Chapter 2
Physical Layer

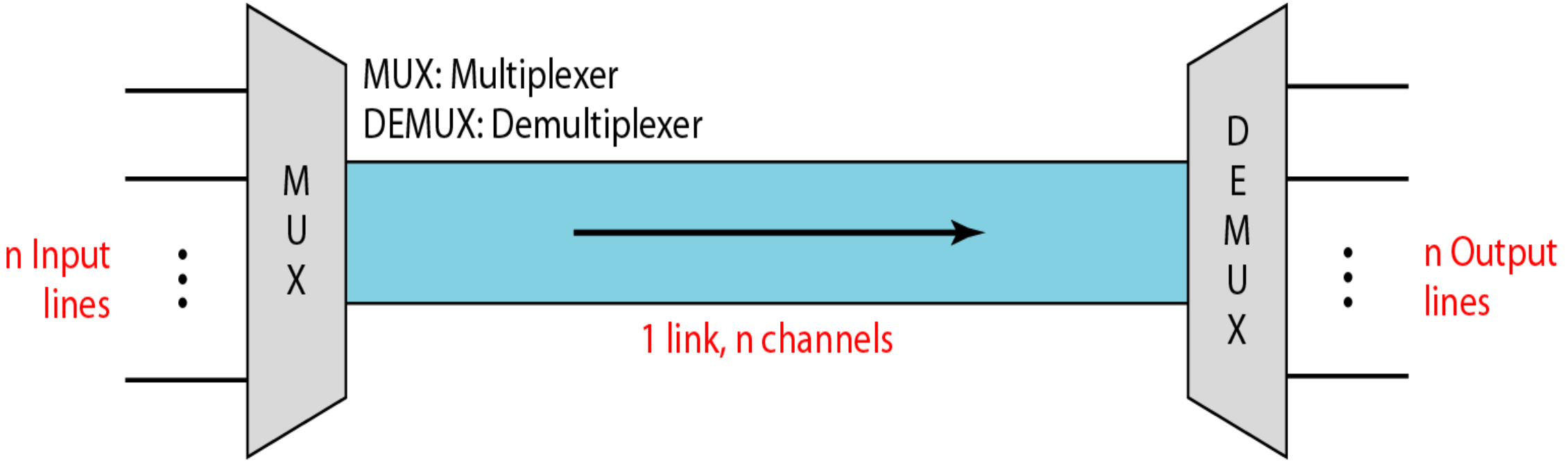
- ***Outline:***
  - 2.3 Multiplexing, Circuit switching, Packet switching, VC Switching, Telecommunication switching system (Networking of Telephone exchanges)
  - 2.4 ISDN: Architecture, Interface, and Signaling

Multiplexing

- Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared. **Multiplexing** is the set of techniques that allows the **simultaneous transmission of multiple signals across a single data link.**
- The aim is to share an expensive resource. For example, in telecommunications, several telephone calls may be carried using one wire. Multiplexing originated in telegraphy, and is now widely applied in communications.
- The **multiplexing divides** the capacity of the high-level communication channel **into several low-level logical channels**, one for each message signal or data stream to be transferred.

Multiplexing

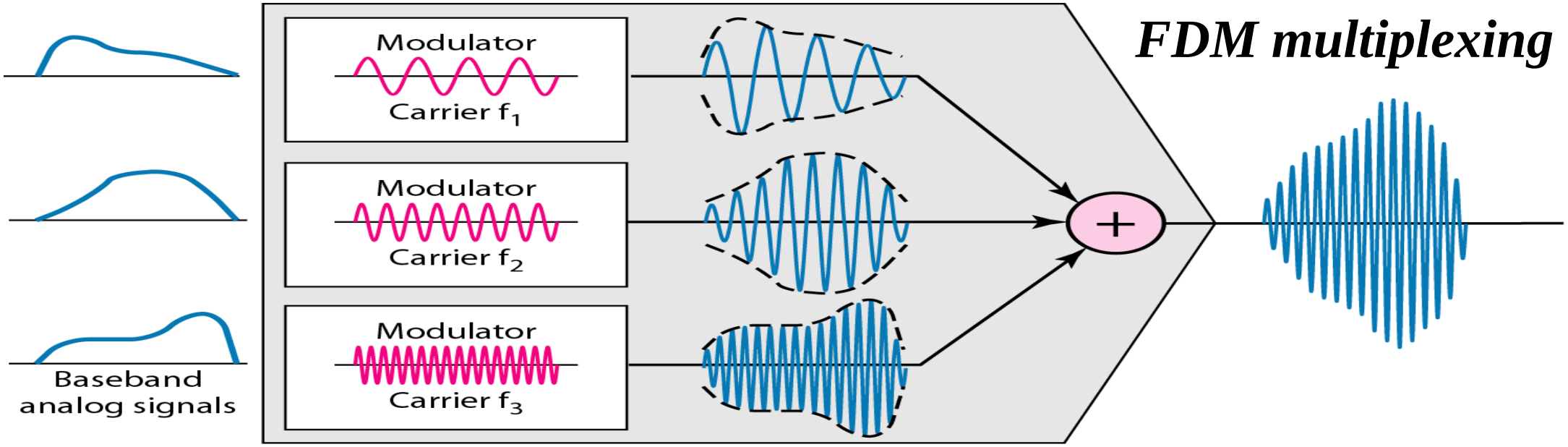
- The lines on the left direct their transmission streams to a multiplexer (MUX), which combines them into a single stream (many-to-one).
- At the receiving end, that stream is fed into a demultiplexer (DEMUX), which separates the stream back into its component transmissions (one-to-many) and directs them to their corresponding lines.



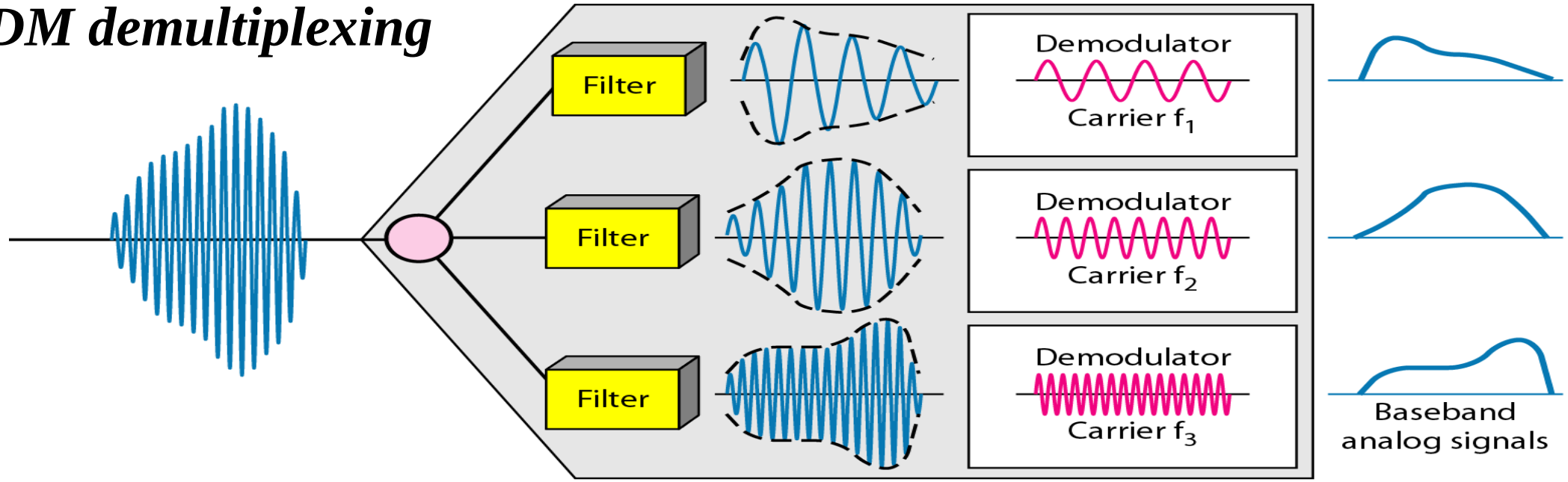
Multiplexing: Frequency-Division Multiplexing (FDM)

