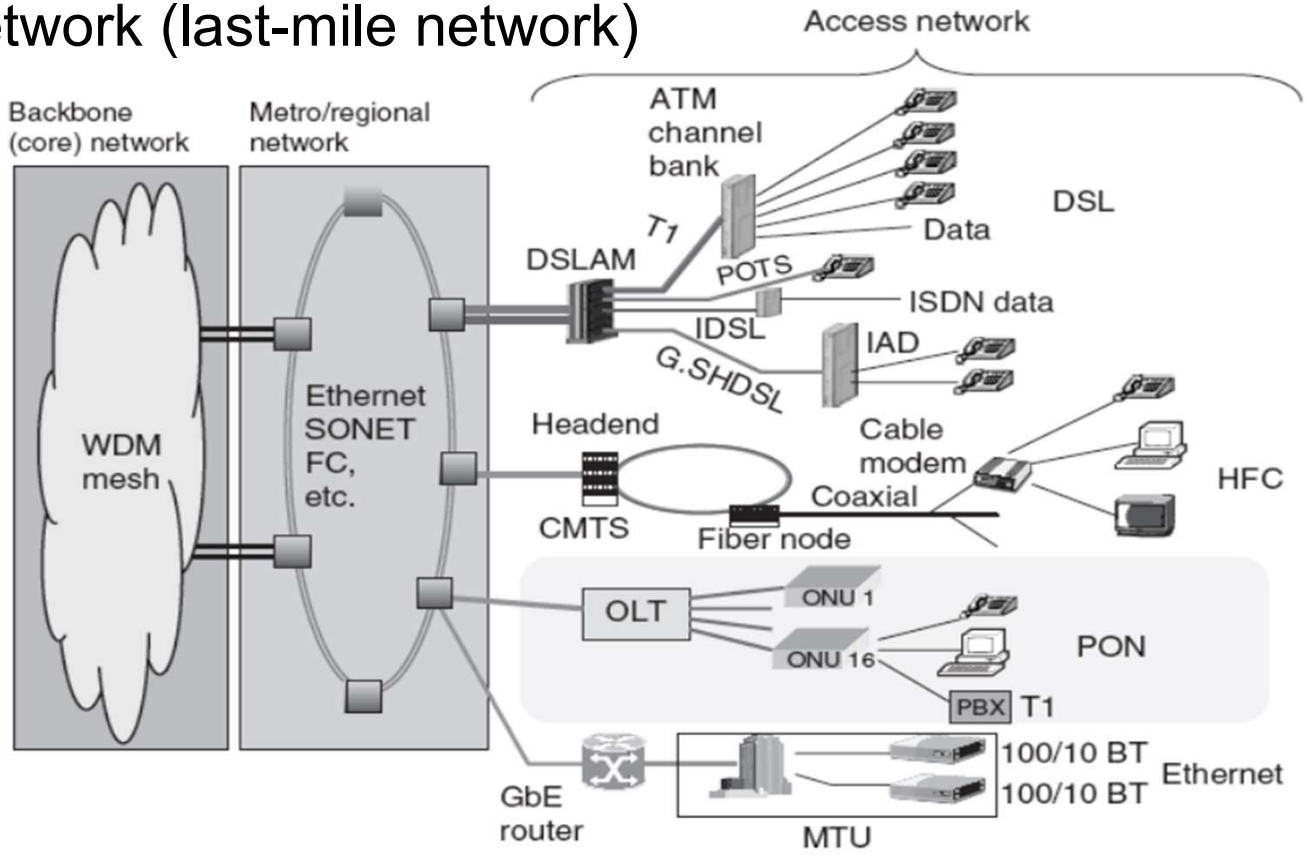
Fiber Optic Communications

Ch 7. Optical access networks

Contents

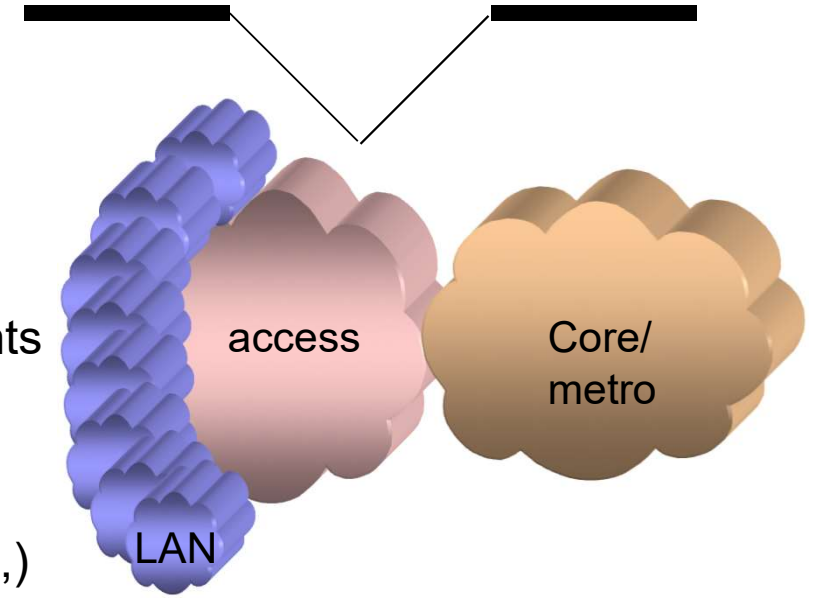
Optical Access Network

- **Networks hierarchy:**
- Backbone (core) network
- Metro (regional) network [historical]
- Access network (last-mile network)



Access network bottleneck

- local area networks *(end users)*
  - get high datarates over short distances
  - use copper cable or wifi
- core networks
  - get high datarate over long distances
  - small number of active network elements
  - use fiber optics
- access networks (first/last mile)
  - long distances (fiber is the best choice,)
  - many network elements and large number of endpoints
    - Optical fiber need multiple optical transceivers
    - copper is the best choice for interconnections
    - But copper severely limits the data rates

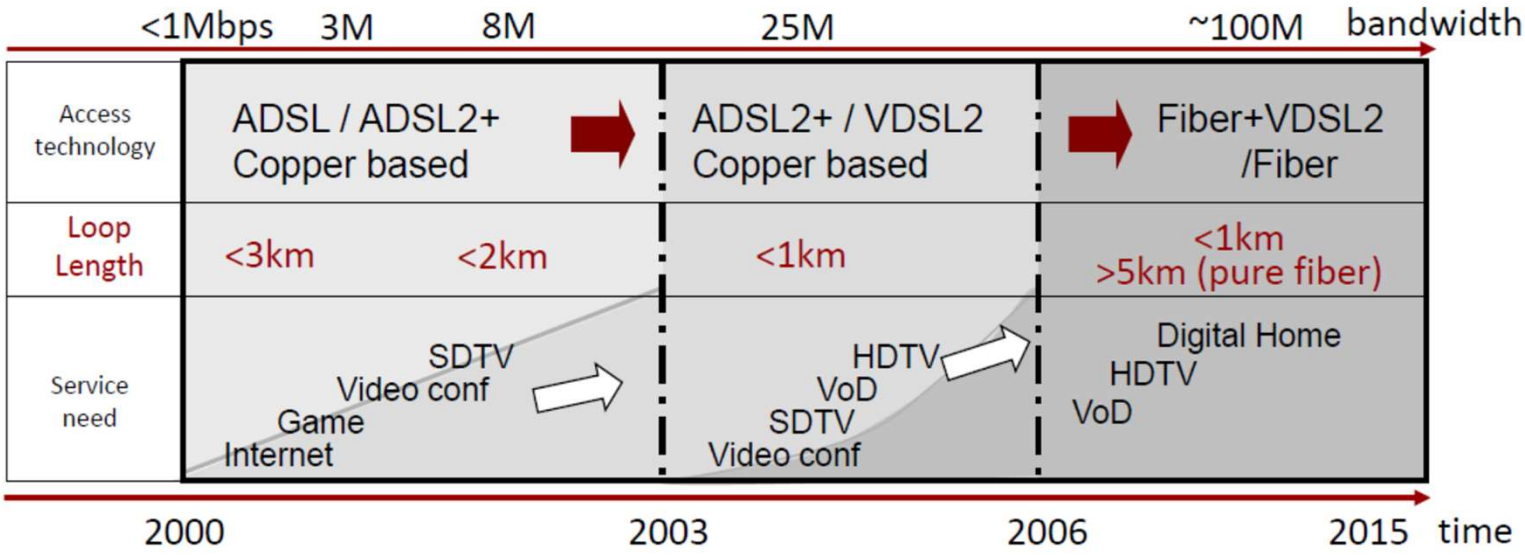


Copper access network suffer from bottleneck

Optical Access Network

- **Fixed Access Technologies Development**

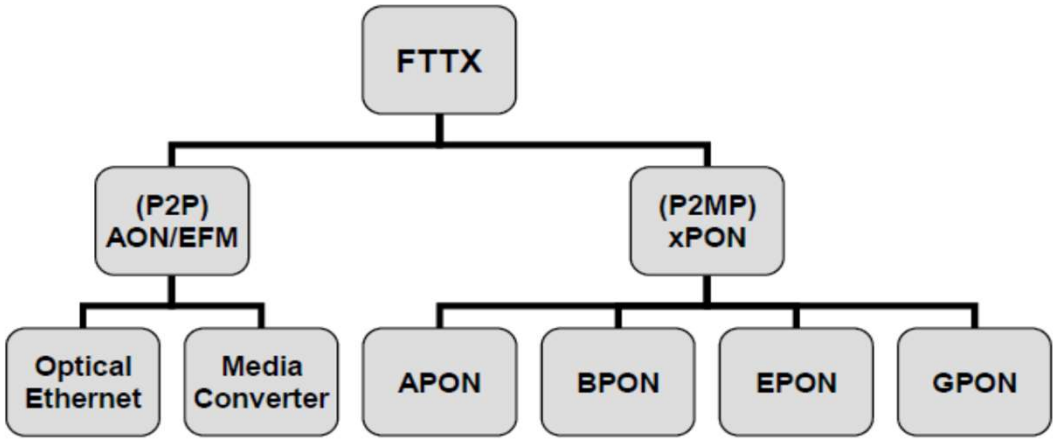
Application	Bandwidth	QoS
Video (SDTV)	3.5 Mbps	Low loss, low jitter, constant bit rate
Video (HDTV)	15 Mbps	Same as above
Telecommuting	10 Mbps	Best effort, bursty
Video gaming	10 Mbps	Low loss, low jitter, bursty
Voice	64 kbps	Low loss, low latency, constant bit rate
Peer-to-peer downloading	100 kbps–100 Mbps	Best effort

