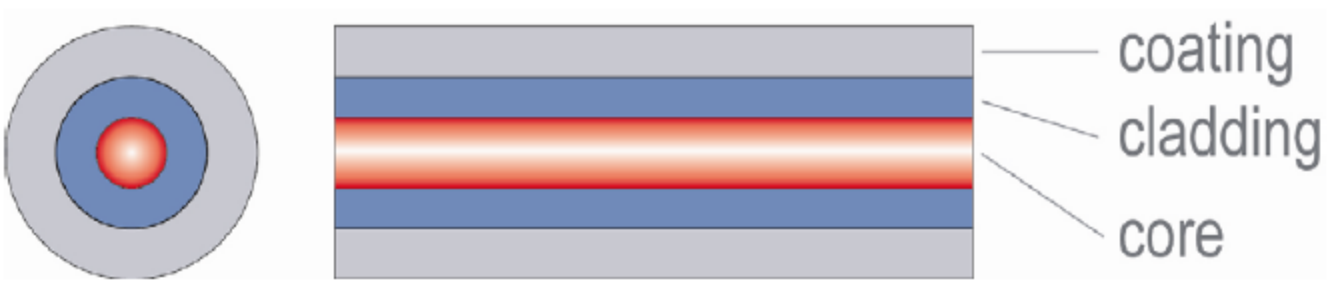
1. Optical Fiber Fundamentals

Optical Fiber Construction

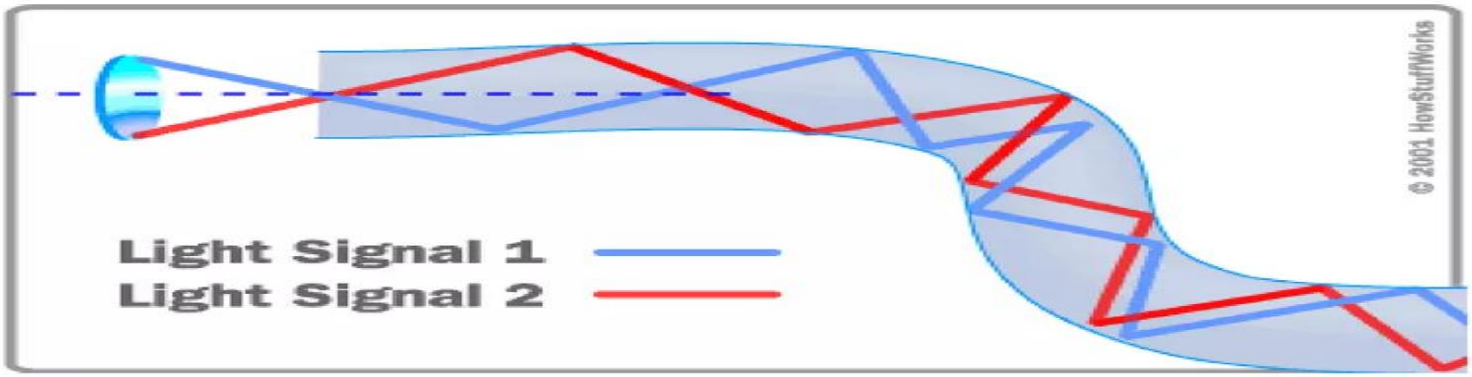
Core: This central section, made of silica or doped silica, is the light transmitting region of the fiber

Cladding: This is the first layer around the core. It is also made of silica, but not the same composition as the core. This creates an optical waveguide which confines the light in the core by total internal reflection at the core-cladding interface.

Coating: The coating consists of one or more layers of polymer that protect the silica structure against physical or environmental damage



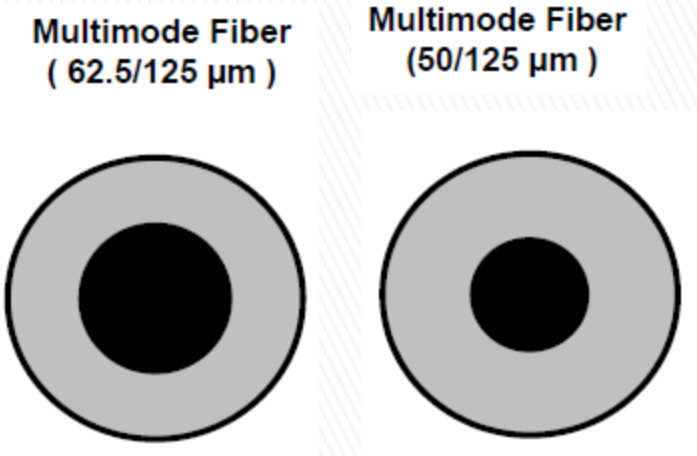
The light is guided down the core of the fiber by the optical cladding which has lower refractive index that traps light in the core through "total internal reflection."



Optical Fiber Types

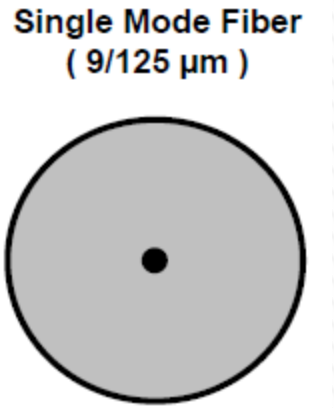
G.651 – MMF – Multimode fiber

- Multimode fibers have a core diameter/cladding diameter ratio of 50/125 microns (10^{-6} meters) and 62.5/125 microns
- Transmit infrared light (wavelength = 850 nm)
- Light Emitting Diodes



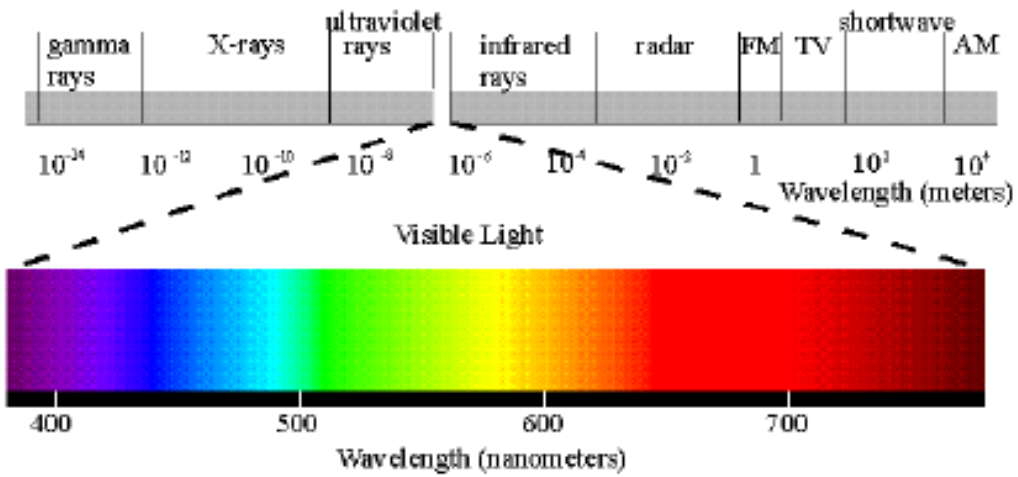
G.652 – SMF – Single Mode fiber

- Single modes fibers have a core/cladding ratio of 9/125 microns
- Transmit laser light (wavelength = 1,310 and 1,550 nm)
- Laser Diodes



