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STUDY OF COMMUNICATION CHANNELS

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***Abstract*- In recent years research on communication channels has increased. Communication Channel refers to a physical medium or a logical connection used to convey information signal. There are different types of communication channels and their applications. This paper presents different types of communication channels, classification of channels based on information theory, channel capacity of various channels, applications and future scope. We can develop such channels in which we can minimize the noise so that smooth flow of information will occur without much distortion and error.**

***Index Terms*- channel, channel capacity, information, noise.**

I. INTRODUCTION

In communication, channel refers either to a physical transmission medium such as a wire or a logical connection such as wireless channels. A channel is used to convey an information signal, for example a digital bit stream, from one or several *senders* (or transmitters) to one or several *receivers*. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second. Communicating data from one location to another requires some form of pathway or medium. These pathways, called communication channels, use two types of media: cable (twisted-pair wire, cable, and fiber-optic cable) and broadcast (microwave, satellite, radio, and infrared). Cable or wire line media use physical wires of cables to transmit data and information. Twisted-pair wire and coaxial cables are made of copper, and fiber-optic cable is made of glass. Wireless media use electromagnetic waves to transmit data and information whose frequency depends upon the type of wave; it is microwave or radio wave or any other wave. In information theory, a channel refers to a theoretical *channel model* with certain error characteristics. In information theory, a channel refers to a theoretical *channel model* with certain error characteristics. In this more general view, a storage device is also a kind of channel, which can be sent to (written) and received from (read) [7].

Fig 1: Communication channel

II. TYPES OF COMMUNICATION CHANNELS

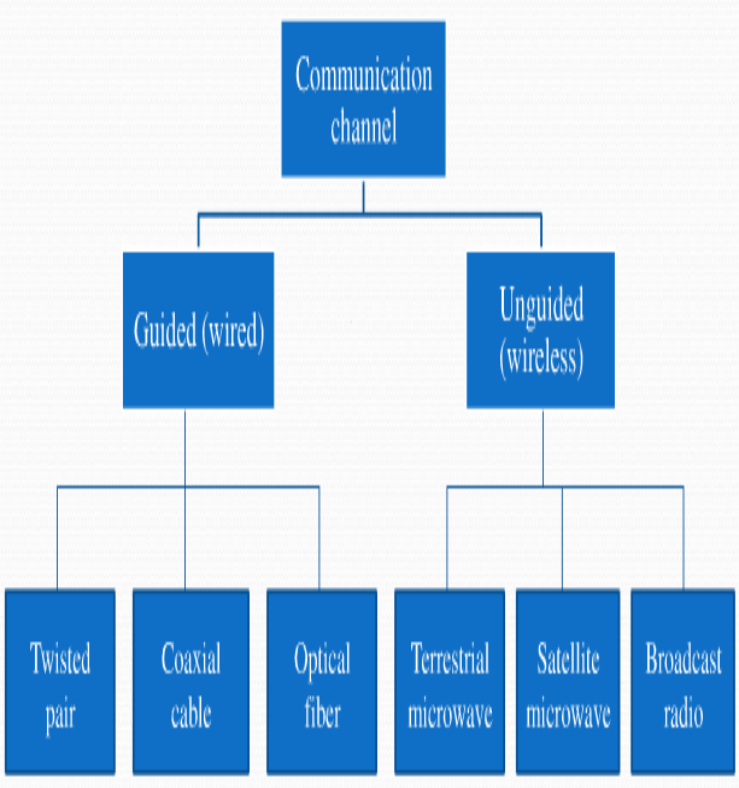

Fig 2: Types of communication channels

A. Twisted-pair cable

- One of the wires carries signal, the other is used only as a ground reference.
- Number of twists per unit length determines the quality of the cable [1].

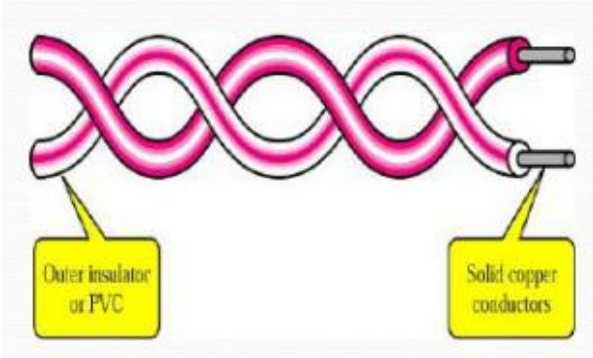

Fig 3: Twisted pair cable

B. Coaxial cable

- Used for both analog and digital signals.
- Effectively used at higher data rate and higher bandwidth.
- For analog signals need amplifiers after every few km.
- For digital signals requires repeaters after every 1 km [1].

