Unit 1:Transmission Fundamentals

- ***Cellphone Generations- 1G and 2G, 2.5G, 3G, 4G, and 5G***
- ***4G-Transmission Introduction and 4G-Transmission Fundamentals***
- ***Time domain concepts***
- ***Frequency domain concepts***
- ***Radio Media- Analog Vs Digital***
- ***Channel capacity***
- ***Transmission media***
- ***Signaling Schemes***

❖ *Cellphone Generations- 1G and 2G, 2.5G and 3G*

1 G

Deployed in Japan by Nippon Telephone and Telegraph Company (NTT) in Tokyo in 1979.

Most popular 1G system during the 1980s

- Advanced Mobile Phone System (AMPS)
- Nordic Mobile Phone System (NMTS)
- Total Access Communication System (TACS)
- European Total Access Communication System (ETACS)

Key features (technology) of the 1G system

- ❑ Frequency 800 MHz and 900 MHz
- ❑ Bandwidth: 10 MHz (666 duplex channels with a bandwidth of 30 KHz)
- ❑ Technology: Analogue switching
- ❑ Modulation: Frequency Modulation (FM)
- ❑ Mode of service: voice only
- ❑ Access technique: Frequency Division Multiple Access

Disadvantages of 1G system

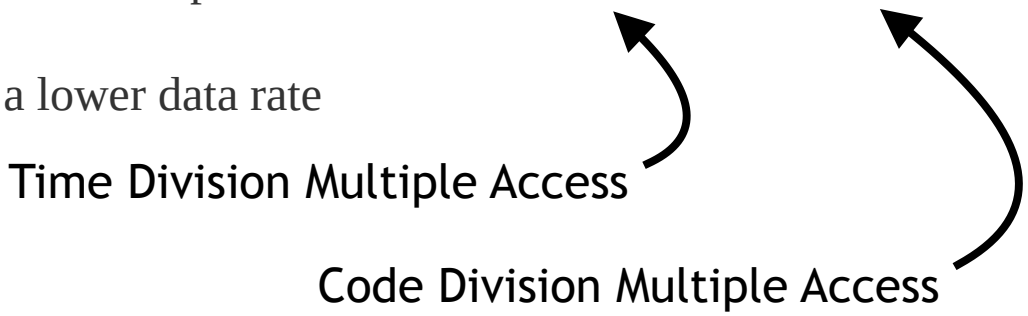
- ~2 to 4 Kbps data rate
- Poor voice quality due to interference
- Poor battery life
- Large-sized mobile phones (not convenient to carry)
- Less security (calls could be decoded using an FM demodulator)
- A limited number of users and cell coverage
- Roaming was not possible between similar systems

2G – Second generation communication system GSM

- Also known as Global System for Mobile Communication (GSM).
- GSM technology became the base standard for further development in wireless standards later.
- This standard was capable of supporting up to 14.4 to 64 kbps (maximum) data rate, which is sufficient for SMS and email services.
- Uses Circuit switching.

Key features of the 2G system

- The digital system (switching)
- SMS services are possible
- Roaming is possible
- Enhanced security
- Encrypted voice transmission
- While in 2G, data services are provided except for complex data(videos).
- While the channelization protocol in 2G is TDMA and CDMA.
- First internet at a lower data rate



Disadvantages of 2G Technology

- Less features on mobile devices
- Low data rate
- Limited mobility
- Limited number of users and hardware capability
- 2G technology had limited data transfer rates, which meant that it could not handle high-speed data transfer.
- 2G technology was vulnerable to interference and hacking.
- 2G technology was not compatible with many new applications and services.
- 2G only gets about 64 K bits per second on a good connection, which is barely enough to carry a voice conversation and is no good for Internet.

2.5G and 2.75G system

- In order to support higher data rates, General Packet Radio Service (GPRS) was introduced and successfully deployed.
- Web browsing, fast speed and multimedia transfer.
- Pocket Switching.
- GPRS was capable of data rates up to 171 kbps (maximum).
- EDGE – Enhanced Data GSM Evolution was also developed to improve the data rate for GSM networks.
- EDGE was capable of supporting up to 473.6kbps (maximum).

3G – Third-generation communication system

Third-generation mobile communication started with the introduction of UMTS – Universal Mobile Terrestrial / Telecommunication Systems.

UMTS has a data rate of 384kbps, and it supports video calling for the first time on mobile devices. After the introduction of the 3G mobile communication system, smartphones became popular across the globe. Specific applications were developed for smartphones that handle multimedia chat, email, video calling, games, social media, and healthcare.

Key features of the 3G system

- ❑ Higher data rate
- ❑ Video calling
- ❑ Enhanced security, more users, and coverage
- ❑ Mobile app support
- ❑ Multimedia message support
- ❑ Location tracking and maps
- ❑ Better web browsing
- ❑ TV streaming
- ❑ High-quality 3D games

3.5G to 3.75 Systems

In order to enhance the data rate in existing 3G networks, two technology improvements are introduced to the network. HSDPA – High-Speed Downlink Packet Access and HSUPA – High-Speed Uplink Packet Access, developed and deployed to the 3G networks. 3.5G network can support up to 2mbps data rate.

3.75 system is an improved version of the 3G network with HSPA+ High-Speed Packet Access Plus. Later this system will evolve into a more powerful 3.9G system known as LTE (Long Term Evolution).

Disadvantages of 3G systems

- Expensive spectrum licenses
- Costly infrastructure, equipment, and implementation
- Higher bandwidth requirements to support a higher data rate
- Costly mobile devices
- Compatibility with older generation 2G systems and frequency bands

4G – Fourth-generation communication system

- 4G systems are enhanced version of 3G networks developed by IEEE, offers higher data rate, and are capable of handling more advanced multimedia services. LTE and LTE advanced wireless technology used in 4th generation systems.
- Furthermore, it has compatibility with the previous versions; thus, easier deployment and upgrade of LTE and LTE advanced networks are possible.
- Simultaneous transmission of voice and data is possible with an LTE system, which significantly improves the data rate. All services, including voice services, can be transmitted over IP packets.
- Complex modulation schemes and carrier aggregation are used to multiply uplink/downlink capacity.
- Wireless transmission technologies like WiMax are introduced in 4G systems to enhance data rate and network performance.

Key features of the 4G system

- ❑ Much higher data rate up to 1Gbps
- ❑ Enhanced security and mobility
- ❑ Reduced latency for mission-critical applications
- ❑ High-definition video streaming and gaming
- ❑ Voice over LTE network VoLTE (use IP packets for voice)

Disadvantages of the 4G system

- Expensive hardware and infrastructure
- Costly spectrum (in most countries, frequency bands are too expensive)
- High-end mobile devices compatible with 4G technology are required, which is costly
- Wide deployment and upgrade are time-consuming

5G – Fifth-generation communication system

5G network is using advanced technologies to deliver ultra-fast internet and multimedia experience for customers. Existing LTE advanced networks will transform into supercharged 5G networks in the future.

In earlier deployments, 5G network will function in non-standalone mode and standalone mode. In non-standalone mode, both LTE spectrum and 5G-NR spectrum will be used together. Control signaling will be connected to the LTE core network in non-standalone mode.

