Unit-2 - Network Concepts

Communication Networks, LANs, MANs, WANs, Circuit switching, Packet switching, ATM Cellular Networks Introduction, Cells, Duplexing, Multiplexing, Voice coding, Multiple Access Techniques: FDMA, TDMA, SDMA, CDMA, Spectral efficiency

Communication Networks, LANs, MANs, WANs

Introduction to Computer Network

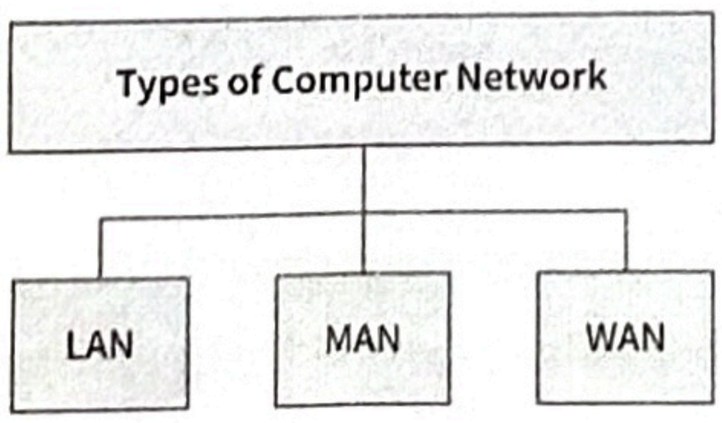
Computer Network is the interconnection between multiple devices. Computer Network allows to send and receive data and information between different connected devices. Different devices in a network are connected through links.

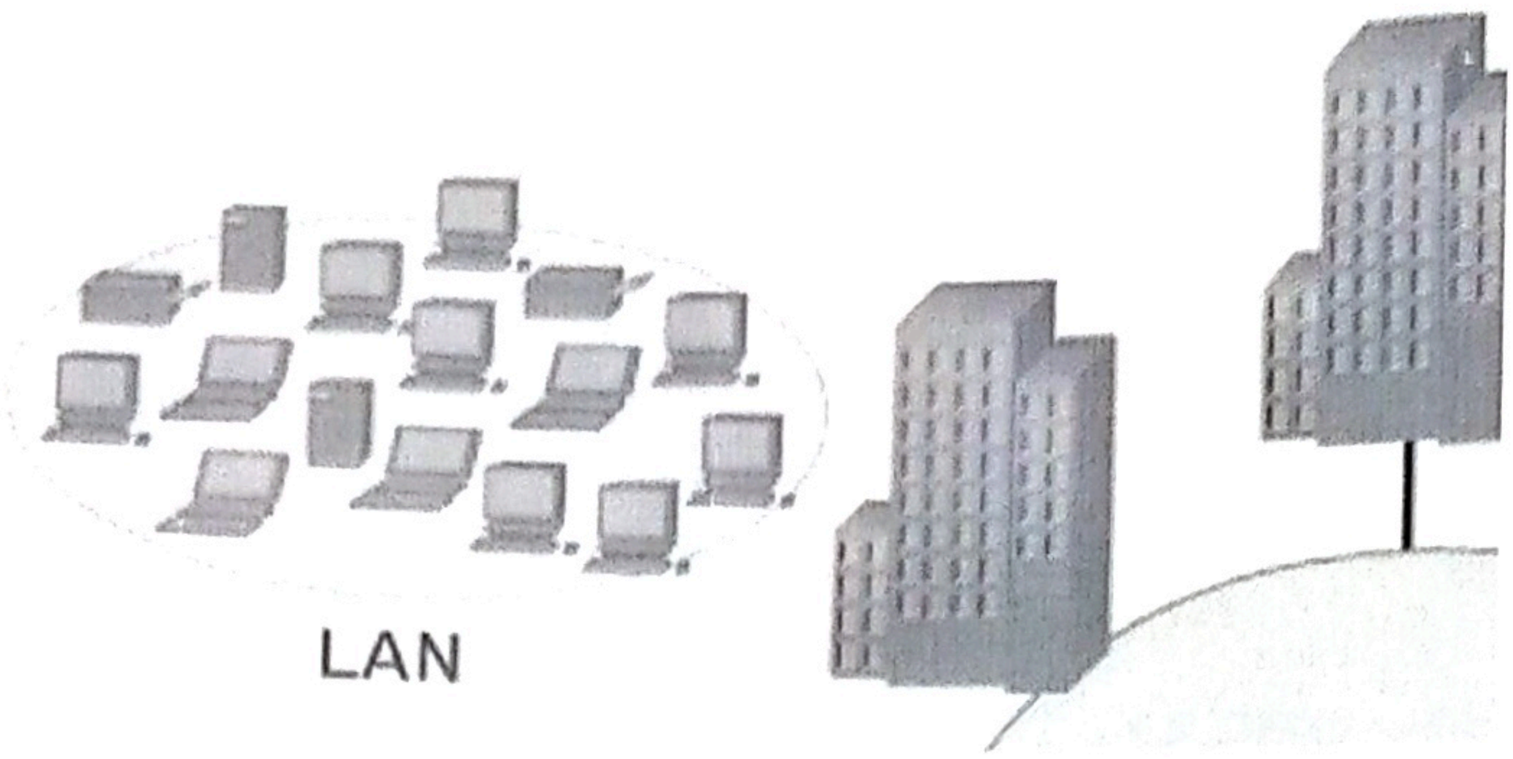
Types of Computer Networks

Based on the size of the network, ownership, and distance covered by the network, there are three types of computer networks

- Local Area Network (LAN)
- Metropolitan Area Network (MAN)
- Wide area network (WAN)

Refer to the below image to show the types of computer networks

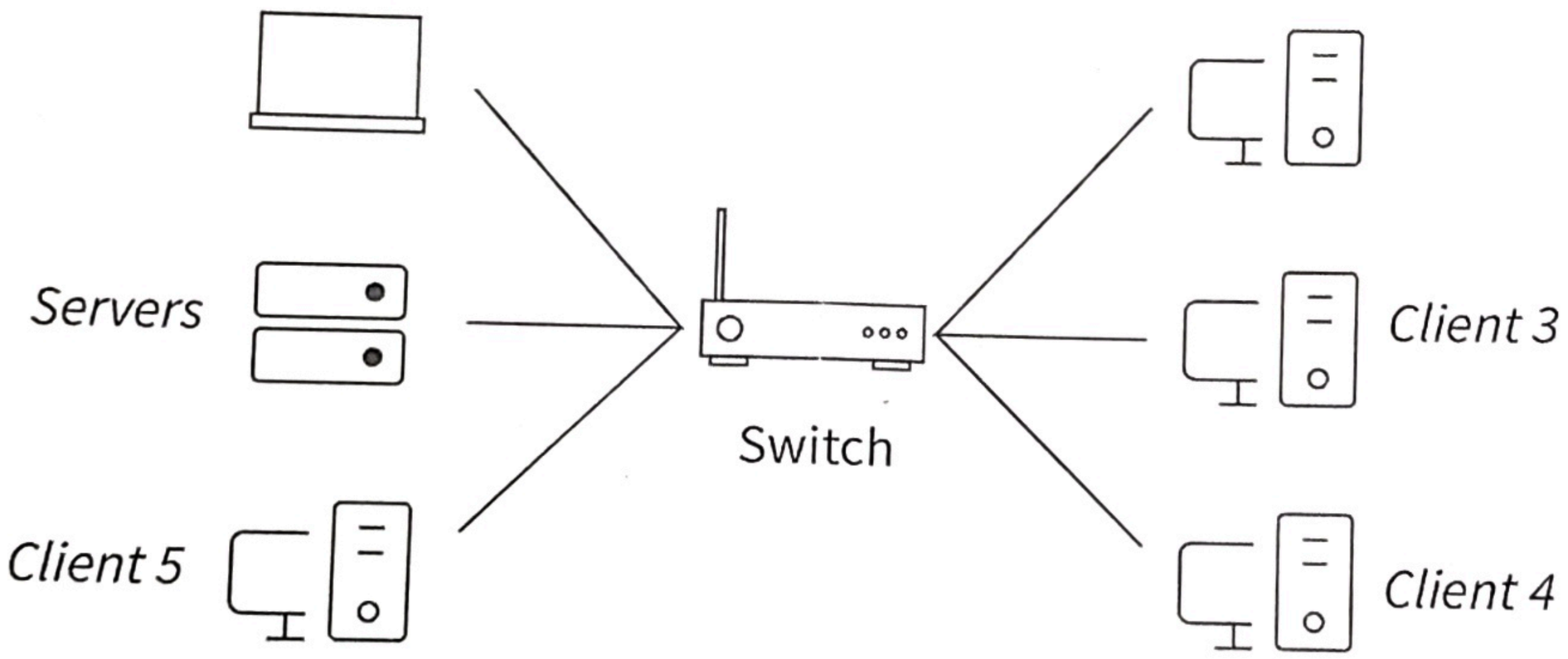




LAN (Local Area Network)

A Local Area Network (LAN) is a group of connected devices that are in a limited area such as a school, office, building, or home. It is a network mostly used for sharing hardware resources such as printers, files, scanners, etc. If we talk about the simplest LAN network then we will consider a computer and a printer connected in a home as the simplest network. The data transmission speed of the LAN is up to 10 Mbps.

Refer to the below image to show LAN

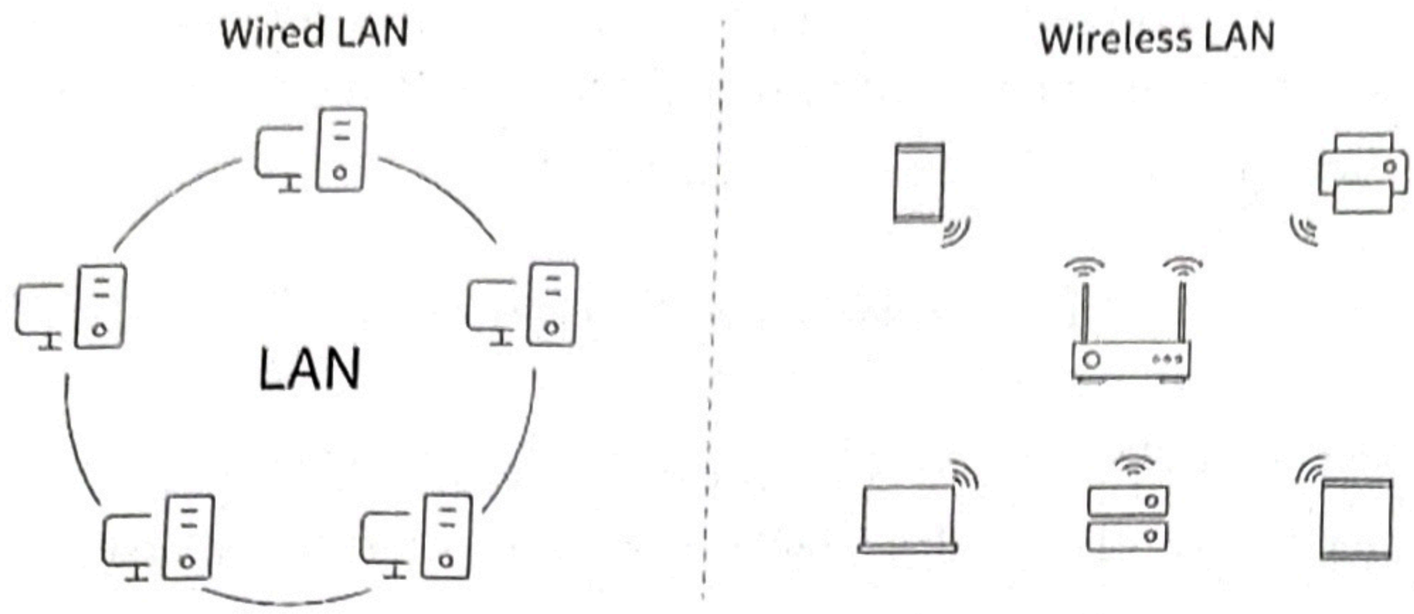


There are two types of LAN:

Wired LAN– In this type of LAN, wired cables such as twisted pair or coaxial cables are used for the connection and transmission of data.

Wireless LAN– In this type of LAN, devices are connected by wireless cables such as radio, and light waves.

Refer to the below image to show the types of LAN



Local Area Network(LAN)

Characteristics

- LAN is a type of network owned by the private owner
- LAN can be used to connect printers, personal computers, etc.
- LAN Networks can be designed very easily.
- Troubleshooting of LAN networks is easy.
- Data transfer rate of the LAN network is about 10 Gbits/s.
- It is a network which is limited to the local area.
- LAN operates relatively faster than the WAN network.

