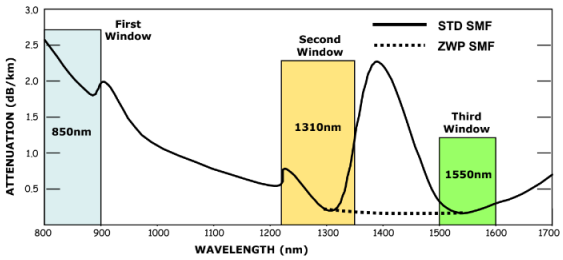
03 - Infastructure PON

03_Infrastructures_PON.pdf

Optical fiber

How they are made

An optical fiber (very thin piece of glass) used to transmite light is over long distances with a minimal loss with difference wavelengths mesured in nanometers (nm)



There are 3 windows where light is used for communication and those are recognised based of attenuation and wavelength:

- first windows is typicall used in multimode fiber
- secondo windows for standard single-mode fiber
- thirs windows is the most commonly used in modem

In the image we can see how much attenuation (signal loss) there is with a certain wavelength.

Channels/attenuation is almost flat, meaning that there is a lower variation of it, resulting in a larger bandwidth able to transmitt more data (higher bitrate) in parallel using multiplexing.

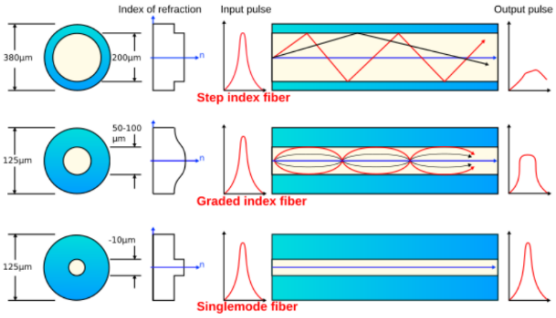
In optic fibers there is no interference thanks because light ins constrained into tube reducing dispersion, so there is no external interferenze so no FEXT between channels.

How they work

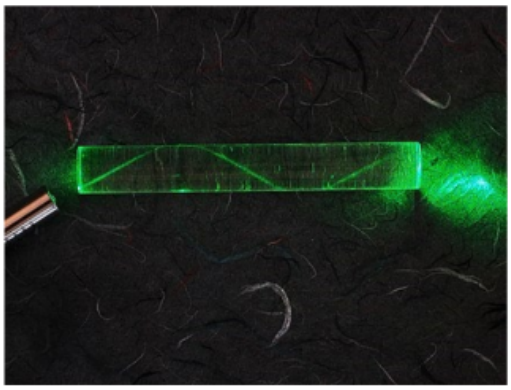
transmission occur through reflection of light

- monomodal: transmitt only one color (a certain bandwidth)
- multimodal: multicolor transmission, receiver will recognize all color and total bit rate is $n_{\text{color}} \times \text{bit\_rate}$(we can have 10 color to 10000, depend on technology)

Smaller is the diameter of fiber, better will be the transmission because the light bounces on fiber’s wall.



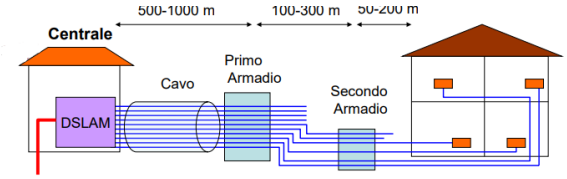
Once light has travelled through the cable, an optic receiver (o fotodettore) will convert light into informations.



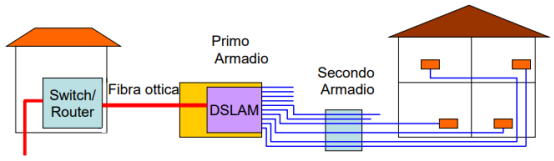
Architecture FTTx

In general we have

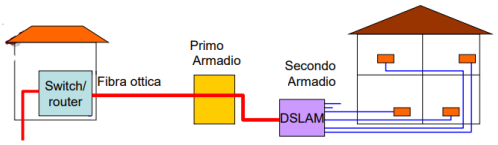
- CO: which is the central office where typical there is a DSLAM for multiplxing, or a switch / router
- Optical fiber which connect cabinets
- Copper or optical fiber to connect cabinets and houses



