UNIT-III - Telephony

- Multiplexing,
- Error detection and correction:
- Many to one, One to many, WDM, TDM, FDM,
- Circuit switching, packet switching and message switching.
- Data link control protocols:
- Line discipline, flow control, error control, synchronous and asynchronous protocols,
- character and bit oriented protocols,
- Link access procedures. Point to point controls:
- Transmission states, PPP layers, LCP, Authentication, NCP
- ISDN: Services, Historical outline, subscriber's access, ISDN Layers and broadcast ISDN.

Telephony

•**Meaning**: Telephony refers to the technology and systems that allow voice communication over a distance.

•It originally meant **telephone calls over wired networks**, but today it includes **mobile phones, VoIP (Voice over Internet Protocol), and internet calling apps**.

Types of Telephony

- **PSTN** Public Switched Telephone Network **(Landline)** → Circuit-switched voice calls.
- **Mobile Telephony** → Cellular networks (2G–5G).
- **VoIP** Voice over Internet Protocol**/ Internet Telephony** → Calls over the internet (Skype, WhatsApp, Zoom).

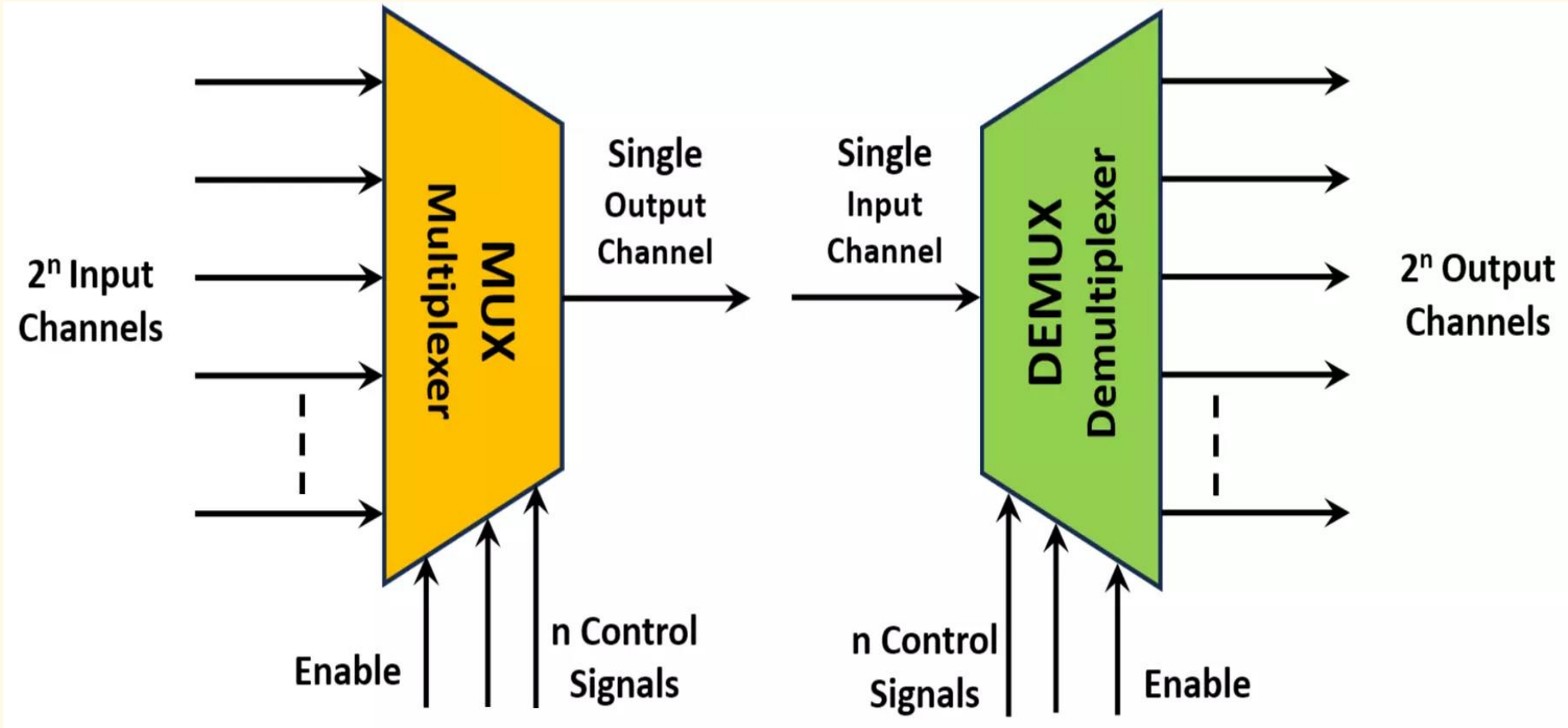
- **1. Many-to-One Communication**
- **Meaning**: Multiple devices send data to **one destination**.
- **Example**:
  - Multiple students emailing their teacher.
  - Sensors sending data to one central server.

2. One-to-Many Communication

•**Meaning**: One device sends data to **multiple destinations**.

•**Example**:

- Teacher sending a message to all students.
- Broadcasting TV or radio.

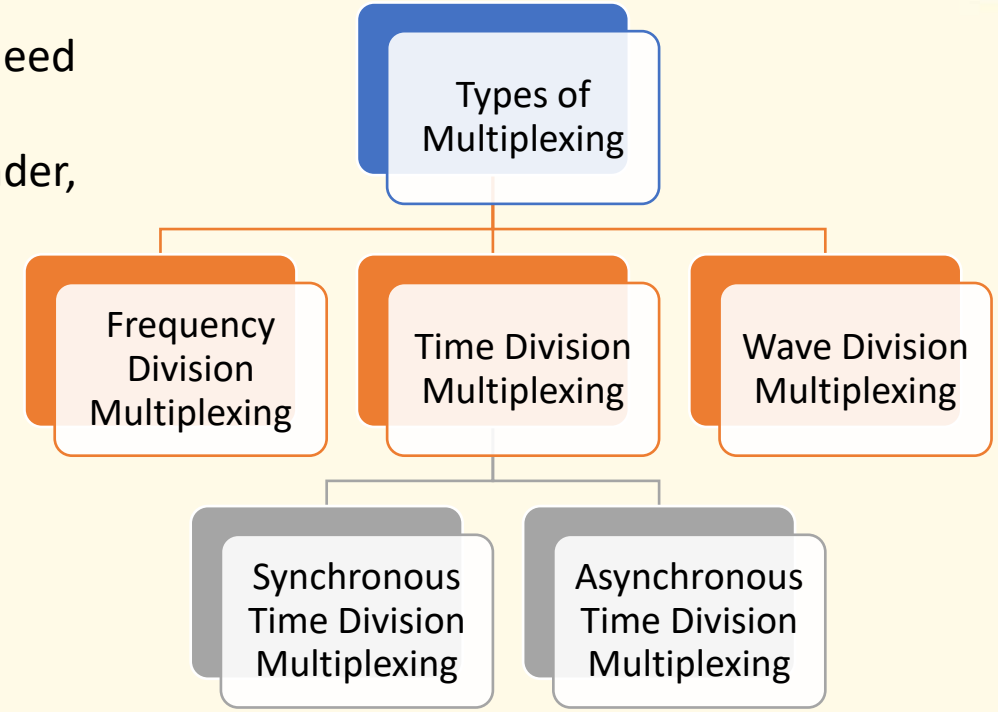


Multiplexing

•Multiplexing is a technique that allows **multiple signals (data, voice, video, etc.) to share a single communication channel** at the same time.

•It increases **efficiency** and reduces **cost**, since we don't need separate channels for each signal.

•Device that does this: **Multiplexer (MUX)** at sender, **Demultiplexer (DEMUX)** at receiver.



Types of Multiplexing

1. FDM (Frequency Division Multiplexing)

•Each signal is assigned a **different frequency range** within the same channel.

•Example: Radio/TV broadcasting.

2. TDM (Time Division Multiplexing)

•Each signal gets a **time slot** in turn, in a round-robin fashion.

•Example: Digital telephony.

- **Synchronous TDM**: Fixed time slots.
- **Statistical TDM (**Asynchronous) : Slots given only when needed.

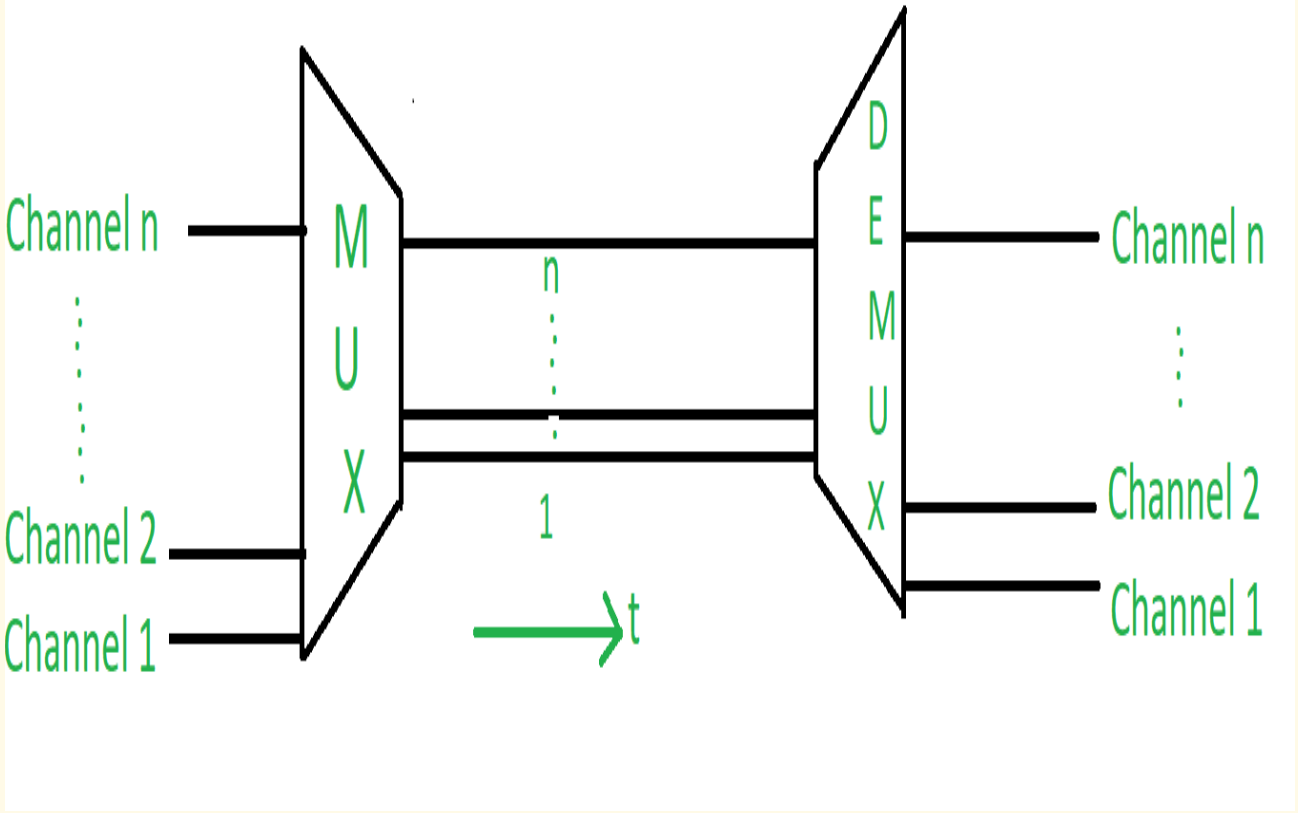
3. WDM (Wavelength Division Multiplexing)