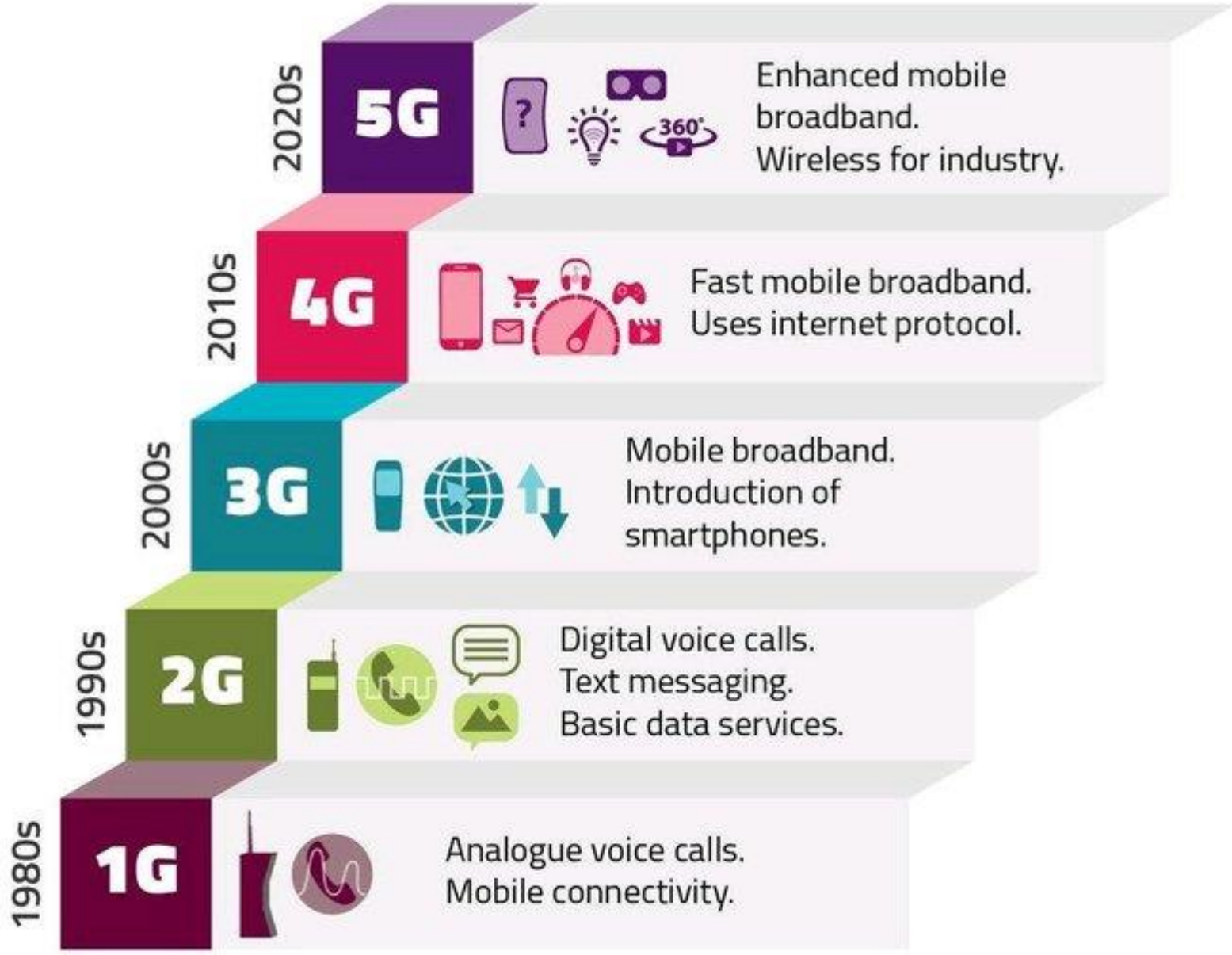
There will be a dedicated 5G core network higher bandwidth 5G – NR spectrum for standalone mode. The sub-6-GHz spectrum of FR1 ranges are used in the initial deployments of 5G networks.

In order to achieve a higher data rate, 5G technology will use millimeter waves and unlicensed spectrums for data transmission. A complex modulation technique has been developed to support massive data rates for the Internet of Things.

Cloud-based network architecture will extend the functionalities and analytical capabilities for industries, autonomous driving, healthcare and security applications.

Key features of 5G technology

- Ultra-fast mobile internet up to 10 Gbps
- Low latency in milliseconds (significant for mission-critical applications)
- Total cost deduction for data
- Higher security and reliable network
- Uses technologies like small cells and beamforming to improve efficiency
- Forward compatibility network offers further enhancements in future
- Cloud-based infrastructure offers power efficiency, easy maintenance, and upgrade of hardware


2020s
5G
Enhanced mobile broadband.
Wireless for industry.
2010s
4G
Fast mobile broadband.
Uses internet protocol.
2000s
3G
Mobile broadband.
Introduction of smartphones.
1990s
2G
Digital voice calls.
Text messaging.
Basic data services.
1980s
1G
Analogue voice calls.
Mobile connectivity.

❖ *4G-Transmission Introduction and 4G-Transmission Fundamentals*

It provides high data transmission speed and is suitable for HD video calling, fast download and upload, live streaming, online gaming, etc.

A 4G system must adhere to the capabilities and features specified by the **ITU(International Telecommunication Union) in IMT advanced**, including transmission technology and data speed.

4G network provides up to 100 Mbps speed to users, far higher than a 3G network.

Features of 4G Mobile Network

- It aims to provide high data transmission speed without interruption at any location.
- As per ITU standard, a 4G network system must have the highest data rates of 100Mbs for highly mobile stations like trains, cars etc.
- It provides seamless switching across heterogenous network areas.
- It is very well suitable for the transmission of voice, data, signals, multimedia, wireless internet, and other broadband services.
- It provides high speed at a low cost.
- Global mobility, service portability, scalable mobile networks.
- It provides a better way for scheduling and calling admission control techniques.

4G Network working

At a basic level, a 4G mobile connection transmits the signal via an antenna over radio frequencies, which allows mobile devices to connect to mobile networks.

The 4G capabilities for transmitting and receiving the signal are based on **Multiple Input and Multiple Output (MIMO)** and **Orthogonal Frequency Division Multiplexing (OFDM) technologies**. Due to these technologies, 4G offers high capacity and bandwidth comparison to 3G.

MIMO technology reduces network congestion as compared to 3G, and hence services can be served to more users without network congestion.

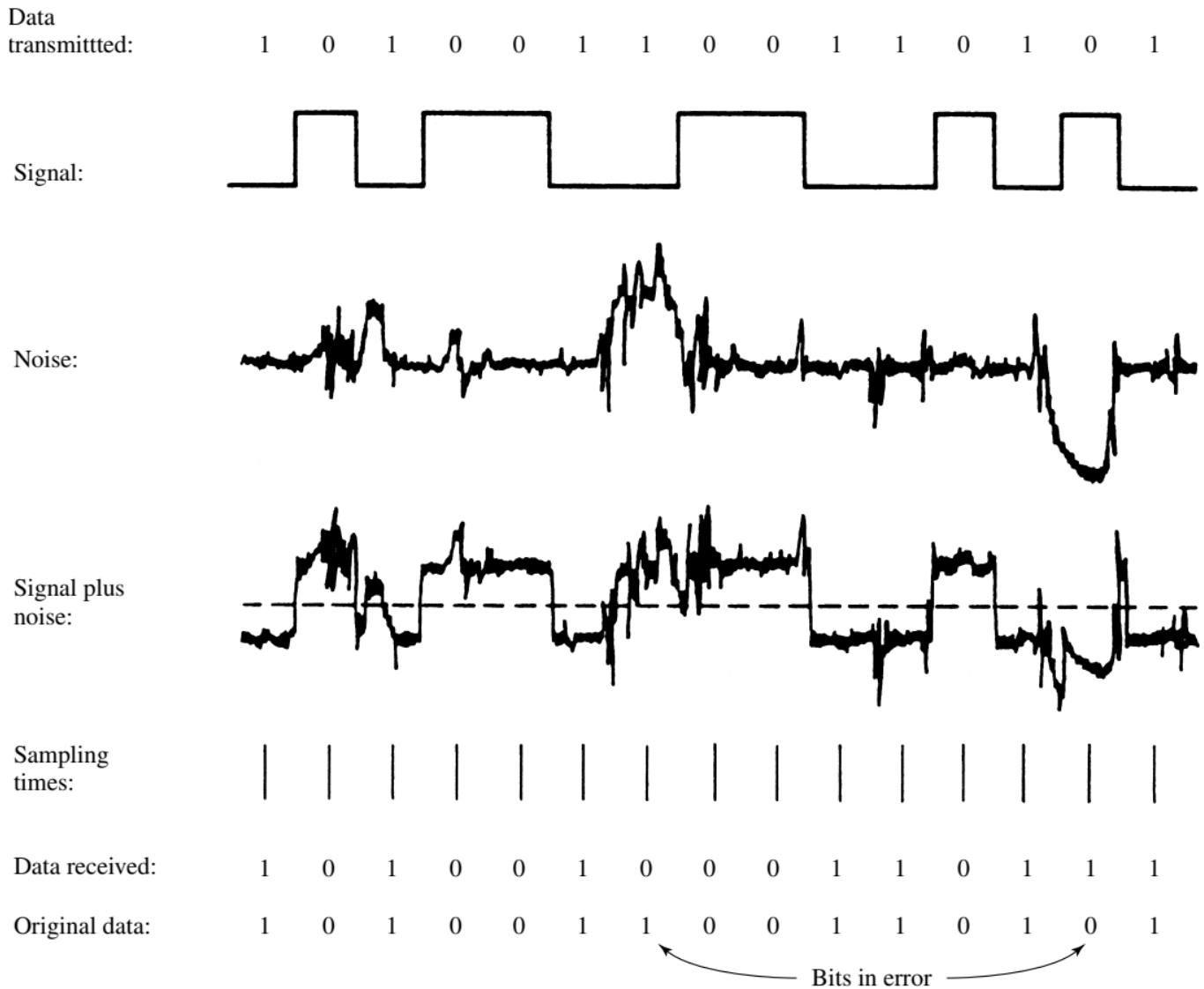
4G network supports all-IP standards for both voice and data transmission. 4G is more efficient for mobile network providers to operate and optimize than managing different network technologies for voice and data because of the all-IP network.

