Physical Layer

The **physical layer** is the lowest layer of the network stack. It is responsible for transmitting bits through a physical medium, such as a copper cable, an optical fibre, or the space through which radio waves travel.

At this layer, data is no longer treated as packets or frames, but as sequences of bits represented through physical signals. The task of the physical layer is therefore to convert 0s and 1s into signals that can travel through the transmission medium and then be interpreted correctly by the recipient.

The transmission media used to create a communication channel within a network are generally divided into three categories according to the physical phenomenon used to transmit the bits:

- **Electrical media:** These use the ability of metals to conduct electrical energy, as in twisted-pair telephone cables.
- **Optical media:** These use light to transmit data, as in optical fibres.
- **Wireless media:** These use electromagnetic waves, as in microwave radio and satellite communications. In this case, the transmission medium can be considered the free space, or surrounding environment, through which the electromagnetic waves propagate.

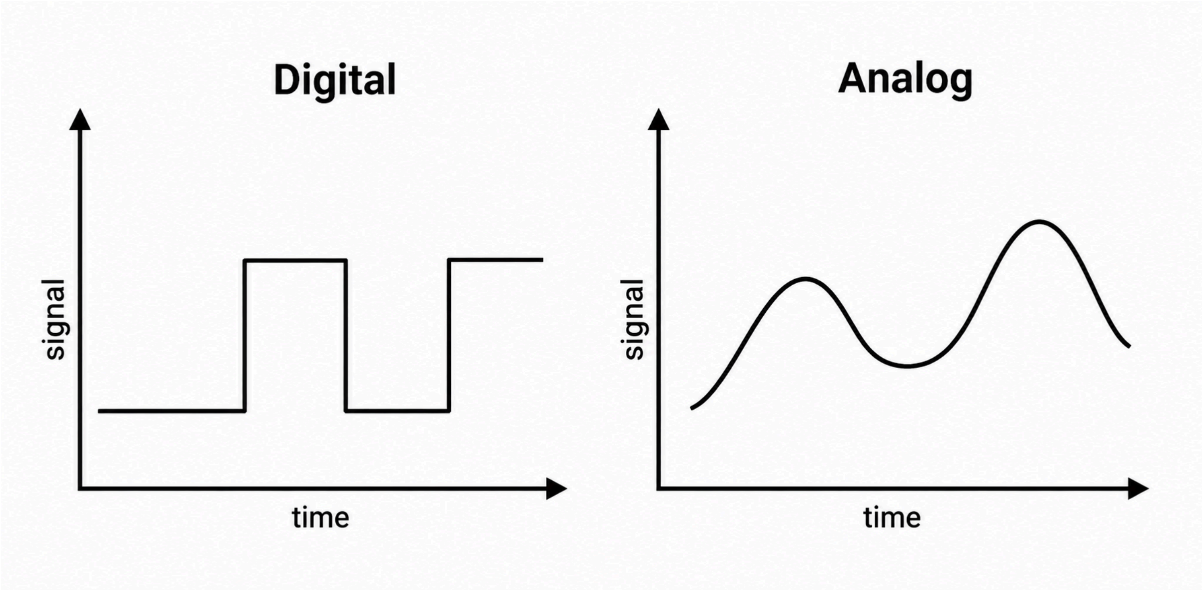
The physical layer must encode data so that it can be carried by the transmission medium.

The encoding method depends on the characteristics of the medium being used. For example, when transmitting information through a copper wire, a physical property such as voltage or current is varied.

A network component is therefore required to convert bits into signals suitable for the medium. This conversion may be performed by different components, such as an Ethernet network interface card, a Wi-Fi module, a modem, or an optical converter.

The device converts bits into physical signals suitable for transmission and performs the reverse conversion when receiving data.

- An **analogue signal** varies continuously over time and can take many intermediate values.
- A **digital signal**, by contrast, represents information using a limited set of distinct values, such as two voltage levels associated with 0 and 1.



Example
A common example of encoding bits through a voltage signal is **Non-Return-to-Zero encoding**, or **NRZ**.

In a simplified NRZ system, the binary value `0` is represented by one voltage level, such as 0 volts, while the binary value `1` is represented by another voltage level, such as +5 volts.