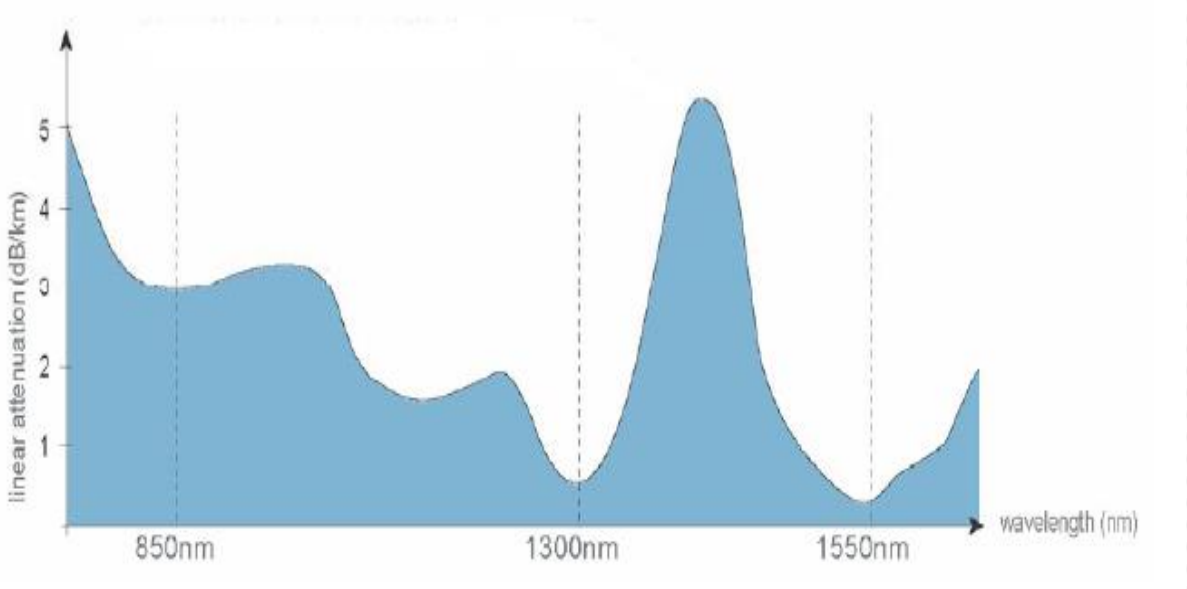
The world of wavelengths

These light sources produce light at certain wavelengths depending upon the materials from which they are made. Most fiber optic sources use wavelengths in the infrared band, specifically 850 nm, 1310nm and 1550nm.



Electromagnetic Spectrum

Attenuation vs. Wavelength of Optical Fiber

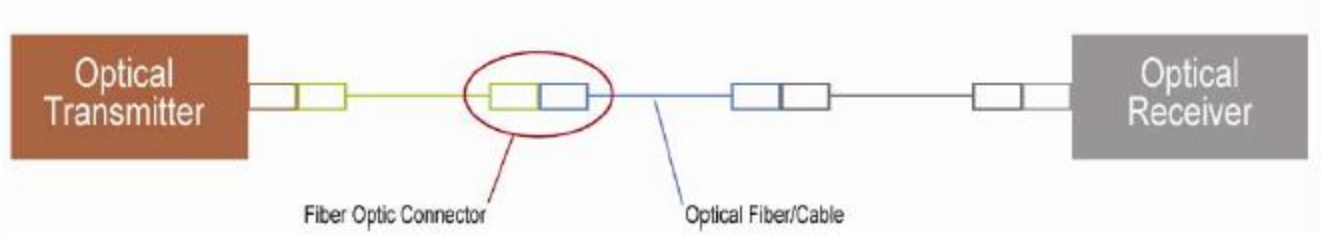


Wavelength	dB/Km
850nm	2.7
1310nm	0.35
1550nm	0.20

Fiber Optic Link Components

There are four main components in a fiber optic link:

- Optical Transmitter
- Optical Fiber Cable
- Connectors
- Optical Receiver



Optical Transmitter

Optical Transmitter uses LED/ LASER Diode as Light Source to convert the electrical signals into optical.

- Light Emitting Diode (LED) is used in multimode applications
- LASER Diode (Light Amplification by Simulated Emission of Radiation Diode) is used in single mode application

Optical Receiver

Optical Receiver uses a photodiode to convert the optical signals into electrical.

- Positive Intrinsic Negative (PIN) (Photo Diode)
- Avalanche Photodiode (APD) (Photo Diode)

Fiber Optic Connecting Method

Fiber Optic Link require a method to connect the transmitter to the receiver.

Methods :

- 1. Fusion Splice
- 2. Mechanical Splice (Connectors)

Fusion Splice

This operation consists of directly linking two fibers by welding with an electric arc or fusion splicer.

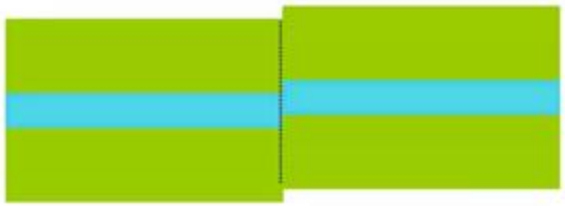
The advantages are fast and sample and very little insertion loss.

The disadvantages are relatively fragile and the initial cost is high.

Joining Fiber with Fusion Splicer

bad alignment

- cores are not centered
- big power loss



good alignment

- cores are centered
- small power loss

Mechanical Splice

A connector terminates the optical fiber inside a ceramic ferrule, using epoxy to hold the fiber.

The advantages are that the connectors are robust, can be chosen according to the applications (such as FC, SC, LC, etc.), can connect/disconnect hundreds of time without damaging the connectors.

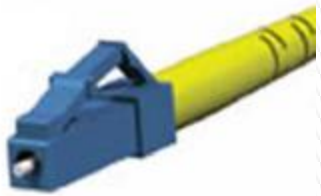
The disadvantages are that the insertion loss can be higher.