- FDM is an **analog technique** that can be applied when the **bandwidth of a link is greater than the combined bandwidths of the signals** to be transmitted.
- In FDM, signals generated by each sending device **modulate different carrier frequencies.** These modulated signals are then **combined into a single composite** signal that can be transported by the link.
- Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal.
- In addition, carrier frequencies must not interfere with the original data frequencies.

FDM multiplexing

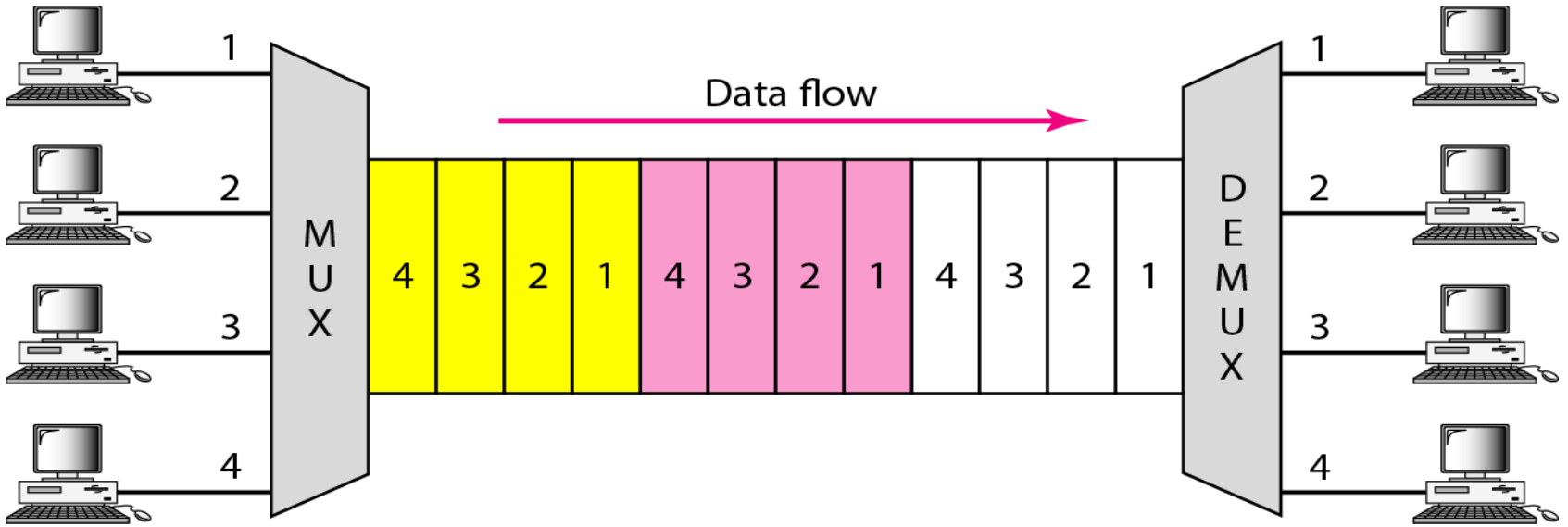


FDM demultiplexing



Multiplexing: Time-Division Multiplexing (TDM)

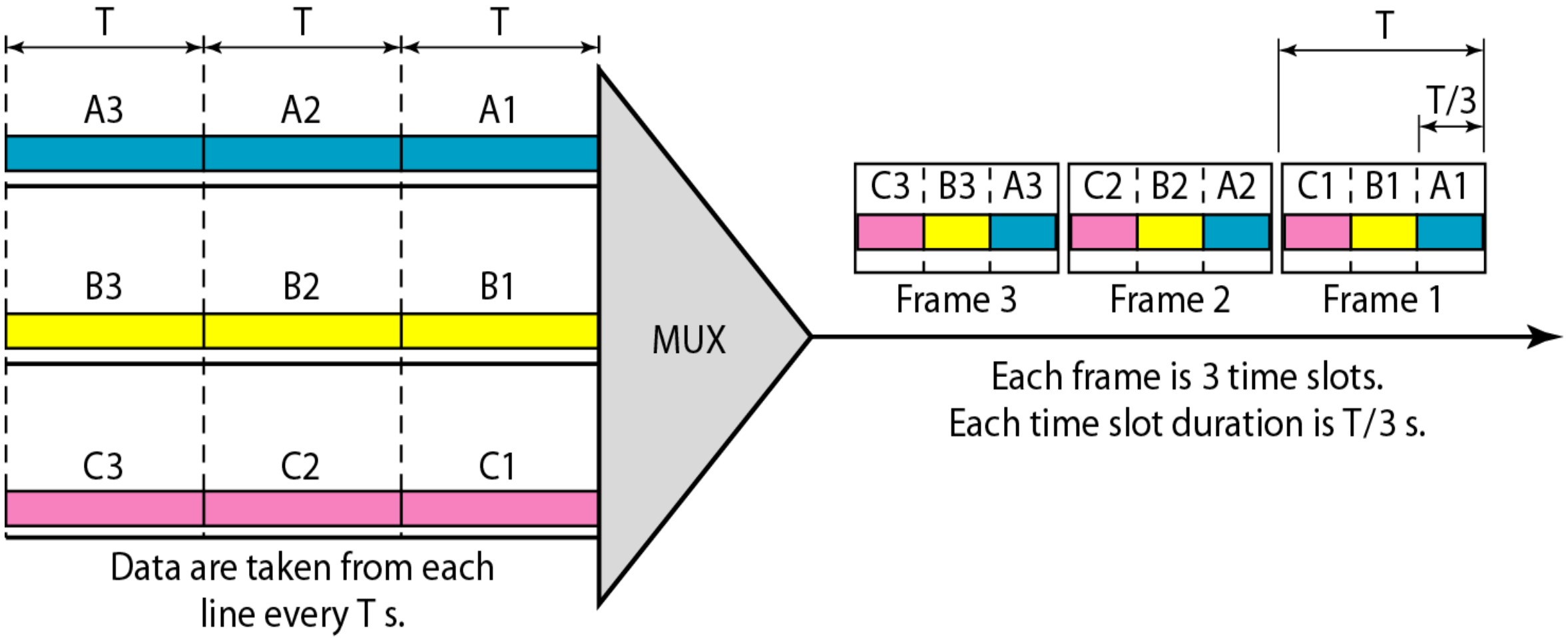
- TDM is a **digital process** that allows **several connections to share** the high bandwidth of a link.
- Instead of sharing a portion of the bandwidth as in FDM, **time is shared**. Each connection occupies a portion of time in the link.
- TDM is a digital multiplexing technique for **combining several low-rate channels into one high-rate one.**



