Elements of the NGAN

- *Optical Line Termination* (OLT), it is the terminating device of optical cables and it can be positioned both in SLs and in SGUs.
- *Optical Network Unit* (ONU): the optical device positioned close to the user: it can be connected, on the user side, to a copper network termination (NT) dello stesso. Multiple ONUs are connected to one OLT. In the FTTC case, the ONU is in the street cabinet. In the FTTB case, the ONU is placed close to the building.
- *Optical Network Termination* (ONT): it it the user's optical termination, in the FTTH architecture
- *Optical Distribution Frame* (ODF): it is the optical permutator, in the exchange, which substitutes the electric wire permutator (MDF). Peripheral devices placed in street cabinets or underground are the SDFs, while, if they are placed inside buildings, they are called DFs.

Elements of the NGAN

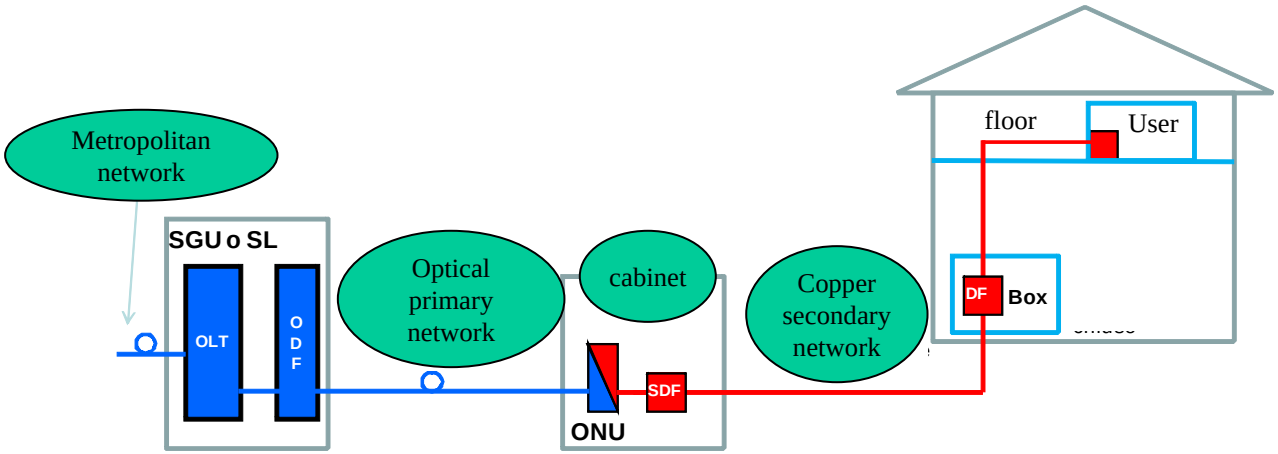
- In some cases optical connections among OLT, ONU and ONT are single-fiber, thus bidirectional transmission is obtained by wavelength division.
- OLT-ONU connections frequently adopt 2 fibers (no neel of wavelength division)
- In other less frequent cases, optical connections are made with two fibers, one active and one spare.

Point-to-Point systems (Point-to-Point, P2P)

- In P2P systems there is a dedicated optical connection from OLT to ONU/ONT, used with Fast Ethernet (100 Mbit/s) or Gigabit Ethernet (1 Gbit/s) technologies
- Generally the access network has a star topology, which is common also in the classic copper access network
- The optical transmission cable is dedicated, thus the transmission capacity is the highest possible
- The P2P architecture has comparatively higher costs
- PON techniques provide an alternative tradeoff trading in performance for cost