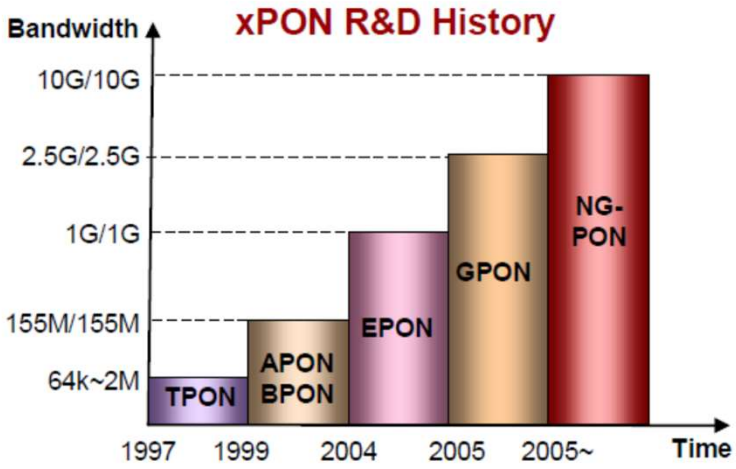


Optical Access Network

• Fixed Access Technologies Development

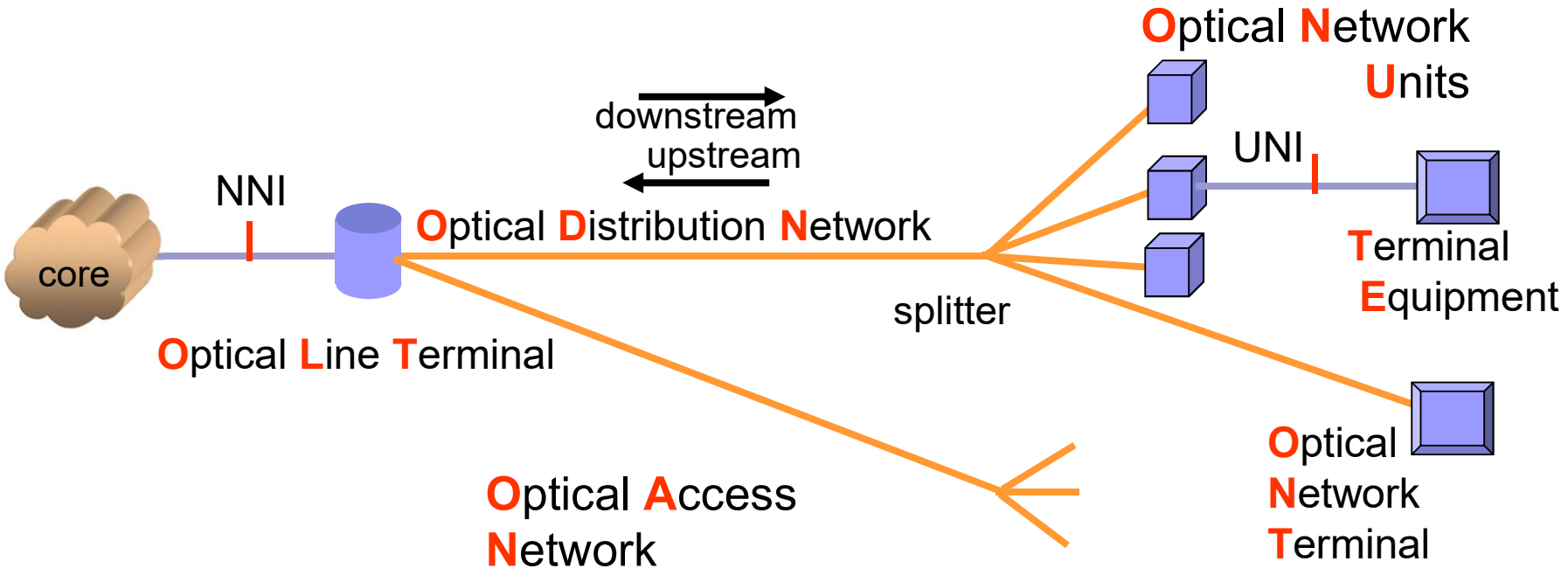
- Solve the bandwidth bottleneck of multi-service for end users
- Solve the problem of coverage limit of copper line
- Protect the investment for long-term development





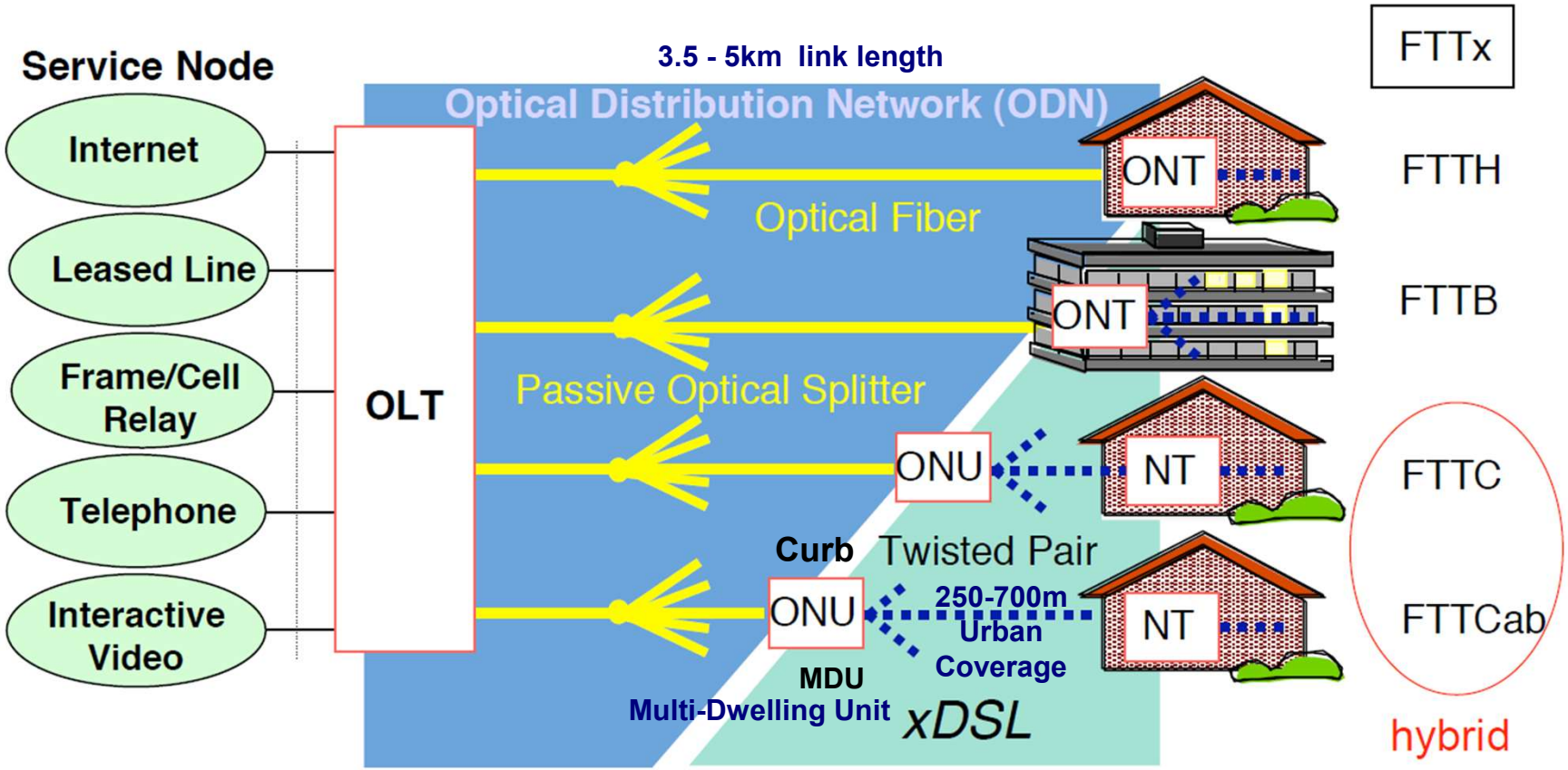
PON components

- the CO head-end is called an **OLT**
- **ONUs** are the CPE devices (sometimes called ONTs in ITU)
- the entire fiber tree (incl. feeder, splitters, distribution fibers) is an **ODN**
- all trees emanating from the same OLT form an **OAN**
- **downstream** is from OLT to ONU (**upstream** is the opposite direction)



Optical Access Network

PON architecture



PON architecture

1. FTTB architecture

As an access scenario for business users, Fiber to The Business (FTTB) scenario falls into single business unit (SBU) and Business Multi-tenant unit (MTU) in terms of capacity. Of them, SBU provides a comparatively small number of ports, including following types: POTS, 10/100/1000BASE-T, RF(33dBmV), and DS1/T1/E1 ports; MTU provides a comparatively larger number of ports, including following types: POTS, 10/100/1000BASE-T, RF and DS1/T1/E1 ports.

2. FTTC & FTTCab architecture

As an access to the curb or the cabinet over fibre, Fiber to The Curb& Fiber to The Cabinet (FTTC & FTTCab) scenario is for the Multi-dwelling unit (MDU), providing a comparatively larger number of ports, including following types: 10/100/1000BASE-T, RF(33dBmV), VDSL2, and so on.

