UNIT-V **12 Hours**

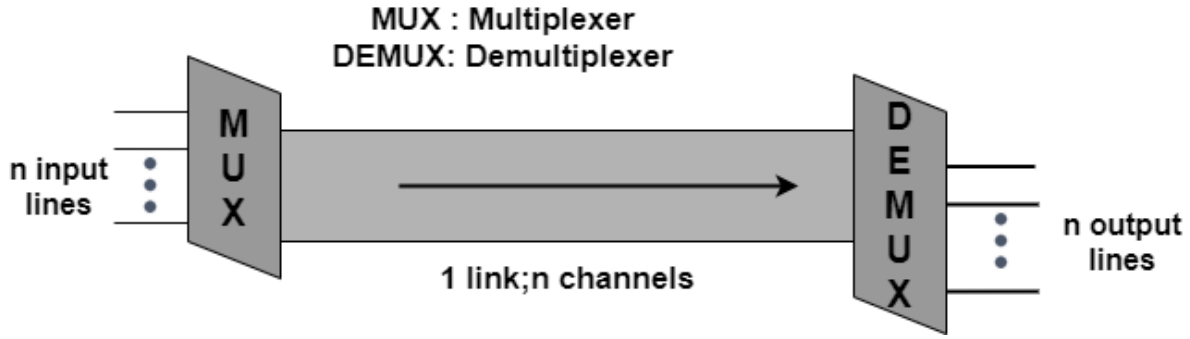
Multiplexing: Frequency-Division Multiplexing, Synchronous Time-Division Multiplexing: Characteristics, TDM Link Control, Digital Carrier Systems Statistical Time-Division Multiplexing: Characteristics, The Concept of Spread Spectrum, Frequency Hopping Spread Spectrum, Direct Sequence Spread Spectrum, Code-Division Multiple Access.

Multiplexing

- The set of techniques that allows the simultaneous transmission of multiple signals across a single data link is commonly referred to as Multiplexing.
- Multiplexing is done by using the hardware that is called as Multiplexer**(MUX)**.
- The Multiplexer**(MUX)** mainly combines 'n' input lines in order to generate '1' output line**(this is simply many-to-one)** on the sender side.
- And on the receiver side, this stream is fed into the demultiplexer**(DEMUX)**, which then separates the stream back to its component transmission **(this is one-to-many)** and then directs them to their corresponding lines.

The main aim of the multiplexing technique is to share **scarce resources**.

Let us understand with the help of a diagram given below to divide 1 link into n channels:



In the above diagram, the word link refers to the physical path, and the word channel simply refers to the portion of the link that carries a transmission between a given pair of lines. Thus 1 link can have many channels.

History of the Multiplexing

In telecommunications, several telephone calls may be carried by using a single wire. Also, Multiplexing was originated in telegraphy in the 1870s. Now, this technique is widely applied in communications. George Owen Squier in telephony was credited with the development of telephone carrier multiplexing in the year 1910.

Need for the Multiplexing

- As we have already told you that multiplexing is basically a set of techniques that mainly allows the transmission of multiple signals simultaneously across a signals data link.

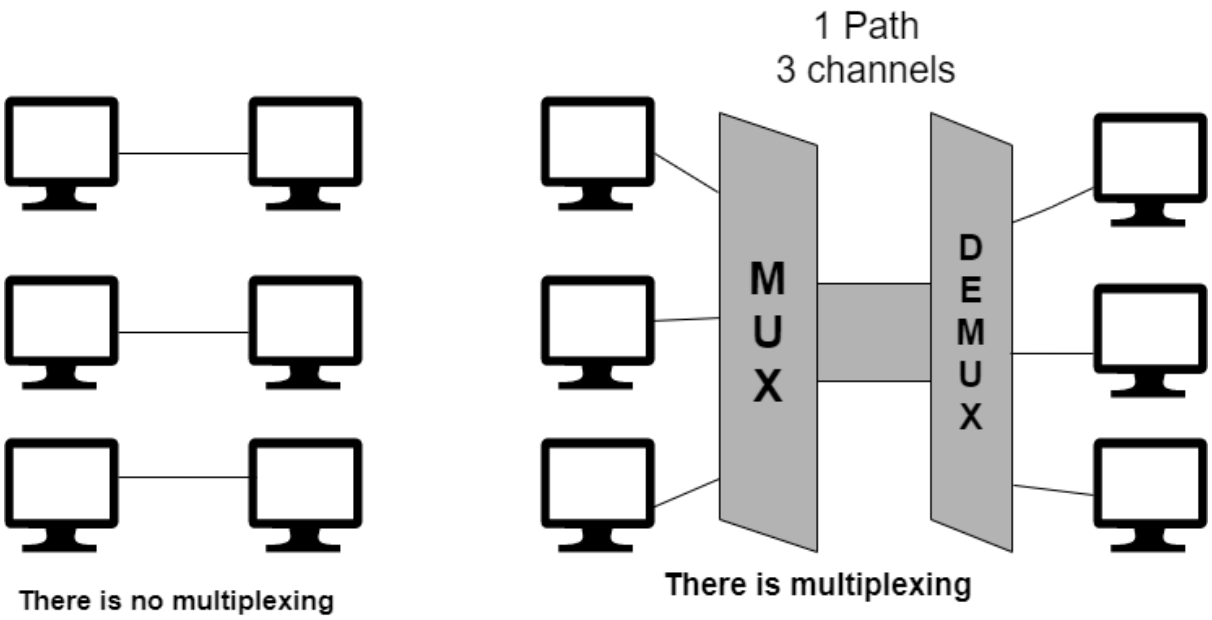
- At the time when there is a need to transmit many signals from the sender side that sends simultaneously then multiplexer is used to convert many signals into one so that on the receiving end we can get them simultaneously.
- As it is very expensive to send many signals differently and it also requires more wires to send. Thus there is a need for multiplexing. Let us take an example of T.V cable distributor who sends many channels through a single wire.

