

Lecture#1

1-Modeling of Information Transmission System

Information transmission system is a system that represents the main building blocks to convey information from one side (source) to another (destination). When this system represent point to point transmission it is called communication system. On the other hand, the information transmission system may represent multipoint to multipoint transmission in the form of shared channel which represent a network connectivity such as Internet.

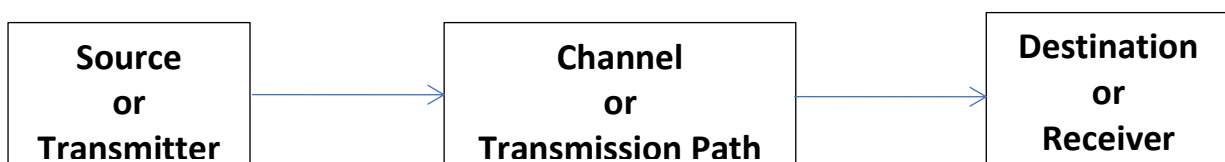
It is important to understand the definition of the following terms;

Signal: Signal is the actual entity that is transmitted from transmitter to receiver. It may be discrete (digital) or analog. Usually electrical or electromagnetic signal. (Example: AM, FM, PSK)

Data: Data denotes the information conveyed in the signal. Data is being carried by the signal. But data may also be stored. Usually binary data, letters, pixel value. Also called the message. (Examples: Text, Music sound, Image, movie, colors)

Information: It is the knowledge that is communicated by the data. Receiving information may be discovered by monitoring human impressions or sensory reaction. (Examples: the meaning of the text, song, image)

A simplified information transmission system is given below;



Usually Low Frequency
Message

Text
Speech
Music (Audio)
Image
Movie (Video)
Row data
Computer file

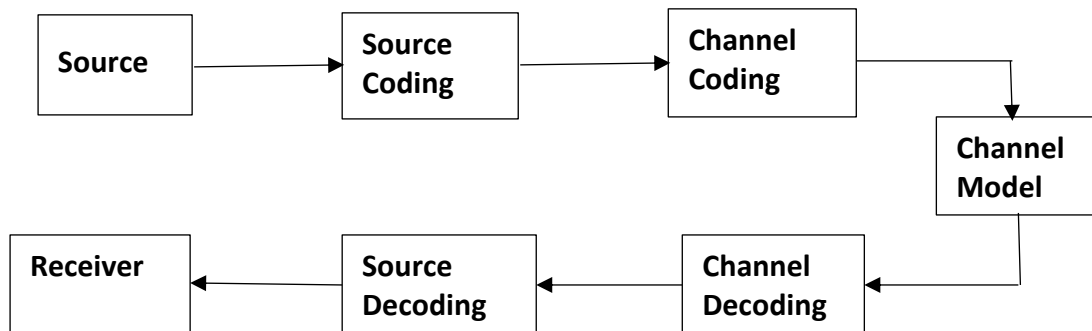
Defined by frequency and the physical media
(contamination by noise and distortion)

-Wired:
2-Wire TL ($f < 1 \text{ GHz}$)
Coaxial Cable ($f < 3 \text{ GHz}$)
Waveguide ($3\text{GHz} < f < 24\text{GHz}$)
Optical Fiber ($f > 30 \text{ GHz}$)
-Wireless:
UHF (300-3000MHz)
X-Band(8-12 GHz)
.....etc

Try its best to extract the
Message signal

The subject of Information Theory and Coding deals with the mathematical representation of a system that transmit information from one side to another. It also covered the quantitatively measure of information and the efficiency of the system main parts. To improve the information transmission source output symbols may be encoded to ease the transmission over the given channel. Error control coding also included in the information transmission system to reduce the error in transmission and hence improve its quality.

The following describe all information transmission system components that will be covered by the subject.

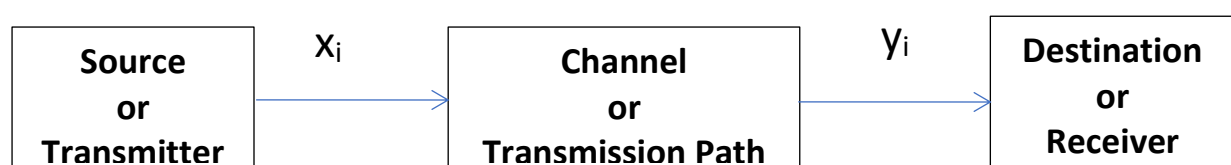


The subject will cover the study of source types (discrete and continuous), channel types, and the possible coding required to improve the performance and quality.

Since the information content of a message is function of its probability, the subject will study the whole system in statistical sense.

2- Measuring of Information

Consider the block diagram of information transmission system model.



x_i = the transmitted symbol y_i = the received symbol

The source has N symbols $\{ x_i \}$ and the receiver is able to receive M symbols $\{ y_i \}$.

We shall study in this lecture the information content of $\{x_i\}$ and the corresponding information received by the receiver.

The information carried by each symbol x_i is called the self-information of x_i denoted by I_{x_i} . Consider now x_i as an event with associated information of I_{x_i} and we need to make some measure of this information. As a common sense for information measure, **one may say that the event with high probability has little information and vice versa**. Thus, if $p(x_i)$ is the probability of the symbol x_i then one can write:

$$I_{x_i} = f(p(x_i)) \text{ where } f(.) \text{ is an inverse function.}$$

Consider next the occurrence of two independent events x_i and x_n at the same time. Then the self-information of both events will add together. Then using:

$$I_{x_n} = f(p(x_n))$$

The total information is given by:

$$I_T = I_{x_i} + I_{x_n} = f(p(x_i)) + f(p(x_n))$$

Since x_i and x_n are independent then: $p(x_i, x_n) = p(x_i) \cdot p(x_n)$

$$\text{Also } I_T = f(p(x_i) \cdot p(x_n)) = f(p(x_i)) + f(p(x_n))$$

Only one function that convert **multiplication into addition** in mathematics, which is the Logarithmic function thus $f(.)$ is **logarithm**. Now we have logarithmic and invers function then, the measure of self-information is given by:

$$I_{x_i} = -\text{Log}_b(p(x_i))$$

The -ve sign is used so that I_{x_i} becomes a +ve quantity (since $0 < p(x_i) < 1$ and its logarithm is -ve always).

The value of b defines the base of the logarithm and also defines the unit of I_{x_i} .

Value of b	10	e	2
The unit of I_{x_i}	Hartley unit	Natural unit (or Nat.)	Bit (or Binary Digit)

We shall use the Bit unit very often. Since there is no logarithmic operator with base-2 in the calculator then we use the following to convert into bit units:

$$\text{Log}_2(A) = \frac{\text{Log}_{10}(A)}{\text{Log}_{10}(2)} = \frac{\ln(A)}{\ln(2)}$$

Example-1

A bag lock consists of 3 decimal digits, find the information required to open such lock in Hartley units and in Bits.

Solution:

The number of possible 3-decimal digits combinations = $N = 10 \times 10 \times 10 = 1000$

Since only one combination will open the lock then $p(x) = 1/N = 1/1000 = 0.001$

$$I_x = -\log_{10}(p(x)) = -\log_{10}(0.001) = -\log_{10}(10^{-3}) = 3 \cdot \log_{10}(10) = 3 \text{ Hartely}$$

To convert the above into Bits unit;

$$I_x = \frac{3}{\log_{10}(2)} = \frac{3}{0.301} = \frac{3}{\log_{10}(2)} = 9.967 \text{ Bits}$$