Multiplexing: Time-Division Multiplexing

- TDM divide into two different schemes: **synchronous and statistical.**
- **In synchronous TDM**, the data flow of **each input connection is divided into units**, where each input occupies **one input time slot**.
- A unit can be 1 bit, one character, or one block of data. Each input unit becomes one output unit and occupies one output time slot.
- If an **input time slot is *T* s**, the output time **slot is *T/n* s**, where *n* is the number of connections.
- In synchronous TDM, the data rate of the link is *n* times faster, and the unit duration is *n* times shorter.

Synchronous time-division multiplexing

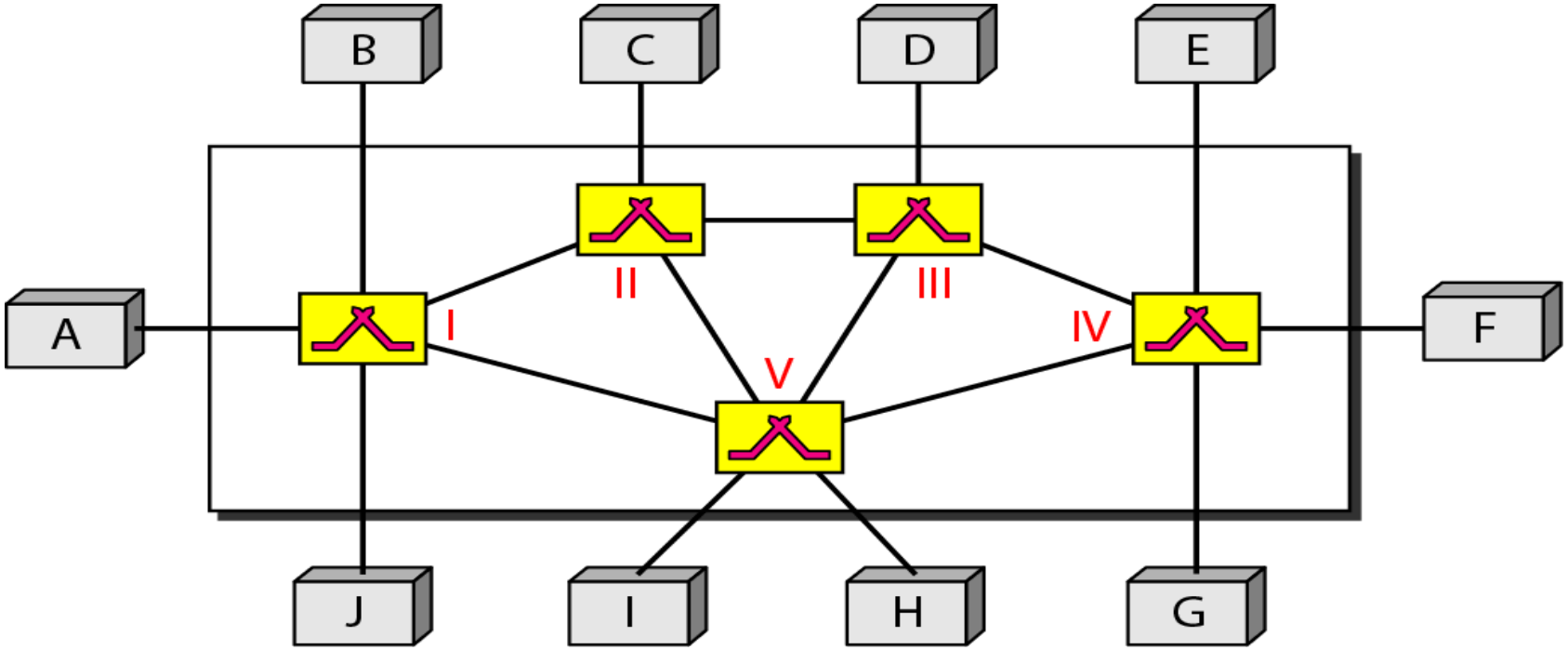


Switching

- Whenever we have multiple devices, we have the **problem of how to connect them to make one-to-one communication** possible.
- One solution is to make **a point-to-point connection** between each pair of devices (a mesh topology) or between a central device and every other device (a star topology).
- These methods, however, are **impractical and wasteful** when applied to very large networks. The number and length of the links require too much infrastructure to be cost-efficient, and the majority of those links would be idle most of the time.
- A **better** solution is **switching**.
- A switched network consists of **a series of interlinked nodes, called switches**.
- Switches are devices capable of **creating temporary connections** between two or more devices linked to the switch.

