Physical layer

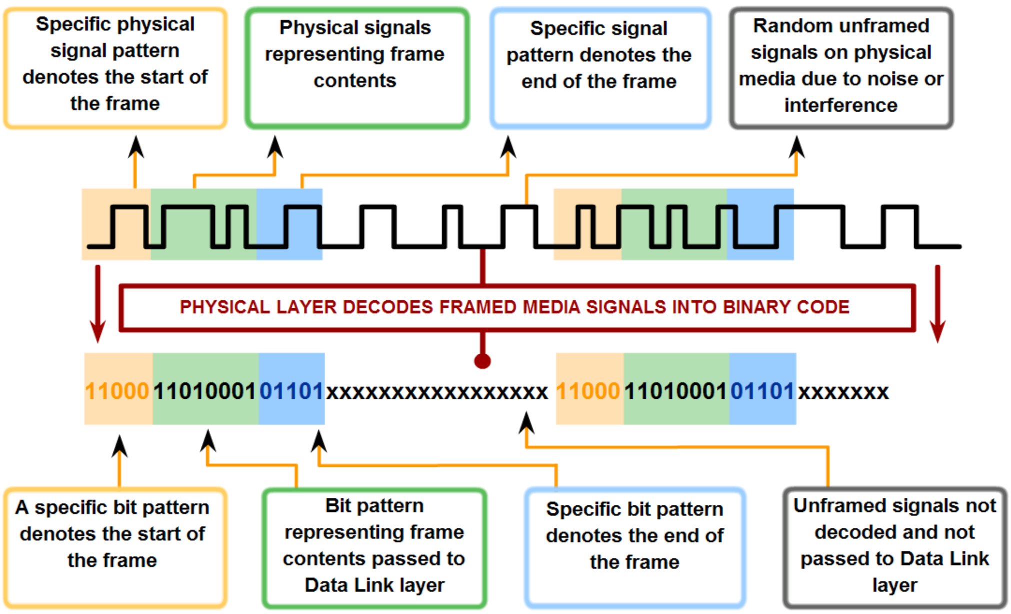
Physical layer in the OSI model plays the role of interacting with actual hardware and signaling mechanism. Physical layer is the only layer of OSI network model which actually deals with the physical connectivity of two different stations. This layer defines the hardware equipment, cabling, wiring, frequencies, pulses used to represent binary signals etc.

Physical layer provides its services to Data-link layer. Data-link layer hands over frames to physical layer. Physical layer converts them to electrical pulses, which represent binary data. The binary data is then sent over the wired or wireless media. The frames that are received from the data link layer are converted into bits for transmission over the medium in this layer. Depending on the type of physical medium, the physical layer may represent the bits as either; light signals, electrical signals or waves for transmission over wireless media.

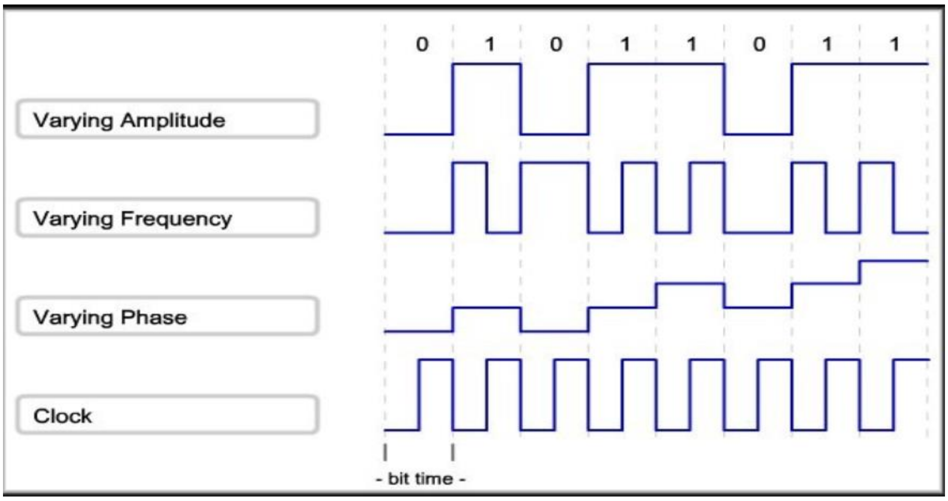
Physical Layer Operation

- **Responsible for specifying the physical medium**
- **Responsible for specifying the signal**: Generation of the electrical/optical/wireless signals that represent the data bits
- **Responsible for specifying the bits:** Data Encoding-Computing the stream of data bits from higher layers into a predefined code

Recognizing Frame Signals



Signaling Bits for the Media



- Amplitude
  The amplitude of a signal is the value of the signal at any point on the wave and is measured normally either in volts, amperes, or watts. That is, it is the vertical distance of the point on the wave from the X-axis.
- Period and Frequency
  Period (T) of an analog signal is the time in seconds required to complete one full cycle. Frequency (f) of an analog signal is its number of cycles per second. The mathematical relation between period (T) and frequency (f) is
  Frequency = 1/Period, (f = 1/T).
- Phase
  Phase expresses the position of the waveform relative to time zero and is measured either in degrees or in radians.