Advantages of Multiplexing

Given below are some advantages of using Multiplexing:

- With the help of multiplexing, more than one signal can be sent easily over a single medium or link.
- Multiplexing helps in the effective utilization of the bandwidth of the medium.

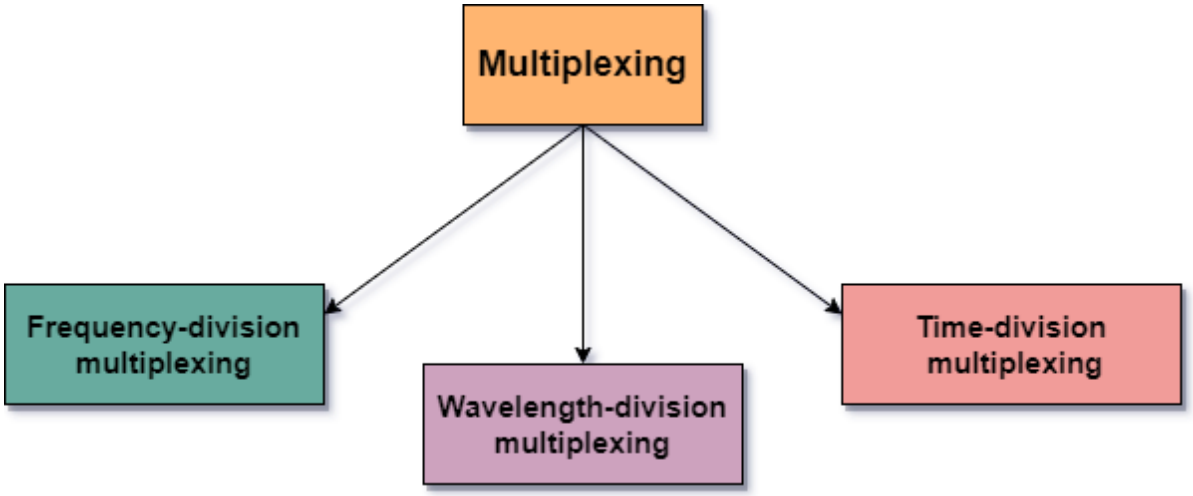
Let us take a look at the given below figure to understand multiplexing vs no-multiplexing:



Categories of Multiplexing

Let us take a look at the different categories of Multiplexing:

- Frequency-division multiplexing
- Wavelength-division multiplexing
- Time-division multiplexing



Let us discuss all the above-given categories one by one in the following sections.

1.Frequency-Division Multiplexing

Frequency-Divison Multiplexing i.e **FDM** is an **analog technique.**

- With this technique, signals having different frequencies are combined in a composite signal and then transmitted on the link
- It is mainly **applied at the time** when the **bandwidth of the link is greater than the combined bandwidths of the signal** to be transmitted.
- In this, each signal is of a different frequency.
- The channel is usually separated by the strips of unused bandwidth that is the **guard bands** in order to prevent the signals from overlapping.
- In the case of frequency division multiplexing, suppose the input signal is in the digital form then it must be converted to analog before giving it as the input to the modulator.