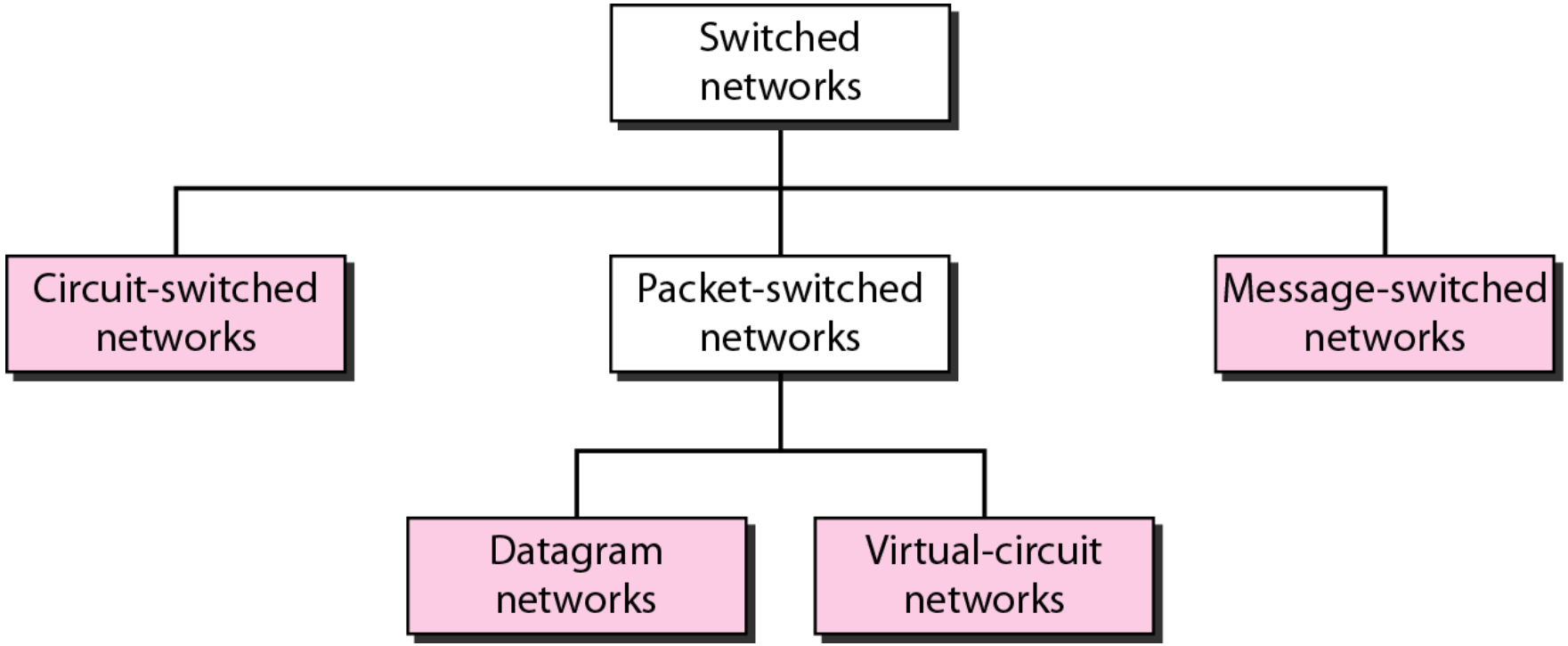
Switching

- In a switched network, some of these nodes are connected to the end systems (computers or telephones, for example). Others are used only for routing.
- The end systems (communicating devices) are labeled A, B, C, D, and so on, and the switches are labeled I, II, III, IV, and V. Each switch is connected to multiple links.



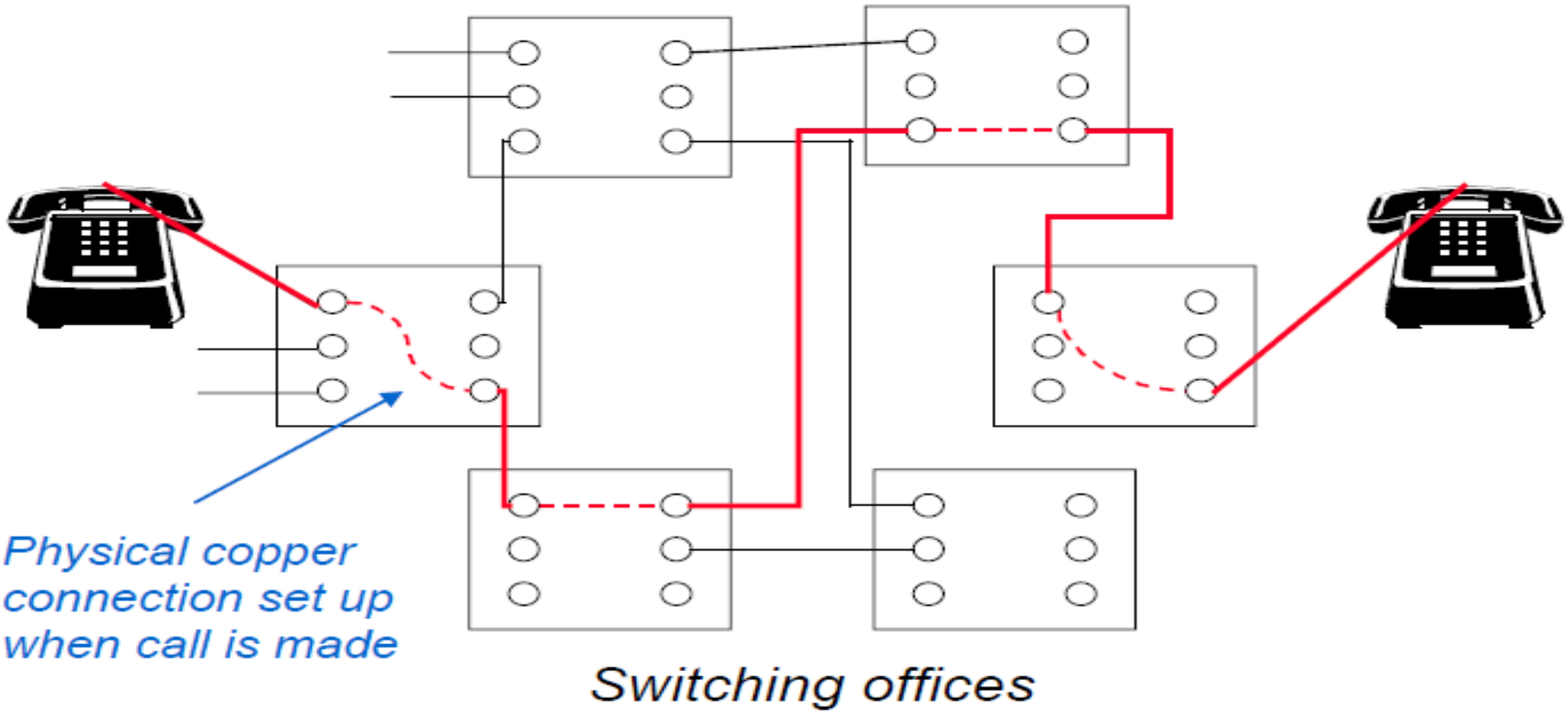
Switching

- Three methods of switching have been important: **circuit switching, packet switching, and message switching.**
- The first two are commonly used today. The **third has been phased out** in general communications but still has networking applications.



Switching: Circuit - Switched Network

- A circuit-switched network is made of a set of switches connected by physical links, in which **each link is divided into *n* channels**. However, ***each connection uses only one dedicated channel on each link.***
- Each link is normally divided into n channels by **using FDM or TDM**.
- In circuit switching, the resources **need to be reserved** during the setup phase; the resources **remain dedicated** for the **entire duration** of data transfer until the teardown phase.
- The actual communication in a circuit-switched network requires three phases: ***connection setup, data transfer, and connection teardown.***
  - ***Setup Phase:*** Before the two parties (or multiple parties in a conference call) can communicate, a dedicated circuit (combination of channels in links) needs to be established. The end systems are normally connected through dedicated lines to the switches, so **connection setup means creating dedicated channels between the switches.**


Physical copper
connection set up
when call is made
Switching offices

Switching: Circuit - Switched Network

- ***Data Transfer Phase:*** After the establishment of the dedicated circuit (channels), the two parties can transfer data**.**
- ***Teardown Phase:*** When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