Suppose we have the bit sequence:

`101010`

Using NRZ encoding, the bits can be represented as follows:

- `1` is encoded as a positive voltage of +5 volts.
- `0` is encoded as 0 volts.

The sequence `101010` is therefore encoded as:

`+5 V, 0 V, +5 V, 0 V, +5 V, 0 V`

Note: This is a simplified example. In real technologies such as Ethernet and Wi-Fi, physical encoding methods may be considerably more complex.

Optical Fibre

Optical fibre is a data-transmission technology that uses pulses of light to carry information through a cable made of thin strands of glass or plastic.

It is one of the most important and effective transmission media used in modern networks because of its high speed, large data-carrying capacity, and resistance to electromagnetic interference.

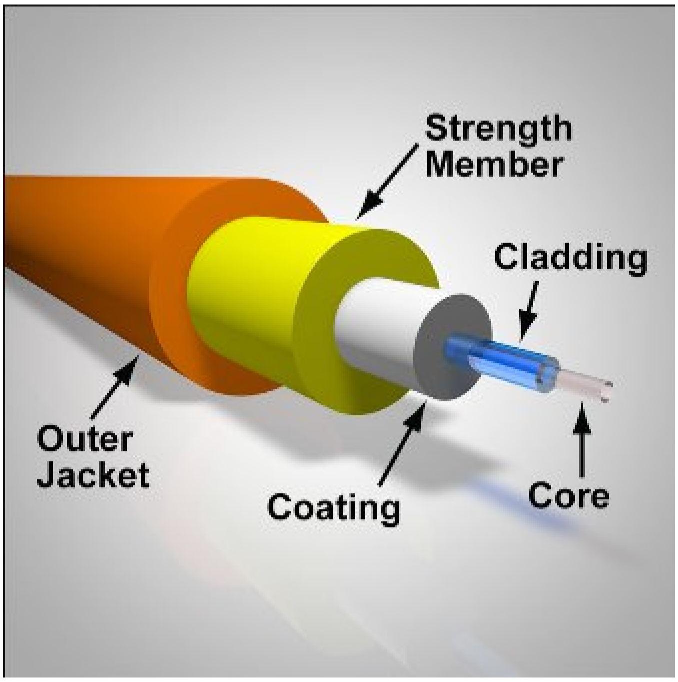
In simplified terms, digital data can be represented as follows:

- `1` = the presence of a light pulse.
- `0` = the absence of a light pulse.

In real technologies, however, the encoding and modulation of light may be more complex.

Because the optical strand is extremely thin and delicate, an optical-fibre cable consists of several protective layers. Its main structure includes:

- **Core:** The glass or plastic central section through which light travels.
- **Cladding:** The layer surrounding the core.
- **Coating:** A plastic protective layer that helps resist scratches, microbending, moisture, and dust.
- **Strength member:** A component that provides mechanical strength. In particular, it protects the cable against tension during installation, bending, compression, impacts, and environmental stress.
- **Outer jacket:** The outermost covering that surrounds and protects the entire optical-fibre cable. It is the part that can be seen and touched when handling the cable.



How Does It Work?

An optical fibre is an extremely thin strand—thinner than a human hair—that can guide light through its interior using a physical principle called **total internal reflection**.

Total internal reflection occurs when a ray of light reaches the boundary between the core and the cladding at a sufficiently large angle. Instead of leaving the core, the light is completely reflected back into it.

This phenomenon works because the core and the cladding have different **refractive indices**.

The refractive index indicates how much light slows down when it travels through a material: the higher the refractive index, the more the light is slowed.

