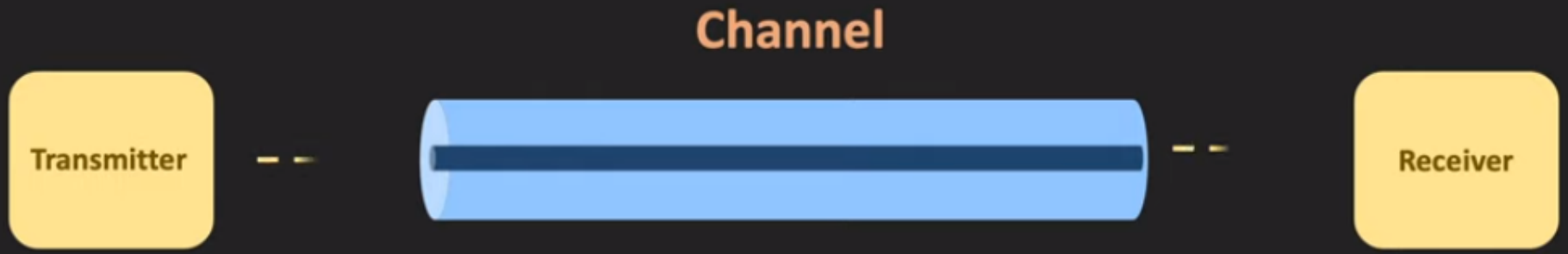
Wireless Network and Mobile Computing

(CSE602)

- Nowadays, the exchange of information is an inseparable part of society.
- With the great advances in communication technologies, communication has become more affordable and faster.
- A technology that is widely used in telephony, data communications, and audio/video broadcasting is multiplexing which can combine multiple communication signals for them to traverse an otherwise single signal communication medium simultaneously.

What is Multiplexing ?



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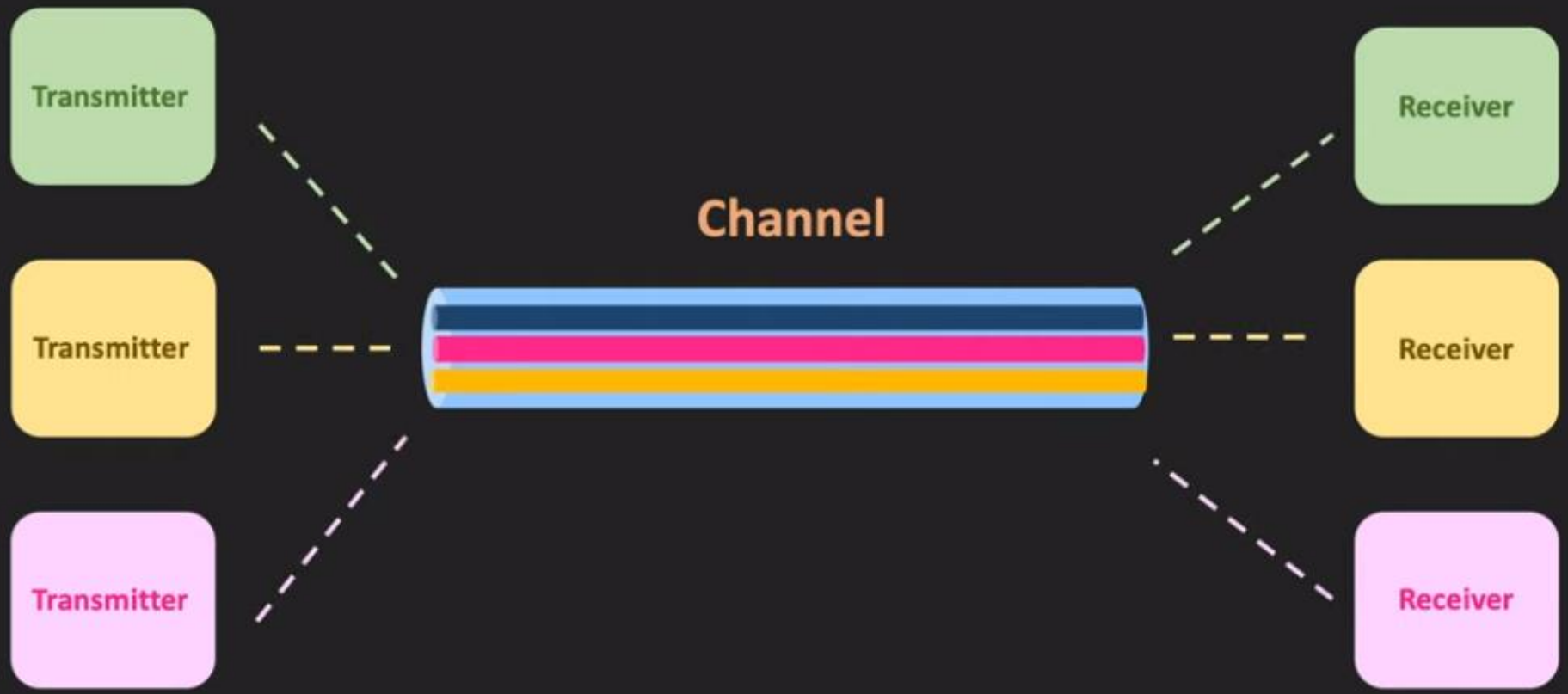

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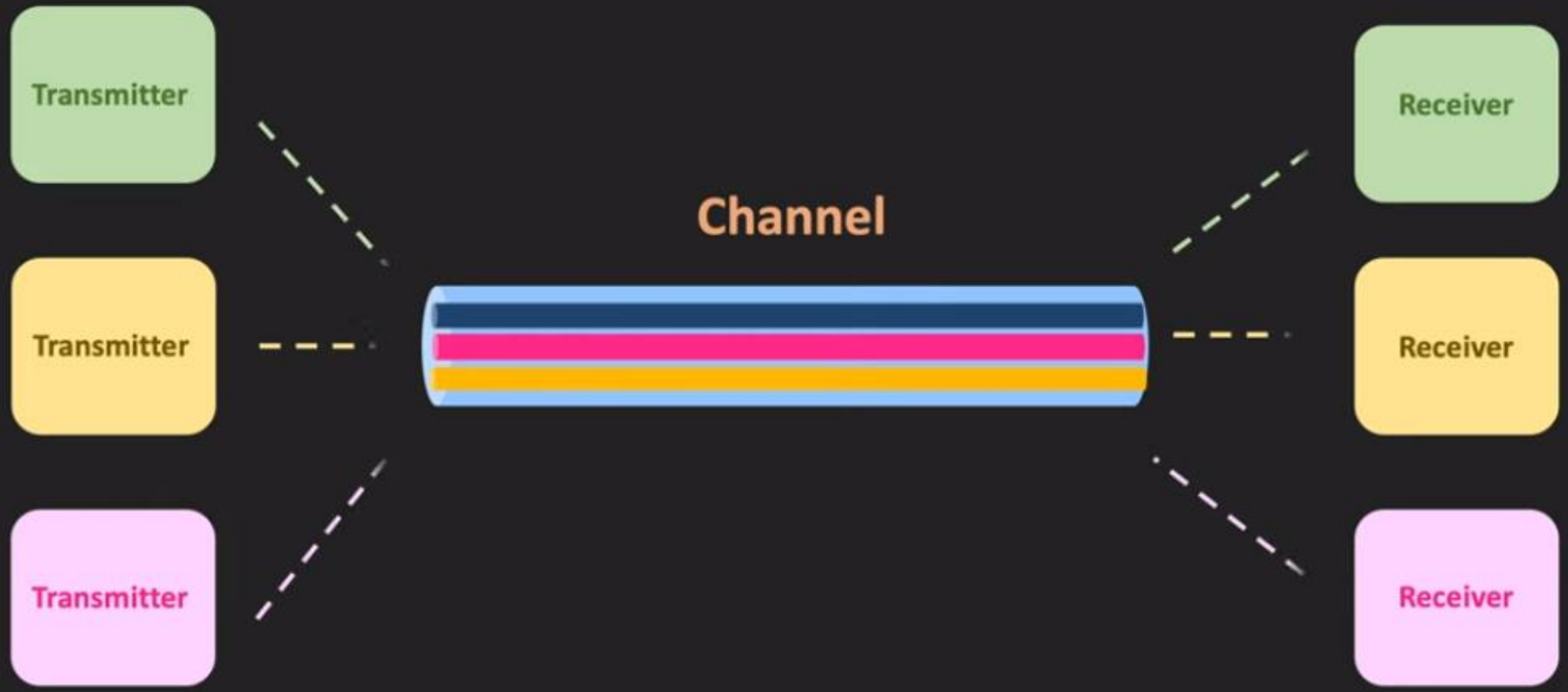
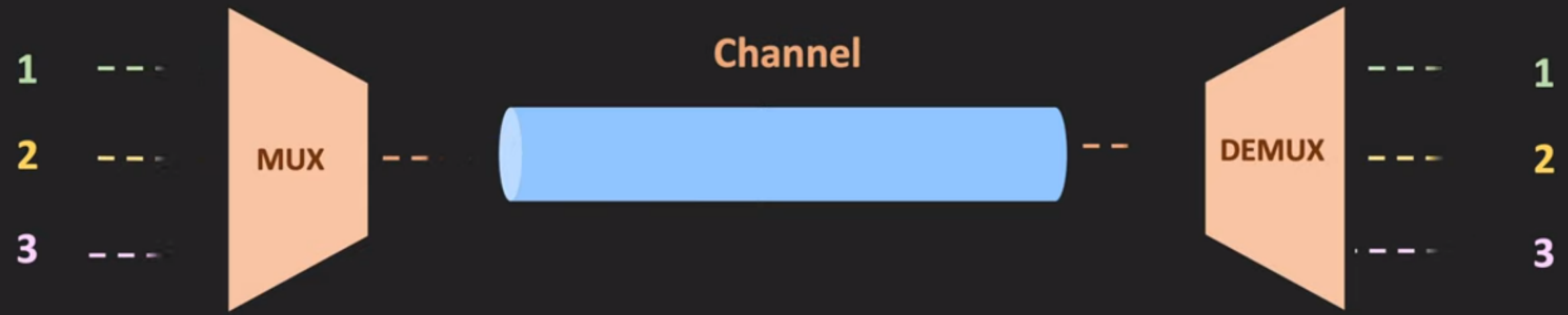


Multiplexing is a technique that allows the simultaneous transmission of multiple signals through a single channel or link

What is Multiplexing ?

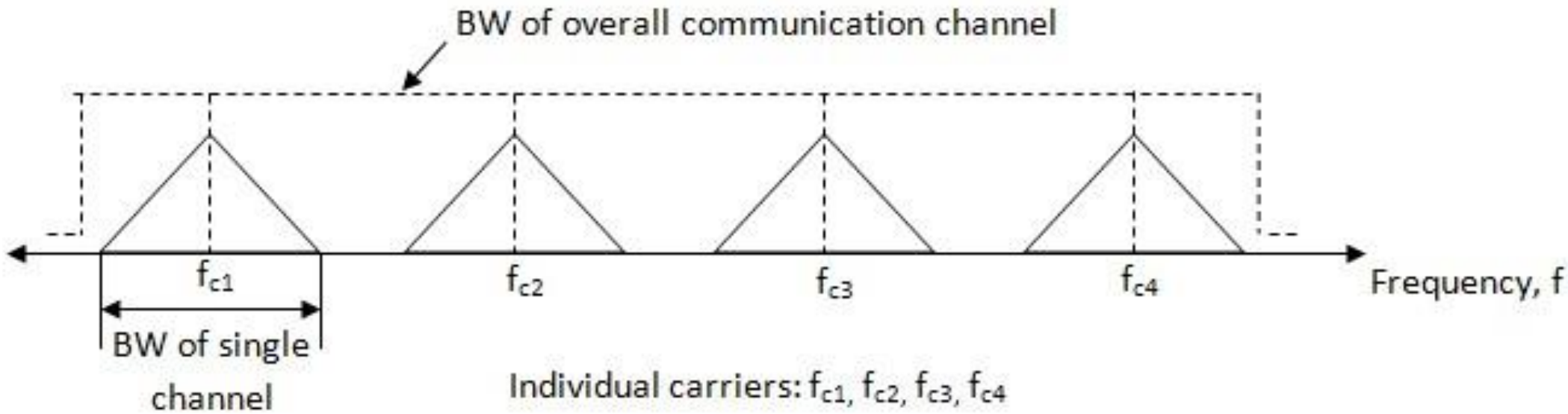


Frequency Division Multiplexing – FDM

- Frequency division multiplexing (FDM) is a multiplexing technique that divides the available bandwidth into multiple sub-bands each of which can carry a signal.
- Therefore, FDM enables concurrent transmissions over a shared communication medium.
- As another common use, FDM enables the system to send a huge amount of data through several segments transmitted over independent frequency sub-bands.

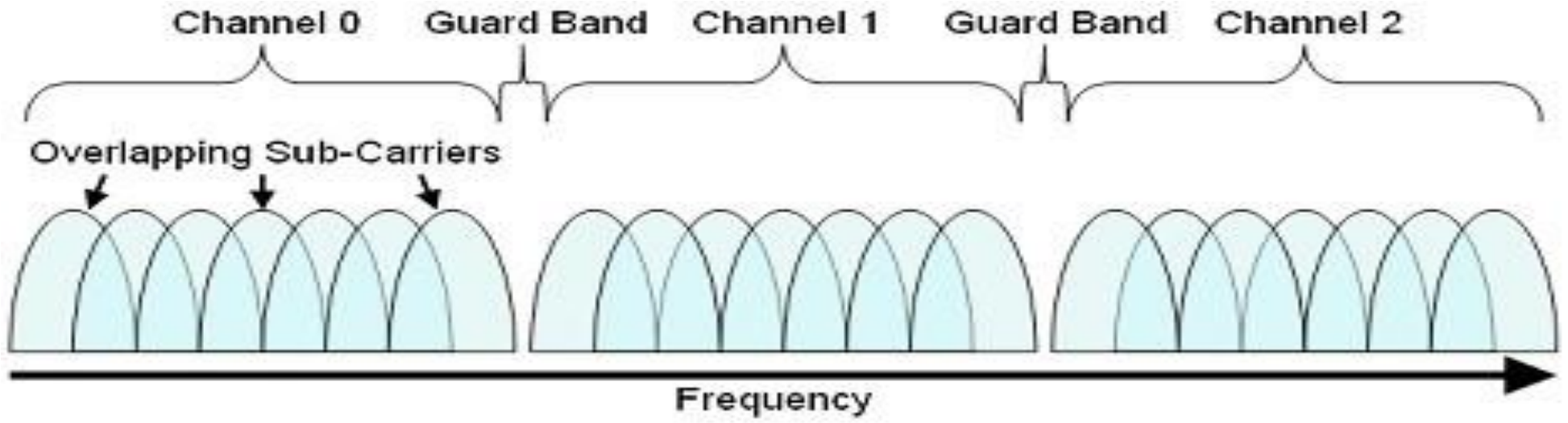
Frequency Division Multiplexing Working Principle

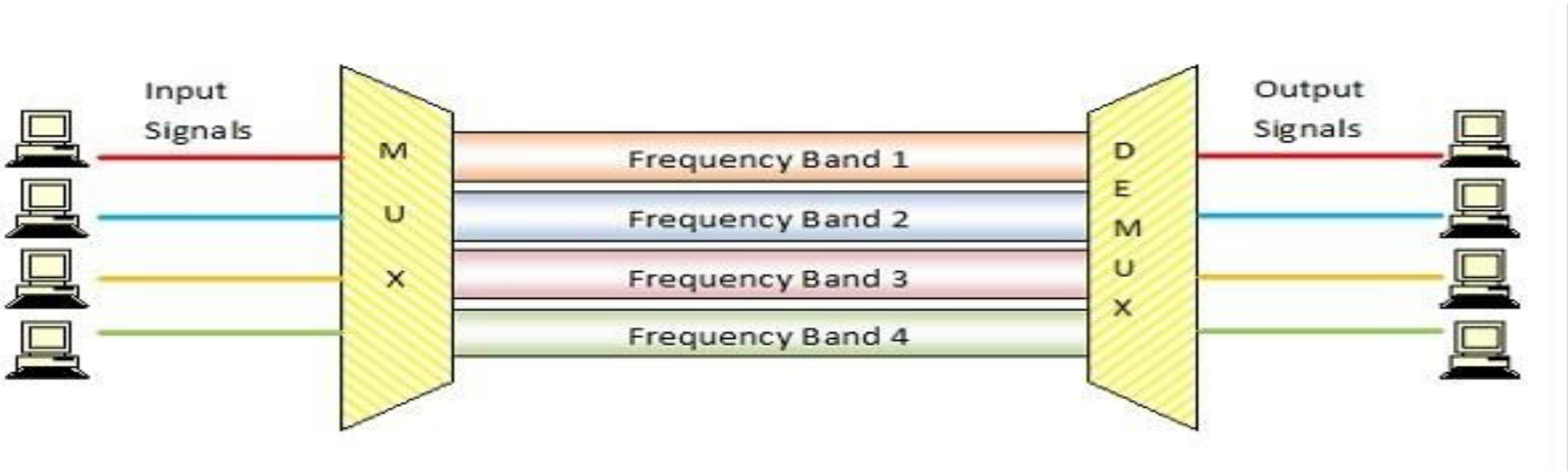
- In FDM, the total bandwidth is divided into a set of frequency bands that do not overlap.
- Each of these bands is a carrier of a different signal that is generated and modulated by one of the sending devices.
- The frequency bands are separated from one another by strips of unused frequencies called **the guard bands**, to prevent overlapping of signals.
- The modulated signals are combined using a multiplexer (MUX) in the sending end. The combined signal is transmitted over the communication channel, thus allowing multiple independent data streams to be transmitted simultaneously. At the receiving end, the individual signals are extracted from the combined signal by the process of demultiplexing (DEMUX).