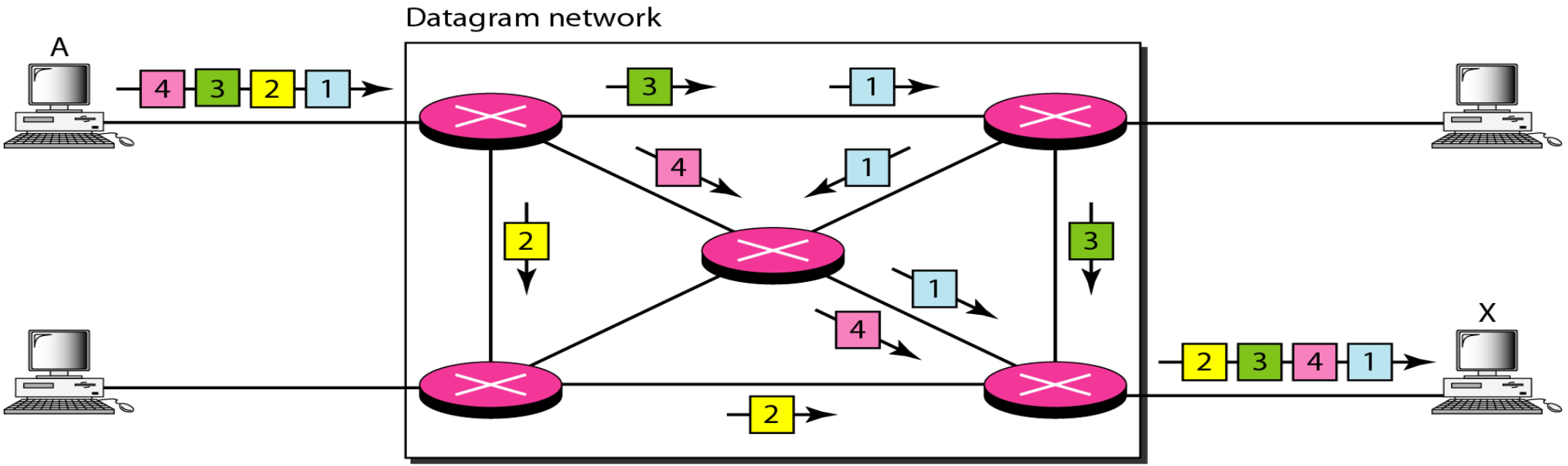
- Switches are set up at the beginning of the connection and maintained throughout the connection
- Expensive (Charging Based per minute)
- Need actual connection
- Each Packet follows same path.
- Bandwidth available is fixed.
- Not a very efficient strategy. A connection “holds” a physical line even during “silence” periods (when there is nothing to transmit)
- Developed for voice traffic (phone)

Switching: Packet - Switched Network

- If the message is going to pass through a packet-switched network, it needs to be **divided into packets of fixed or variable size**. The size of the packet is determined by the network and the governing protocol.
- In a packet-switched network, **there is no resource reservation; resources are allocated on demand.**
- The **allocation** is done on a **first come, first-served** basis. When a switch receives a packet, no matter what is the source or destination, the packet must **wait if there are other packets being processed**.
- **In a datagram network**, each packet is **treated independently** of all others. Even if a packet is **part of a multipacket** transmission, the network treats it as though it **existed alone**. Packets in this approach are referred to as datagrams.
- Datagram switching is normally **done at the network layer**.

Datagram Network

- In this example, all four packets (or datagrams) belong to the same message, but may travel different paths to reach their destination.
- This approach can cause the datagrams of a transmission **to arrive at their destination out of order** with different delays between the packets. Packets may also **be lost or dropped** because of a lack of resources.
- **In most protocols**, it is the responsibility of an **upper-layer protocol** to reorder the datagrams or ask for lost datagrams before passing them on to the application.



Datagram Network

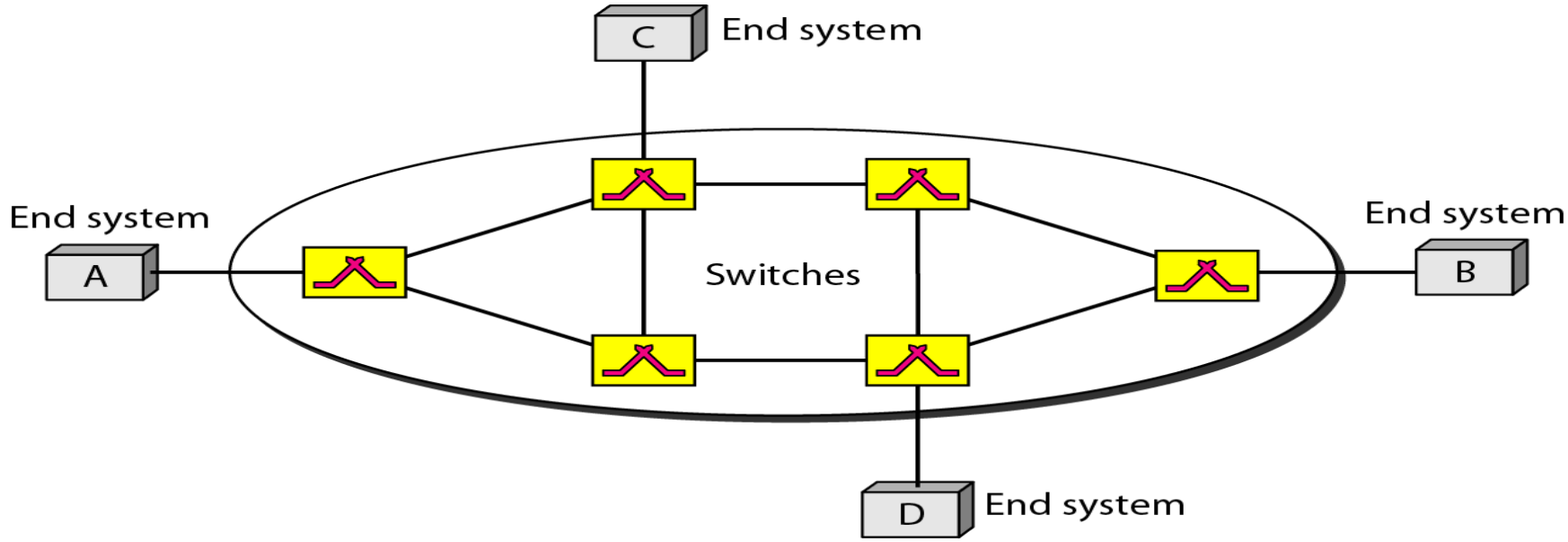
- The datagram networks are sometimes referred to as connectionless networks.
- The term ***connectionless*** here means that the switch (packet switch) does not keep information about the connection state. There are **no setup or teardown phases**.
- A switch in a datagram network uses a **routing table** that is based on the **destination address.**
- The **destination address in the header** of a packet in a datagram network remains the **same during the entire journey** of the packet.
- The **efficiency of a datagram network** is **better** than that of a **circuit-switched** network; **resources are allocated only when there are packets to be transferred**. If a source sends a packet and there is a delay of a few minutes before another packet can be sent, the resources can be reallocated during these minutes for other packets from other sources.