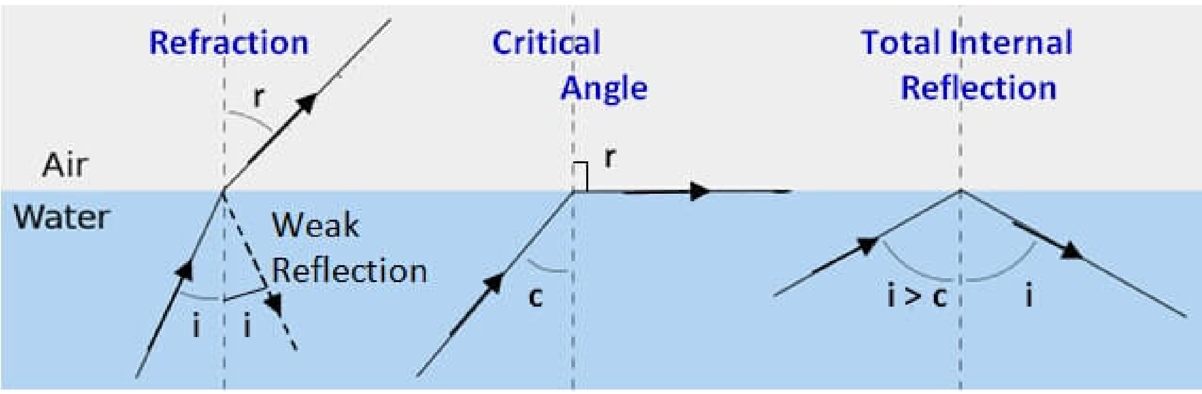
In an optical fibre, the core has a higher refractive index than the cladding.

When light travels through the core and reaches the boundary with the cladding, it tends to change direction.

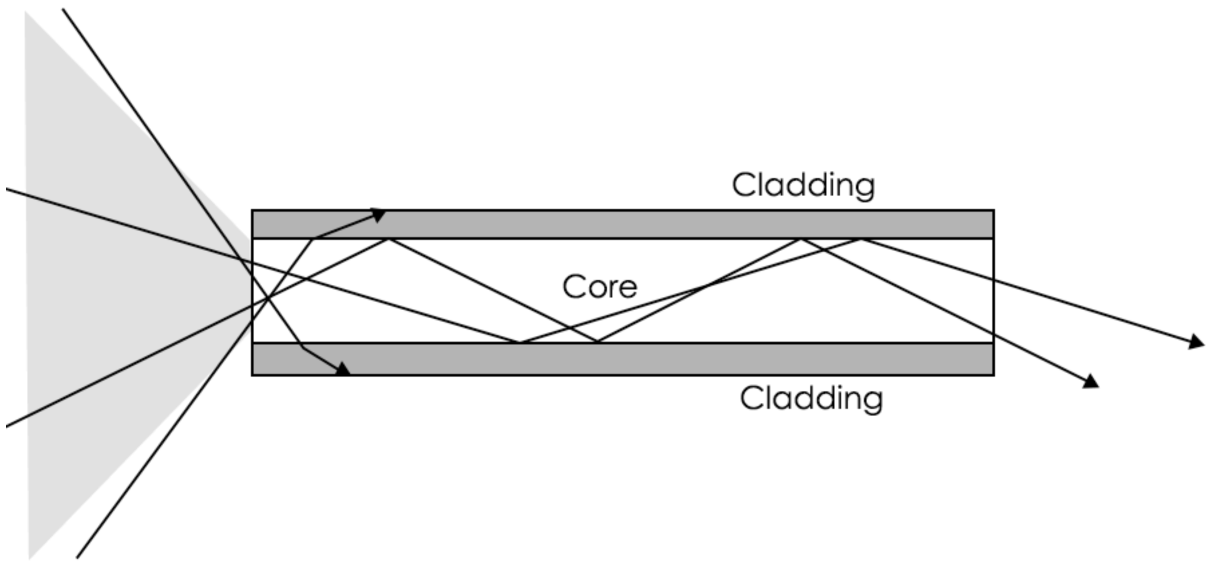
Because it is travelling from a material with a higher refractive index to one with a lower refractive index, the light bends away from the line perpendicular to the boundary between the two materials.

If the angle at which the light reaches the boundary is sufficiently large, the refracted light would have to travel almost parallel to that boundary. Beyond a particular angle, called the **critical angle**, there is no possible direction in which the light can propagate into the cladding.

The light therefore remains inside the core and is completely reflected.



In this way, light pulses remain guided inside the fibre and can travel over long distances.



This effect guides light along the entire length of the fibre, even across extremely long distances.

As a metaphor, we can imagine an optical fibre as a tunnel of mirrors: the light is guided along its path until it reaches the other end of the fibre.