Analog and Digital Transmission

- **Analog transmission** is a means of transmitting analog signals without regard to their content; the signals may represent analog data (e.g., voice).
- In either case, the analog signal will suffer attenuation that limits the length of the transmission link.
- To achieve longer distances, the analog transmission system includes amplifiers that boost the energy in the signal. Unfortunately, the amplifier also boosts the noise components.
- With amplifiers cascaded to achieve long distance, the signal becomes more and more distorted.
- For analog data, such as voice, quite a bit of distortion can be tolerated and the data remain intelligible.

Digital transmission

- We have mentioned that a digital signal can be propagated only a limited distance before attenuation endangers the integrity of the data.
- To achieve greater distances, repeaters are used.
- A repeater receives the digital signal, recovers the pattern of ones and zeros, and re transmits a new signal. Thus, the attenuation is overcome.
- The same technique may be used with an analog signal if the signal carries digital data.
- At appropriately spaced points, the transmission system has retransmission devices rather than amplifiers.
- The retransmission device recovers the digital data from the analog signal and generates a new, clean analog signal. Thus, noise is not cumulative.


Data transmittted:
1 0 1 0 0 1 1 0 0 1 1 0 1 0 1
Signal:
Noise:
Signal plus noise:
Sampling times:
Data received:
1 0 1 0 0 1 0 0 0 1 1 0 1 1 1
Original data:
1 0 1 0 0 1 1 0 0 1 1 0 1 0 1
Bits in error

Noiseless Channel: Advantages:

1.Maximum data rate is high

2.Error-free transmission

3.Low latency

4.High signal quality

5.Suitable for critical applications

6.Easy to design and implement

7.Useful for benchmarking

❖ *Time domain concepts*

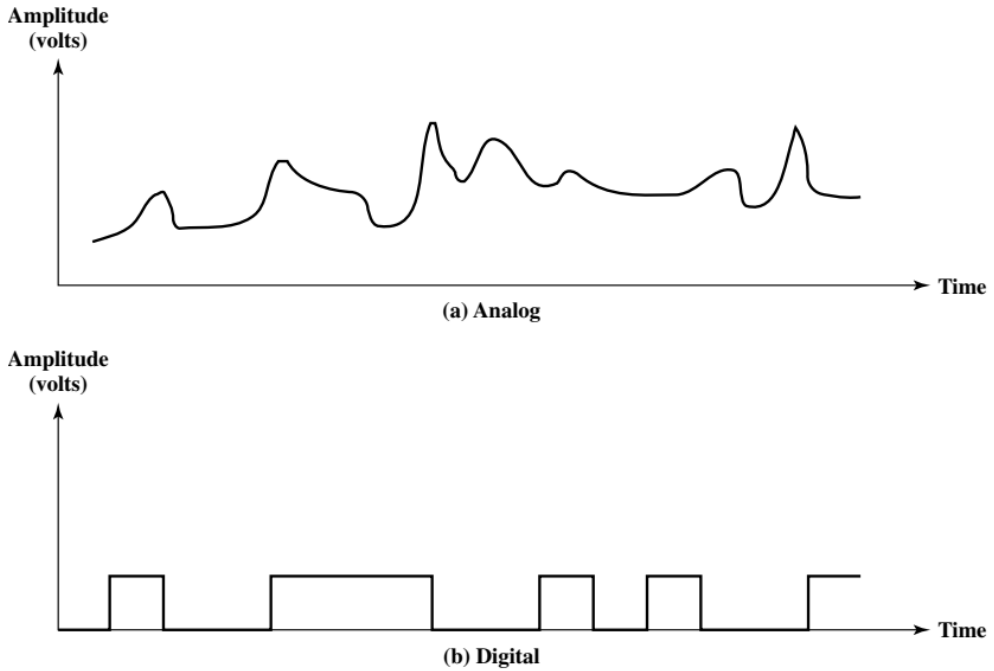


Figure 1 Analog and Digital Waveforms

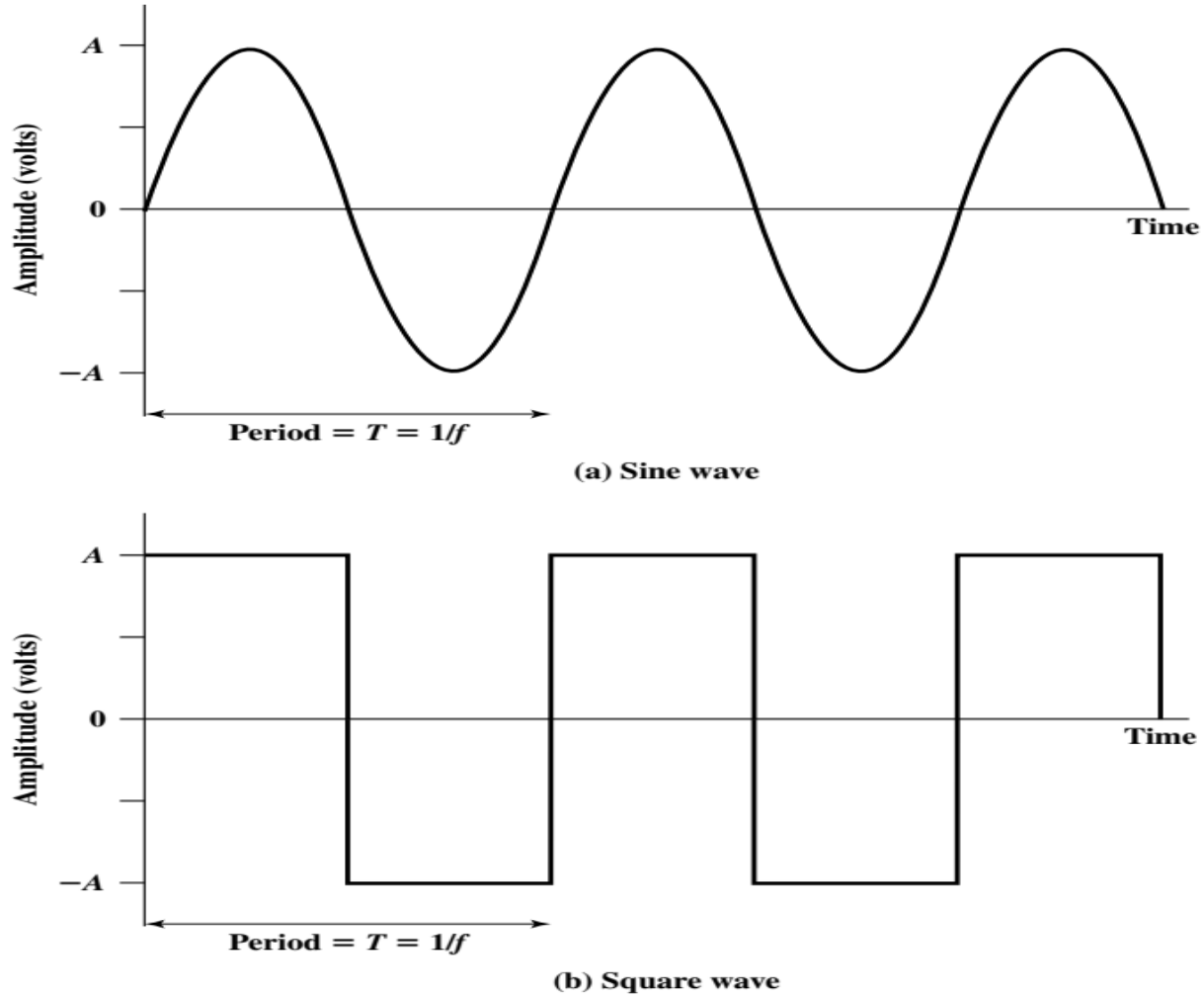


Figure 2 Examples of Periodic Signals

The simplest sort of signal is a **periodic signal**, in which the same signal pattern repeats over time. Figure 2 shows an example of a periodic analog signal (sine wave) and a periodic digital signal (square wave).

$$s(t + T) = s(t) \qquad -\infty < t < +\infty$$

The sine wave is the fundamental analog signal. A general sine wave can be represented by three parameters: peak amplitude (A), frequency (f), and phase (φ).

The **peak amplitude** is the maximum value or strength of the signal over time; typically, this value is measured in volts.

The **frequency** is the rate [in cycles per second, or Hertz (Hz)] at which the signal repeats. An equivalent parameter is the period (T) of a signal, which is the amount of time it takes for one repetition; therefore, T=1/f.

Phase is a measure of the relative position in time within a single period of a signal.