Commonly Used Connectors

- FC (Ferrule Connector): still used in measuring equipment

FC-Ferrule Connector

- LC (Lucent Connector): used on small form-factor pluggable transceivers

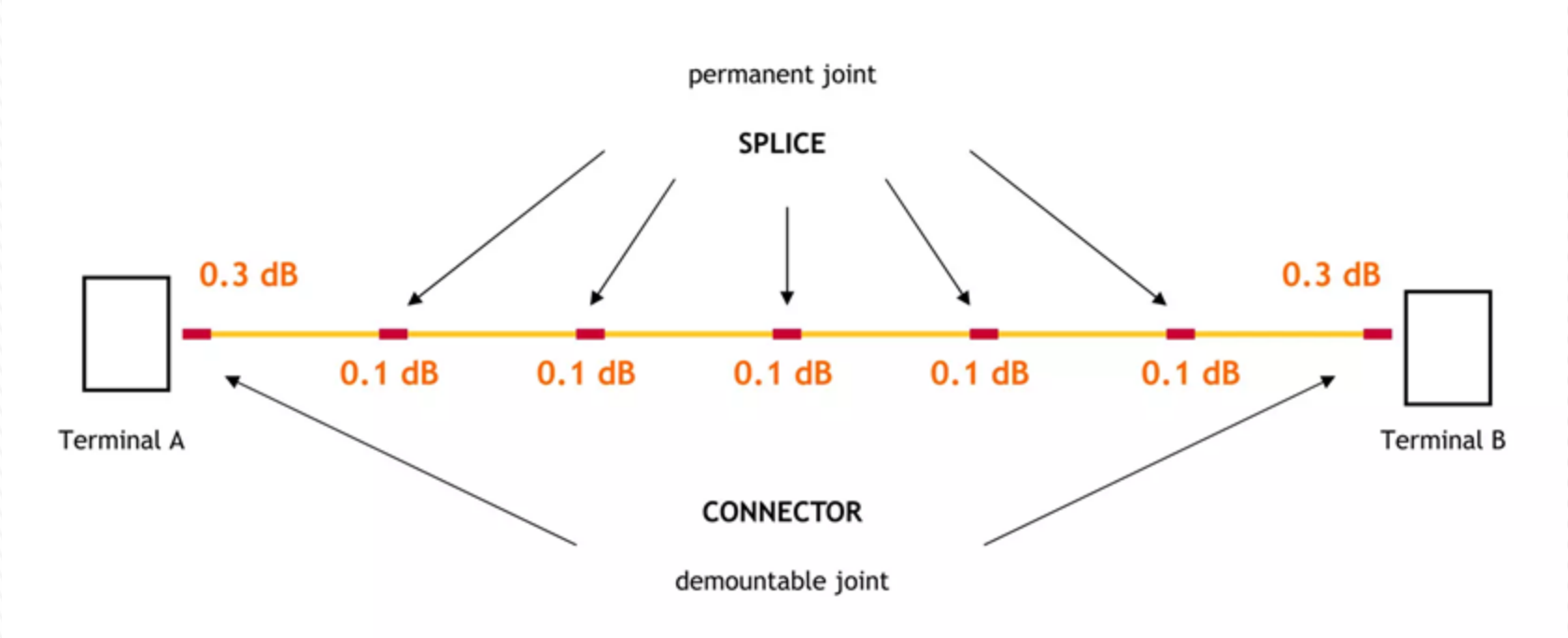


LC-Lucent Connector

- SC (Subscriber Connector): used in telecom and data connections

SC-Subscriber Connector

Fiber Connections and Losses



Structure of Optical Fiber

Fig-8,
Overhead

Under Ground

Optical Transmission Performance	Single Mode 1310/1550nm	Multimode 850 nm			
	9/125µm (OS2)	50/125µm (OM1)	50/125µm (OM2)	50/125µm (OM3)	50/125µm (OM4)
Max Attenuation (dB/Km)	0.35/ 0.20	3.0	2.7	2.7	2.7

Optical Distribution Box (ODB)

- 19" Rack Mount
- Drawer Type Design
- Structure made from Electro Galvanize Steel for durability and lightweight

Joint Closure – Dome Type

- Support optical cable link, branch, distribution
- Made of high impact polycarbonate plastic
- Can be used in wall-mounting, aerial on pole and underground

Joint Closure – Horizontal Type

- Support optical cable link, branch, distribution
- Made of high impact polycarbonate plastic
- Can be used in wall-mounting, aerial on pole and underground

Fiber Testing with OTDR

- OTDR = Optical Time Domain Reflectometer
- To troubleshoot FTTH or P2P network link from one end
- To diagnose faults exceeding specification
- To verify loss of FTTH splitter
- To verify GPON / 10 GPON power level
- To pinpoint location of macro-bends or breaks

Fiber Testing with Power Meter

- To test link loss measurement
- To check SM and MM links specification
- To check continuity and fiber identification

CSM1 Power Meter

Advantages of Fiber

- High bandwidth
- Smaller-diameter, lighter-weight cables
- Lack of crosstalk between parallel fibers
- Immunity to electromagnetic interference (EMI)
- High-quality transmission
- Lower installation and operating costs by comparing with copper cable

Questions

- What are the three parts of an optical fiber?
- What are two type of optical fiber?
- Which wavelengths are commonly used in single mode fiber?
- Why we need to use OTDR?
- Please describe one benefit of Optical Fiber.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PON

Passive Optical Networking

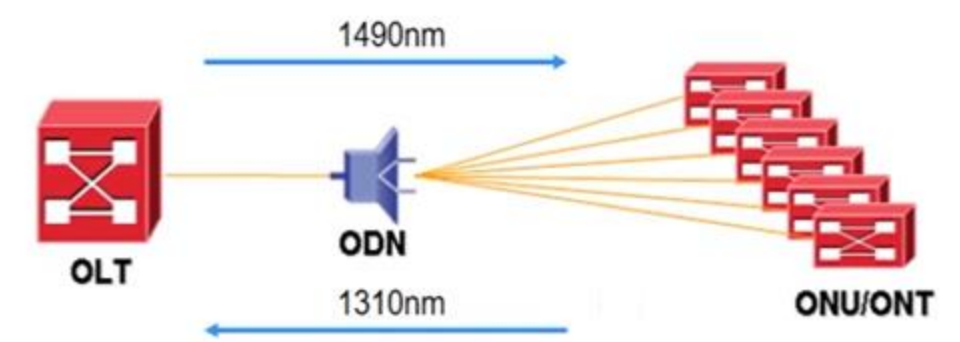
2. PON Fundamentals

Terminology

PON = Passive Optical Network (published by ITU-T).

- Optical Line Terminal (OLT) – Devices that multiplex all optical signals from ONTs and converted into electrical signal.
- Optical Network Termination (ONT) – Devices that connect end-user of PON network and converted into optical signal.
- Optical Network Unit (ONU) – Devices that connect multiple end-users of PON network and converted into optical signal.
- Splitters – Devices that multiplex/demultiplex fiber optic signals to/from a single upstream fiber optic cable. (1:4, 1:8, 1:32, 1:64, and 1:128)
- Optical Distribution Network (ODN) – Compose of physical fiber and optical devices including splitters that distributed signals to users in telecommunication network.

Wavelength Division Multiplexing (WDM) is a technology that multiplexes a two optical carriers signals onto a single fiber core that uses different wavelengths.



GPON adopts WDM to transmit data of different upstream/downstream wavelengths over the same ODN. Wavelengths range from 1310 nm in the upstream direction and from 1490 nm in the downstream direction.

Additional a Wavelength for Video

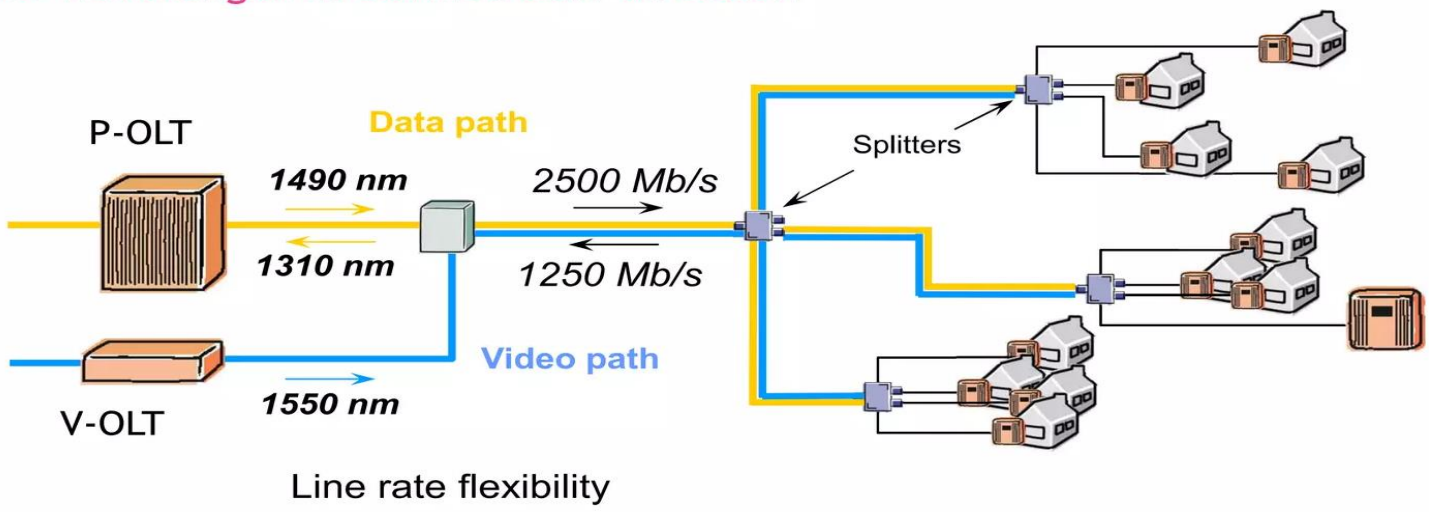
PON lambdas

Voice and data over a single fiber

- two wavelengths in opposite directions (Upstream and Downstream)