Frequency Division Multiplexing

From the above diagram, in **FDM** the transmission path is divided into **three parts** and each part mainly **represents a channel** that carries **one transmission**.

Advantages

Given below are some advantages of using FDM:

- The Simultaneous transmission of a large number of signals is done easily.
- The demodulation of FDM multiplexing is easy.
- There is no need for synchronization between the transmitter and receiver for proper operation.
- In the case of slow narrowband fading, there is only one single channel that gets affected.

Disadvantages

There are some drawbacks of using FDM:

- Communication channels must have a very large bandwidth.
- There occurs the problem of crosstalk while using FDM.
- In the case of wideband fading, all channels in the FDM gets affected.
- There is a need for a large number of filters and modulators.

Applications

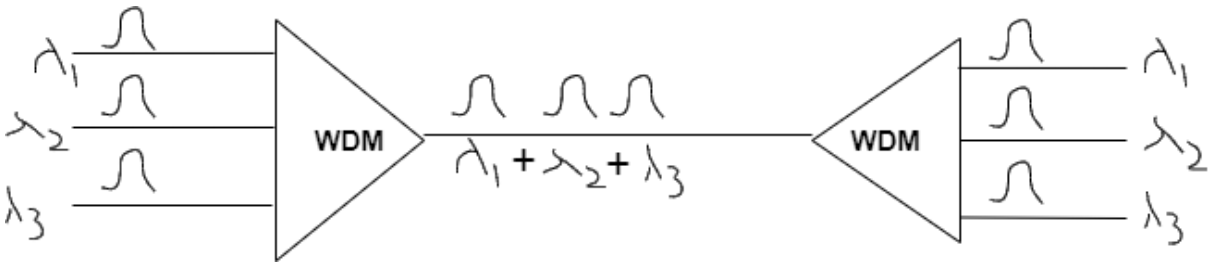
The main applications of FDM are as follows:

- One of the main applications of FDM is that it is AM and FM radio broadcasting.
- Another application of FDM is that it is used in television broadcasting.
- FDM is also used by first-generation cellular telephones.

2.Wavelength-Division Multiplexing

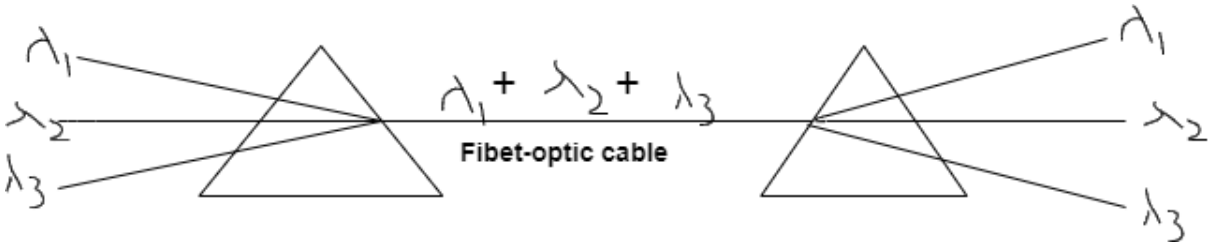
Wavelength-Divison Multiplexing i.e **WDM** is an **analog technique.**

- This technique is **similar to FDM**.
- With the help of Wavelength Divison multiplexing **different signals** that include: **optical or light** signals are transmitted **through the Optical fiber.**
- With the help of the WDM technique, the high data rate capability of optical fiber cable gets utilized.
- With this technique, various light waves from different sources are combined into a composite light signal and this signal is transmitted across the channel to the receiver.
- On the receiver side, this composite light signal gets broken down into different light waves with the help of Demultiplexer.
- The process of combining and splitting the light waves is done with the help of **Prism.**
- This Prism helps to bend the beam of light on the basis of the angle of incidence and frequency of light.
- In the WDM technique mainly the role of the multiplexer is played by the Prism and it then combines the various optical signals in the order to form a composite signal after that this composite signal is transmitted through an Optical fiber cable.



The above Figure indicates Wavelength Divison Multiplexing

Let us take a look at the diagram given below where we will use prism for wavelength-division multiplexing and demultiplexing.



Advantages

Given below are some advantages of using WDM:

- With the help of WDM, the full-duplex transmission is possible.
- WDM is easy to reconfigure.
- Various Signals can be transmitted simultaneously with the help of WDM.
- This technique is less expensive and the expansion of the system is easy.
- This technique provides high security.
- As we are using an optical fiber in WDM; also Optical components are more reliable and they also provide high bandwidth.