3. FTTH architecture

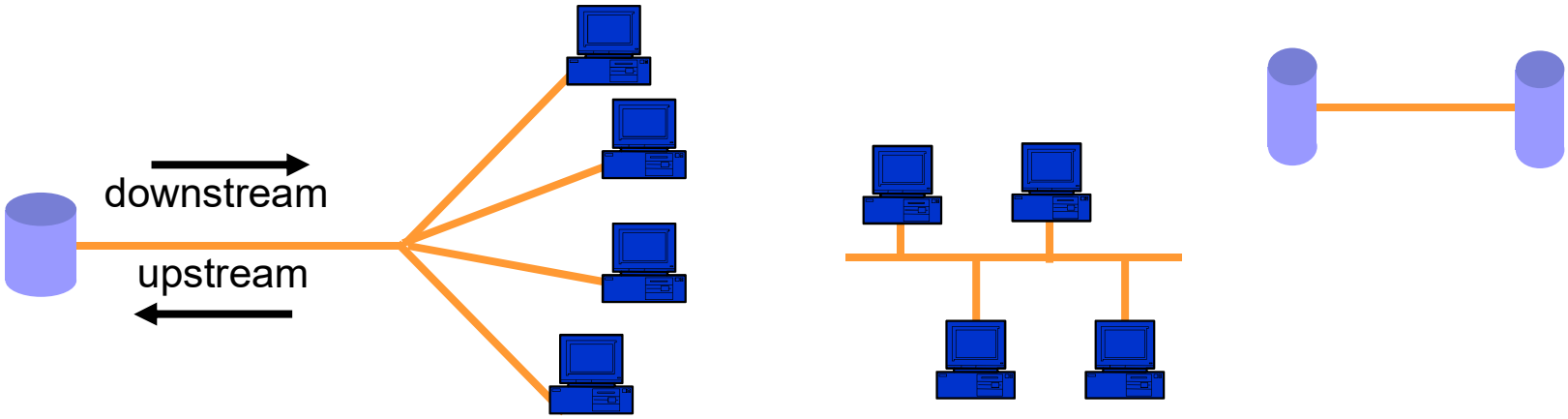
As an access to the home over fibre, Fiber to The Home (FTTH) scenario is mainly for the single family unit (SFU), providing a comparatively small number of ports, including following types: POTS, 10/100/1000BASE-T, and RF(18dBmV).

PON characteristics (almost for all PON types)

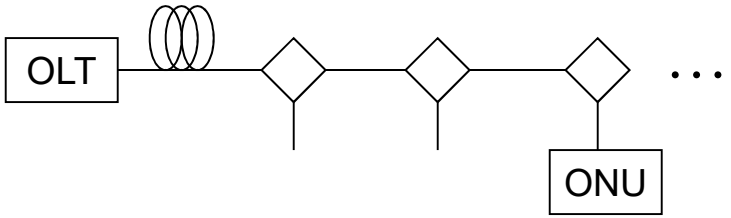
- OLT and ONU consist of
  - Layer 2 (Ethernet MAC, ATM adapter, etc.)
  - optical transceiver using **W**avelength **D**ivision **D**uplexing ()
  - optionally: **W**avelength **D**ivision **M**ultiplexer
- downstream transmission
  - OLT broadcasts data downstream to all ONUs in ODN
  - ONU captures data destined for its address, discards all other data
  - encryption needed to ensure privacy
- upstream transmission
  - ONUs share bandwidth using **T**ime **D**ivision **M**ultiple **A**ccess
  - OLT manages the ONU timeslots
  - ranging is performed to determine ONU-OLT propagation time
- additional functionality
  - **P**hysical **L**ayer **O**AM
  - Autodiscovery
  - **D**ynamic **B**andwidth **A**llocation

PON access technique

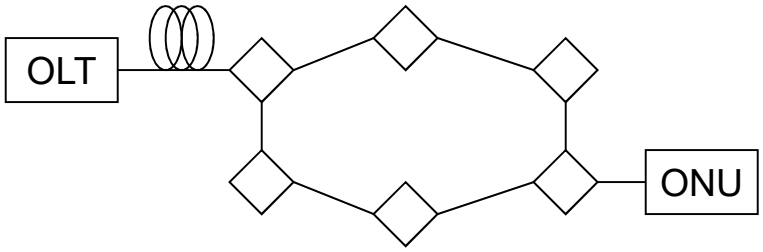
- PON has a unique architecture
  - (broadcast) point-to-multipoint in DS direction
  - (multiple access) multipoint-to-point in US direction
- Ethernet – multipoint-to-multipoint - avoids collisions with CSMA/CD
  - (can't work for point-to-multipoint US PON , ONUs don't see each other)
- ATM - point to point - avoids collisions isn’t necessary
  - (can't work for point-to-multipoint DS PON since all ONUs see all DS data)



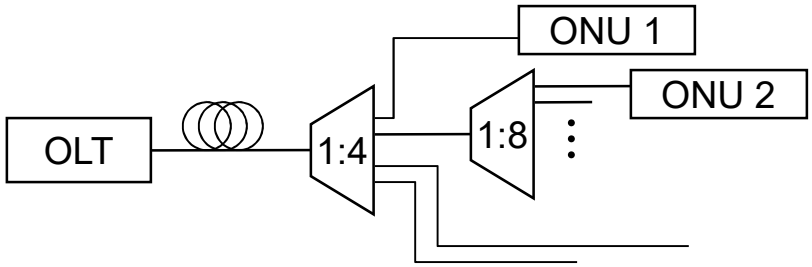
PON topology

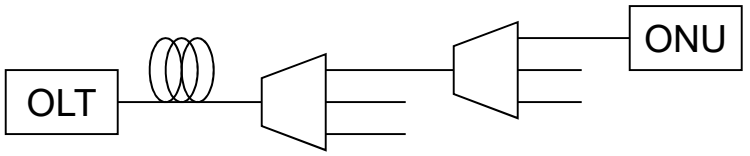


Linear Bus: lossy, fiber lean



Ring: lossy, protected





Simple or Cascaded Star: low loss

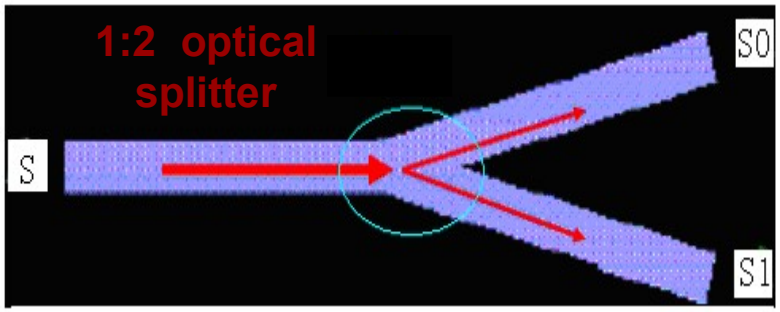
Power Budget

Optical lossless splitter: ∑(Power_in) - ∑(Power_out of all branches)

attenuation $dB = 10 \cdot \log\left(\frac{Power\_in}{Power\_out}\right)$

Gain or Loss in dB

Attenuation of 1:2 splitter: 3.01 dB
Attenuation of 1:16 splitter: 12.04 dB
Attenuation of 1:64 splitter :18.06 dB



PRODUCT SPECIFICATIONS[1]

	1x4	1x8	1x16	1x32
	"Premium" Grade			
Maximum Insertion Loss[2] (dB)	7.0	10.3	13.4	16.8
Typical Insertion Loss (dB)	6.6	9.6	12.8	16.0
Uniformity (dB)	< 0.5	< 0.5	< 0.8	< 0.9
	"A" Grade			
Maximum Insertion Loss (dB)	7.4	10.7	14.0	17.2
Typical Insertion Loss (dB)	7.0	10.1	13.5	16.5
Uniformity (dB)	< 0.6	< 0.8	< 1.0	< 1.1
Operating Wavelength (nm)	1250-1650			
Maximum PDL[3] (dB)	< 0.15			< 0.2
Return Loss (dB)	> 55			
Operating Temperature (°C)	-40 to +85			
Storage Temperature (°C)	-40 to +85			
FTTH Tray Package[4] (mm)	40x4x4			55x7x4
Rack[5]	19" 1U			
Fiber Type (standard)	In: SMF-28e Tight Buffer 900um, 1±0.1m Length Out: SMF-28e Bare Ribbon 1±0.1m Length			

Power Budget

- OLT, ONU transmitter, receiver parameters:

Items	Unit	Single fibre
OLT:		**OLT**
•Mean launched power MIN	dBm	+1.5
•Mean launched power MAX	dBm	+5
•Minimum sensitivity	dBm	-28
•Minimum overload	dBm	-8
•Downstream optical penalty	dB	0.5
ONU:		**ONU**
•Mean launched power MIN	dBm	0.5
•Mean launched power MAX	dBm	+5
•Minimum sensitivity	dBm	-27
•Minimum overload	dBm	-8
•Upstream optical penalty	dB	0.5

Table G.984.2 – Classes for 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**
NOTE – The requirements of a particular class may be more stringent for one system type than for another, e.g. the class C attenuation range is inherently more stringent for TCM systems due to the use of a 1:2 splitter/combiner at each side of the ODN, each having a loss of about 3 dB.				

Power Budget - Typical Range Calculation Example

LB = Link Budget

PS = Sensitivity

PO = Output Power

$$L_B = P_O\big|_{\mathrm{dB}} - P_S\big|_{\mathrm{dB}}$$

Assume:

GPON 1310nm

Trans. Power = 0dbm Single-mode fiber

Rec. Sensitivity= -23dbm

$$R_B = \frac{L_B - SIL - ConnLoss}{OpticLoss}$$

Optical loss = 0.35 db/km

Total Connector Loss = 2dB

Splitter Insertion Loss 1X32 = 17dB

Supplimentary SIL = 0dB

Max Fiber Length: ~11Km

PON Types

- many types of PONs have been defined
  - **APON** ATM PON
  - **BPON** Broadband PON (explained in ITU-T G.983.x)
  - **GPON** Gigabit PON (explained in ITU-T G.984.x)
  - **EPON** Ethernet PON (explained in IEEE 802.3-2005 clauses 64 and 65 and other 802.3 clauses)
  - **GEPON** Gigabit Ethernet PON
  - **CPON** CDMA PON
  - **WPON** WDM PON
- in this course we will focus on GPON and EPON (including GEPON)

