

## **4.6 Shannon – Fano Encoding:**

First the messages are ranked in a table in descending order of probability. The table is then progressively divided into subsections of probability near equal as possible. Binary 0 is attributed to the upper subsection and binary 1 to the lower subsection. This process continues until it is impossible to divide any further, the following steps show the algorithmic procedure of Shannon – Fano encoding:

- 1- List the symbols in descending order of the probabilities.
- 2- Divide the table into as near as possible two equal values of probability.
- 3- Allocate binary 0 to the upper section and binary 1 to the lower section.
- 4- Divide both the upper section and the lower section into two.
- 5- Allocate binary 0 to the top half of each section and binary 1 to the lower half.
- 6- Repeat steps (4) and (5) until it is not possible to go any further.

Symbol	Probability	Step1	Step2	Step3	Step4	Step5	Code
X <sub>1</sub>	0.25	0	0	--			00
X <sub>2</sub>	0.25	0	0.5	1	--		01
X <sub>3</sub>	0.15	1	0.5	0	0		100
X <sub>4</sub>	0.1	1		0	0.25	1	101
X <sub>5</sub>	0.1	1		1	0.25	0	110
X <sub>6</sub>	0.08	1		1	0.15	0	1110
X <sub>7</sub>	0.06	1		1		1	0.07
X <sub>8</sub>	0.01	1		1		1	11111

For this example we can evaluate the efficiency of this system:

$$L = 2.72 \text{ digits / symbol}$$

$$H = 2.67 \text{ bits / symbol}$$

$$\eta = (H / L) * 100\% = ((2.67) / (2.72)) * 100\% = 98.2\%.$$

## **4.7 Link Throughput:**

We can define throughput as the number of information bits in a frame (or frames) divided by the total time taken to transmit and acknowledge the frame (or frames). The major factors that cause throughput to be less than the transmission rate are listed below as follows:

**1- Frame overheads:** Not all of the contents of a frame are information bits.

Typically, in addition to information bits, a frame also contains a header and a trailer. The header contains control information such as an address and sequence numbers. The trailer normally contains error-checking bits which are often called a frame check sequence.

**2- Propagation delay:** This is the time that it takes for a frame to propagate from one end of a link to the other; that is, the difference in time between the first bit of a frame leaving the send node and arriving at the receive node.

**3- Acknowledgements:** Normally, some form of ARQ is used and time may be spent waiting for acknowledgements to reach the sending node, the acknowledgements will normally be much shorter than the information frames, that leads the acknowledgement time will be shorter as compared with the transmission time.

**4- Retransmissions:** Frames may need to be retransmitted as a result of errors or frames being discarded for whatever reason, always the retransmission occurs when the acknowledgment signal is not received at the sending node within certain period.

**5- Processing time:** Time is spent at the sending and receiving nodes in processing the data, this includes detecting (and possibly correcting) errors and also the implementation of flow control. If wireless links are used there will be further processing delays associated with the modulation and demodulation process.