Unit 2

B230503T Data and Communication Networks

Transmission Media: Guided and unguided, Attenuation. Distortion, noise, throughput, propagation speed and time, wavelength. Shannon Capacity and comparison of media.

What is Transmission media?

- Transmission media is a communication channel that carries the information from the sender to the receiver. Data is transmitted through the electromagnetic signals.
- The main functionality of the transmission media is to carry the information in the form of bits through LAN (Local Area Network).
- It is a physical path between transmitter and receiver in data communication.
- In a copper-based network, the bits in the form of electrical signals.
- In a fibre based network, the bits in the form of light pulses.
- In OSI (Open System Interconnection) phase, transmission media supports the Layer 1. Therefore, it is considered to be as a Layer 1 component.
- The electrical signals can be sent through the copper wire, fibre optics, atmosphere, water, and vacuum.
- The characteristics and quality of data transmission are determined by the characteristics of medium and signal.
- Transmission media is of two types are wired media and wireless media. In wired media, medium characteristics are more important whereas, in wireless media, signal characteristics are more important.
- Different transmission media have different properties such as bandwidth, delay, cost and ease of installation and maintenance.
- The transmission media is available in the lowest layer of the OSI reference model, i.e., Physical layer.

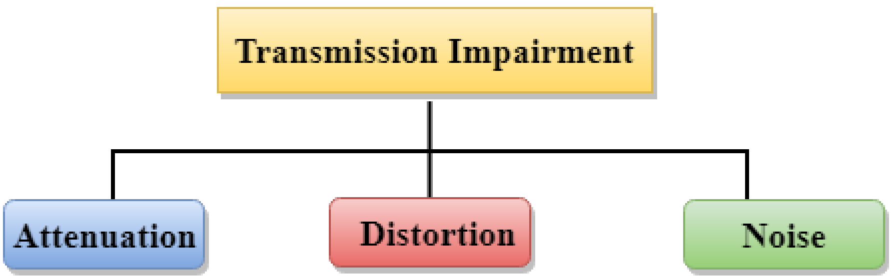
Some factors need to be considered for designing the transmission media:

Bandwidth: All the factors are remaining constant, the greater the bandwidth of a medium, the higher the data transmission rate of a signal.

Transmission impairment: When the received signal is not identical to the transmitted one due to the transmission impairment. The quality of the signals will get destroyed due to transmission impairment.

Interference: An interference is defined as the process of disrupting a signal when it travels over a communication medium on the addition of some unwanted signal.

Causes of Transmission Impairment:

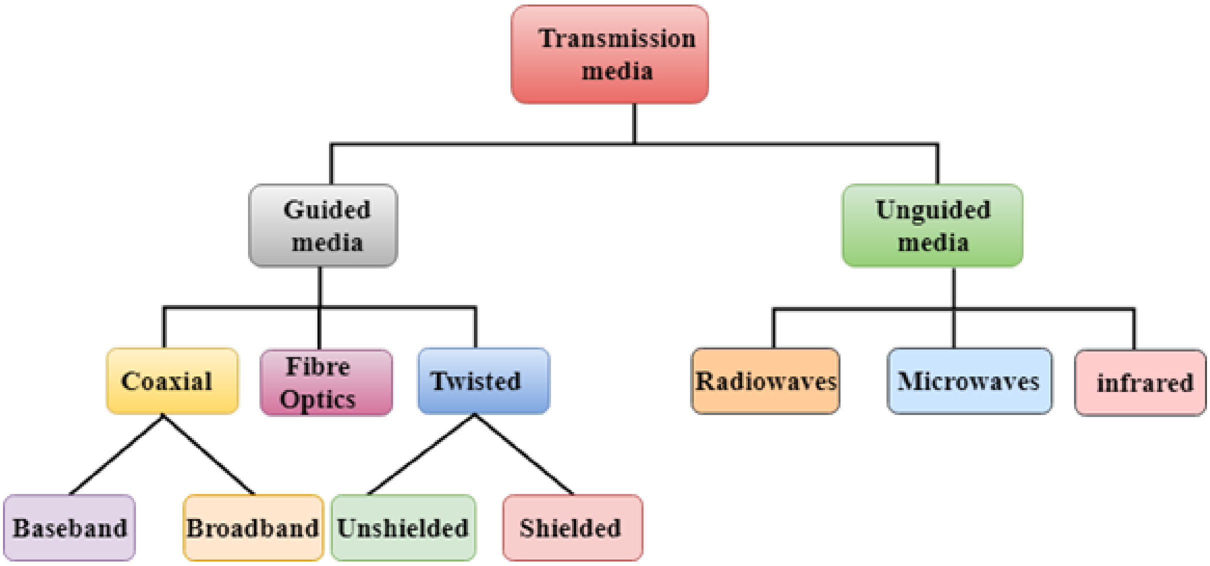


Attenuation: Attenuation means the loss of energy, i.e., the strength of the signal decreases with increasing the distance which causes the loss of energy.