Virtual-circuit Network

- A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has **some characteristics of both**.
  1) As in a circuit-switched network, there **are setup and teardown phases** in addition to the data transfer phase.
  2) Resources can be allocated **during the setup phase**, as in a circuit-switched network, or on demand, as in a datagram network.
  3) As in a datagram network, **data are packetized and each packet carries an address in the header.** It defines what should be the next switch and the channel on which the packet is being carried.
  4) As in a circuit-switched network, all **packets follow the same path established during the connection.**
  5) A virtual-circuit network is normally **implemented in the data link layer**, while a circuit-switched network is implemented in the physical layer and a datagram network in the network layer.

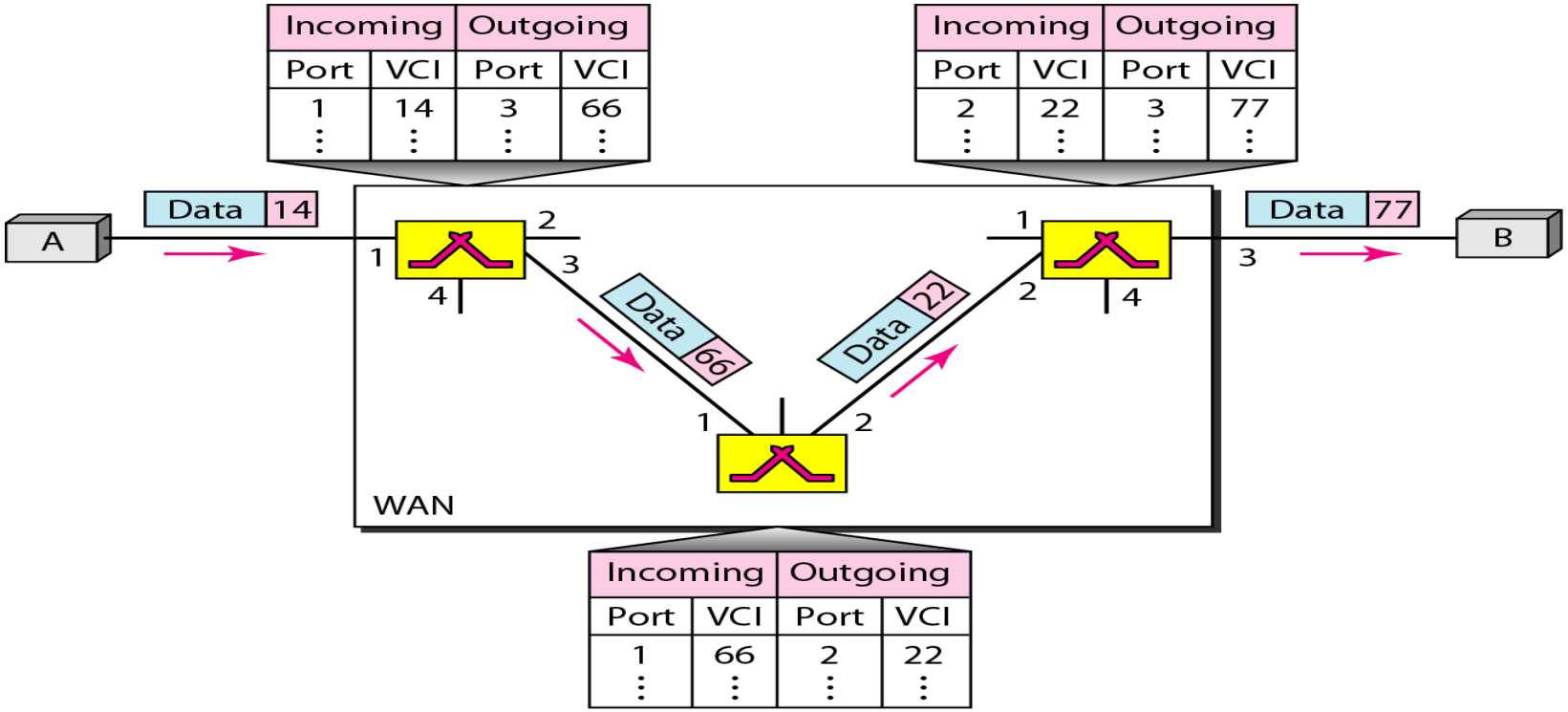
Virtual-circuit Network

- A virtual-circuit network goes through three phases : **setup, data transfer, and teardown**.
- **In the setup phase:** the source and destination **use their global addresses** to help switches make table entries for the connection.
- **In the teardown phase:** the source and destination **inform the switches to delete the corresponding entry**.
- **Data Transfer Phase** :To transfer a frame from a source to its destination, all switches need to have a table entry for this virtual circuit. This means that the switch holds four pieces of information for each virtual circuit that is already set up.



Virtual-circuit Network

- In a virtual-circuit network, two types of addressing are involved: **global and virtual-circuit identifier (VCI) .**
- **Global address:** an address that can be unique in the scope of the network or internationally if the network is part of an international network.
- VCI is a small number that has **only switch scope**; it is used by a frame between two switches. When a frame **arrives at a switch, it has a VCI**; when it **leaves, it has a different VCl.**



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

Figure 2-44. A comparison of circuit-switched and packet-switched networks.