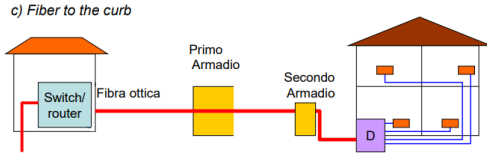
a) Best current architecture



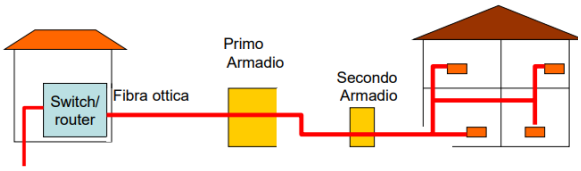
b) Fiber to the cabinet



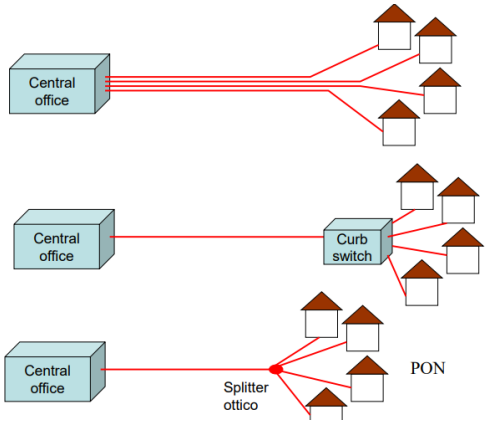
c) Fiber to the curb



d) Fiber to the building

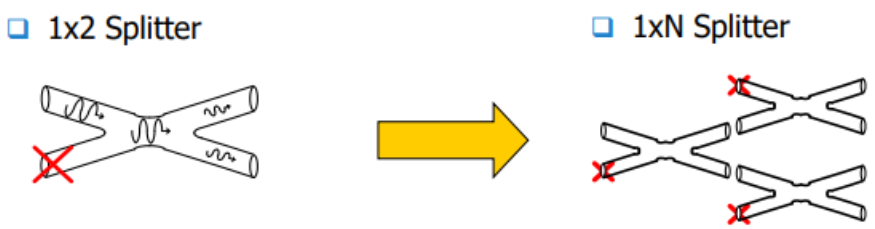


e) Fiber to the home



From the central office we have different possibility to put the cable and link houses

- Cable from CO to houses (high cost due to diggings)
- Curb switch, a device used to send signal only to the correct path
- Optical splitter: passive device use to split signal



Optical splitter is made by different optic fibers fused together, close one part or the splitter and the signal is splitted in more way but the signal is reduced but we have a brodcast signal, everyone receive traffic of everyone.

Higher is the splitting, higher is the $\text{Loss} \approx 3\text{dB} \times \log_2(\#\text{ONUs})$ (Optical Network Unit)

Photodiodes: on receiver side, photodiodes are used to convert optical signals into electrical signals.

To ensure reliable transmission (since fiber optics are used exclusively), the infrastructure can be made more robust by utilizing two parallel fibers. In the event of an issue, such as an attack on one fiber, the other can maintain network operation. This approach is often applied in ring infrastructures, which are commonly used in access networks with fiber optics. In metropolitan areas, these can form "rings of rings" to enhance resilience and reliability

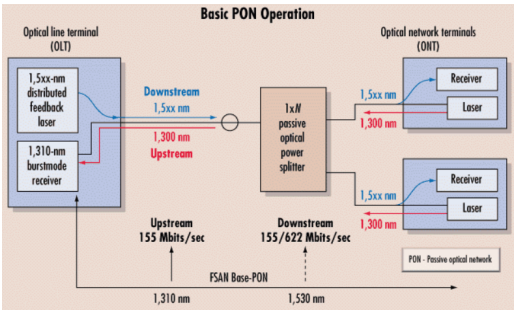
Passive Optical Network (PON)

PON infrastructure

Passive Optical Networks (PON) are infrastructure that use passive components, such as optical splitters, to distribute fiber optic connections. Since these components don’t require electricity, they’re called “passive.”

In a PON, two wavelengths are used to ensure efficient transmission. One wavelength is dedicated to downstream traffic (from the central office to the users), and another is used for upstream traffic (from users back to the central office). Physically, a single fiber is shared for both directions, with the wavelengths separated by frequency division.

We can build an infrastructure like the one on the right using passive splitter to have more branches.



Key components in a PON are:

- **OLT (Optical Line Terminal)**: The OLT transmits data within the PON infrastructure.
- **ONT (Optical Network Terminal)**: The ONT is the receiving device located at the user's end of the network.
- **Photodiodes**: These convert optical signals into electrical signals, enabling communication over the network.