Advantages

- LAN allows sharing of computer hardware like printers, scanners, etc. which may reduce the cost of buying expensive computer hardware.
- LAN permits to share of a single internet facility among the devices connected to LAN.
- LAN provides high security and fault tolerance capability.
- It allows the transmission of data between people and devices at a high transmission rate.

Disadvantages

- LAN reduces the cost by allowing sharing of computer hardware, but the initial installation cost of LAN is very high.
- Technical and skilled manpower is required for the configuration and installation of the LAN network.
- Due to the sharing of computer resources among the devices, sometimes the operation speed of the network may slow down.

MAN (Metropolitan Area Network)

A Metropolitan Area Network or MAN is a network connecting devices across an entire town, entire city, or any other small region. This is a network larger than LAN but smaller than the WAN. WAN stands for Wide Area Network which is used to connect devices geographically such as across the country or continent. MAN network works between LAN and WAN. MAN can be used to connect multiple LAN networks. When one LAN uses modems, direct digit devices, and any other media types to connect with other LAN, then it covers a large area which is considered a Metropolitan Area Network (MAN).

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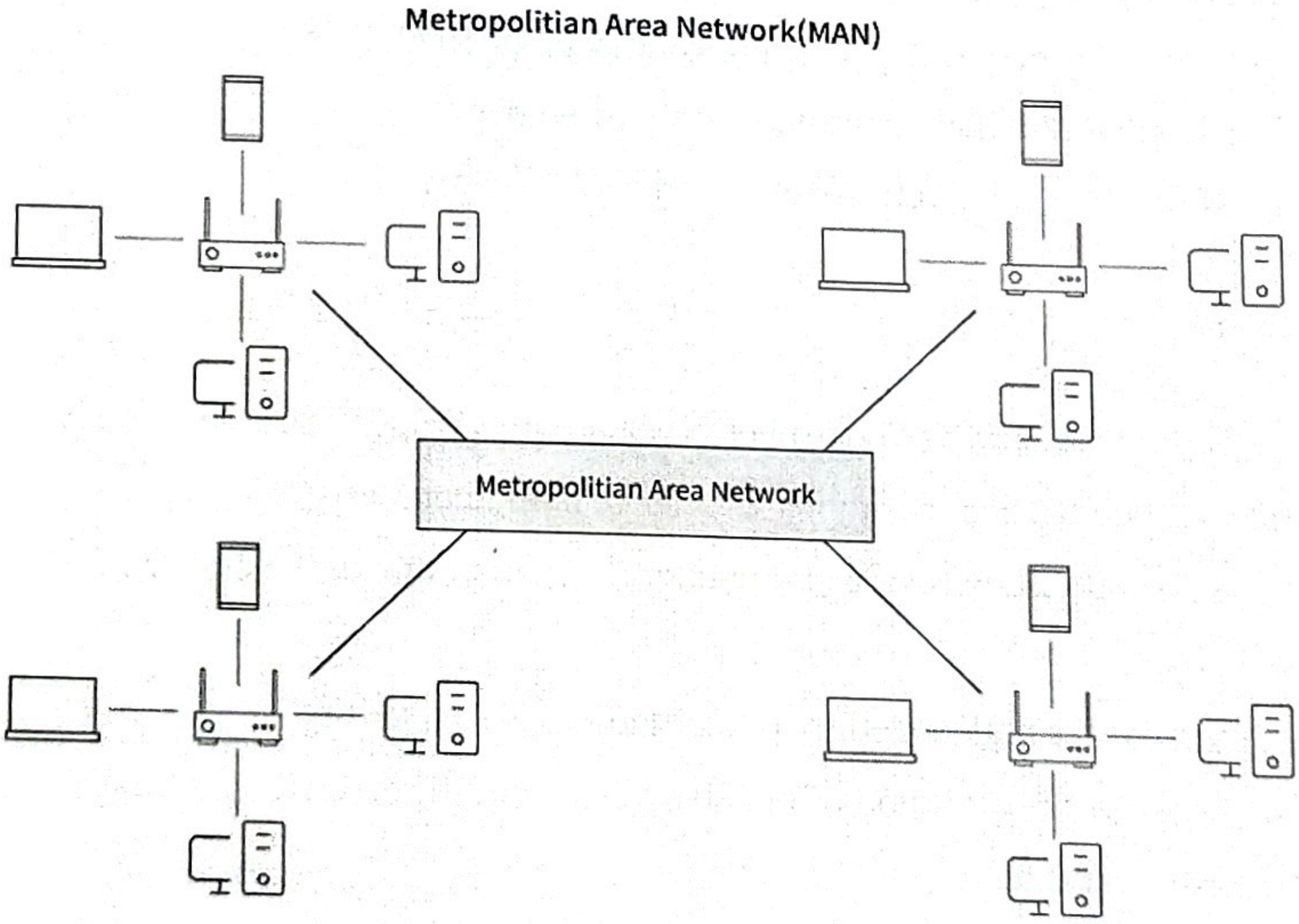

Characteristics

- MAN is a larger network in comparison to LAN.
- MAN network generally covers the towns and cities in a maximum of 50 km range
- MAN is the most used medium in cables and optical fibers.

Advantages

- MAN network connects all the branches of the company that exist in the same city.
- Dual Bus in MAN networks permits bidirectional data transfer concurrently.
- MAN network is considered economical as it allows the sharing of resources among all the branches of the company which are in the city.

WAN (Wide Area Network)

WAN stands for Wide Area Network is a type of computer network which can cover a large geographical area such as a continent, or a country. The size of the WAN network is larger than the LAN and MAN network. When the size of the network grows more than the MAN then it is considered a WAN. Usually, telecommunication networks are considered a Wide Area Network. WAN Network could be an interconnection between two or more LANs that are connected through telephone lines or radio waves.

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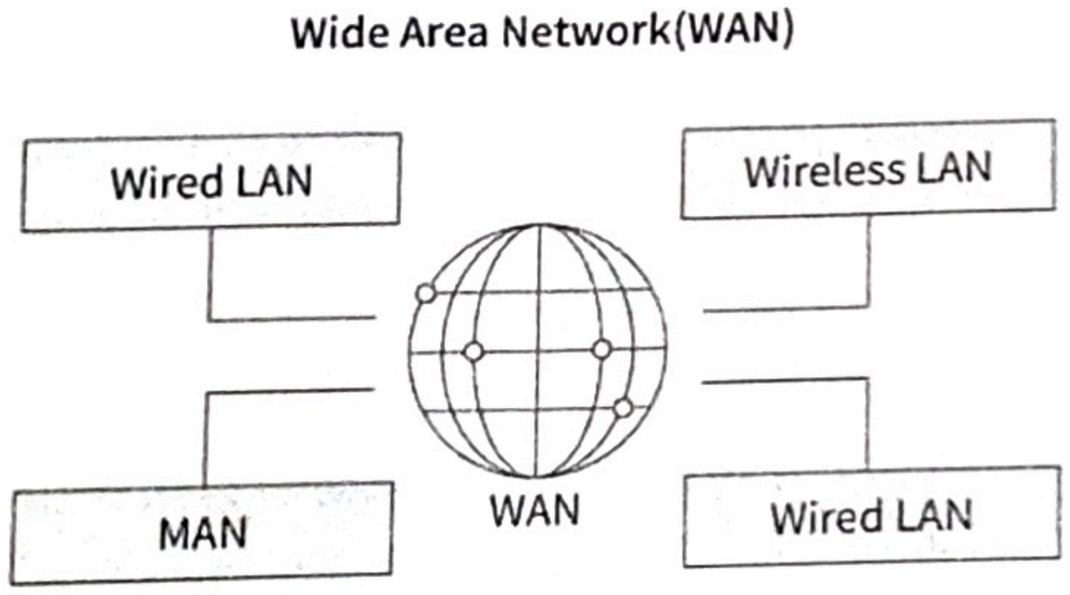


Characteristics

- WAN is used to cover a large geographical area, like a country.
- WAN can be used to connect within the world and around the world.
- Any office and organization can use WAN to form its global integrated network.

Advantages

- WAN allows covering a large geographical area.
- Offices situated at longer distances from each other can easily communicate through WAN.
- Allows connecting devices like mobile phones, laptops, tablets, etc.

Disadvantages

- There are more chances of error and issues because of the use of more technologies and wide coverage.
- Provides less security in comparison to other types of networks.
- The initial and configuration cost of WAN is very high.
- Skilled technicians and network administrators are required for the setup of this network.

Circuit switching

Circuit switching has been the dominant technology for both voice and data communications. Communication via circuit switching implies that there is a dedicated communication path between two stations. That path is a connected sequence of links between network nodes. On each physical link, a channel is dedicated to the connection. The most common example of circuit switching is the telephone network.

Step 1: Connection Establishment

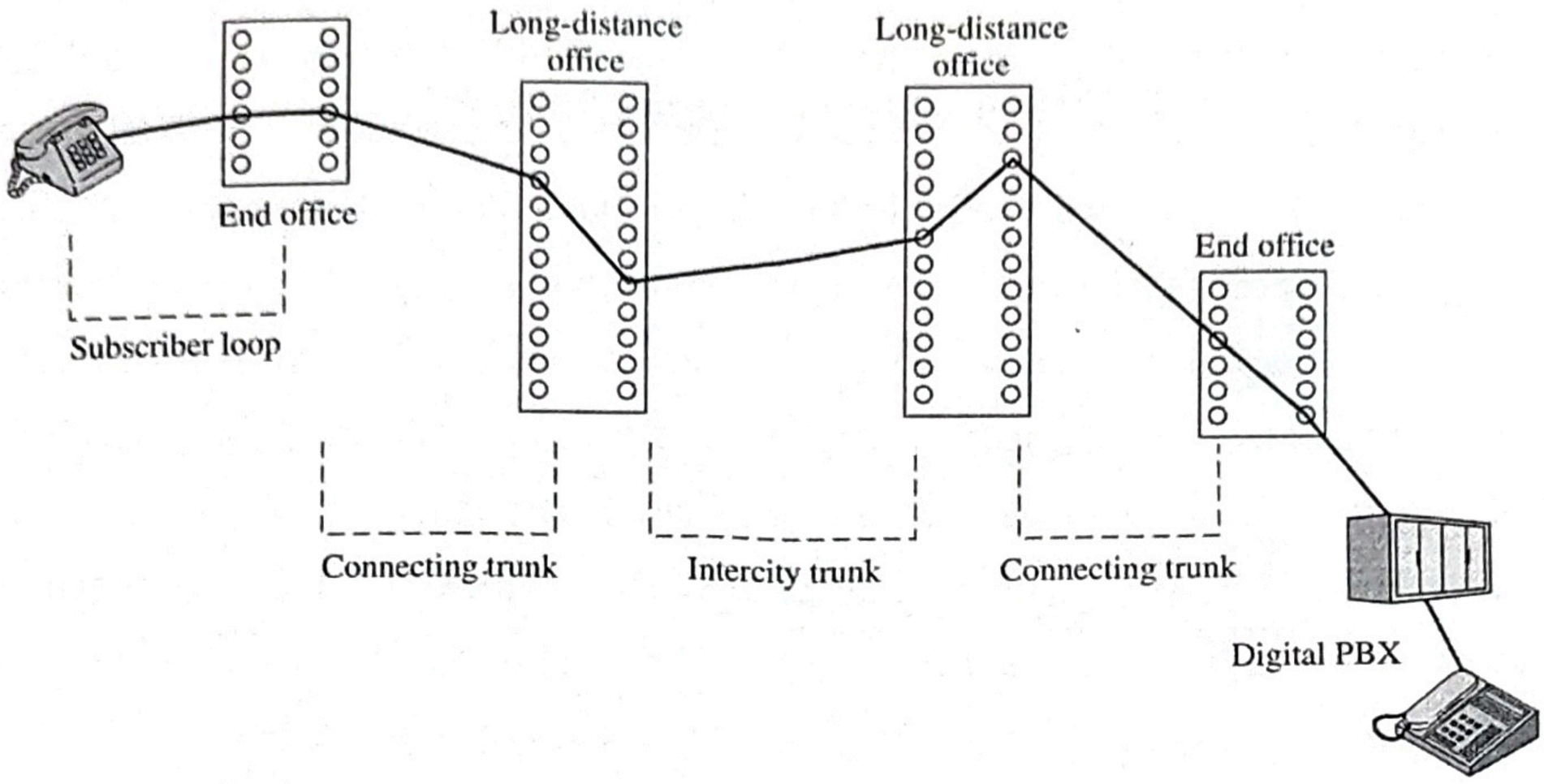
A dedicated network is established between the source and the destination with the help of several intermediate switching centers. When the transmitter and receiver transfer signals across the circuit, they can request and receive communication signals.

