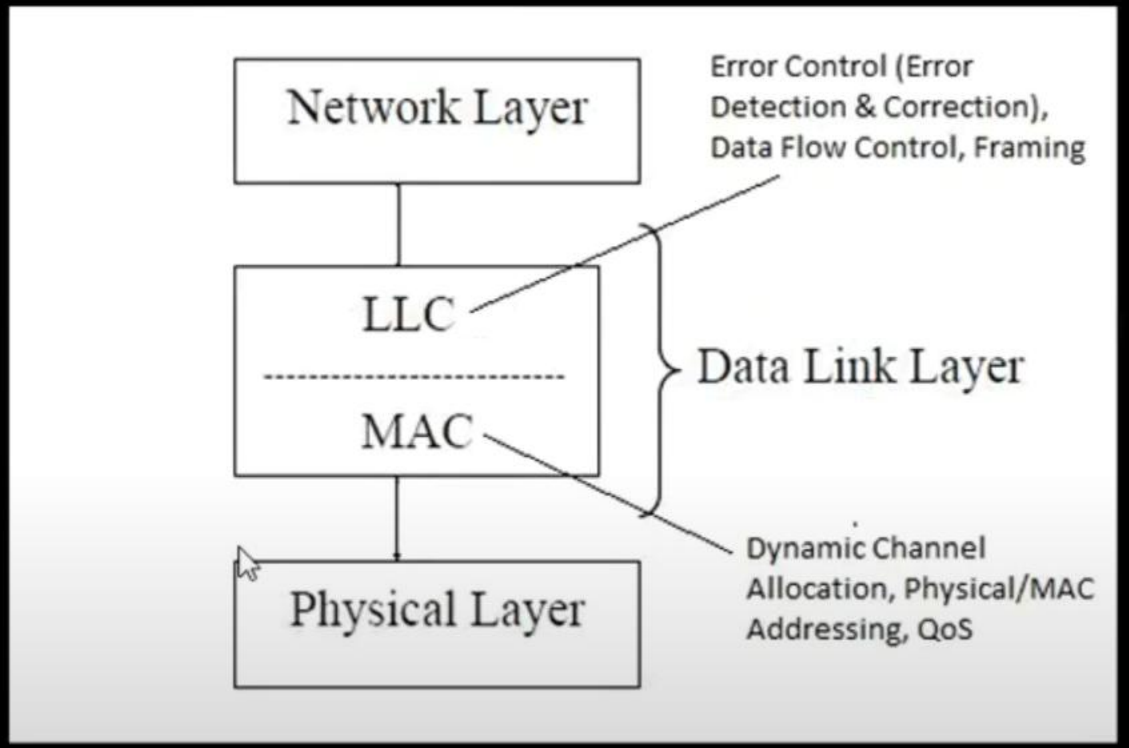
Sublayers of Data Link Layer :

The **Data Link Layer** in the OSI model is divided into two sublayers:

1. **Logical Link Control (LLC)**
   Also called **Data Link Control (DLC)**
2. **Medium Access Control (MAC)**



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🔑 1. Logical Link Control (LLC / DLC)

- Handles communication between **Network Layer** and **MAC sublayer**.
- Provides **flow control** (controls speed of data between sender and receiver).
- Allows **multipoint communication** (many devices on a network can talk).
- Adds **sequence numbers** to frames to keep them in correct order.

Example:

Imagine you're sending a series of pages to a printer. LLC ensures:

- Pages are **numbered correctly**.
- Printer **receives pages in order**.
- If the printer is slow, the sender **pauses** until it’s ready.

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❖ What is Medium Access Control (MAC)?

When multiple computers/devices are connected to the **same network cable or Wi-Fi**, they **share the same medium** to send data.

Problem?

👉 If all devices try to send data at the same time — **data gets mixed (collision)**!

So, we use **MAC protocols** to decide:

🗣️❓ “Kaun pehle bolega (send karega)?”

🕒 “Kab bolega?”

❌ “Collision kaise avoid hoga?”

MAC sublayer decides **“who will send data and when”** over a shared communication medium (like a cable or Wi-Fi).

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MAC Protocol

- Random Access Protocol
  - ALOHA
    - Pure
    - Slotted
  - CSMA
  - CSMA/CD
  - CSMA/CA
- Controlled Access Control
  - Reservation
  - Polling
  - Token passing
- Channelization Protocol
  - FDMA
  - TDMA
  - CDMA

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1.Random Access Protocol

- 📌 "Jo pehle aaye, pehle try kare" — but risk of collision hota hai.
- **No one has priority**, everyone tries to send whenever they want.
- If two send at the same time, there's a **collision**.
- In random access protocol, one or more stations cannot depend on another station nor any station control another station
- Random Access Protocol is a type of **Media Access Control (MAC) protocol** used in computer networks. It allows **multiple devices** to send data **without taking permission**. Each device transmits **whenever it has data**, which may lead to **data collisions** if more than one device sends at the same time.

Example:

Soch tu aur tera dost dono ek hi time par teacher se kuch puchne lag jaate ho — dono ki baat samajh nahi aati, teacher confuse ho jaati hai.

Yehi hota hai **collision** in Random Access Protocol.

2. Controlled Access Protocol :

Controlled Access Protocol is a **Media Access Control (MAC) method** where devices **take turns** to use the communication channel.

In this method, a **central control or a system** decides **which device can send data and when**, so that **no collision** happens.

✓ Key Points:

i. **Turn-based system** – Only one device is allowed to send at a time.
ii. **No collisions** – Since access is controlled, devices don't interfere.
iii. It is **more efficient** than Random Access when many devices are present.
iv. Common in **LANs (Local Area Networks)**.

Example:

Soch tu aur tere doston ko teacher ne bola:
"Ek-ek karke apna answer bolo."
Ab sabko apna number milta hai, koi ek time pe bolta hai.
Na koi interfere karta hai, na teacher confuse hoti hai.
Yehi hota hai **Controlled Access – sabko turn milta hai, collision nahi hota**.

3. ✍ Channelization Access Protocol :

Channelization Protocol is a method in which the **available bandwidth** (data-carrying capacity) of a channel is **divided among multiple users**, so they can **communicate at the same time without collision**.
It is mainly used in **Cellular Networks** and **Wireless Communication**.

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✅ Key Points:

- Bandwidth is **divided** into **channels**.
- Each user gets **a separate channel**, so no interference.
- All users can send data **simultaneously**.
- Best suited for **wireless networks** like mobile phones.

Example:

Soch ek sadak hai jahan se log guzarte hain.
Agar sab log ek hi raste se chalein, to **bheed ho jaayegi (collision)**.
To kya kiya jaata hai? **Alag-alag lanes bana diye jaate hain** — jaise bike lane, car lane, truck lane.
Bas yahi hota hai **Channelization Protocol** — **har user ko ek alag lane milti hai** taaki sab safe aur smooth travel karein 🚗🛣️.