Video

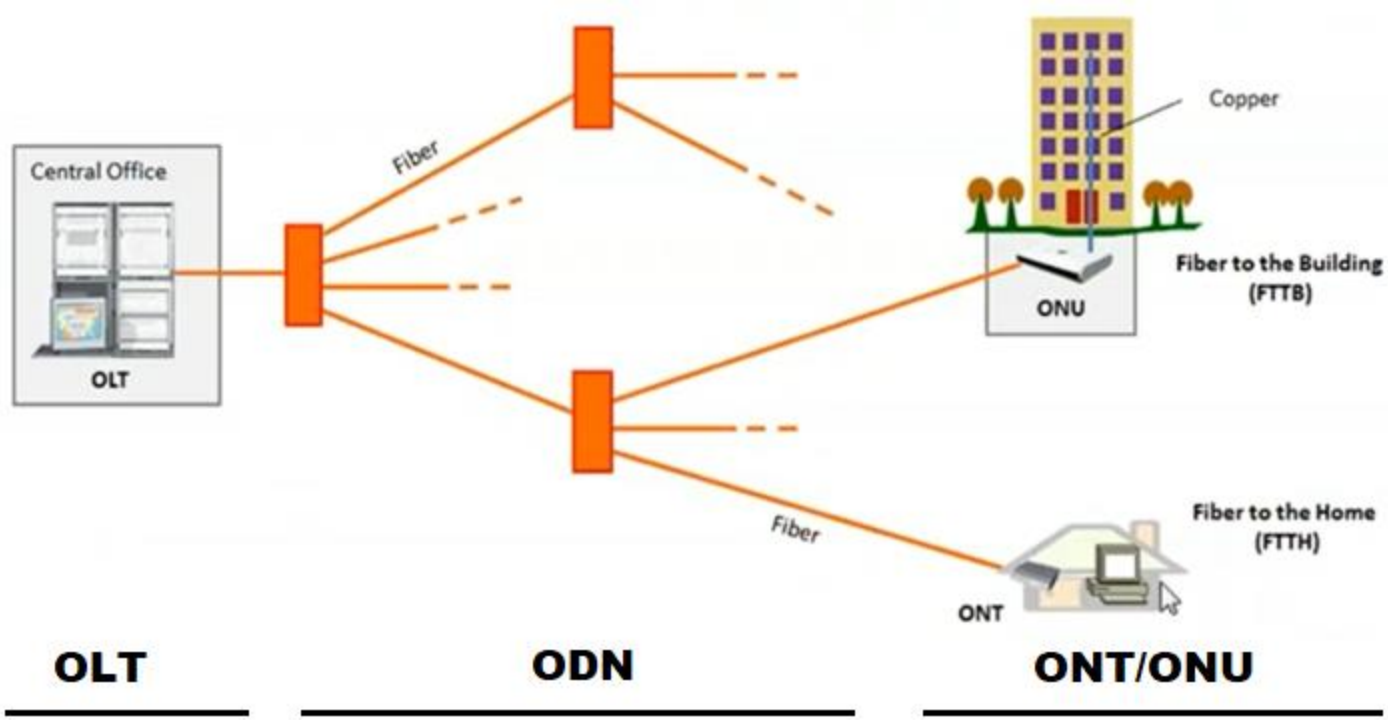
- one wavelength in downstream direction



Line rate flexibility

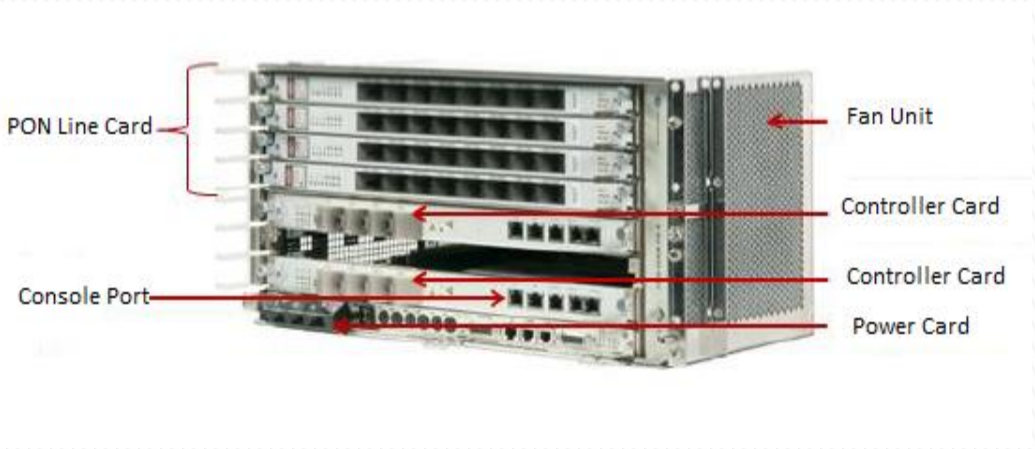
PON Limitations

- Maximum fiber distance between OLT and ONU/ONT is 20 Km
- Split ratio: Restricted by path loss, PON with passive splitters ([16, 32, 64, or 128 way)
- Rate : 1.25 Gbps Up , 2.5 Gbps down (for GPON)



Optical Line Terminal (OLT) Architecture

- 6.4 Tbps backplane capacity
- 2.5 Tbps switching matrix
- 100 Gbps uplink capacity
- All services on a single platform
- 2 controller cards (Redundancy)
- 4 PON Line Cards