Step 2: Transfer of Data

When the circuit is established, data and speech signals may be sent between the source and the destination. The link between the two ends persists as long as they communicate.

Step 3: Circuit Disconnection

The circuit is disconnected when one of the users requests the disconnect. When a connection is disconnected, all intermediary linkages between the sender and the receiver are terminated.

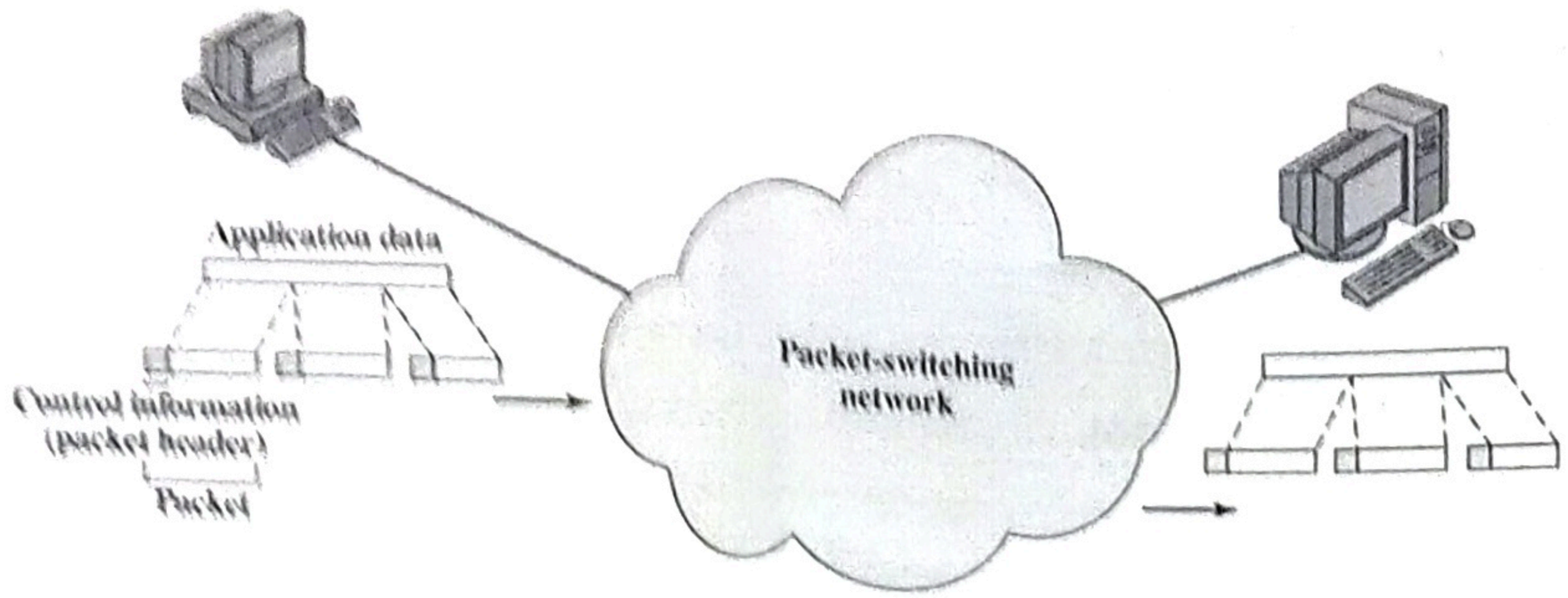


Packet switching

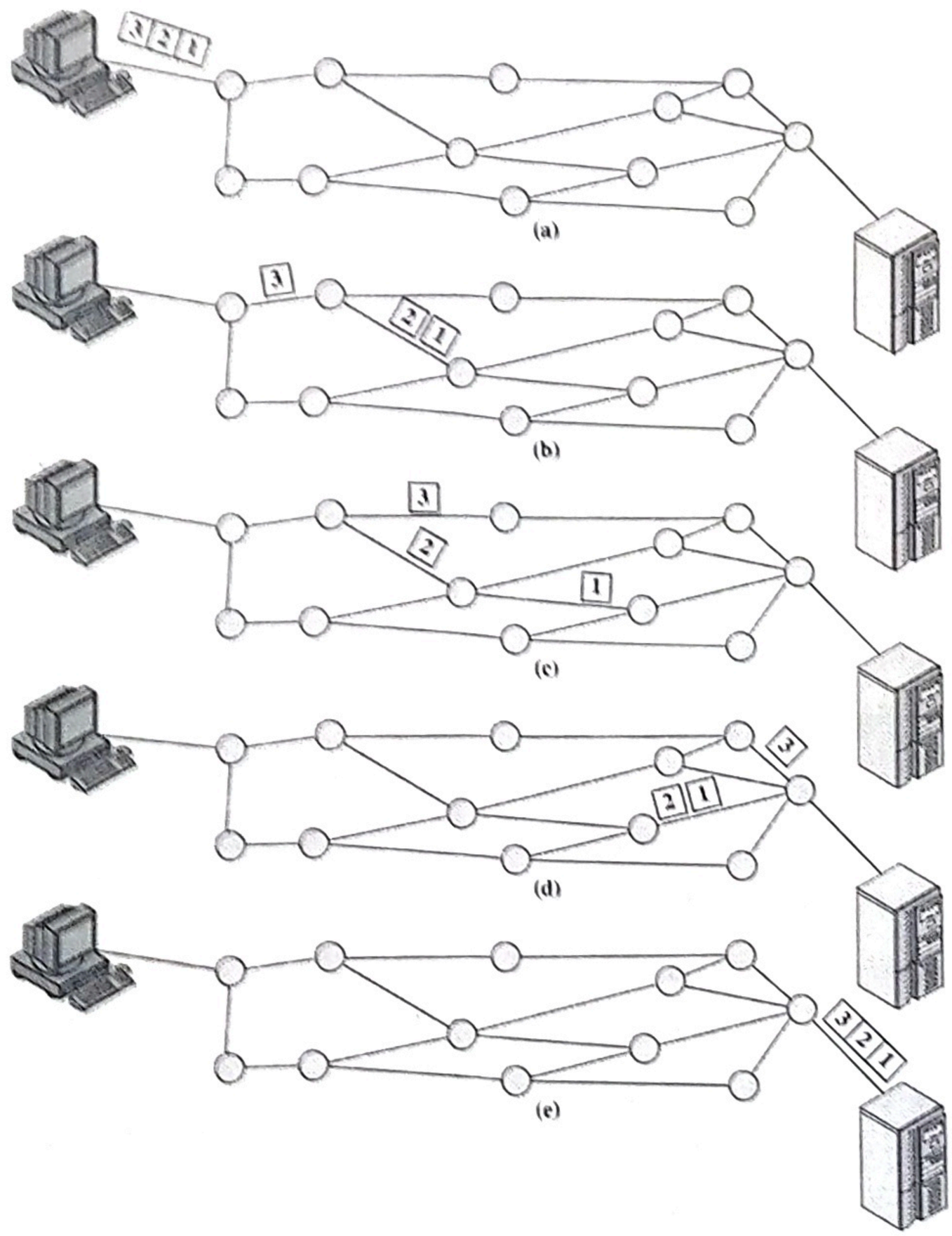
Packet switching is the transfer of small pieces of data across various networks. These data chunks or "packets" allow for faster, more efficient data transfer. Often, when a user sends a file across a network, it gets transferred in smaller data packets, not in one piece.

Packet Switching uses the **Store and Forward** technique while switching the packets; while forwarding the packet each hop first stores that packet then forwards. This technique is very beneficial because packets may get discarded at any hop for some reason. More than one path is possible between a pair of sources and destinations. Each packet contains the Source and destination address using which they independently travel through the network. In other words, packets belonging to the same file may or may not travel through the same path. If there is congestion at

some path, packets are allowed to choose different paths possible over an existing network.



Packet Switching: Datagram Approach



A transmitting computer or other device sends a message as a sequence of packets (a). Each packet includes control information indicating the destination station (computer, terminal, etc.). The packets are initially sent to the node to which the sending station attaches. As each packet arrives at this node, it stores the packet briefly, determines the next leg of the route, and queues the packet to go out on that link. Each packet is transmitted to the next node (b) when the link is available. All of the packets eventually work their way through the network and are delivered to the intended destination.

In the **datagram** approach, each packet is treated independently, with no reference to packets that have gone before. This approach is illustrated in above figure. Each node chooses the next node on a packet's path, taking into account information received from neighboring nodes on traffic, line failures, and so on. So the packets, each with the same destination address, do not all follow the same route (c), and they may arrive out of sequence at the exit point (d). In this example, the exit node restores the packets to their original order before delivering them to the destination (e). In some datagram networks, it is up to the destination rather than the exit node to do the reordering. Also, it is possible for a packet to be destroyed in the network. For example, if a packet-switching node crashes momentarily, all of its queued packets may be lost. Again, it is up to either the exit node or the destination to detect the loss of a packet and decide how to recover it. In this technique, each packet, treated independently, is referred to as a datagram.

The packet-switching approach has a number of advantages over circuit switching:

• Line efficiency is greater, since a single node-to-node link can be dynamically shared by many packets over time. The packets are queued up and transmitted as rapidly as possible over the link. By contrast, with circuit switching, time on a node-to-node link is reallocated using synchronous time division multiplexing. Much of the time, such a link may be idle because a portion of its time is dedicated to a connection that is idle.

• A packet-switching network can carry out data-rate conversion. Two stations of different data rates can exchange packets, since each connects to its node at its proper data rate.

• When traffic becomes heavy on a circuit-switching network, some calls are blocked; that is, the network refuses to accept additional connection requests until the load on

the network decreases. On a packet-switching network, packets are still accepted, but delivery delay increases.

• Priorities can be used. Thus, if a node has a number of packets queued for transmission, it can transmit the higher-priority packets first. These packets will therefore experience less delay than lower-priority packets. Packet switching also has disadvantages relative to circuit switching:

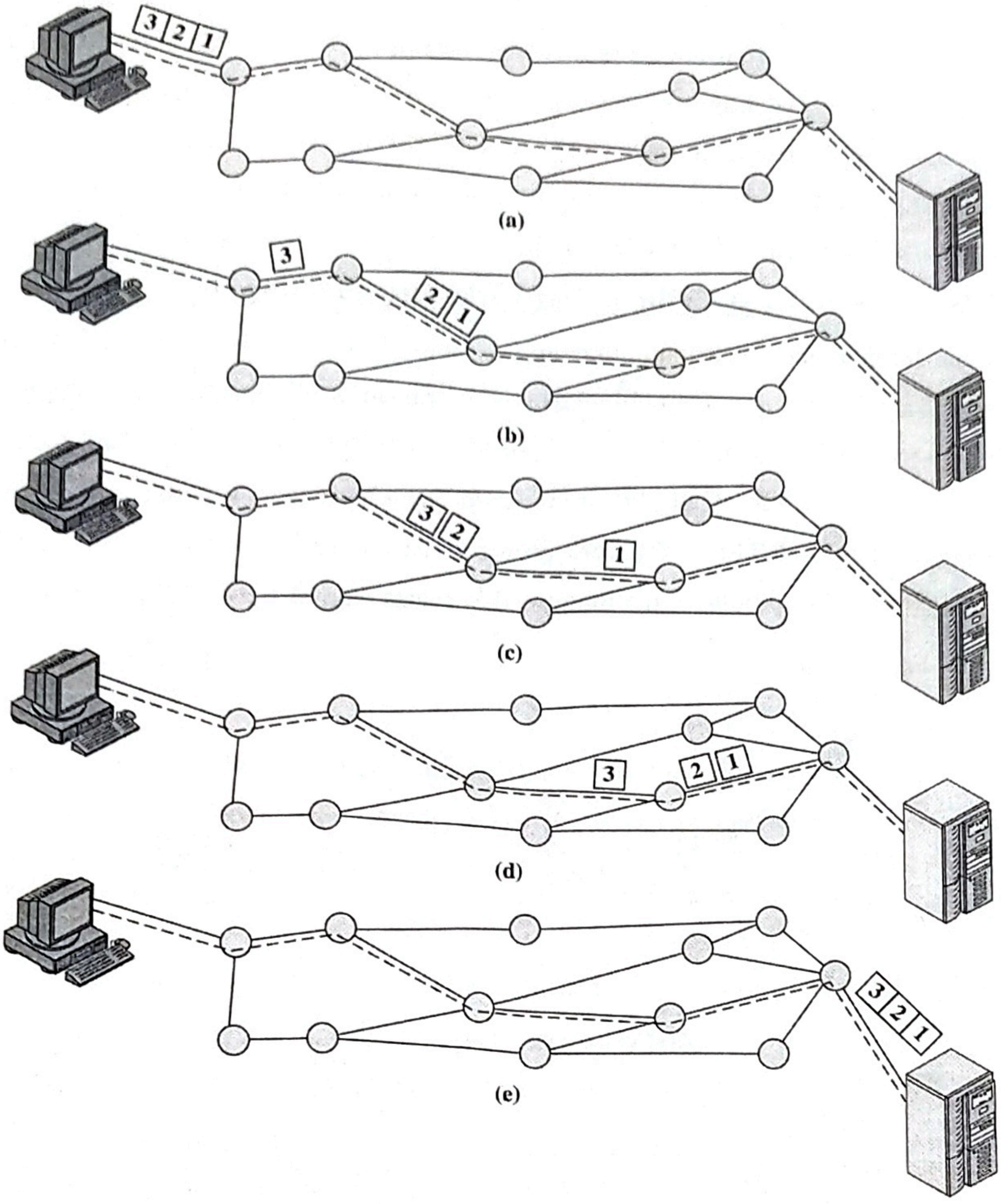
• Each time a packet passes through a packet-switching node it incurs a delay not present in circuit switching. At a minimum, it incurs a transmission delay equal to the length of the packet in bits divided by the incoming channel rate in bits per second; this is the time it takes to absorb the packet into an internal buffer. In addition, there may be a variable delay due to processing and queuing in the node.