Manchester Encoding

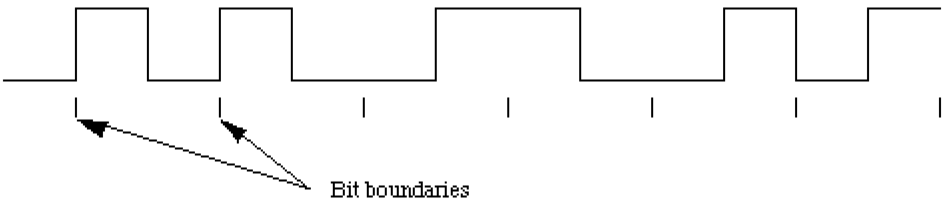
Manchester encoding (first published in 1949) is a synchronous clock encoding technique used by the physical layer to encode the clock and data of a synchronous bit stream. In this technique, the actual binary data to be transmitted over the cable are not sent as a sequence of logic 1's and 0's (known technically as Non Return to Zero (NRZ)). Instead, the bits are translated into a slightly different format that has a number of advantages over using straight binary encoding (i.e. NRZ).

In the Manchester encoding shown, a logic 0 is indicated by a 0 to 1 transition at the centre of the bit and a logic 1 is indicated by a 1 to 0 transition at the centre of the bit. Note that signal transitions do not always occur at the 'bit boundaries' (the division between one bit and another), but that there is always a transition at the centre of each bit. The Manchester encoding rules are summarised below:

Original Data	Value Sent
Logic 0	0 to 1 (upward transition at bit centre)
Logic 1	1 to 0 (downward transition at bit centre)

Note that in some cases you will see the encoding reversed, with 0 being represented as a 0 to 1 transition. The two definitions have co-existed for many years. The Ethernet Blue-Book and IEEE standards (10 Mbps) describe the method in which a Logic 0 is sent as 0 to 1 transition, and a Logic 1 as a one to zero transition (where a zero is represented by a less negative voltage on the cable). Note that because many physical layers employ an inverting line driver to convert the binary digits into an electrical signal, the signal on the wire is the exact opposite of that output by the encoder. Differential physical layer transmission, (e.g. 10BT) does not suffer this inversion.

The following diagram shows a typical Manchester encoded signal with the corresponding binary representation of the data (1,1,0,1,0,0) being sent.



The waveform for a Manchester encoded bit stream carrying the sequence of bits 110100.

Note that signal transitions do not always occur at the 'bit boundaries' (the division between one bit and another), but that there is **always** a transition at the centre of each bit.The encoding may be alternatively viewed as a phase encoding where each bit is encoded by a postive 90 degree phase transition, or a negative 90 degree phase transition. The Manchester code is therefore sometimes known as a **Biphase Code**.

A Manchester encoded signal contains frequent level transitions which allow the receiver to extract the clock signal using a Digital Phase Locked Loop (DPLL) and correctly decode the value and timing of each bit. To allow reliable operation using a DPLL, the transmitted bit stream must contain a high density of bit transitions. Manchester encoding ensures this, allowing the receiving DPLL to correctly extract the clock signal.

The bi-phase Manchester encoding can consume up to approximately twice the bandwidth of the original signal (20 MHz). This is the penalty for introducing frequent transitions. For a 10 Mbps LAN, the signal spectrum lies between the 5 and 20 MHz. Manchester encoding is used as the physical layer of an Ethernet LAN, where the additional bandwidth is not a significant issue for coaxial cable transmission, the limited bandwidth of CAT5e cable necessitated a more efficient encoding method for 100 Mbps transmission using a 4b/5b MLT code. This uses three signal levels (instead of the two levels used in Manchester encoding) and therefore allows a 100 Mbps signal to occupy only 31 MHz of bandwidth. Gigabit Ethernet utilises five levels and 8b/10b encoding, to provide even more efficient use of the limited cable bandwidth, sending 1 Gbps within 100 MHz of bandwidth.

Example of Manchester Encoding

The pattern of bits " 0 1 1 1 1 0 0 1 " encodes to " 01 10 10 10 10 01 01 10".

Another more curious example is the pattern " 1 0 1 0 1 etc" which encodes to "10 01 10 01 10 " which could also be viewed as "1 00 11 00 11 0 ". Thus for a 10 Mbps Ethernet LAN, the preamble sequence encodes to a 5 MHz square wave! (i.e., One half cycle in each 0.1 microsecond bit period.)

Thinking more about sending bits

A transmission rate of 10 Mbps implies that each bit is sent in 0.1 microseconds. For a coaxial cable, the speed at which the signal travels along the cable is approximately 0.77 times the speed of light (i.e. 0.77x3x10E8). A bit therefore occupies 23 metres of cable. Under the same conditions the smallest frame would be 13.3 km!

Channel Capacity

The speed of transmission of information is said to be the channel capacity. We count it as data rate in digital world. It depends on numerous factors such as:

- **Bandwidth:** The physical limitation of underlying media.
- **Error-rate:** Incorrect reception of information because of noise.
- **Encoding:** The number of levels used for signaling.

Data carrying capacity in the physical layer

The various physical media offer transfer of data at different speeds. The data transfer rate can be measured using three metrics.

1. Bandwidth – the capacity of the line. This is measured in bp/s (bits per second), kb/s kilobit per second and mb/s megabit per second.
2. Throughput – this is the actual transferred data over a certain amount of time, in most cases it is usually less than the bandwidth.
3. Goodput – the actual useable data that has been transferred over a certain period of time is known as goodput.