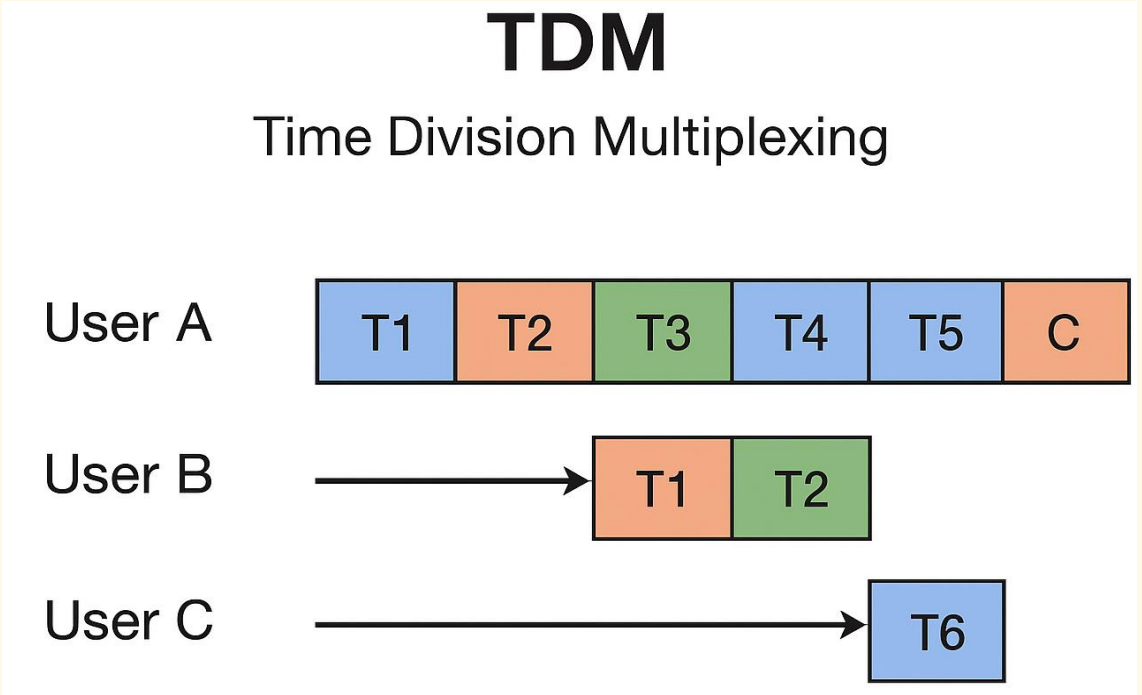
•Used in optical fiber communication.

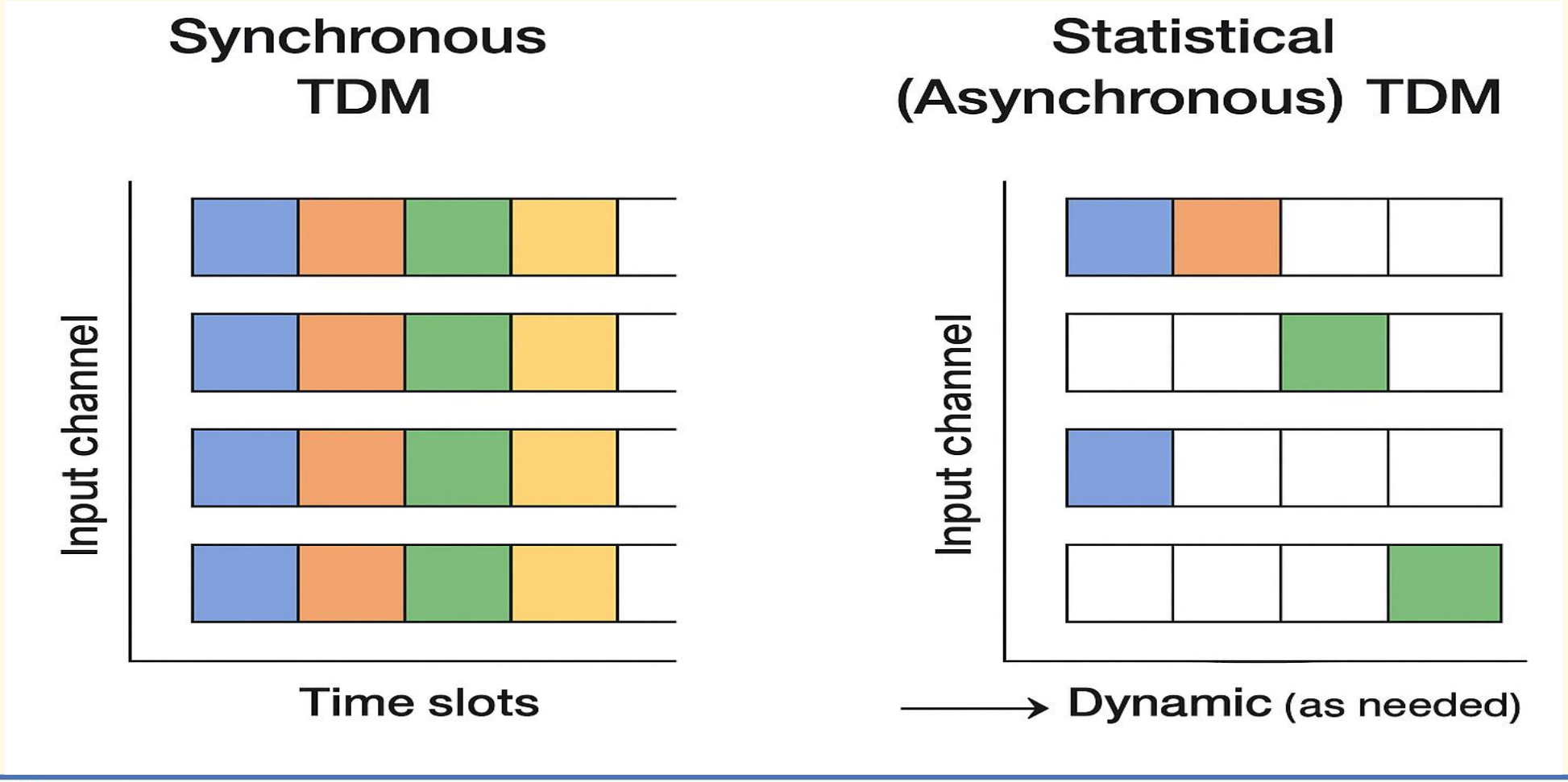
•Different signals use **different light wavelengths (colors)**.

•Example: High-speed internet via fiber optic cable.

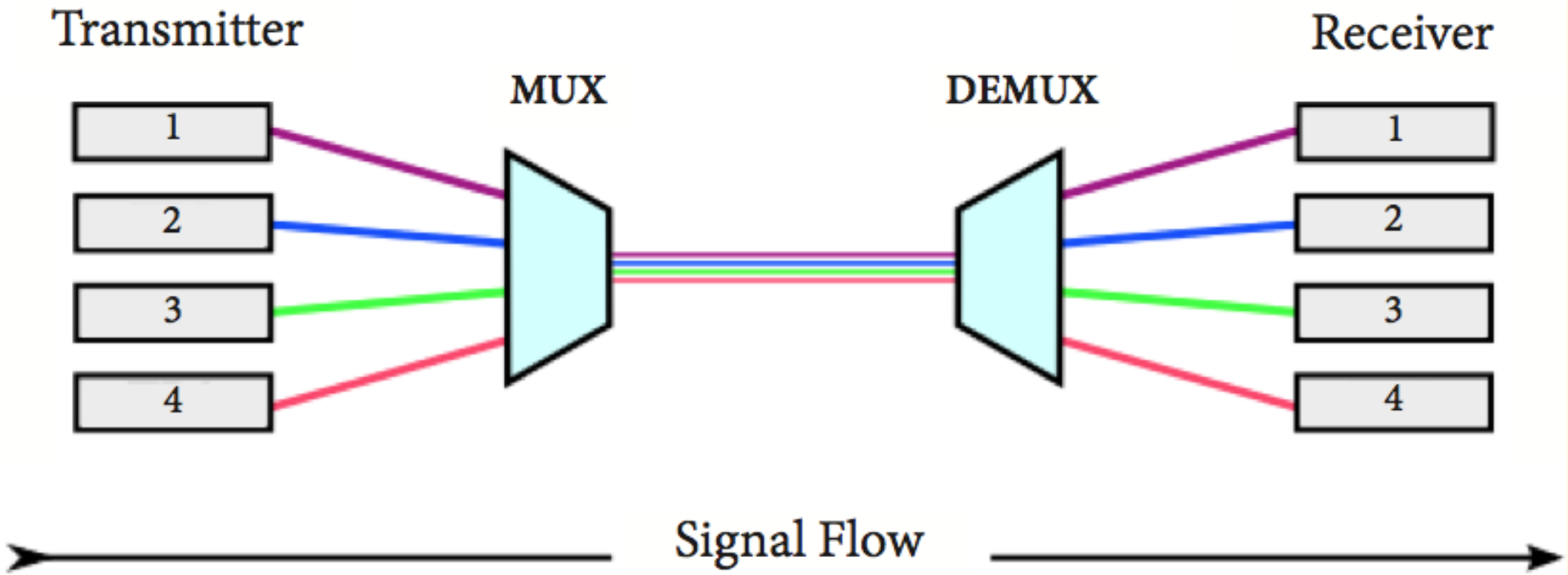
. **FDM (Frequency Division Multiplexing)**







Wavelength Division Multiplexing (WDM)



1. Error Detection

- Find if an error has happened during transmission.
- **Error Detection** → Like **spell-check underline** in MS Word.
  - It shows: "There is a mistake!" but you have to correct it yourself.
  - **Detection = Underline the mistake**

- **Techniques**:

1.Parity Bit

- Add 1 extra bit to make total number of 1's even (even parity) or odd (odd parity).
- Example: Data 1010 → Even parity → 10101.

2.Checksum

- Add all data segments, send the sum. Receiver checks sum for errors.

3.Cyclic Redundancy Check (CRC)

- Sender divides data by a fixed binary divisor → remainder sent as CRC.
- Receiver divides again → if remainder = 0 → no error.

- **Types of Parity**
- **Even Parity**
  - The parity bit is set so that the total number of 1s (including the parity bit) is **even**.
  - Example:
    Data = 1010001 (3 ones → odd)
    Add parity bit = 1 → total 4 ones → **even parity**
    Transmitted data: 10100011
- **Odd Parity**
  - The parity bit is set so that the total number of 1s (including the parity bit) is **odd**.
  - Example:
    Data = 1010001 (3 ones → already odd)
    Add parity bit = 0 → total remains 3 → **odd parity**
    Transmitted data: 10100010

2. Error Correction

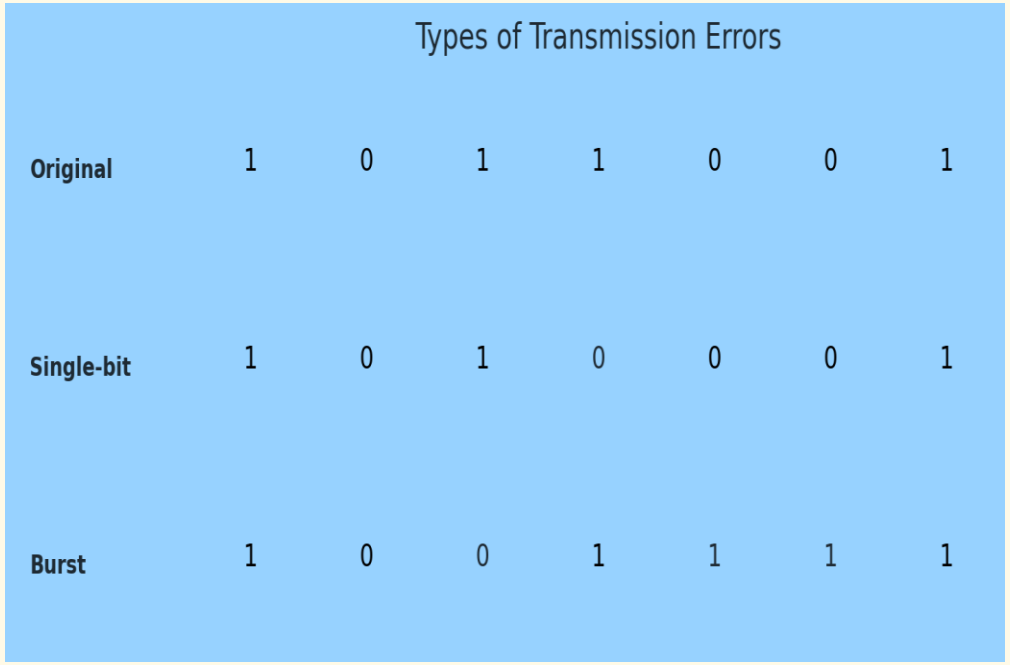
- **Goal**: Not only detect but also **fix the error** at receiver side.
- **Error Correction** → Like **autocorrect in mobile typing**.
  - It not only finds the mistake but also **fixes it automatically**.
- **Correction = Fix the mistake**

- **Techniques**:
  - **Automatic Repeat Request (ARQ)**
    - If error detected → receiver asks sender to retransmit.
    - Types: Stop-and-Wait ARQ, Go-Back-N ARQ, Selective Repeat ARQ.
  - **Forward Error Correction (FEC)**
    - Extra redundant bits are sent along with data.
    - Receiver can correct errors **without retransmission**.
    - Example: Hamming Code.