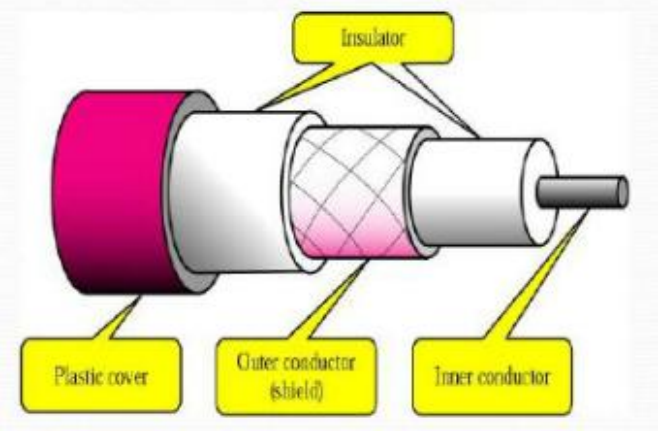

Fig 4: Coaxial cable

C. Optical fiber cable

- Optical fiber consists of a core and a cladding layer, selected for total internal reflection due to the difference in the refractive index between the two.
- There are two main types of material used for optical fibers. These are glass and plastic. They offer widely different characteristics and therefore fibers made from the two different substances find uses in very different applications.
- Modern fiber cables can contain up to a thousand fibers in a single cable, with potential bandwidth in the terabytes per second. In some cases, only a small fraction of the fibers in a cable may be actually "lit" [2].

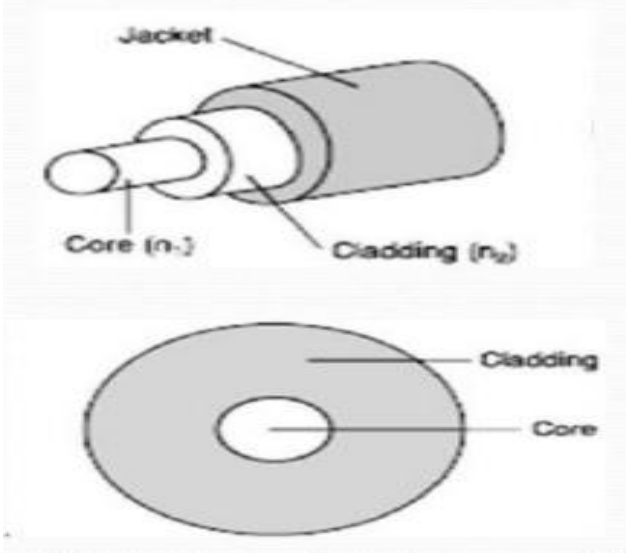

Fig 5: Fiber optic cable

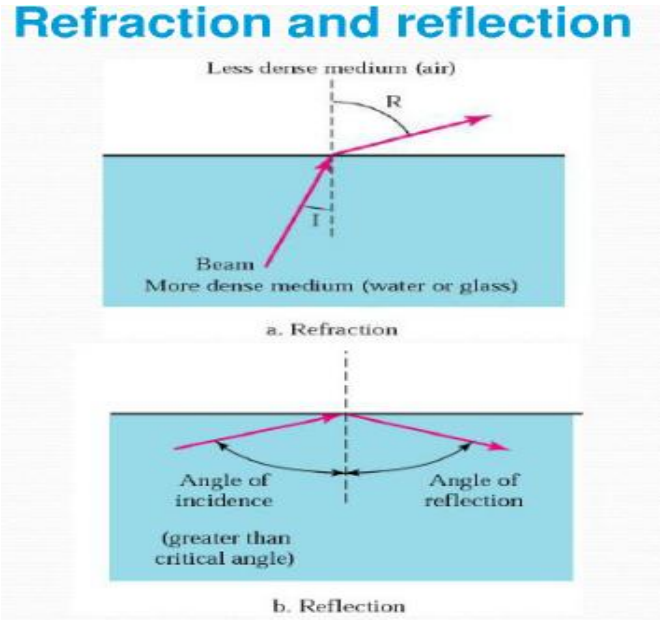

Fig 6: Reflection and Refraction

D. Terrestrial microwave

- Requires fewer repeaters.
- Use a parabolic dish to focus a narrow beam.
- 1-40 GHz frequencies [1].