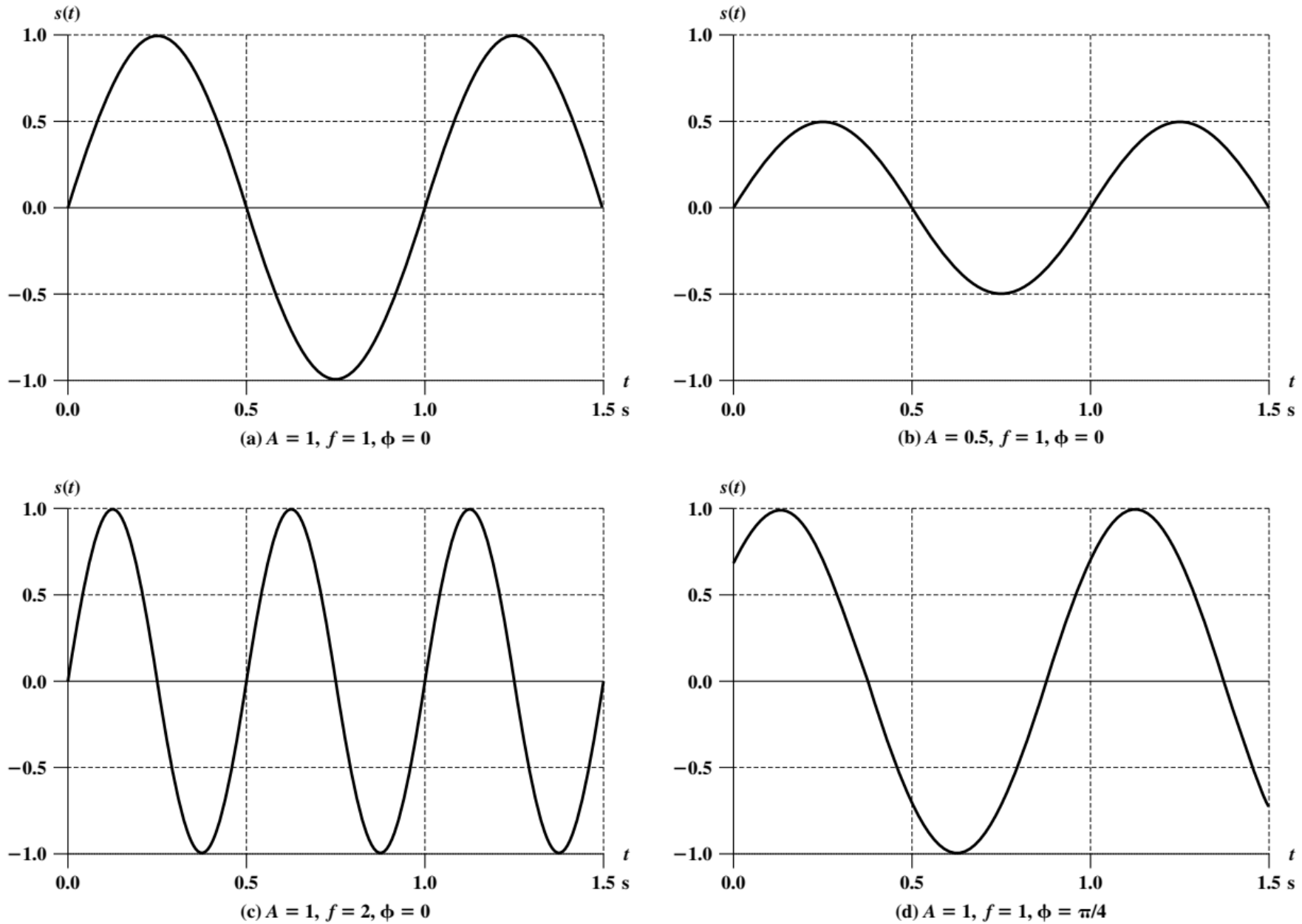
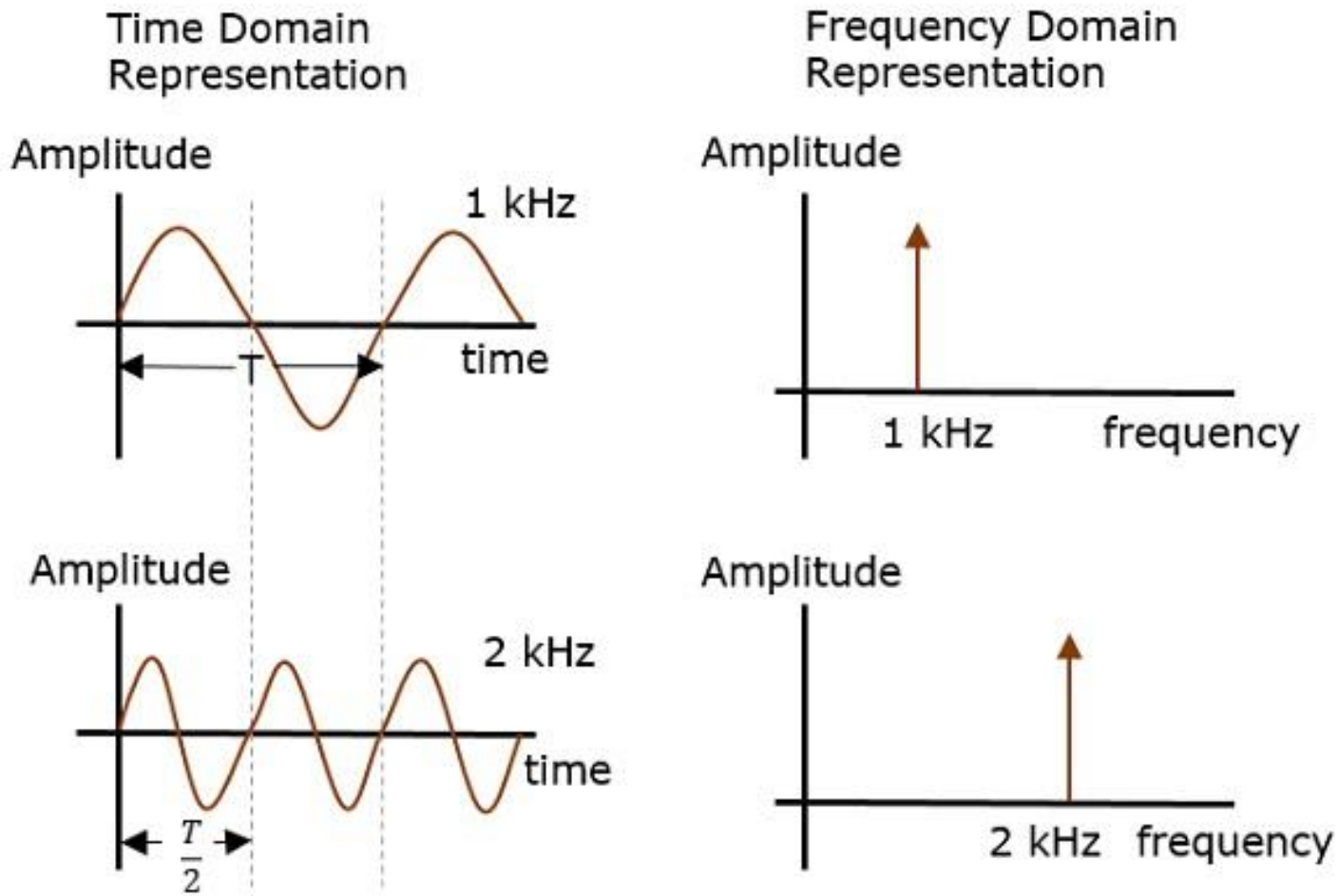


Figure 3 $s(t) = A \sin(2\pi ft + \phi)$

❖ *Frequency domain concepts*



❖ *Channel capacity*

The maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions is referred to as the **channel capacity**.

There are four concepts here that we are trying to relate to one another:

- **Data rate:** This is the rate, in bits per second (bps), at which data can be communicated.
- **Bandwidth:** This is the bandwidth of the transmitted signal as constrained by the transmitter and the nature of the transmission medium, expressed in cycles per second, or Hertz.
- **Noise:** For this discussion, we are concerned with the average level of noise over the communications path.
- **Error rate:** This is the rate at which errors occur, where an error is the reception of a 1 when a 0 was transmitted or the reception of a 0 when a 1 was transmitted.

$$C = B \log_2(1 + \mathrm{SNR})$$

Question 1 : A telephone line normally has a bandwidth of 3000 Hz assigned for data communication. The SNR is usually 31. What will be the capacity for this channel?

Question 2 : The SNR is often given in decibels. Assume that SNR(dB) is 36 and the channel bandwidth is 2 MHz. Calculate the theoretical channel capacity.