Disadvantages

There are some drawbacks of using WDM:

- There is the use of optical equipment so cost increases.
- Utilization of bandwidth can be inefficient which causes difficulty in wavelength tuning.
- The main concern in this technique is scalability.

3.Time-Division Multiplexing

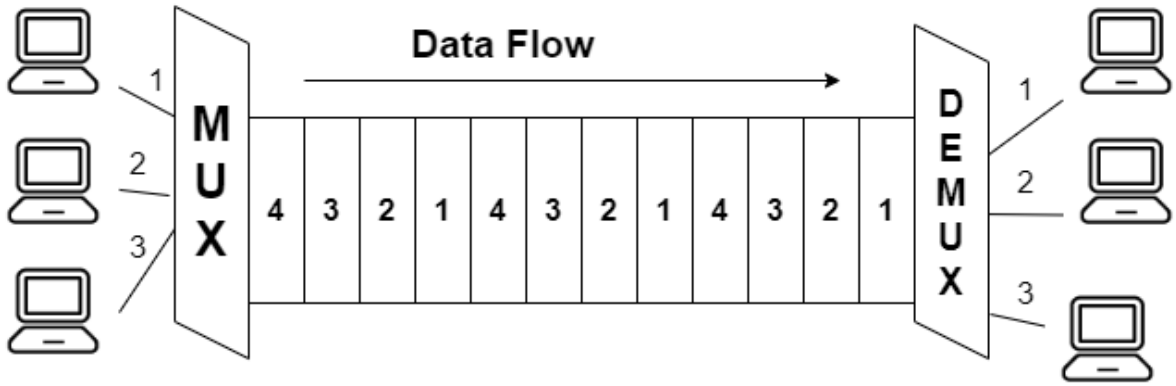
Time-Divison multiplexing is a digital technique for multiplexing.

- In this technique, the channel/link is divided on the basis of time instead of frequency.

- The total available time on the channel is divided between the different users on the channel.
- A particular time interval is allotted to each user on the channel and it is known as time slot/slice.
- In the time-division multiplexing, the data rate capacity should be much greater than the data rate that is required by the sending and receiving device.

TDM is further categorized into two:

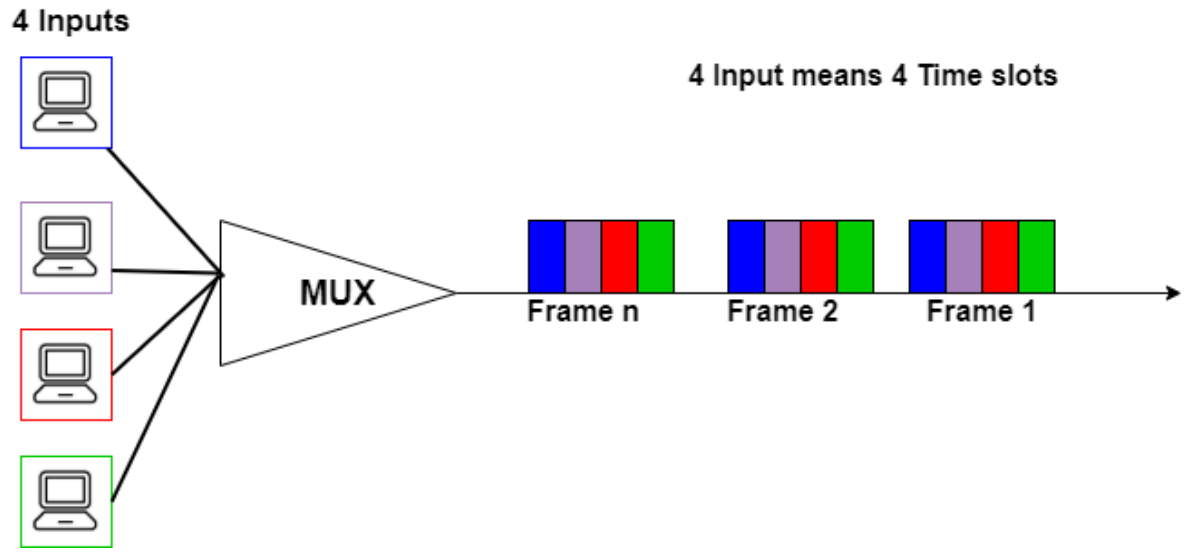
- Synchronous Time-Divison Multiplexing
- Asynchronous Time-Divison Multiplexing



1.**Synchronous Time-Divison Multiplexing**

In Synchronous TDM, each of the Input connection has an allotment in the output even if it is not sending the data.

