PART D: Communication Channels

In telecommunications and computer networking, a communication channel or **Channel** refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel. A channel is used to convey or transfer an information signal, for example a digital bit stream, from one or several *senders* 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.

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). So we can define the **Channel of communication** *as a link between the sender and receiver, through which we can send messages (information) across*, so it must be noise-free and suitable for both ends of the connection. The communication channels can take several forms depending on the means and purpose that used for it. **In information theory**, the communication channel will be without memory, where that the output depends on the input. Information channel can be defined, by identifying a set of conditional probabilities for every possible X and Y values.

The set of values are formulated in the form of a matrix called the channel matrix, as follows:

$$P(_{Y|X}) = \quad \overset{Y_n}{X_m \begin{bmatrix} P(Y1|X1) & \cdots & P(Yn|X1) \\ \vdots & \ddots & \vdots \\ P(Y1|Xm) & \cdots & P(Yn|Xm) \end{bmatrix}}$$

✓ Types Of Channels

In information theory, it is common to start with memory less channels in which the output probability distribution only depends on the current channel input. A channel model may either be digital (quantified, e.g. binary) or analog.

❖ Analog Channel models

In an analog channel model, the transmitted message is modeled as an analog signal. Examples of analog channel models are:

- Noise model
- Interference model
- Frequency response model
- Radio frequency propagation model

❖ Digital channel models

In a digital channel model, the transmitted message is modeled as a digital signal at a certain protocol layer. Underlying protocol layers, such as the physical layer transmission technique, is replaced by a simplified model. Examples of digital channel models are:

- Binary symmetric channel (BSC)
- Binary bursty bit error channel model
- Binary erasure channel (BEC)
- Packet erasure channel

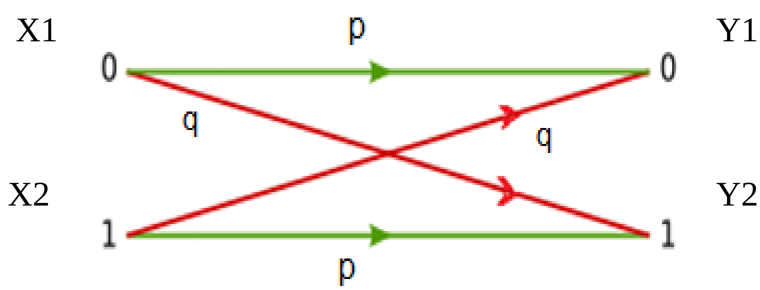
✓ Some observations:

- Symmetric Channel : defined as those in which the conditional probability values P(y|x) are set in row are the same as in the corresponding column, means that the rows of the matrix are all permutations of each other, and so are the columns. Symmetric channel matrix (implying has the same number of input symbols and output symbols).

$$P_{(Y|X)} = \begin{matrix} 1/3 & 1/3 & 1/6 & 1/6 \\ 1/3 & 1/6 & 1/3 & 1/6 \\ 1/6 & 1/3 & 1/6 & 1/3 \\ 1/6 & 1/6 & 1/3 & 1/3 \end{matrix}$$

- Binary Symmetric Channel (BSC): Is a common communications channel model used in coding theory and information theory. In this model, a transmitter wishes to send a bit (usually called 0 and 1), and the receiver receives a bit. It is **assumed** that the bit is *usually* transmitted correctly. The transmission is not perfect, and occasionally the receiver gets the wrong bit. BSC has only two inputs and two outputs. The values of channel matrix are as follows:

  All conditional probability on the correct recipient equal to $P_{(Y1|X1)} = P_{(Y2|X2)} = p$, and all conditional probability on the incorrect recipient equal to $P_{(Y1|X2)} = P_{(Y2|X1)} = q$.



$$P_{(X|Y)} = \begin{bmatrix} p & q \\ q & p \end{bmatrix}$$

- Uniform Symmetric Channel (BSC): Channel is symmetrical and regular if the values in each row and each column are the same, except for the main elements of the diameter of the matrix.

$$P(Y|X) = \begin{array}{c|cccc} & Y_1 & Y_2 & \cdots & Y_N \\ X_1 & p & {}^{q}/_{M-1} & \cdots & {}^{q}/_{M-1} \\ X_2 & {}^{q}/_{M-1} & p & \cdots & {}^{q}/_{M-1} \\ \vdots & \vdots & & \ddots & \vdots \\ X_M & {}^{q}/_{M-1} & {}^{q}/_{M-1} & \cdots & p \end{array}$$

Note: N = M.

***Example*:** Let p = 0.7, q = 0.3, N = M = 4 then ${}^{q}/_{M-1}$ = 0.3/3 = 0.1:

$$\mathbf{P_{(Y|X)}} = \begin{array}{cccc} \mathbf{0.7} & \mathbf{0.1} & \mathbf{0.1} & \mathbf{0.1} \\ \mathbf{0.1} & \mathbf{0.7} & \mathbf{0.1} & \mathbf{0.1} \\ \mathbf{0.1} & \mathbf{0.1} & \mathbf{0.7} & \mathbf{0.1} \\ \mathbf{0.1} & \mathbf{0.1} & \mathbf{0.1} & \mathbf{0.7} \end{array}$$