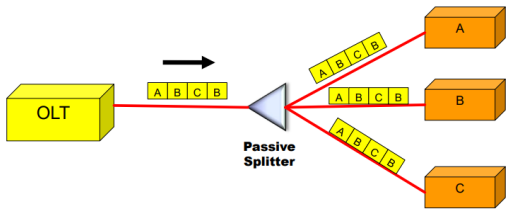
Time Division Multiple Access (TDMA)

In PONs, data is broadcast to multiple devices. Therefore, a method is required to ensure each receiver only processes the data intended for it.

With TDMA (Time Division Multiple access), the channel is divided into time slots, and the OLT organizes data to be transmitted within specific slots.

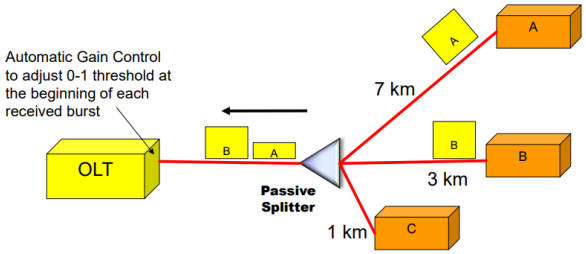
In downstream scenario, OLT work as a control center

The OLT assigns time slots to each ONT and includes the destination MAC address within the data. This enables the receiving ONT to determine if the incoming data is relevant.



Different case is for the upstream: OLT is a crucial component because it manges everything about traffic (otherwise ONU will interfere each others)

Due to distances, some signal will be attenuate, so OLT will “calculate” for ONU the amount of power required in a way all packets arrive with the same power. It will consider also propagation time and other usefull informations.



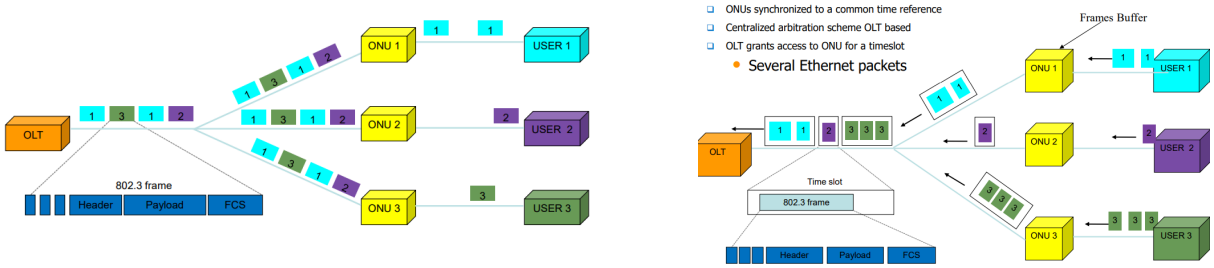
OLT as central control unit

Thank to OLT whihc for as a central unit, ONU must not care about synchronization and other stuff, infact withouth a central unit ONU must be fully synchronized and aware of the distance.

OLT will work of that way to mange traffics

1. performe a probing of ONU veriyfing their distance saying them the behavior to follow in order to don’t cause interference (so organizing scheduling considering also propagation delay)
2. in terms of receiving, OLT receive light, if ONU are different distance the light arrive with different attenuation (which depend by the distance). In OLT, if attenuation are different the idea is to transmitt at power that is configured in a way that when it arrive in OLT they are all the same

Ethernet Passive Optical Network (EPON)



- **Downstream**: In PONs, downstream transmission uses ethernet frames (802.3 indicate the ones for optic fiber) , which include a Frame Check Sum (FCS) and a MAC address in the header to identify the recipient.
- **Upstream**: For upstream traffic, each ONT aggregates incoming data into a single packet. The OLT manages transmission synchronization to prevent collisions and interference.