BW of overall communication channel
f_{c1}
f_{c2}
f_{c3}
f_{c4}
Frequency, f
BW of single channel
Individual carriers: f_{c1}, f_{c2}, f_{c3}, f_{c4}

Guard Band

- For FDM to work properly, frequency overlap must be avoided. A guard band is a narrow frequency range that separates two ranges of wider frequency.
- This ensures that simultaneously used communication channels do not experience interference which would result in decreased quality of both transmissions.





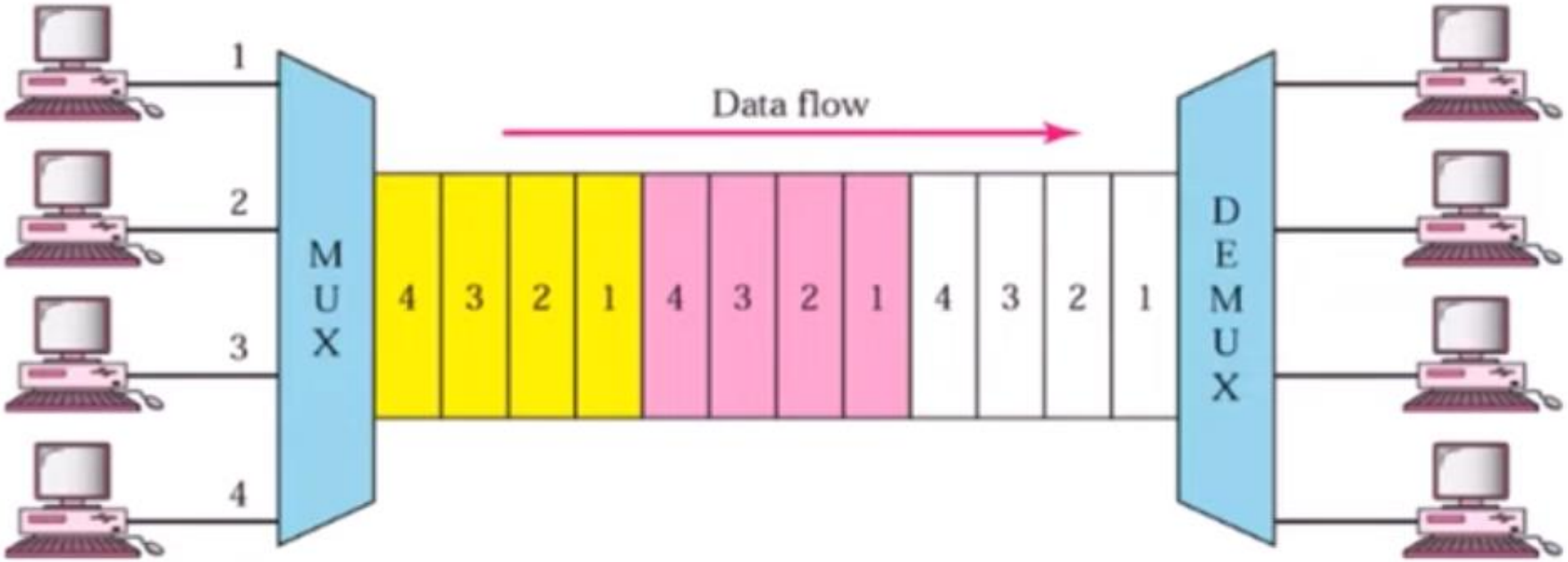
It has 4 frequency bands, each of which can carry a signal from 1 sender to 1 receiver. Each of the 4 senders is allocated a frequency band.
The four frequency bands are multiplexed and sent via the communication channel. At the receiving end, a demultiplexer regenerates the original four signals as outputs.

Applications of FDM

- FDM is commonly used in TV networks.
- FDM is used in Radio Broadcasting.
- The first-generation cellular telephone uses FDM.
- Frequency Division Multiplexing System is also used in Satelite Communication system. It helps to transmit multiple channels of data in satellite communication.
- Frequency Division Multiplexing System is used in the telephone system. FDM helps to transmit multiple phone calls over a single transmission line or a single link.

Time Division Multiplexing

1. TDM is the digital multiplexing technique.
2. In TDM, the channel/link is not divided on the basis of frequency but on the basis of time.
3. Total time available in the channel is divided between several users.
4. Each user is allotted a particular a time interval called time slot or time slice during which the data is transmitted by that user.
5. Thus each sending device takes control of entire bandwidth of the channel for fixed amount of time.
6. In TDM all the signals to be transmitted are not transmitted simultaneously. Instead, they are transmitted one-by-one.

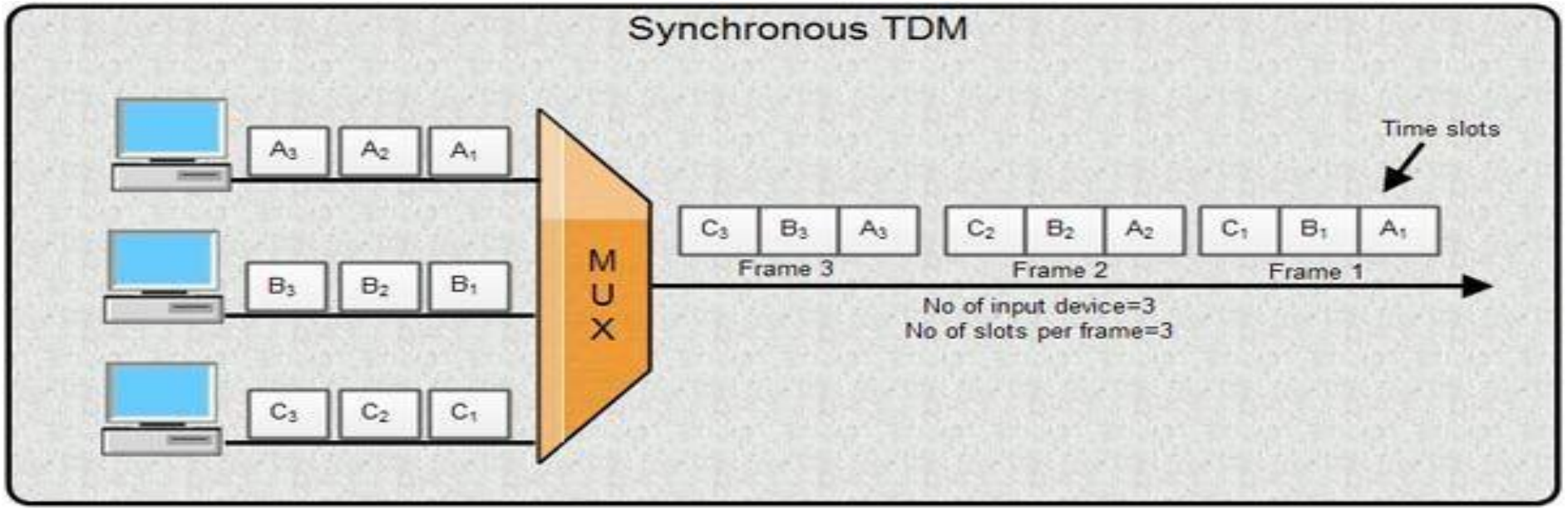


Types of TDM

- Synchronous TDM
- Asynchronous TDM

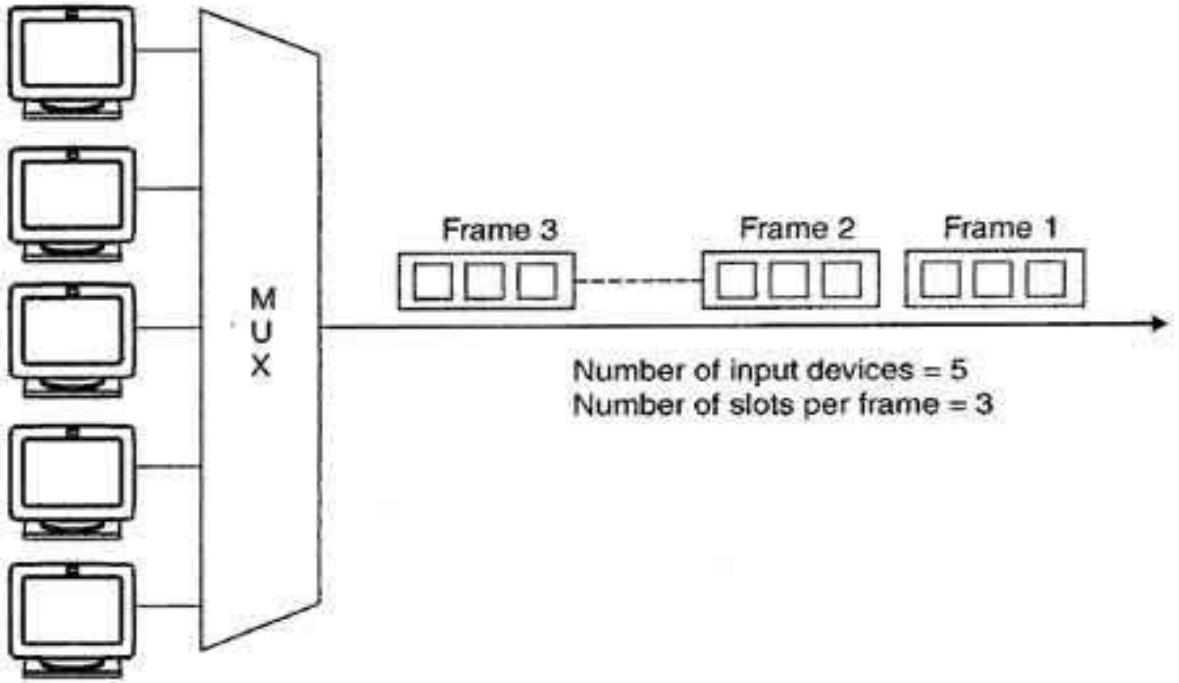
Synchronous TDM

1. In synchronous TDM, each device is given same **time slot** to transmit the data over the link, irrespective of the fact that the device has any data to transmit or not. Hence the name Synchronous TDM. Synchronous TDM requires that the total speed of various input lines should not exceed the capacity of path.
2. Each device places its data onto the link when its **time slot** arrives *i.e.* each device is given the possession of line turn by turn.
3. If any device does not have data to send then its time slot remains empty.
4. The various time slots are organized into **frames** and each frame consists of one or more time slots dedicated to each sending device.
5. If there are *n* sending devices, there will be *n* slots in frame *i.e.* one slot for each device.



Asynchronous TDM

1. It is also known as statistical time division multiplexing.
2. Asynchronous TDM is called so because is this type of multiplexing, time slots are not fixed *i.e.* the slots are flexible.
3. In synchronous TDM, if we have *n* input lines then there are *n* slots in one frame. But in asynchronous it is not so.
4. In asynchronous TDM, if we have *n* input lines then the frame contains not more than *m* slots, with *m* less than *n (m < n).*



Asynchronous TDM

5. In this system slots are not predefined, the slots are allocated to any of the device that has data to send.
6. The multiplexer scans the various input lines, accepts the data from the lines that have data to send, fills the frame and then sends the frame across the link.
7. If there are not enough data to fill all the slots in a frame, then the frames are transmitted partially filled.

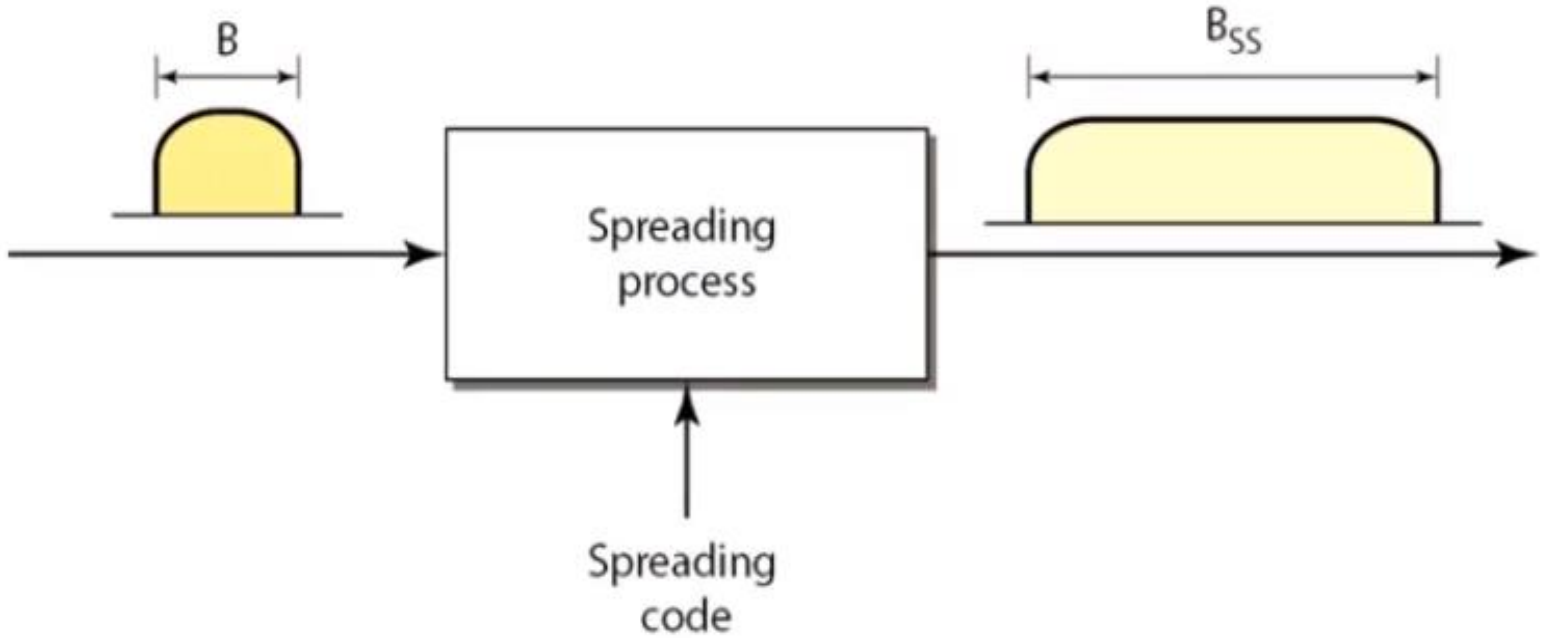
Advantages of TDM :
1. Full available channel bandwidth can be utilized for each channel.
2. The problem of crosstalk is not severe.

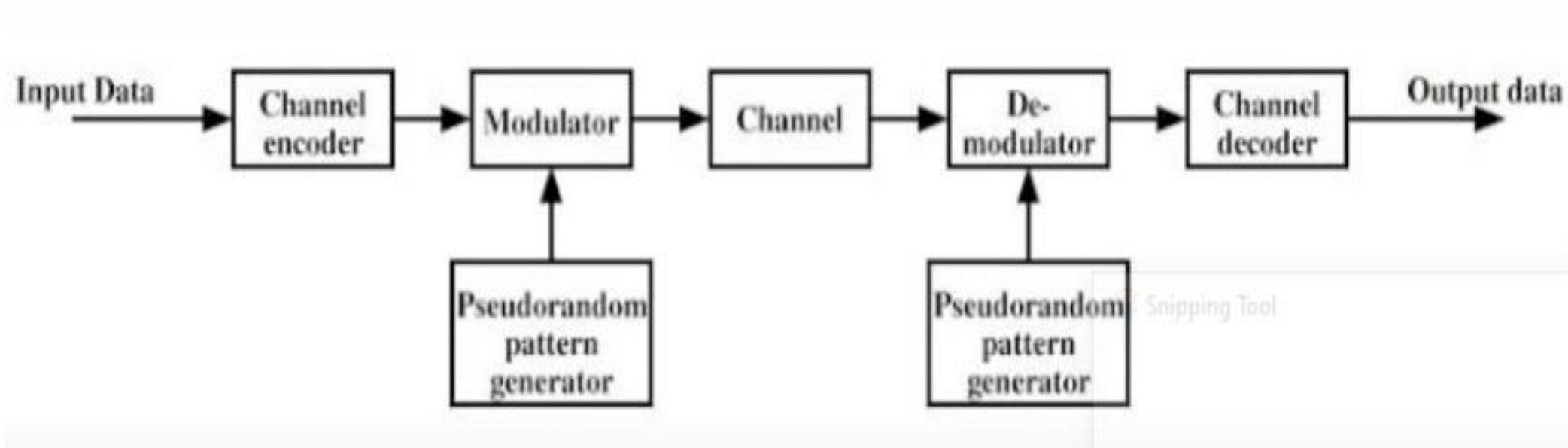
Disadvantages of TDM :
1. Synchronization is essential for proper operation.