- In this multiplexing, each device is given the same time slot in order to transmit data over the link whether it has to send data to the receiver or not.
- Each device places data on the link whenever its time slot arrives Thus control is given to each device turn by turn.
- In case if any devices do not have any data to send then in that case the time slot for that device remains empty.
- In this multiplexing, if there are 'n' sending devices then simultaneously there will be 'n' time slots which means one time slot for each device.
- Also, time slots are organized in the form of frames, where each frame consists of one or more time slots.



Advantages

- This technique is easy to implement.
- The performance is guaranteed in using this technique.

Disadvantages

- If a user has no data to transmit in that case time slots will get wasted.
- In this multiplexing, the capacity of the transmission link must be always higher than the total capacity of the input lines.

2.**Asynchronous Time-Divison Multiplexing**

Another name of Asynchronous TDM is Statical Time Divison Multiplexing. In this time slots are not fixed, rather time slots are allocated dynamically in order to improve the efficiency of bandwidth.

- The total speed of all the Input lines can be greater than the capacity of the path.
- In this Multiplexing, there are n input lines and m slots; thus always (m<n).
- There is no concept of predefined slots rather than slots are allocated dynamically on demand.
- In this multiplexing, the multiplexor mainly accepts the incoming input data and then it creates a frame that contains only data without any empty slots.
- Each slot mainly contains the address part that is used to identify the source of the input data.
- The number of frames in this multiplexing depends upon the statical analysis of the number of input lines.

Thus in the above diagram, out of 6 only 4 devices are sending data that are 1,2,4,6. In the above diagram, you can see that the data part contains the address in order to determine the source of the data. Like **A1**(data along with its source).

Advantages

- In this multiplexing, there is an efficient use of the capacity of transmission.

Disadvantages

- In this Multiplexing, frames are of different sizes.
- There is a need for the buffer address information is also needed because there are no separate slots assigned for each user.
- This technique does not provide a fixed waiting time guarantee.

Spread Spectrum in Mobile Computing

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, electromagnetic signal, or acoustic 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."

Now, spread spectrum technology is widely used in radio signals transmission because it can easily reduce noise and other signal issues.

Example of Spread Spectrum

Let's see an example to understand the concept of spread spectrum in wireless communication:

We know that a conventional wireless signal frequency is usually specified in megahertz **(MHz)** or gigahertz **(GHz).** It does not change with time (Sometimes it is exceptionally changed in the form of small, rapid fluctuations that generally occur due to modulation). Suppose you want to listen to FM stereo at frequency 104.8 MHz on your radio,

and then once you set the frequency, the signal stays at 104.8 MHz. It does not go up to 105.1 MHz or down to 101.1 MHz. You see that your set digits on the radio's frequency dial stay the same at all times. The frequency of a conventional wireless signal is kept as constant to keep bandwidth within certain limits, and the signal can be easily located by someone who wants to retrieve the information.

In this conventional wireless communication model, you can face at least two problems:

1. A signal whose frequency is constant is subject to catastrophic interference. This interference occurs when another signal is transmitted on or near the frequency of a specified signal.
2. A constant-frequency signal can easily be intercepted. So, it is not suitable for the applications in which information must be kept confidential between the source (transmitting party) and the receiver.

The spread spectrum model is used to overcome with this conventional communication model. Here, the transmitted signal frequency is deliberately varied over a comparatively large segment of the electromagnetic radiation spectrum. This variation is done according to a specific but complicated mathematical function. If the receiver wants to intercept the signal, it must be tuned to frequencies that vary precisely according to this function.

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.

Usage of Spread Spectrum

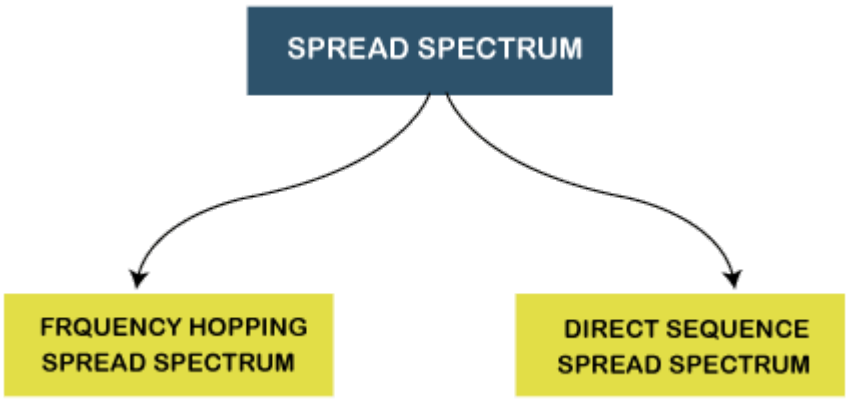
There are many reasons to use this spread spectrum technique for wireless communications. The following are some reasons:

- It can successfully establish a secure medium of communication.
- It can increase the resistance to natural interference, such as noise and jamming, to prevent detection.
- It can limit the power flux density (e.g., in satellite down links).
- It can enable multiple-access communications.