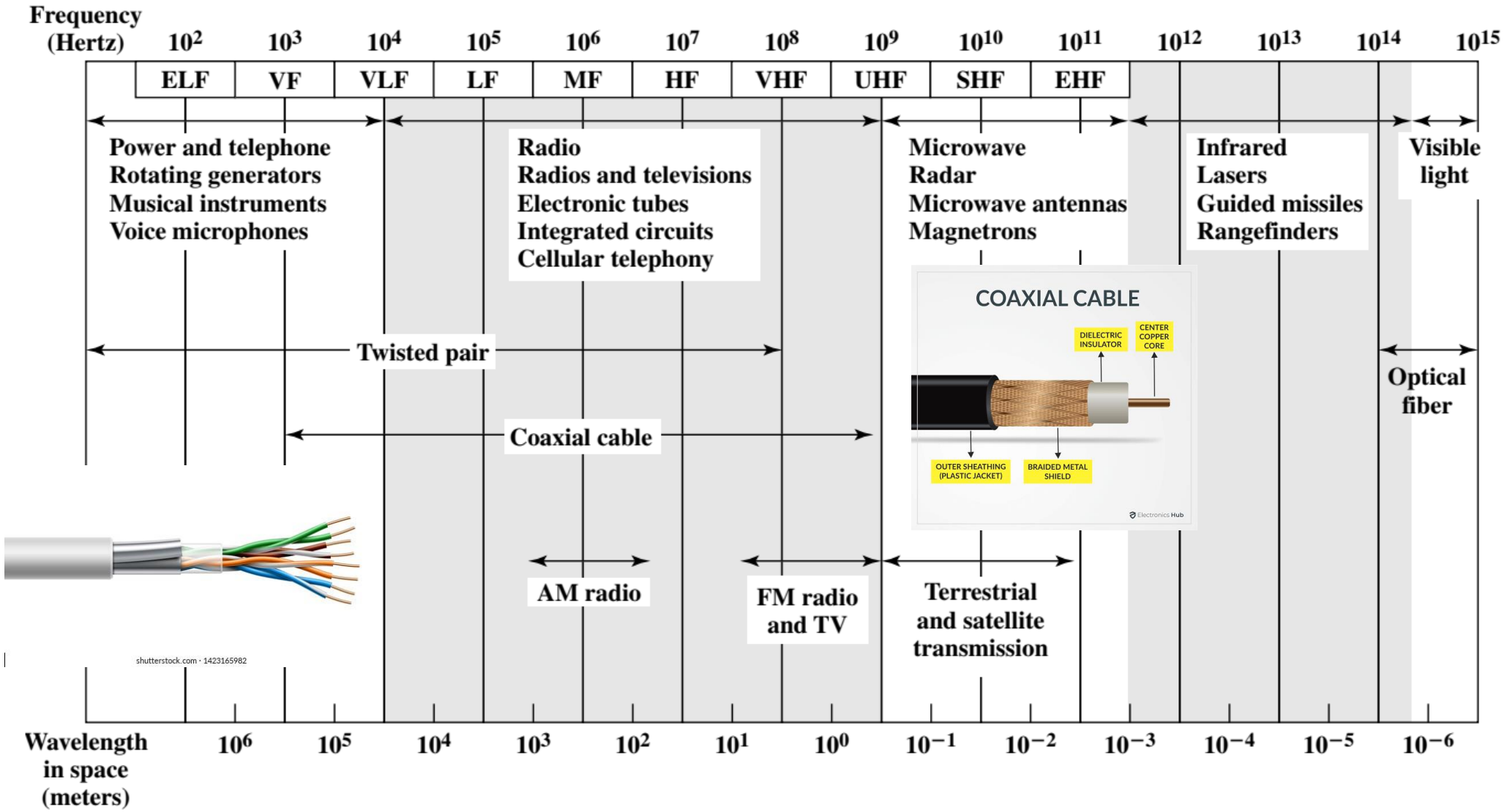
Question 3 : A telephone line normally has a frequency range 3 MHz to 5 MHz assigned for data communication. The SNR is usually 15. What will be the capacity for this channel?

Transmission Media

In a data transmission system, the **transmission medium** is the physical path or Virtual Path between transmitter and receiver.

Transmission media can be classified as guided or unguided.

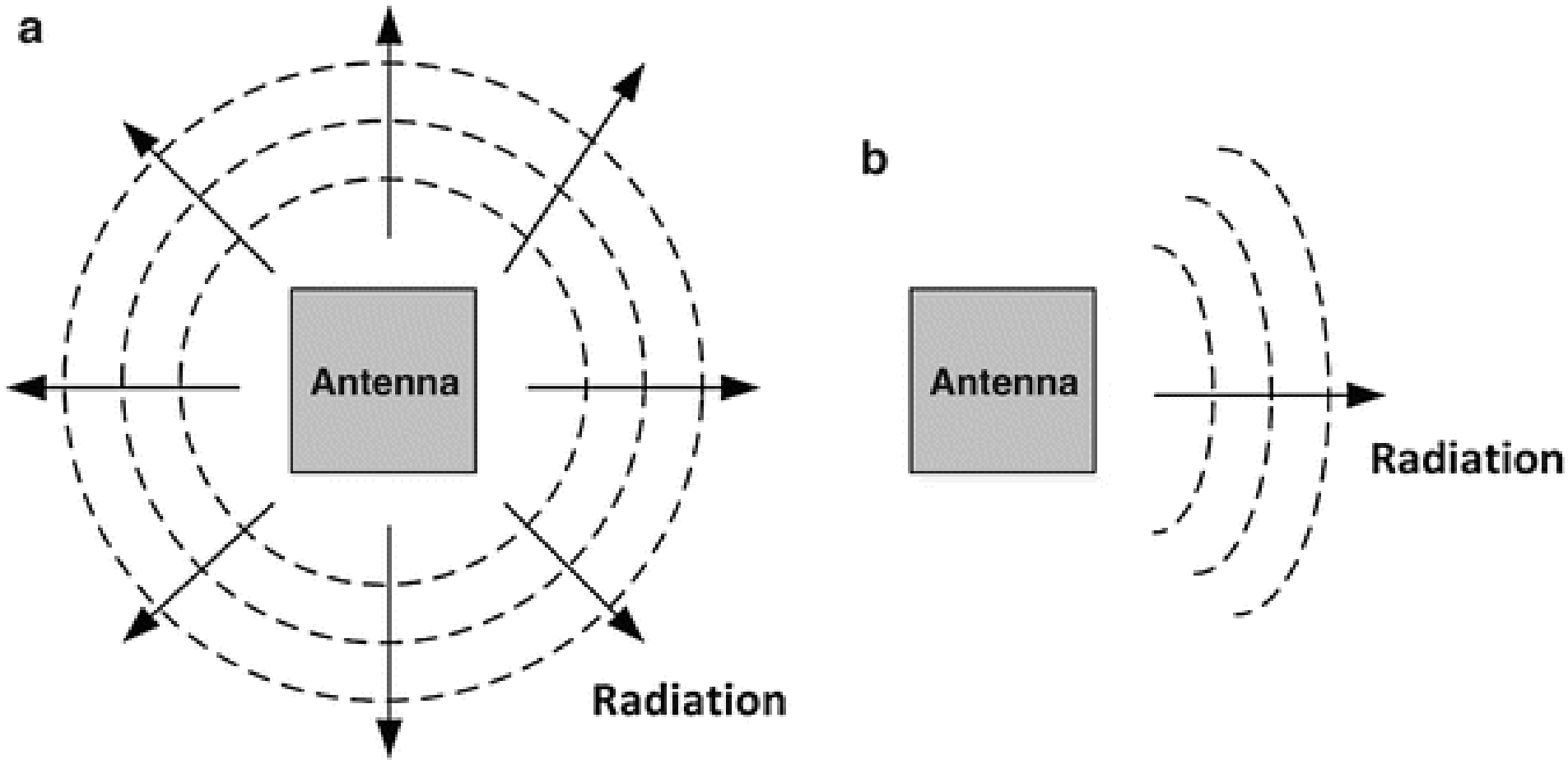
- With **guided media**, the waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, or optical fiber.
- The atmosphere and outer space are examples of **unguided media**, which provide a means of transmitting electromagnetic signals but do not guide them; this form of transmission is usually referred to as **wireless transmission**.



ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

There are basically two types of configurations for wireless transmission:

Omnidirectional and Directional.



Terrestrial Microwave

Physical Description

- The most common type of microwave antenna is the parabolic “dish.”
- The antenna is fixed rigidly and focuses a narrow beam to achieve line-of-sight transmission to the receiving antenna.
- Microwave antennas are usually located at substantial heights above ground level to extend the range between antennas and to be able to transmit over intervening obstacles.
- To achieve long-distance transmission, a series of microwave relay towers is used, and point-to-point microwave links are strung together over the desired distance.