Spread Spectrum

- Spread spectrum is a technique used for wireless communications in telecommunication and radio communication.
- In this technique, the frequency of the transmitted signal, i.e., an electrical signal or electromagnetic signal, is deliberately varied and generates a much greater bandwidth than the signal would have if its frequency were not varied.
- In other words, "Spread Spectrum is a technique in which the transmitted signals of specific frequencies are varied slightly to obtain greater bandwidth as compared to initial bandwidth."

- Spread Spectrum modulation spreads the spectrum of transmitted signals into wider range.
- The spreading code is used to spread the spectrum of transmitted signals.




Input Data
Channel encoder
Modulator
Channel
De-modulator
Channel decoder
Output data
Pseudorandom pattern generator
Pseudorandom pattern generator

Reasons to use Spread Spectrum

- Spread spectrum signals are distributed over a wide range of frequencies and then collected and received back to the receiver. On the other hand, wide-band signals are noise-like and challenging to detect.
- Initially, the spread spectrum was adopted in military applications because of its resistance to jamming and difficulty intercepting.
- Now, this is also used in commercial wireless communication.
- It is most preferred because of its useful bandwidth utilization ability.
- It can successfully establish a secure medium of communication.

- **Characteristics of the Spread Spectrum are:**

1.Higher channel capacity.

2.Ability to resist multipath propagation.

3.They cannot easily intercept any unauthorized person.

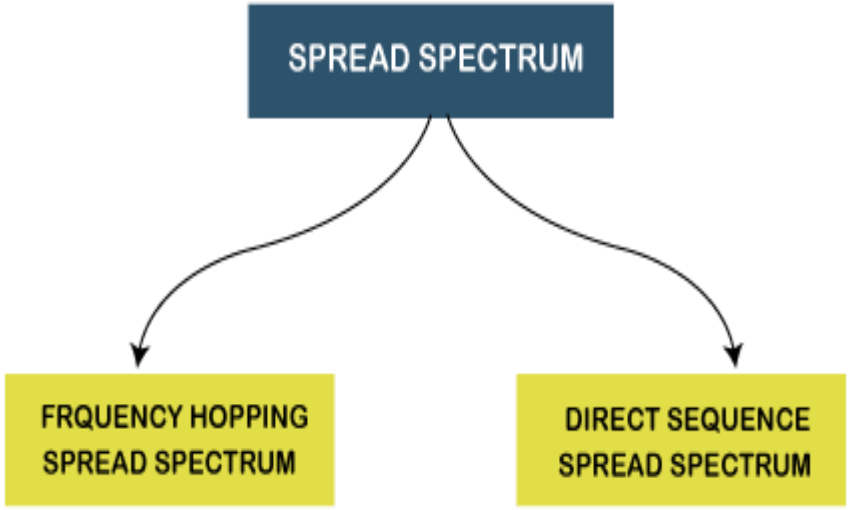
4.They are resistant to jamming.

5.The spread spectrum offers multiple access capabilities.

Types of Spread Spectrum

Spread Spectrum can be categorized into two types:

- Frequency Hopping Spread Spectrum (FHSS)
- Direct Sequence Spread Spectrum(DSSS)



Frequency Hopping Spread Spectrum (FHSS)

- The Frequency Hopping Spread Spectrum or FHSS allows us to utilize bandwidth properly and maximum. In this technique, the whole available bandwidth is divided into many channels and spread between channels, arranged continuously.
- The frequency slots are selected randomly, and frequency signals are transmitted according to their occupancy.
- The transmitters and receivers keep on hopping on channels available for a particular amount of time in milliseconds.
- So, you can see that it implements the frequency division multiplexing and time-division multiplexing simultaneously in FHSS.

FHSS process

1. Frequency of carrier is periodically modified following a specified sequence of frequency.

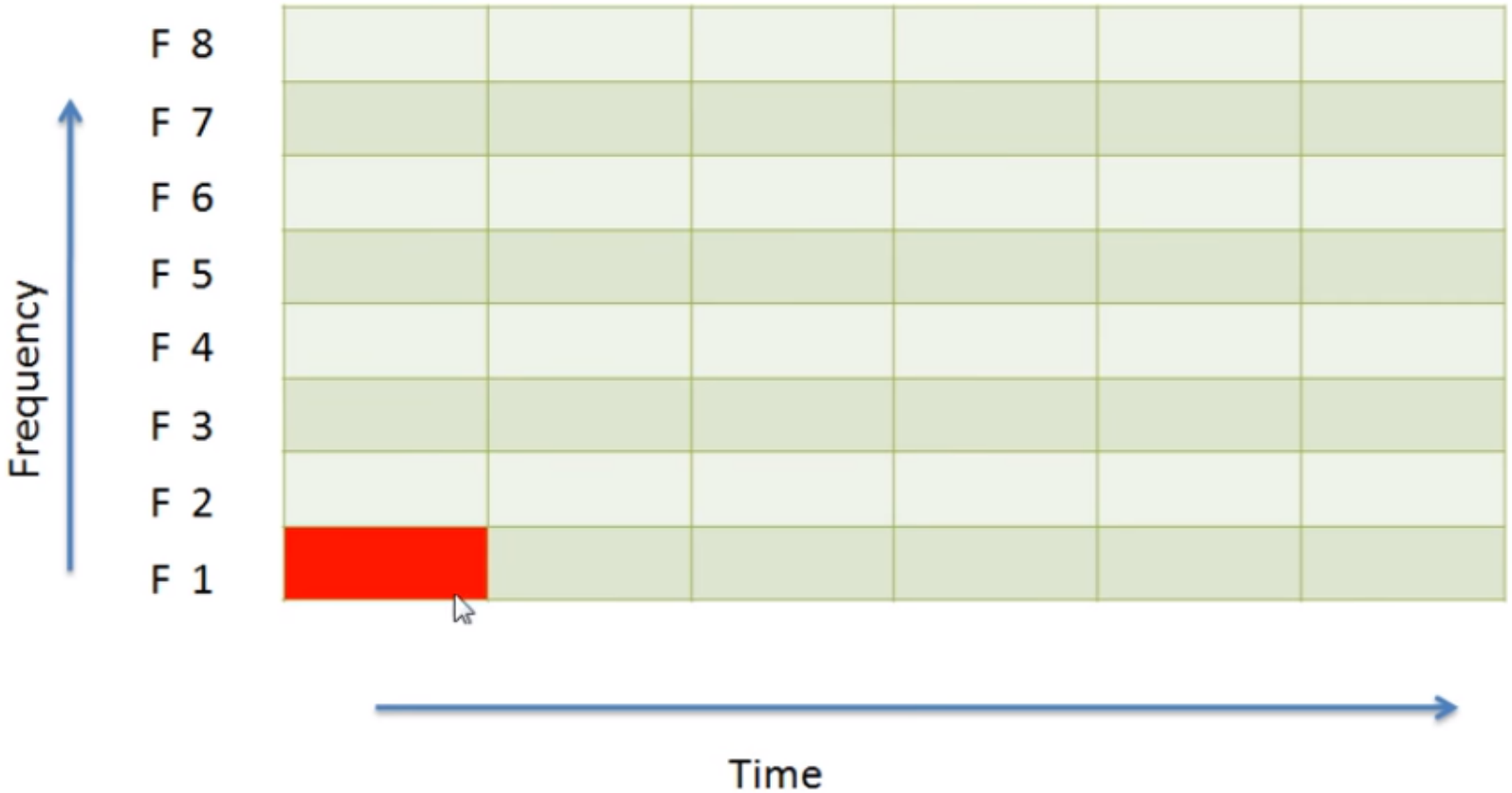
2. This sequence is known as hopping sequence or spreading code.

3. The amount of time spent on each frequency or hop is known as dwell time.

4. Following frequency hopping sequence, message is modulated.

FHSS Example

Let's say sender A want to send some data. Hopping sequence for A is F1,F5,F3,F8



FHSS Example

Let's say sender A want to send some data. Hopping sequence for A is F1,F5,F3,F8

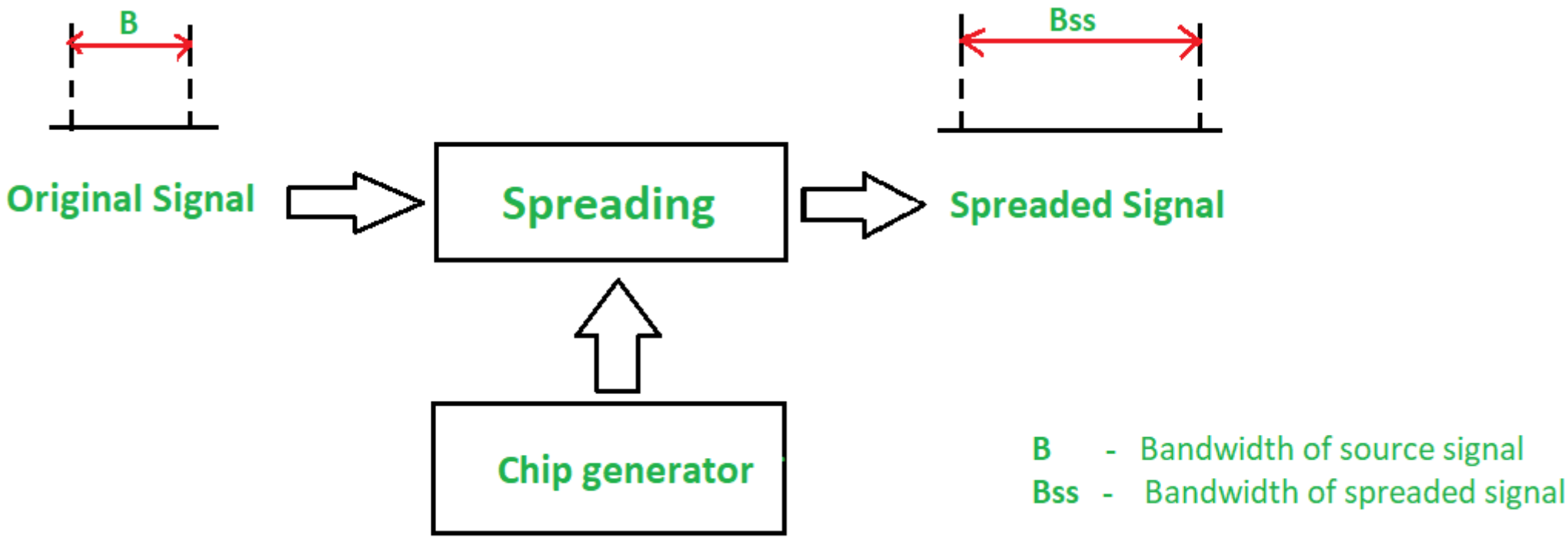
The Frequency Hopping Spread Spectrum or FHSS can also be classified into two types:

- **Slow Hopping:** In slow hopping, multiple bits are transmitted on a specific frequency or same frequency.
- **Fast Hopping:** In fast hopping, individual bits are split and then transmitted on different frequencies.

- Applications of Frequency Hopping Spread Spectrum (FHSS)
- The Frequency Hopping Spread Spectrum or FHSS is used in wireless local area networks (WLAN) standard for Wi-Fi.
- FHSS is also used in the wireless personal area networks (WPAN) standard for Bluetooth.

Direct Sequence Spread Spectrum (DSSS)

- The Direct Sequence Spread Spectrum (DSSS) is a spread-spectrum modulation technique primarily used to reduce overall signal interference in telecommunication.
- The Direct Sequence Spread Spectrum modulation makes the transmitted signal wider in bandwidth than the information bandwidth.
- Here, each data bit is replaced with n bits using a spreading code called **chips,** and the bit rate of the chip is called as **chip-rate**.



B - Bandwidth of source signal
Bss - Bandwidth of spreaded signal

Direct Sequence Spread Spectrum

Every user assigned a spreading code. This secret code is used to encode the signal.

This code is multiplied with original message and resultant message is then transmitted.

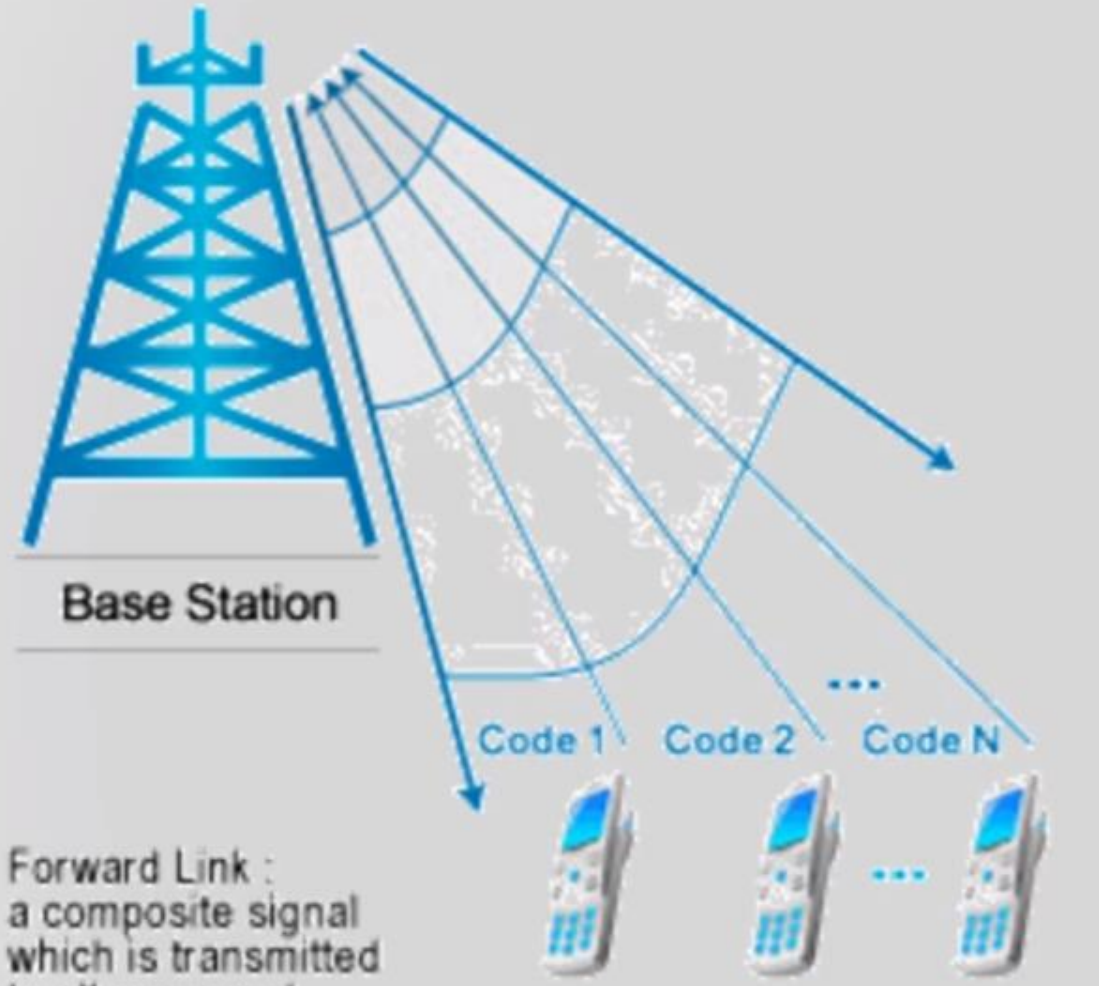
Receiver use same spreading code to decode the message to retrieve original message.

- In Direct Sequence Spread Spectrum or DSSS technique, the data that needs to be transmitted is split into smaller blocks.
- After that, each data block is attached with a high data rate bit sequence and is transmitted from the sender end to the receiver end.
- Data blocks are recombined again to generate the original data at the receiver's end, which was sent by the sender, with the help of the data rate bit sequence.
- If somehow data is lost, then data blocks can also be recovered with those data rate bits.
- The main advantage of splitting the data into smaller blocks is that it reduces the noise and unintentional inference.