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❖ Pure ALOHA (Additive Links On-line Hawaii Area) :

Pure ALOHA is a **random access protocol** used in computer networks to send data **without checking** if the channel is free.

It was developed by the **University of Hawaii** to connect computers on different islands using radio.

In Pure ALOHA, **any device can send data at any time**, and then **waits for an acknowledgment**. If the acknowledgment is not received (due to collision), the sender waits for some time and **resends the data**.

✓ 📉 Efficiency of Pure ALOHA:

- It has **very low efficiency** – only **18.4%**.
- This means **only 18.4% of total time** is used to send successful data. Baaki time data loss hota hai due to collision.

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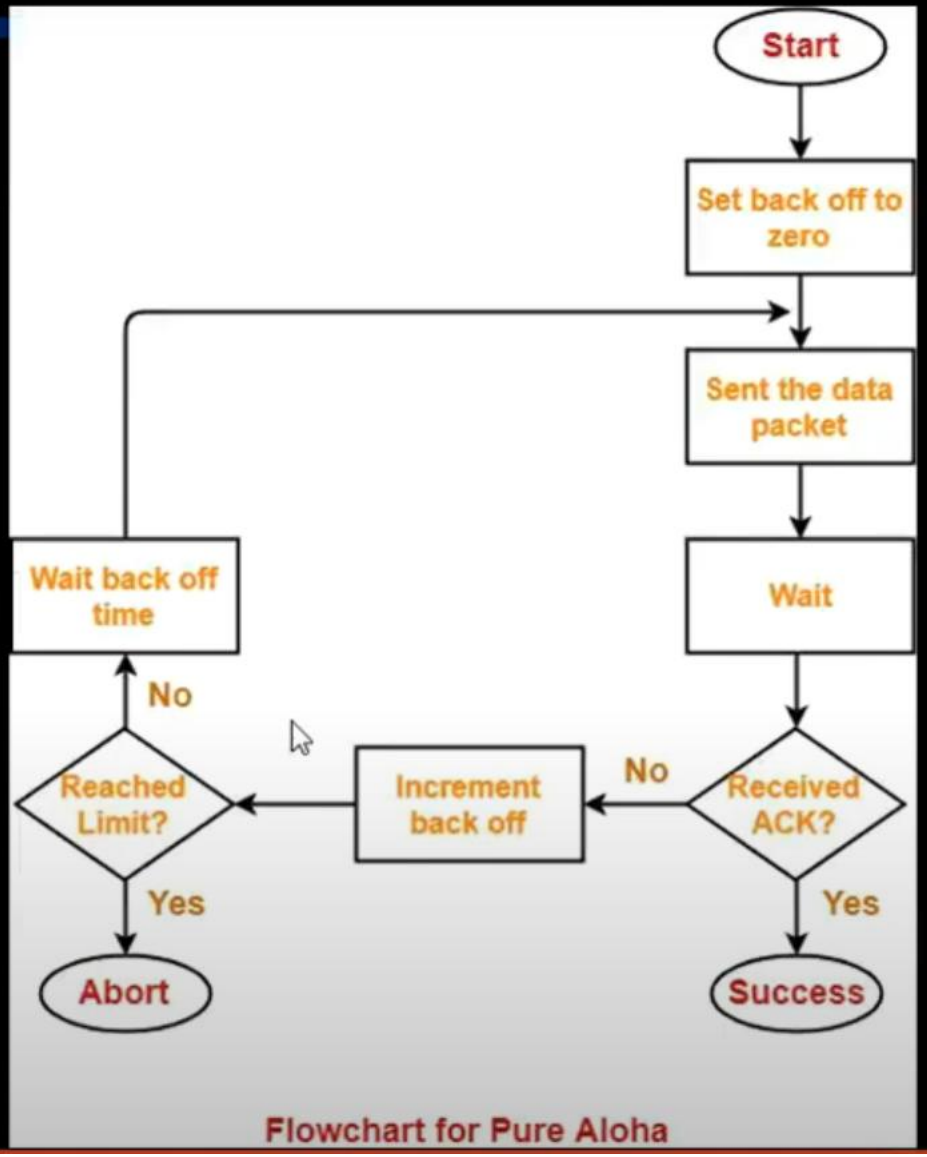
Example:

Soch ek classroom hai jahan **sab students bina permission ke ek saath bolte hain**.

Agar do ya zyada students ek saath bolenge, to **teacher kuch bhi nahi sun paayegi** — yehi hota hai **collision**.

Fir teacher bolegi "dobara bolo ek-ek karke", to bachche **random time baad firse bolte hain**.

Yehi hota hai **Pure ALOHA** ka system.



Flowchart for Pure Aloha

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🔁 **Step-by-step :**

i. **Start**
→ The process begins — the device is ready to send data.

ii. **Set backoff to zero**
→ Backoff time means the waiting time after a collision. Initially, it's set to **0**.

iii. **Send the data packet**
→ The device sends its data packet to the network.

iv. **Wait**
→ After sending, the device **waits for an acknowledgment (ACK)** from the receiver.

v. **Received ACK?**

i. If **Yes** → data is successfully received 🎉 → **Success**.

ii. If **No** → that means **collision happened** 💥.

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vi. Increment backoff

→ **Since there was a collision, the device increases the backoff count (how many times it has retried).**

vii. Reached limit?

i. If **Yes** → Too many retries → **Abort** ✗ (stop trying).

ii. If **No** → Wait for some **backoff time** (random delay), then go back and **try sending again**.

viii. Repeat from step 3 after waiting.

✓ **Advantages of Pure ALOHA:**

i. **Very simple and easy to implement.**

ii. **Good for low-traffic networks.**

✗ **Disadvantages of Pure ALOHA:**

i. High chance of **collision**.

ii. **Low efficiency** (only 18.4%).

iii. Not suitable for **high-traffic** environments.