Types of Spread Spectrum

Spread Spectrum can be categorized into two types:

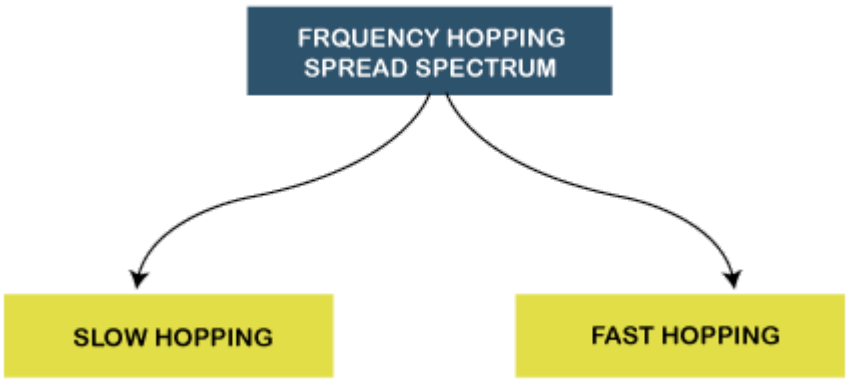
- Frequency Hopping Spread Spectrum (FHSS)
- Direct Sequence Spread Spectrum(DSSS)



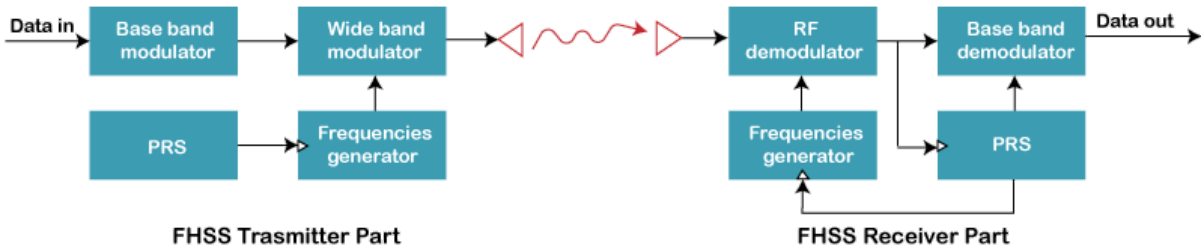
Frequency Hopping Spread Spectrum (FHSS)

- 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.

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.



Advantages of Frequency Hopping Spread Spectrum (FHSS)

The following are some advantages of frequency hopping spread spectrum (FHSS):

- The biggest advantage of Frequency Hopping Spread Spectrum or FHSS is its high efficiency.
- The Frequency Hopping Spread Spectrum or FHSS signals are highly resistant to narrowband interference because the signal hops to a different frequency band.
- It requires a shorter time for acquisition.
- It is highly secure. Its signals are very difficult to intercept if the frequency-hopping pattern is not known; that's why it is preferred to use in Military services.
- We can easily program it to avoid some portions of the spectrum.
- Frequency Hopping Spread Spectrum or FHSS transmissions can share a frequency band with many types of conventional transmissions with minimal mutual interference. FHSS signals add minimal interference to narrowband communications, and vice versa.
- It provides a very large bandwidth.

- It can be simply implemented as compared to DsSS.

Disadvantages of Frequency Hopping Spread Spectrum (FHSS)

The following are some disadvantages of Frequency Hopping Spread Spectrum (FHSS):

- FHSS is less Robust, so sometimes it requires error correction.
- FHSS needs complex frequency synthesizers.
- FHSS supports a lower data rate of 3 Mbps as compared to the 11 Mbps data rate supported by DSSS.
- It is not very useful for range and range rate measurements.
- It supports the lower coverage range due to the high SNR requirement at the receiver.
- Nowadays, it is not very popular due to the emerging of new wireless technologies in wireless products.

Applications of Frequency Hopping Spread Spectrum (FHSS)

Following is the list of most used applications of Frequency Hopping Spread Spectrum or 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. In DSSS, the message bits are modulated by a bit sequencing process known as a spreading sequence. This spreading-sequence bit is known as a chip. It has a much shorter duration (larger bandwidth) than the original message bits. Following are the features of Direct Sequence Spread Spectrum or DSSS.