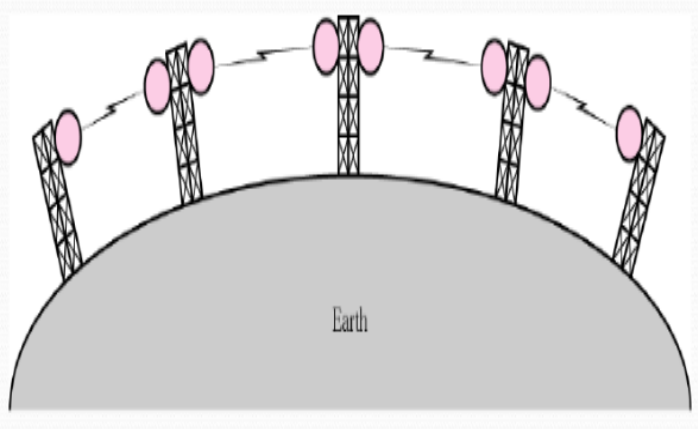

Fig 7: Microwave communication

E. Satellite communication

- Receives on one frequency, and transmits on another frequency.
- Height 35,784km.
- Spaced at least 3-4 apart [1].

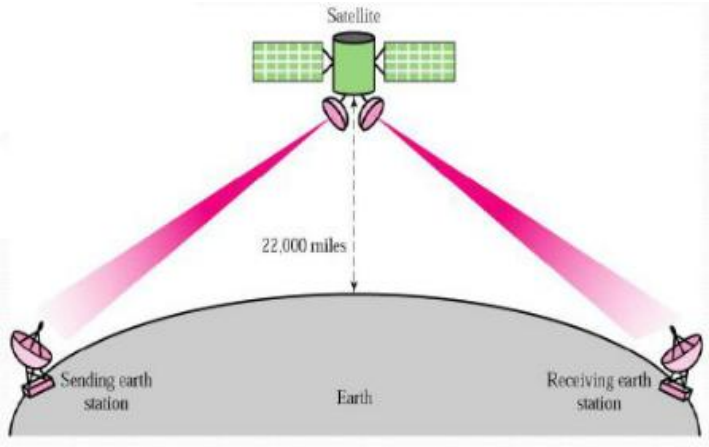

Fig 8: Satellite communication

F. Broadcast Radio

- Radio frequency range is 3 kHz to 300 GHz.
- It is unidirectional.
- Suffers from multipath interference.
- Are used for multicasts communication, such as radio, television and paging system [1].