Distortion: Distortion occurs when there is a change in the shape of the signal. This type of distortion is examined from different signals having different frequencies. Each frequency component has its own propagation speed, so they reach at a different time which leads to the delay distortion.

Noise: When data is travelled over a transmission medium, some unwanted signal is added to it which creates the noise.

Classification of Transmission Media:



Transmission media

Guided Transmission Media

UnGuided Transmission Media

Guided Media

It is defined as the physical medium through which the signals are transmitted. It is also known as Bounded media.

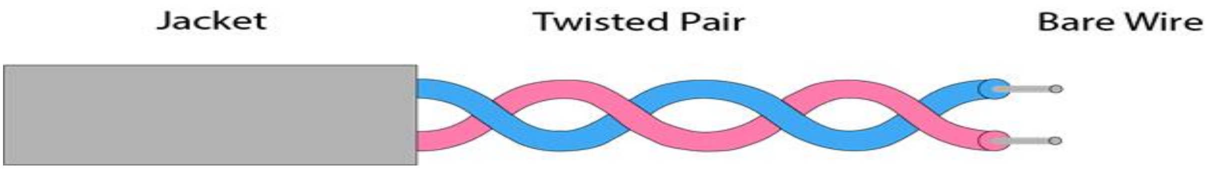
Types of Guided media:

Twisted pair:

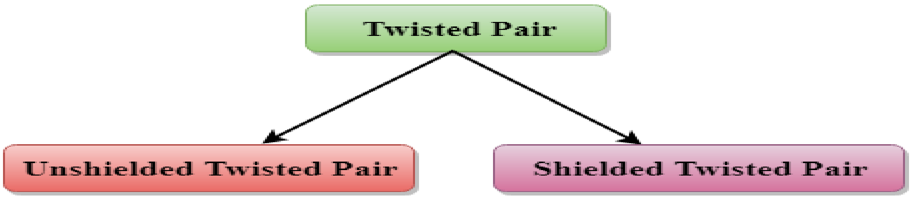
Twisted pair is a physical media made up of a pair of cables twisted with each other. A twisted pair cable is cheap as compared to other transmission media. Installation of the twisted pair cable is easy, and it is a lightweight cable. The frequency range for twisted pair cable is from 0 to 3.5 KHz.

A twisted pair consists of two insulated copper wires arranged in a regular spiral pattern.

The degree of reduction in noise interference is determined by the number of turns per foot. Increasing the number of turns per foot decreases noise interference.



Types of Twisted pair:



Unshielded Twisted Pair:

An unshielded twisted pair is widely used in telecommunication. Following are the categories of the unshielded twisted pair cable:

Category 1: Category 1 is used for telephone lines that have low-speed data.

Category 2: It can support upto 4Mbps.

Category 3: It can support upto 16Mbps.

Category 4: It can support upto 20Mbps. Therefore, it can be used for long-distance communication.

Category 5: It can support upto 200Mbps.

Advantages of Unshielded Twisted Pair:

- It is cheap.
- Installation of the unshielded twisted pair is easy.
- It can be used for high-speed LAN.

Disadvantage:

This cable can only be used for shorter distances because of attenuation.

Shielded Twisted Pair

A shielded twisted pair is a cable that contains the mesh surrounding the wire that allows the higher transmission rate.

Characteristics of Shielded Twisted Pair:

- The cost of the shielded twisted pair cable is not very high and not very low.
- An installation of STP is easy.
- It has higher capacity as compared to unshielded twisted pair cable.
- It has a higher attenuation.
- It is shielded that provides the higher data transmission rate.

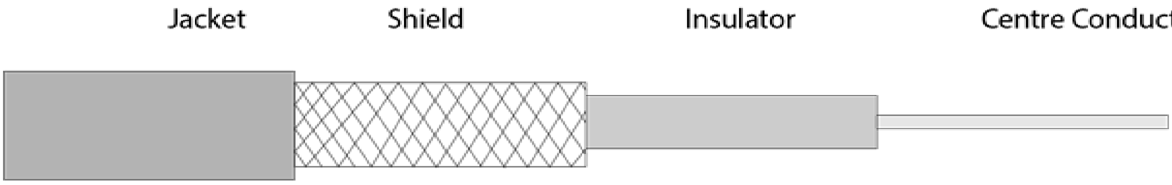
Disadvantages:

- It is more expensive as compared to UTP and coaxial cable.
- It has a higher attenuation rate.

Coaxial Cable

- Coaxial cable is very commonly used transmission media, for example, TV wire is usually a coaxial cable.

- ❖ The name of the cable is coaxial as it contains two conductors parallel to each other.
- ❖ It has a higher frequency as compared to Twisted pair cable.
- ❖ The inner conductor of the coaxial cable is made up of copper, and the outer conductor is made up of copper mesh. The middle core is made up of non-conductive cover that separates the inner conductor from the outer conductor.
- ❖ The middle core is responsible for the data transferring whereas the copper mesh prevents from the EMI (Electromagnetic interference).