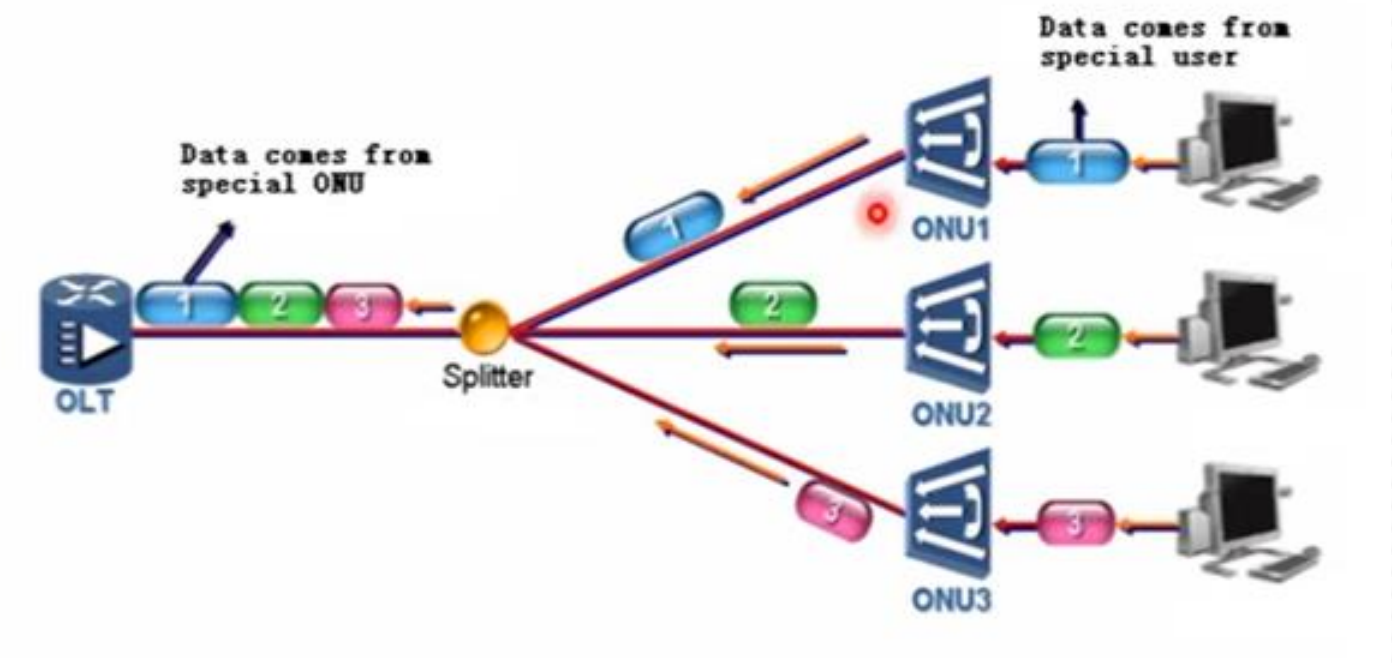


Optical Network Terminal, ONT

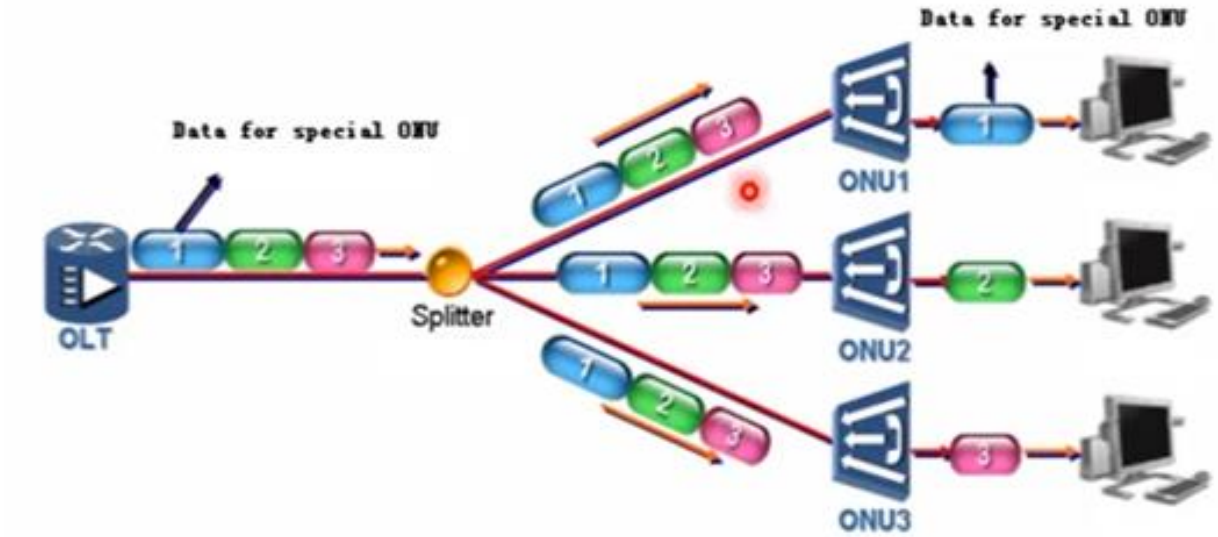
- 4 x RJ-45 10/100/1000 Ethernet port
- 2 x POTS port (Optional)
- Support Bridge mode
- Support Routed mode (NAT, Firewall, port forwarding, DMZ and DNS)
- Voice interworking (POTS vs VoIP)
- Support RSSI

RSSI = Received Signal Strength Indication

GPON Upstream Data (TDMA Mode)

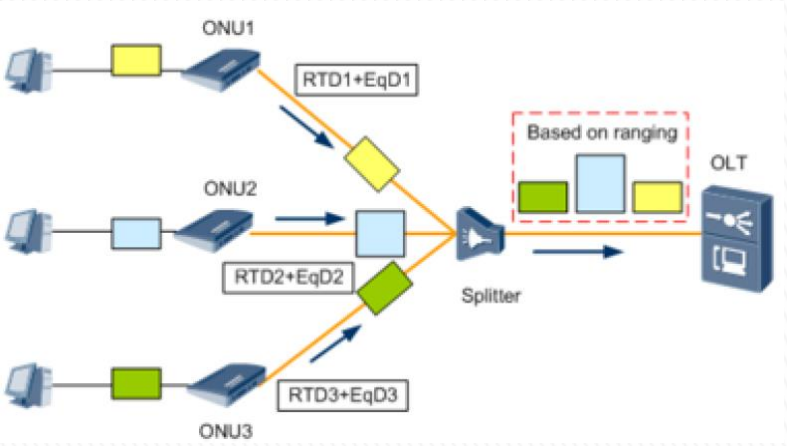


GPON Downstream Data (Broadcast Mode)



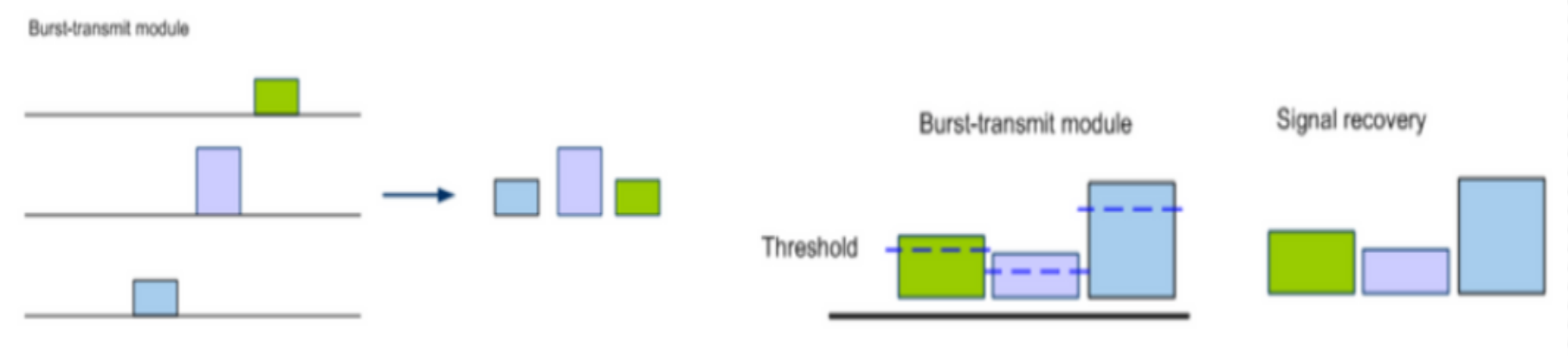
Ranging (same Time)

In order to prevent data collisions, OLT range with individual ONU to get the round trip delay (RTD) (To measure) and add with Equalization Delay (EqD) (To calculate) for its time slot to be uniformed all time slot.