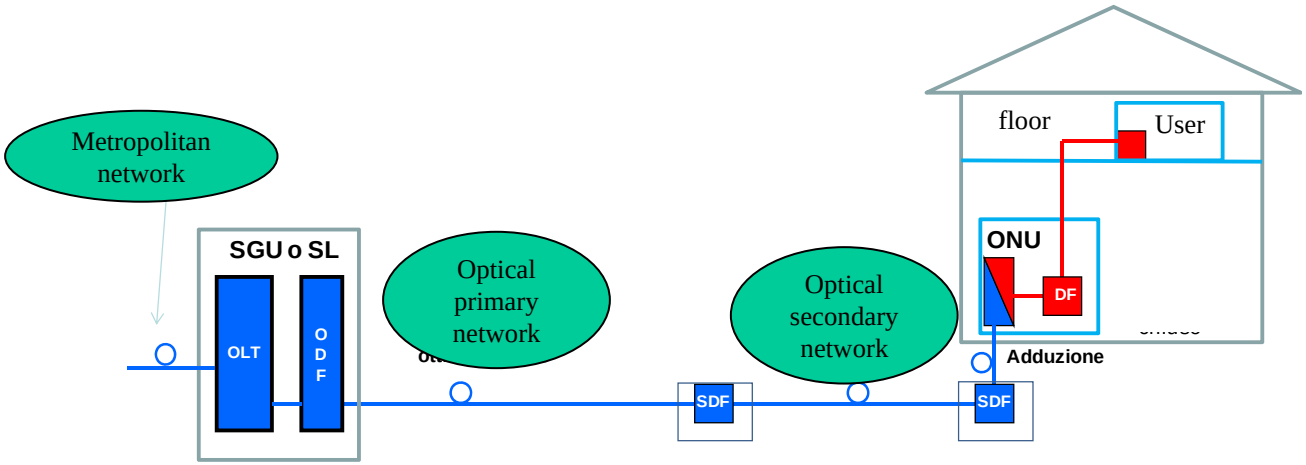
Point-to-Point systems (Point-to-Point, P2P)

- The Figure shows a P2P-FTTC system
- The connection between the SGU/SL to the street cabinet (*armadio*) is optical
- The street cabinet accommodates the ONU to terminate and connect optical fibers and copper lines
- On the copper network, transmission is frequently done through VDSL2



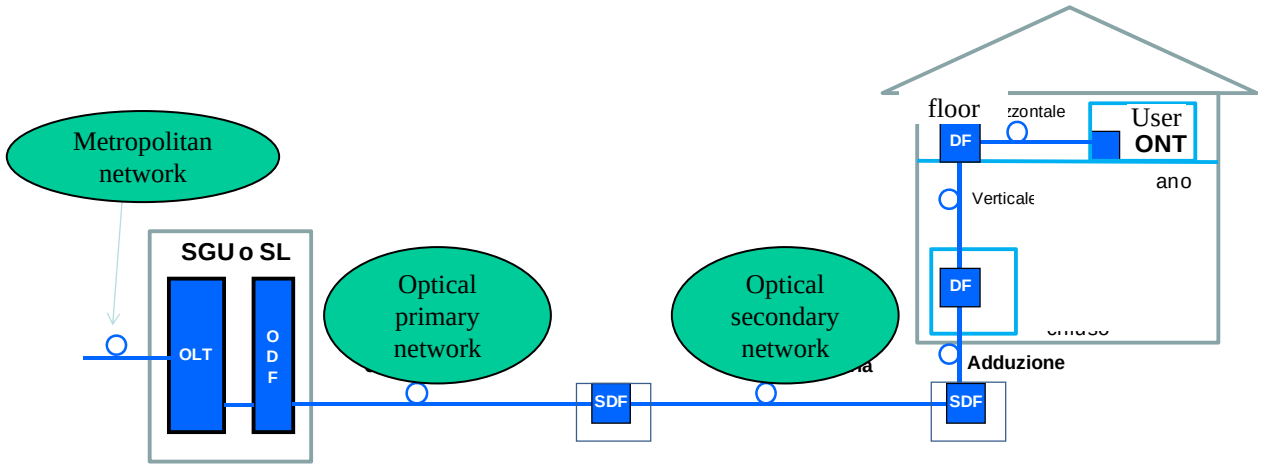
Point-to-Point systems (Point-to-Point, P2P)