GPON Standards

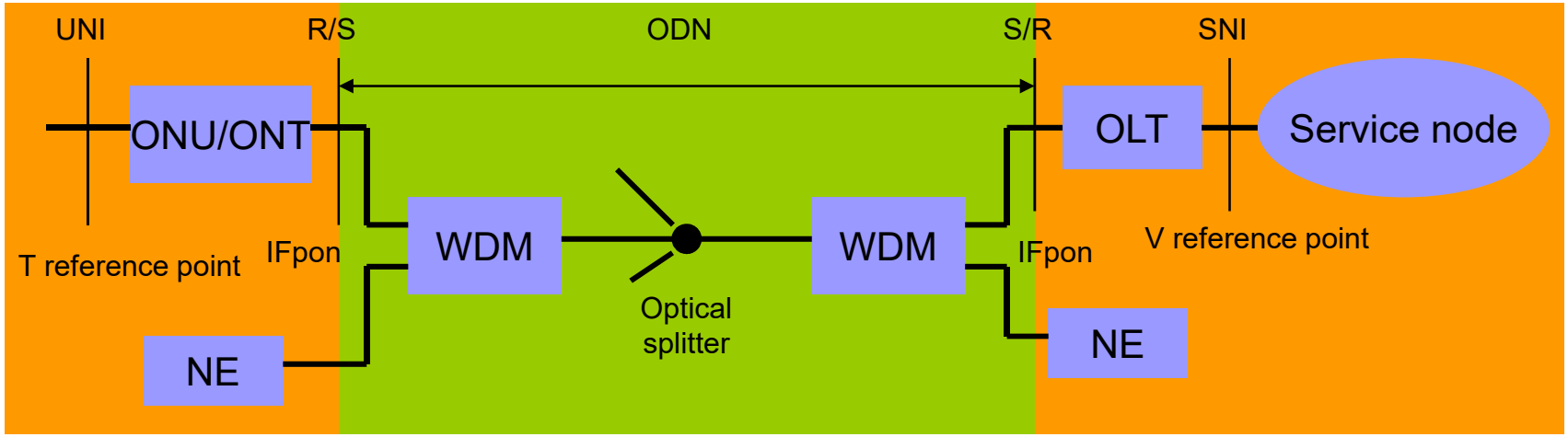
- ITU-T G.984.1
  - Parameter description of GPON network
  - Requirements of protection switch-over networking
- ITU-T G.984.2
  - Specifications of ODN parameters
  - Specifications of 2.488Gbps downstream optical port
  - Specifications of 1.244Gbps upstream optical port
  - Overhead allocation at physical layer
- ITU-T G.984.3
  - Specifications of TC layer in the GPON system
  - GTC multiplexing architecture and protocol stack;
  - GTC frame
  - ONU registration and activation
  - DBA specifications
  - Alarms and performance

GPON Standards

- ITU-T G.984.4
  - OMCI message format
  - OMCI device management frame
  - OMCI working principle

Optical Access Network

GPON Network Model Reference



ONU Optical Network Unit

ONT Optical Network Terminal

ODN Optical Distribution Network

OLT Optical Line Terminal

WDM Wavelength Division Multiplex Module

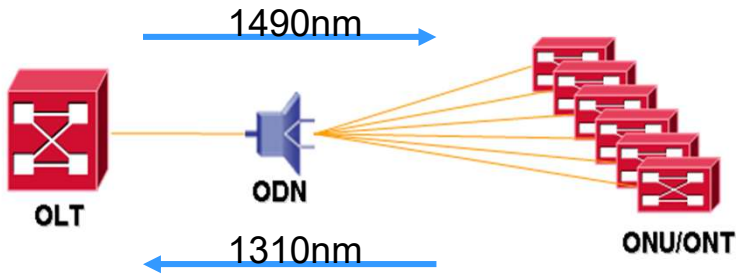
NE Network Element

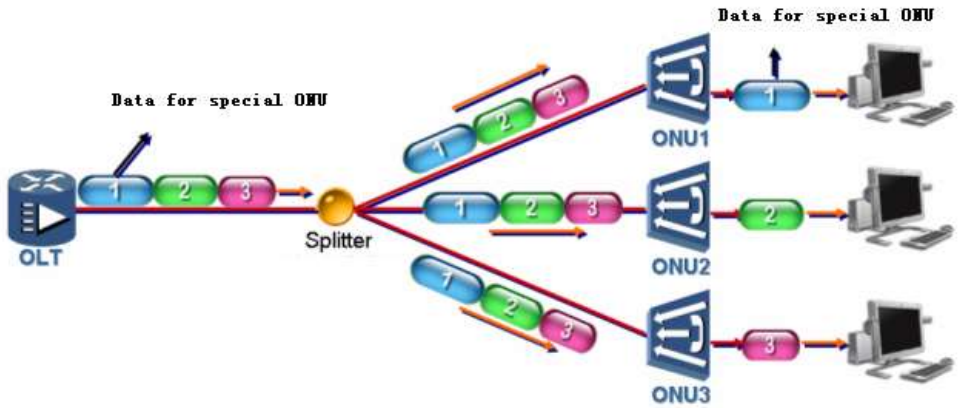
SNI Service Node Interface

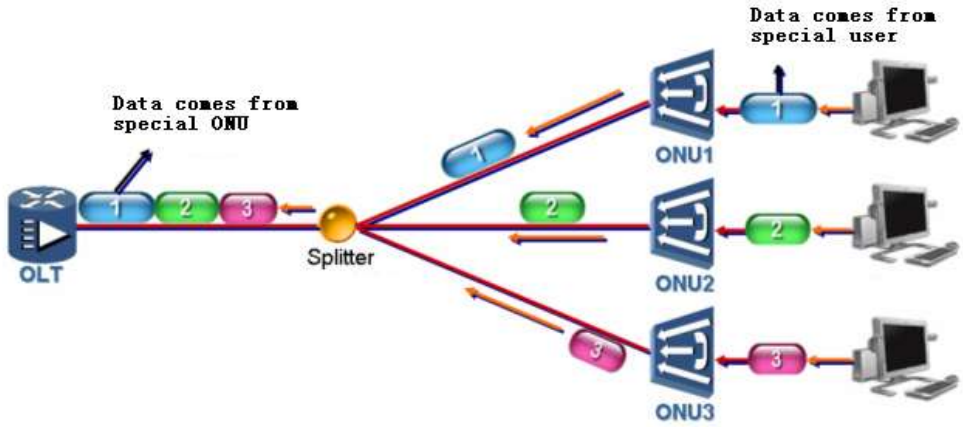
UNI User Network Interface

GPON access and duplexing

- Uplink access – broadcast mode
- Uplink access – TDMA mode
- Wave division duplexing
  - 1490 nm downlink
  - 1310 nm uplink



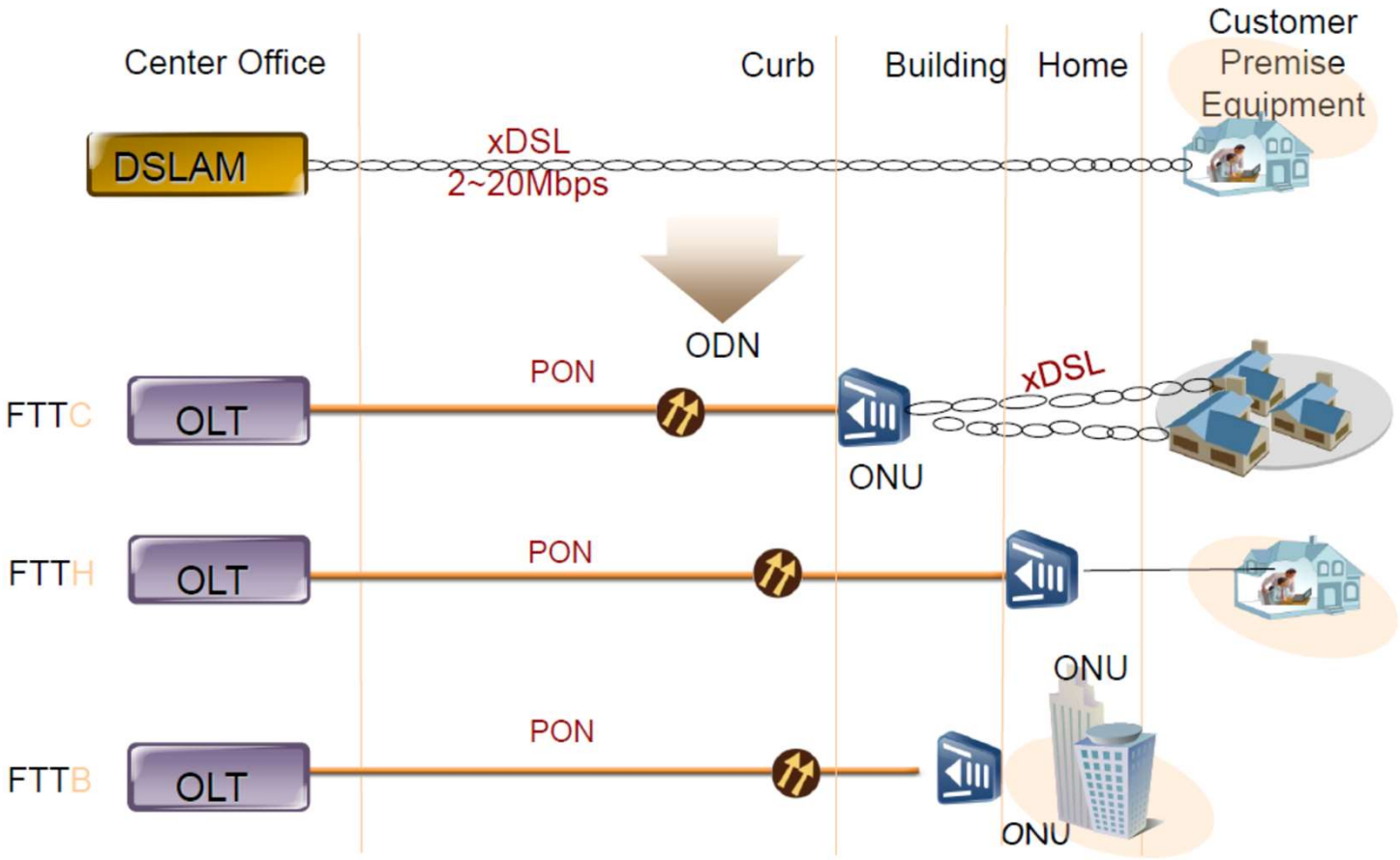




Basic Performance Parameters of GPON

- GPON identifies 7 transmission speed combination:
  - 0.15552 Gbit/s up, 1.24416 Gbit/s down
  - 0.62208 Gbit/s up, 1.24416 Gbit/s down
  - 1.24416 Gbit/s up, 1.24416 Gbit/s down
  - 0.15552 Gbit/s up, 2.48832 Gbit/s down
  - 0.62208 Gbit/s up, 2.48832 Gbit/s down
  - 1.24416 Gbit/s up, 2.48832 Gbit/s down
  - 2.48832 Gbit/s up, 2.48832 Gbit/s down
- Maximum logical reach: 60 km
- Maximum physical reach: 20 km
- Maximum differential fibre distance: 20 km
- Split ratio: 1：64, it can be up to1：128