Applications

A primary use for terrestrial microwave systems is in long-haul telecommunications service.

Microwave is commonly used for both voice and television transmission.

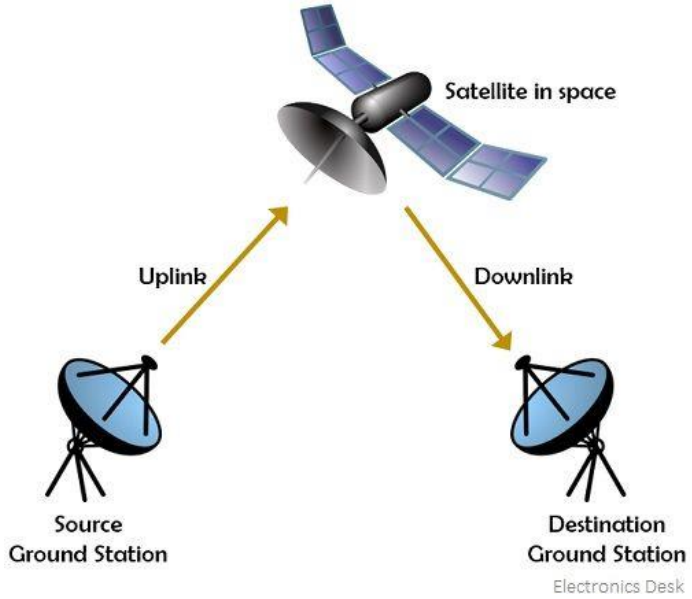
Satellite Microwave

Physical Description

A communication satellite is, in effect, a microwave relay station.

It is used to link two or more ground-based microwave transmitter/receivers, known as earth stations, or ground stations.

The satellite receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink).



Applications

- Television distribution
- Long-distance telephone transmission
- Private business networks

Broadcast Radio

Physical Description

The principal difference between broadcast radio and microwave is that the former is omnidirectional and the latter is directional.

Thus broadcast radio does not require dish-shaped antennas, and the antennas need not be rigidly mounted to a precise alignment.

Unit-2 - Network Concepts

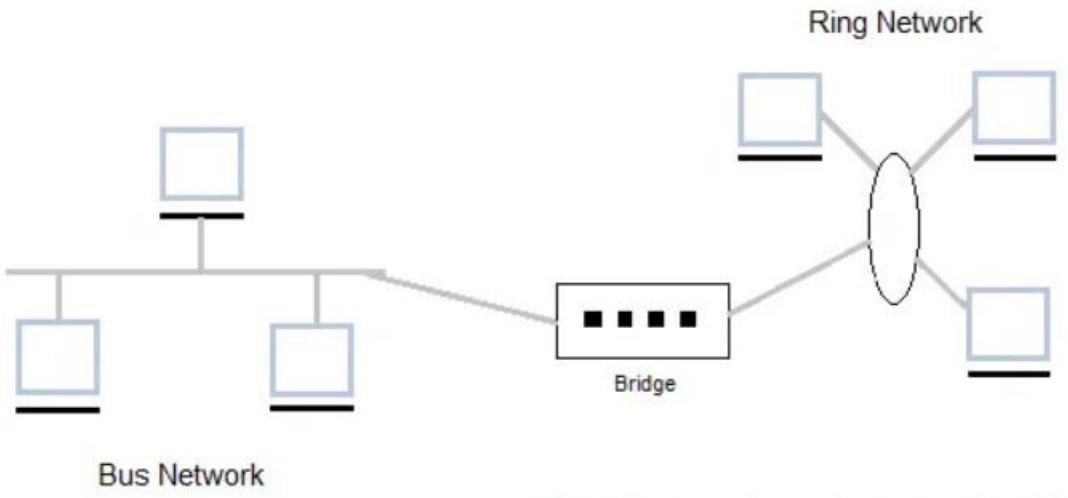
- ***Communication Networks, LANs, MANs, WANs***
- ***Circuit switching***
- ***Packet switching***
- ***ATM Cellular Networks Introduction***
- ***Cells, Duplexing, Multiplexing,***
- ***Voice coding,***
- ***Multiple Access Techniques: FDMA, TDMA, SDMA, CDMA***
- ***Spectral efficiency***

- ***Communication Networks, LANs, MANs, WANs***

- ***Local Area Network (LAN)***
- ***Metropolitan Area Network (MAN)***
- ***Wide Area Network (WAN)***

Local Area Network (LAN)

- Designed for small physical areas such as an office, group of buildings or a factory.
- LANs are used widely as it is easy to design and to troubleshoot.
- Personal computers and workstations are connected to each other through LANs.
- We can use different types of topologies through LAN, these are Star, Ring, Bus, Mesh etc.
- LAN networks are also widely used to share resources like printers, shared hard-drive etc.



Characteristics of LAN

- LAN's are private networks, not subject to tariffs or other regulatory controls.
- LAN's operate at relatively high speed when compared to the typical WAN.
- There are different types of Media Access Control methods in a LAN, the prominent ones are Ethernet, Token ring.
- It connects computers in a single building, block or campus, i.e. they work in a restricted geographical area.

Applications of LAN

- One of the computer in a network can become a server serving all the remaining computers called clients. Software can be stored on the server and it can be used by the remaining clients.
- Connecting Locally all the workstations in a building to let them communicate with each other locally without any internet access.
- Sharing common resources like printers etc. are some common applications of LAN.

Advantages of LAN

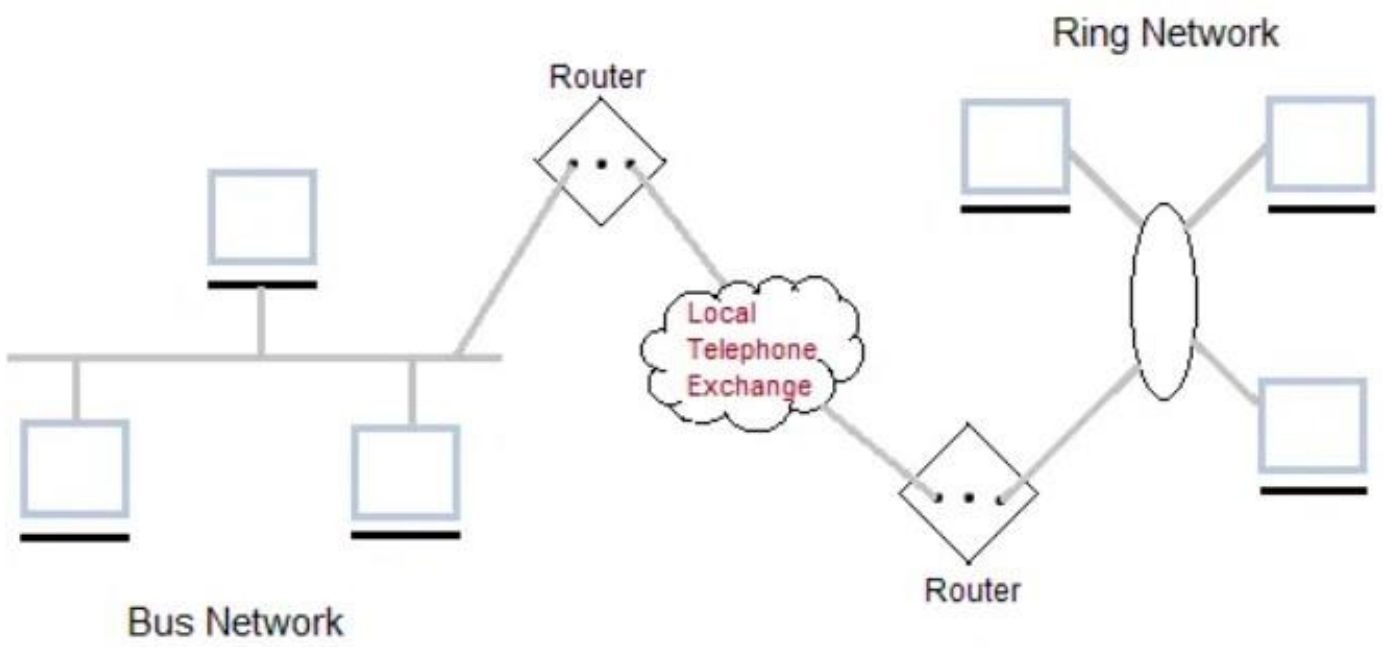
- Resource Sharing
- Software Applications Sharing
- Easy and Cheap Communication
- Centralized Data
- Data Security
- Internet Sharing

Disadvantages of LAN

- High Setup Cost
- Privacy Violations
- LAN Maintenance Job
- Covers Limited Area

Metropolitan Area Network (MAN)

- It was developed in 1980s.It is basically a bigger version of LAN.
- It is also called MAN and uses the similar technology as LAN.
- It is designed to extend over the entire city. It can be means to connecting a number of LANs into a larger network or it can be a single cable.