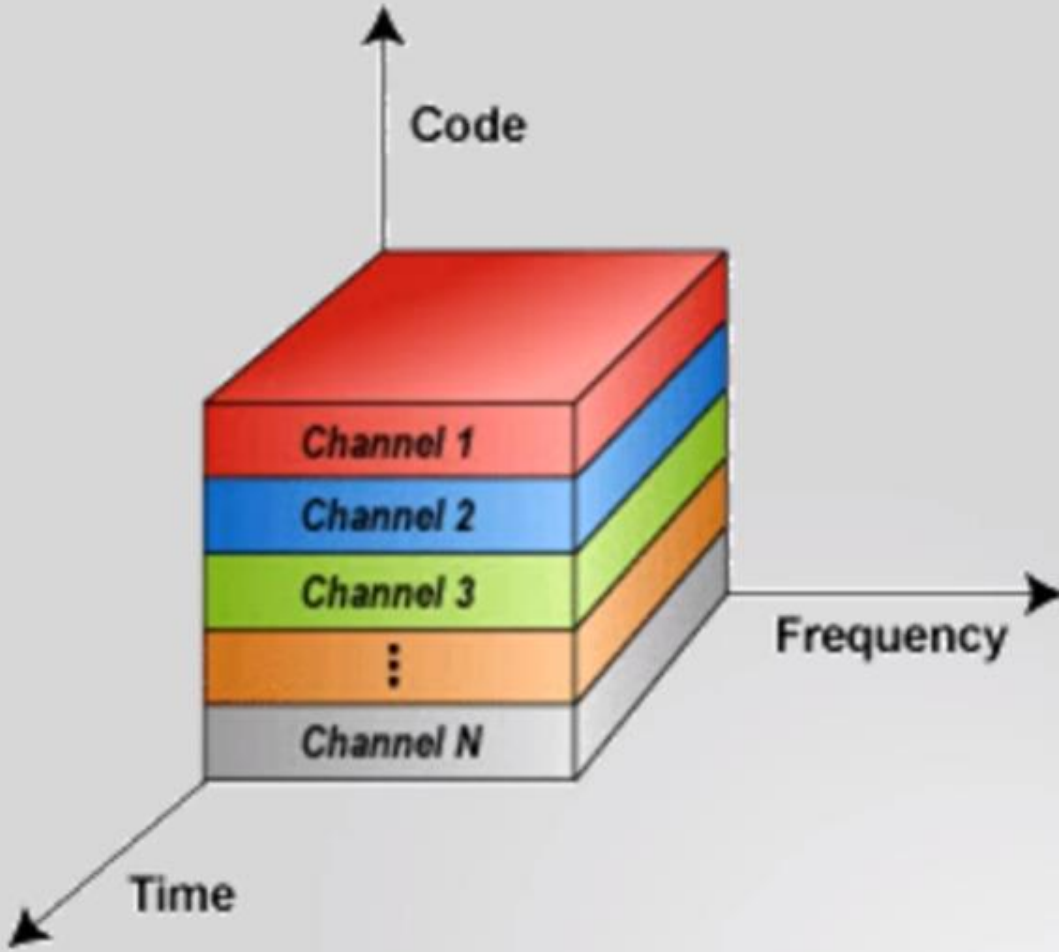
Code Division Multiple Access

- It is basically a channel access method and is also an example of multiple access.
- Multiple access basically means that information by several transmitters can be sent simultaneously onto a single communication channel.
- Code Division Multiple Access system is very different from time and frequency multiplexing.
- In this system, a user has access to the whole bandwidth for the entire duration. The basic principle is that different CDMA codes are used to distinguish among the different users.
- There are multiple users which are provided or assigned variant CDMA codes and thus the users can access the entire band of frequencies or the whole bandwidth.

Code Division Multiple Access - CDMA

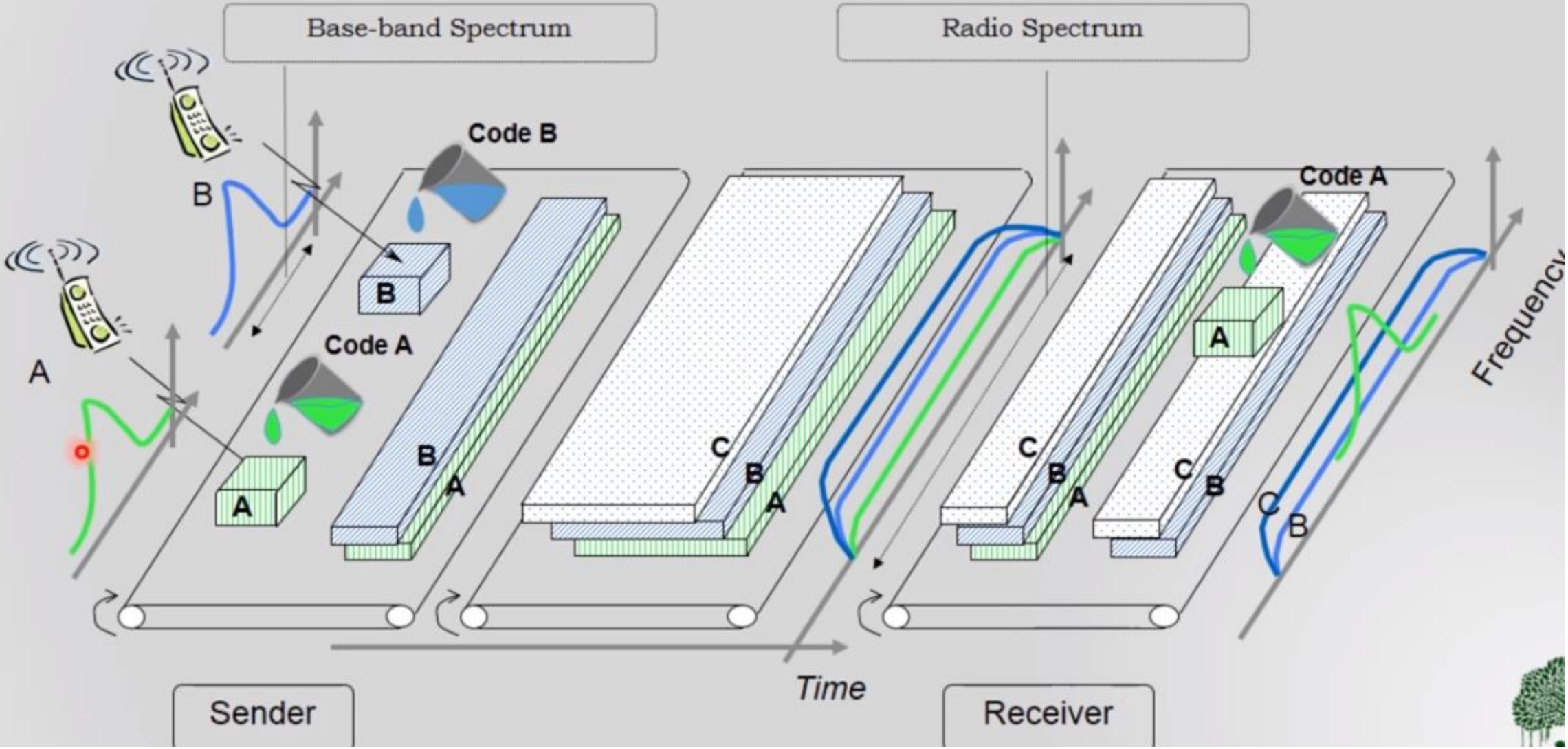


Forward Link :
a composite signal
which is transmitted
to all users and
differentiated by codes

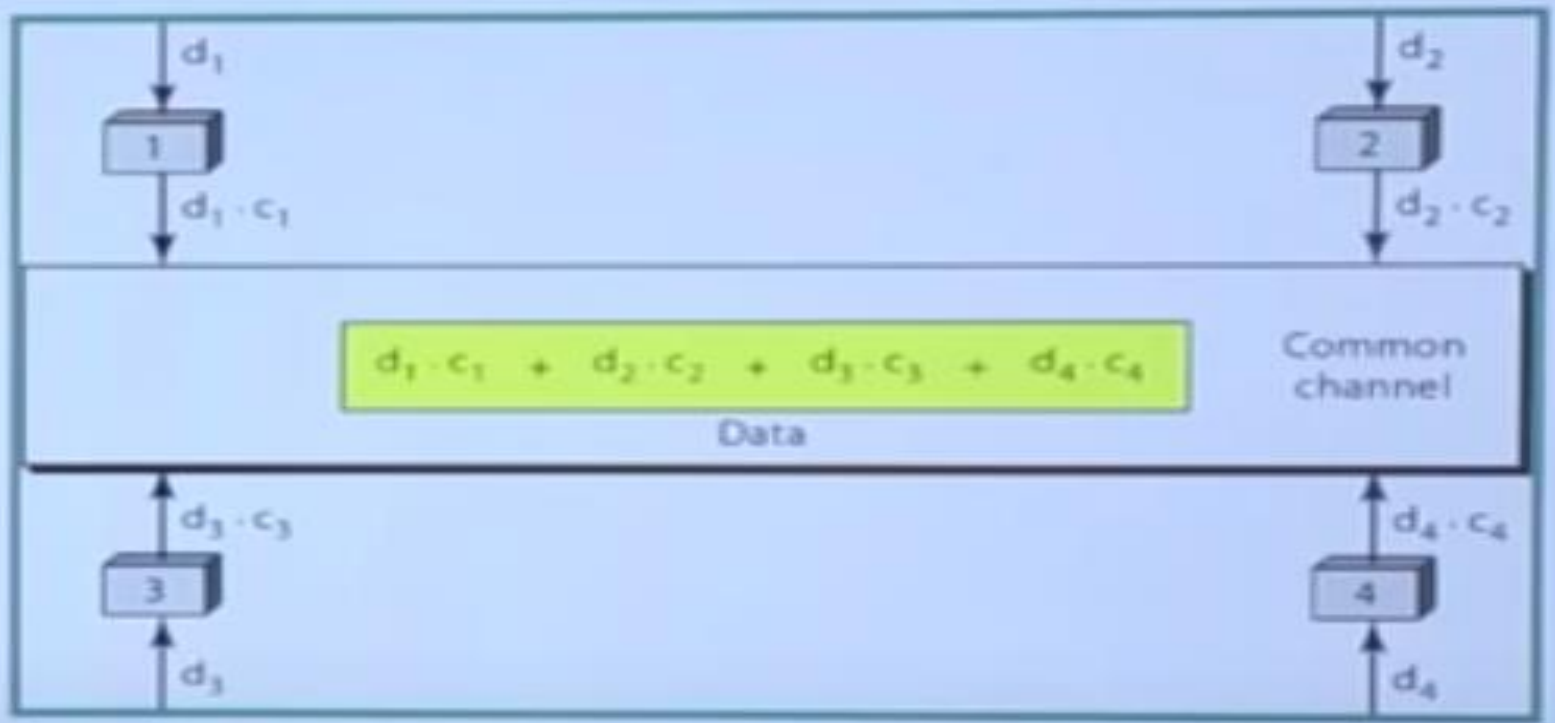


CDMA in which each channel is assigned a unique code
which is orthogonal to codes used by other users.

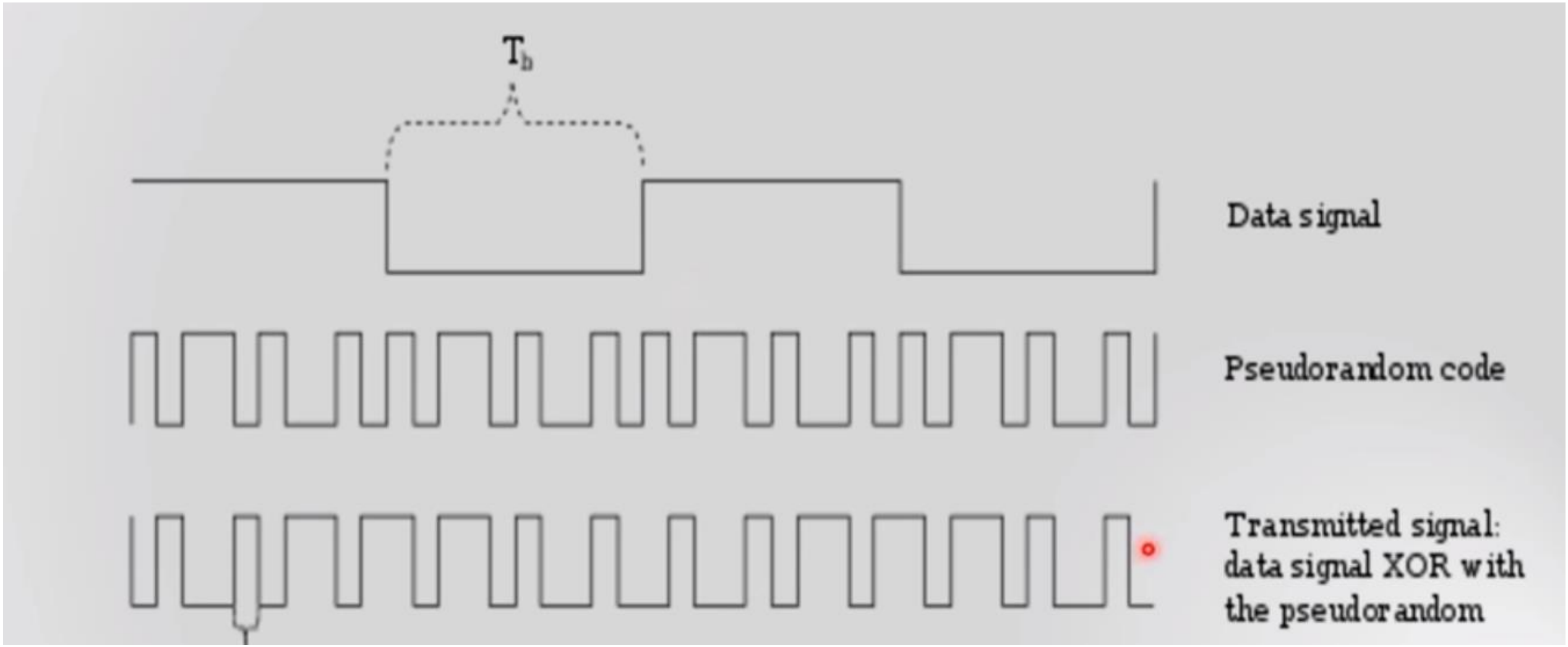
Working of CDMA



In CDMA, one channel carries all transmissions simultaneously.



Simple idea of communication with code


T_b
Data signal
Pseudorandom code
Transmitted signal:
data signal XOR with
the pseudorandom

Applications of CDMA:

1. It is *used for wireless systems* with a fixed base station and many mobile stations at a varying distance from it.

2. *Used in satellite systems* so that many signals can use a transponder, making it more efficient.

Communication Satellite Transponder

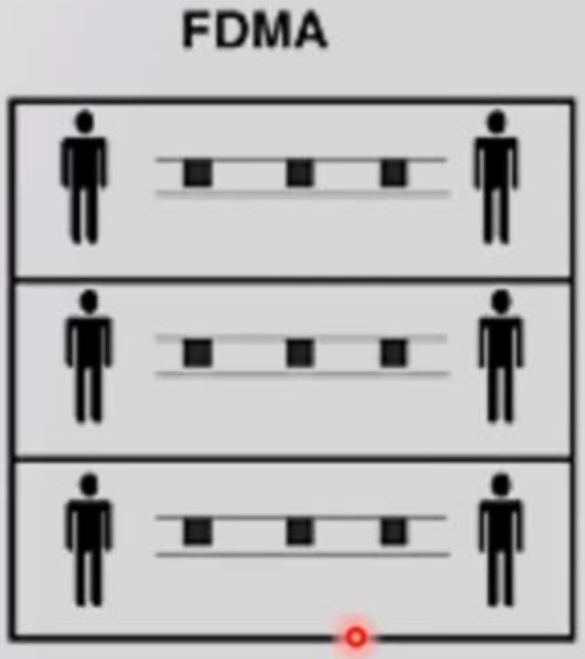
A communication satellite's transponder is the series of interconnected units that form a communications channel between the receiving and the transmitting antennas. It is mainly used in satellite communication to transfer the received signals.

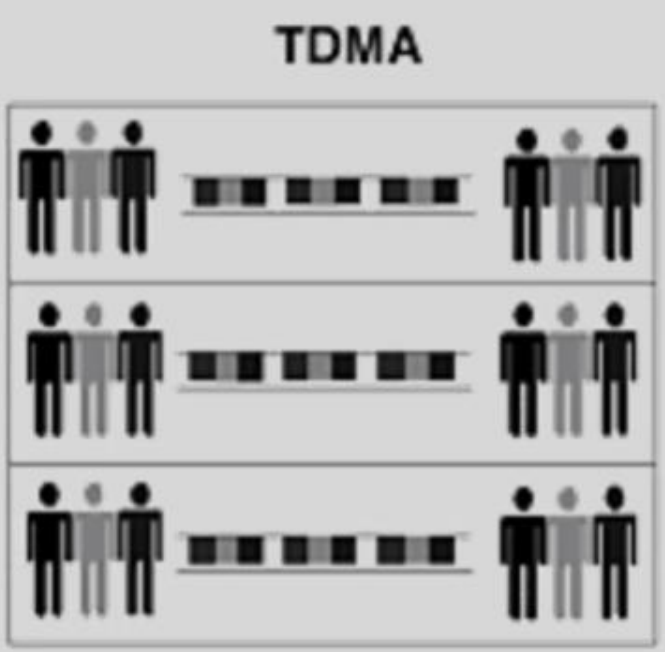
3. Used in *digital cellular telephone services* because it permits more users to occupy a given band.

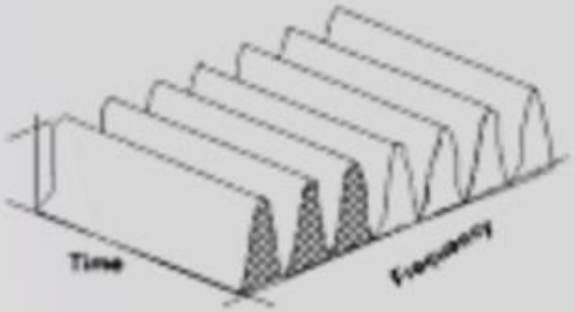
4. *Wideband CDMA* (W-CDMA) is used for digital cell phone systems to accommodate voice transmission along with high-speed data, FAX and internet communication.