adsl have a good behavior until 1.5 km to work well

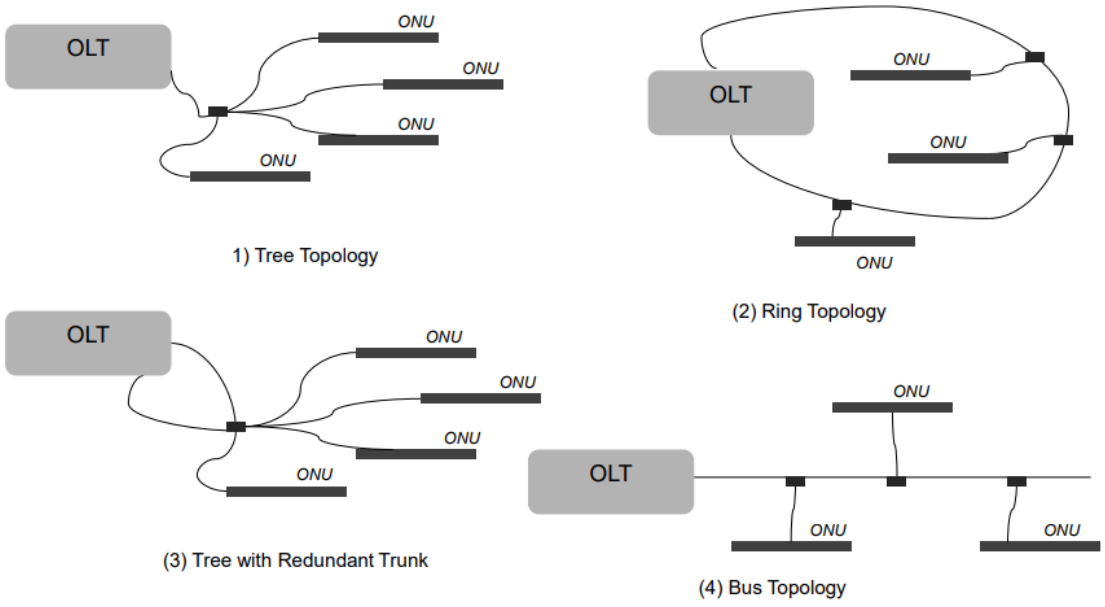
Wavelength Division Multiplexing (WDM)

PON Evolution: Beyond a single wavelength for downstream and upstream, PONs can also employ **Wavelength Division Multiplexing (WDM)**, which allows multiple wavelengths to be carried over the same fiber.

- **Multi-Mode Fibers**: These fibers can support multiple wavelengths, with each “color” or wavelength assigned to different sets of users.
- **Technological Challenges**: Supporting multiple wavelengths requires compatible lasers and photodiodes capable of filtering and processing the correct colors.
- **Optical Routers (AWG)**: Arrayed Waveguide Gratings (AWGs) can route specific wavelengths to designated outputs, all within the optical domain, without requiring electricity.

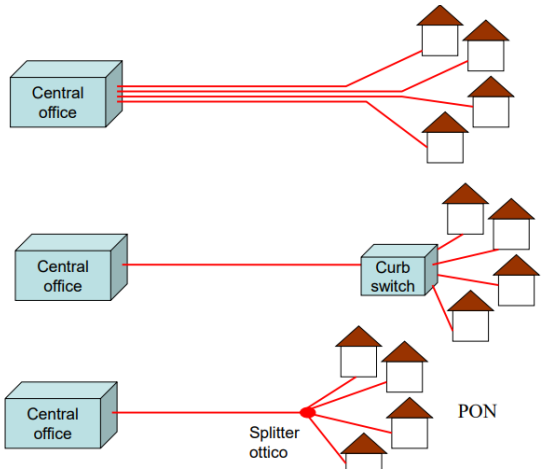
- **Limitations**: AWGs may introduce signal attenuation, and the number of users is limited by the available wavelengths. To expand capacity, additional fibers can be laid in parallel, creating a scalable architecture.

Type of infrastructures



PON configuration can also be implemented using ring topologies (especially in metropolitan areas) instead of the traditional tree structure.

Exam question



Question: Do we need this type of infrastructure PON in the first scenario?

- **Answer for the First Scenario**: No. In the first setup, the central office connects directly to each home without any intermediate device like a curb switch or splitter. This configuration typically requires a dedicated line for each connection, which does not rely on shared infrastructure. Consequently, there is no need for an additional component to manage data distribution among multiple users.

Question: In the second scenario, do we need any additional infrastructure?

- **Answer for the Second Scenario**: Potentially, yes. In the second setup, there is a **curb switch** between the central office and the homes. This switch can handle multiple data packets simultaneously and has the capability to recognize each receiver individually.
    - If there are multiple packets, the switch identifies the intended recipient and manages traffic independently for both downstream and upstream transmission.
    - The curb switch can handle packets arriving at different power levels and times. It uses an internal buffer to resolve queuing and manage data flow efficiently.
    - This means the curb switch can effectively manage traffic without needing additional infrastructure, as it is designed to handle packet routing and power level adjustments as needed.

Overall, in the second scenario, the infrastructure can manage data distribution and traffic effectively due to the presence of the curb switch, which handles these functions independently.

In the second? we may need something, but the switch recognize itself the receiver. if there are multiple packets the switch reconize it and the swtich manage it independently, same for down/upstream. it can receiver at different power and time. switch solve the queue using a buffer.