• Because the packets between a given source and destination may vary in length, may take different routes, and may be subject to varying delay in the switches they encounter, the overall packet delay can vary substantially. This phenomenon, called jitter, may not be desirable for some applications (for example, in real-time applications, including telephone voice and real-time video).

• To route packets through the network, overhead information, including the address of the destination, and often sequencing information must be added to each packet, which reduces the communication capacity available for carrying user data. This is not needed in circuit switching once the circuit is set up.

• More processing is involved in the transfer of information using packet switching than in circuit switching at each node. In the case of circuit switching, there is virtually no processing at each switch once the circuit is set up.

Packet Switching: Virtual-Circuit Approach

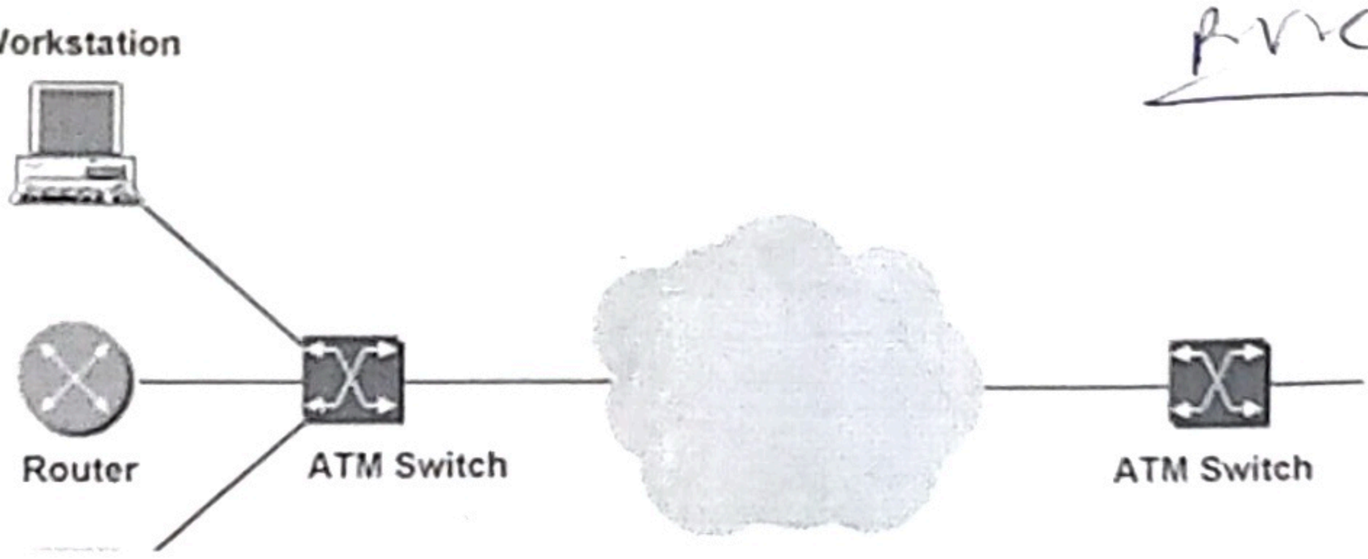


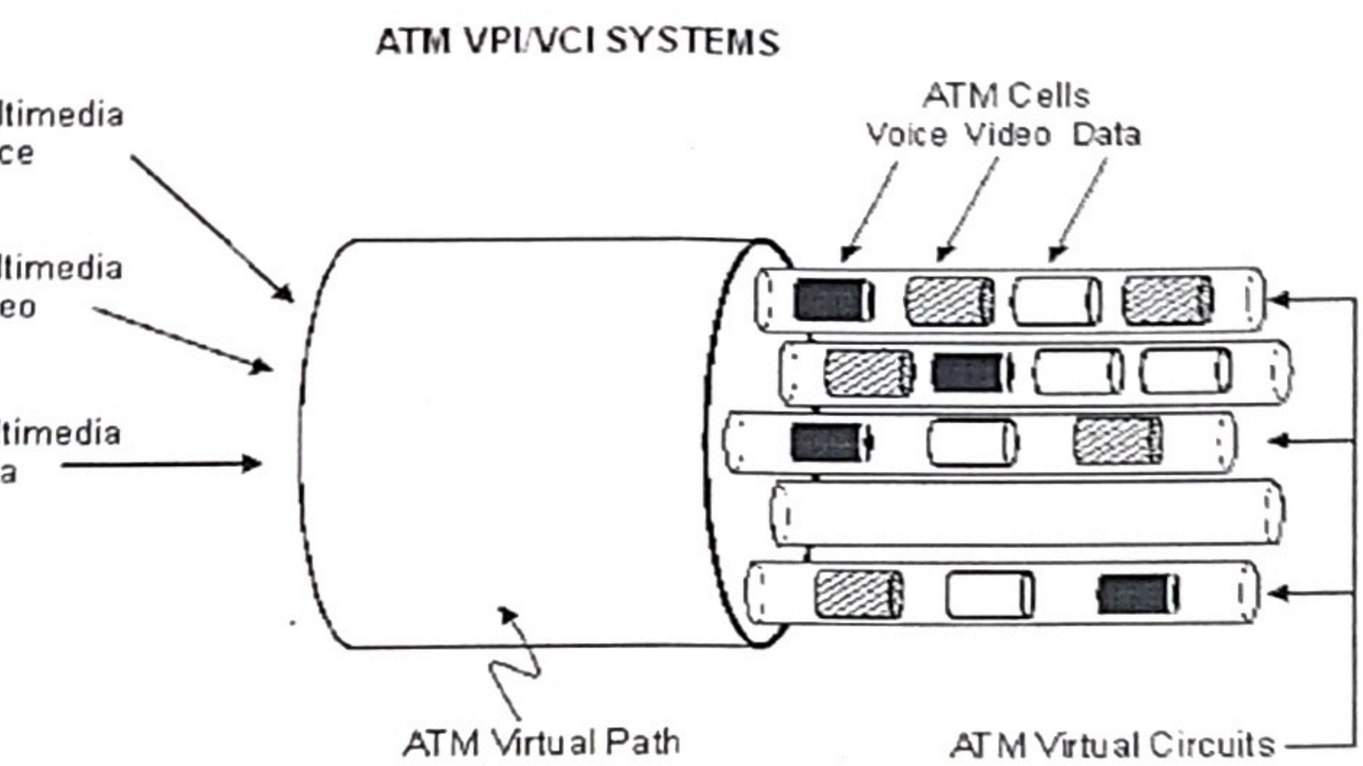
In the **virtual circuit** approach, a preplanned route is established before any packets are sent. Once the route is established, all the packets between a pair of communicating parties follow this same route through the network. This is illustrated in Figure 8. Because the route is fixed for the duration of the logical connection, it is somewhat similar to a circuit in a circuit-switching network and is referred to as a virtual circuit. Each packet contains a virtual circuit identifier as well as data. Each node on the preestablished route knows where to direct such packets; no routing decisions are required. At any time, each station can have more than one virtual

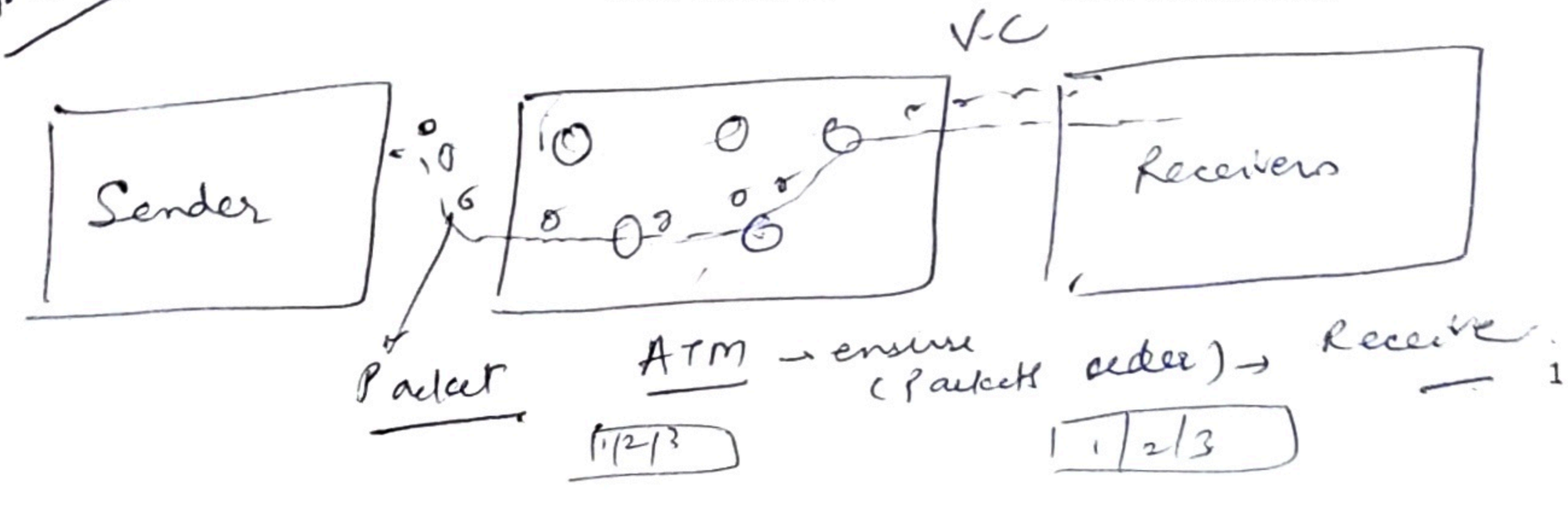
circuit to any other station and can have virtual circuits to more than one station. So the main characteristic of the virtual circuit technique is that a route between stations is set up prior to data transfer. Note that this does not mean that this is a dedicated path, as in circuit switching. A packet is still buffered at each node and queued for output over a line. The difference from the datagram approach is that, with virtual circuits, the node need not make a routing decision for each packet. It is made only once for all packets using that virtual circuit.