- 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.
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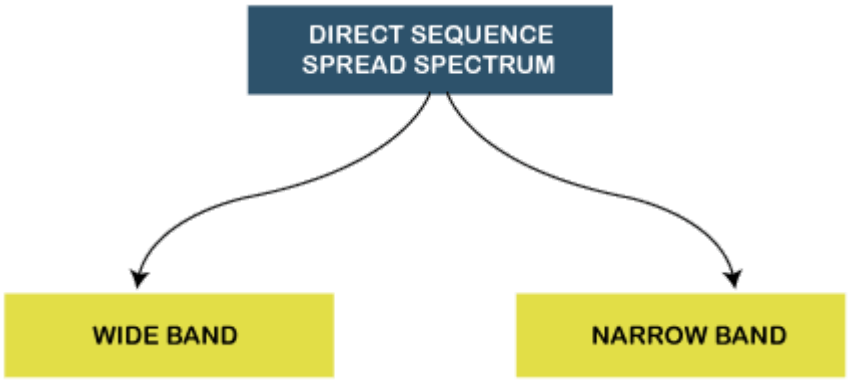
- If somehow data is lost, then data blocks can also be recovered with those data rate bits.
- The main advantage of splitting the data into smaller blocks is that it reduces the noise and unintentional inference.

The Direct Sequence Spread Spectrum or DSSS can also be classified into two types:

- Wide Band Spread Spectrum
- Narrow Band Spread Spectrum



Advantages of Direct Sequence Spread Spectrum (DSSS)

The following are some advantages of Direct Sequence Spread Spectrum or DSSS:

- Direct Sequence Spread Spectrum or DSSS is less reluctant to noise; that's why the DSSS system's performance in the presence of noise is better than the FHSS system.
- In Direct Sequence Spread Spectrum or DSSS, signals are challenging to detect.
- It provides the best discrimination against multipath signals.
- In Direct Sequence Spread Spectrum, there are very few chances of jamming because it avoids intentional interference such as jamming effectively.

Disadvantages of Direct Sequence Spread Spectrum (DSSS)

The following are some disadvantages of Direct Sequence Spread Spectrum or DSSS:

- The Direct Sequence Spread Spectrum or DSSS system takes large acquisition time; that's why its performance is slow.

- It requires wide-band channels with small phase distortion.
- In DSSS, the pseudo-noise generator generates a sequence at high rates.

Applications of Direct Sequence Spread Spectrum (DSSS)

Following is the list of most used applications of Direct Sequence Spread Spectrum or DSSS:

- Direct Sequence Spread Spectrum or DSSS is used in LAN technology.
- Direct Sequence Spread Spectrum or DSSS is also used in Satellite communication technology.
- DSSS is used in the military and many other commercial applications.
- It is used in the low probability of the intercept signal.
- It supports Code division multiple access.

Statistical time division multiplexing

- STDM is more efficient than standard TDM. In standard TDM, time slots are allotted to channels even when there is no data to transmit.
- This leads to wasted bandwidth. STDM was originally developed to address this inefficiency, where the time allocation to lines happens only when it is actually required.
- This is attained through intelligent devices that are ideal for identifying an idle terminal.

  STDM is same as TDM, with the exception that every signal is assigned a slot based on priority and demand. This indicates that STDM is an "on-demand" service as opposed to a fixed one.
- Standard TDM and various other circuit switchings are executed at the physical layer in the OSI and TCP/IP model, while STDM is executed at the data link layer and above.
- The MPEG transport stream used for digital TV transmission. STDM is used to permit multiple data, audio and video streams of different data rates to be broadcasted across a bandwidth-limited channel.