Coaxial cable is of two types:

Baseband transmission: It is defined as the process of transmitting a single signal at high speed.

Broadband transmission: It is defined as the process of transmitting multiple signals simultaneously.

Advantages of Coaxial cable:

- ❖ The data can be transmitted at high speed.
- ❖ It has better shielding as compared to twisted pair cable.
- ❖ It provides higher bandwidth.

Disadvantages of Coaxial cable:

- ❖ It is more expensive as compared to twisted pair cable.
- ❖ If any fault occurs in the cable causes the failure in the entire network.

Difference between Baseband and Broadband Transmission:

Baseband and broadband are the two main types of signalling techniques. These terminologies were created to categorize various types of signals based on signal formats or modulation techniques. The broadband transmission sends many signals at once and utilizes analogue signals, whereas baseband transmission sends just one signal at a time and uses digital signals.

What is Baseband Transmission?

It is a method of transmission where a single signal is either transmitted or received in the type of discrete pulses of a single frequency across a communication medium like a cable. The baseband signal's frequency is not changed, and the signal's bandwidth is almost 0. Baseband systems do not use frequency shifting, so only one signal uses the entire bandwidth of the system at once. Therefore, any remaining bandwidth is wasted.

In this technology, several devices in a network interact with one another by sending and receiving data on a single communication channel that is shared by all connected devices and utilizing the channel's full bandwidth. The data is either transmitted or received at any time. All the devices in the network must be able to understand the same type of signal. However, Time Division Multiplexing (TDM) enables sharing of the same media. The baseband signal is frequently utilized in wired Local Area Networks (LANs) that are based on Ethernet.

Advantages and Disadvantages of Baseband Transmission

There are various advantages and disadvantages of baseband transmission. Some advantages and disadvantages of baseband transmission are as follows:

Advantages:

It has a simple structure.

It is easy to install.

Its maintenance is simple and easy.

It has low-cost installation.

Disadvantages:

It may be only utilized for voice and data.

It has a short coverage and a limited range.

It works only on a limited distance.

What is Broadband Transmission?

Broadband Transmission sends data in the form of analog signals, allowing signals to be sent at multiple frequencies simultaneously. This broadband transmission is unidirectional. In other words, the data is only transmitted in one direction at the same time. As a result, it may send or receive data but not perform both operations at the same time.

Broadband transmission utilizes Frequency Division Multiplexing (FDM). The bandwidth in FDM is split into a number of frequency bands, each of which transmits a different signal. A multiplexer separates the numerous signals at the receiving end. It is typically more expensive to maintain and install due to the extra hardware involved. However, they cover more distance than baseband transmission. Broadband transmission is typically utilized via cable TV, several types of Digital Subscriber Lines (DSL), Asynchronous Transfer Mode (ATM), and Power Line communication.

Advantages and Disadvantages of Broadband Transmission

There are various advantages and disadvantages of broadband transmission. Some advantages and disadvantages of broadband transmission are as follows:

Advantages:

The main advantage of broadband transmission is its speed. It offers a fast speed for data transmission.

It has a large bandwidth provision for data transmission.

The data transmission may take place for a large distance.

Disadvantages:

It needs some extra hardware for data transmissions like Multiplexers and De-multiplexers.

The broadband transmission maintenance and cost are high.

Key differences between Baseband and Broadband Transmission:

Some of the main differences between Baseband and Broadband Transmission are as follows:

Baseband transmission is a data transmission technique in which one signal needs the whole bandwidth of the channel to transfer the data. In contrast, broadband transmission is a transmission technology in which many signals with different frequencies send data across a single channel at the same time.

Manchester and differential Manchester encoding are used in baseband. In contrast, broadband transmission does not utilize any digital encoding, but it utilizes the PSK (Phase shift keying) encoding.

Baseband transmission signals travel over shorter distances because attenuation is most noticeable at higher frequencies, which causes a signal to travel short distances without losing power. In contrast, the signals in broadband transmissions may travel across larger distances.

The baseband transmission utilizes digital signalling for signal transmission. In contrast, broadband transmission utilizes analog signalling for transmitting analog signals.

Another distinction between broadband and baseband transmission is the direction of signal transmission. Baseband transmission allows signals to be sent in both directions simultaneously. In contrast, broadband transmission allows signals to be sent in only one way.

Baseband transmission utilizes the bus topology. In contrast, broadband transmission utilizes both bus and tree topologies.

Baseband transmission utilizes time division multiplexing. In contrast, broadband transmission utilizes frequency division multiplexing.

Baseband transmission is simple and easy to install and maintain. In contrast, broadband transmission is complex to install and maintain.

Baseband transmission is less expensive to design. In contrast, broadband transmission is costly to design.