GPON architecture

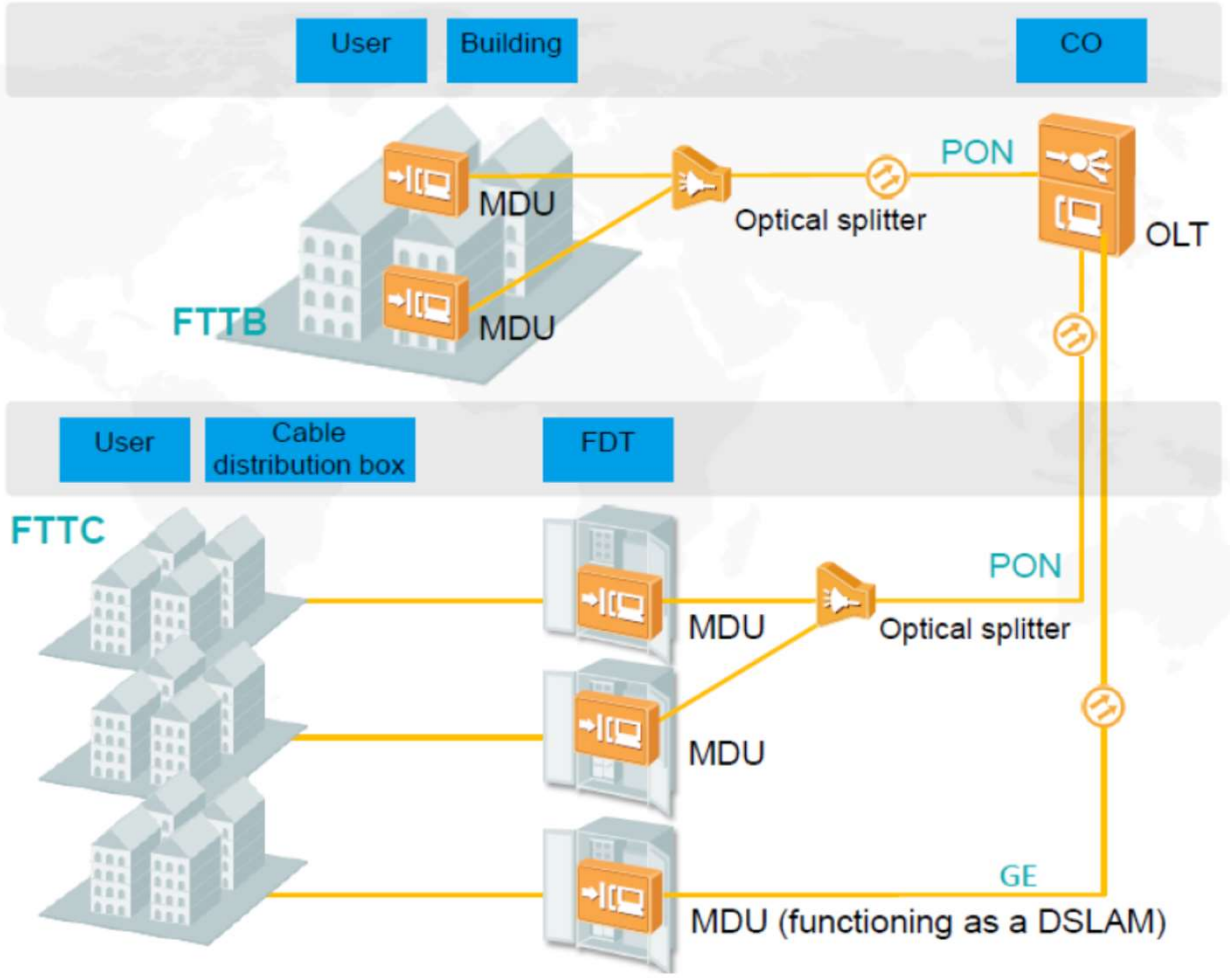


GPON architecture

FTTB: indicates fiber to the building. In this scenario, optical fibers are routed from a CO to access devices that locate in buildings, such as in light-current wells or basements. Then, the access devices connect to copper (xDSL) or Cat 5 (LAN) lines that are routed to user homes, implementing service access. FTTB applies to business zones and residential areas with high population densities.

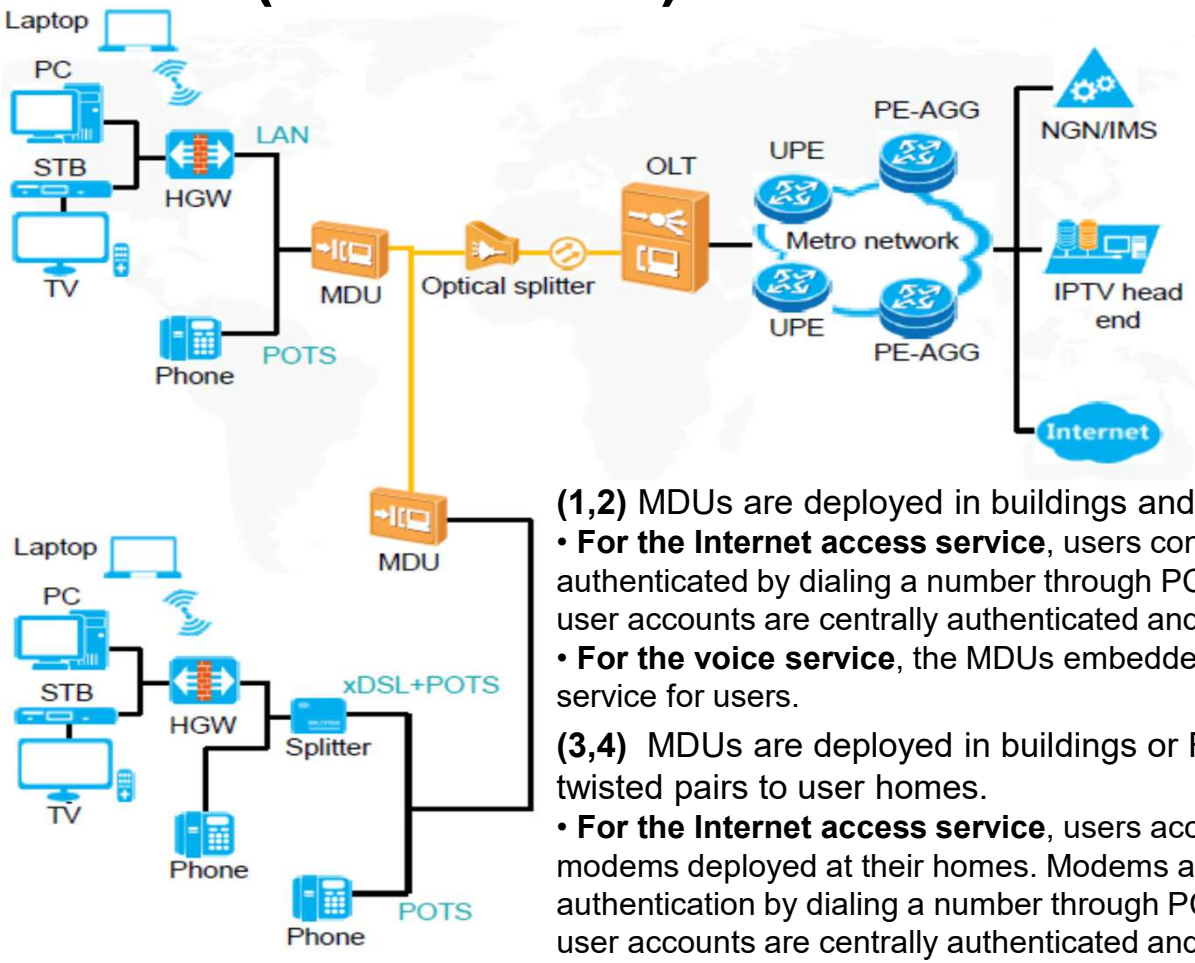
FTTC: indicates fiber to the curb. In this scenario, optical fibers are routed from a CO to access devices that locate at fiber distribution terminals (FDTs) along the curb or in cable distribution compartments/FDTs in residential areas. Then, the access devices connect to copper (xDSL) lines that are routed to user homes, implementing service access. FTTC applies to areas with low population densities.

FTTB / FTTC network structure



Optical Access Network

FTTB (LAN+POTS) and FTTB/FTTC (xDSL+POTS)



(1,2) MDUs are deployed in buildings and connect Cat 5 lines to user homes.