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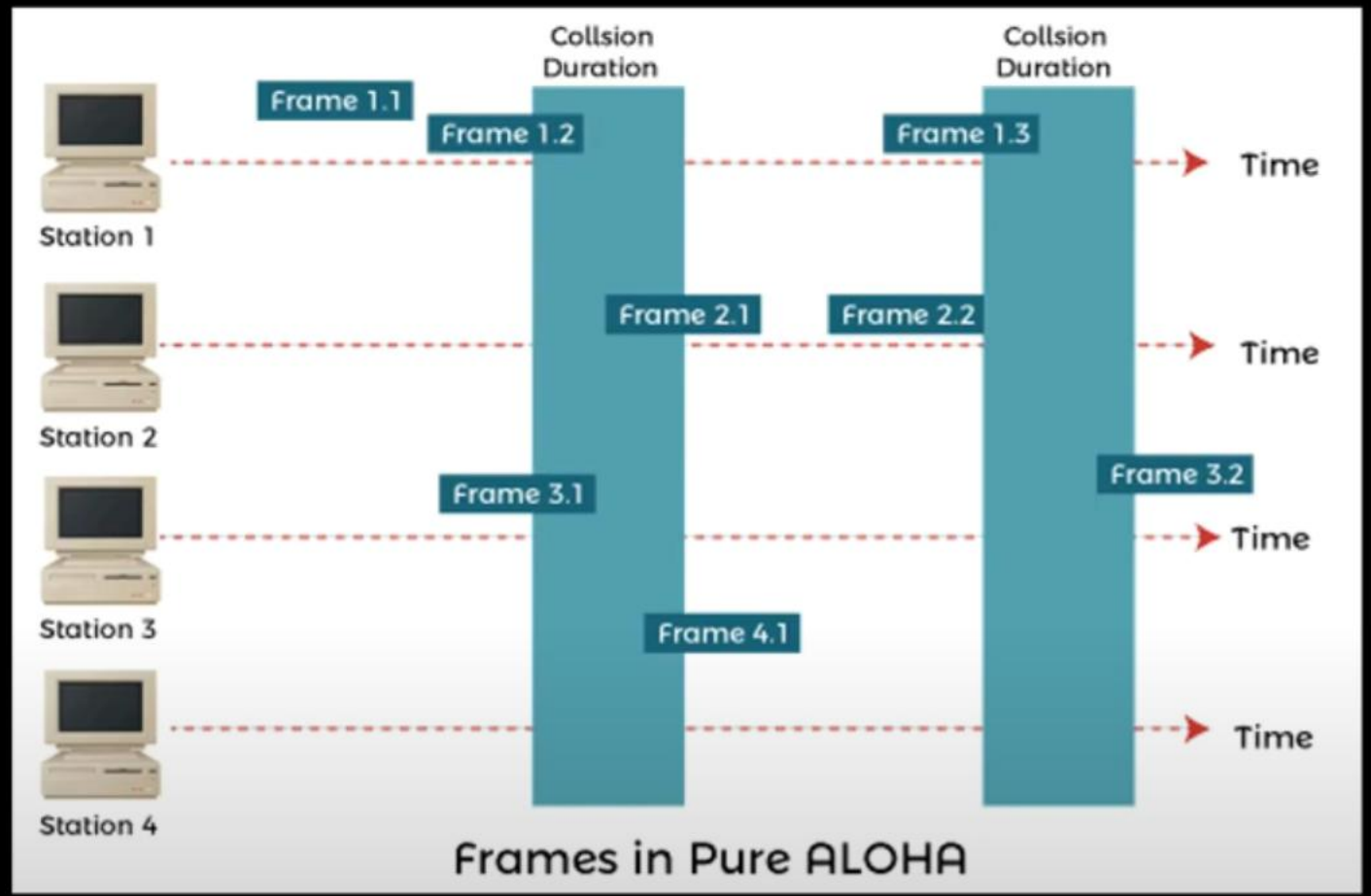

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❖ Slotted ALOHA?

Slotted ALOHA is an **improved version** of Pure ALOHA that reduces the chances of collision.

☞ Main Idea:

In Slotted ALOHA, **time is divided into slots** and devices can only send data **at the beginning of a time slot**, not anytime they want (like Pure ALOHA).

Slotted ALOHA is a multiple access protocol where the time is divided into fixed-size slots, and a station can only send data at the beginning of these slots. This helps in reducing collisions and improving efficiency.

Efficiency:

- **Slotted ALOHA Efficiency ≈ 36%**
  Means out of 100 attempts, around **36** can succeed if all work properly.

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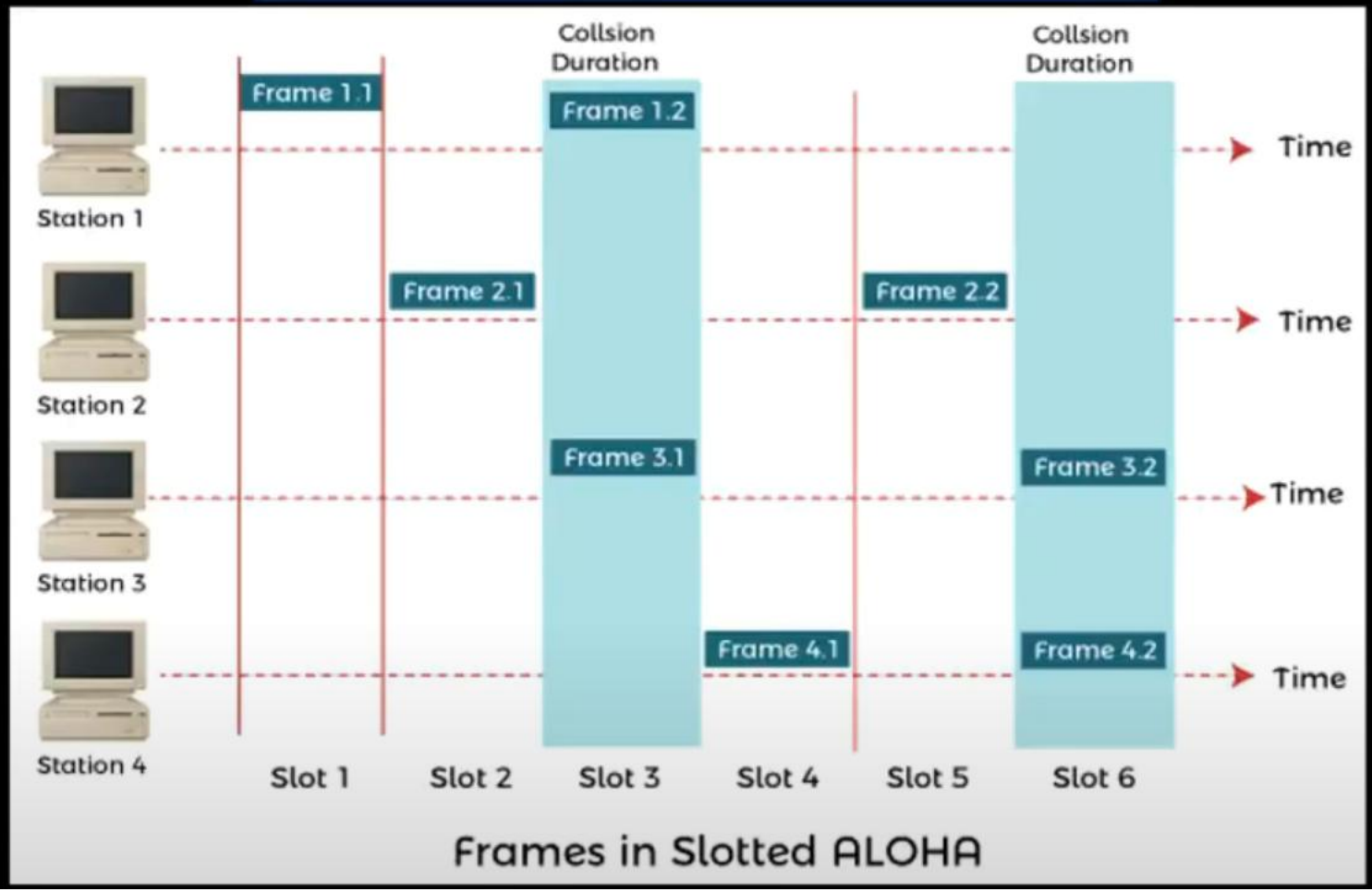

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🔄 **Let's go Slot-by-Slot:**

✅ **Slot 1:**

- **Only Station 1** sends Frame 1.1 → No one else sends → ✅ **Success**.