Baseband transmission contains 50 ohm impedance. In contrast, broadband transmission contains 70 ohm impedance.

Head-to-head comparison between Baseband and Broadband Transmission

Here, you will learn the head-to-head comparisons between Baseband and Broadband Transmission. The main differences between Baseband and Broadband Transmission are as follows:

Features	Baseband Transmission	Broadband Transmission
Definition	It is a data transmission technique in which one signal needs the whole bandwidth of the channel to transfer the data.	It is a transmission technology in which many signals with different frequencies send data across a single channel at the same time.
Signal Type	It utilizes digital signals.	It utilizes analog signals.
Signal transmission	The signals may be transmitted in both directions.	The signal may transmit only one direction.
Direction	It is bidirectional in nature.	It is unidirectional in nature.

Type		
Multiplexing	It uses Time Division Multiplexing (TDM).	It uses Frequency Division Multiplexing (FDM).
Topology	It operates with bus topology.	It operates with both bus and tree topology.
Number of Channels	It utilizes the same channel for sending and receiving data.	It utilizes two channels, one for transmission and the second for data reception.
Distance Covered	Signals are only capable of travelling limited distances. Attenuation is needed for long distances.	Signals may be transmitted across long distances without attenuation.
Installation and Maintenance	It is simple and easy to install and maintain.	It is complex to install and maintain.
Cost	It is less expensive to design.	It is costly to design.
Encoding Technique	Manchester and differential Manchester encoding are used in baseband.	It doesn't utilize any digital encoding, but it utilizes the PSK (Phase shift keying) encoding.
Impedance	It contains a 50-ohm impedance.	It contains a 70-ohm impedance.
Transfer medium	It utilizes coaxial cables, wires, and twisted-pair cables as the transfer medium for digital signals.	It sends digital signals via coaxial cable, optical fibre cables, and radio waves.
Application	It is usually found in Ethernet.	It is usually found in telephone networks and cables.

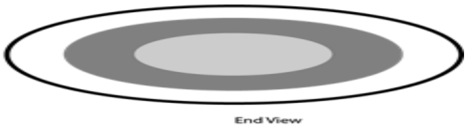
The two main categories of signalling are baseband and broadband transmissions. Baseband transmission utilizes the digital signal or electrical impulse that may be transported in a physical medium like wires. On the other hand, broadband transmission utilizes analogue signalling, which uses optical or electromagnetic wave signals. The baseband transmission utilizes the complete channel's bandwidth to broadcast a signal. In contrast, broadband transmission divides the channel's bandwidth into varying frequency ranges to transmit many signals simultaneously.

Fibre Optic:

- ❖ Fibre optic cable is a cable that uses electrical signals for communication.
- ❖ Fibre optic is a cable that holds the optical fibres coated in plastic that are used to send the data by pulses of light.
- ❖ The plastic coating protects the optical fibres from heat, cold, electromagnetic interference from other types of wiring.

- Fibre optics provides faster data transmission than copper wires.

Diagrammatic representation of fibre optic cable:



Basic elements of Fibre optic cable:

Core: The optical fibre consists of a narrow strand of glass or plastic known as a core. A core is a light transmission area of the fibre. The more the area of the core, the more light will be transmitted into the fibre.

Cladding: The concentric layer of glass is known as cladding. The main functionality of the cladding is to provide the lower refractive index at the core interface as to cause the reflection within the core so that the light waves are transmitted through the fibre.

Jacket: The protective coating consisting of plastic is known as a jacket. The main purpose of a jacket is to preserve the fibre strength, absorb shock and extra fibre protection.

Following are the advantages of fibre optic cable over copper:

Greater Bandwidth: The fibre optic cable provides more bandwidth as compared copper. Therefore, the fibre optic carries more data as compared to copper cable.

Faster speed: Fibre optic cable carries the data in the form of light. This allows the fibre optic cable to carry the signals at a higher speed.

Longer distances: The fibre optic cable carries the data at a longer distance as compared to copper cable.

Better reliability: The fibre optic cable is more reliable than the copper cable as it is immune to any temperature changes while it can cause obstruct in the connectivity of copper cable.

Thinner and Sturdier: Fibre optic cable is thinner and lighter in weight so it can withstand more pull pressure than copper cable.

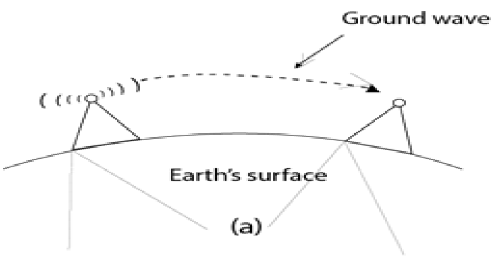
UnGuided Transmission

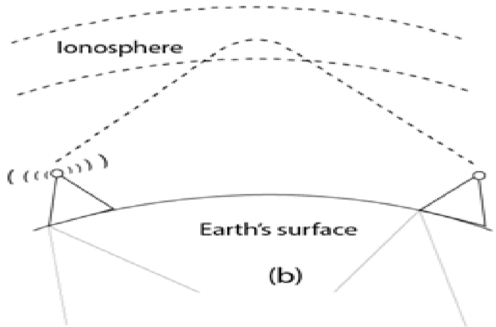
- An unguided transmission transmits the electromagnetic waves without using any physical medium. Therefore it is also known as wireless transmission.
- In unguided media, air is the media through which the electromagnetic energy can flow easily.