ATM Cellular Networks Introduction

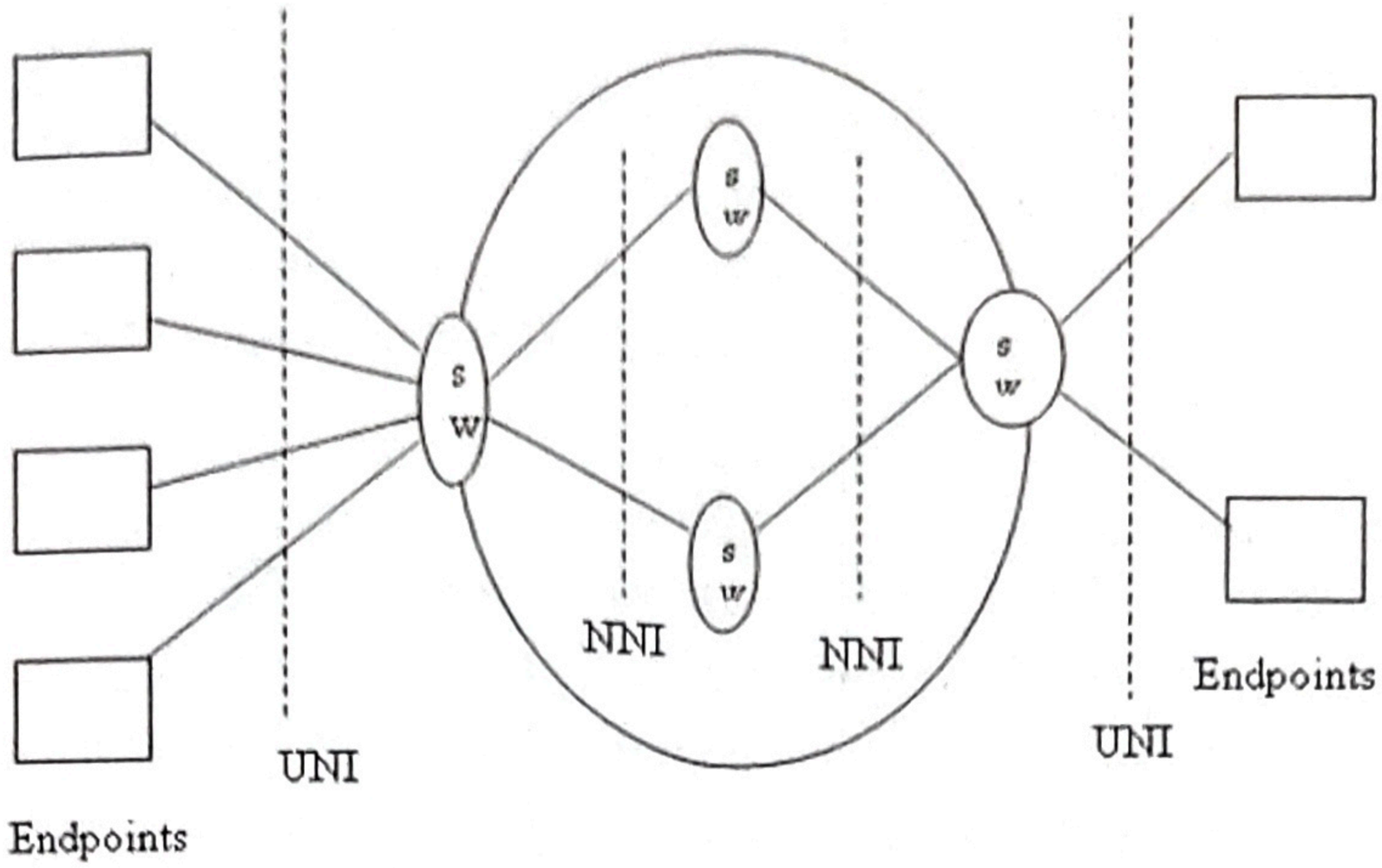
It is an International Telecommunication Union- Telecommunications Standards Section (ITU-T) efficient for call relay and it transmits all information including multiple service types such as data, video, or voice which is conveyed in small fixed-size packets called cells. Cells are transmitted asynchronously and the network is connection-oriented. ATM is the core protocol used over the synchronous optical network (SONET) backbone of the Integrated Services Digital Network (ISDN).







ATM Network Interfaces

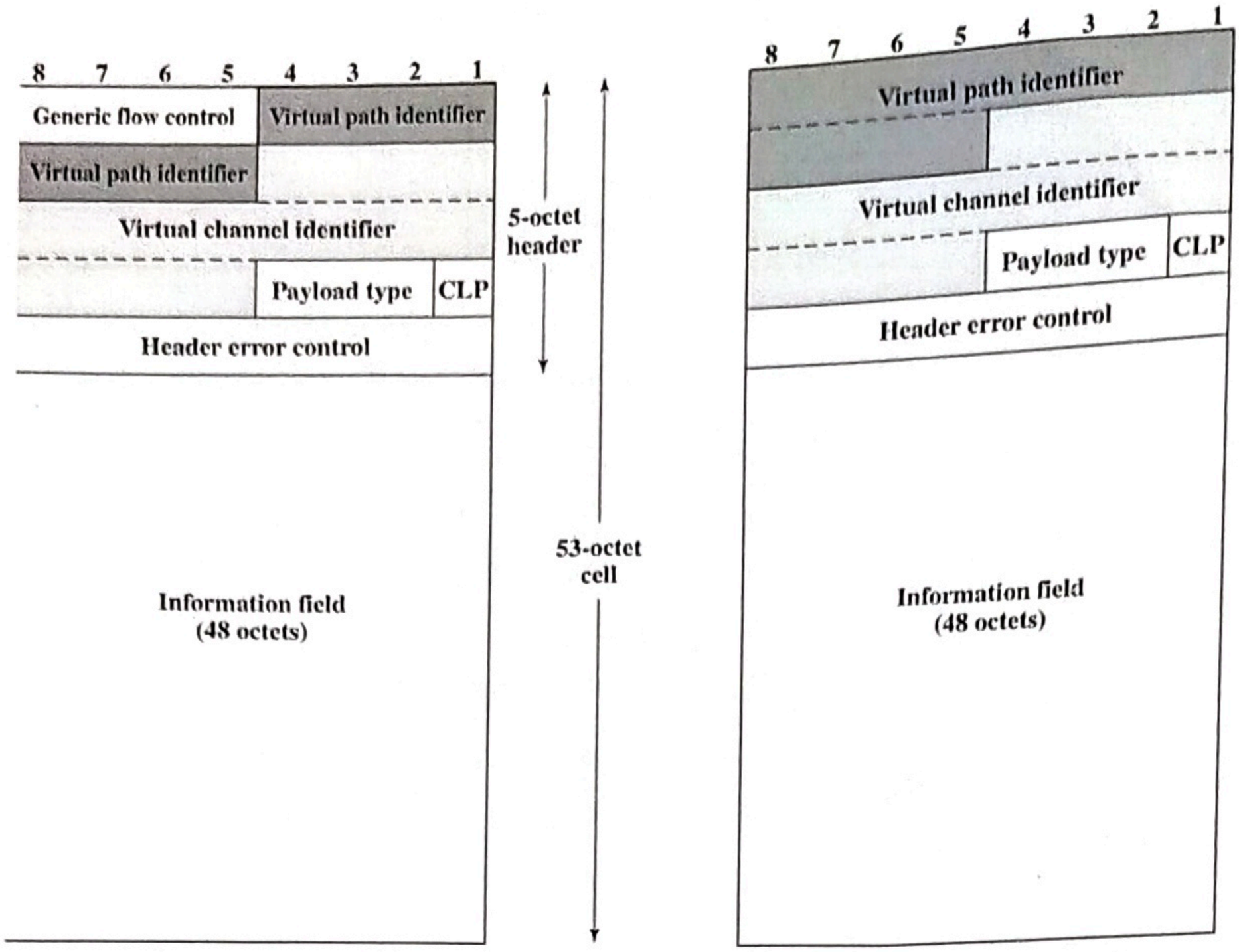


There are two kinds of interfaces in ATM. An interface that connects two or more networks, called Network to Network Interface (NNI) and an interface to connect the user to the network, called User to Network Interface (UNI)

ATM Cells

ATM uses fixed-size cells, consisting of a 5-octet header and a 48-octet information field. There are several advantages to the use of small, fixed-size cells. First, the use of small cells may reduce queuing delay for a high-priority cell, because it waits less if it arrives slightly behind a lower-priority cell that has gained access to a resource (e.g., the transmitter). Second, it appears that fixed-size cells can be switched more efficiently, which is important for the very high data rates of ATM. With fixed-size cells, it is easier to implement the switching mechanism in hardware.

Below Figure a shows the header format at the user-network interface. Figure b shows the cell header format internal to the network. Internal to the network, the Generic Flow Control field, which performs end-to-end functions, is not retained. Instead, the Virtual Path Identifier field is expanded from 8 to 12 bits



(a) User-network interface

(b) Network-network interface

This allows support for an expanded number of VPCs internal to the network, to include those supporting subscribers and those required for network management.

The **Generic Flow Control** (GFC) field can be used for control of cell flow at the local user-network interface. The details of its application are for further study. The field could be used to assist the customer in controlling the flow of traffic for different qualities of service. One candidate for the use of this field is a multiple priority level indicator to control the flow of information in a service-dependent manner. In any case, the GFC mechanism is used to alleviate short-term overload conditions in the network.

The **Virtual Path Identifier** (VPI) field constitutes a routing field for the network. It is 8 bits at the user-network interface and 12 bits at the network-network interface, allowing for more virtual paths to be supported within the network.

The **Virtual Channel Identifier** (VCI) field is used for routing to and from the end user. Thus, it functions much as a service access point.

The **Payload Type** (PT) field indicates the type of information in the information

field. Table 1 shows the interpretation of the PT bits. A value of 0 in the first bit indicates user information (that is, information from the next higher layer).

The **Cell Loss Priority** (CLP) field is used to provide guidance to the network in the event of congestion. A value of 0 indicates a cell of relatively higher priority, which should not be discarded unless no other alternative is available. A value of 1 indicates that this cell is subject to discard within the network.

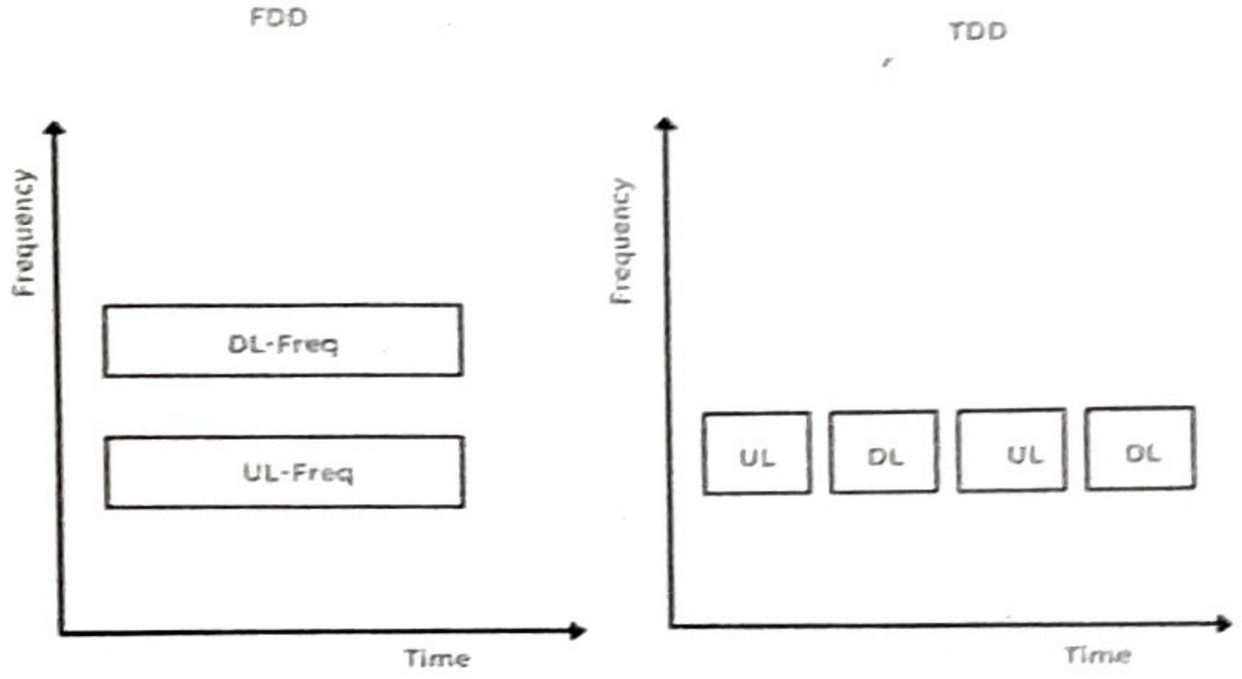
The **Header Error Control** (HEC) field is an 8-bit error code that can be used to correct single-bit errors in the header and to detect double-bit errors.

Duplexing

Generally, duplexing refers to how a node separates transmissions from receptions. The technologies of today enable speech and data transmission in both directions. Duplexing is the name for this specific capability to permit simultaneous bidirectional data transport. Duplexing is possible in both the time and frequency domains.