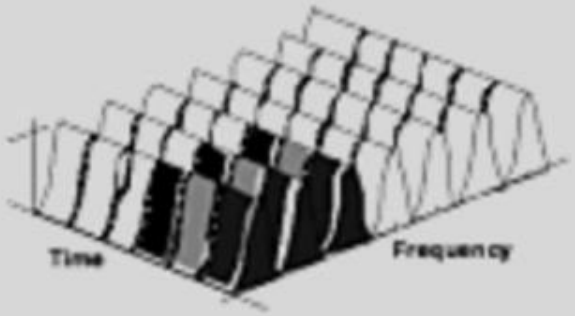
5. CDMA is also used in the *military* because of immunity to noise.

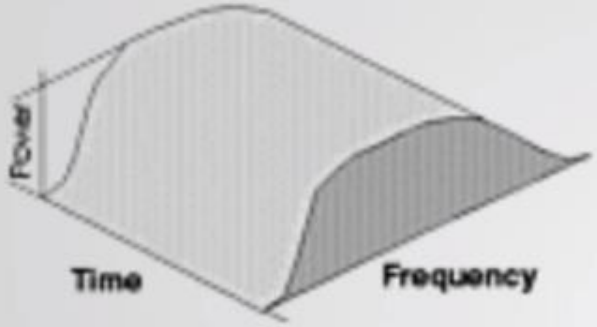
Comparison of FDMA – TDMA – CDMA







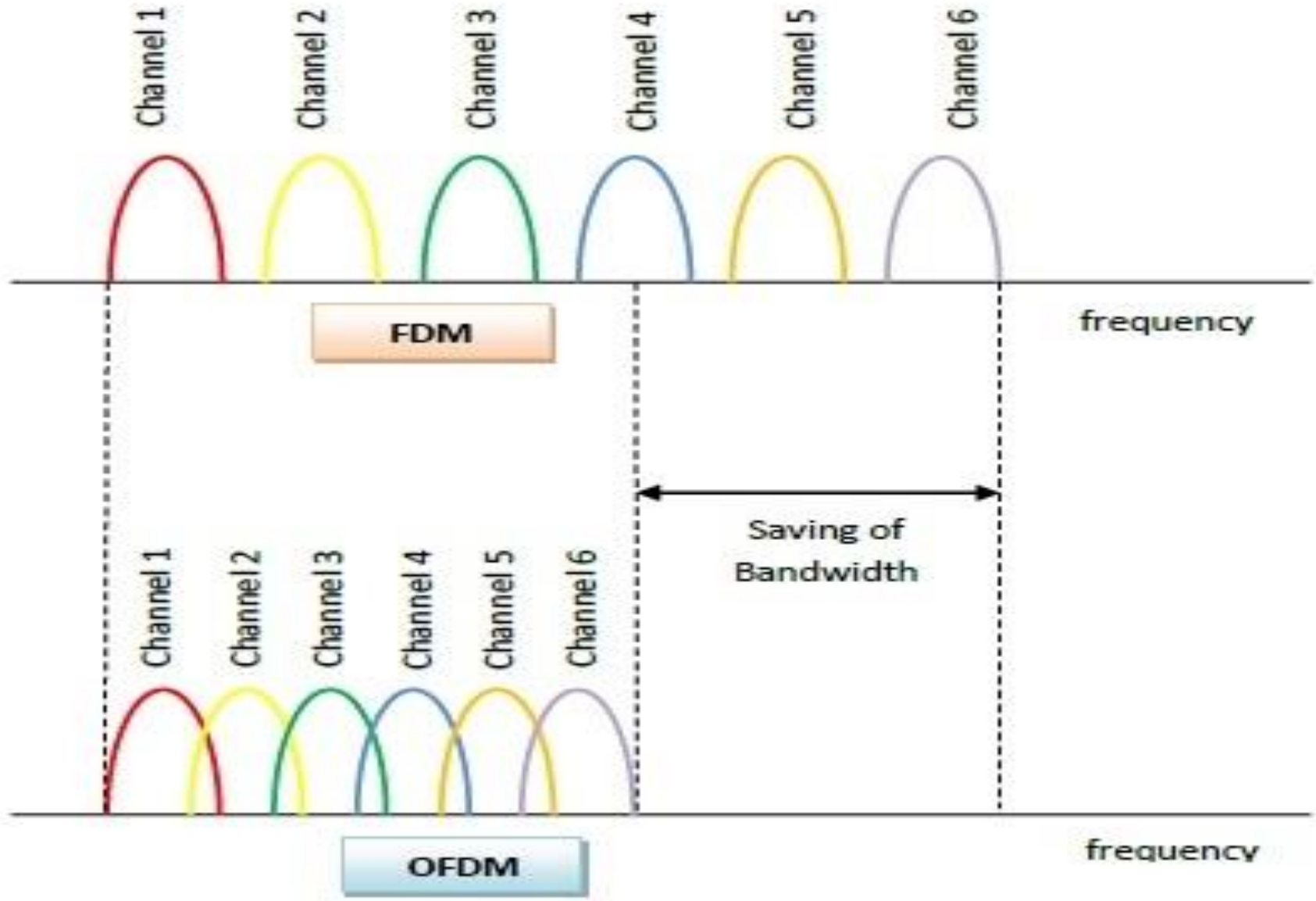


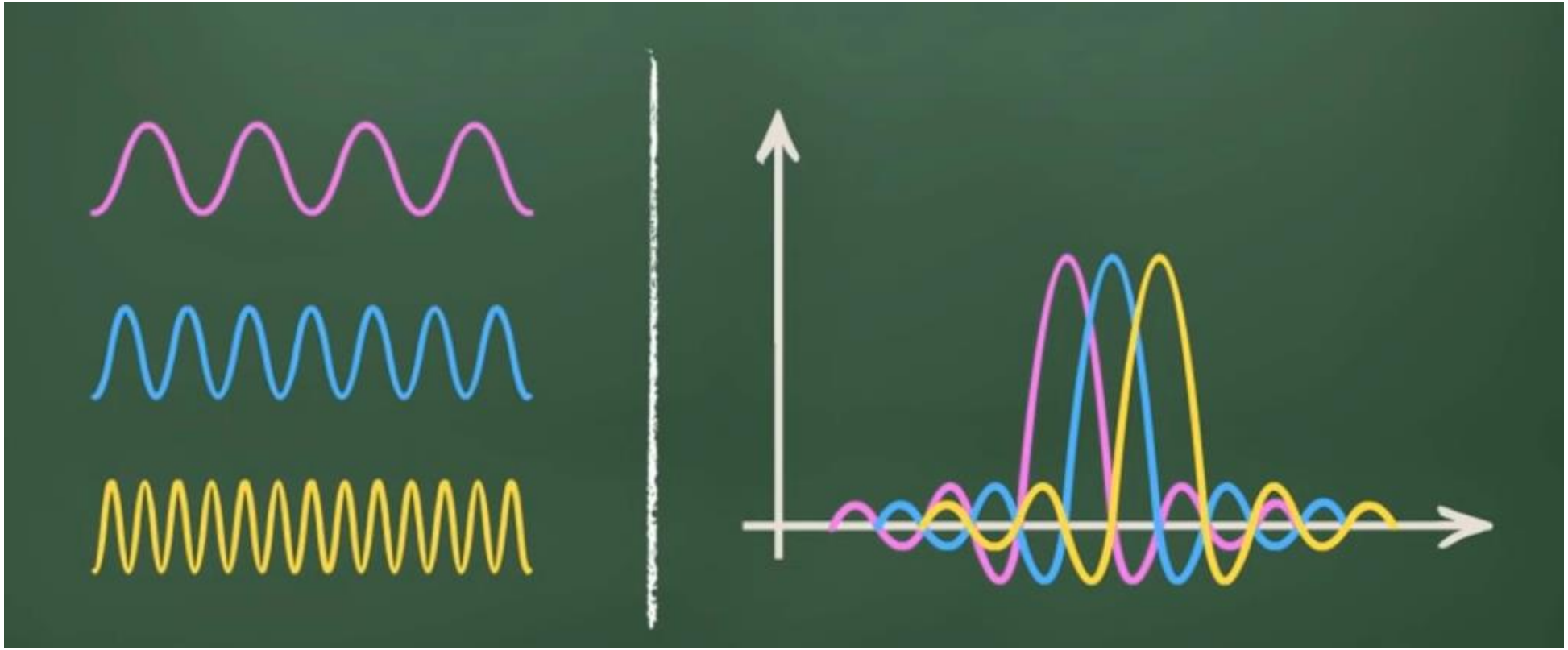


GURUKULA

Orthogonal Frequency Division Multiplexing (OFDM)

- In data communications and networking, orthogonal frequency-division multiplexing (OFDM) is a method of digital data modulation, whereby a single stream of data is divided into several separate sub-streams for transmission via multiple channels.
- OFDM uses the principle of frequency division multiplexing (FDM), where the available bandwidth is divided into a set of sub-streams having separate frequency bands.


Channel 1
Channel 2
Channel 3
Channel 4
Channel 5
Channel 6
FDM
frequency
Saving of
Bandwidth
Channel 1
Channel 2
Channel 3
Channel 4
Channel 5
Channel 6
OFDM
frequency

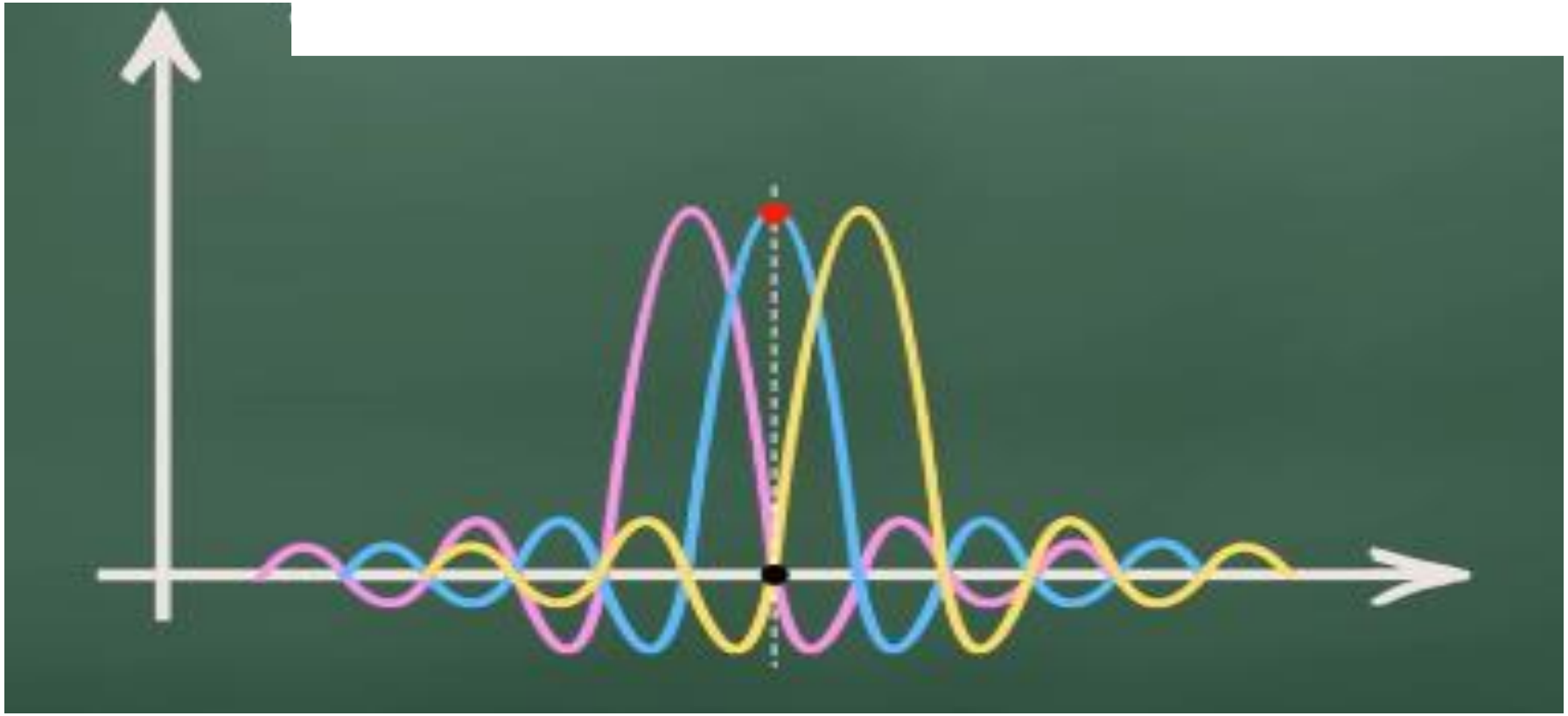


Suppose we have three different signals to send over one shared channel

OFDM would combine them closely together in a way they are orthogonal to each other.

Orthogonal means two or multiple objects act independently

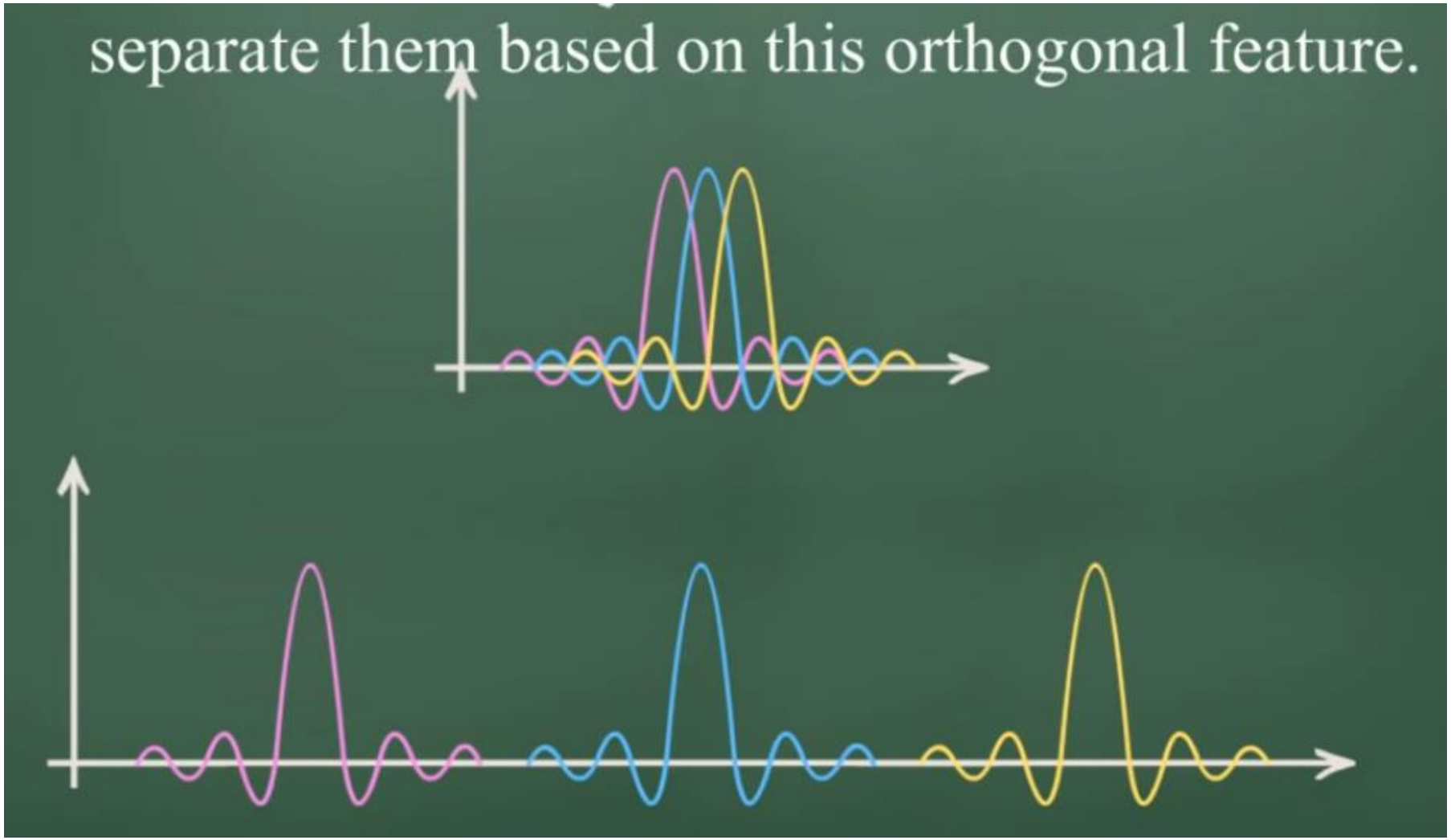
In this case, any neighbor signals in OFDM operate without dependence or interference with one other



Orthogonal means signals are multiplexed in a way the peak of one signal occurs at null of other neighbor signal

While one signal is at its peak, the other signals are at their zero-point, allowing the receiver to differentiate between each signal.

At he receiving end multiplexer would



Working Principle of OFDM

- OFDM is a specialized FDM having the constraint that the sub-streams in which the main signal is divided, are orthogonal to each other.
- A main property of orthogonal signals is that they do not interfere with each other.
- When any signal is modulated by the sender, its sidebands spread out either side.
- A receiver can successfully demodulate the data only if it receives the whole signal. In case of FDM, guard bands are inserted so that interference between the signals, resulting in cross-talks, does not occur.
- However, since orthogonal signals are used in OFDM, no interference occurs between the signals even if their sidebands overlap. So, guard bands can be removed, thus saving bandwidth.