Unguided transmission is broadly classified into three categories:

Radio waves:

- Radio waves are the electromagnetic waves that are transmitted in all the directions of free space.
- Radio waves are omnidirectional, i.e., the signals are propagated in all the directions.
- The range in frequencies of radio waves is from 3Khz to 1 khz.
- In the case of radio waves, the sending and receiving antenna are not aligned, i.e., the wave sent by the sending antenna can be received by any receiving antenna.
- An example of the radio wave is FM radio.





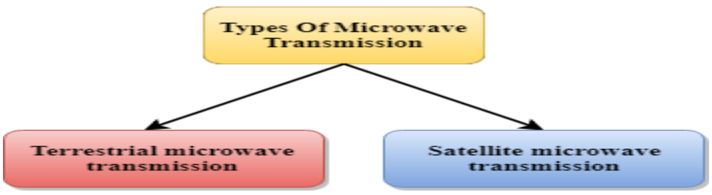
Applications of Radio waves:

- A Radio wave is useful for multicasting when there is one sender and many receivers.
- An FM radio, television, cordless phones are examples of a radio wave.

Advantages of Radio transmission:

- Radio transmission is mainly used for wide area networks and mobile cellular phones.
- Radio waves cover a large area, and they can penetrate the walls.
- Radio transmission provides a higher transmission rate.

Microwaves:



Microwaves are of two types:

Terrestrial microwave and Satellite microwave communication.

Terrestrial Microwave Transmission:

- Terrestrial Microwave transmission is a technology that transmits the focused beam of a radio signal from one ground-based microwave transmission antenna to another.
- Microwaves are the electromagnetic waves having the frequency in the range from 1GHz to 1000 GHz.
- Microwaves are unidirectional as the sending and receiving antenna is to be aligned, i.e., the waves sent by the sending antenna are narrowly focussed.
- In this case, antennas are mounted on the towers to send a beam to another antenna which is km away.
- It works on the line of sight transmission, i.e., the antennas mounted on the towers are the direct sight of each other.

Characteristics of Microwave:

Frequency range: The frequency range of terrestrial microwave is from 4-6 GHz to 21-23 GHz.

Bandwidth: It supports the bandwidth from 1 to 10 Mbps.

Short distance: It is inexpensive for short distance.

Long distance: It is expensive as it requires a higher tower for a longer distance.

Attenuation: Attenuation means loss of signal. It is affected by environmental conditions and antenna size.

Advantages of Microwave:

- Microwave transmission is cheaper than using cables.
- It is free from land acquisition as it does not require any land for the installation of cables.
- Microwave transmission provides an easy communication in terrains as the installation of cable in terrain is quite a difficult task.
- Communication over oceans can be achieved by using microwave transmission.

Disadvantages of Microwave transmission:

Eavesdropping: An eavesdropping creates insecure communication. Any malicious user can catch the signal in the air by using its own antenna.

Out of phase signal: A signal can be moved out of phase by using microwave transmission.

Susceptible to weather condition: A microwave transmission is susceptible to weather condition. This means that any environmental change such as rain, wind can distort the signal.

Bandwidth limited: Allocation of bandwidth is limited in the case of microwave transmission.

Satellite Microwave Communication:

- A satellite is a physical object that revolves around the earth at a known height.
- Satellite communication is more reliable nowadays as it offers more flexibility than cable and fibre optic systems.
- We can communicate with any point on the globe by using satellite communication.

How Does Satellite work?

- The satellite accepts the signal that is transmitted from the earth station, and it amplifies the signal. The amplified signal is retransmitted to another earth station.

Advantages of Satellite Microwave Communication:

- The coverage area of a satellite microwave is more than the terrestrial microwave.
- The transmission cost of the satellite is independent of the distance from the centre of the coverage area.

- Satellite communication is used in mobile and wireless communication applications.
- It is easy to install.
- It is used in a wide variety of applications such as weather forecasting, radio/TV signal broadcasting, mobile communication, etc.

Disadvantages of Satellite Microwave Communication:

- Satellite designing and development requires more time and higher cost.
- The Satellite needs to be monitored and controlled on regular periods so that it remains in orbit.
- The life of the satellite is about 12-15 years. Due to this reason, another launch of the satellite has to be planned before it becomes non-functional**.**

Infrared:

- An infrared transmission is a wireless technology used for communication over short ranges.
- The frequency of the infrared in the range from 300 GHz to 400 THz.
- It is used for short-range communication such as data transfer between two cell phones, TV remote operation, data transfer between a computer and cell phone resides in the same closed area.