Time slot = RTD + EqD

Burst Technology (same Amplitude)



- ONU transmits Burst
- OLT receive Bust
- OLT disable weak optical signal (if under threshold)
- OLT adjust dynamically uniform optical signal level (if above threshold)

Dynamic Bandwidth Allocation (DBA)

- OLT monitors for congestion, bandwidth usage, and configuration

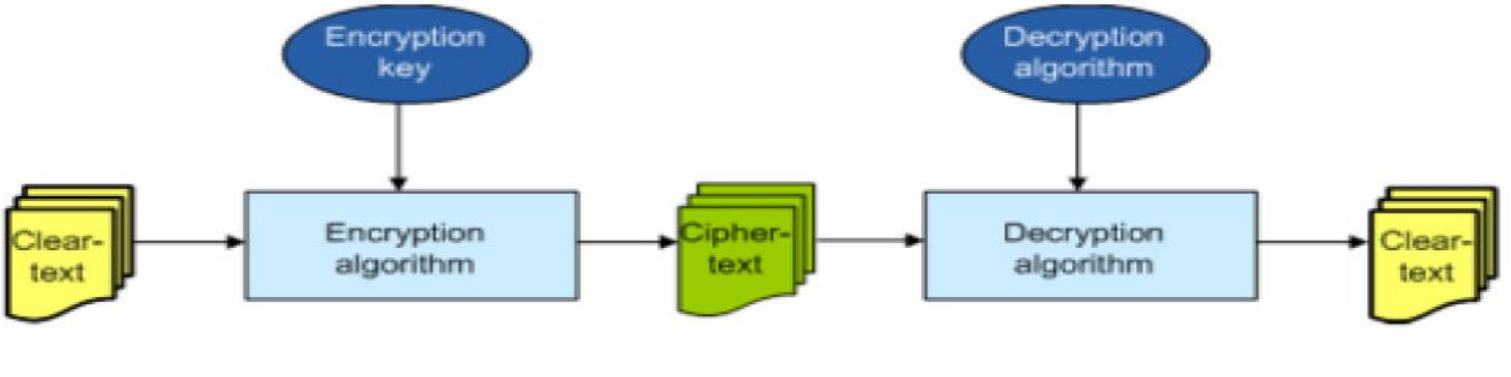
- OLT send Bandwidth Map to ONU
- ONU allocate respective Bandwidth to OLT

Forward Error Correction (FEC)

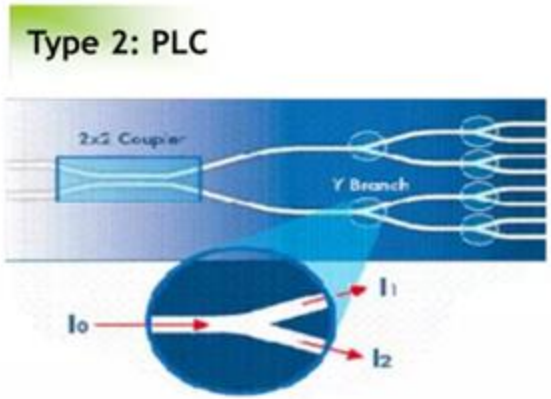
- Transmission can make the bit errors which can degrade quality.
- FEC enables the Receive end to check and correct the bit errors.
- Don’t need data retransmission.
- Supports FEC in the downstream direction only.
- Improved transmission quality.

Line Encryption

- OLT broadcasts to all ONUs.
- Individual ONU should correct data (to prevent data from unauthorized ONU)
- GPON utilizes the AES128 algorithm to encrypt data packets.



Splitter



PLC – Planar Lightwave Circuit

- Built into glass waveguides
- Solid state
- No mechanical parts
- Compact
- Splits: 1x4, 1x8, 1x16, 1x32
- Splits: 2x4, 2x8, etc

Splitter - Example

CONNECTORISED

- Flexible
- Patch cords included
- Easy to replace

Available with factory terminated pigtails

Power Budgeting - Losses

Potential Losses:

- 1. splitters loss
- 2. Fiber loss (< 0.35 dB per km)
- 3. Splice Loss (< 0.2 dB)
- 4. Connector loss (< 0.6 dB)
- 5. Fiber bending loss

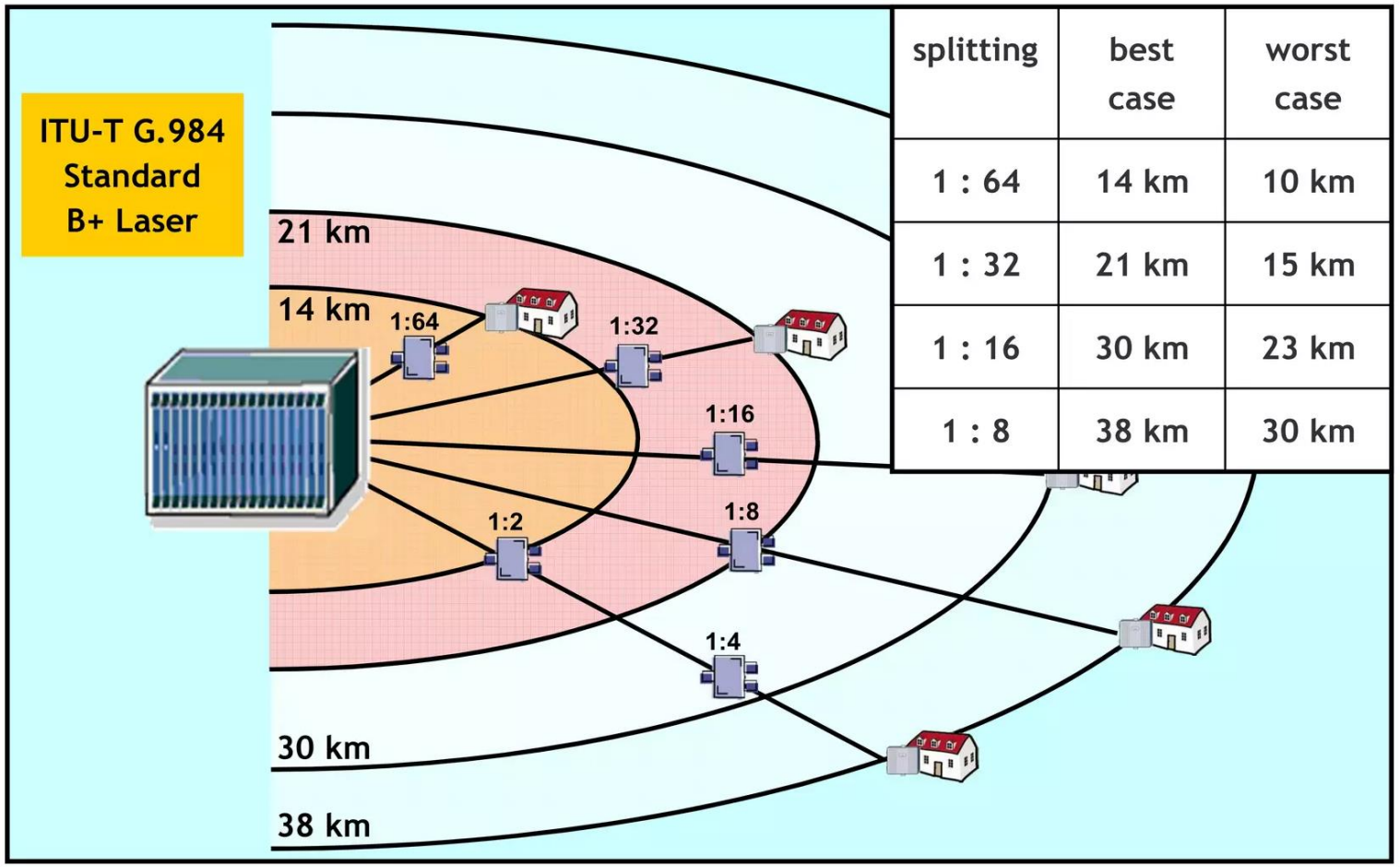
Optical Splitters	Loss [dB]
Splitter 1 x 64	20.1
Splitter 1 x 32	17.4
Splitter 1 x 16	13.8
Splitter 1 x 8	10.5
Splitter 1 x 4	7.0

Power Budgeting – Allowable Optical Path Loss

	Class-A	Class-B	Class-B+	Class-C
Minimum Loss	5 dB	10 dB	13 dB	15 dB
Maximum Loss	20 dB	25 dB	28 dB	30 dB