Types of Errors

1. Single-Bit Error
•Only one bit in the data unit is altered (0 → 1 or 1 → 0).
•Example: Sent 1011001 → Received 1010001.

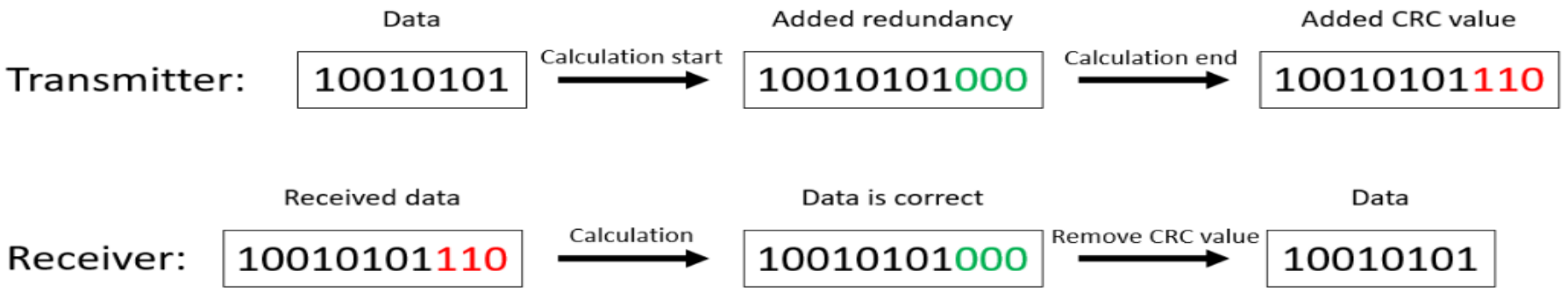
2. Burst Error
•Two or more consecutive bits are altered.
•Common in noisy channels.
•Example: Sent 1011001 → Received 1001111.



Error Type	Meaning	Example
Single-bit Error	Only 1 bit is changed	1011001 → 1010001
Burst Error	Two or more consecutive bits changed	1011001 → 1001111

CYCLIC REDUNDANCY CHECK

Nerd Corner



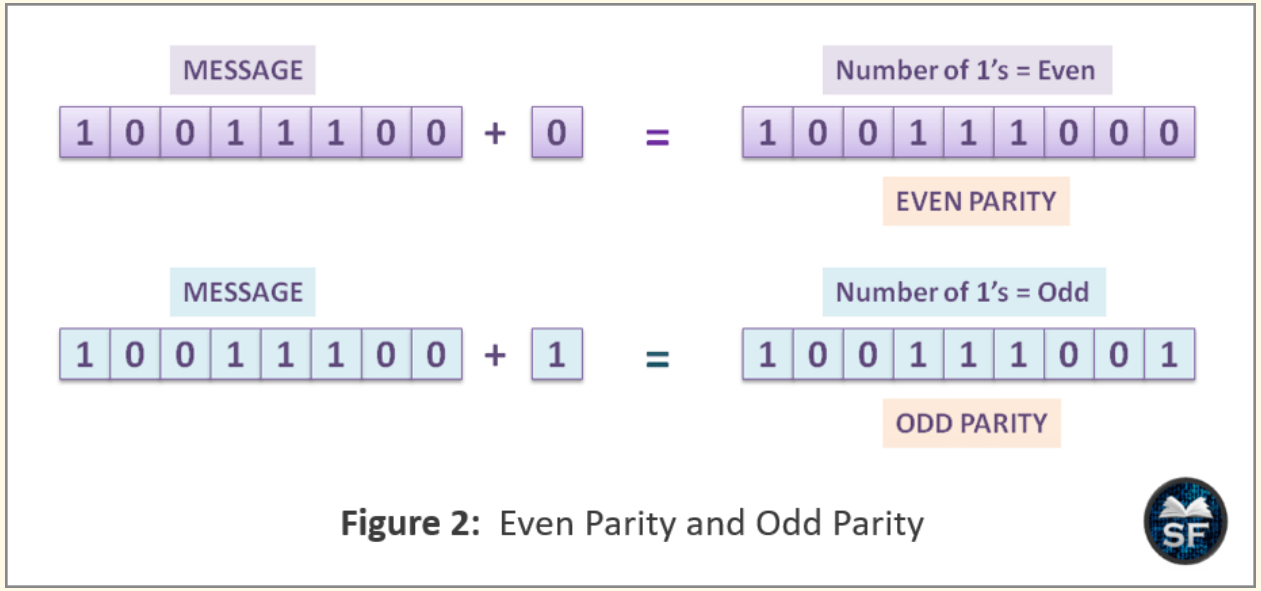
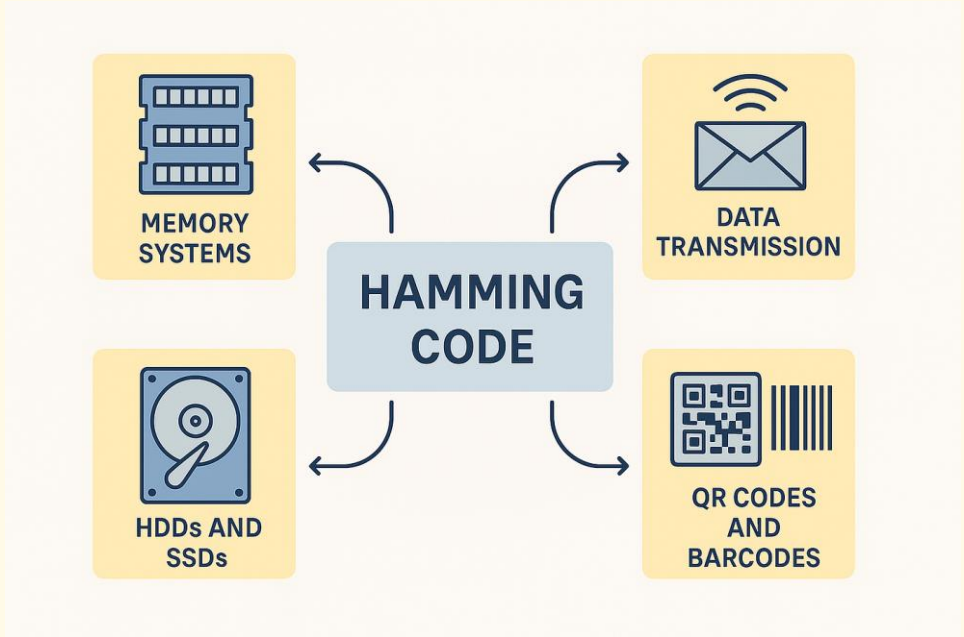


Figure 2: Even Parity and Odd Parity

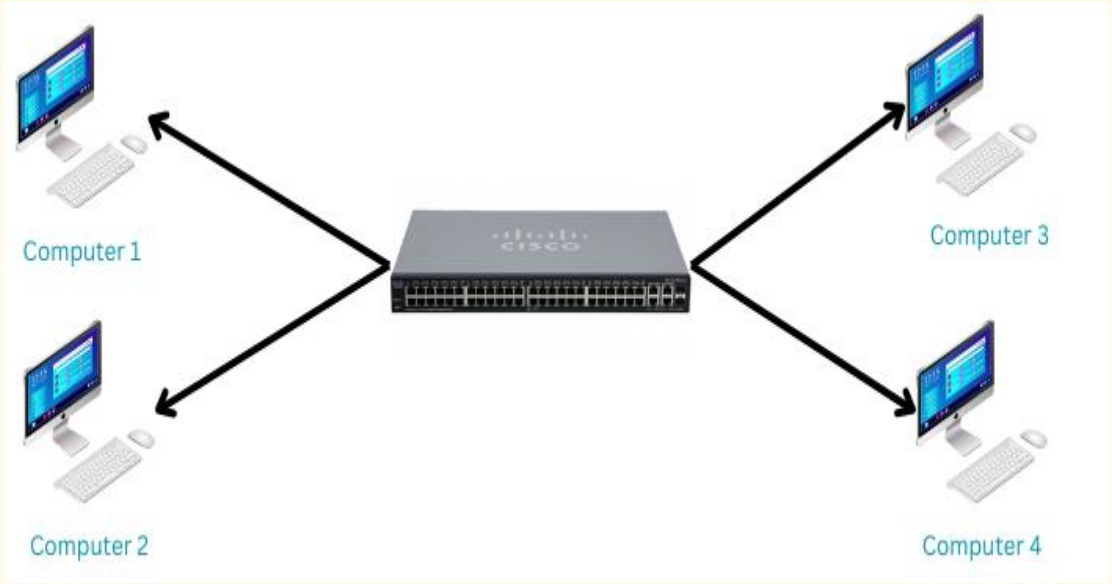


Switching

•When data is sent in a network, it usually passes through many devices (like switches/routers).

•**Switching = process of moving data from sender to receiver through the best path.**

•It decides **which route/path** the data should take.



Types of Switching

1. Circuit Switching

•A **dedicated physical path** is created between sender and receiver before communication.

•Like a **telephone call** → once connected, the line is only for you until the call ends.

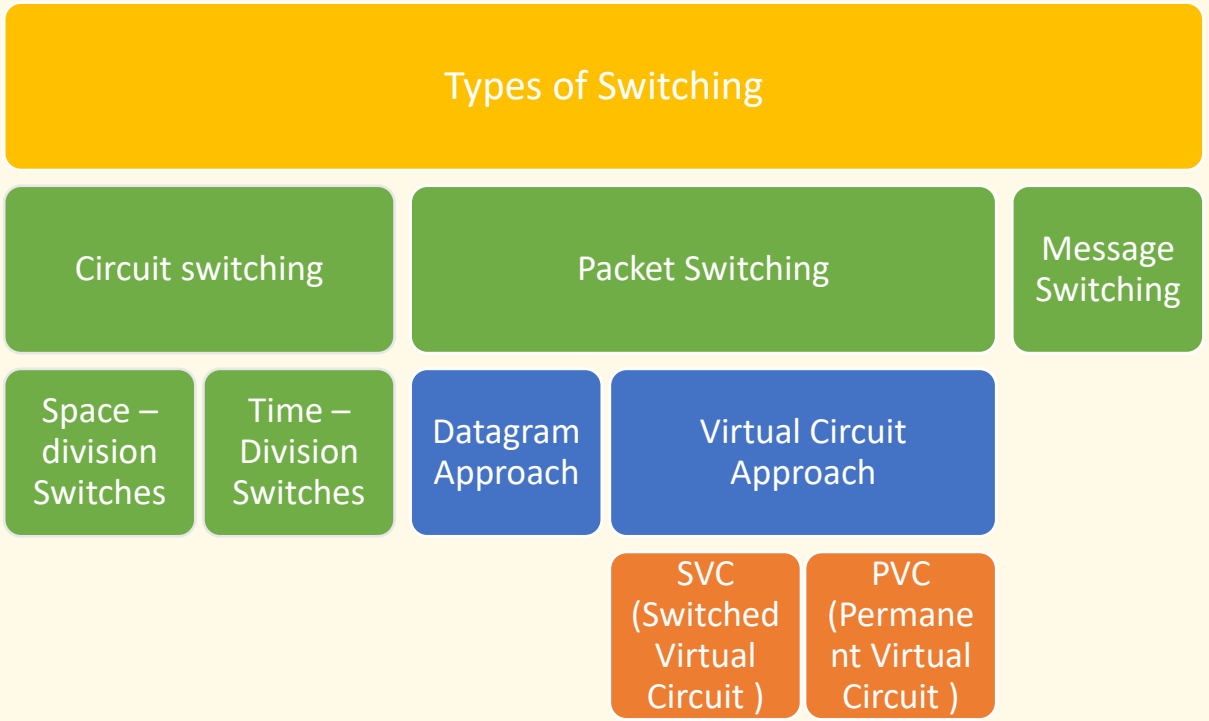
Advantages:

•Reliable (path fixed).