Characteristics of Infrared:

- It supports high bandwidth, and hence the data rate will be very high.
- Infrared waves cannot penetrate the walls. Therefore, the infrared communication in one room cannot be interrupted by the nearby rooms.
- An infrared communication provides better security with minimum interference.
- Infrared communication is unreliable outside the building because the sun rays will interfere with the infrared waves.

Bandwidth (in digital systems) between two given nodes is the maximal amount of data per unit time that can be transmitted from one node to the other. Digital bandwidth is synonymous with bit rate and data rate. The actual bandwidth of a network is determined by a combination of the physical media and the technologies chosen for signaling and detecting network signals. Current information about the physics of unshielded twisted-pair (UTP) copper cable puts the theoretical bandwidth limit at over 1 Gbps. However, in practice the actual bandwidth is determined by the signaling methods, NICs, and other network equipment that is chosen. Therefore, the bandwidth is not determined solely by the limitations of the medium.

Wavelength: Wavelength is a measure of distance a signal can travel in a period. It is the distance between corresponding points. The units of wavelength are meter, centimetres, etc.

Throughput defines how much useful data can be transmitted per unit time. It is equal to the bandwidth if there is no protocol. However, in most practical cases the throughput is less than the bandwidth for two reasons:

- **Protocol overhead**: protocols use some bytes to transmit protocol information. This reduces the throughput
- **Protocol waiting times**: some protocols may force you to wait for some event.

Delay in data networks is generally the round trip delay (also called Round Trip Time - RTT) for a packet within the network. Network delay is composed of the following parts:

- **Processing delay** - time routers take to process the packet header.
- **Queuing delay** - time the packet sits in routing queues.
- **Transmission delay** - time it takes to push the packet's bits onto the link
- **Propagation delay** - the time taken by the front of a signal to reach the destination. Propagation of an electromagnetic signal is the speed of light (also called celerity). It depends on the wavelength and the medium in which the signal is propagating. For example propagation of signal in twisted pair is 0.66c where c is speed of light.

There is a certain minimum level of delay that will be experienced due to the time it takes to transmit a packet serially through a link. Onto this is added a more variable level of delay due to network congestion. Network delays can range from a few milliseconds to several hundred milliseconds.

Input: A network with bandwidth of 10 Mbps can pass only an average of 12, 000 frames per minute where each frame carries an average of 10, 000 bits. What will be the throughput for this network?
Output: We can calculate the throughput as-
Throughput = (12, 000 x 10, 000) / 60 = 2 Mbps
The throughput is nearly equal to one-fifth of the bandwidth in this case.
Propagation Time: It is the time required for a bit to travel from the source to the destination. Propagation time can be calculated as the ratio between the link length (distance) and the propagation speed over the communicating medium. For example, for an electric signal, propagation time is the time taken for the signal to travel through a wire.
Propagation time = Distance / Propagation speed

Example:
Input: What will be the propagation time when the distance between two points is 12,000 km? Assuming the propagation speed to be 2.4 * 10^8 m/s in cable.
Output: We can calculate the propagation time as-
Propagation time = (12000 * 10000) / (2.4 * 10^8) = 50 ms
Transmission Time: Transmission time is a time based on how long it takes to send the signal down the transmission line. It consists of time costs for an EM signal to propagate from one side to the other, or costs like the training signals that are usually put on the front of a packet by the sender, which helps the receiver synchronize clocks. The transmission time of a message relies upon the size of the message and the bandwidth of the channel.
Transmission time = Message size / Bandwidth

Example:
Input: What will be the propagation time and the transmission time for a 2.5-kbyte message when the bandwidth of the network is 1 Gbps? Assuming the distance betweensender and receiver is 12, 000 km and speed of light is 2.4 * 10^8 m/s.