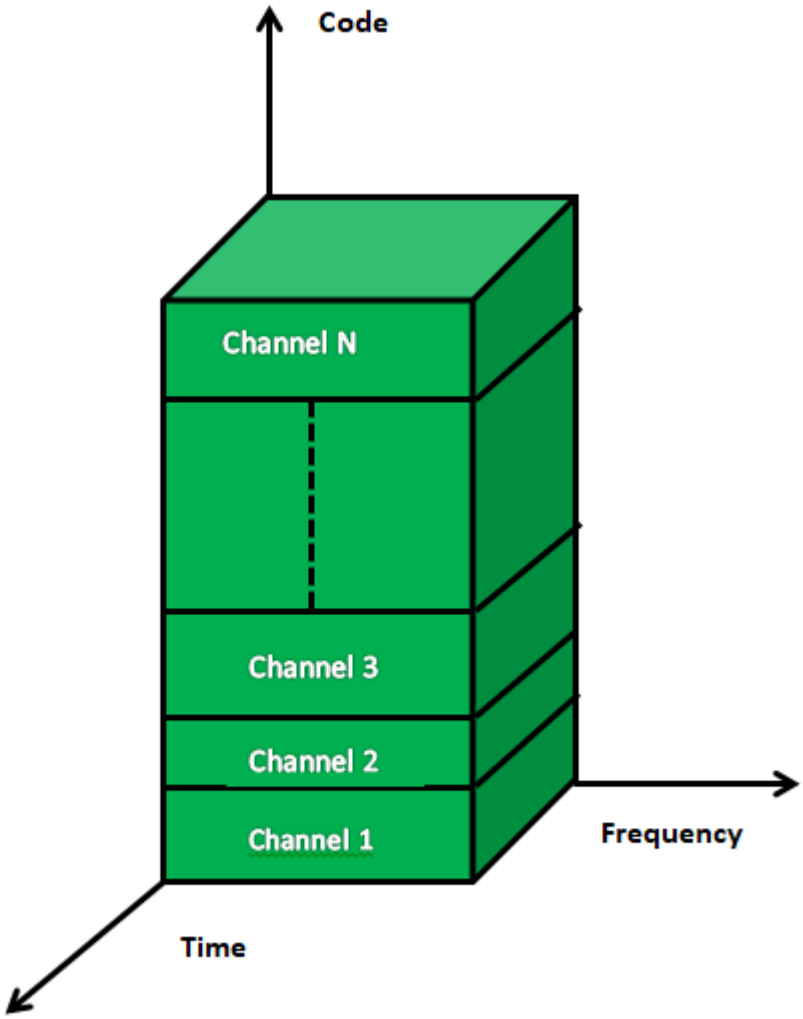
- The TCP and UDP protocols, in which data streams from various application processes are multiplexed together.
- The Frame relay packet-switching and X.25 protocols, in which the packets have different lengths.
- The Asynchronous Transfer Mode packet-switched protocol, in which the packets maintain a fixed length.

Code division multiple access

- 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. This method does not limit the frequency range of the user.
- Hence, with the help of CDMA, multiple users can share a band of frequencies without any kind of undue interference between them. CDMA makes the use of spectrum technology along with analog to digital conversion(ADC).
- It is thus used by various radio communication technologies. Mainly, it is used for mobile communication.

History

- CDMA technology has been in use for a long time. In 1935, the first time this subject was published by Dmitry Ageev. CDMA also came in use during the time of World War-II in order to stop the efforts of jamming transmissions.
- Thus it made its application in the military field and was used in anti-jamming, ranging, etc. It was used in 1957 by Leonid Kupriyanovich while he was making a model of automatic wearable mobile phone.
- Finally, in the year 1993, the Telecommunications Industry Association(TIA) approved the standards for CDMA technology. 16 million subscribers were recorded to use the CDMA systems in September 1998. Currently, CDMA is being supported by 22 countries.



Characteristics of CDMA

- It allows more users to connect at a given time and thus provides improved data and voice communication capacity.
- A full spectrum is used by all the channels in CDMA.
- CDMA systems make the use of power control to eliminate the interference and noise and to thus improve the network quality.
- CDMA encodes the user transmissions into distinct and unique codes in order to secure its signals.
- In CDMA systems all the cells can thus use the same frequency.
- CDMA systems have a soft capacity.Thus there is no particular limit to the number of users in a CDMA system but with increase in the number of users the performance degrades.

Advantages

- Increased user capacity is an advantage of the CDMA as it supports a lot more users in comparison to TDMA or FDMA.
- CDMA is more secure as the information transmitted is below the noise floor making the intrusion of the spectrum difficult.
- CDMA systems have comparatively fewer dropouts than GSM. Thus, it can also be used in rural areas.
- The cost of the calls in CDMA is lower in comparison to the cost in GSM.

- CDMA provides a high quality of voice with almost no noise during the calls.
- Using CDMA problems like multipath and fading do not occur.
- CDMA has a very low power requirement.

Disadvantages

- CDMA lacks the facility of international roaming which is provided by GSM.
- Since there is no limit to the number of users the system performance degrades with an increase in the number of users.
- Self-jamming problem occurs in CDMA systems because of loss of orthogonality.
- The problem of channel pollution occurs in CDMA systems which thus degrades the quality of audio.