•No delay once connection is set.

Disadvantages:

•Connection setup takes time.



Types of Circuit Switching

Type	How it works	Example Use
Space Division	Separate physical paths for each connection	Old telephone exchange
Time Division	Same path, but different time slots for users	Digital telephone systems

2. Packet Switching

•Data is broken into **small packets**.

•Each packet may travel through **different paths** and then reassembled at the receiver.

•Used in **Internet**.

Advantages:

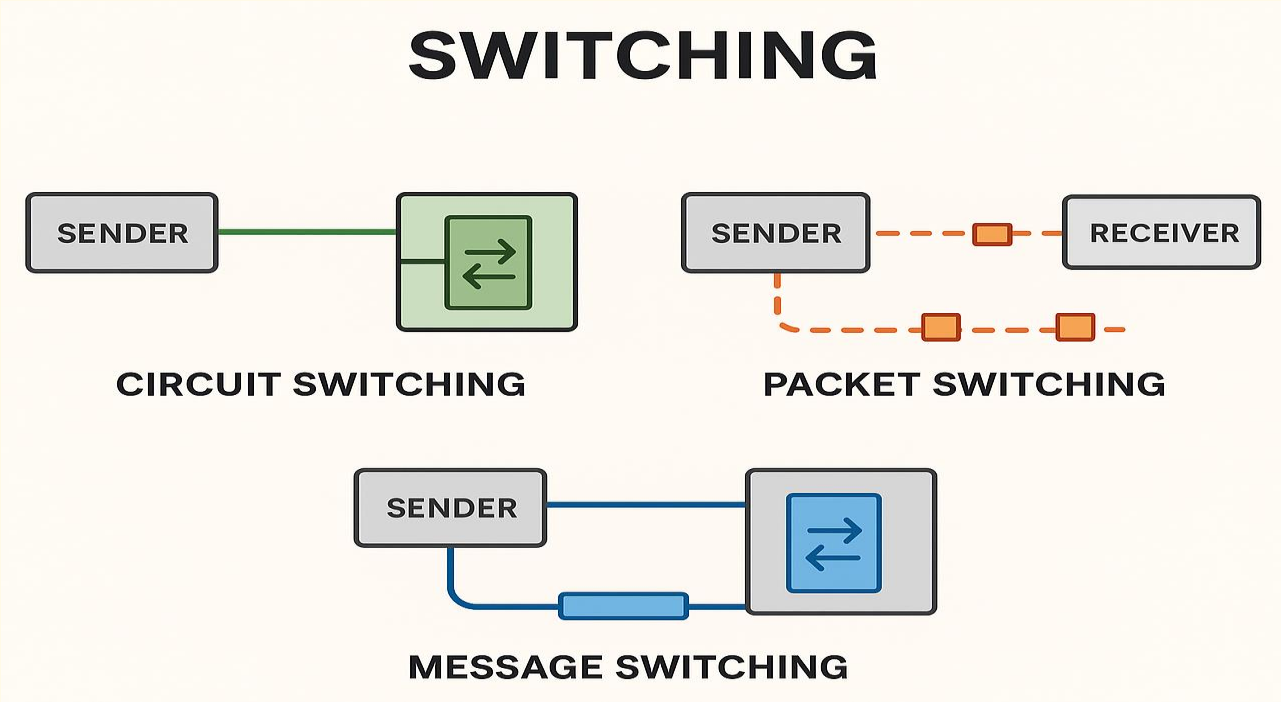
•Efficient use of network.

•Faster and cheaper.

Disadvantages:

•Packets may arrive out of order or get delayed.

•Needs error checking.



Types of Packet Switching

Type	How it Works	Order of Packets	Example
Datagram	Each packet chooses its own path	May arrive out of order	Internet (IP)
Virtual Circuit	Path set before sending packets	Always in correct order	ATM, Frame Relay

Types of Virtual Circuit Approach

Virtual Circuit Type	Description	Example	Advantage	Disadvantage
SVC (Switched)	Temporary, created per session	Phone call style	Efficient use of resources	Setup delay
PVC (Permanent)	Always available path	Leased line style-always open	No setup delay	Wastes bandwidth when idle

3. Message Switching

•Entire message is sent from one switch to another (stored temporarily) until it reaches the destination.

•Like **Post office system** → message stored and forwarded.

✅ Advantages:

•No need for a dedicated path.

•Useful for long messages.

❌ Disadvantages:

•More delay (store-and-forward).

•Needs large storage in switches.

Types of Switching

Switching Type	How it Works	Example	Advantage	Disadvantage
Circuit	Dedicated path	Telephone call	Reliable, fixed path	Wastes bandwidth
Packet	Data split into packets	Internet	Efficient, fast	Packets may delay
Message	Whole message stored & forwarded	Telegraph/Post	No fixed path needed	Slow, needs storage

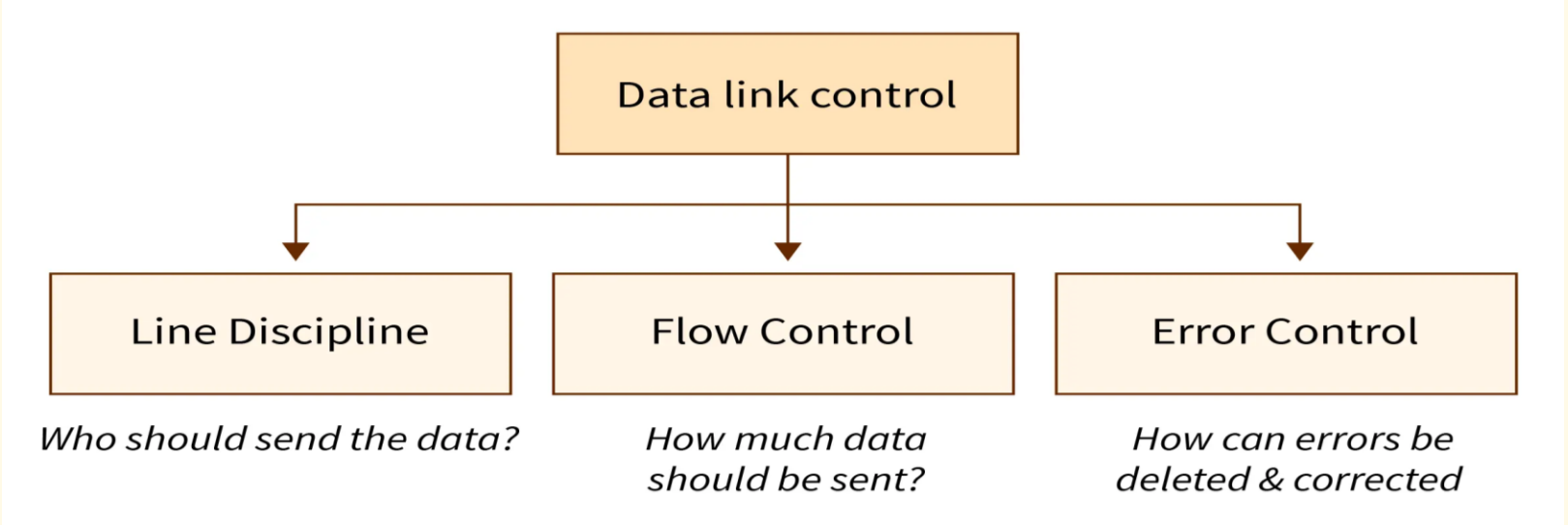
Data Link Control (DLC)

•The **data link layer** (2nd layer of OSI model) is responsible for **error-free and orderly delivery** of data between two directly connected devices.

•The set of methods used for this is called **Data Link Control**.

👉 In short: **DLC makes sure data frames are sent correctly, in order, and without errors or duplication.**

Functions of Data Link Control



1. Line Discipline

👉 Ensures **who will use the link at a particular time**.

•Controls **when a device can send data**.

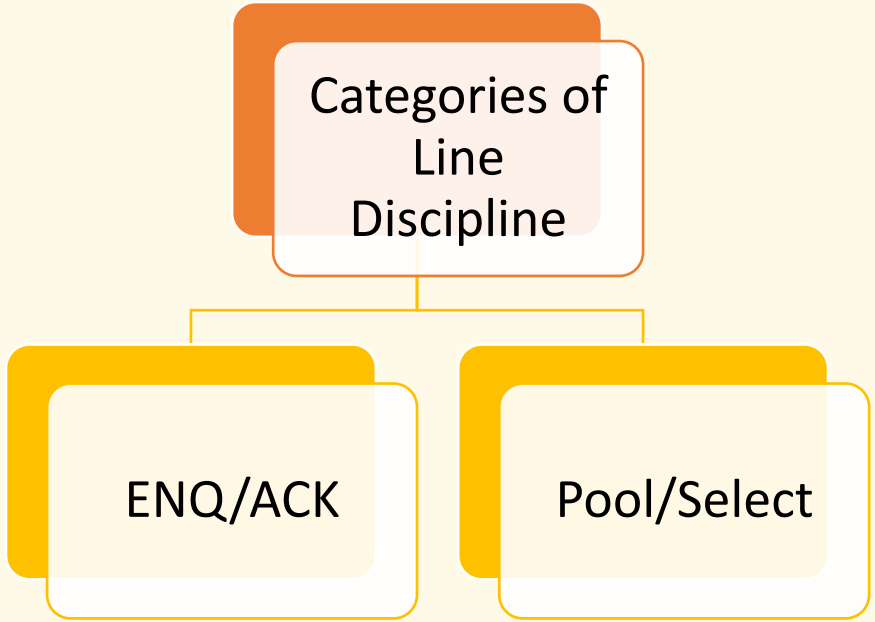
•Maintains **orderly communication** between sender and receiver.

✅ **Functions**:

•Decide **who should speak first**.

•Decide **who will listen/respond**.

•Example: Poll/Select method in multipoint lines.