✅ **Slot 2:**

- **Only Station 2** sends Frame 2.1 → ✅ **Success**.

❌ **Slot 3:**

- **Collision occurs!**
  - Station 1 sends Frame 1.2
  - Station 3 sends Frame 3.1
  - Both send **at the same time slot** → ❌ **Collision** (Data is lost)

✅ **Slot 4:**

- Only Station 4 sends Frame 4.1 → ✅ **Success**

✅ **Slot 5:**

- Only Station 2 sends Frame 2.2 → ✅ **Success**

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❌ **Slot 6:**

- **Another collision!**
  - Station 3 sends Frame 3.2
  - Station 4 sends Frame 4.2
  - Both sent in the **same slot** → ❌ **Collision**

Important Point:

- In **Slotted ALOHA, if two or more stations choose the same slot, collision will happen**, and both data frames will be lost.
- If **only one station** uses a slot → the data is sent successfully.

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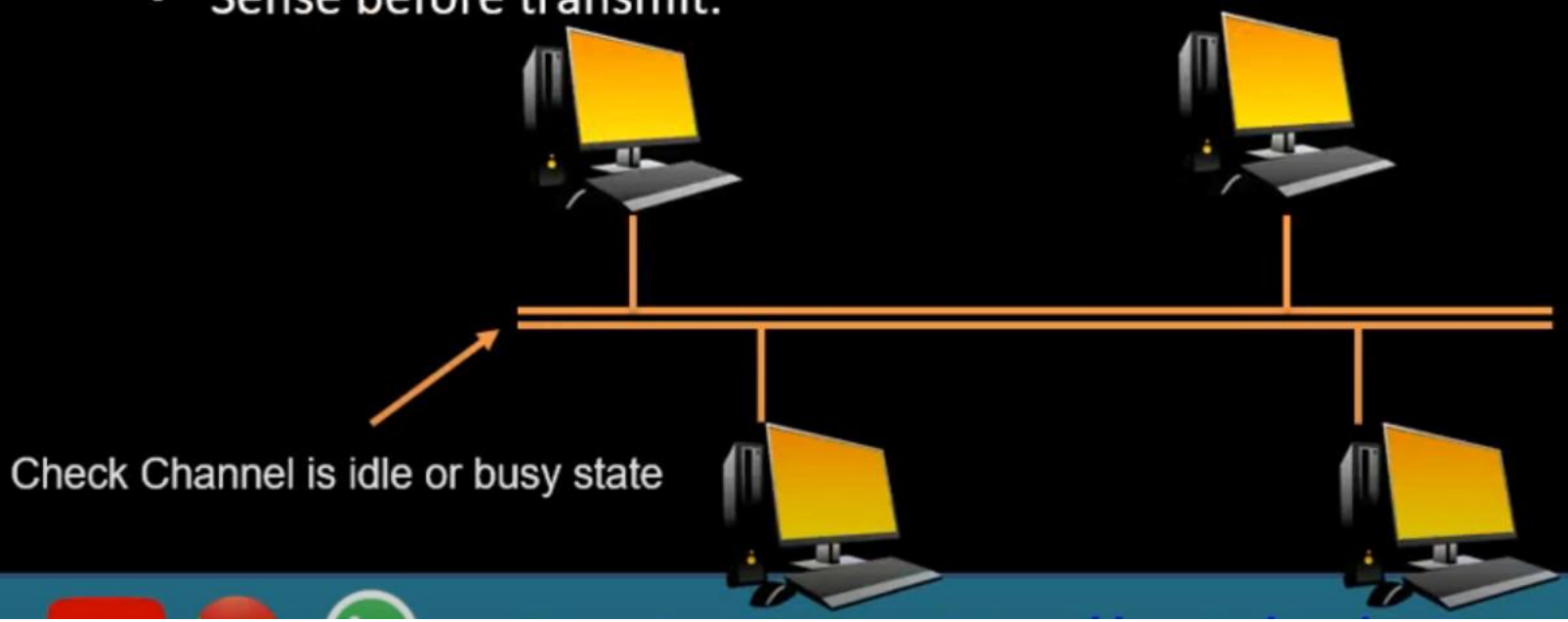
❖ CSMA (Career sense multiple access) :

- CSMA stands for Carrier Sense Multiple Access, a network protocol that controls how devices transmit data on a shared network. CSMA helps prevent collisions when multiple devices try to send data at the same time.
- Sense before transmit.



Simple Imagination / Example:

📞 Think of a Phone Call:

Suppose you and your friends are talking on a group call.

- Only one person can talk at a time.
- Before talking, you will listen first if anyone else is already speaking.
- If the line is clear, you start speaking.
- If someone is already talking, you wait for the line to become free.

This is exactly how CSMA works.

Types of CSMA:

There are two types of CSMA :-

1. Persistent
2. No Persistent

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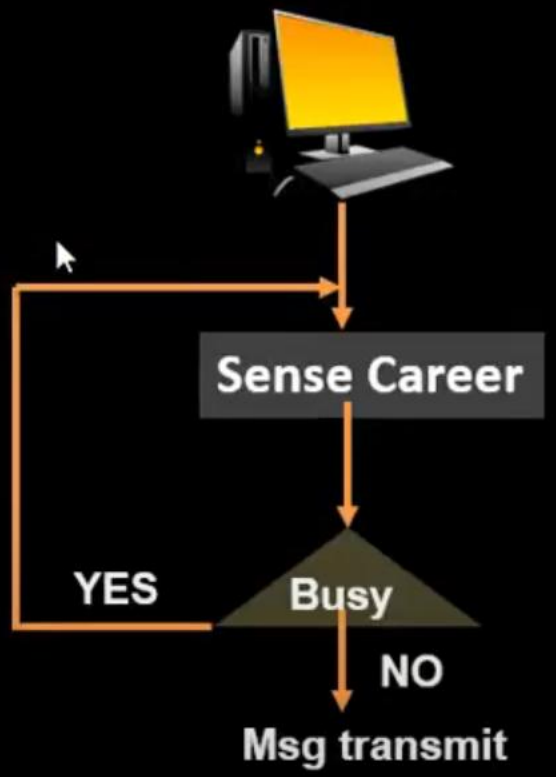
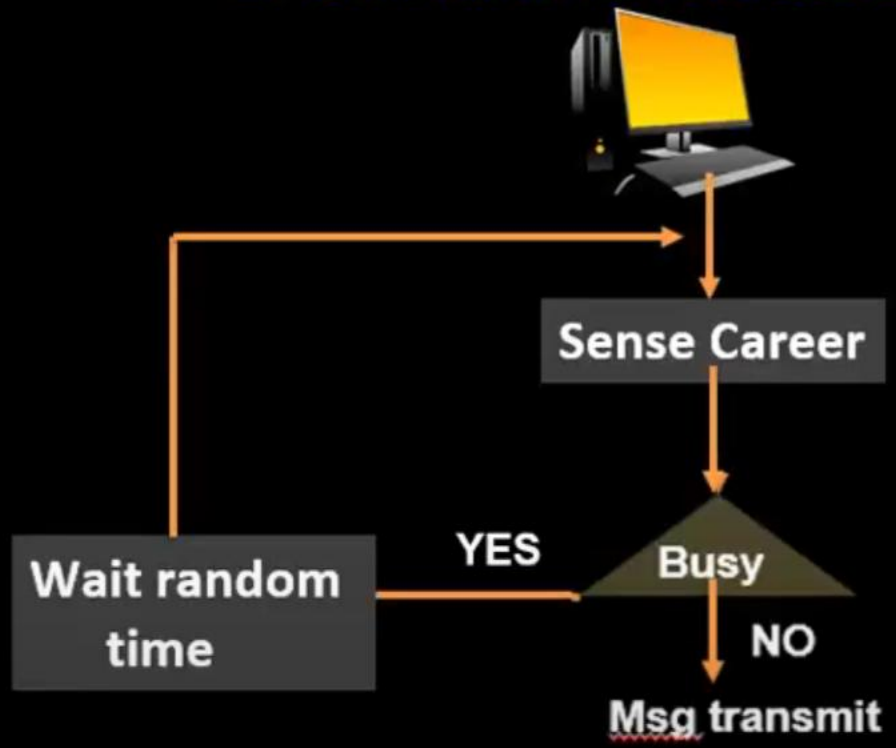
1. CSMA with Persistence :



2. CSMA with No Persistence :



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🌐 CSMA/CD (Carrier Sense Multiple Access with Collision Detection) –(VIMP)

CSMA/CD is a network protocol used in wired Ethernet to **avoid and handle collisions** during data transmission. It ensures that **only one device sends data at a time** on the network channel.

📌 Key Points:

i. **Carrier Sense**: Listen to the channel before sending.
ii. **Multiple Access**: All devices share the same communication channel.
iii. **Collision Detection**: Detect if two devices send data at the same time.

📄 Real-life Example for Understanding:

Imagine a classroom where many students want to speak (send data):

- Each student first checks if no one is speaking (carrier sense).
- If the room is silent, the student speaks (sends data).
- If two students speak at once, they realize the collision and say “sorry” (jam signal).
- They wait for some time (backoff), and then try again.

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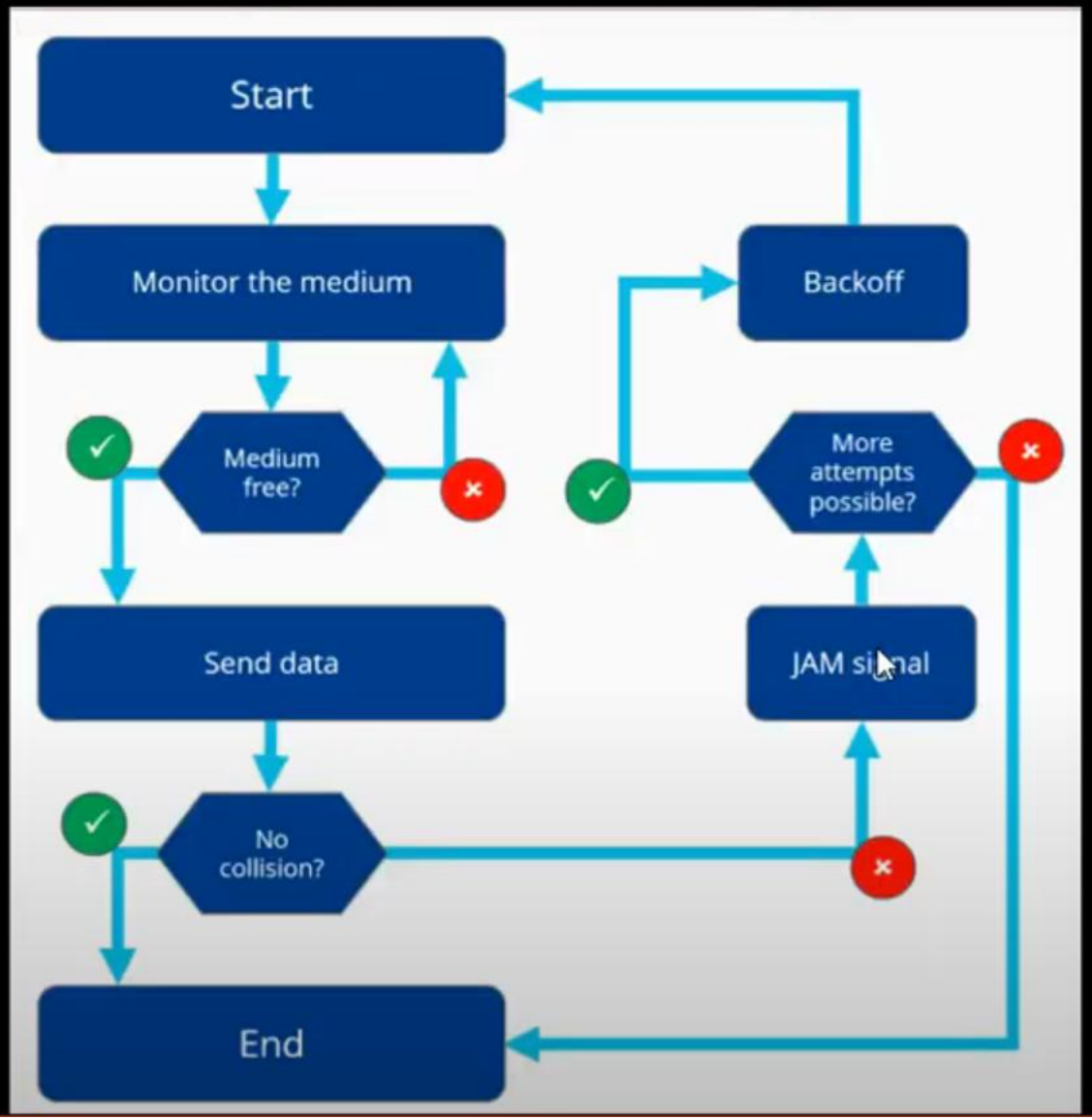

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Working Steps of CSMA/CD:

1. Start

The device wants to send data on the network.