Output: We can calculate the propagation and transmission time as-

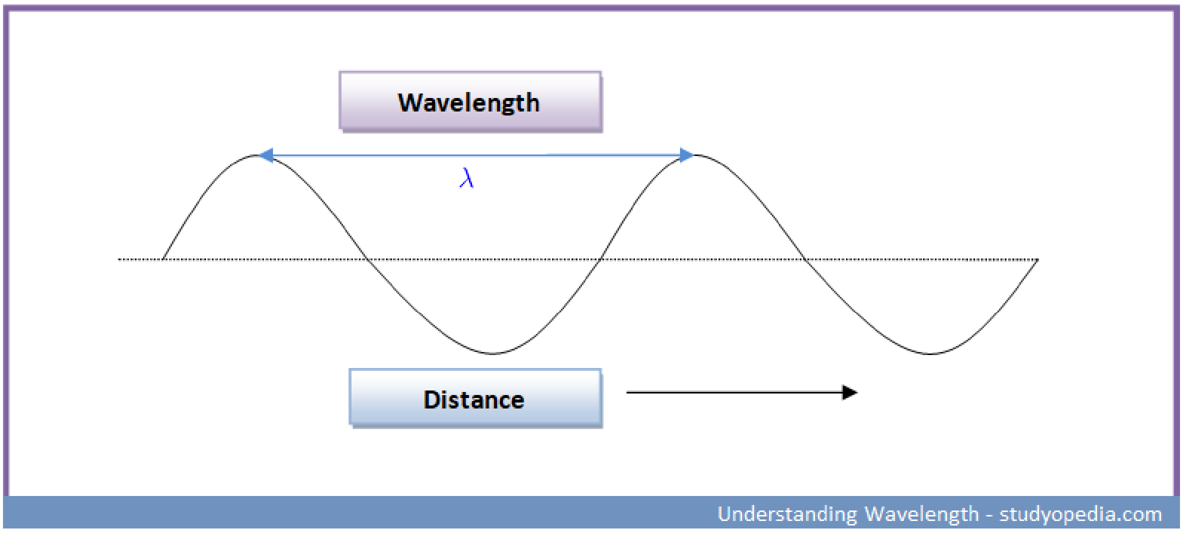
Propagation time = (12000 * 10000) / (2.4 * 10^8) = 50ms
Transmission time = (2560 * 8) / 10^9 = 0.020ms

Note: Since the message is short and the bandwidth is high, the dominant factor is the propagation time and not the transmission time (which can be ignored).
Queuing Time: Queuing time is a time based on how long the packet has to sit around in the router. Quite frequently the wire is busy, so we are not able to transmit a packet immediately. The queuing time is usually not a fixed factor, hence it changes with the load thrust in the network. In cases like these, the packet sits waiting, ready to go, in a queue. These delays are predominantly characterized by the measure of traffic on the system. The more the traffic, the more likely a packet is stuck in the queue, just sitting in the memory, waiting.
Processing Delay: Processing delay is the delay based on how long it takes the router to figure out where to send the packet. As soon as the router finds it out, it will queue the packet for transmission. These costs are predominantly based on the complexity of the protocol. The router must decipher enough of the packet to make sense of which queue to put the packet in. Typically the lower-level layers of the stack have simpler protocols. If a router does not know which physical port to send the packet to, it will send it to all the ports, queuing the packet in many queues immediately. Differently, at a higher level, like in IP protocols, the processing may include making an ARP request to find out the physical address of the destination before queuing the packet for transmission. This situation may also be considered as a processing delay.

JITTER
Jitter is another performance issue related to delay. In technical terms, jitter is a “packet delay variance”. It can simply mean that jitter is considered as a problem when different packets of data face different delays in a network and the data at the receiver application is time-sensitive, i.e. audio or video data. Jitter is measured in milliseconds (ms). It is defined as interference in the normal order of sending data packets. For example: if the delay for the first packet is 10 ms, for the second is 35 ms, and for the third is 50 ms, then the real-time destination application that uses the packets experiences jitter.

Shannon Capacity and comparison of media:

Wavelength: Wavelength is a measure of distance a signal can travel in a period. It is the distance between corresponding points. The units of wavelength are meter, centimeters, etc.



The Wavelength depends on frequency and medium.

Frequency and Wavelength are inversely related to each other.

Wavelength = Propagation Speed/ Frequency

$$\lambda = \frac{c}{f}$$

Above,

f = frequency

c = Propagation Speed

Shannon Capacity

Shannon Capacity, named after Claude Shannon, since he introduced it.

Claude Shannon was an American electrical engineer, mathematician and properly known as "the father of information theory".

To determine the theoretical highest data rate for a channel, he introduced the following Shanon Capacity formulae in 1944.

Shannon Capacity (C) = B log2 (1 + S/N)

As shown above,

S = Signal Power in Watts

N = Noise power in Watts

B = Channel Bandwidth

C = Shannon Capacity in bits/ second (bps)

S/N = Signal to noise ratio

Maximum Data Rate (channel capacity) for Noiseless and Noisy channels: As early as 1924, an AT&T engineer, Henry Nyquist, realized that even a perfect channel has a finite transmission capacity. He derived an equation expressing the maximum data rate for a finite-bandwidth noiseless channel. In 1948, Claude Shannon carried Nyquist's work further and extended to it the case of a channel subject to random (that is, thermodynamic) noise (Shannon, 1948). This paper is the most important paper in all of the information theory.

Data rate governs the speed of data transmission. A very important consideration in data communication is how fast we can send data, in bits per second, over a channel. Data rate depends upon 3 factors:

- The bandwidth available
- Number of levels in digital signal
- The quality of the channel – level of noise

Two theoretical formulas were developed to calculate the data rate: one by Nyquist for a noiseless channel, another by Shannon for a noisy channel.