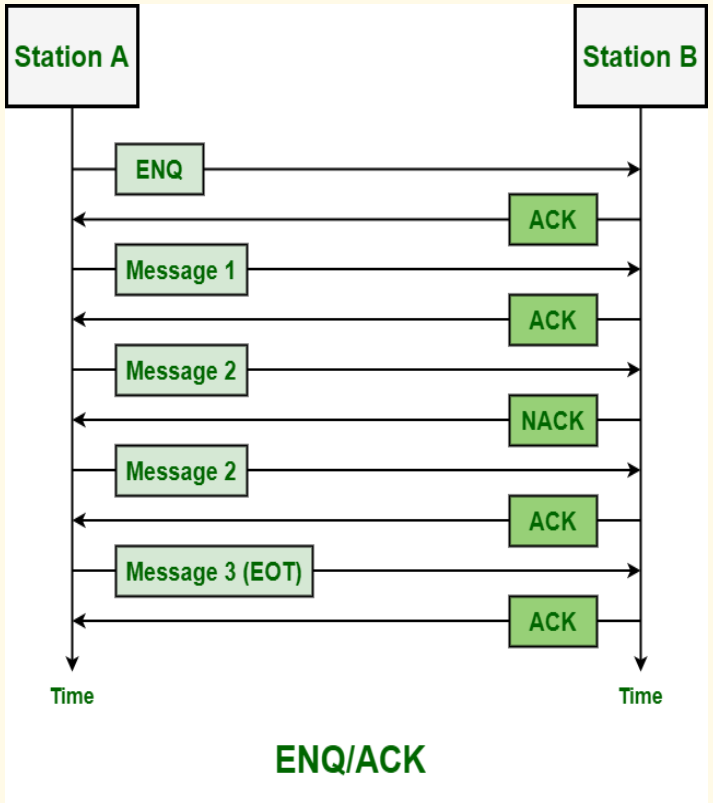


1. ENQ/ACK (Enquiry/Acknowledgement)

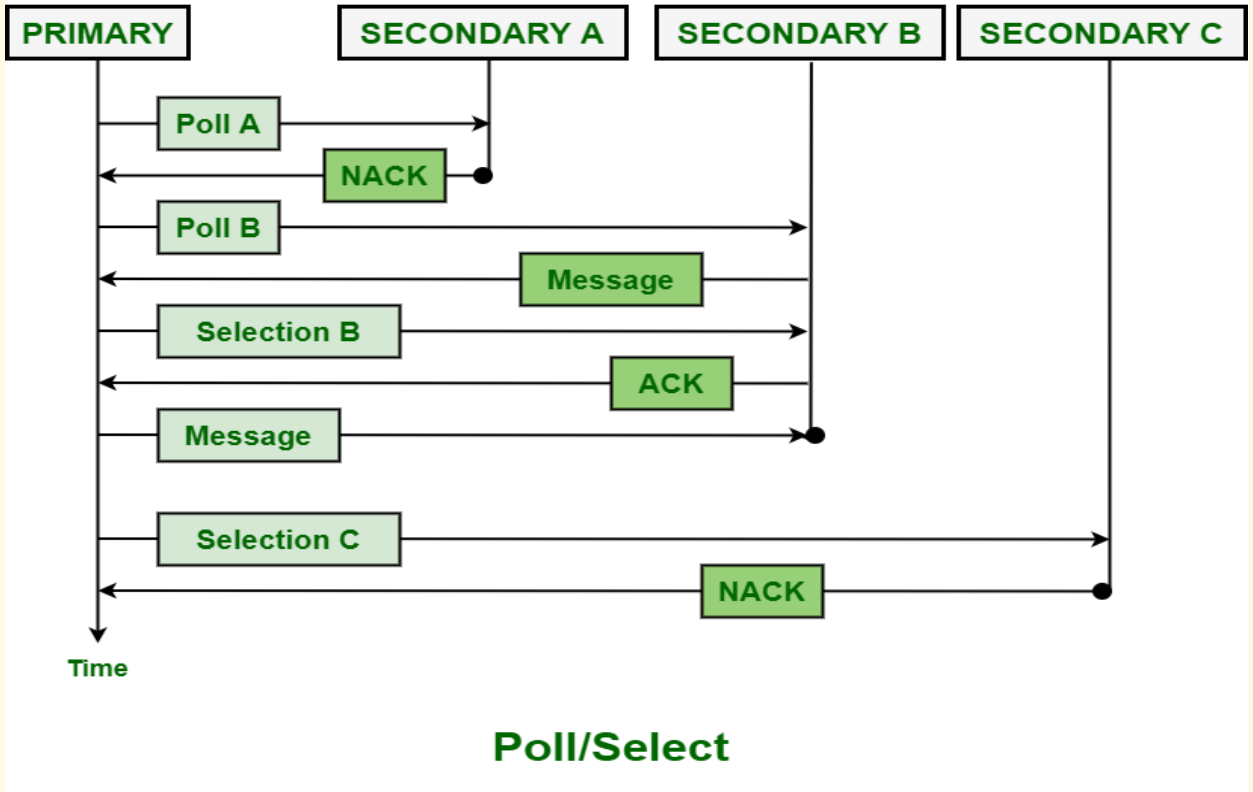
- Used when the **receiver is ready** to accept data.
- Sender first sends an **ENQ (enquiry) signal** to ask "Are you ready?".
- Receiver replies with an **ACK (acknowledgement)** if it is ready.
- Then the sender transmits the data.
- Ensures that the receiver is not overloaded.

2. Polling/Selecting

- Used when there are **multiple devices** connected to one line.
- **Polling**: The **primary device** asks each secondary device one by one if it has data to send.
- **Selecting**: The primary device tells a specific secondary device that it can receive data.
- Useful in multi-point communication (e.g., mainframe and terminals).



ENQ/ACK



Poll/Select

2. Flow Control

👉 Ensures the **sender does not overwhelm the receiver** with too much data.

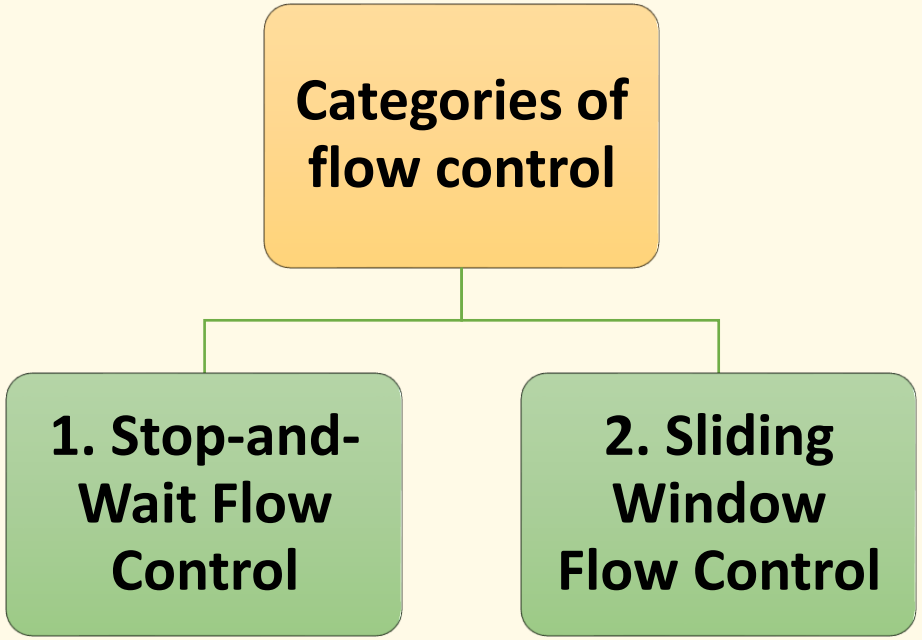
•Controls the **rate of data transmission**.

✅ **Functions**:

•Match sender's speed with receiver's ability.

•Prevent data loss due to buffer overflow.

•Methods: **Stop-and-Wait**, **Sliding Window**.

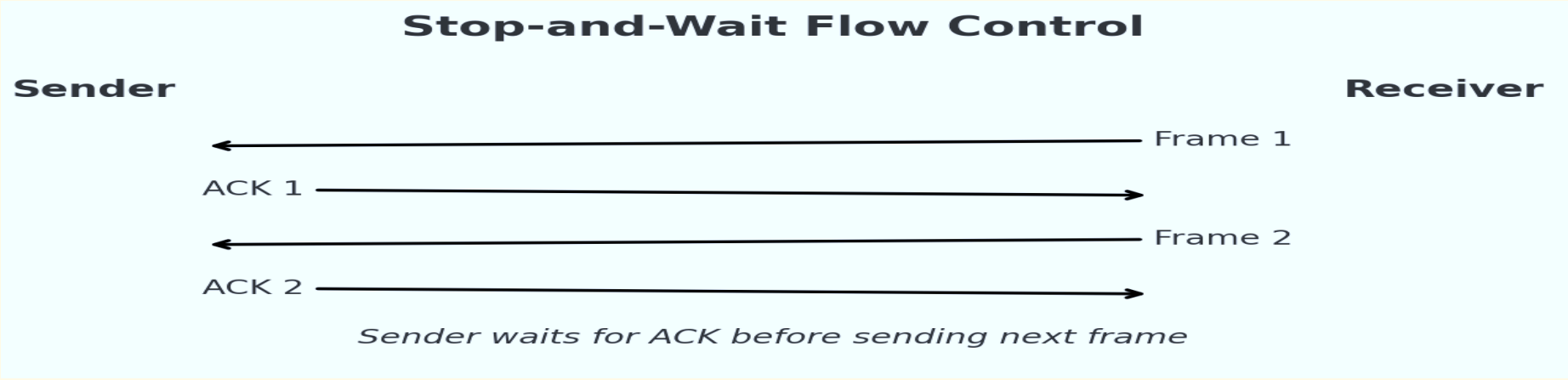


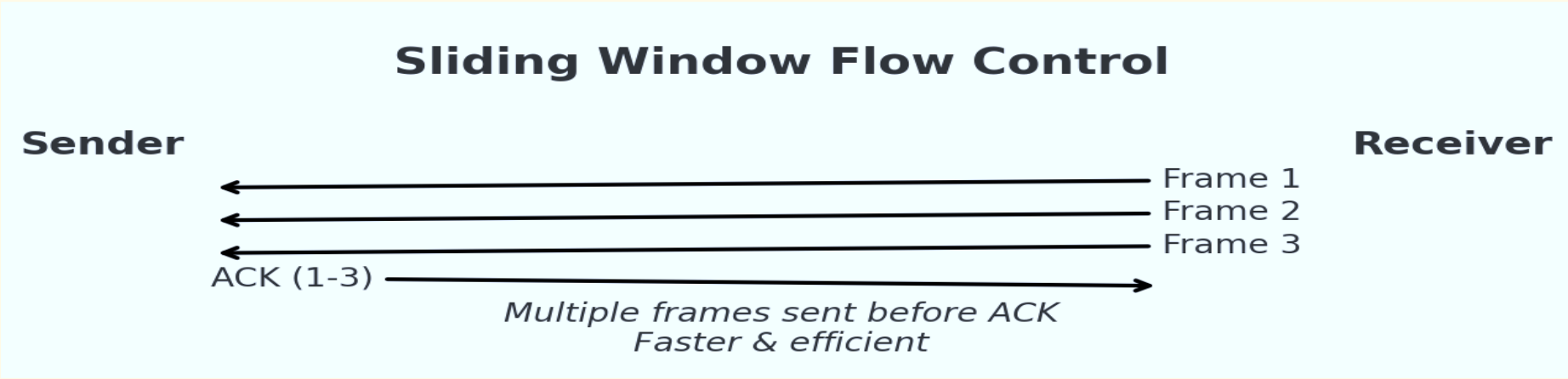
1. Stop-and-Wait Flow Control

- Sender sends **one frame at a time**.
- After sending, it **waits for acknowledgement (ACK)** from the receiver.
- Next frame is sent **only when ACK is received**.
- Simple but **slow**, because sender remains idle while waiting.

2. Sliding Window Flow Control

- Sender can send **multiple frames** before waiting for ACK.
- A "window" size decides how many frames can be sent at once.
- Receiver also has a window size to control how many frames it can accept.
- Faster and more efficient than stop-and-wait.
- Used in most modern protocols (e.g., TCP).





3. Error Control

👉 Ensures data is received **without errors and in correct order**.

•If errors are found, they are **detected and corrected** (or retransmitted).

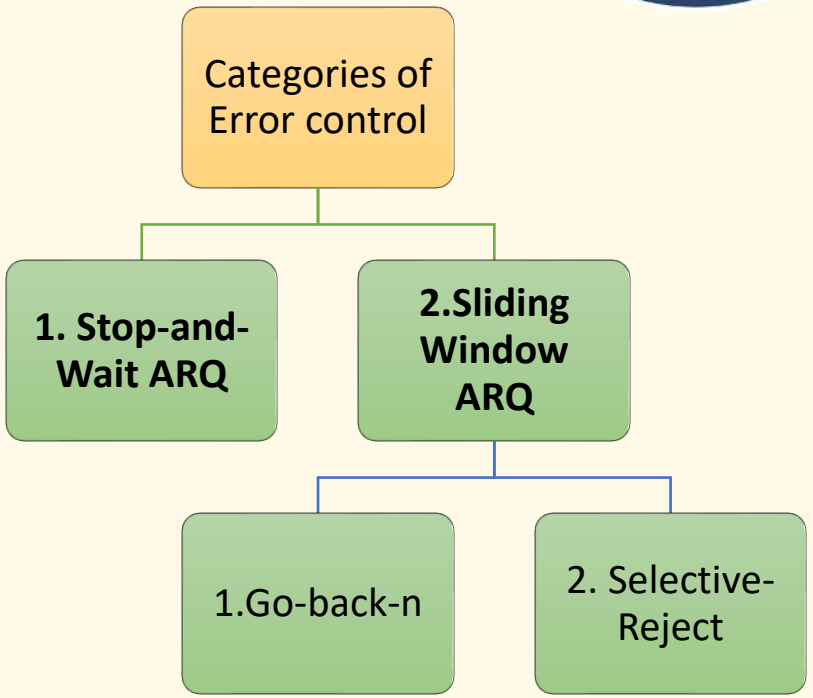
✅ **Functions**:

•Detect errors (using parity, CRC, checksum).