- Frequency Division Duplexing (FDD)
- Time Division Duplexing (TDD)

DL- Downlink
UL- Uplink



Frequency Division Duplexing (FDD)

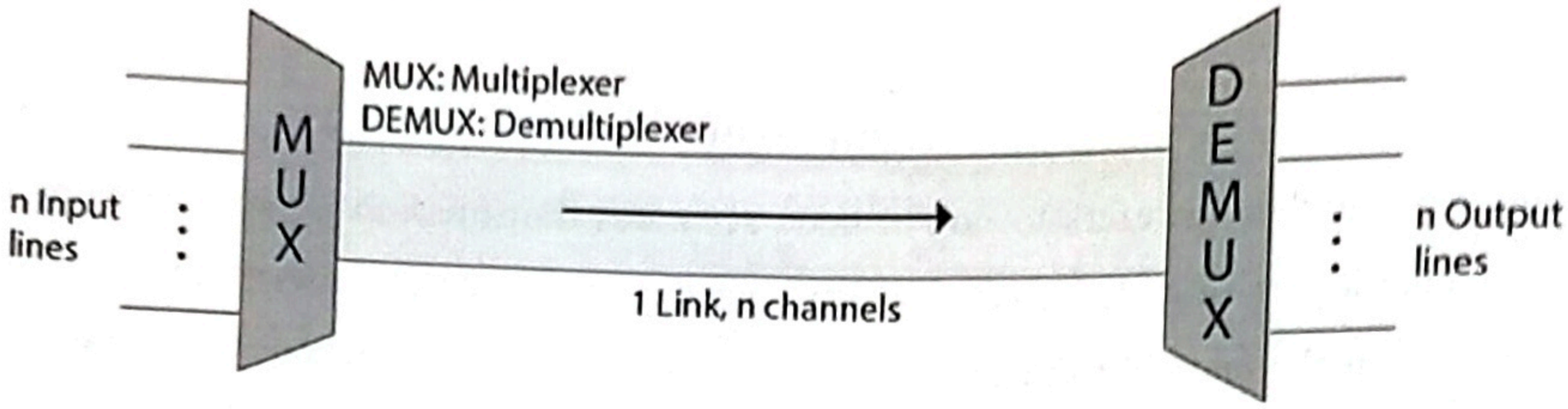
The simultaneous transfer is achieved by using two different frequency bands, one for uplink transmission and the other for downlink transmission.

Time Division Duplexing (TDD)

This duplexing method employs the full frequency range for the period of the one-time slot for transmission and the following slot for the reception.

Multiplexing

Multiplexing refers to the combination of signals (e.g., packets), and multiple access means by which multiple signals are separated, and both of these terms can refer to either transmissions or receptions.



- The 'n' input lines are transmitted through a multiplexer and multiplexer combines the signals to form a composite signal.
- The composite signal is passed through a Demultiplexer and demultiplexer separates a signal to component signals and transfers them to their respective destinations.

Advantages of Multiplexing:

- More than one signal can be sent over a single medium.
- The bandwidth of a medium can be utilized effectively.

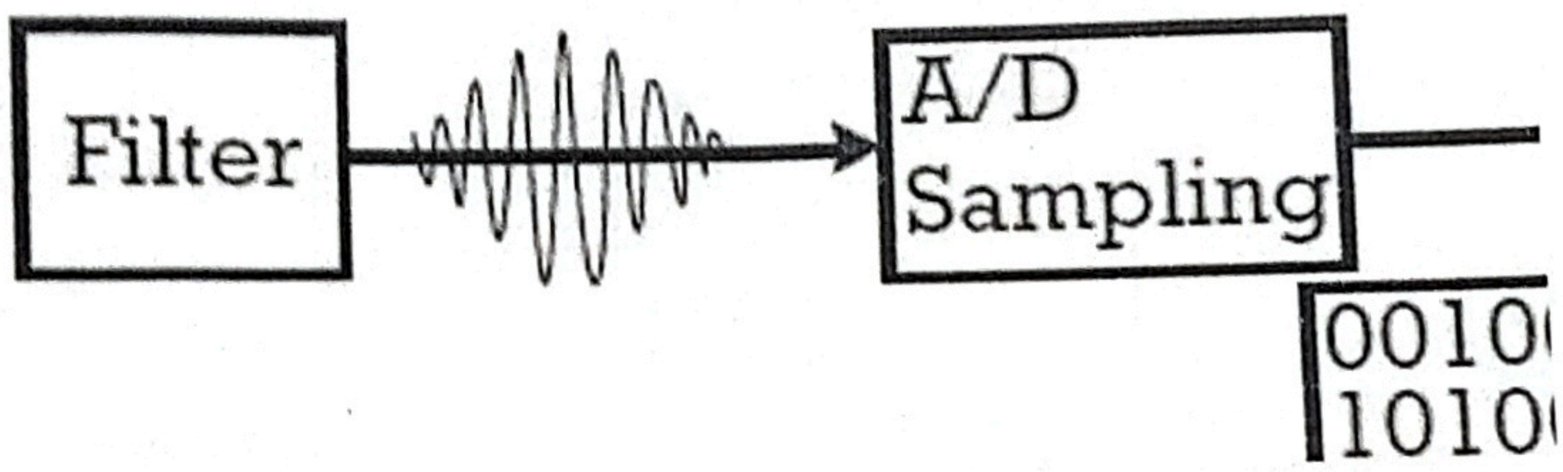
Voice coding

Vocoders can encode speech at a very low bit rate. Even if the result does not sound like the original audio signal. In a hybrid coder a vocoder is used to encode the voice signal. The decoded sample of the result is then compared to the original sample.

Earlier days voice was transmitted without applying any compression method to the voice samples. This used to occupy more bandwidth on the channel. This was prevalent in first generation analog systems.

In current generation wireless standards such as 2G, 3G and 4G voice us transformed into digital 1's and 0's. This digital data is modulated on transmitted carrier using digital modulation techniques such as ASK, PSK , FSK etc. Now-a-days BPSK, QPSK, 16QAM, 64QAM modulations are widely used.

In order to use digital modulation, analog voice signal is converted into digital. This is done using A to D converter. ADC converter samples level of voice signal and transmits bit stream of ones and zeros in order to indicate either relative (differential step up or down) or absolure level. The two parameters viz. A to D sampling rate and number of bits needed to represent steps are important for A to D conversion.



Based on the above techniques,single voice channel data rate is about 64 Kbps in PCM (Pulse Code Modulation) standard. This takes up more bandwidth in wireless channel transmission. As we know bandwidth is very scarse resource in wireless system based communication. Techniques such as ADPCM represents samples differentially and hence data rate is reduced to 32 kbps from 64 kbps. However this is still higher.

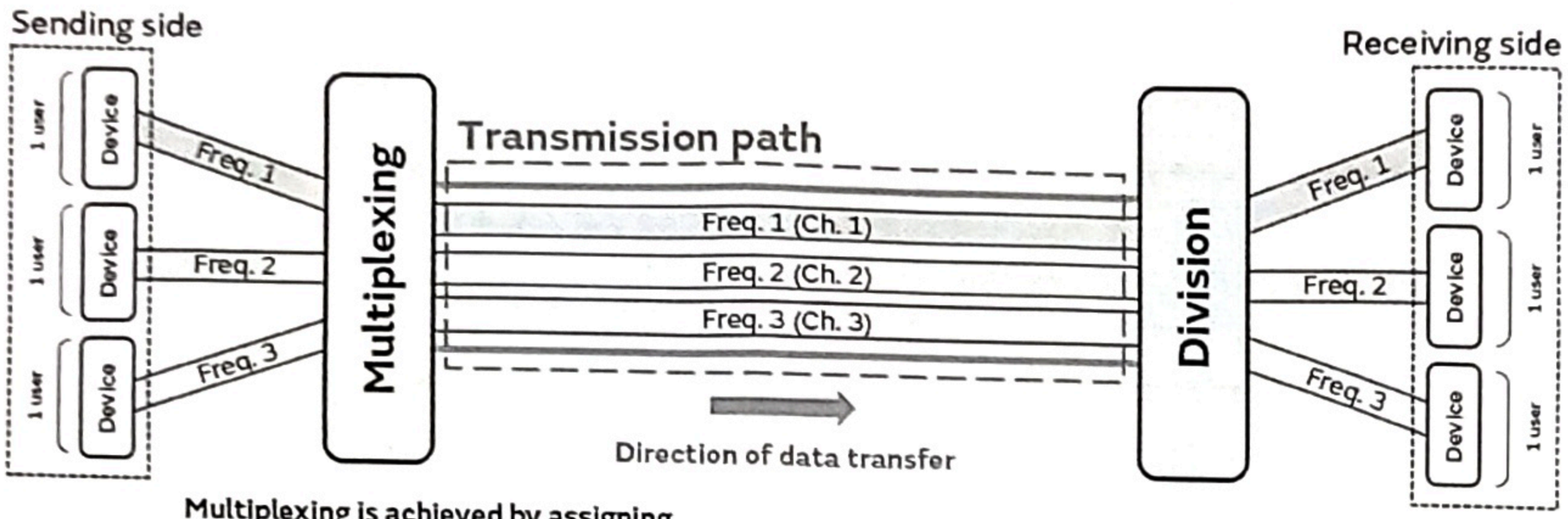
In order to further reduce the data rate complex vocoders have been developed. The function performed by vocoder is referred as vocoding. Vocoders represent voice signal in the form of bits using the technique known as codebook. Using vocoders data rates below 13 kbps can be achieved.

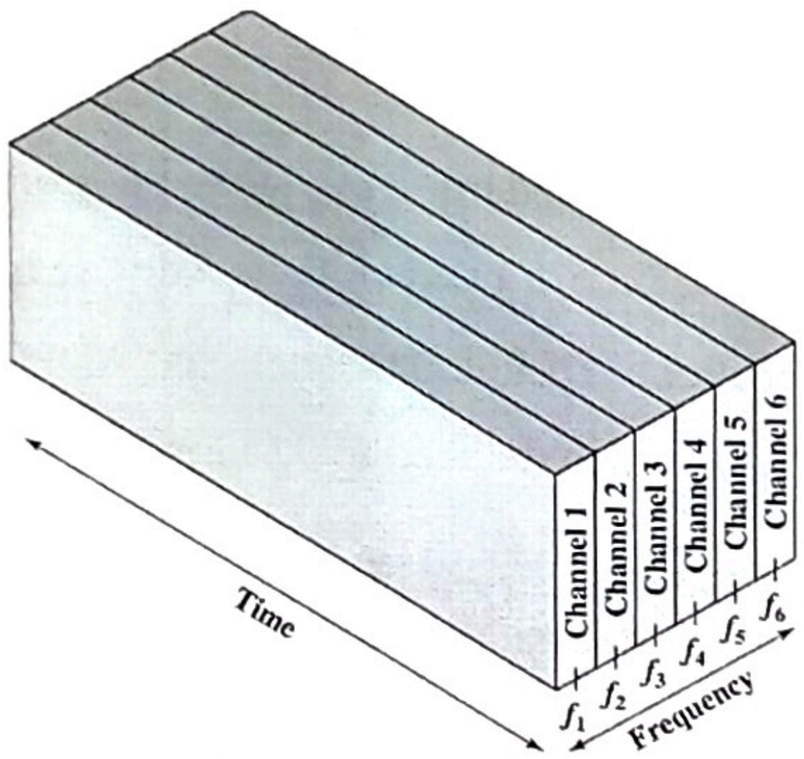
Figure depicts vocoding process. Before vocoding process, analog signal is converted into digital signal. This process compresses amount of bits required to represent analog voice via prediction.