- The Figure shows a P2P-FTTB system
- The optical connection reaches the building, then the vertical copper cabling connects the user
- The ONU is placed at the basement of the building, and it is where optical/electrical conversion occurs



Point-to-Point systems (Point-to-Point, P2P)

- The Figura shows a P2P-FTTH system
- Both horizontal and vertical cabling inside the building are made with optical fibers
- Optical terminations in DFs are placed both at the building basement and at each floor
- For a transmission speed of 100 Mbit/s a single fiber is used;
- For 1 to 10 Gbit/s and long distance from building to SGU/SL, two fibers are used, one for uplink and one for downlink



Passive Optical Network, PON

- A PON network used only passive devices between OLT and ONU/ONT
- The capacity of optical fibers is shared among groups of users
- Passive devices can be splitters; a splitter divides the capacity of one optical fibers among a number n of optical fibers at its output
- Conversely, it multiplexes the signal from multiple fibers onto a single fiber, in the opposite direction

Passive Optical Network, PON

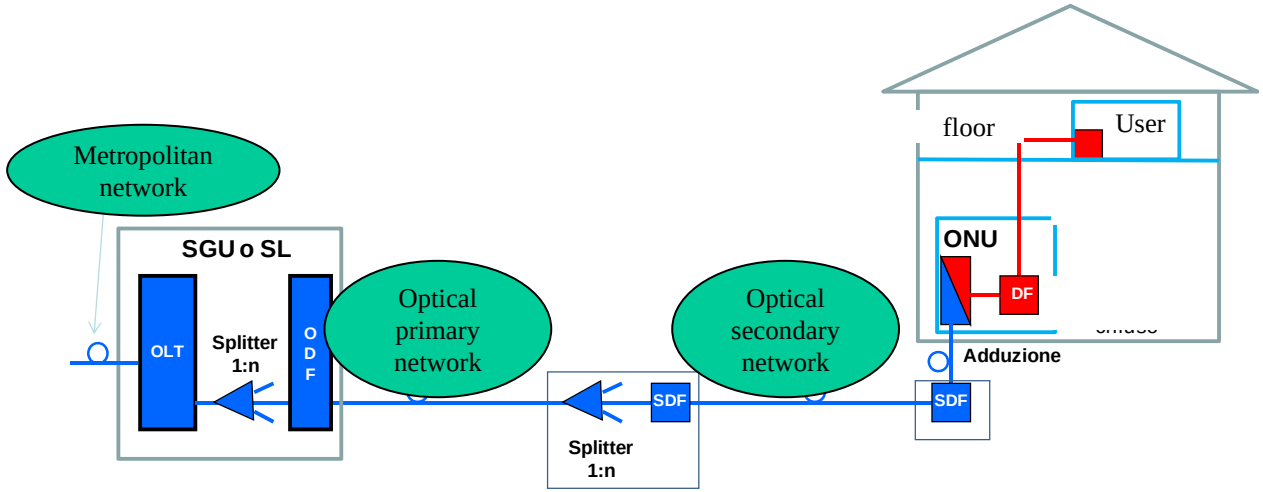
- A splitter is characterized by its split ratio (1:*n*), o split ratio, where *n* is the number of optical fibers at its output (in the downlink direction)
- *n* can vary, typical values are 32, 64, and 128
- The signal at the input of the splitter (in the downlink direction) is broadcasted on the *n* output optical fibers
- Privacy is thus an issue and it can be coped with through encryption
- In the upstream direction, n signals converge into one optical fiber, thus a multiple access method to share the capacity of this single physical resource is needed

Passive Optical Network, PON

- PON systems require comparatively less optical fibers to reach a given number of users, thus, costs are smaller than with P2P systems
- However, sharing the capacity of one fiber among *n* users degrades