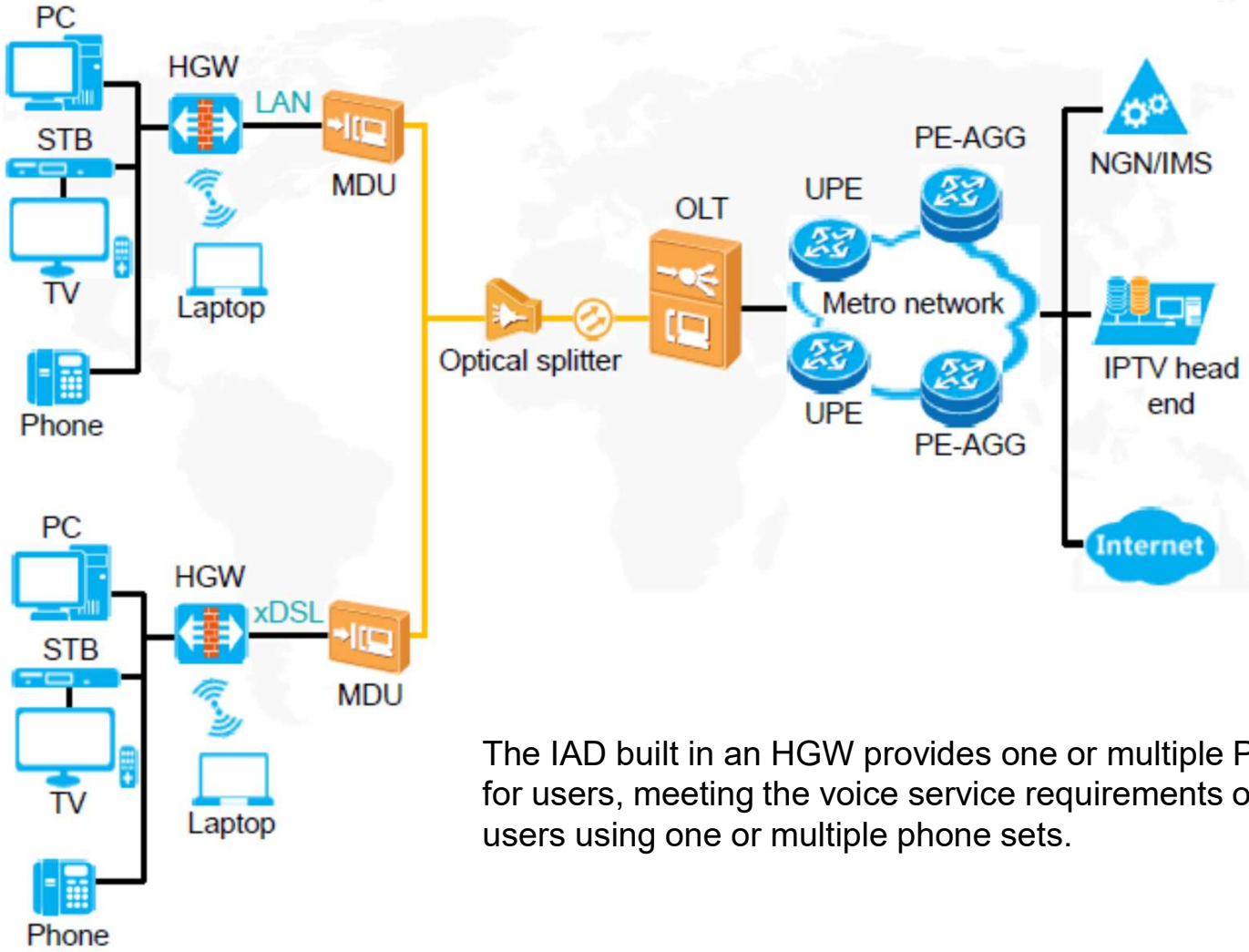
- **For the Internet access service**, users connect to an MDU using Cat 5 lines and are authenticated by dialing a number through PCs. Each user has a separate account. All user accounts are centrally authenticated and managed on the BRAS.
- **For the voice service**, the MDUs embedded with a voice module provide the VoIP service for users.

(3,4) MDUs are deployed in buildings or FDTs along the curb, and connect twisted pairs to user homes.

- **For the Internet access service**, users access the Internet at a high speed using the modems deployed at their homes. Modems are Layer 2 devices and therefore require authentication by dialing a number through PCs. Each user has a separate account. All user accounts are centrally authenticated and managed on the BRAS.
- **For the voice service**, the MDUs embedded with a voice module provide the VoIP service for users.

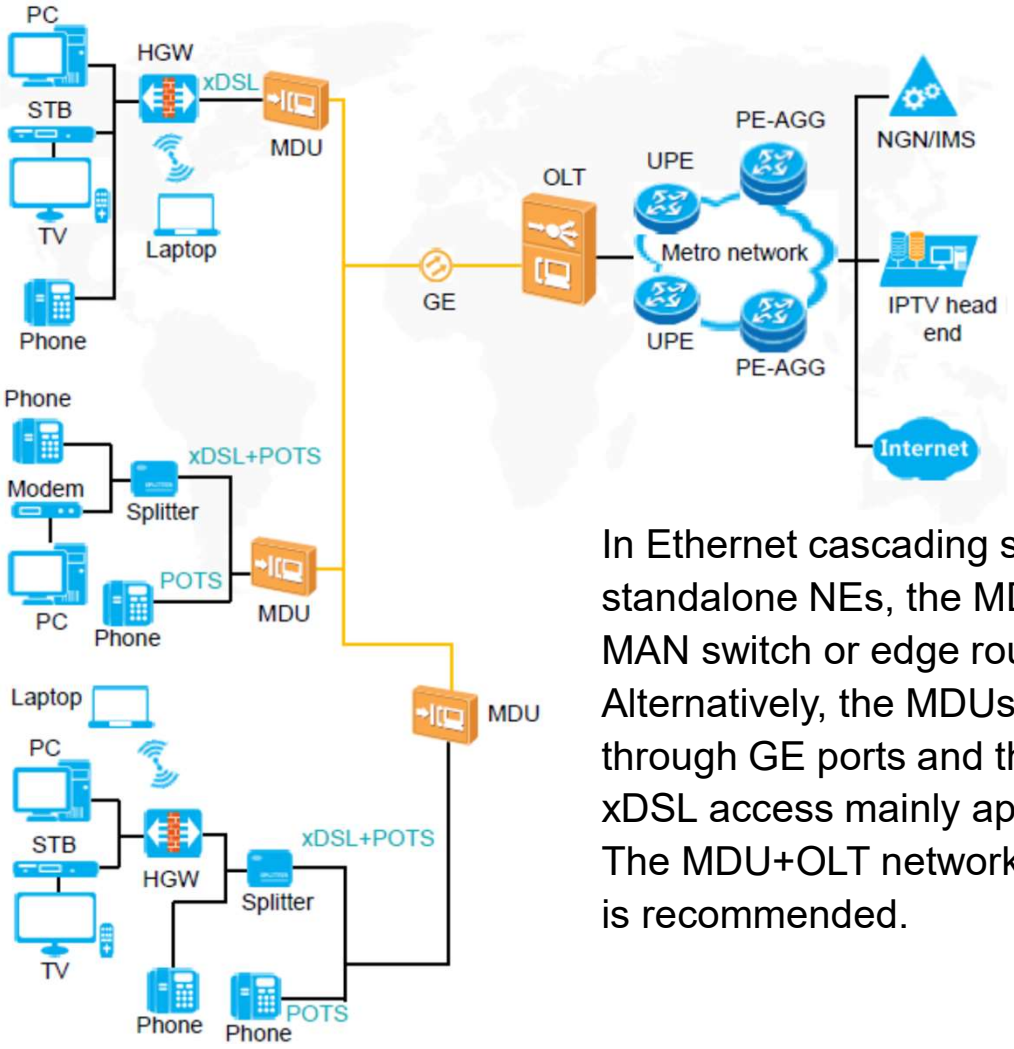
Optical Access Network

FTTB/C+HGW (Voice Service Is Provided by HGWs)



The IAD built in an HGW provides one or multiple POTS ports for users, meeting the voice service requirements of residential users using one or multiple phone sets.

Ethernet Cascading in FTTB/FTTC

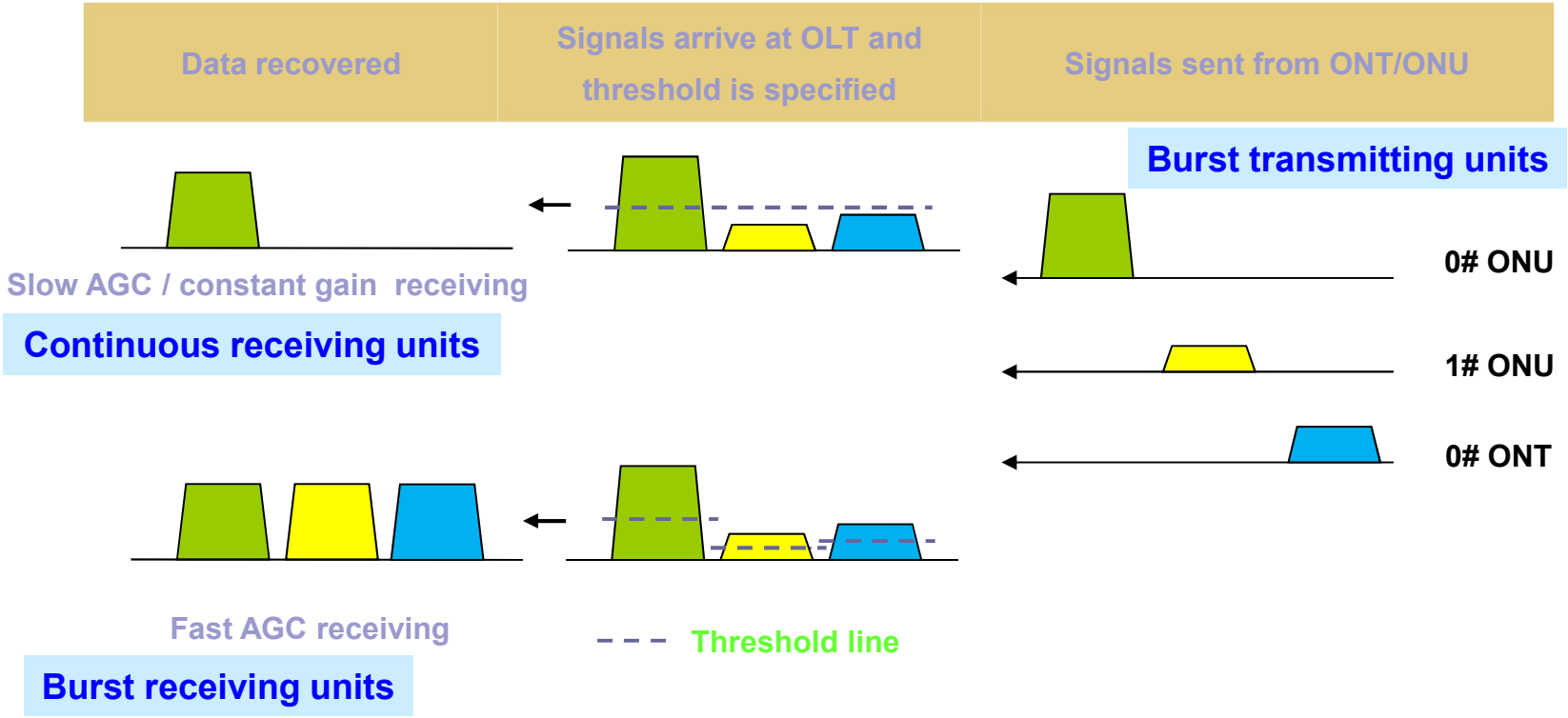


In Ethernet cascading scenarios where MDUs are standalone NEs, the MDUs transmit data upstream to a MAN switch or edge router through GE ports.
Alternatively, the MDUs transmit data upstream to the OLT through GE ports and then to a MAN switch or edge router.
xDSL access mainly applies on the user side.
The MDU+OLT networking shown in the figure on this slide is recommended.