Virtual Circuits vs. Datagram

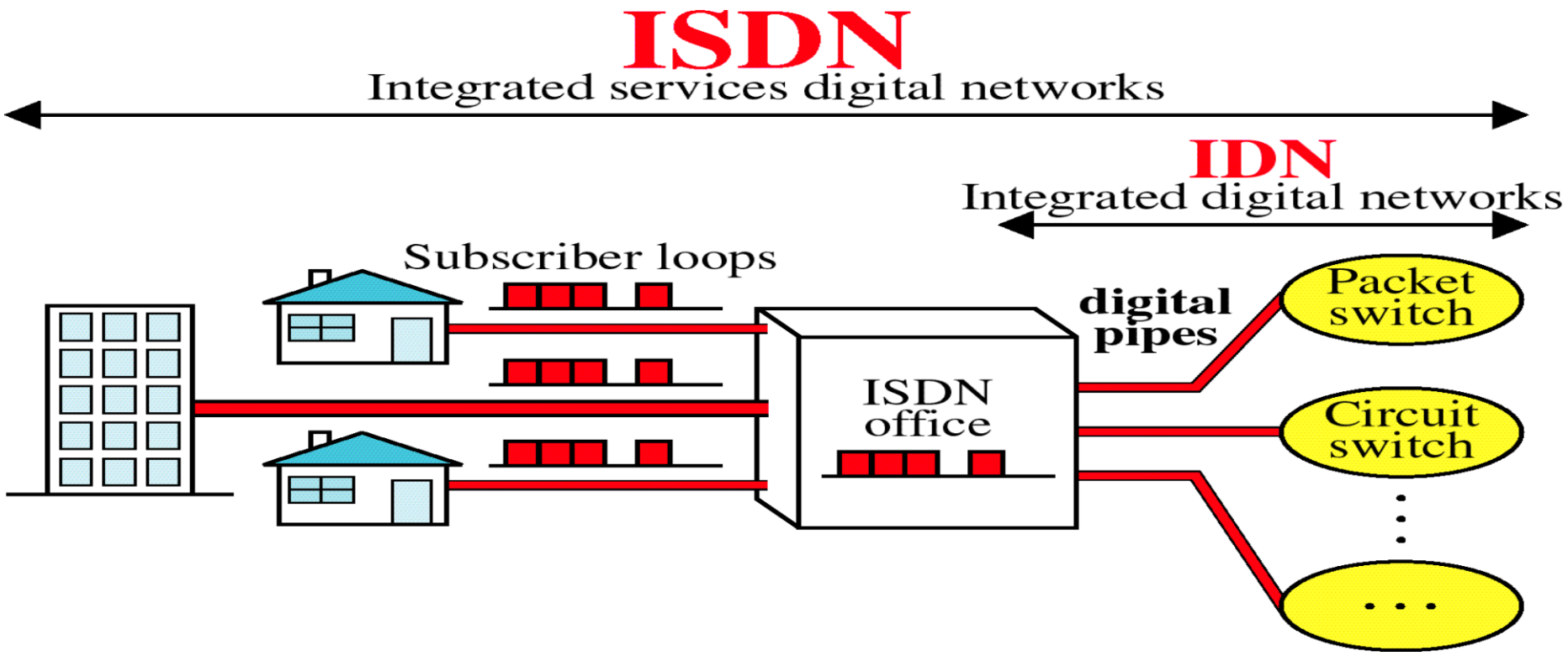
- Virtual circuits
  - Network can provide sequencing and error control
  - Packets are forwarded more quickly
    - No routing decisions to make
  - Less reliable
    - Loss of a node looses all circuits through that node
- Datagram
  - No call setup phase
    - Better if few packets
  - More flexible
    - Routing can be used to avoid congested parts of the network

ISDN: Integrated Services Digital Network

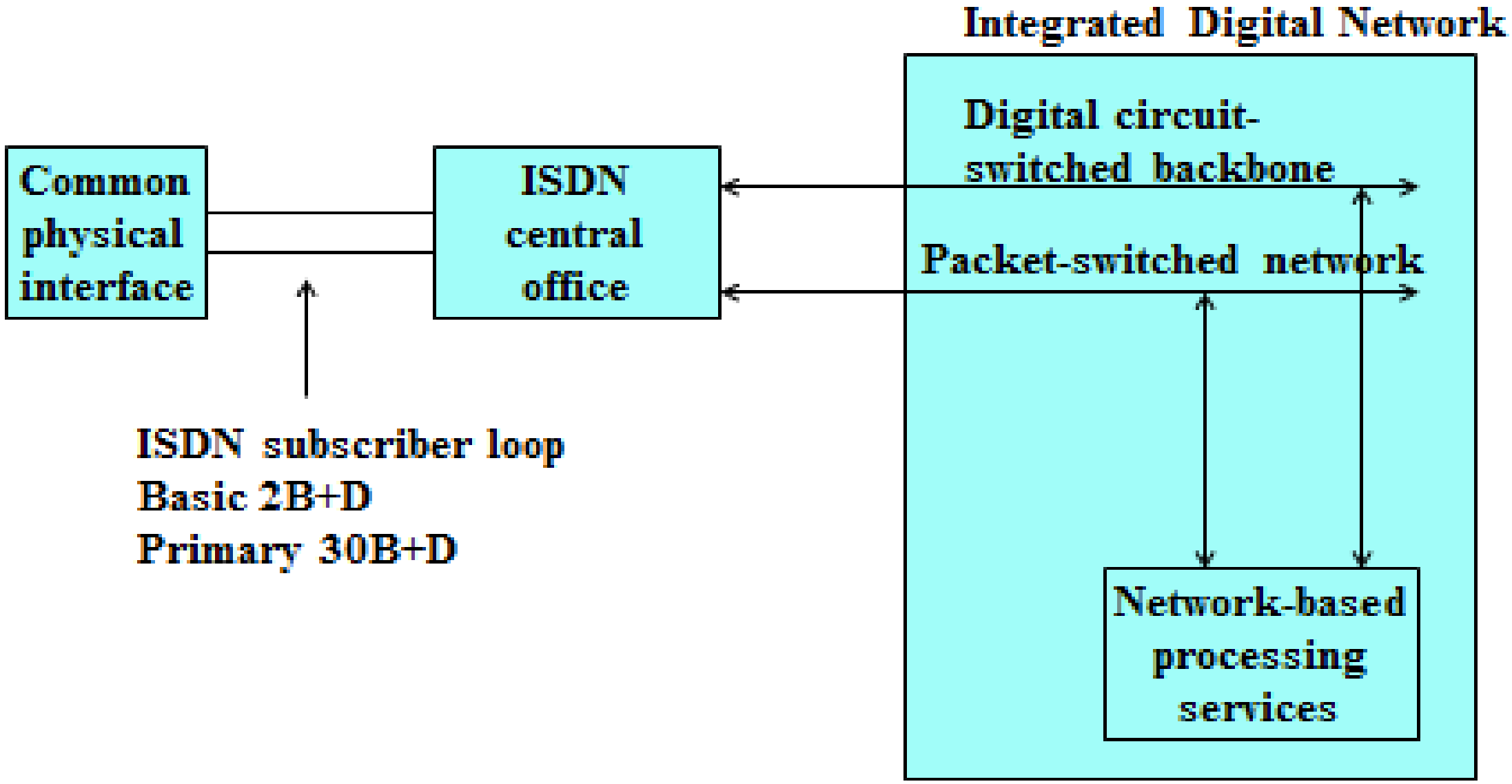
- The traditional PSTN was based on an analog connection between the customer premises and the **local exchange, also called the local loop**. The analog circuits introduce limitations on the bandwidth that can be obtained on the local loop. Circuit restrictions do not permit analog bandwidths greater than approximately 3000 Hz.
- ISDN was developed by ITU-T in 1976.
- ***ISDN is a set of protocols that combines digital telephone and data transport services.***
- The whole **idea** is to **digitize the telephone network** to permit the transmission of audio, video, and text over exiting telephone lines.
- The **goal of ISDN is to form a wide area network that provides universal end-to-end connectivity over digital media**. This can be done by integrating all of the separate transmission services into one without adding new links or subscriber lines.

ISDN: Integrated Services Digital Network

- The ISDN **integrate customer services** with IDN.
- ISDN incorporates all communication connections in a home or building into a single interface.
- **In the figure below**, each user is linked to the central office through a digital pipe. These pipes can be of different capacities to allow different rates of transmission and support different subscriber needs.