Characteristics of MAN

- It generally covers towns and cities (50 km)
- Communication medium used for MAN are optical fibers, cables etc.
- Data rates adequate for distributed computing applications.

Advantages of MAN

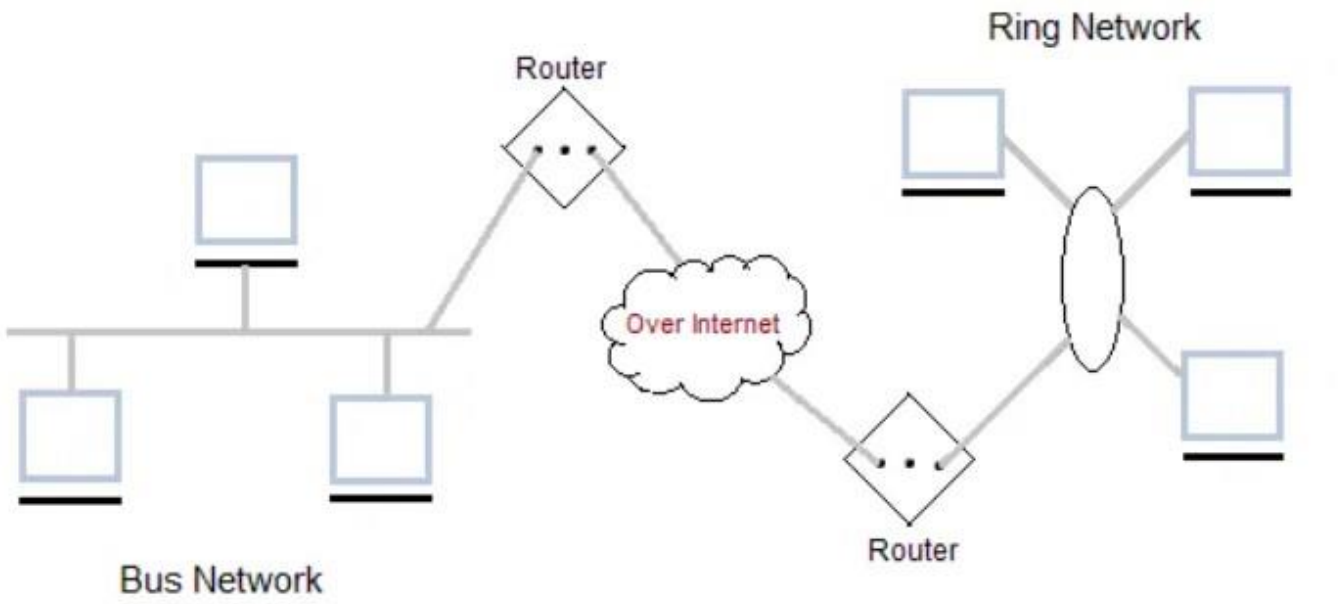
- Extremely efficient and provide fast communication via high-speed carriers, such as fiber optic cables.
- It provides a good back bone for large network and provides greater access to WANs.
- The dual bus used in MAN helps the transmission of data in both directions simultaneously.
- A MAN usually encompasses several blocks of a city or an entire city.

Disadvantages of MAN

- More cable required for a MAN connection from one place to another.
- It is difficult to make the system secure from hackers and industrial espionage(spying) graphical regions.

Wide Area Network (WAN)

- WAN can be private or it can be public leased network.
- It is used for the network that covers large distance such as cover states of a country.
- It is not easy to design and maintain.
- Communication medium used by WAN are PSTN or Satellite links.



Characteristics of WAN

- It generally covers large distances(states, countries, continents).
- Communication medium used are satellite, public telephone networks which are connected by routers.

Advantages of WAN

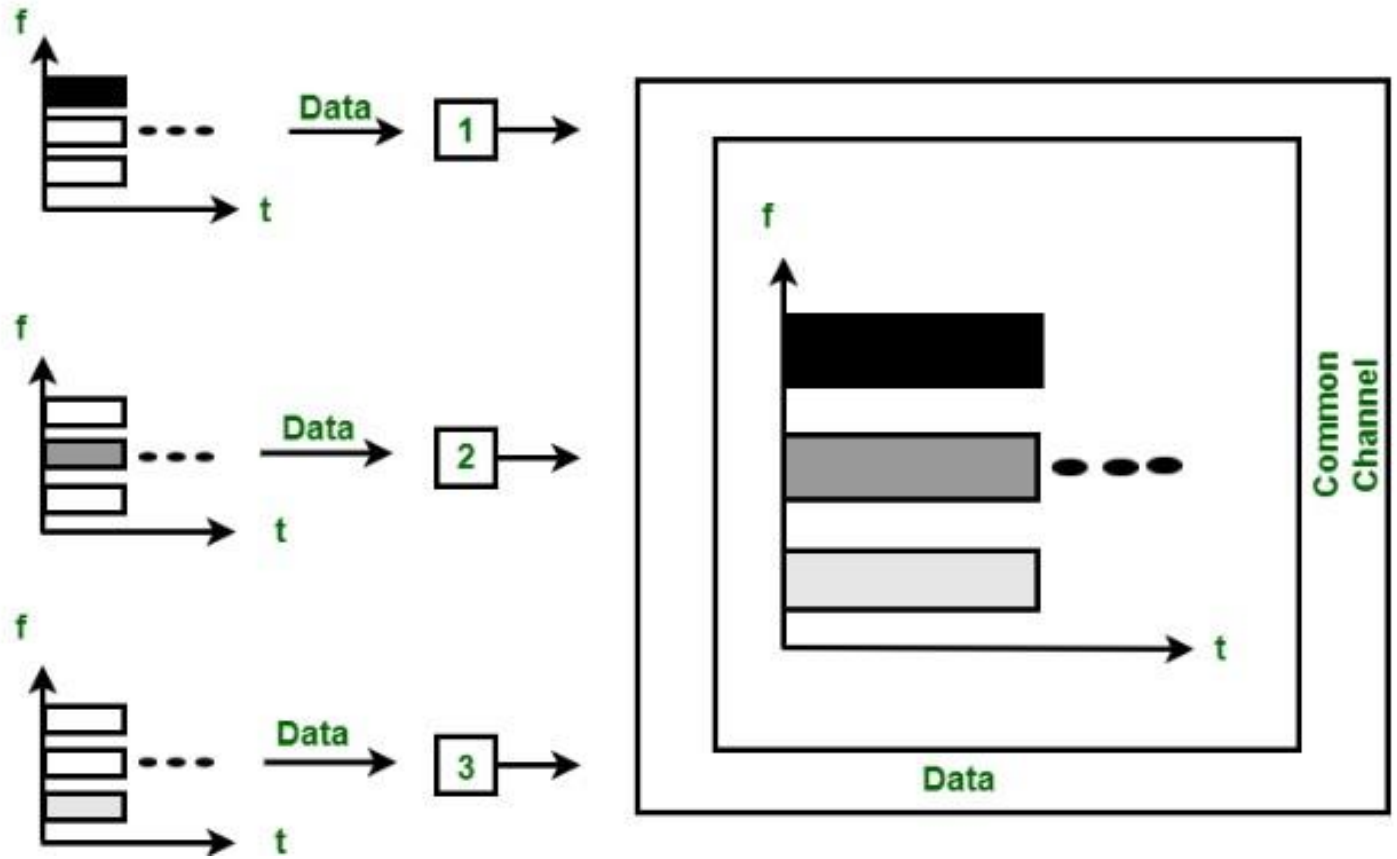
- Covers a large geographical area so long distance business can connect on the one network.
- Shares software and resources with connecting workstations.
- Messages can be sent very quickly to anyone else on the network. These messages can have picture, sounds or data included with them (called attachments).
- Expensive things(such as printers or phone lines to the internet) can be shared by all the computers on the network without having to buy a different peripheral for each computer.
- Everyone on the network can use the same data. This avoids problems where some users may have older information than others.