GPON Key Technologies

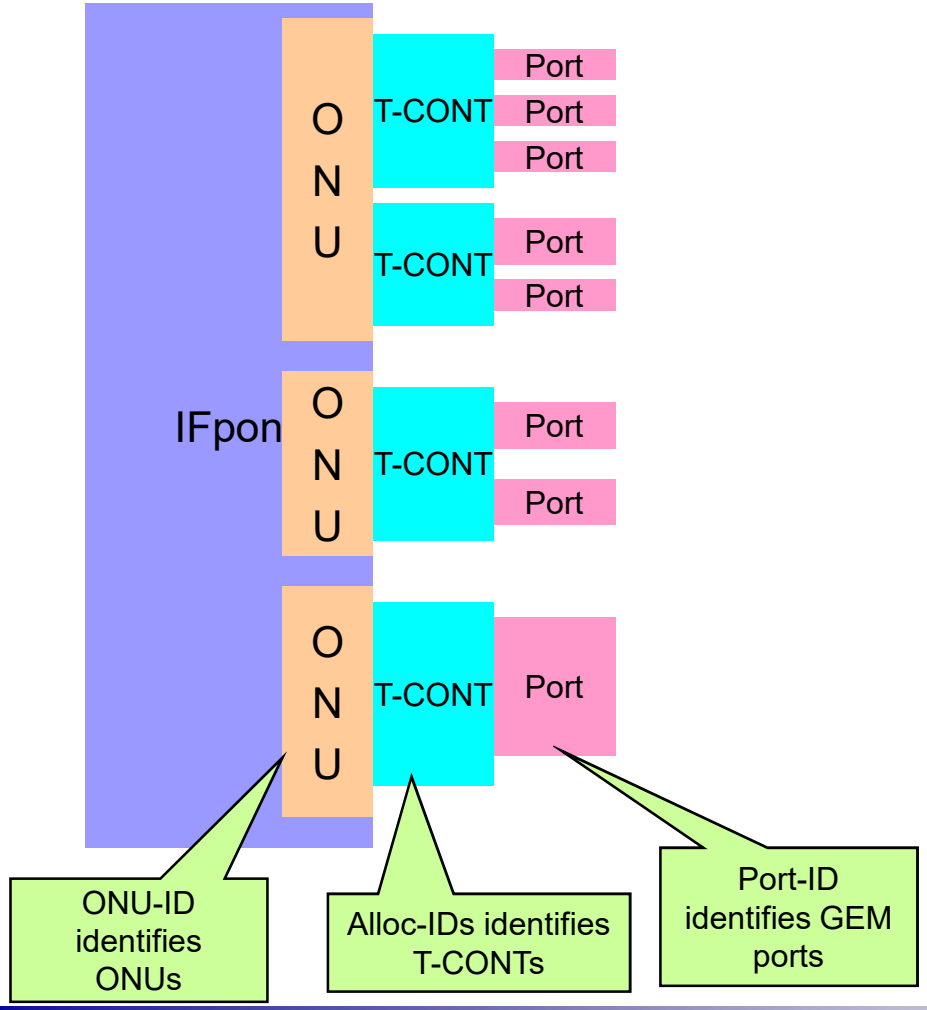
1. Burst mode optical receiver
2. Multiplexing Architecture
3. Network Protection Mode
4. Encryption
5. Dynamic Bandwidth Assignment (DBA)
6. Management System

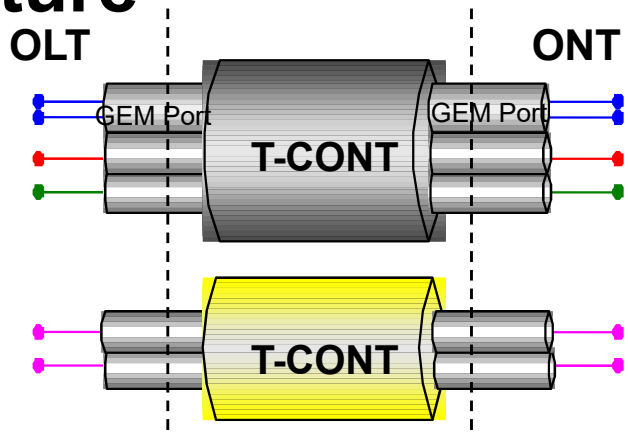
Burst Optical/Electric - Fast automatic gain control (Fast AGC)



- Fast-enable and disable ability
- Split ratio (>10dB)

GPON Multiplexing Architecture





- GEM Port is the smallest service-carrying unit and the most basic encapsulation structure
- T-CONT: Transmission Containers is an ONU object representing a group of logical connections that appear as a single entity for transmit upstream data units. T-CONT is used for the dynamic bandwidth assignment of the upstream bandwidth.
- IF pon: GPON interface.
- Base on the mapping scheme, service traffic is carried to different GEM ports and then to different T-CONTs. The mapping between the GEM port and the T-CONT is flexible. A GEM Port can correspond to a T-CONT; or multiple GEM Ports can correspond to the same T-CONT.
- A GPON interface of an ONU contains one or multiple T-CONTs.

GPON Encapsulation

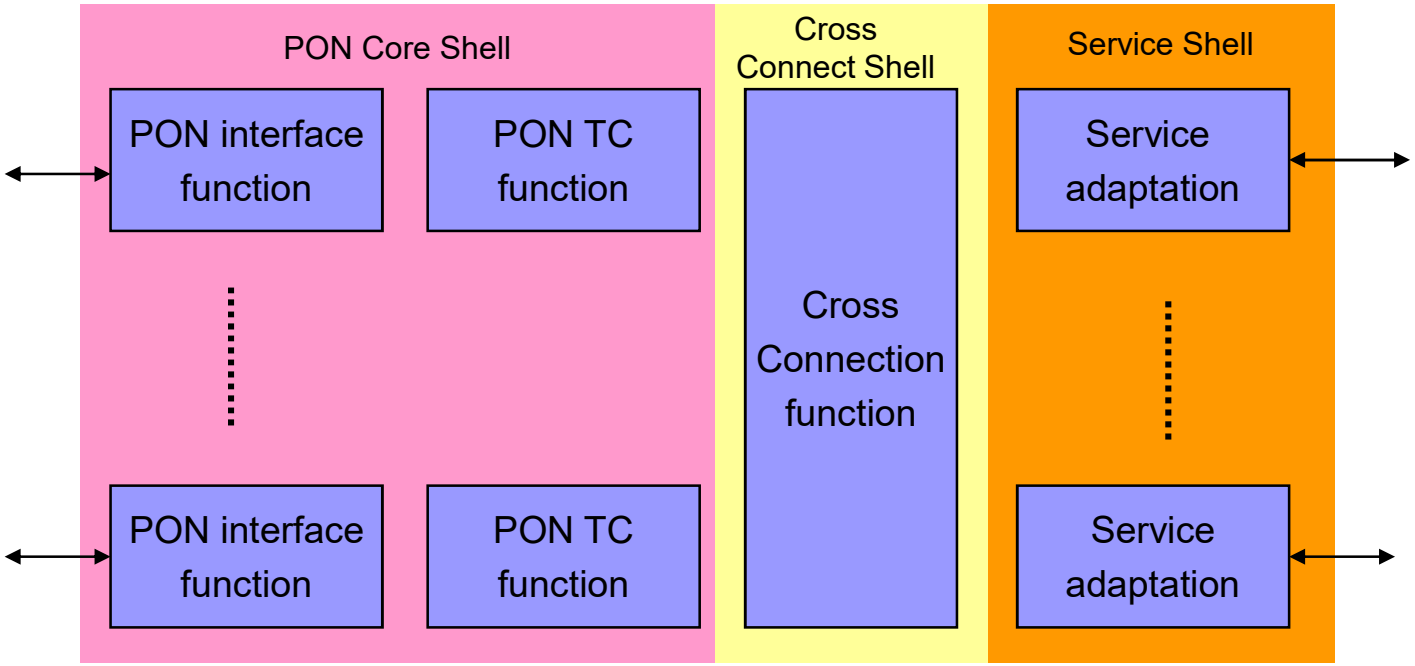
- **GEM** - GPON encapsulation mode

GEM frame is the smallest service-carrying unit and the most basic encapsulation structure. All service streams are encapsulated into the GEM frame and transmitted over GPON lines. The service streams are identified by GEM ports and every GEM port is identified by a unique Port-ID. The Port-ID is globally allocated by the OLT. That is, the ONUs connected to the OLT cannot use GEM ports that have the same Port-ID. The GEM port is used to identify the virtual service channel that carries the service stream between the OLT and the ONU. It is similar to the VPI/VCI of the ATM virtual connection.