2. Monitor the Medium

The device first listens to the network channel to check if it is free or busy.

3. Check if Medium is Free:

If **free**, it proceeds to send the data.

If **busy**, it **waits** and keeps checking again.

4. Send Data

When the medium is found free, the device sends its data.

5. Collision Detection

While sending, the device monitors the channel to check if a collision (data clash) occurs.

6. If No Collision:

The data is successfully transmitted.

The process **ends**.

7. If Collision Detected:

The device sends a **JAM signal** to inform all devices about the collision.

This helps other devices know that the data was not transmitted successfully.

8. Check Retry Limit:

If retry limit is **not reached**, the device waits for a **random backoff time** (this prevents repeated collision), and then tries again.

If retry limit is **exceeded**, the device stops trying and **gives up** the transmission.

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✓ Advantages:

- Network pe **collision detect** ho jaata hai
- **Wired medium** ke liye best hai
- Bandwidth **waste hone se bachti hai**

✗ Disadvantages:

- Wireless networks mein **use nahi ho sakta**
  (kyunki wireless mein hum detect nahi kar paate easily ke kisi aur ka data aa raha hai)
- High traffic mein still **delays** ho sakte hain

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CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)(V.IMP)

- CSMA/CA is a network protocol used to **avoid data collisions before they happen**. It is commonly used in **wireless networks (like Wi-Fi)** where detecting collisions is difficult.
- CSMA/CA is a method used to **minimize data collisions** in networks, especially in **wireless communication**, by **reserving the medium before transmission**. It uses RTS/CTS messages to coordinate data transfer and ensures more reliable communication.
- CSMA/CA focuses on **avoiding collisions**, unlike CSMA/CD which **detects** them after they happen.

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Real-life Example:

Imagine a group of students in a classroom:

- A student wants to speak (send data).
- He first checks if the teacher (channel) is listening.
- Before speaking, he **raises his hand (RTS)**.
- If the teacher gives permission (CTS), he speaks.
- After he finishes, the teacher says "okay" (ACK).

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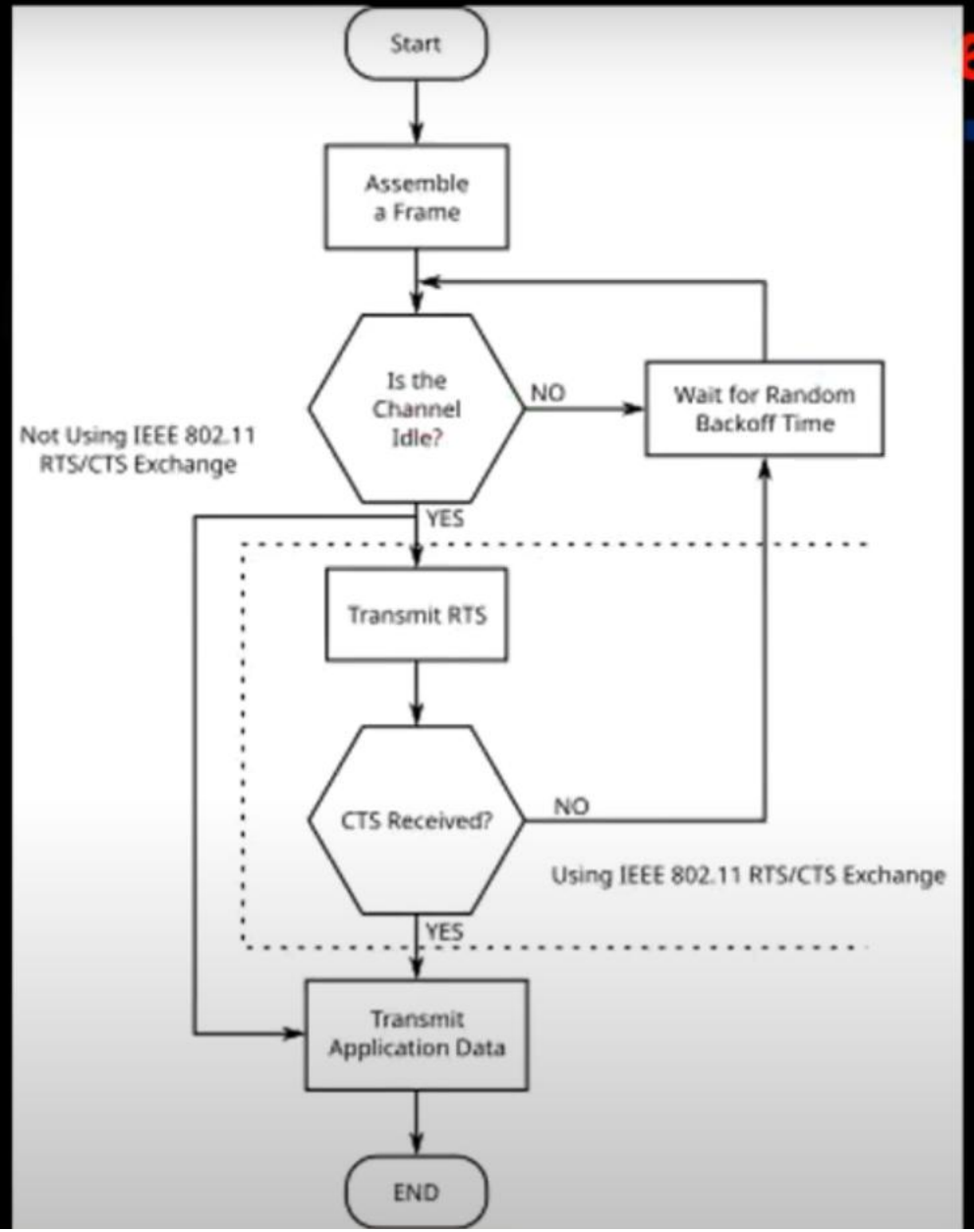

🔄 Working Steps of CSMA/CA:

1.Start

A device wants to send data over the wireless medium.

2.Check if Medium is Free

The device **listens to the channel** to check whether the medium is currently free or busy.

3.If Medium is Busy:

1. The device **waits** until the channel becomes free.
2. After it becomes free, it **waits for a random backoff time** (this helps avoid collision with other devices also waiting).

4.Send Request to Send (RTS) Signal:

The device sends an **RTS (Request To Send)** signal to the receiver.

5. Receive Clear to Send (CTS) Signal:

If the receiver is ready, it replies with a **CTS (Clear To Senda)** signal.

6. Send Data

Once CTS is received, the device starts **sending data**.

7. Acknowledgement (ACK)

After receiving the data successfully, the receiver sends an **ACK (Acknowledgment)** to confirm successful delivery.

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What is Channel Allocation?

Channel Allocation refers to the process of assigning available communication channels (frequencies) to different users in a network so they can transmit data without interference.