•Correct errors (using Hamming code, retransmission).

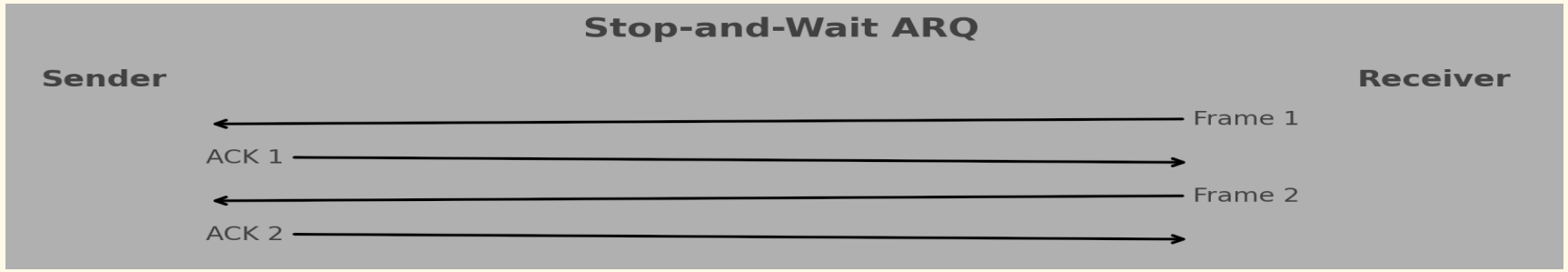
•Ensure **no duplicate frames** are received.

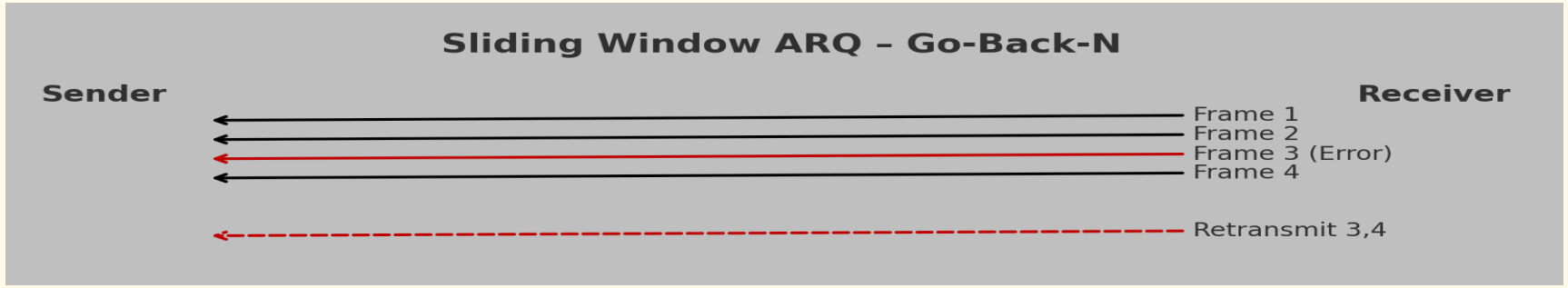
•Techniques: **ARQ (Stop-and-Wait, Go-Back-N, Selective Repeat)**.

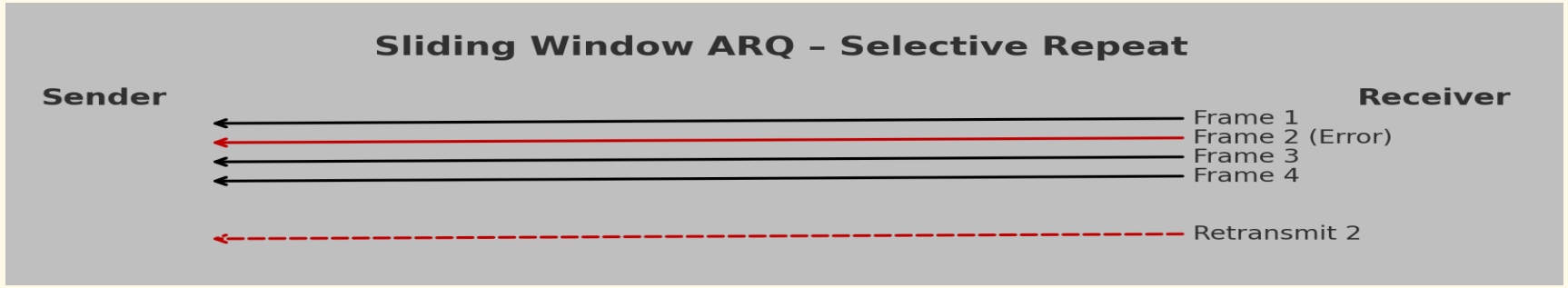


Categories of error control using ARQ (Automatic Repeat request). **protocols that combine error detection + retransmission**.

ARQ Type	Working	Efficiency	Example Use
Stop-and-Wait ARQ	Sender sends **1 frame → waits for ACK** before sending the next.	**Low** (idle time, less bandwidth use)	Simple links, small data transfer
Sliding Window ARQ (Go-Back-N)	Sender sends multiple frames. If one frame is lost/corrupted, it **retransmits that frame + all after it**.	**Higher than Stop-and-Wait**, but wasteful on errors	Modern data networks., long-distance links
Sliding Window ARQ (Selective Repeat / Selective Reject)	Sender retransmits **only the erroneous frame**, not the rest.	**Highest efficiency**, saves bandwidth	TCP/IP, modern reliable protocols





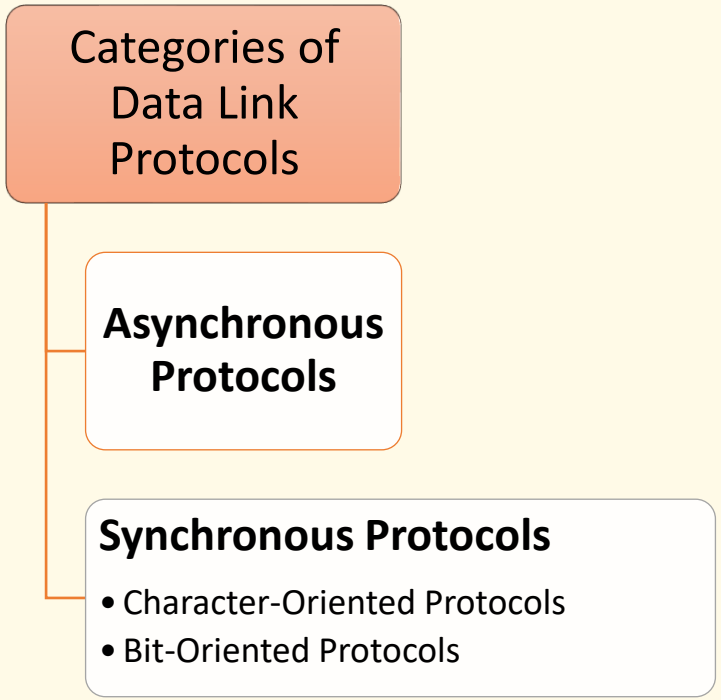


Control Type	Function (Simple)	Example
Line Discipline	Decides who can send/receive data	Poll/Select
Flow Control	Prevents sender from sending too fast	Stop-and-Wait, Sliding Window
Error Control	Detects & corrects transmission errors	ARQ, Hamming Code

Data Link Protocols are the rules and methods used at the **Data Link Layer** of the OSI model to ensure reliable communication between two directly connected devices.

1. Asynchronous Protocols

- Data is sent **character by character**.
- Each character is wrapped with:
  - **Start bit** → tells receiver that a character is coming.
  - **Stop bit(s)** → marks the end of the character.
- No need for sender & receiver to stay perfectly synchronized.
- **Simple but slower** (extra bits for each character).



Asynchronous Protocol

Sender **Receiver**

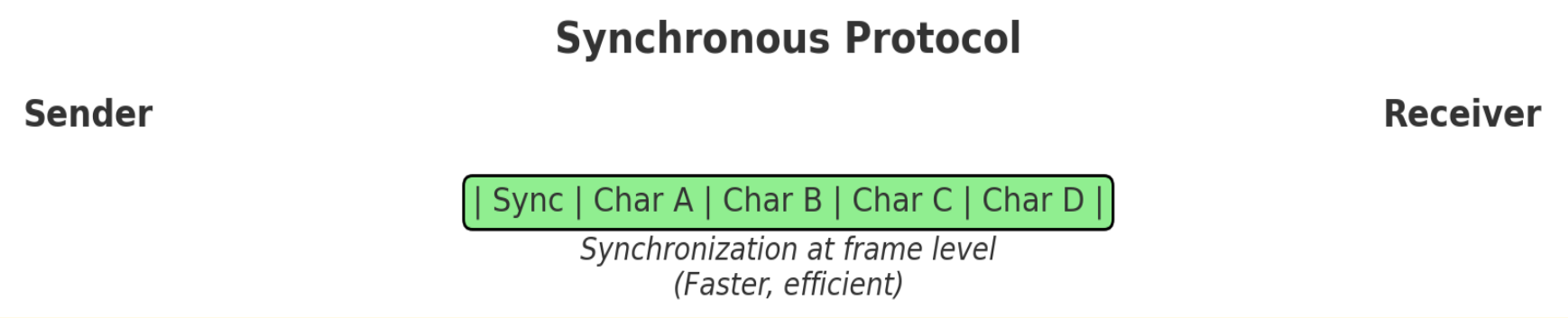
| Start | Char A | Stop | | Start | Char B | Stop |

Each character has its own start & stop bits
(Slower, simple)

Protocol	Block Size / Method	Error Control	Features	Speed
XMODEM	128 bytes	Checksum / CRC	Oldest, simple	Slow
YMODEM	1 KB	CRC(**CRC → Cyclic Redundancy Check)**	Batch transfer	Medium
ZMODEM	Streaming	CRC, Resume	Fast, reliable	High
Blast	Streaming	CRC	High-speed variant	Very High
Kermit	Sliding Window	CRC, ARQ(Automatic Repeat reQuest)	Portable, flexible	High

- **2. Synchronous Protocols**

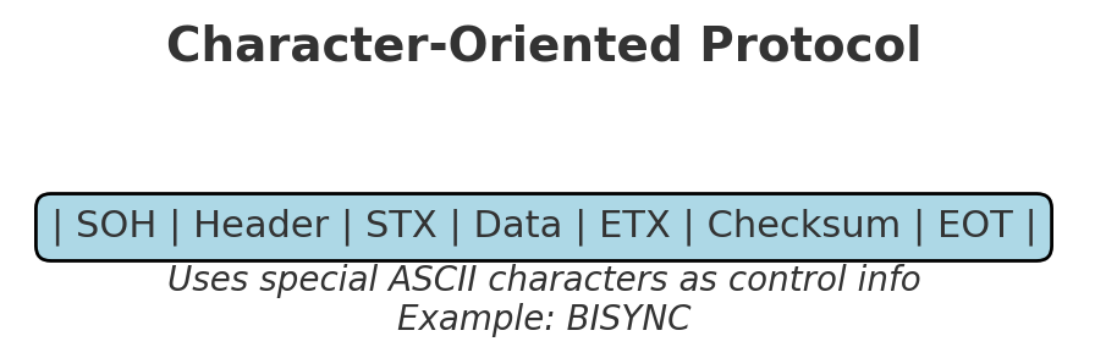
•Data is sent in **blocks (frames)**, not character by character.
•No start/stop bits for every character → higher efficiency.
•Sender & receiver must stay synchronized using **synchronization characters or clock signals**.
•**Faster and more efficient** than asynchronous.



1.Character-Oriented Protocols

- Use **characters (bytes)** as control information.
- Example:
  - **BISYNC (Binary Synchronous Communication)** – IBM standard.
- Limitation: Confusion when control characters appear in data.