1. Noiseless Channel: Nyquist Bit Rate, For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate

Nyquist proved that if an arbitrary signal has been run through a low-pass filter of bandwidth, the filtered signal can be completely reconstructed by making only 2*Bandwidth (exact) samples per second. Sampling the line faster than 2*Bandwidth times per second is pointless because the higher-frequency components that such sampling could recover have already been filtered out. If the signal consists of L discrete levels, Nyquist's theorem states:

BitRate = 2 * Bandwidth * log2(L) bits/sec

In the above equation, bandwidth is the bandwidth of the channel, L is the number of signal levels used to represent data, and BitRate is the bit rate in bits per second.

Bandwidth is a fixed quantity, so it cannot be changed. Hence, the data rate is directly proportional to the number of signal levels.

Note –Increasing the levels of a signal may reduce the reliability of the system.

Examples:

Input1 : Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. What can be the maximum bit rate?

Output1 : BitRate = 2 * 3000 * log2(2) = 6000bps

Input2 : We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

Output2 : 265000 = 2 * 20000 * log2(L)

log2(L) = 6.625

L = 26.625 = 98.7 levels

The amount of thermal noise present is measured by the ratio of the signal power to the noise power, called the SNR (Signal-to-Noise Ratio).

2. **Noisy Channel :** Shannon Capacity – In reality, we cannot have a noiseless channel; the channel is always noisy. Shannon capacity is used, to determine the theoretical highest data rate for a noisy channel:

Capacity = bandwidth * log2(1 + SNR) bits/sec

In the above equation, bandwidth is the bandwidth of the channel, SNR is the signal-to-noise ratio, and capacity is the capacity of the channel in bits per second.

Bandwidth is a fixed quantity, so it cannot be changed. Hence, the channel capacity is directly proportional to the power of the signal, as SNR = (Power of signal) / (power of noise).

The signal-to-noise ratio (S/N) is usually expressed in decibels (dB) given by the formula:

10 * log10(S/N)

So for example a signal-to-noise ratio of 1000 is commonly expressed as:

10 * log10(1000) = 30 dB.

This tells us the best capacities that real channels can have. For example, ADSL (Asymmetric Digital Subscriber Line), which provides Internet access over normal telephonic lines, uses a bandwidth of around 1 MHz. the SNR depends strongly on the distance of the home from the telephone exchange, and an SNR of around 40 dB for short lines of 1 to 2km is very good. with these characteristics, the channel can never transmit much more than 13Mbps, no matter how many or how few signals level are used and no matter how often or how infrequently samples are taken.

Examples:

Input1 : A telephone line normally has a bandwidth of 3000 Hz (300 to 3300 Hz) assigned for data communication. The SNR is usually 3162. What will be the capacity for this channel?

Output1 : C = 3000 * log2(1 + SNR) = 3000 * 11.62 = 34860 bps

Input2 : 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.

Output2 : SNR(dB) = 10 * log10(SNR)

SNR = 10(SNR(dB)/10)

SNR = 103.6 = 3981

Hence, C = 2 * 106 * log2(3982) = 24 MHz

Difference between Guided and Unguided Media:

Guided Media: In this type of media, signal energy is enclosed and guided within a solid medium. The guided media is used either for point-to-point links or a shared link with various connections. In guided media, interference is generated by emissions in the adjacent cables. Proper shielding of guided media is required to reduce the interference issue.

Unguided Media: In the unguided media, the signal energy propagates through a wireless medium. Wireless media is used for radio broadcasting in all directions. Microwave links are chosen for long-distance broadcasting transmission unguided media. Interference is also a problem in unguided media, overlapping frequency bands from competing signals can alter or eliminate a signal. Let's see the difference between the Guided Media and Unguided Media.

S.No.	Guided Media	Unguided Media
1.	The guided media is also called wired communication or bounded transmission media.	The unguided media is also called wireless communication or unbounded transmission media.
2.	The signal energy propagates through wires in guided media.	The signal energy propagates through the air in unguided media.
3.	Guided media is used for point-to-point communication.	Unguided media is generally suited for radio broadcasting in all directions.
4.	It is cost-effective.	It is expensive.

S.No.	Guided Media	Unguided Media
5.	Discrete network topologies are formed by the guided media.	Continuous network topologies are formed by the unguided media.
6.	Signals are in the form of voltage, current, or photons in the guided media.	Signals are in the form of electromagnetic waves in unguided media.
7.	Examples of guided media are twisted pair wires, coaxial cables, and optical fiber cables.	Examples of unguided media are microwave or radio links and infrared light.
8.	By adding more wires, the transmission capacity can be increased in guided media.	It is not possible to obtain additional capacity in unguided media.
9.	It sends out a signal that indicates which way to go.	It does not indicate which way to travel.
10.	For a shorter distance, this is the best option.	For longer distances, this method is used.
11.	It is unable to pass through walls.	It can pass through walls.