Disadvantages of WAN

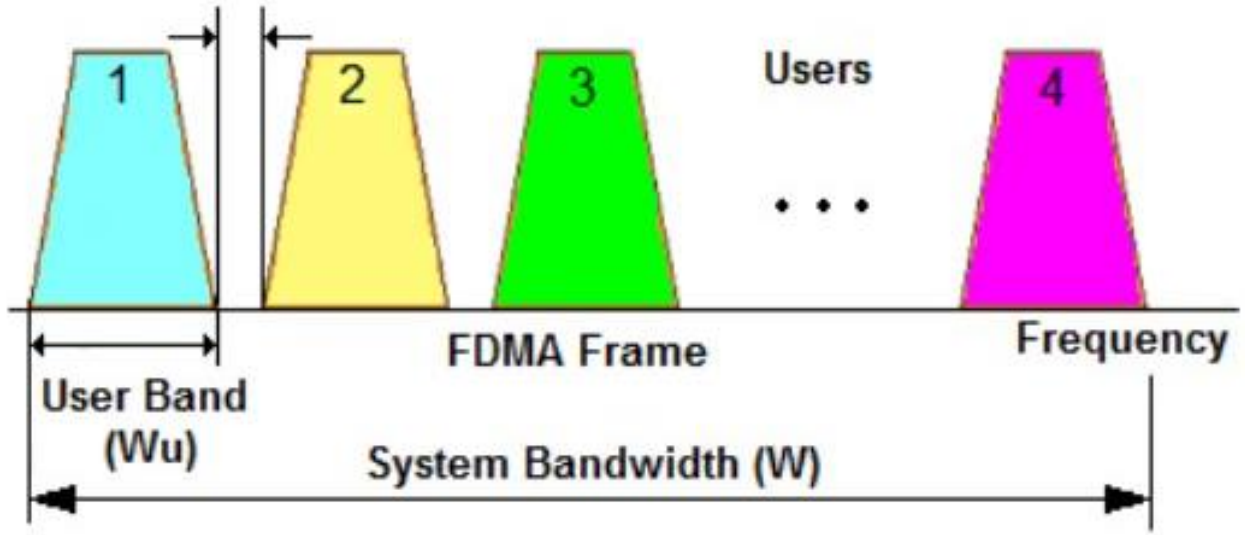
- Need a good firewall to restrict outsiders from entering and disrupting the network.
- Setting up a network can be an expensive, slow and complicated. The bigger the network the more expensive it is.
- Once set up, maintaining a network is a full-time job which requires network supervisors and technicians to be employed.
- Security is a real issue when many different people have the ability to use information from other computers. Protection against hackers and viruses adds more complexity and expense.

❖ *Multiple Access Techniques: FDMA, TDMA, SDMA, CDMA*

This bandwidth is divided into various frequency bands.
Each station is allocated a band to send data and that band is reserved for the particular station for all the time.



Guard band


1
2
3
Users
4
FDMA Frame
Frequency
User Band
(Wu)
System Bandwidth (W)

Advantages of FDMA

- FDMA uses simple hardware resources and is easy to set up.
- It efficiently handles smaller groups of users.
- The system isn’t overly complicated.
- All stations can transmit continuously without waiting their turn.
- It lowers the amount of data transmitted, which can increase capacity.
- It reduces interference between symbols, improving communication quality.

Disadvantages of FDMA

- FDMA works only with analog signals.
- It lacks flexibility, so existing traffic patterns must change gradually.
- Transponders need extensive bandwidth.
- It doesn’t support high traffic capacity.
- RF filters must meet strict adjacent channel rejection standards, which can increase costs.
- The maximum bit rate per channel is small and remains fixed.

1. TV signals have a band width of 6 MHz The number of TV channels that can be accommodated in a band width 12 GHz is-

2. TV signals have a band width of 5 MHz The number of TV channels that can be accommodated in a band width 600 MHz is-
   (Guard band for the TV signals is 1 MHz)

In a FDM system, 10 channels are multiplexed: Each channel having a BW of 50 kHz. If the guard band between the channels are 1 kHz, the minimum bandwidth required for transmission is

Multiple Access Technique - TDMA

- TDMA’s full structure is Time Division Multiple Access utilizes time rather than recurrence.
- It is utilized to encourage channel sharing without impedance. The diverse client has a similar time allotment of the total time accessible.
- Every client to assign a time allotment in which the client can get to the divert and in each opening, just a single client is permitted to send or get.

- **Advantages of Time Division Multiple Access :**
- It can convey 64 kbps to 120 Mbps of information rates.
- Versatile helped handoff conceivable.
- Efficient use of bandwidth.
- Reduced interference.
- Adaptable piece rate.
- Cost-effective.
- Increased Scalability.
- No recurrence watch band required.
- No need of an exact narrowband channel.
- Double band 800/1900 MHz.

Disadvantages of Time Division Multiple Access :

- Long wait an turn on time.
- Time slot wasting.
- Bandwidth wasting.
- Real time application.
- Synchronization issues.
- Organization and range arranging is concentrated..
- Adjustment was vital for high information rates.

If link transmits 2000 frames per second, and each slot has 16 bits, then the transmission rate of circuit of TDM is-

Multiple Access Technique - CDMA

- CDMA is a form of multiplexing which allows many signals to occupy a transmission channel and optimizing the use of available bandwidth.
- Therefore, the receiver separates the signals from the users by cross correlation of the received signal with each of the user unique code sequences.
- If the code sequence is designed to have a small cross correlation, it can minimize the crosstalk inherent.

Multiple Access Technique - CDMA

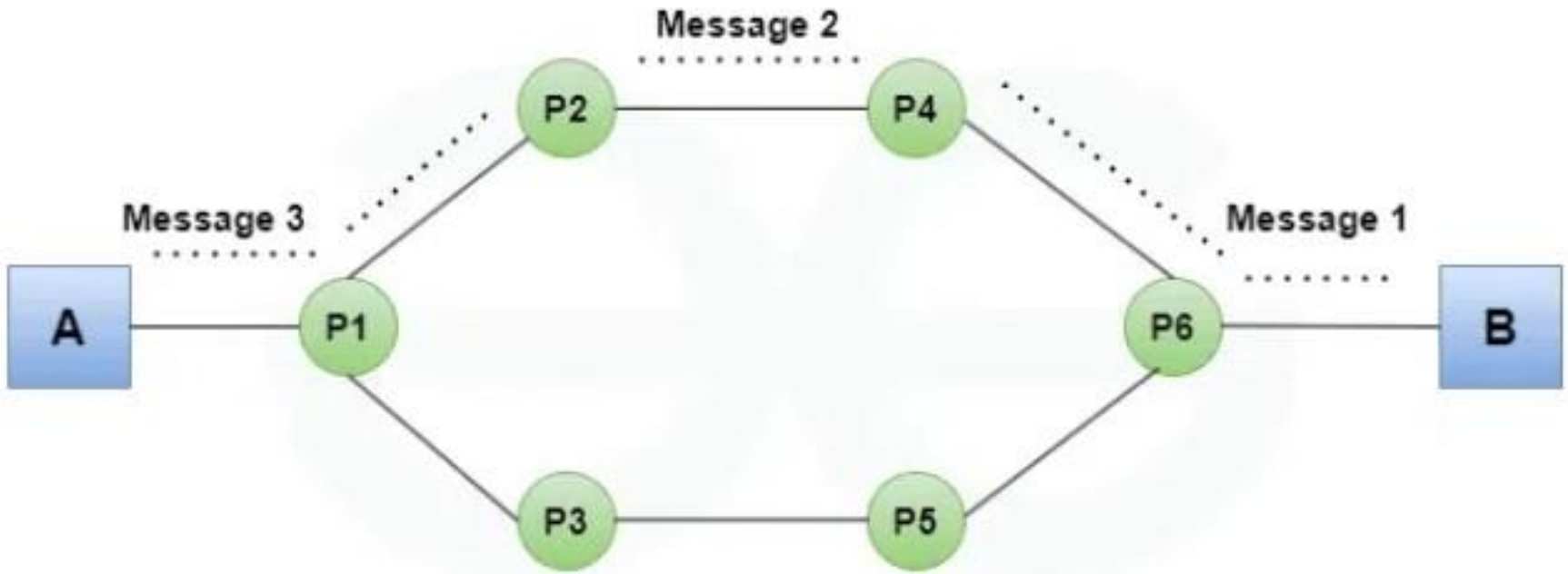
Advantages :

1. Efficient utilization of specific frequency spectrum.
2. Flexible distribution of resources.
3. Large signal bandwidth reduces the multipath fading.
4. Addition of users is easy and no limit for the number of users.
5. Highly secured from hackers.
6. Better signal quality.
7. No sense of handoff when changing cells.

Disadvantages :

1. The overall quality of service decreases when the number of users increases.
2. Self-jamming.
3. Near far problem occurs.

Circuit Switching



Phases of Circuit Switching

•**Circuit Establishment:** A dedicated circuit between the source and destination is constructed via a number of intermediary switching center’s. Communication signals can be requested and received when the sender and receiver communicate signals over the circuit.

•**Data Transfer:** Data can be transferred between the source and destination once the circuit has been established. The link between the two parties remains as long as they communicate.

•**Circuit Disconnection:** Disconnection in the circuit occurs when one of the users initiates the disconnect. When the disconnection occurs, all intermediary linkages between the sender and receiver are terminated.