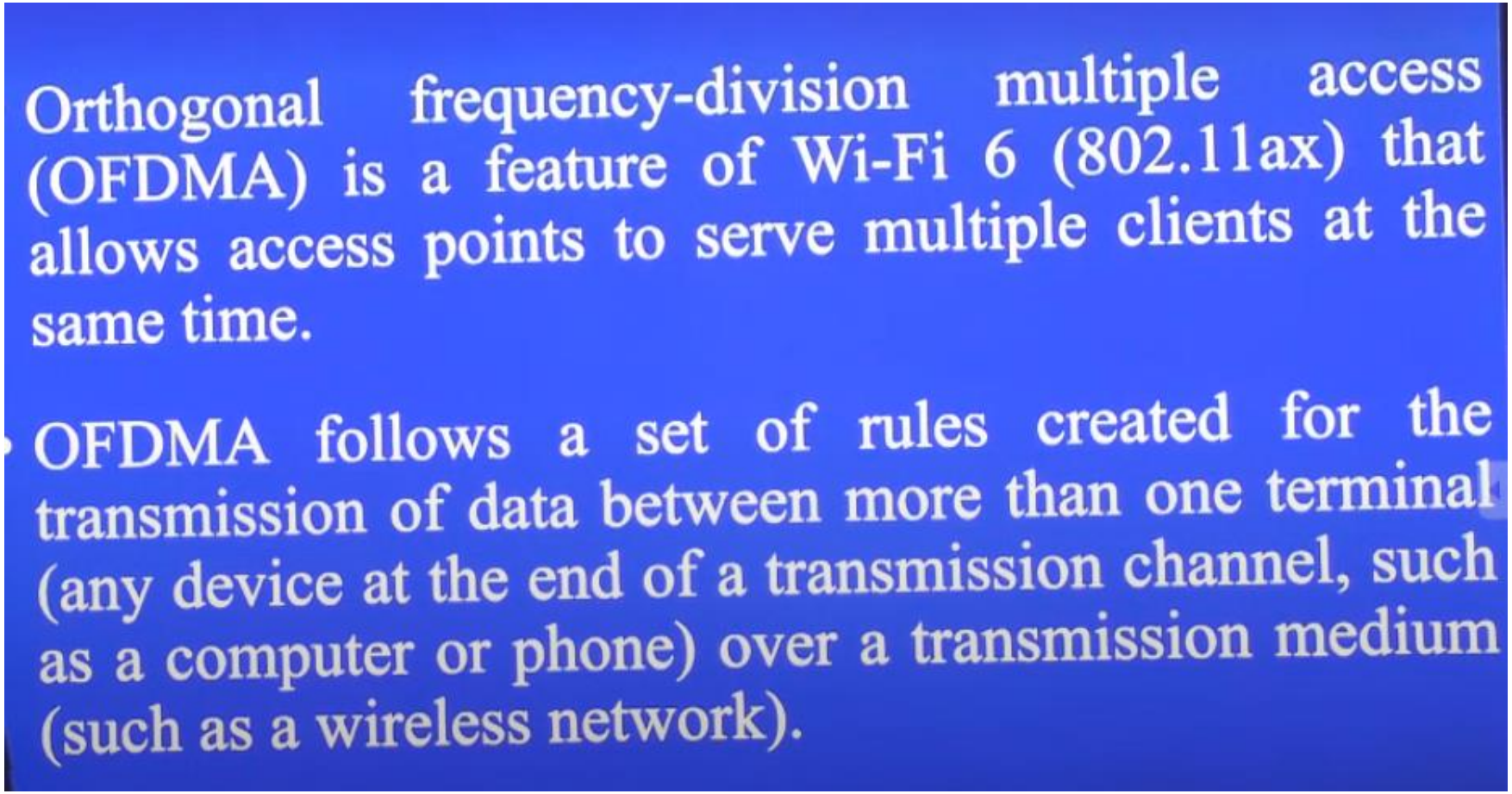
- Usages

OFDM is used in the following area –

- Wi-Fi
- 4G wireless communications
- digital television
- radio broadcast services

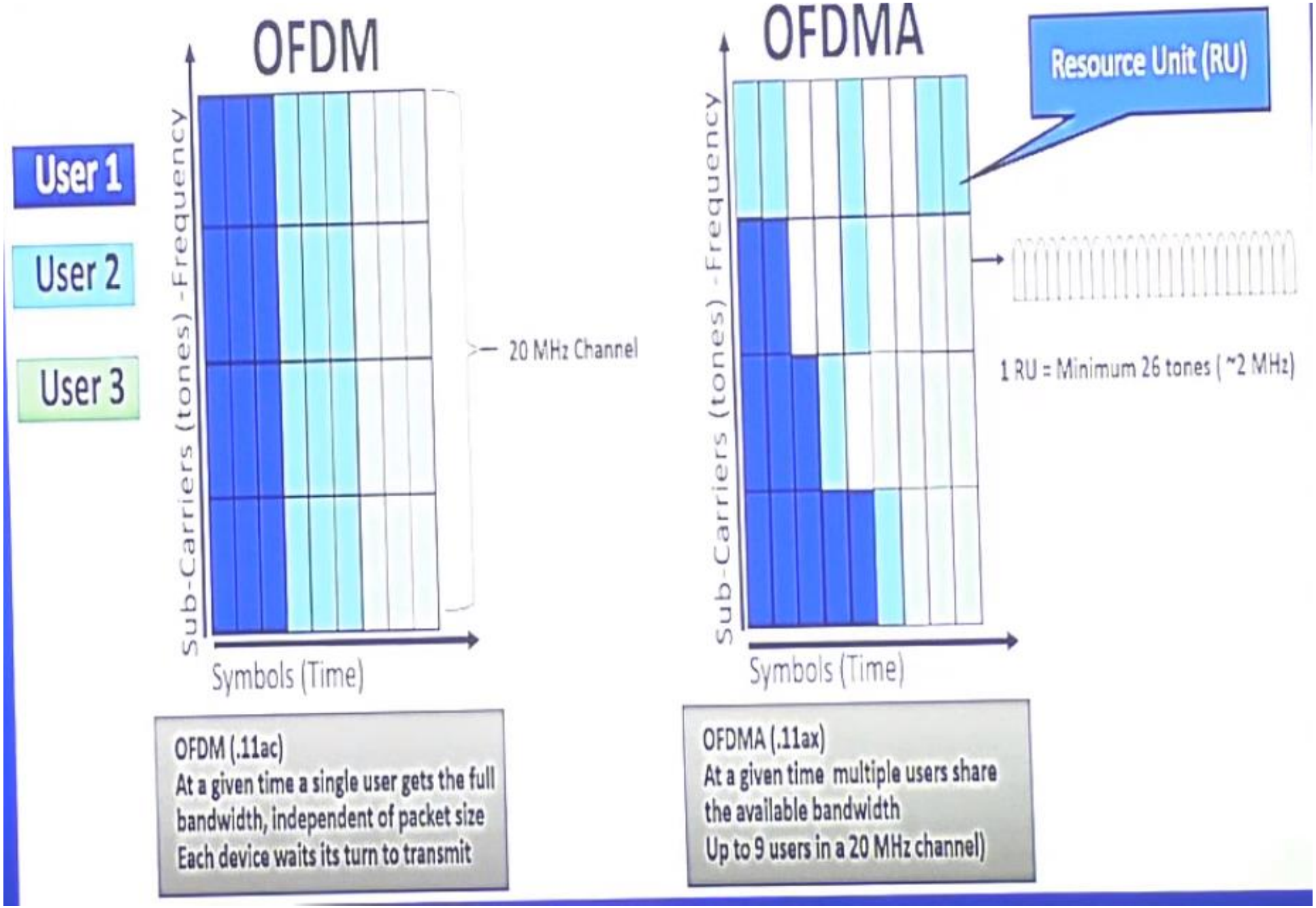
- Even though OFDM helped receivers efficiently separate each signal, the lingering limitation is that wireless access points can only process one user's data transmission at a time for each channel.
- Basically, if multiple users are on one channel, each one has to wait its turn. Thankfully, OFDMA in WiFi 6 has introduced a solution to this issue.

Orthogonal Frequency division multiple access(OFDMA)

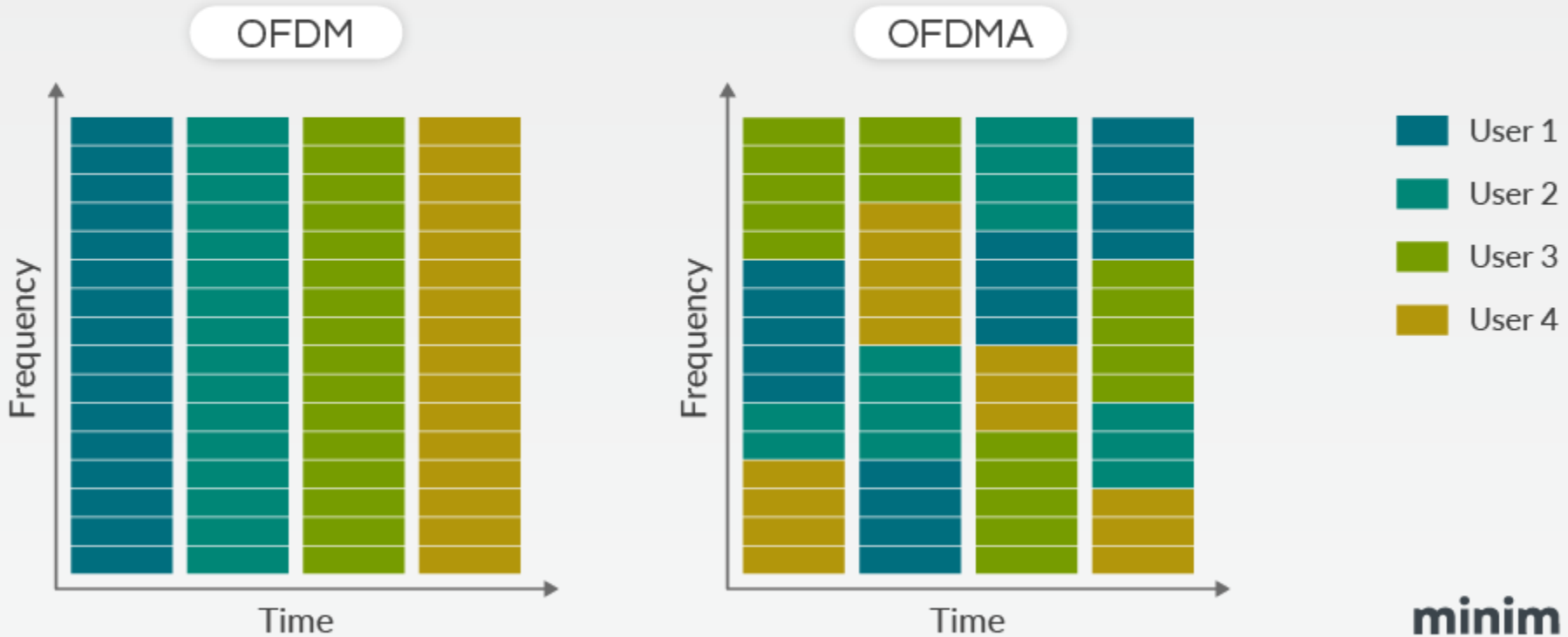


- OFDMA is the latest implementation of structuring data transmissions with a new innovation. It takes the traditional channels of OFDM and subdivides them into smaller channel sections, carrying data through resources units (RUs).

- OFDMA is a multi-user version of OFDM that allows multiple users to share the available bandwidth and transmit simultaneously.


OFDM
User 1
User 2
User 3
Sub-Carriers (tones) -Frequency
Symbols (Time)
20 MHz Channel
OFDM (.11ac)
At a given time a single user gets the full bandwidth, independent of packet size
Each device waits its turn to transmit
OFDMA
Resource Unit (RU)
1 RU = Minimum 26 tones (~2 MHz)
Sub-Carriers (tones) -Frequency
Symbols (Time)
OFDMA (.11ax)
At a given time multiple users share the available bandwidth
Up to 9 users in a 20 MHz channel)

OFDM vs OFDMA



CH:2 CELLULAR SYSTEM

What is Cellular System ?

- In cellular system, the service area is divided into cells. A transmitter is designed to serve an individual cell. The system seeks to make efficient use of available channels by using low-power transmitters to allow frequency reuse at much smaller distances.
- Small geographical area refers to cell

Basic Cellular Systems

- A basic cellular system consists of three parts: a mobile unit, a base station, and a mobile switching centre (MSC)

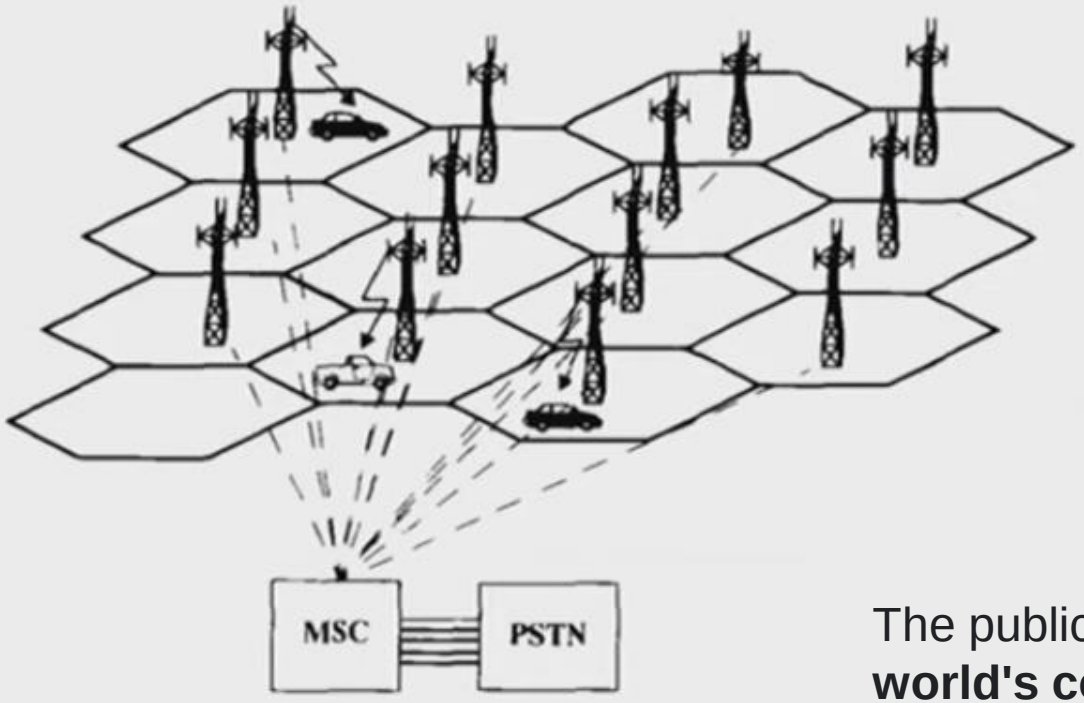
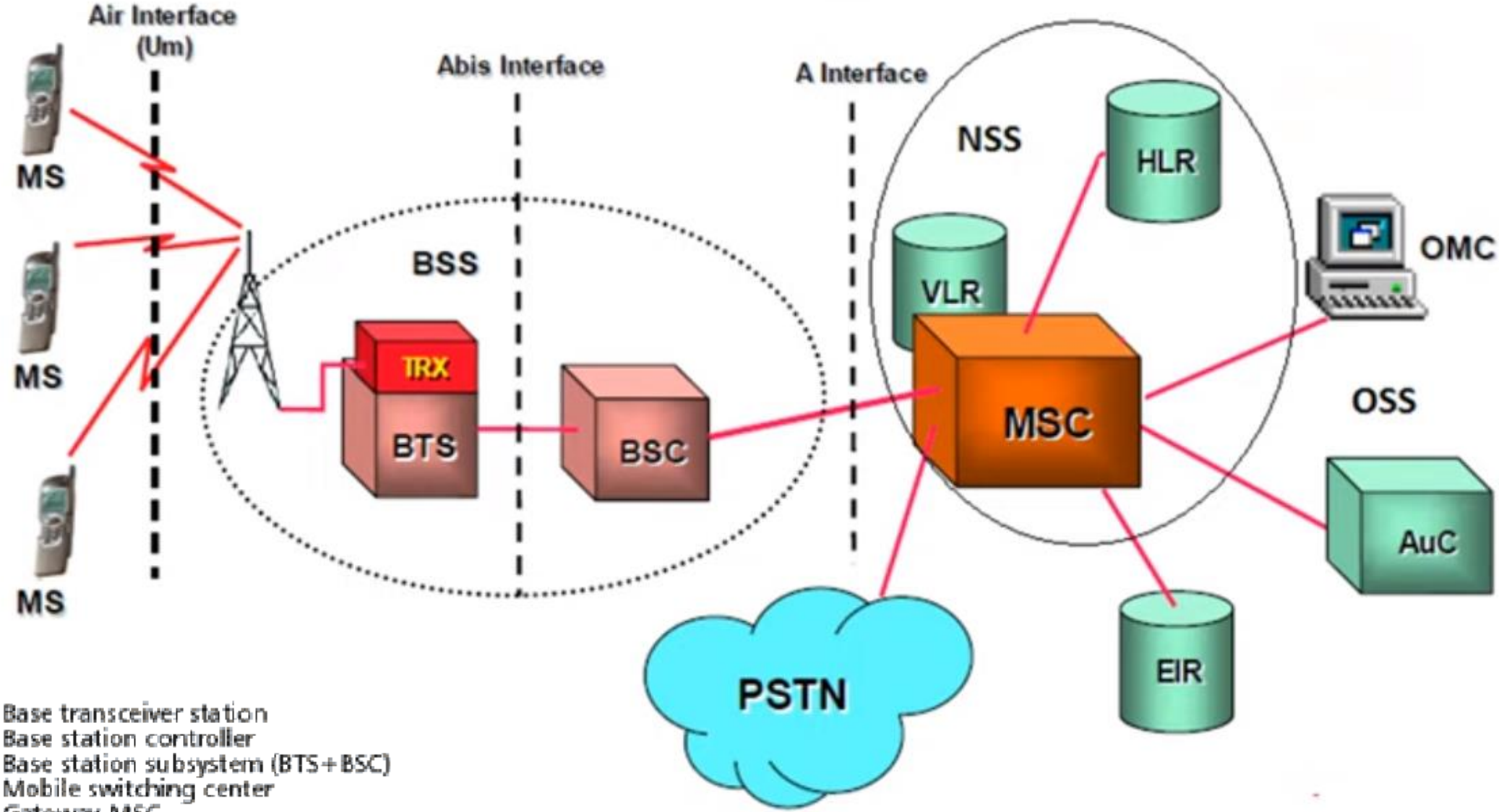


Figure 1: Shows the Illustration Cellular System

The public switched telephone network, or PSTN, is **the world's collection of interconnected voice-oriented public telephone networks**

GSM (**Global System for Mobile communication**)

- GSM (Global System for Mobile communication) is a digital mobile network that is widely used by mobile phone users.
- GSM uses a variation of time division multiple access (TDMA) and is the most widely used of the three digital wireless telephony technologies: TDMA, GSM and code-division multiple access (CDMA).