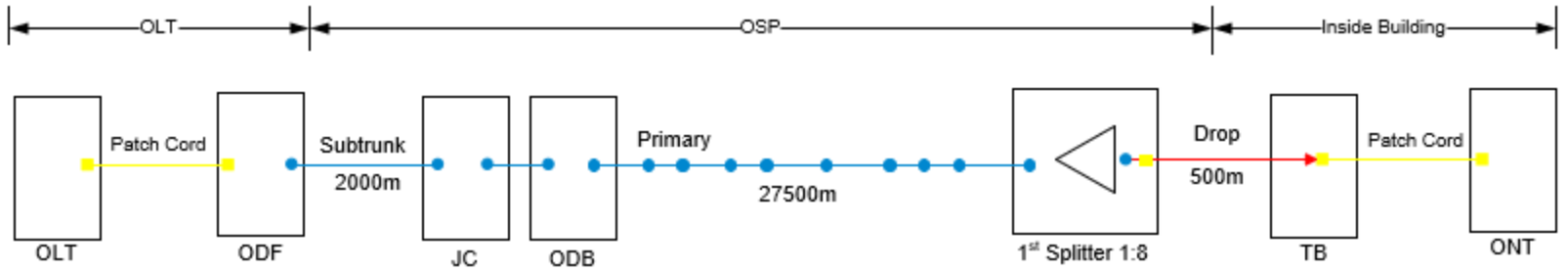
OLT Port SFP Connector

Maximum range per splitter - configuration



splitting	best case	worst case
1 : 64	14 km	10 km
1 : 32	21 km	15 km
1 : 16	30 km	23 km
1 : 8	38 km	30 km

Link Budget Calculation based on 1:8 Splitter (Class B+)

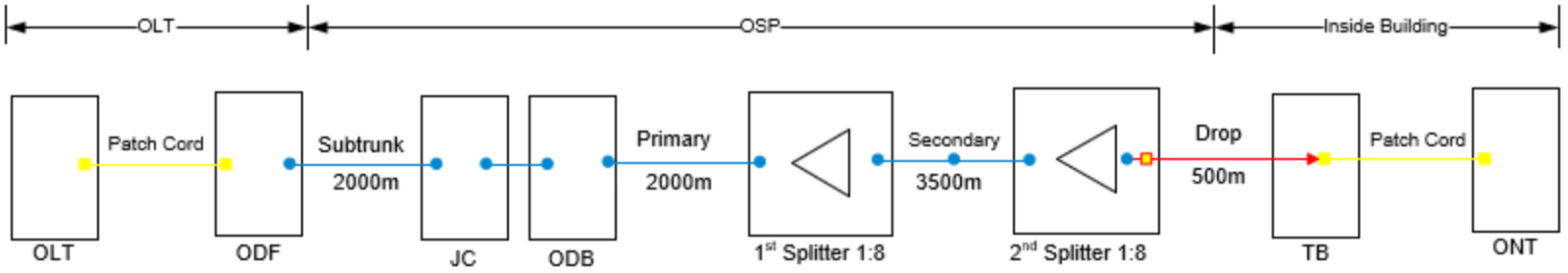


Total Loss = Splitter Attenuation + Adapter Attenuation x Qty of Adapter + Splice Attenuation x Qty of Splice + Fiber Attenuation x Cable Length

=	10.5	+	(0.3 x 3)	+	(0.1 x 14)	+	(0.35 x 30)
=	10.5	+	0.9	+	1.4	+	10.5
=	23.3 dB	<	28 dB (Pass)				

Adapter Splicing Assemble Connector

Link Budget Calculation based on 1:8 x 2 Splitters (Class B+)



Total Loss = Splitter Attenuation + Adapter Attenuation x Qty of Adapter + Splice Attenuation x Qty of Splice + Fiber Attenuation x Cable Length

= (10.5 + 10.5) + (0.3 x 3) + (0.1 x 9) + (0.35 x 8)

= 21 + 0.9 + 0.9 + 2.8

= 25.6 dB < 28 dB (Pass)