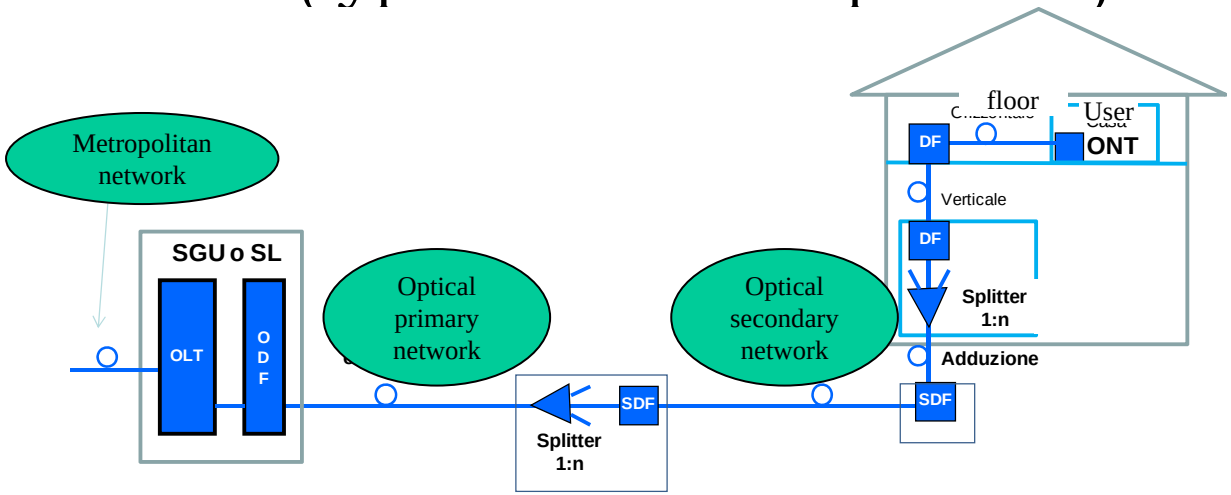
Passive Optical Network, PON

- The Figure shows a FTTB-PON system
- Splitters are frewquently placed in small underground cabinets
- Splitting can be performed multiple times, as shown in the figure
- The purpose of the splitter in the SGU/SL is to divide the bandwidth of the PON network among a set of branches departing from the ODF
- The Figure shows one of these n branches
- The purpose of the second splitter is to reduce the number of optical fibers in the secondary access network and thus reduce costs
- If the SGU splitter has ratio 2 and the other splitter has ratio 4, a PON rooted at the OLT reaches 8 ONUs at the building



Passive Optical Network, PON

- The Figure shows a PON-FTTH system
- Usually splitters are placed in small street undergroud cabinets and inside the building
- The ratio of the street splittere is frequently 1:2 - 1:4, and for the in-building splitter the ratio is 1:8 - 1:32
- This adds up to a total split ratio ranging from 1:16 to 1:128 (typical values in practice)



TDM-PON

- Time Division Multiplexing PONs use two different wavelengths for uplink and downlink communications
- The OLT applies the procedures for the coordinated access to the broadcast optical channel
- In TDM PONs the OLT uses time division: time is divided into slots and each branch ONU-ONT has a dedicated time slot
- In order to avoid collisions, a synchronization signal must be distributed to ONTs, in order to compensate the different round trip delays due to different total length of optical fiber branches
- Two important standards defining how TDM-PONs operate are
  - ITU G.984 Gigabit-capable-PON (GPON)
  - 802.3ah Ethernet-PON (EPON)