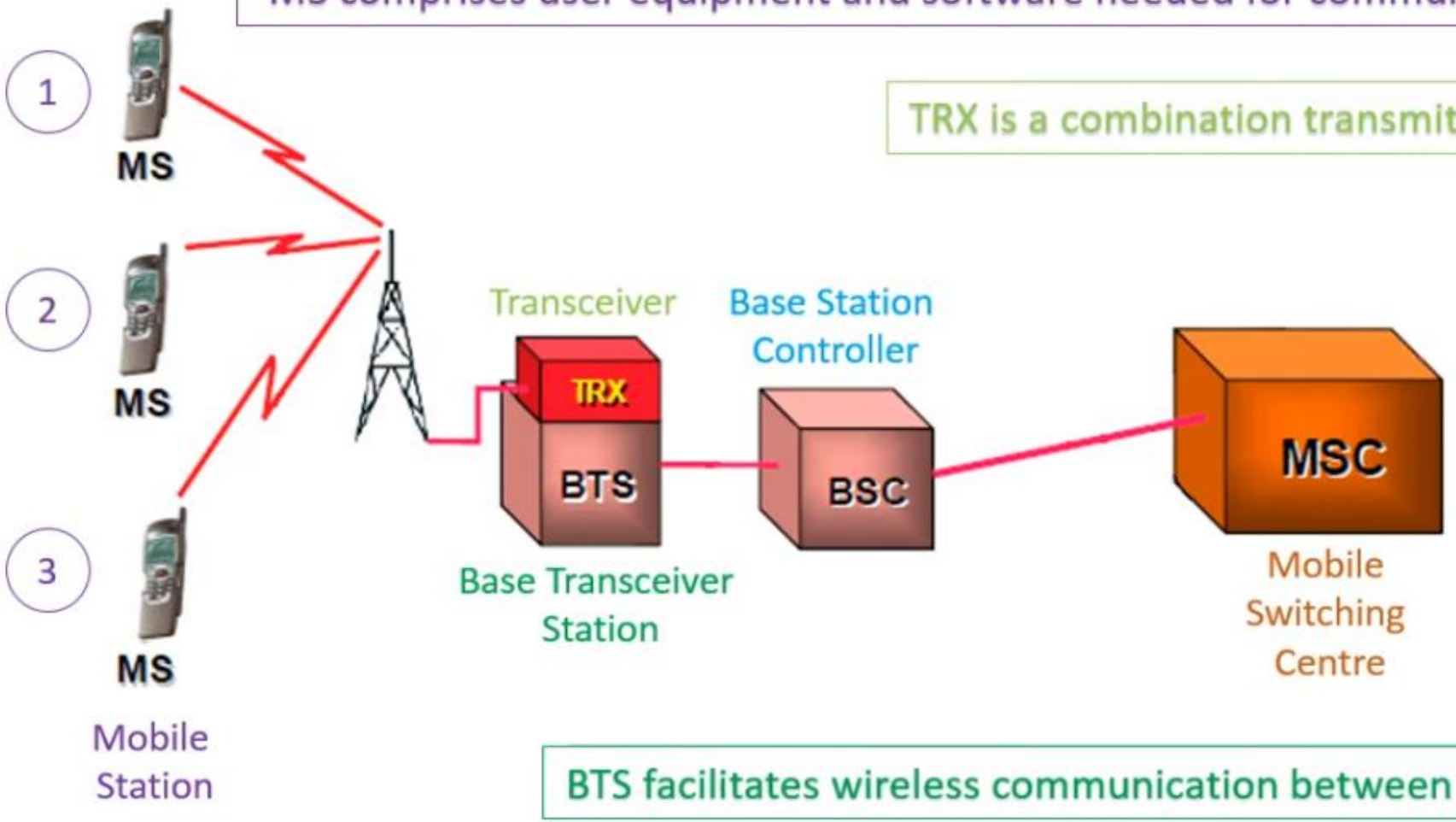


BTS Base transceiver station
BSC Base station controller
BSS Base station subsystem (BTS+BSC)
MSC Mobile switching center
GMSC Gateway MSC

GSM Architecture

MS Mobile station
HLR Home location register
VLR Visited location register
EIR Equiment identity register
AUC Authentication center

MS comprises user equipment and software needed for communication with a mobile network



TRX is a combination transmitter/receiver in a single package

Mobile Station (MS)
=
Mobile Equipment (ME)
+
Subscriber Identity Module (SIM)

BTS facilitates wireless communication between user equipment and a network

BSC controls one or more base transceiver stations (BTS)

MSC is associated with communication switching functions such as call set-up, release and routing

- A GSM network comprises of many functional units. These functions and interfaces are explained in this chapter. The GSM network can be broadly divided into –
- The Mobile Station (MS)
- The Base Station Subsystem (BSS)
- The Network Switching Subsystem (NSS)
- The Operation Support Subsystem (OSS)

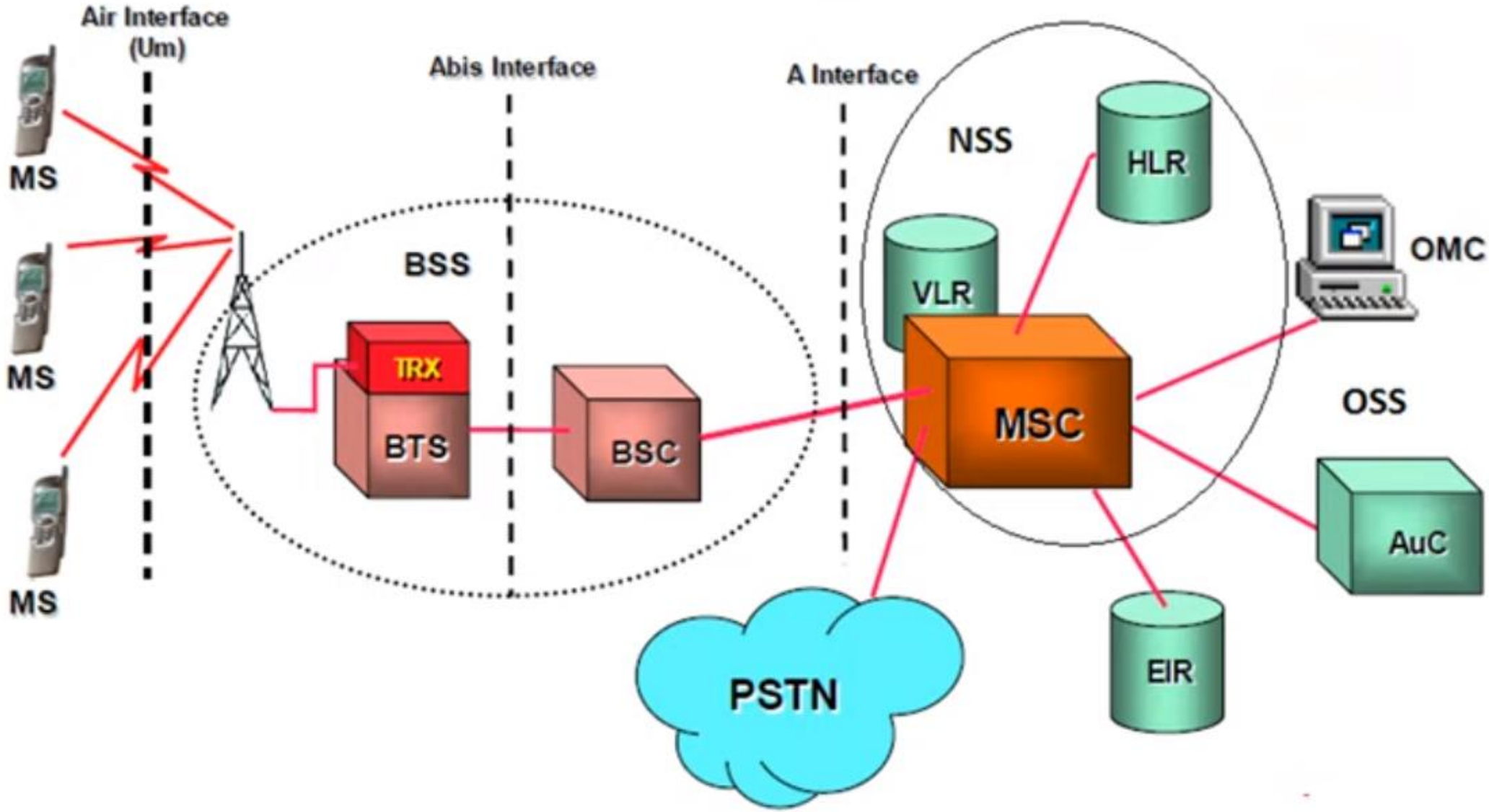
The Mobile Station

- The mobile station is a cell phone with a display, digital signal processor, and radio transceiver regulated by a SIM card that functions on a system.
- Hardware and the SIM card are the two most essential elements of the MS.
- The MS (Mobile stations) is most widely recognized by cell phones, which are components of a GSM mobile communications network that the operator monitors and works.

The base station system (BSS)

- It serves as a connection between the network subsystem and the mobile station. It consists of two parts:
- **The Base Transceiver Station (BTS):** The BTS is responsible for **radio connection protocols** with the MS and contains the cell's radio transceivers.
- Companies may implement a significant number of BTSs in a big metropolitan area.
- Each network cell has transceivers and antennas that make up the BTS.

- **The Base Station Controller (BSC):** The BSC is responsible for managing the radio resources of one or more BTS(s).
- This manages radio channel configuration and handovers. The BSC serves as the link seen between mobile and MSC.
- Additionally, the BSC is responsible for intercell handover and transmits the BSS and MS power within its jurisdiction.



GSM Architecture

The network switching system (NSS)

- NSS is a GSM element that provides flow management and call processing for mobile devices moving between base stations.
- **Mobile Services Switching Center (MSC)**: Mobile Switching Center is integral to the GSM network architecture's central network space.
- The MSC supports call switching across cellular phones and other fixed or mobile network users.
- It also monitors cellular services, including registration, location updates, and call forwarding to a roaming user.

Home Location Register (HLR):

- **I**t is a set of data items used for storing and managing subscriptions.
- It provides data for each consumer as well as their last known position.
- The HLR is regarded as the most significant database because it preserves enduring records about users.
- When a person purchases a membership from one of the operators, they are enlisted in that operator’s HLR.

Visitor Location Register (VLR):

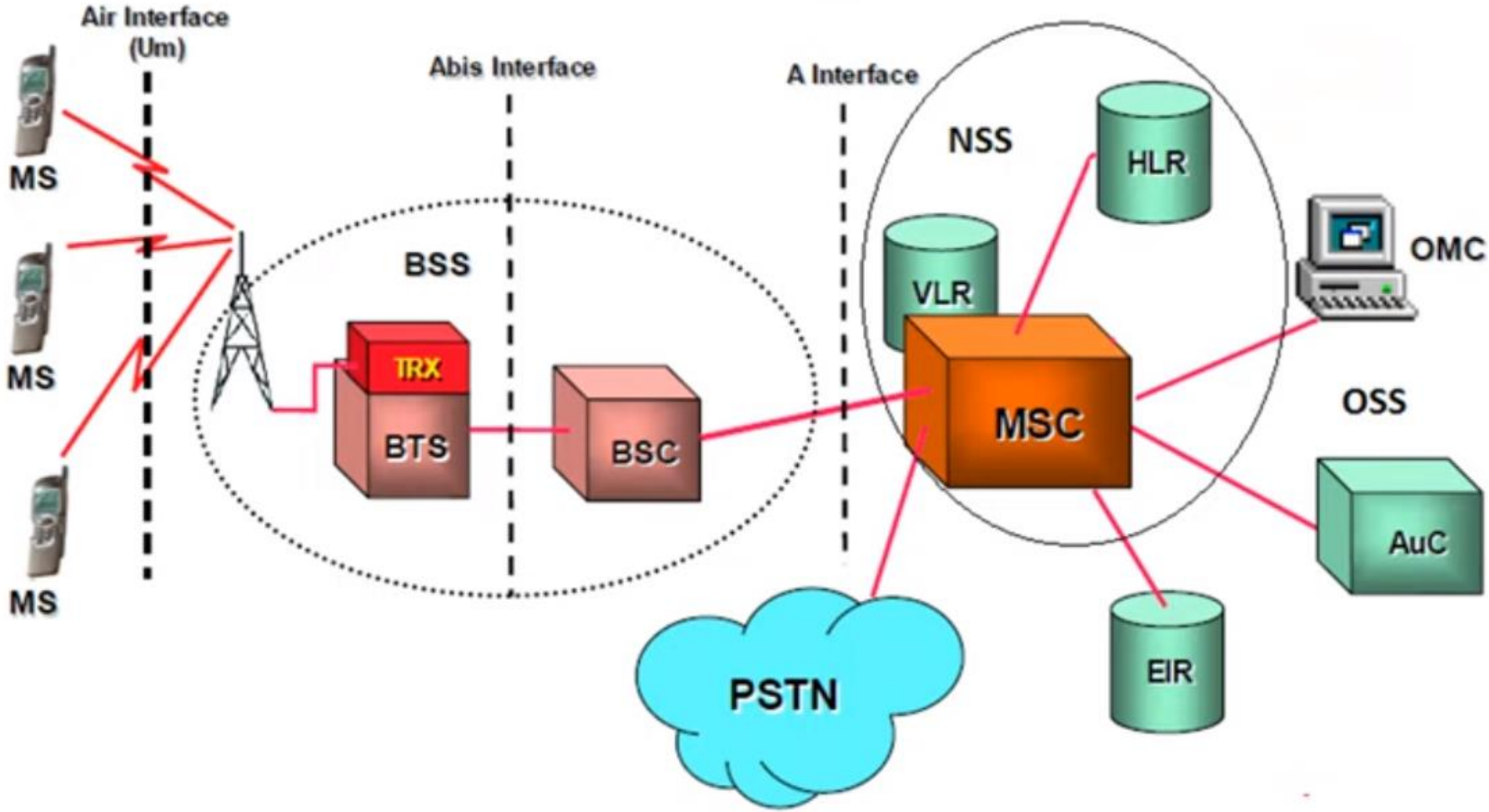
- VLR is a database that provides subscriber information necessary for the MSC to service passengers.
- This includes a short-term version of most of the data stored in the HLR.
- The visitor location register can also be run as a standalone program, but it is usually implemented as a component of the MSC.

Equipment Identity Register (EIR):

- It is the component that determines if one can use particular mobile equipment on the system.
- This consists of a list of every functioning mobile device on the system, with each mobile device recognized by its own International Mobile Equipment Identity (IMEI) number.