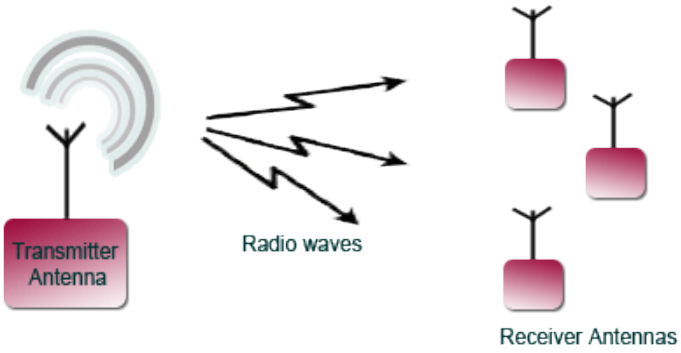

Fig 9: Radio communication

III. DISCRETE CHANNELS

- If we apply a sequence $x_1, x_2, \ldots, x_n$ from an alphabet X at the input of a channel, then at the output we will receive a sequence $y_1, y_2, \ldots, y_n$ belonging to an alphabet Y.
- Usually the probability distributions over the outputs depend on the input and on the state of the channel.
- Some channels have memory. For example, the output symbol y_n might be dependent on previous inputs or outputs.
- Causal behavior: In general $y_1, y_2, \ldots, y_n$ do not need to consider inputs beyond $x_1, x_2, \ldots, x_n$
- Given an input alphabet X , an output alphabet Y and a set of states S, a discrete channel is defined as a system of conditional probability distributions $P(y_1, y_2, \ldots, y_n|x_1, x_2, \ldots, x_n; s)$ where $x_1, x_2, \ldots, x_n \in X$, $y_1, y_2, \ldots, y_n \in Y$ and $s \in S$.
- $P(y_1, y_2, \ldots, y_n|x_1, x_2, \ldots, x_n; s)$ can be interpreted as the probability that the sequence $y_1, y_2, \ldots, y_n$ will appear at the output of the channel if the sequence $x_1, x_2, \ldots, x_n$ is applied at the input and the initial state of the channel is s.
- Initial state here is defined as the state before applying x_1 at the input [3].

IV. DISCRETE MEMORYLESS CHANNELS

- A discrete channel is memory less if $P(y_1, y_2, \ldots, y_n|x_1, x_2, \ldots, x_n; s)$ does not depend on s so it can be written as $P(y_1, y_2, \ldots, y_n|x_1, x_2, \ldots, x_n)$
  $P(y_1, y_2, \ldots, y_n|x_1,x_2, \ldots, x_n) = P(y_1|x_1)\ P(y_2|x_2) \ldots P(y_n|x_n)$.
  Where x1, $x_2, \ldots, x_n \in X$, $y_1, y_2, \ldots, y_n \in Y$ and $s \in S$.

V. INFORMATION POSSESSED BY A CHANNEL

- Let the input uncertainty be H(X), H(Y) is the output uncertainty and the conditional uncertainties H(X|Y) and H(Y |X). We define the information processed by

the channel as

$$I(X; Y) = H(X) - H(X|Y) = H(Y) - H(Y|X)$$

- The information processed by a channel depends on the input Distribution $p_x(x)$.
- We may vary the input distribution until the information reaches a maximum; the maximum information is called the ***channel capacity***. $C = \max_{p_x(x)} I(X; Y)$.

VI. PROPERTIES OF CHANNEL CAPACITY

- $C \geq 0$, since $I(X; Y) \geq 0$.
- $C \leq \log |X|$, since $C = \max I(X; Y) \leq \max H(X) = \log |X|$
- $C \leq \log |Y|$, for the same reason.
- $I(X; Y)$ is a continuous function on $p_x(x)$.
- $I(X; Y)$ is a concave function of $p_x(x)$.

VII. CLASSIFICATION OF CHANNELS

A. *LOSELESS CHANNEL*

- A channel is lossless if $H(X|Y) = 0$ for all input distributions. Input is determined from the output and no transmission errors can occur.

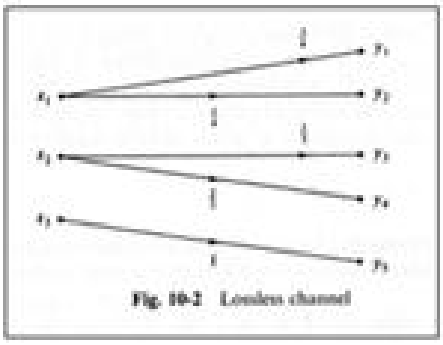

Fig 10: Lossless channel

B. *DETERMINISTIC CHANNEL*

- A channel is deterministic if $P(Y = y_i|X = x_j) = 1$ or 0 for all i, j. The output is determined by the input, that is, $H(Y|X) = 0$ for all input distributions [4].

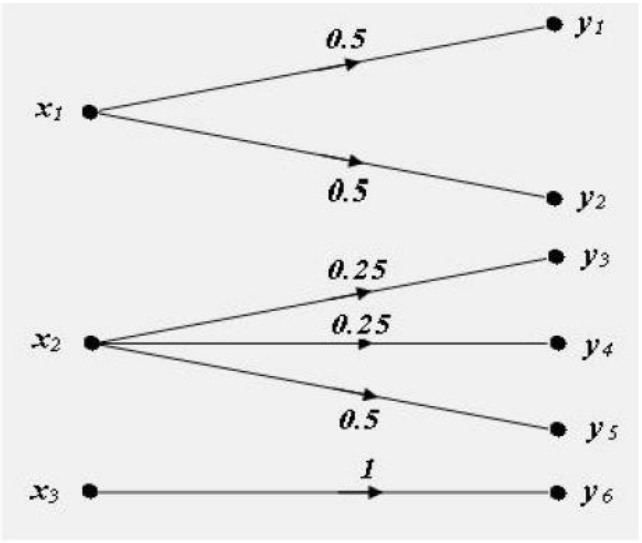

Fig 11: Deterministic channel

C. *NOISELESS CHANNEL*

- A channel is noiseless if it is lossless and deterministic.