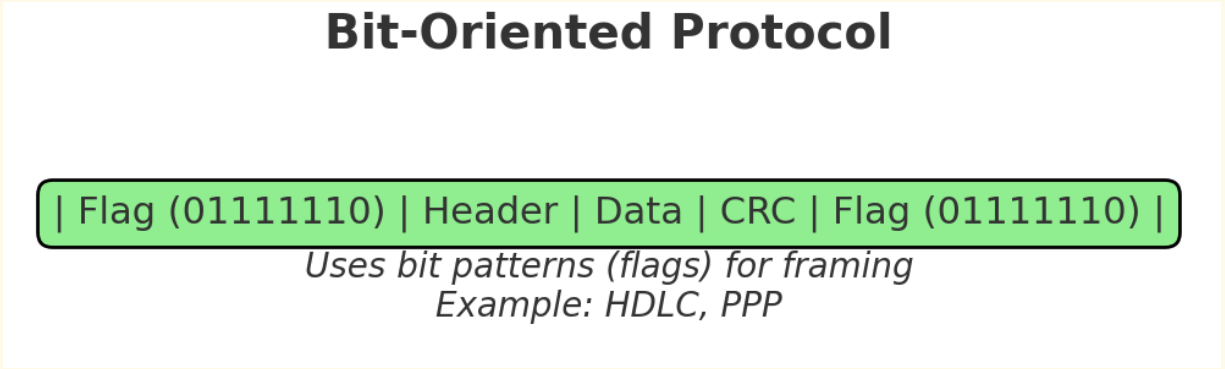
- **SOH → Start of Header**
- **STX → Start of Text**
- **ETX → End of Text**
- **EOT → End of Transmission**



2.Bit-Oriented Protocols

- Use **bits** as control information (flags, bit-stuffing).
- More efficient than character-oriented.
- Examples:
  - **HDLC (High-Level Data Link Control)**
  - **SDLC (Synchronous Data Link Control)**
  - **PPP (Point-to-Point Protocol)**

- **CRC** → Cyclic Redundancy Check
- **HDLC** → High-Level Data Link Control
- **PPP** → Point-to-Point Protocol



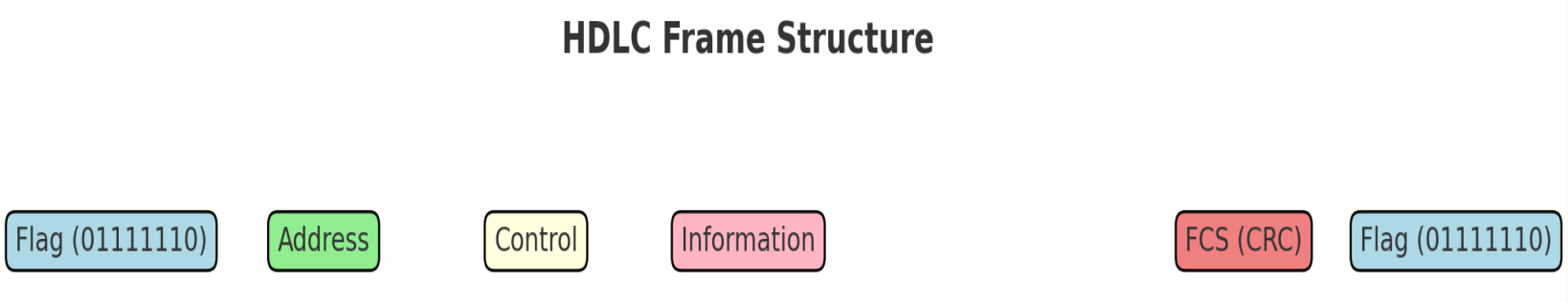
The **most popular Bit-Oriented Protocols** are ✅

1.HDLC (High-Level Data Link Control)

- ISO standard for data link layer communication.
- Uses bit-stuffing and special flag (01111110).
- Widely used in WANs and point-to-point links.

HDLC Frame Structure diagram ✅

- **Flag (01111110)** → Start/End of frame
- **Address** → Identifies sender/receiver
- **Control** → Flow & error control
- **Information** → Actual data (payload)
- **FCS (CRC)** → Error detection
- **Flag (01111110)** → End of frame



2.SDLC (Synchronous Data Link Control)

It's a protocol at the **data link layer** of the OSI model developed by IBM for computer networks.

It is **not** the same as Software Development Life Cycle.

- **Flag** – Marks start and end of frame (01111110).
- **Address** – Station address on multipoint link.
- **Control** – Type of frame, sequence numbers.
- **Information** – Data being sent.
- **CRC** – Error detection.
- **Flag** – Marks frame end.

Flag 8 Bits	Address 8 Bits	Control 8 Bits	Information Variable Length	CRC 32 bits	Flag 8 bits

3.LANs

- **Full form → Local Area Networks**
- A computer network within a **small geographic area** (office, school, campus, building).
- High-speed, low-cost communication.
- Common technologies: **Ethernet, Wi-Fi**.

✅ Example: College computer lab, Office LAN.

🔹 **4. LAPs**

This term is used in **Data Link Layer protocols**. Different variants exist:

1.LAP (Link Access Procedure) → General HDLC-based protocol for reliable data transfer.

2.LAPB (Link Access Procedure, Balanced) → Used in **X.25 WAN networks**.

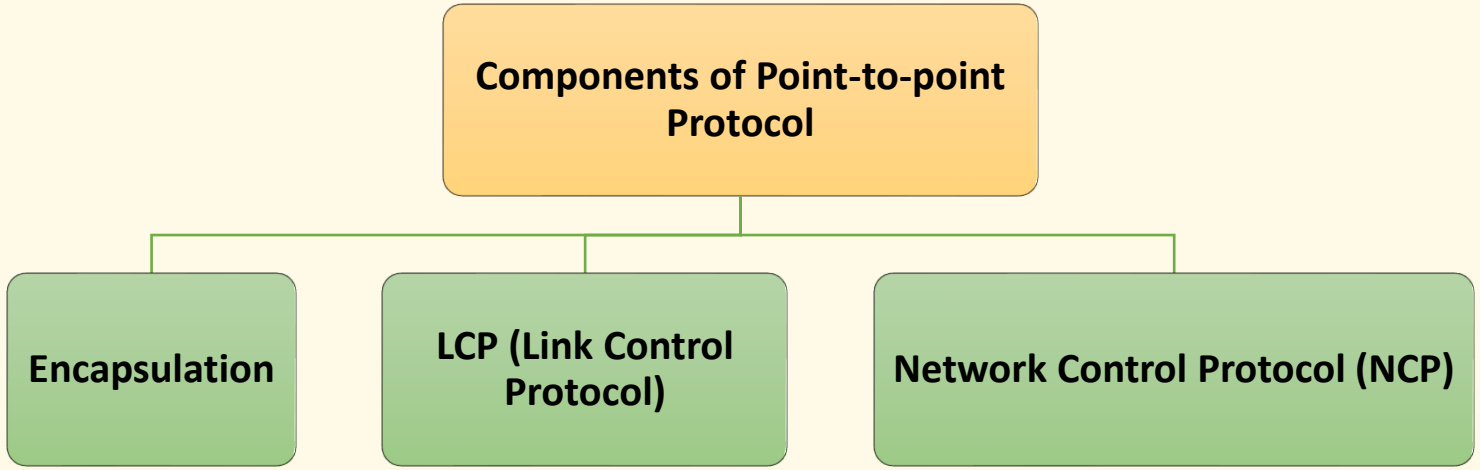
3.LAPD (Link Access Procedure for D-channel) → Used in **ISDN networks**.

4.LAPM (Link Access Procedure for Modems) → Used in error-correcting modems.

Protocol	Full Form	Where Used	Purpose
LAP	Link Access Procedure	General HDLC-based data link protocol	Provides reliable data transfer
LAPB	Link Access Procedure, Balanced	X.25 WAN networks	Balanced (peer-to-peer) communication between DTE & DCE
LAPD	Link Access Procedure for D-channel	ISDN networks (D-channel signaling)	Handles signaling messages between user equipment and network
LAPM	Link Access Procedure for Modems	Error-correcting modems	Provides reliable data transmission over telephone lines

PPP = Point-to-Point Protocol

- Works at the **Data Link Layer (Layer 2)**
- Used to send data between **two directly connected nodes**
- Often used for **serial links, DSL, and VPNs**



Component	Function
Encapsulation	Defines how data is packaged into PPP frames for transmission.
LCP (Link Control Protocol)	Establishes, configures, tests, and manages the PPP link itself.
NCP (Network Control Protocol)	Establishes and configures multiple network layer protocols (like IP, IPv6, etc.) over PPP.

(1) Encapsulation

•PPP **wraps network layer packets (IP, IPX, etc.)** into a standard PPP frame.

Protocol 8-16 bits	Information Field	Padding

•**Protocol field** → says *which protocol*.
•**Information field** → carries *the data*.
•**Padding field** → fills up to minimum frame length.

2.LCP = Link Control Protocol

- A **sub-protocol of PPP**
- Works at the **Data Link Layer**
- Used to **establish, configure, test, maintain, and terminate** a PPP link between two nodes.

Flag	Address	Control	Protocol	LCP Message	FCP	Flag
Start/ end of frame	PPP address field	PPP ctrl field	Tells this is LCP	Actual LCP data (0xC021)	Error check	End/ start

3.NCP = Network Control Protocol

- A set of protocols used within **PPP (Point-to-Point Protocol)**.
- Works at the **Data Link Layer** but configures **Network Layer protocols**.
- After **LCP** establishes the link, **NCP** configures and enables different network layer protocols over the PPP link.

Code	Identifier	Length	Data

- **Code** → tells what kind of message.
- **Identifier** → matches requests with replies.
- **Length** → total length of NCP message.
- **Data** → actual configuration options for the network layer protocol.

PPP Frame Format

Field	Size	Description
Flag	1 byte (8 bits)	Marks the **start and end** of a frame. Always 01111110.
Address	1 byte	Usually set to 11111111 (broadcast).
Control	1 byte	Usually set to 00000011 (unnumbered frame).
Protocol	1–2 bytes	Identifies the **protocol** of the payload (e.g., IP, IPCP, LCP).
Payload / Data	Variable	Encapsulated **network layer packet** (e.g., IP packet).
FCS	2 or 4 bytes	**Frame Check Sequence** for error detection (CRC).
Flag	1 byte	Marks the **end of the frame**.

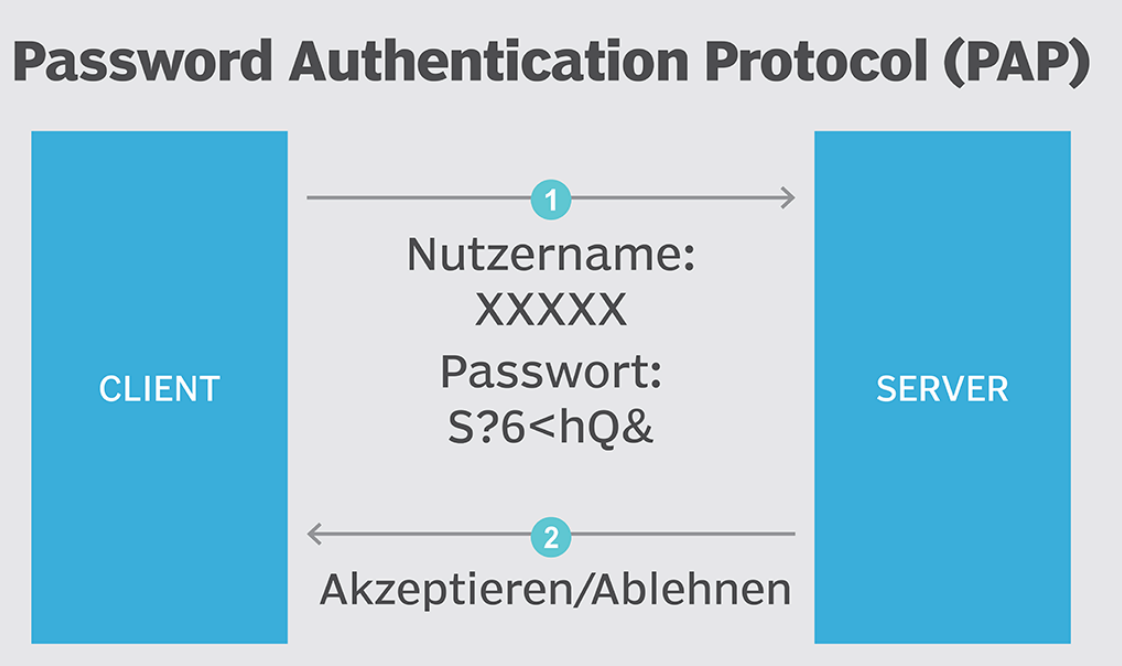
Authentication in PPP is a way to **check if the other side is really who it says it is** before sending data. Authentication means validating the identity of a user who needs to access a set of resources.
There are **two main types**:

PPP Authentication Protocols Methods

- PAP Password Authentication Protocol
- Challenge Handshake Authentication Protocol (CHAP)

1.PAP (Password Authentication Protocol)

- Works like **giving a password** to the other side.
- Steps:
  - Client sends username & password.
  - Server checks it.
  - If correct → connection allowed.
- **Problem:** Password is sent as plain text → not very safe.