Authentication Center (AuC):

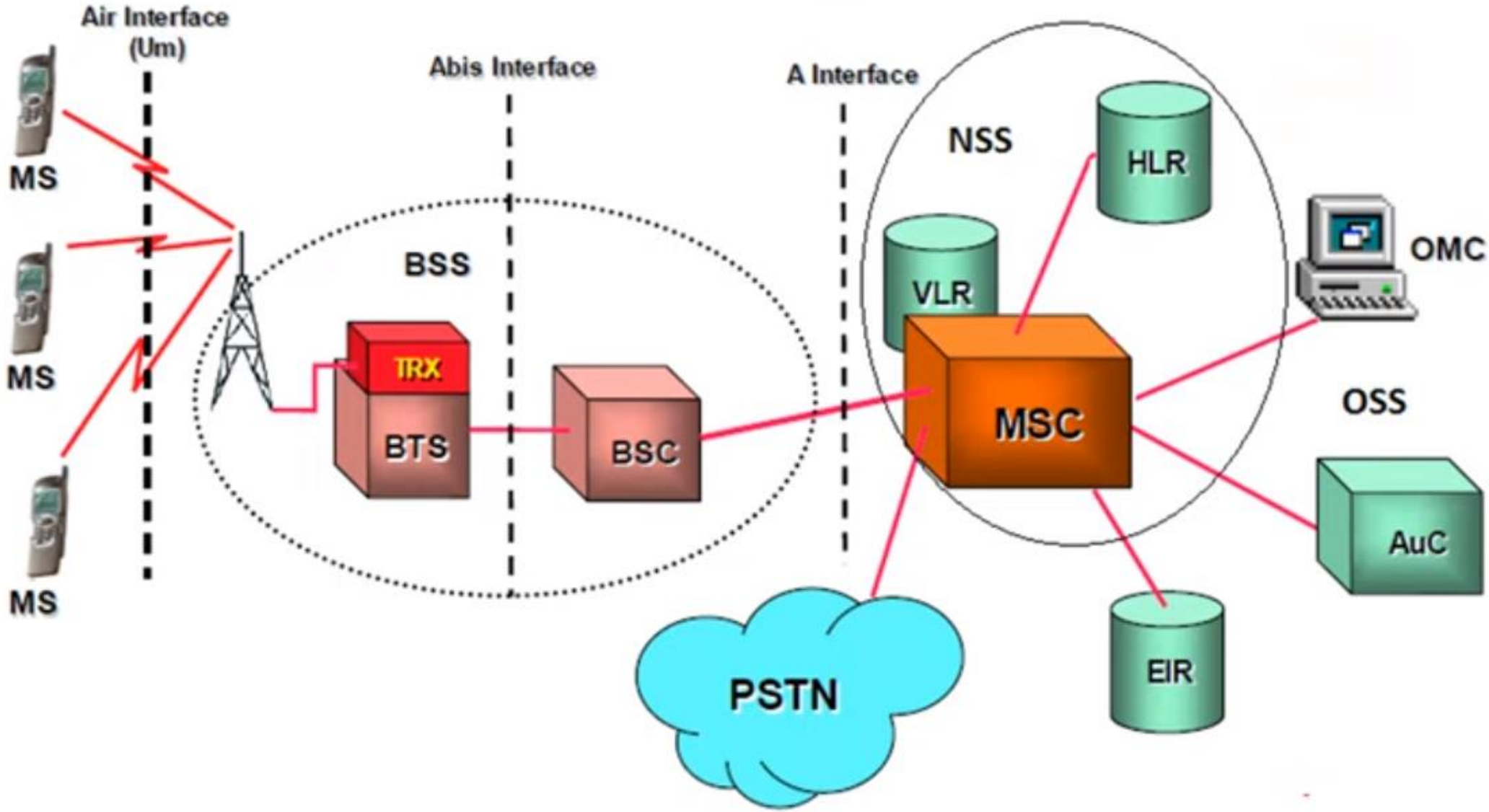
- The AUC is a unit that offers verification and encryption factors to ensure the user's identity and the privacy of every call.
- The verification center is a secure file that contains the user's private key in the SIM card.
- The AUC shields network operators from various types of fraud prevalent in the modern-day cellular world.



GSM Architecture

The operations and support system (OSS)

- The operation support system (OSS) is a part of the overall GSM network design.
- This is linked to the NSS and BSC components. The OSS primarily manages the GSM network and BSS traffic load.
- As the number of BS increases due to customer population scaling, a few maintenance duties are shifted to the base transceiver stations, lowering the system’s financial responsibility.
- The essential purpose of OSS is to have a network synopsis and assist various services and maintenance organizations with their routine maintenance arrangements.



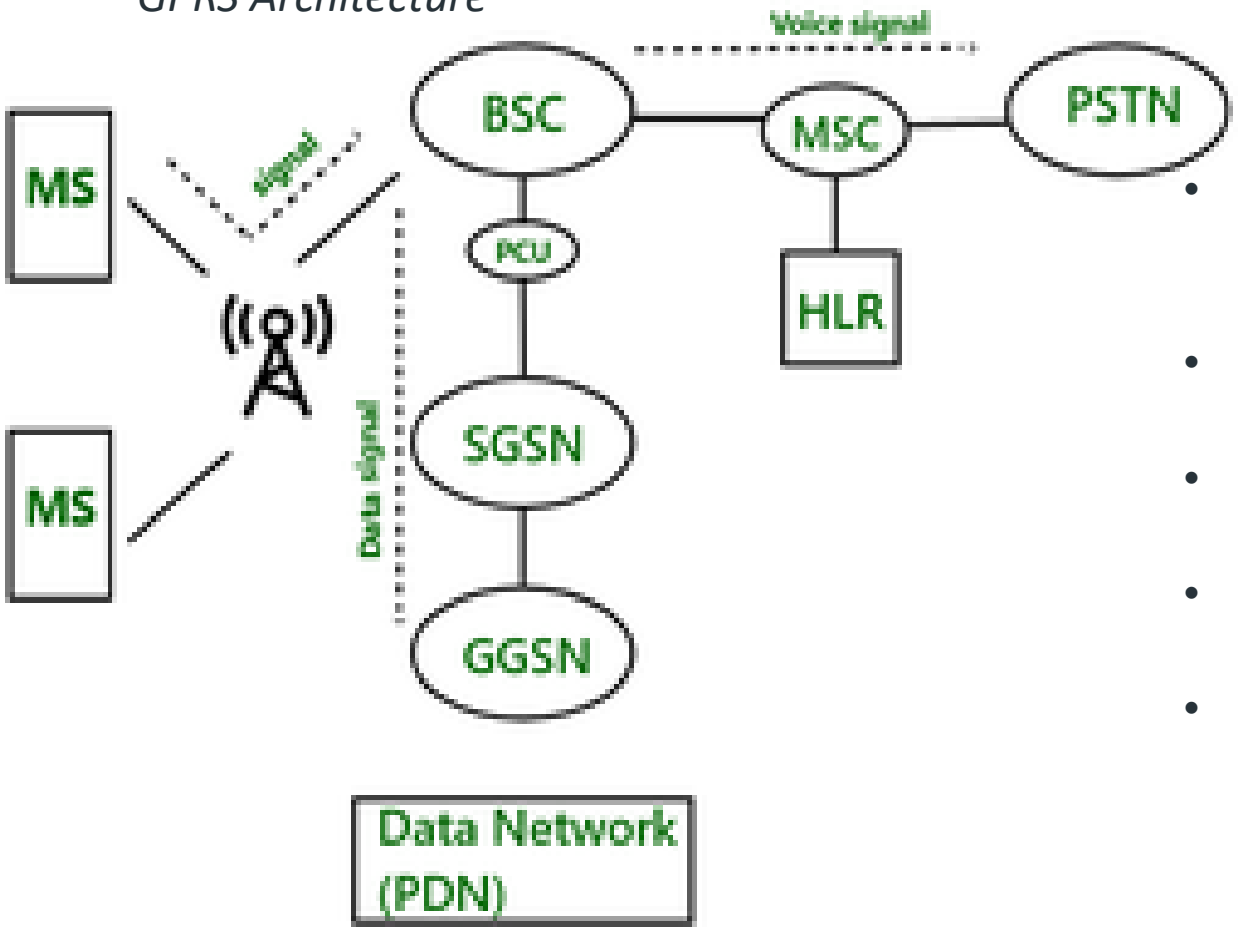
GSM Architecture

GSM interface	Description with position
Um	It is the air interface used between MS and BTS.It carries the GSM bursts carrying data and control information. Also referred as Air interface.
A or **Asub**	It is used between BSC and MSC/VLR. It supports 2Mbps standard digital connection as per CCITT. (Consultative committee on international telegraphy and telephony)
Abis	It is used between BTS and BSC. It supports two types of communication links viz. traffic channel at 64 kbps and signaling channel at 16 kbps.

GPRS

- **GPRS** stands for **General Packet Radio Service**. It is the modified version of GSM architecture service.
- In GSM architecture we can only transport the voice signal. But if signal consists of the data then only GSM architecture cannot use.
- For that there are two more software components are used, SGSN (Serving GPRS supporting Node) and GGSN (Gateway GPRS supporting Node).

GPRS Architecture



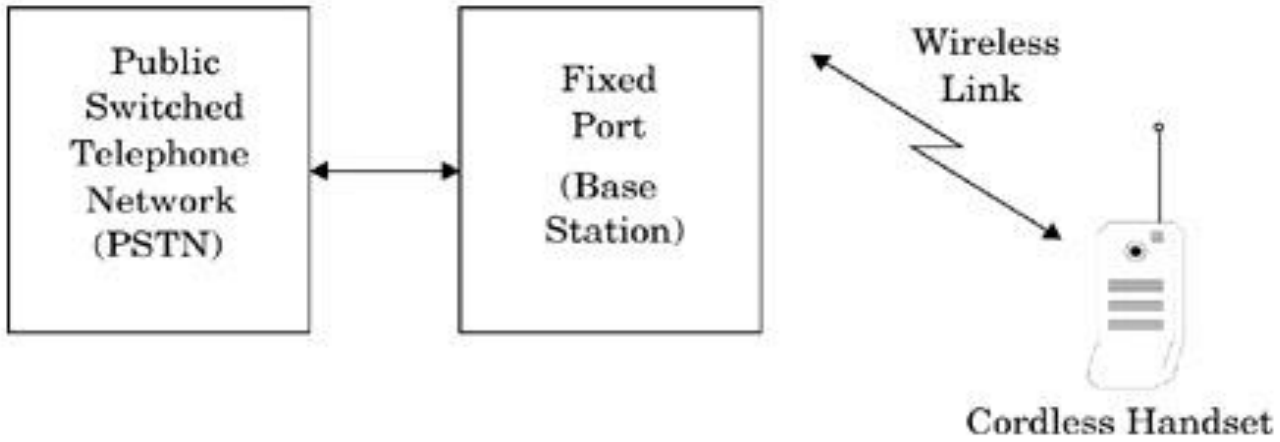
- In GSM architecture there is one component called BSC. But in GPRS there is one component is added to BSC called PCU. PCU stands for Packet Control Unit.
- If signal comes to BSC and that signal contains data, then PCU routes to the SGSN.
- Interface is used between BSC and PCU is FRI (fly-robot interface) interface.
- After signal comes to SGSN, it delivers the data packet to the GGSN.
- GGSN routes the data packet to the data network (PDN-Predefined Data Network).

Task of SGSN (Serving GPRS supporting Node)**:**
1.Packet Delivery
2.Data Compression
3.Authentication of GPRS users
4.Registration of mobile in network
5.billing

Task of GGSN (Gateway GPRS supporting Node**):**
1.Mediator between GPRS between backbone and external data networks.
2.Saves current data for the SGSN address of the participant as well as their profile and data for authentication and invoice.

Cordless System

- Unlike a corded telephone, a cordless telephone needs mains electricity to power the base station.
- The cordless handset is powered by a rechargeable battery, which is charged when the handset sits in its cradle.



•1st generation cordless telephone systems could cover only distance of a few ten meters(approximately 50m)and can be operated solely as extension telephones to a transceiver connected to a subscriber line on the PSTN and are primarily for in-home use.

•2nd generation cordless telephone systems could cover distance of a few hundred meters which allows subscribers to use their handsets at many outdoor locations within urban centers.

•Cordless telephone systems provide the user with limited range and mobility, as it is not possible to maintain a call if the user travels outside the range of the base station.

•Cordless Telephone Systems are full duplex communication systems that use radio to connect a portable handset to a dedicated base station, which is also connected to a dedicated telephone line with a specific telephone number on PSTN.

•The fixed port of a cordless telephone is nothing but the base unit on which cordless handset is placed, is connected to a telephone line and an adapter to produce a dc supply for various electronic circuits inside the base unit.

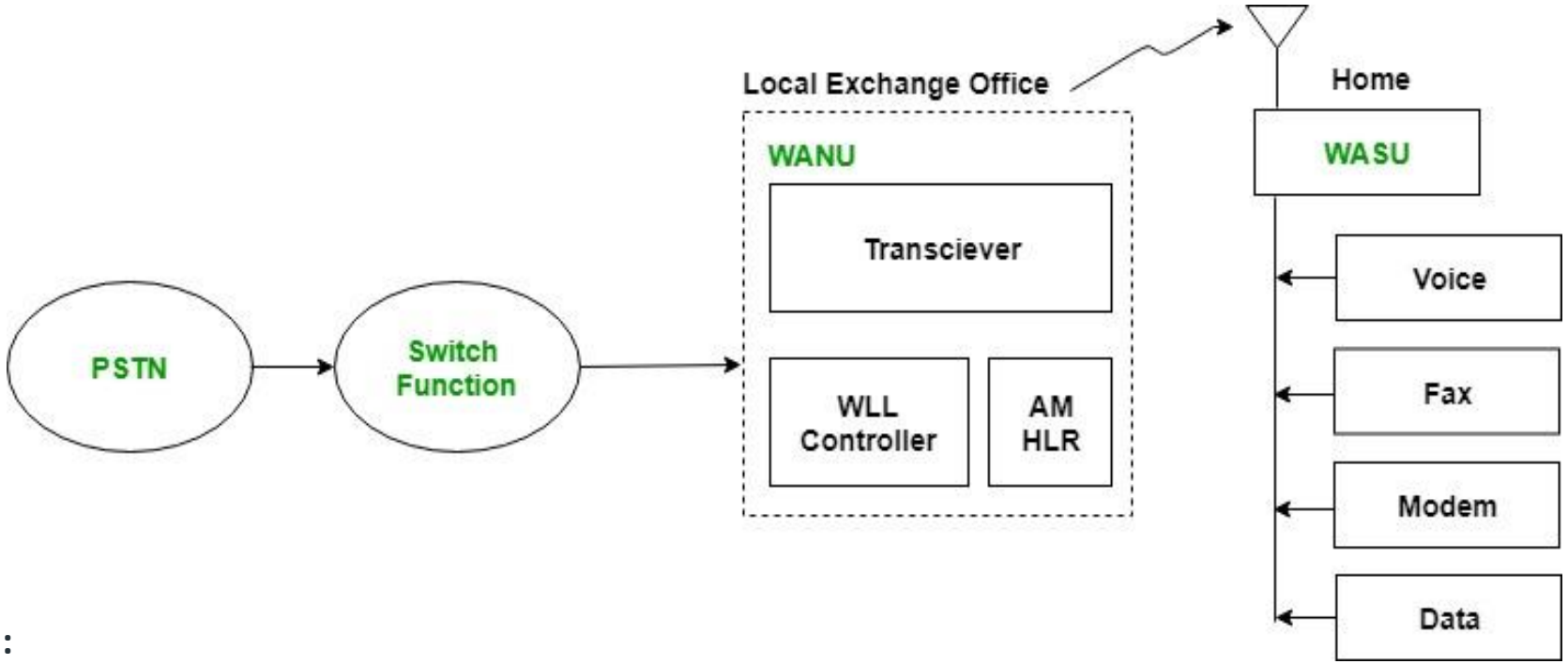
•The communication between the base unit and the handset is wireless and the range is limited to 50 meters.

•In the base unit all call processing circuits like amplifiers. In addition a transceiver is also present which is used for communication with the handset.

•In handset also the transceiver along with an antenna, amplifier, microphone and loud speaker are present.

Wireless Local Loop

- Local loop is a circuit line from a subscriber’s phone to the local central office (LCO).
- But the implementation of local loop of wires is risky for the operators, especially in rural and remote areas due to less number of users and increased cost of installation.
- Hence, the solution for it is the usage of wireless local loop (WLL) which uses wireless links rather than copper wires to connect subscribers to the local central office.



1.PSTN:

It is Public Switched Telephone Network which is a circuit switched network. It is a collection of world's interconnected circuit switched telephone networks.

2.Switch Function:

Switch Function switches the PSTN among various WANUs.

3.WANU:

It is short for Wireless Access Network Unit. It is present at the local exchange office. All local WASUs are connected to it. Its functions includes: Authentication, Operation & maintenance, Routing, Transceiving voice and data. It consists of following sub-components:

1. Transceiver: It transmits/receives data.
2. WLL Controller: It controls the wireless local loop component with WASU.
3. AM: It is short for Access Manager. It is responsible for authentication.
4. HLR: It is short for Home Location Register. It stores the details of all local WASUs.

4.WASU:

It is short for Wireless Access Subscriber Units. It is present at the house of the subscriber. It connects the subscriber to WANU and the power supply for it is provided locally.

Advantages of WLL:

- It eliminates the first mile or last mile construction of the network connection.
- Low cost due to no use of conventional copper wires.
- Much more secure due to digital encryption techniques used in wireless communication.
- Highly scalable as it doesn’t require the installation of more wires for scaling it.

Features of WLL:

•Internet connection via modem
•Data service
•Voice service
•Fax service