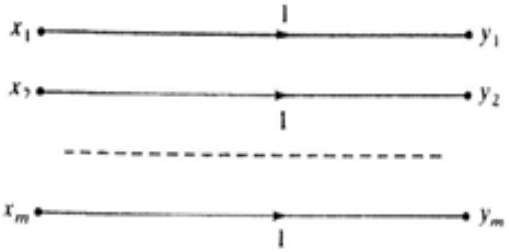

Fig 12: Noiseless channel

D. *USELESS CHANNEL*

- A channel is useless (or zero-capacity) if $I(X; Y) = 0$ for all input distributions. Input X and output Y are independent.

E. *SYMMETRIC CHANNEL*

- A channel is symmetric if the rows of the channel transition matrix are permutations of each other, and the columns are permutations of each other.
- The entry at the i-th row and j-th column denotes the conditional probability $P(Y = y_j|X = x_i)$ that y_j is received given that x_i was sent.
- A channel is weakly symmetric if the rows of the channel transition matrix are permutations of each other, and the sums of the columns are equal [5].

F. *BINARY SYMMETRIC CHANNEL*

- It is the basic example of a noisy communication system

- Binary input and binary output. The output is equal to the input with probability 1 − p. With probability p a 0 is received as 1, and vice-versa [7].

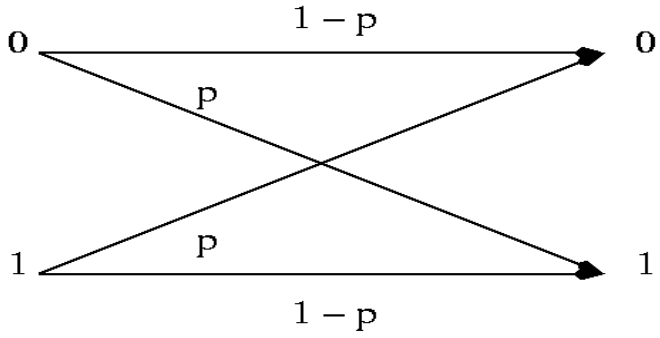

Fig 13: Binary symmetric channel

G. *BINARY ERASURE CHANNEL*

- Bits are lost instead of being flipped.
- A fraction α of bits is lost and the receiver knows that a bit was supposed to arrive.
- Packet communications [7].

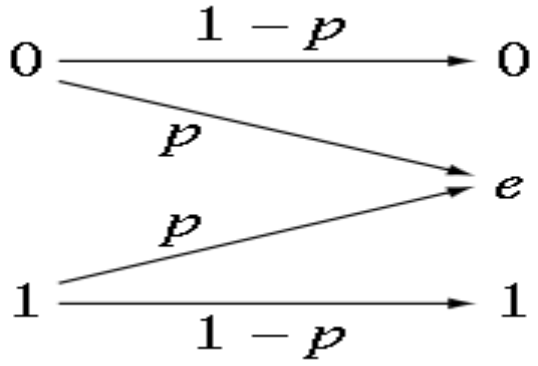

Fig 14: Binary erasure channel

VIII. APPLICATIONS

Channels are widely used in communication systems because we cannot imagine a communication system without channel. So whenever we talk about communication system we also talk about channel because without channel it is not possible to have a communication system. We need channel for each and every communication system [6].

IX. FUTURE SCOPE

- We can develop such channels in which we can minimize the noise so that smooth flow of information will occur without much distortion and error.
- In future we can get more detailed knowledge and characteristics of the channels present we can also develop new channels for our communication systems.

X. CONCLUSION

- Communication channel is essential for communication systems. The characteristics are important in selecting channel because they directly affect the communication quality.
- Different types of communication channels have different transmission characteristics and costs, they are used in different application.

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