Multiple Access Techniques

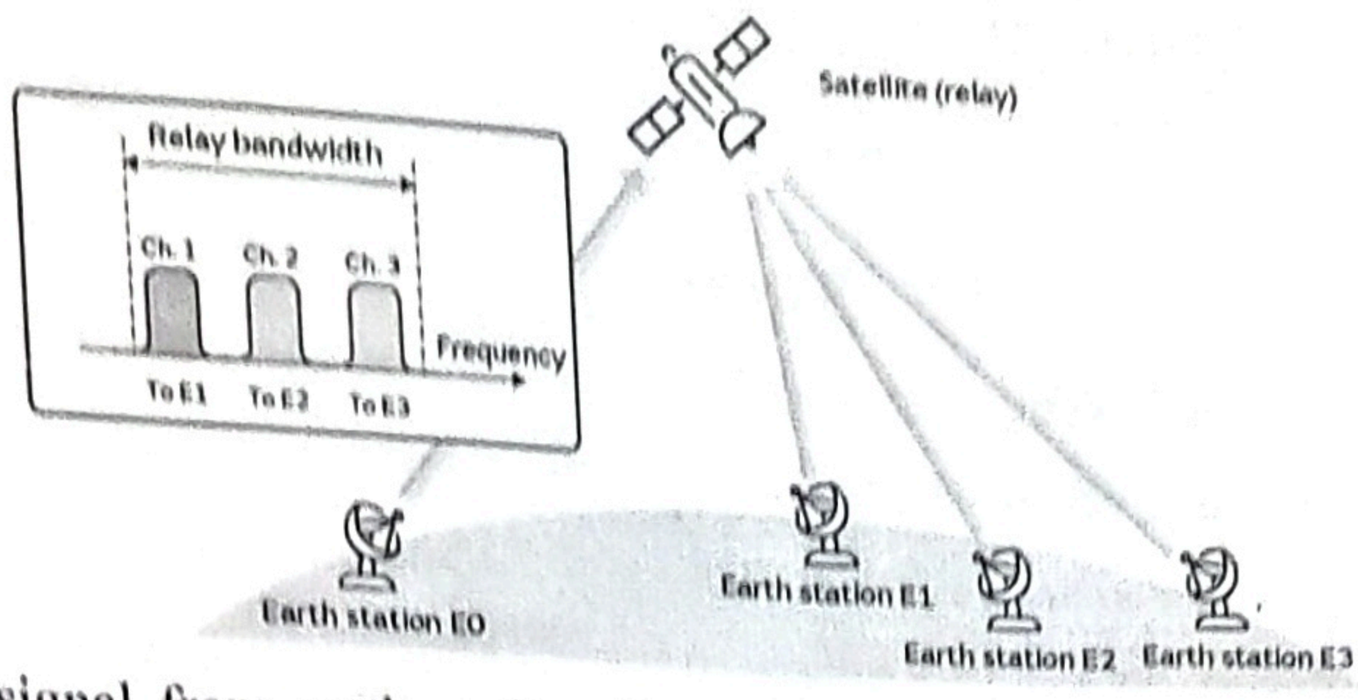
FDMA

FDMA divides up data streams from multiple users and assigns them to channels using different frequency bands, all of which share a single transmission path. Adoption of FDMA began in the 1980s, and it was used to carry cellphone and car phone calls under the analog 1st generation mobile communication system (1G).





(a) Frequency division multiplexing



The data signal from earth station E0, consisting of data streams targeted at earth stations E1 to E3, modulated and assigned to different frequencies arranged at equally spaced intervals within the bandwidth supported by the satellite relay, is sent in a manner that ensures that the adjacent signal frequency bands do not overlap (to prevent interference). When earth stations E1 to E3 receive these signals, they are divided up according to the frequency each station is able to receive, and the data streams are extracted.

Advantages

1. In terms of hardware resources, it is very simple and easy to use.
2. Because FDMA is efficient, it can manage a smaller user population.
3. The system's complexity is modest.
4. All stations may constantly run for 24 hours without waiting for their chance.
5. The reduced information bit rate can have a positive impact on capacity.
6. It reduces inter-symbol interference.

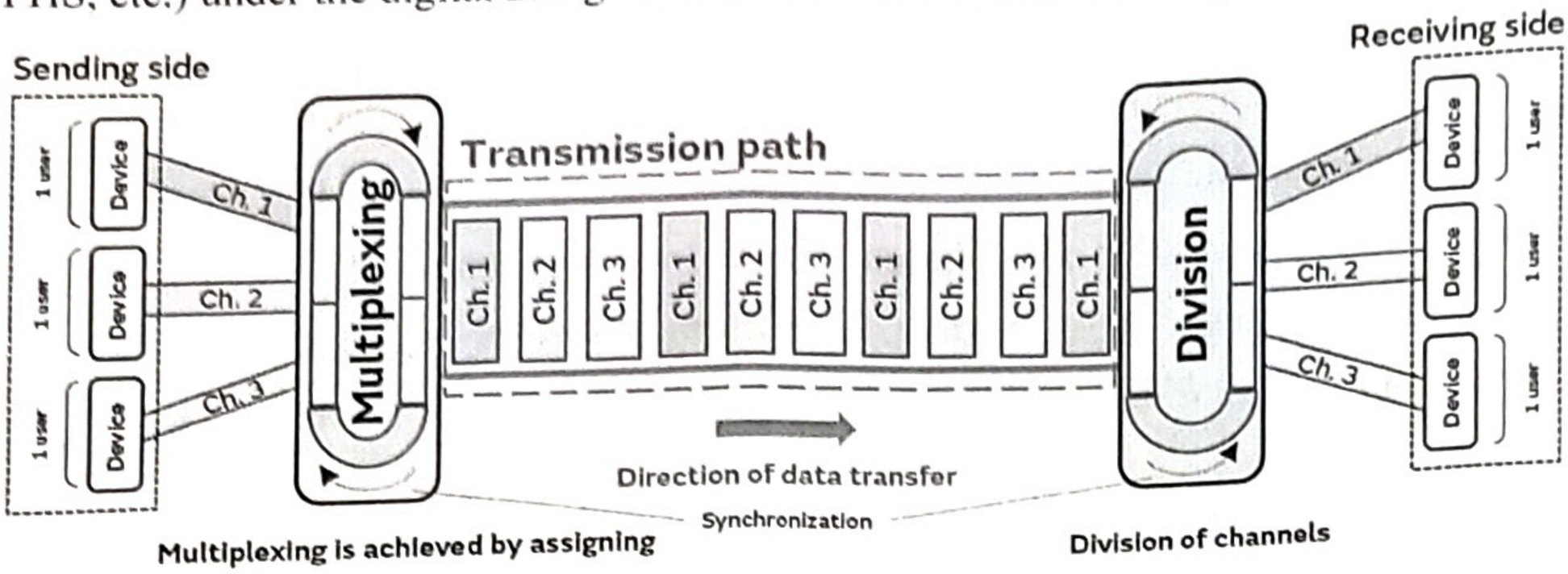
Disadvantages

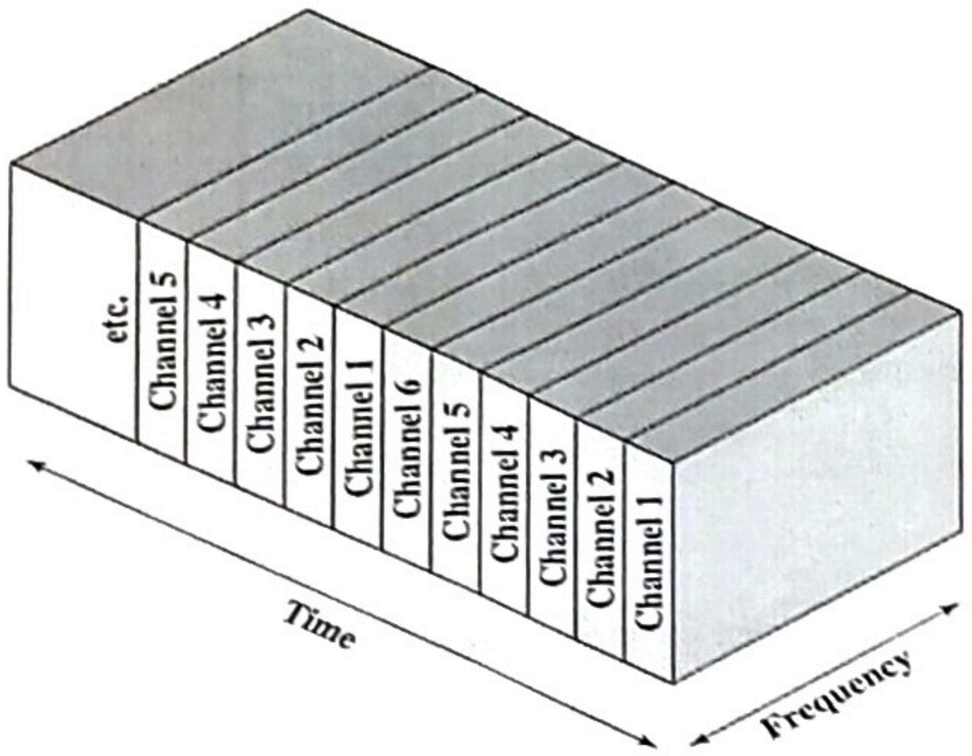
1. It only works with analogue signals.
2. There isn't much room for flexibility. Therefore, existing traffic patterns must be slowly changed.
3. The transponders require extensive bandwidth.
4. The traffic's carrying capacity is not very high.
5. RF (Radio Frequency) filters must fulfil stringent adjacent channel rejection specifications. It can enhance the system's cost.

6. The highest bit rate per channel is small and fixed.

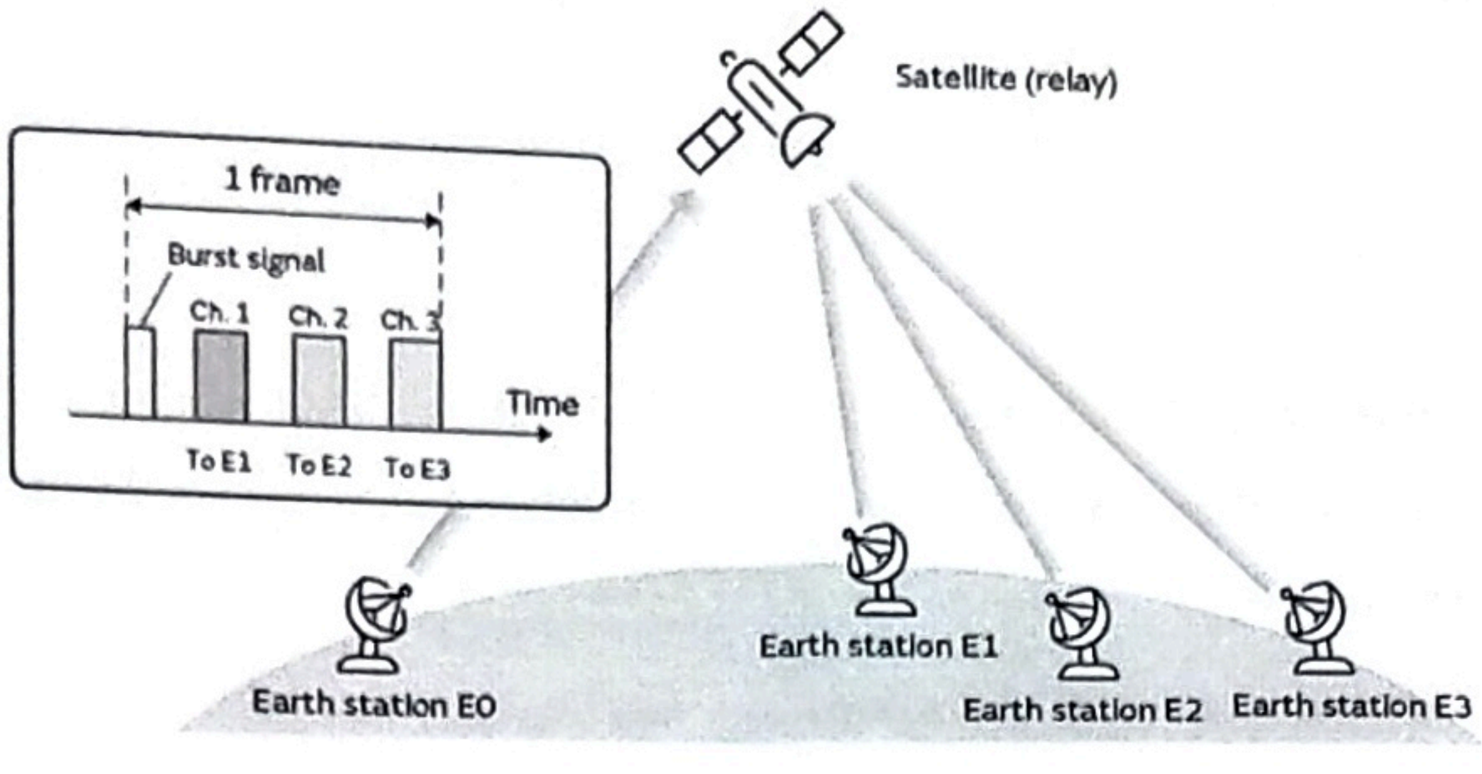
TDMA

TDMA divides up data streams from multiple users into uniform time intervals and assigns them to channels, all of which share a single transmission path. Adoption of TDMA began in the 1990s, and it was used to carry mobile phone calls (GSM, PDC, PHS, etc.) under the digital 2nd generation mobile communication system (2G).





(b) Time division multiplexing



The data signal is sent from earth station E0, delimited by time frames and consisting of "slots" used as channels, excluding the standard burst signal*6 embedded in each frame, and each channel is assigned one of the data streams targeted at earth stations E1 to E3. Then, at each earth station from E1 to E3 the signal is divided up in a manner synchronized with the transmission timing of earth station E0, and the data streams are extracted. Note that TDMA was adopted for satellite communication in addition to FDMA from around 1985. To ensure stability and prevent interference with communication, TDMA requires that the channel switching speed, etc., be synchronized between the sending side and receiving side. Earth station E0 inserts a signal called a burst at the beginning of each frame for synchronization control.