Just like in a classroom, each student gets their turn to speak—similarly, in a network, each user is assigned a specific channel to communicate efficiently.

✓ Why is Channel Allocation Important?

- To **avoid interference** between users
- To make **efficient use of bandwidth**
- To ensure **smooth and reliable communication**

Types of Channel Allocation Schemes:

There are two main types of channel allocation:

1. Fixed Channel Allocation (FCA)

- In this method, each user or base station is **permanently assigned** a specific frequency channel.
- Even if the user is not actively communicating, the channel remains **reserved** and **cannot be used** by others.

📌 **Example:** Like a **reserved seat in a train**. Even if the person doesn't sit, no one else can take it.

✅ **Advantages:**

- Simple and easy to implement
- No delay in channel assignment

❌ **Disadvantages:**

- **Wastes channels** if users are inactive
- Not suitable for traffic that changes frequently

2. Dynamic Channel Allocation (DCA)

- In this method, channels are **not fixed**. They are assigned **dynamically** whenever a user wants to communicate.
- After communication is complete, the channel is **released** and can be used by others.

📌 **Example:** Like booking an **Uber or Ola taxi**. You get a car when you need it, and after the ride, it becomes available for the next user.

✅ **Advantages:**

- Efficient use of available channels
- Better suited for networks with **changing traffic patterns**

❌ **Disadvantages:**

- More **complex** system
- May cause **delay** in assigning channels

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🔰 What is a Standard in Networking?

A **standard** in networking is like a **set of rules** or **guidelines** that everyone follows to **communicate properly** over a network.

🔸 Imagine if every phone company used a **different language**, phones wouldn't work together, right?

👉 So, to make sure **all devices can connect and understand each other**, we need **standard rules** — these are called **LAN Standards**.

💡 Why Standards are Important?

✅ Devices from different companies can work together (e.g., HP laptop connects to TP-Link router)

✅ Communication becomes reliable and fast

✅ Helps in managing, securing, and designing networks

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Now let's learn the Top 5 LAN Standards one by one

✓ 1. **IEEE 802.3 (Ethernet - Wired LAN) :**

IEEE 802.3 is the **most widely used standard** for Local Area Networks (LANs).

It defines how devices on a **wired network** communicate using **Ethernet cables**.

◆ **How It Works:**

- Uses **CSMA/CD** (Carrier Sense Multiple Access with Collision Detection)
- Devices check if the cable is **free**
- If free → send data
- If two devices send together → **collision happens**
- Devices wait random time and try again

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Characteristics:

- Speed: 10 Mbps to 10 Gbps or more
- Cable: Twisted Pair, Coaxial, Fiber Optic
- Topology: Star / Bus
- Very reliable and low-latency

Real-World Example:

Used in **offices**, **schools**, **data centers** where high-speed internet and security are important.

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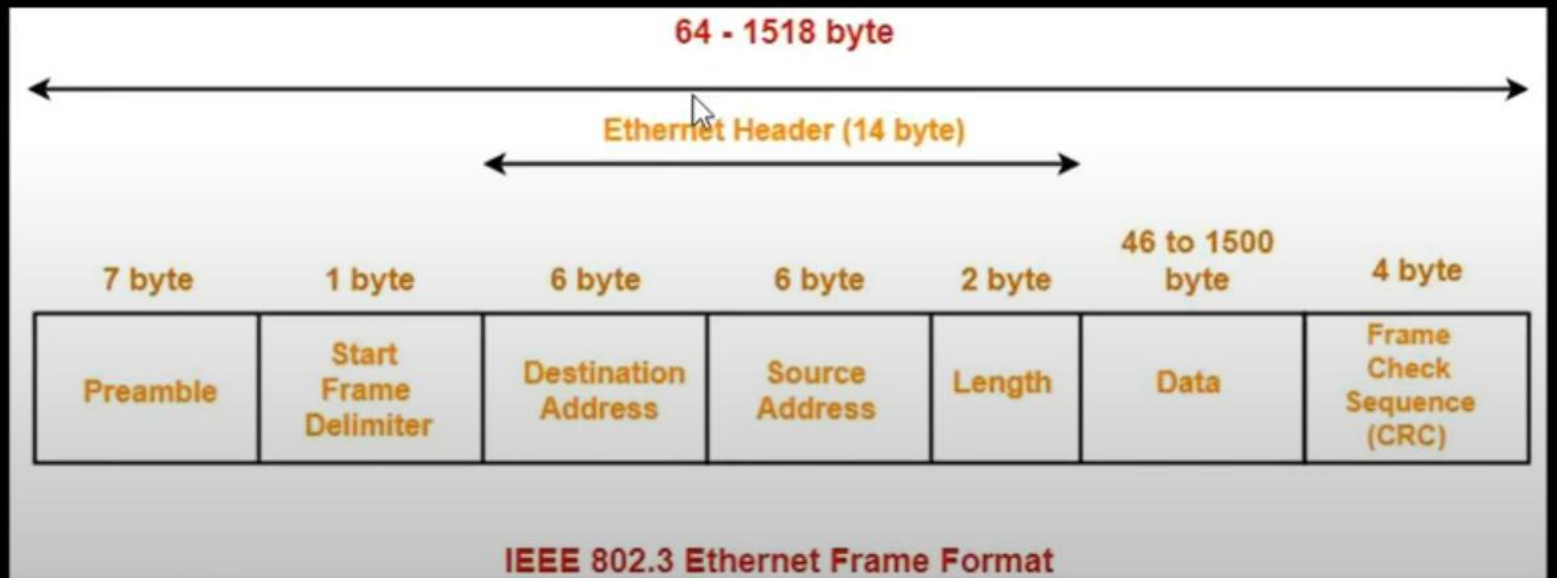
What is Ethernet Frame Format?(IMP)

Ethernet Frame is the **standard format of data** used when one computer sends data to another over a **wired LAN** using the IEEE **802.3 standard** (released in 1983).

Imagine it like a **courier package**:

- It has **address** (who is sending and receiving)
- It has **the actual message (data)**
- It also has some **important tags/checks** to avoid damage or misdelivery.



IEEE 802.3 Ethernet Frame Format

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Field	Size	Meaning
Preamble	7 Bytes	Sync signal
SFD	1 Byte	Start of Frame
Destination	6 Bytes	Receiver's MAC address
Source	6 Bytes	Sender's MAC address
Length/Type	2 Bytes	Data length or protocol type
Data	46–1500B	Actual message
CRC	4 Bytes	Error detection (checksum)

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✓ 2. IEEE 802.11 – Wireless LAN (Wi-Fi)

IEEE 802.11 is the standard used for **wireless networking**, which we call **Wi-Fi**.