2. CHAP (Challenge Handshake Authentication Protocol)

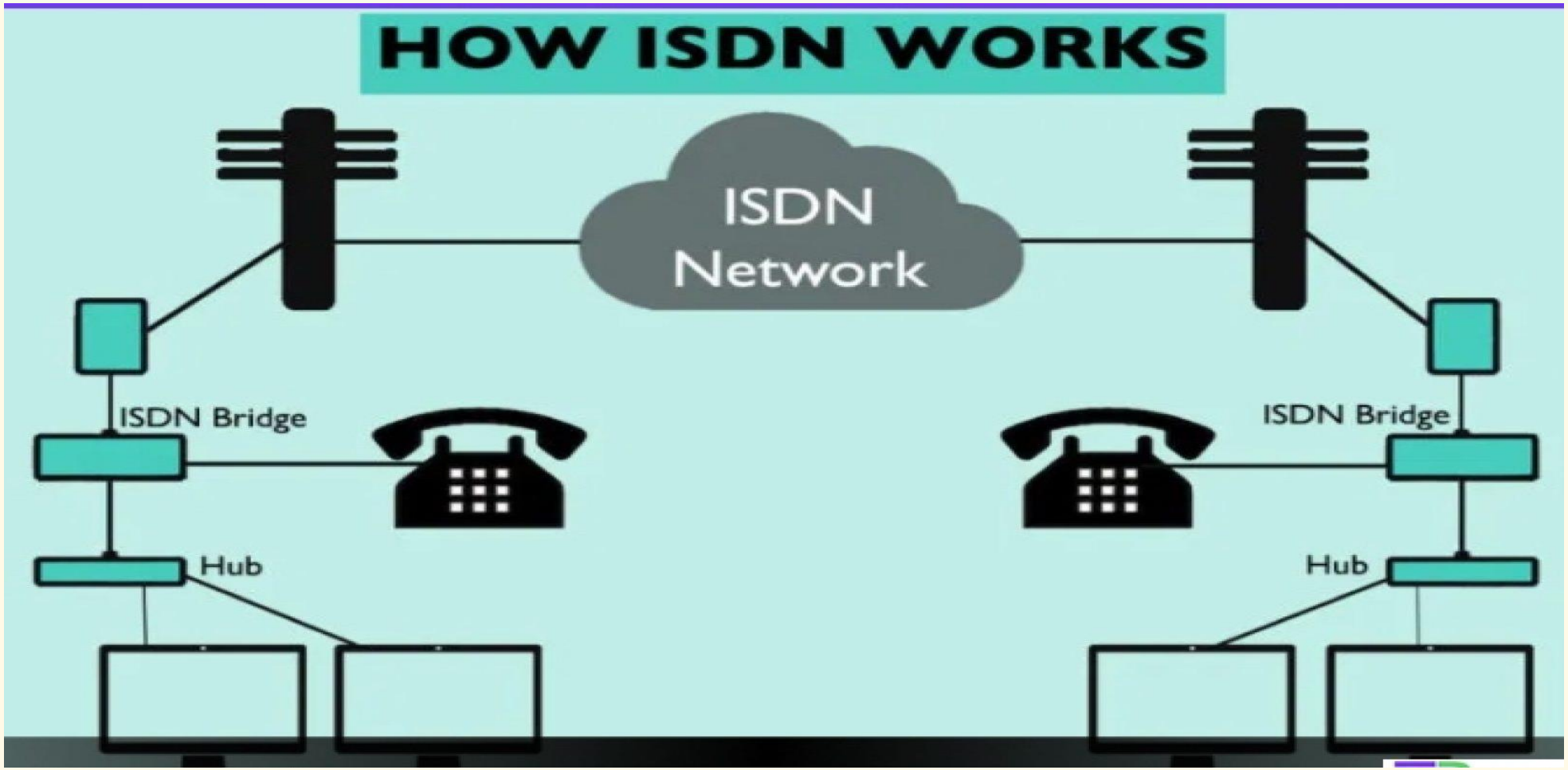
- Works like a **secret question with a code**.
- Steps:
  - Server sends a random “challenge.”
  - Client mixes challenge with password and sends a code (hash).
  - Server checks the code.
- **Safer:** Password is **never sent directly**.

Challenge-Handshake Authentication Protocol (CHAP)

ISDN (Integrated Services Digital Network):

ISDN was first **officially defined in 1988** in the **CCITT Red Book**.
ISDN is a set of communication standards that allows **voice, video, and data** to be transmitted **digitally over ordinary telephone lines**.

- It replaces the old analog phone system with a **digital system**, providing **faster and clearer** connections.
- Works on the **digital network** instead of analog signals.



ISDN services:

1.Bearer Services (B-Services)

•Provide **digital transmission of user data** at **64 Kbps** (B channel).

•Can carry **voice, data, or video**.

•Examples:

- Telephony (voice calls)
- Video conferencing
- High-speed data transfer

2.Teleservices

•Provide **end-to-end communication** between users.

•Can be **voice or data oriented**.

•Examples:

- **Voice telephony** (digital phone call)
- **Facsimile (fax)**
- **Videotelephony**

3.Supplementary Services

•Add **extra features** to basic ISDN services.

•Examples:

- Call forwarding
- Call waiting
- Caller ID
- Conference calling

Subscriber Access to ISDN

1 Bearer Channel (B Channel)

- **Purpose:** Carries **user data** (voice, video, or data).
- **Speed:** 64 Kbps per channel.
- **Usage:** Standard for **most ISDN services** like phone calls or internet data.
- **Example:** A digital voice call or sending a file.

2.Data Channel / Delta Channel (D Channel)

•**Purpose:** Carries **signaling and control information** between the user and the network.

•**Speed:**

- BRI: 16 Kbps
- PRI: 64 Kbps (Europe) / 64 Kbps (North America)

•**Usage:** Sets up, manages, and terminates connections; does **not carry user data**.

3.H Channel

- **Purpose:** High-speed **bearer channel** for data-intensive applications.
- **Speed:** Multiple B channels combined:
  - **H0:** 384 Kbps (6 B channels)
  - **H11:** 1.536 Mbps
  - **H12:** 1.920 Mbps
- **Usage:** Video conferencing, large file transfer, or high-speed internet.

Advantages	Disadvantages
Digital and clear	Expensive
Voice, data, video	Limited speed (64 Kbps B channel)
Quick connection	Needs special equipment
Flexible channels	Declining usage

ISDN follows a structure similar to the **OSI model**, but specifically designed for **digital network services**. It has **three main layers**:

1.Physical Layer

•Connects **subscriber equipment** to the ISDN network.

•Deals with **transmission of raw bits** over the line.

•Includes:

- **NT1 (Network Termination 1)** – interface to the line
- **Cables, connectors, and signaling**

2.Data Link Layer (LAPD – Link Access Protocol for D Channel)

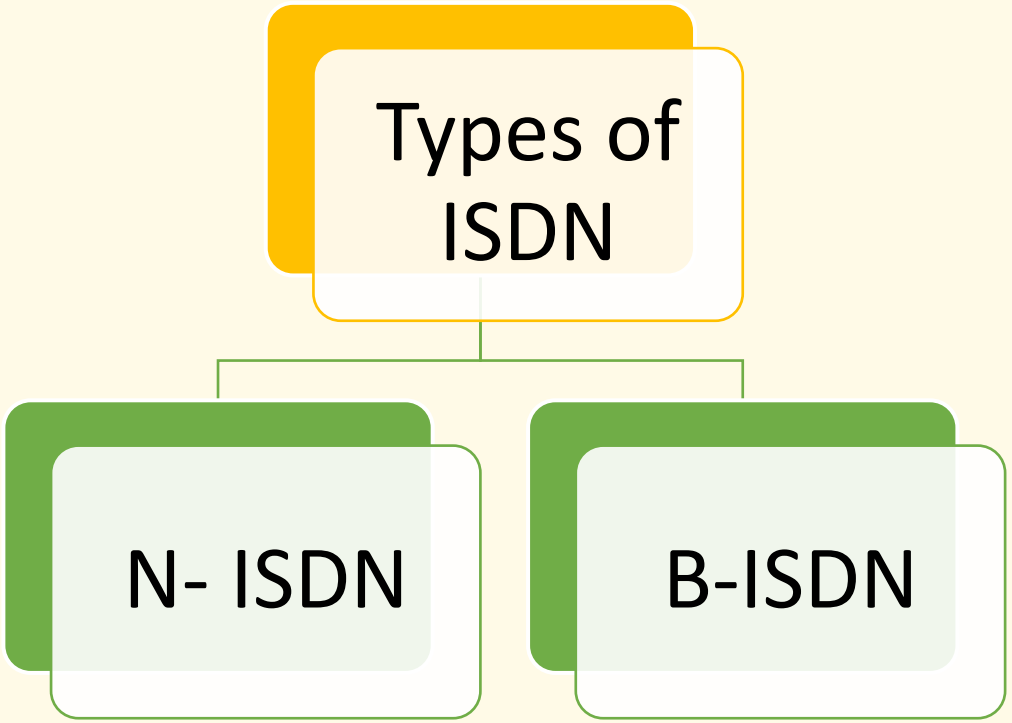
•Manages **error-free transmission over D channel**.

•Handles:

- Framing
- Error detection and correction
- Flow control

3. Network Layer

- Handles **signaling and call control**.
- Uses **D channel** for:
  - Call setup
  - Routing
  - Management of connections



1. Narrowband ISDN (N-ISDN)

- **Speed:** Standard BRI (2B + 1D) or PRI (23/30B + 1D)
- **Channels:**
  - **B channel:** 64 Kbps (user data)
  - **D channel:** 16–64 Kbps (signaling)
- **Usage:** Voice, low-speed data, fax

2.Broadband ISDN (B-ISDN)

- **Speed:** High-speed digital network, using fiber optics
- **Channels:**
  - High-speed channels (H0, H11, H12) for large data transfer
- **Usage:** Video conferencing, multimedia, high-speed internet
- **Example:** Video-on-demand, large corporate networks

Term	Full Form	Description
BRI	**Basic Rate Interface**	Used in **ISDN (Integrated Services Digital Network)** for small-scale connections. It provides **2 B-channels** (Bearer channels) and **1 D-channel** (Delta channel). ➡️ **2B + 1D = 2 × 64 kbps + 1 × 16 kbps = 144 kbps total.**
PRI	**Primary Rate Interface**	Used for **larger or business networks**. The number of channels depends on the region: ➡️ **North America/Japan:** 23B + 1D = **1.544 Mbps (T1 line)** ➡️ **Europe/India:** 30B + 1D = **2.048 Mbps (E1 line)**
B Channel	**Bearer Channel**	Carries **voice, video, or data** (each 64 kbps).
D Channel	**Delta Channel**	Carries **signaling and control information**.

Feature	N-ISDN (Narrowband ISDN)	B-ISDN (Broadband ISDN)
Speed	Low-speed, standard channels (64 Kbps B channel)	High-speed, uses H channels (384 Kbps – 1.92 Mbps)
Channels	B (64 Kbps), D (16–64 Kbps)	H0, H11, H12 (high-speed)
Transmission	Usually over copper telephone lines	Usually over **fiber optic lines**
Usage	Voice, fax, low-speed data	Video conferencing, multimedia, high-speed data
Interface	BRI (2B+1D), PRI (23/30B+1D)	High-speed interfaces (H channels)
Adoption	Widely used in homes/offices	Mostly experimental / specialized networks
Service Type	Narrowband services	Broadband / multimedia services