TDM-PON

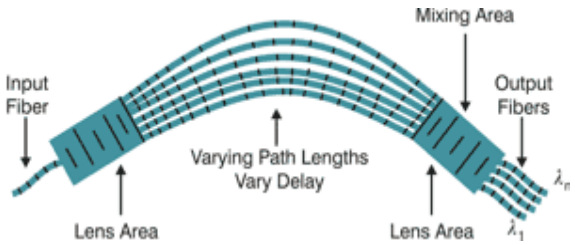
- GPON uses a set of wavelength “windows”: 1480 nm -1500 nm for the downlink channeland 1260 nm -1360 nm for the uplink
- GPON can operate at a speed of about 2,5 Gbit/s (precisely 2,48832 Gbit/s) in downstream and about 1,25 Gbit/s (precisely 1,24416 Gbit/s) in upstream
- Teh maximum admitted split ratio is 1:128
- The maximum length of the connection can exceed 20 km
- GPON can transport natively both ATM frames and Ehternet frames through encapsulation

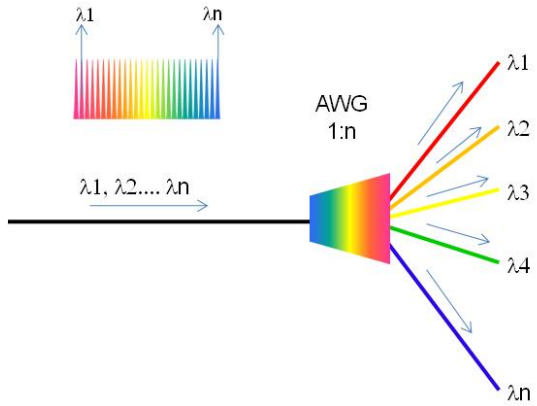
TDM-PON and WDM-PON

- EPON transports natively Ethernet frames and it used the wavelength 1490 nm downstream and 1310 nm uptream
- The transmission capacity is symmetric equal to 1,25 Gbit/s
- A single EPON can reach 32 users, with maximum distance equal to about 20 km
- In order to increase the transmission capacity of optical access networks, Wavelength Division Multiplexing can be used effectively
- Coarse WDM (CWDM) allows 18 wavelengths, Dense WDM (DWDM) allows 162 wavelengths

WDM-PON

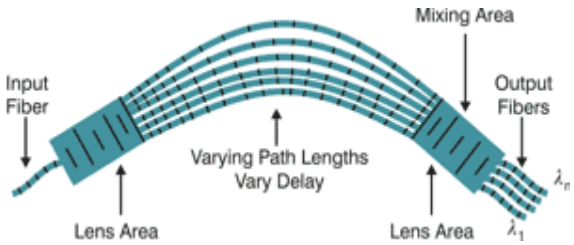
- The basic device to build a WDM PON is the Arrayed Waveguide Grating (AWG)
- It is a passive device that passively routes different wavelengths to different optical fibers

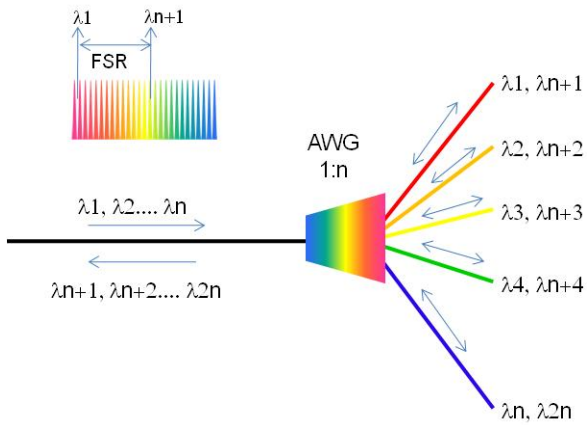




WDM-PON

- The AWG is bidirectional, thus, in the uplink direction, it multiplexes multiple incoming wavelengths into a single optical fiber
- In order to connect n users, 2n wavelengths are needed
- For each user, a wavelength is for the downlink channel and another wavelegth serves the uplink channel





WDM-PON

- WDM PON allow a simple sharing model of access network resources among operators
- Channels from different operators are multiplexed into a single fiber by a first AWG (downlink)
- Then, the second AWG demultiplexes user specific signals