ISDN Architecture



ISDN Channels

- The Digital pipe is made up of channels - one of three types: ***Bearer (B) channel, Data (D) channel, and Hybrid (H) channel.***
- **B - Channels**
  - Data rate of 64kbps
  - Basic user channel and can carry any type of digital information in full-duplex mode.
  - *For example, digital data or PCM-encoded voice or low data-rate information.*
- **D - Channels**
  - Data rate cab be either 16 or 64 kbps.
  - *Primary function is to carry control signalling for the B channels.*
  - *Less use for low data rate telemetry and alarm transmission.*
- **H - Channels**
  - Data rates 384kbps or 1536kbps or 1920kbps
  - *Suit for high data rate applications such as video, high-quality audio, teleconferencing etc.*

ISDN Channels

- **Basic Rate Interface (BRI)**
  - The ISDN Basic Rate Interface (BRI) service **offers two B channels and one D channel (2B+D).**
  - Each BRI B channel operates at 64 kbps and is meant to carry user data.
  - ISDN BRI can provide access at 128 kbps when using both B channels.
  - The BRI D channel operates at 16 kbps and is meant to carry control and signaling information, although it can support user data transmission under certain circumstances.
  - The D-channel signaling protocol comprises Layers 1 through 3 of the OSI reference model.
- **Primary Rate Interface (PRI)**
  - In North America and Japan, ISDN PRI service offers 23 B channels and 1 D channel, known ad T1.
  - The PRI D channel runs at 64 kbps.
  - ISDN PRI in Europe, Australia, and other parts of the world provides 30 B channels plus 1 64-kbps D channel, known as E1.

ISDN Functional Groups

- **Function group:** A set of functions implemented by a device and software
- **Network Termination1 (NT1):** **Physical Layer device**. It controls the physical and electrical termination of the ISDN at the user's premises and connects the user's internal system to the digital subscriber loop.
- **A network termination 2 (NT2):** it performs functions at the **physical, data link, and network layer**. *NT2s provide multiplexing (layer 1), flow control (layer 2), and packetizing (layer 3). E.g. Private Branch Exchange (PBX)*
- **Terminal equipment1 (TE1)** is any device **that supports the ISDN standards**. Examples: digital telephones, integrated voice/data terminals.
- **TE2** devices are **not immediately compatible with an ISDN network** but can be used with the help of another device called a terminal adapter (TA).
- A **terminal adapter (TA)** converts information received in non-ISDN format from a TE2 into a format capable of being carried by the ISDN

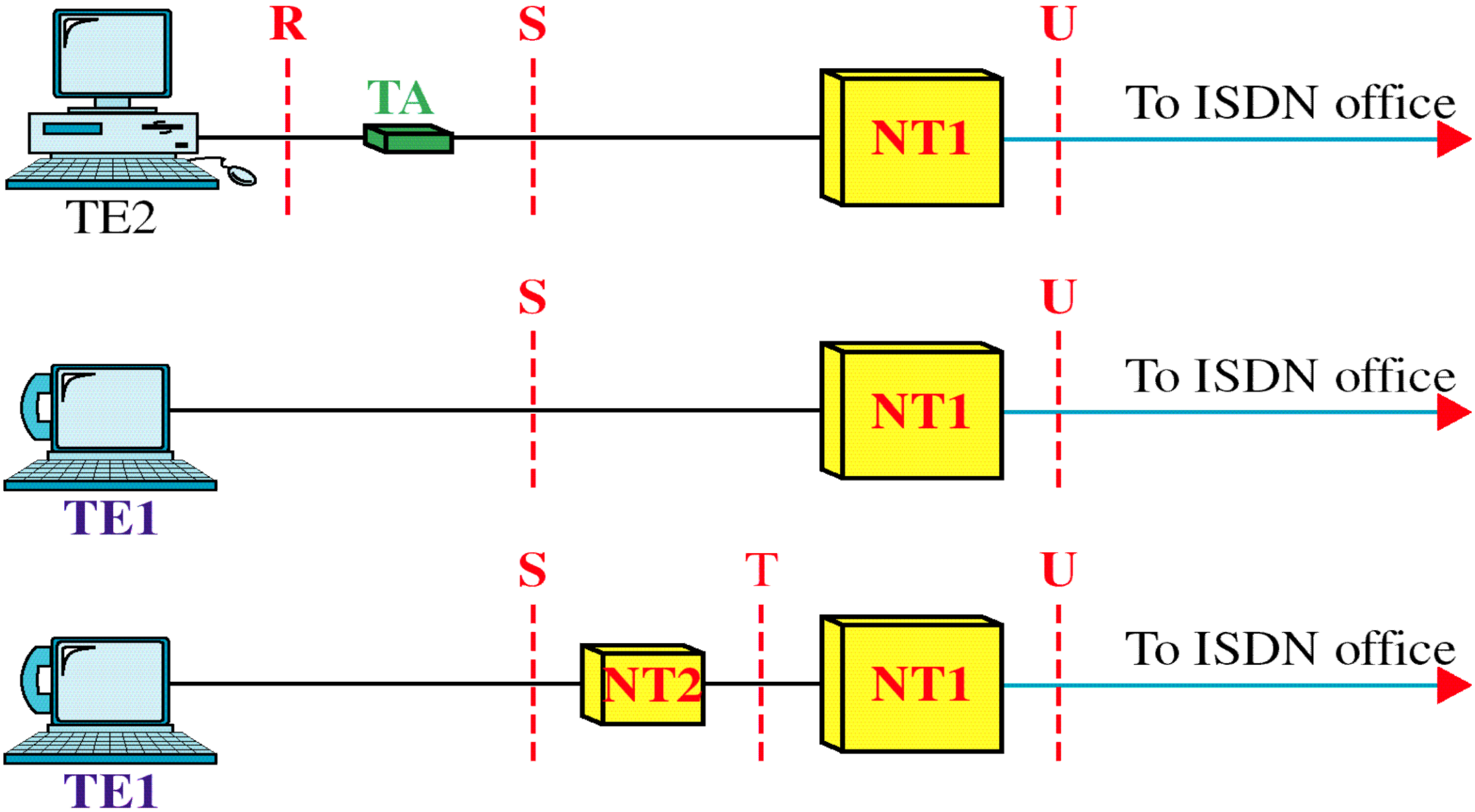
ISDN Reference Points

- **R:** References the ***connection between a non-ISDN compatible device TE2 and a Terminal Adapter (TA),*** for example an RS-232 serial interface.

- **S:** References the points that connect into **the customer switching device** NT2 and enables calls between the various types of customer premises equipment.

- **T:** Electrically identical to the S interface, it references the outbound connection from the NT2 to the ISDN network or NT1.

- **U:** References the connection between the NT1 and the ISDN network owned by the telephone company.


R
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TE1

Thank You
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References:

- Data Communications and Networking " Behrouz A. Forouzan"
- Computer Networks "A. S. Tanenbaum" Fifth Edition
- Data and Computer Communications "William Stallings" Tenth Edition.