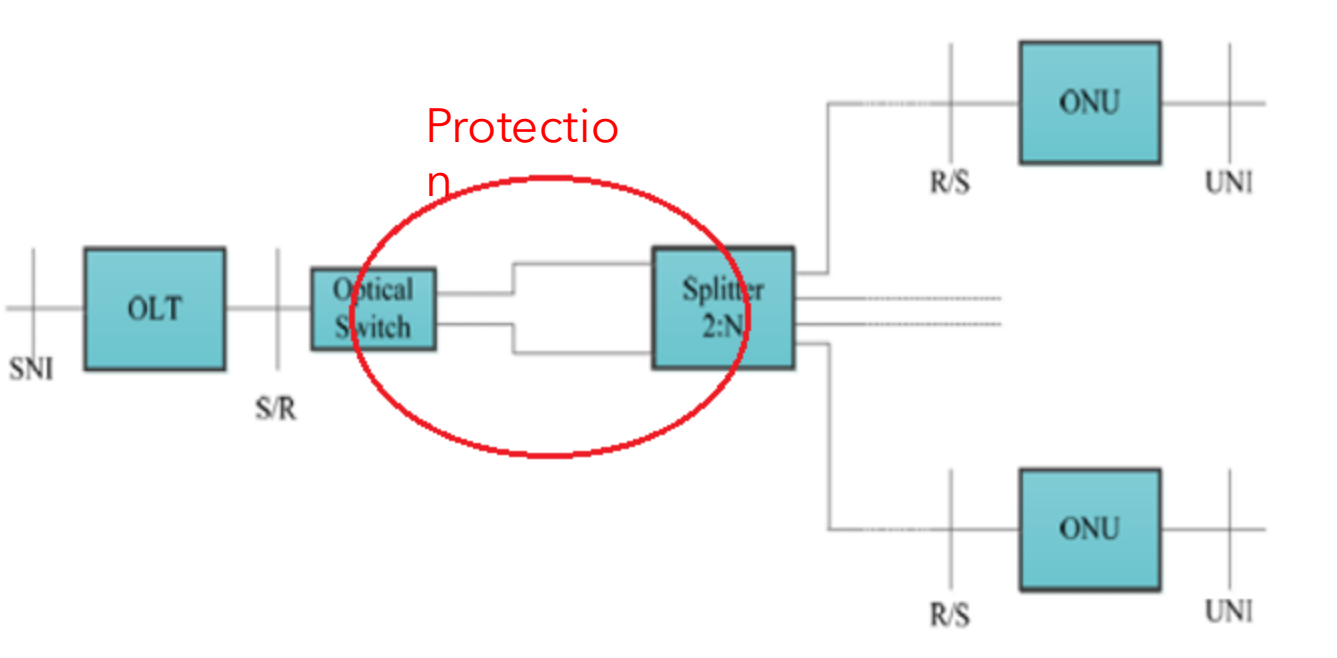
Adapter Splicing Assemble Connector

Network Protection

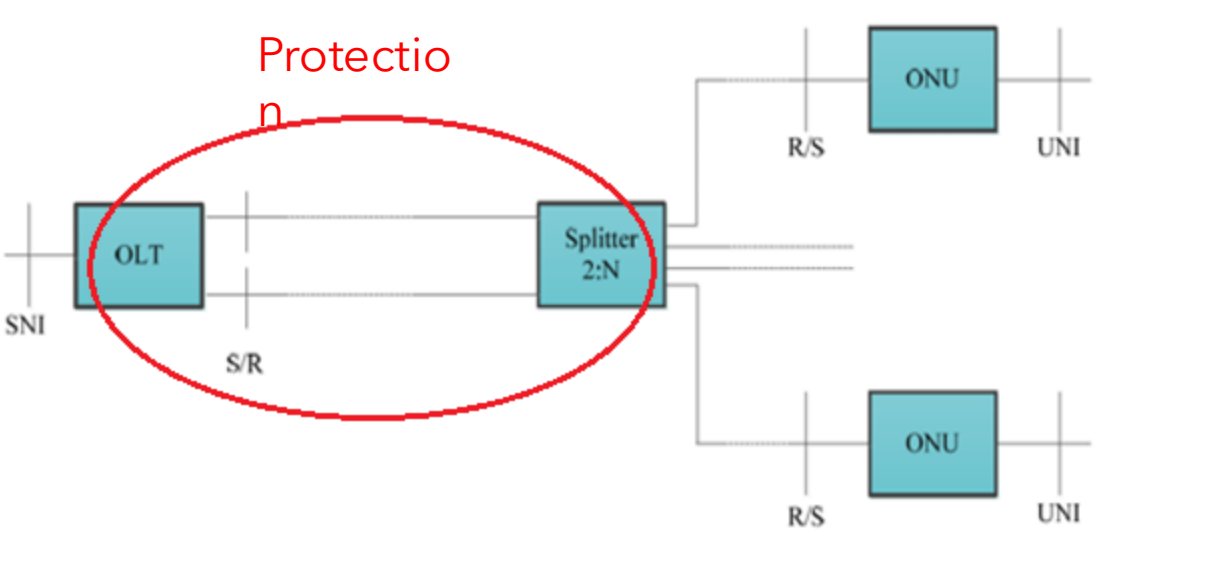
ITU-T G.984.1 specifies 3 types of redundancy between OLT and ONT.

	OLT Port	ODN	ONU
Type-A	No	Yes	No
Type-B	Yes	Yes	No
Type-C	Yes	Yes	Yes

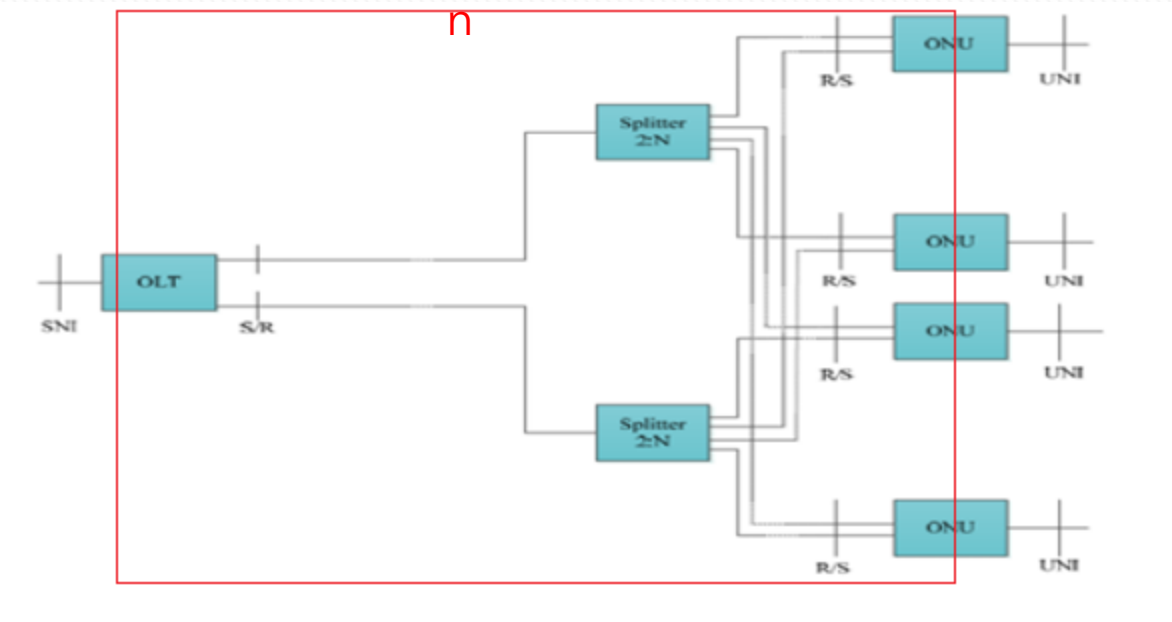
Network Protection Modes; Type A

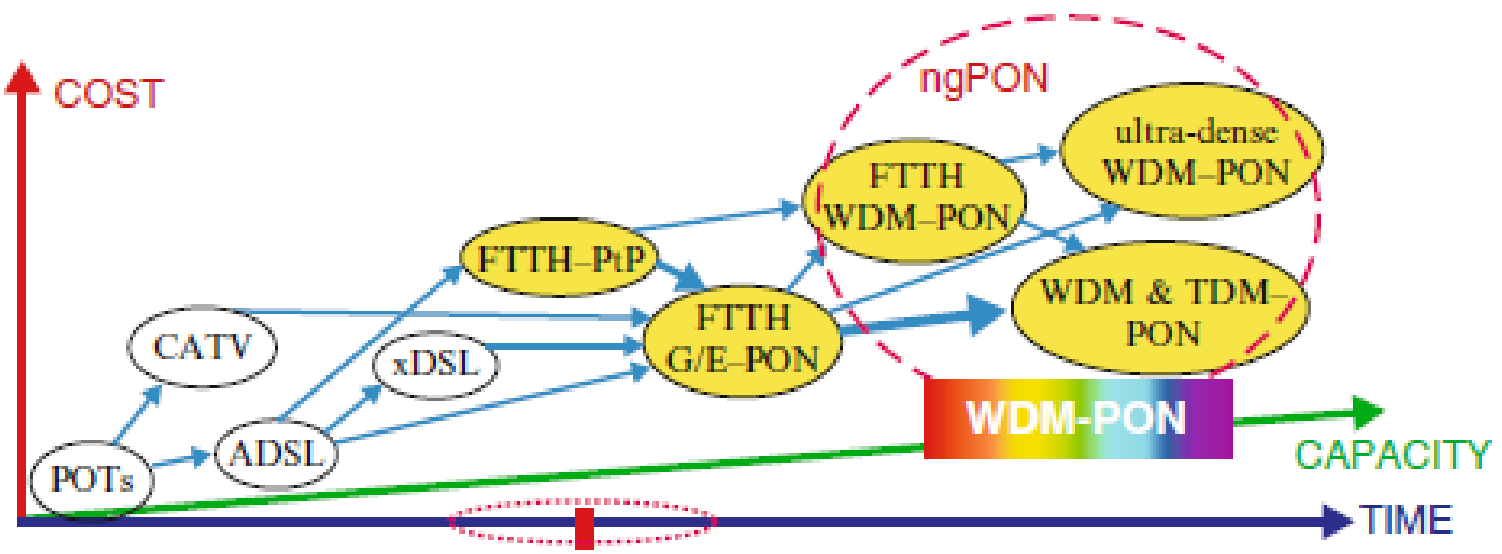


Network Protection Modes; Type B



Network Protection Modes; Type C





Evolution of access technologies

NG-PON Features

- High splitting ration (> 64)
- High speed (> 1 Gbps)
- Bidirectional transmission, symmetrical data rate, single fiber access
- Long reach (> 20 Km)
- Passive

PON benefits

- Purely passive fiber plant
  - Low maintenance costs and high reliability
- Share feeder fiber over multiple users
  - Less fibers needed; less ports needed at CO
- Fiber is virtually not limiting the bandwidth
  - Much higher bandwidth x distance than copper networks
- Fiber's bandwidth can be further exploited by WDM or equipment upgrade
  - Installed fiber infrastructure is future-proof
- PON offers bundled services over a single fiber
  - Triple play – vice/ data / video

Questions

- What is PON?
- What are component of PON system?
- Which wavelength is used for downstream in PON system?
- Which class is commonly used for redundancy?
- Please describe one benefit of PON system.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THANK YOU!