◆ How It Works:

- Uses **CSMA/CA** (Collision Avoidance instead of Detection)
- Devices **listen** before sending
- If medium is busy → wait and try later
- Can use **RTS/CTS** (Request to Send / Clear to Send) to avoid collisions

◆ Types of 802.11:

- 802.11a – 54 Mbps, 5 GHz
- 802.11b – 11 Mbps, 2.4 GHz
- 802.11g – 54 Mbps, 2.4 GHz
- 802.11n – up to 600 Mbps (dual-band)
- 802.11ac – up to several Gbps (modern Wi-Fi)

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Characteristics:

- No cables, more flexibility
- Limited range
- Used in homes, cafes, colleges, etc.

Real-World Example:

Your mobile, laptop, or smart TV connected to your Wi-Fi router – that's 802.11 in action.

✓ 3. IEEE 802.5 – Token Ring

IEEE 802.5 is an older LAN standard developed by IBM.
Here, devices are connected in a **ring topology** and pass a **token** to control who can send data.

◆ How It Works:

- Only the device with the **token** can transmit
- Token moves from one device to another in a circle
- This avoids collisions

◆ Characteristics:

- Speed: 4 Mbps or 16 Mbps
- Topology: Logical Ring, but often physically wired as Star
- No collision, but slower than Ethernet

✓ Real-World Example:

Think of it like a group discussion where only the person holding the mic can speak.
Used in old banking networks, but now replaced by Ethernet.

✓ 4. IEEE 802.4 – Token Bus

Token Bus is similar to Token Ring but uses a **bus topology** instead of a ring.

◆ How It Works:

- Devices connected in a bus (single main cable)
- A **token** is passed logically (not physically)
- Only the device with the token can transmit

◆ Characteristics:

- Used in **industrial control systems**
- Prevents collision like Token Ring
- Slower adoption in modern networks

✓ Real-World Example:

Factory automation systems use Token Bus where timing is important and communication must be well-organized.

✓ 5. IEEE 802.1 – LAN Management Standard

This standard doesn't define how devices send data, but **how to manage and control the network**.

◆ Features of IEEE 802.1:

- VLAN (Virtual LANs): Divide one network into small virtual parts
- Spanning Tree Protocol (STP): Prevent looping in switches
- Network security protocols
- Bridging and routing between LANs

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❖ Difference between 802.3 802.4 and 802.5 IEEE Standards.

Feature	IEEE 802.3	IEEE 802.4	IEEE 802.5
Name	Ethernet	Token Bus	Token Ring
Access Method	CSMA/CD (Carrier Sense Multiple Access with Collision Detection)	Token Passing on a Bus	Token Passing in a Ring
Topology	Bus or Star	Bus	Ring
Transmission	Broadcast	Broadcast	Unicast (one by one)
Speed	10 Mbps to 400 Gbps	1 to 10 Mbps	4 Mbps or 16 Mbps
Who sends data?	Anyone can try to send anytime	Only device with token sends data	Only device with token sends data
Token Used?	✗ No token used	✓ Yes	✓ Yes
Collision Possibility	Yes (handled by CSMA/CD)	No	No
Used in	Most common networks (LANs, Internet)	Industrial networks (rare now)	IBM networks (mostly old now)
Easy Example	Like kids shouting in class — if 2 shout together, teacher stops them (collision)	Like passing a talking stick on a bench	Like passing a chit in circular order

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🔁 Bridge –

A **bridge** is a **network device** used to **connect two or more LAN segments** and make them work as a single network. It filters data and **forwards only necessary traffic** to the correct segment.

Example -

Soch lo do alag-alag classrooms hain, aur dono mein students hain (devices).

Bridge ek teacher hai jo **sirf un messages ko dusre class mein bhejta hai jo zaroori hote hain**.

- Agar Class A ka student Class B ke student ko message bhejna chahta hai, to bridge check karega aur sirf wohi message dusri class mein forward karega.

🛠️ Features of Bridge:

- Works at **Data Link Layer (Layer 2)**.
- Uses **MAC addresses** to forward data.

- **Reduces traffic** by filtering unnecessary data.
- Cheaper and simpler than routers.

🔀 Link Layer Switch –

A **Link Layer Switch** is an advanced version of a bridge with **multiple ports**. It connects many devices in a LAN and **forwards data based on MAC addresses**.

Example :

Soch lo ek classroom mein har desk ke liye ek personal teacher ho (switch ke ports). Agar student A ko student C se baat karni hai, to teacher (switch) **seedha A ke message ko C tak bhejta hai** – bina dusre students ko disturb kiye.

🛠️ Features of Switch:

- Also works at **Data Link Layer (Layer 2)**.
- Uses **MAC address table** to forward frames to the correct device.
- **Much faster and smarter** than a bridge.
- Commonly used in modern networks (LAN).
- Reduces collision and increases speed.

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What is a Learning Bridge?

A **Learning Bridge** is a type of bridge (Layer 2 device) that **automatically learns the MAC addresses** of devices connected to its ports. It **builds a table** (called a **MAC Address Table** or **Forwarding Table**) to decide where to send incoming frames.

Easy Real-Life Example :

Soch lo ek teacher hai (Learning Bridge), aur uske paas teen doors (ports) hain.

- Jab bhi koi student (device) ek message bhejta hai, teacher dekhta hai:
  "Yeh student kaunse door se bol raha hai?"
  Fir us student ka naam (MAC address) likh leta hai us door ke against.
- Agli baar jab kisi aur student ne us student ko message bhejna ho,
  teacher seedha **usi door se message bhej deta hai** – bina sabko disturb kiye.

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⚙️❓ How It Works (Step-by-Step):

- **Frame Receive – Bridge receives a data frame.**
- **Learn Source Address – It notes the MAC address of sender and the port from which it came.**
- **Update MAC Table – It saves this info in the MAC table.**
- **Check Destination – It checks if it knows the destination MAC address.**
- **Forward or Broadcast:**
  - If found → Forwards the frame to the correct port.
  - If not found → Broadcasts to all ports except the incoming one.

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🌲 What is Spanning Tree Algorithm?

The **Spanning Tree Algorithm (STA)** is a method used in networking to **prevent loops** when multiple bridges/switches are used in a LAN.

It helps in forming a **loop-free logical topology** even if the physical network has loops.

🤔 Real-Life Example: Bhool Bhulaiyaa (Maze Game)

Soch ek maze hai (your LAN), jisme kai raste (bridges/switches) ek hi jagah tak le jaate hain. Agar sab raste khule honge, to koi banda (data packet) ghoomta hi rahega — ek loop ban jayega.

👉 Isiliye maze ka ek **guide (STA)** hota hai, jo decide karta hai:

- Kaunsa rasta open rahega,
- Kaunsa close hoga (backup ke liye),
- Taaki har jagah bas **ek hi safe rasta** ho without any loops.

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Why We Need STA?

In networks with multiple switches, loops can:

- Confuse devices (data goes in circles),
- Cause duplicate data,
- Crash the entire network due to broadcast storms.

So STA creates a structure like a tree, where:

- All devices are connected,
- But there is no cycle/loop.

Thank You...