Advantages

1. As cell sizes reduce, TDMA delivers significant investment dollars in space, support, and base-station hardware.
2. It may transmit data at speeds ranging from 64 kbps to 120 Mbps.
3. It separates clients based on time guarantees that no interference from concurrent transmission will occur.
4. TDMA enables administrators to do administrations such as fax, voiceband information, SMS, and applications such as mixed media and video conferencing.
5. It extends the client's battery life by communicating alone for a part of the time during discussions.

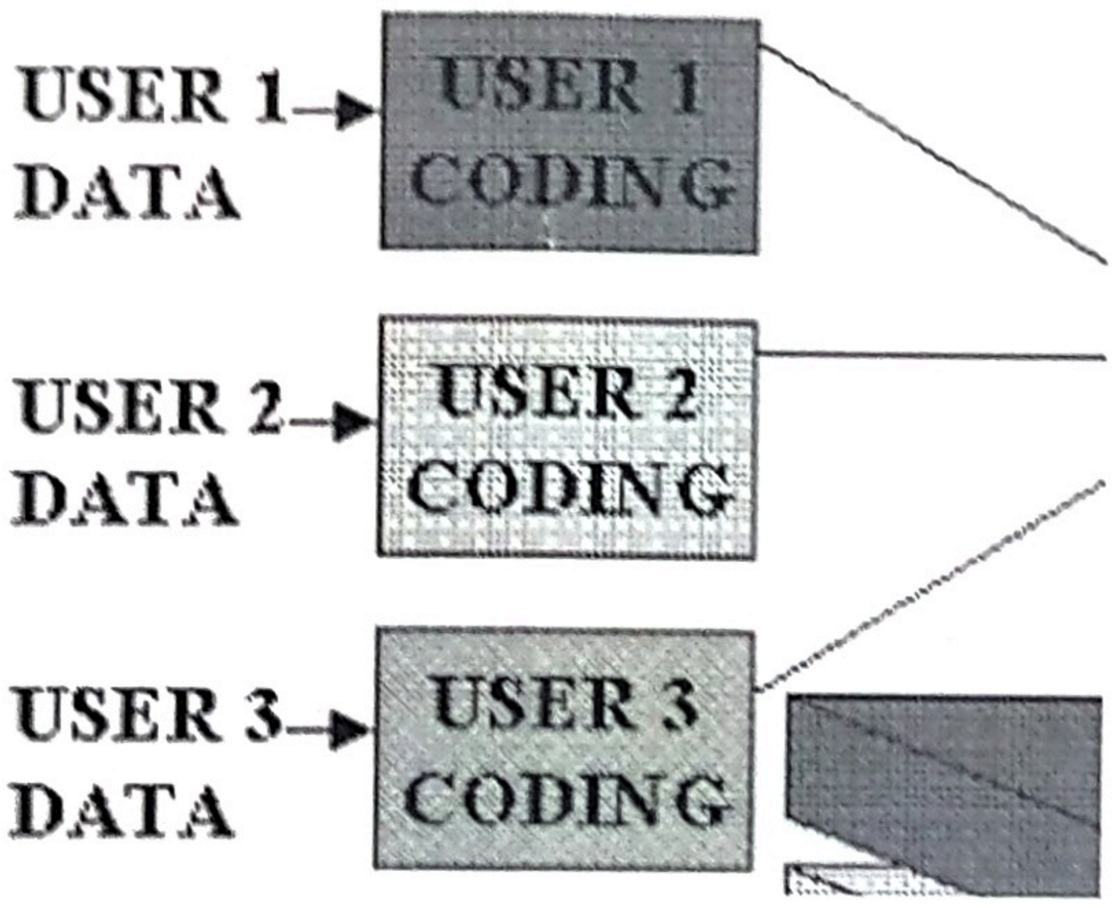
6. TDMA may surely adapt to information transmission and voice correspondence.

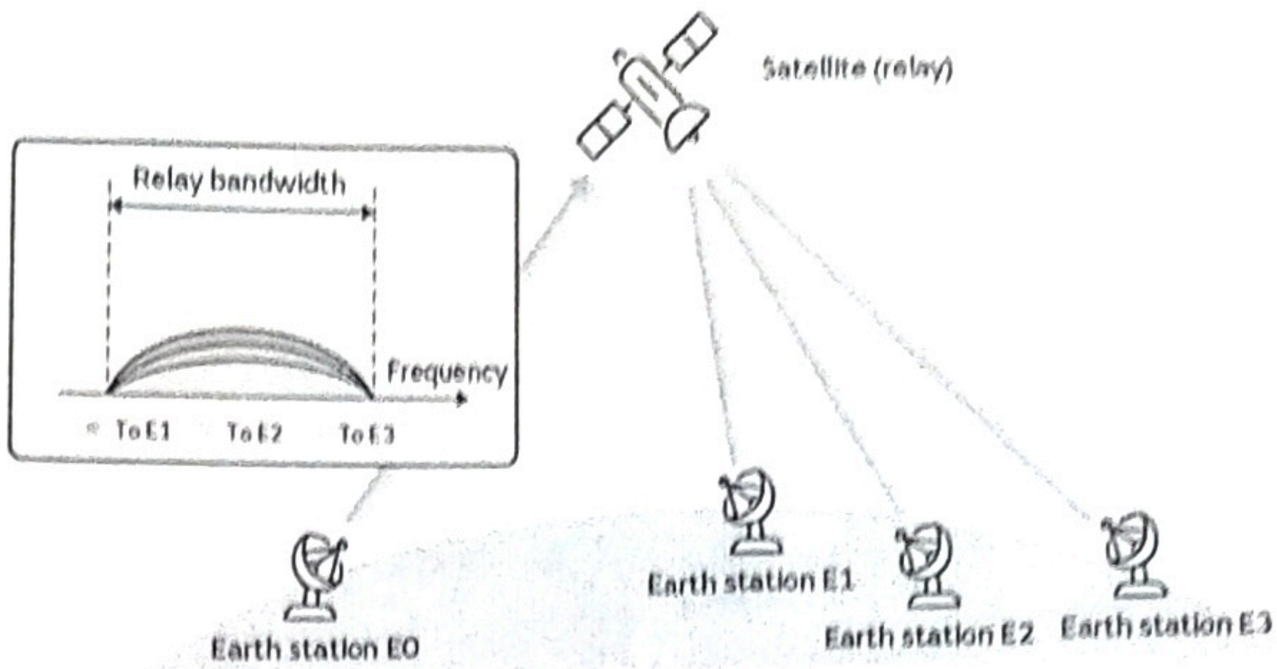
Disadvantages

1. The user won't be connected to a call if all of the time slots in the current cell and the cell they are entering are already taken because they have been allotted a specific slot.
2. In TDMA, frequency/slot allocation will be complicated.
3. In TDMA, high data rates needed equalization.
4. Network and spectrum planning is a complex and time-consuming process requiring great expertise and resources.
5. The focus is on organization and range arranging.

CDMA

CDMA generates signals in which the data streams of users are mixed with unique identifier codes, and the signals of all the users are overlaid within the same frequency band and conveyed via a single transmission path. CDMA is used to carry mobile phone calls under the 3rd generation mobile communication system (3G) introduced in the 2000s.





Earth station E0 mixes the identifier codes assigned to earth stations E1 to E3 on the receiving side with the data signals targeted at each earth station, generating signals with frequency bands wider than that of the original data signals, and adds them together to create a multiplexed signal that it sends to the satellite relay.

Earth stations E1 to E3 each receive the multiplexed signals from the satellite relay, mix in the earth station identifier codes to divide up the signals, and extract data only from the signal that matches their own identifier code.

Note that adoption of CDMA for satellite communication began in the 1990s.

Advantages

1. It has an extremely high spectral capacity to support many users in MHz of bandwidth.
2. There is no need for synchronization.
3. CDMA channels are difficult to decode, so they enhance cellular communication security.
4. It offers better secure transmission.
5. Dropouts occur only when the user is twice the distance from the base station.

Disadvantages

1. One of the main issues with the CDMA system is channel pollution, which occurs when a user's phone has two or more cell sites, but only one of them is powerful.

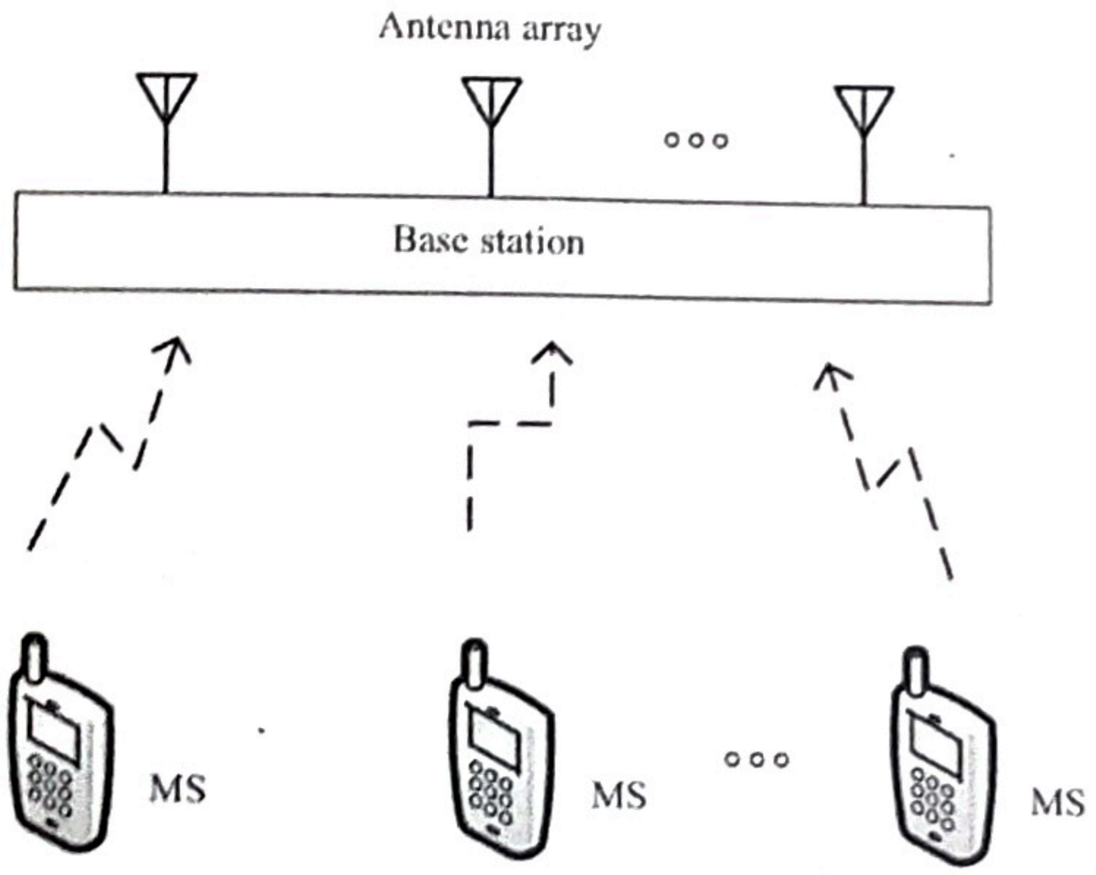
2. It is not a mature organization because the CDMA is still new compared to GSM.
3. CDMA needed time synchronization.
4. As the number of users rises, the CDMA system's performance decreases.
5. It has a high price because of the greater equipment.

SDMA

Spatial Division Multiple Access (SDMA) – SDMA uses multiple antennas at the transmitter and receiver to separate the signals of multiple users that are located in different spatial directions.

Space division multiple access or spatial division multiple access is a technique which is MIMO (multiple-input multiple-output) architecture and used mostly in wireless and satellite communication. It has the following features.

- All users can communicate at the same time using the same channel.
- SDMA is completely free from interference.
- A single satellite can communicate with more satellites receivers of the same frequency.
- The directional spot-beam antennas are used and hence the base station in SDMA, can track a moving user.
- Controls the radiated energy for each user in space.



Spectral efficiency

Spectral efficiency refers to the amount of data that can be transmitted over a specific bandwidth. It can be use to compare how efficiently two different systems utilize the same frequency.

Since frequency spectrum is limited, it has to be utilized efficiently. A given bandwidth is said to be used effectively if maximum information can be transmitted over it.