- **T-CON** - Transmission Container

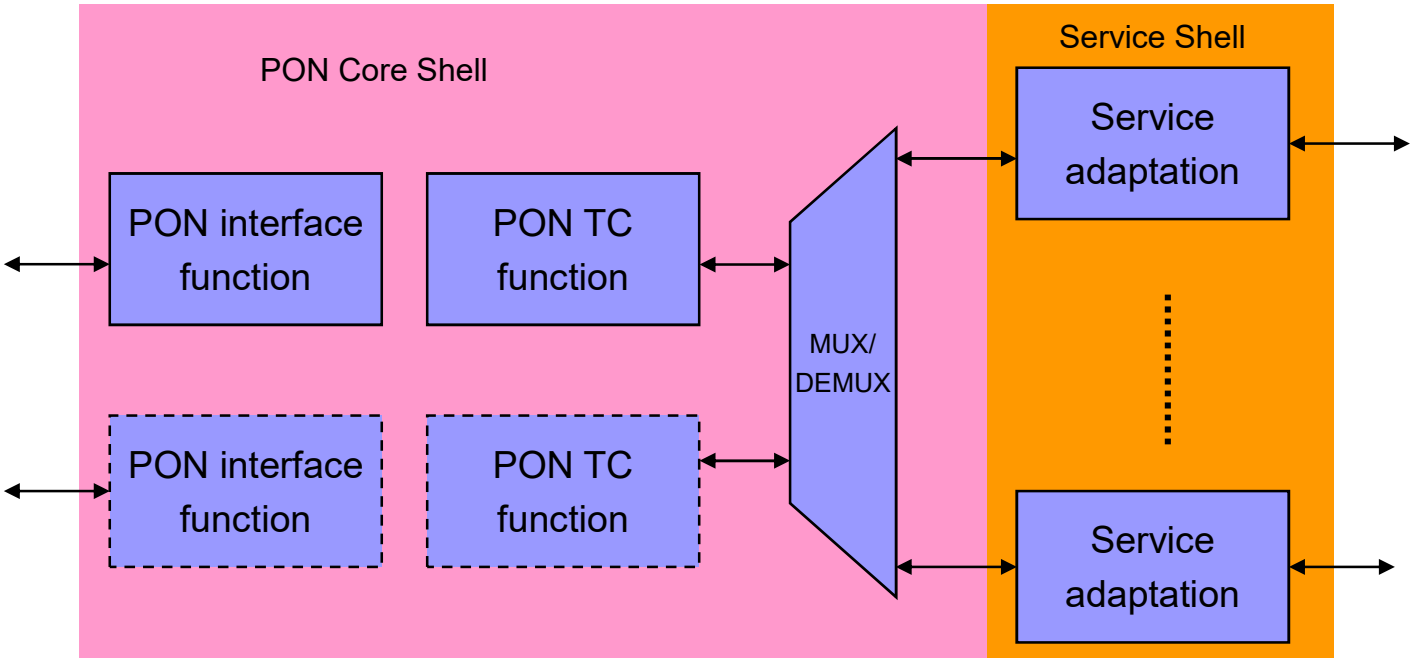
T-CONT is an ONU object representing a group of logical connections that appear as a single entity for the purpose of upstream bandwidth assignment on the PON. For a given ONU, the number of supported T-CONTs is fixed. The ONU autonomously creates all the supported T-CONT instances during ONU activation or upon OMCI (ONU Management and Control Interface) MIB reset. The OLT uses the OMCC (ONU Management and Control Channel) to discover the number of T-CONT instances supported by a given ONU and to manage those instances.

OLT Functional Blocks



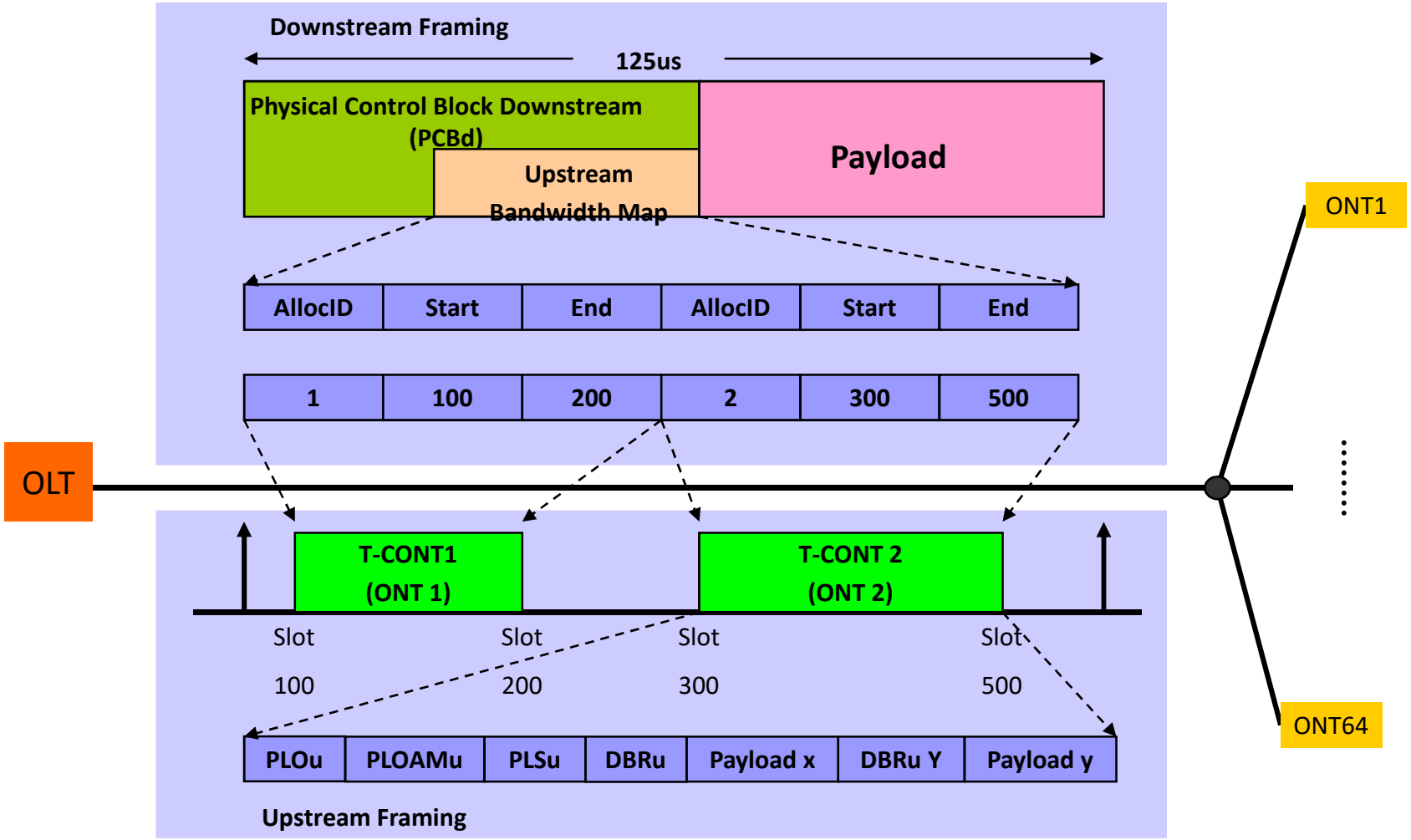
- PON core shell consists of two parts: PON interface function and PON TC function. PON TC function includes framing, media access control, OAM, DBA, and delineation of Protocol Data Unit (PDU) for the cross connect function, and ONU management.
- The Cross-connect shell provides a communication path between the PON core shell and the Service shell, as well as cross-connect functionality.
- Service Shell provides translation between service interfaces and TC frame interface of the PON section.

ONU/ONT Functional Blocks

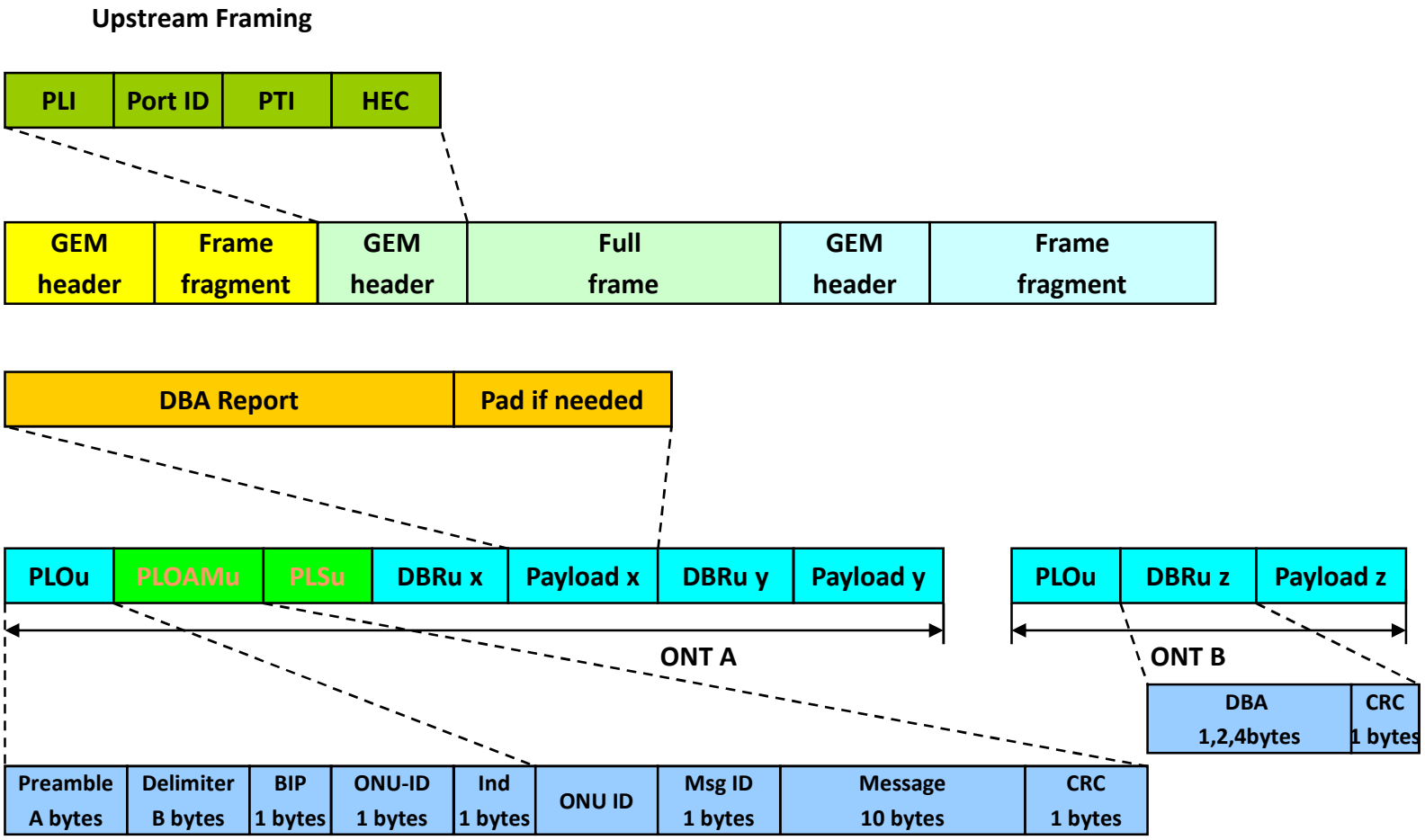


➢ The functional building blocks of the G-PON ONU are mostly similar to the functional building blocks of the OLT. Since the ONU operates with only a single PON Interface (or maximum 2 interfaces for protection purposes), the cross-connect function can be omitted. However, instead of this function, service MUX and DMUX function is specified to handle traffic.

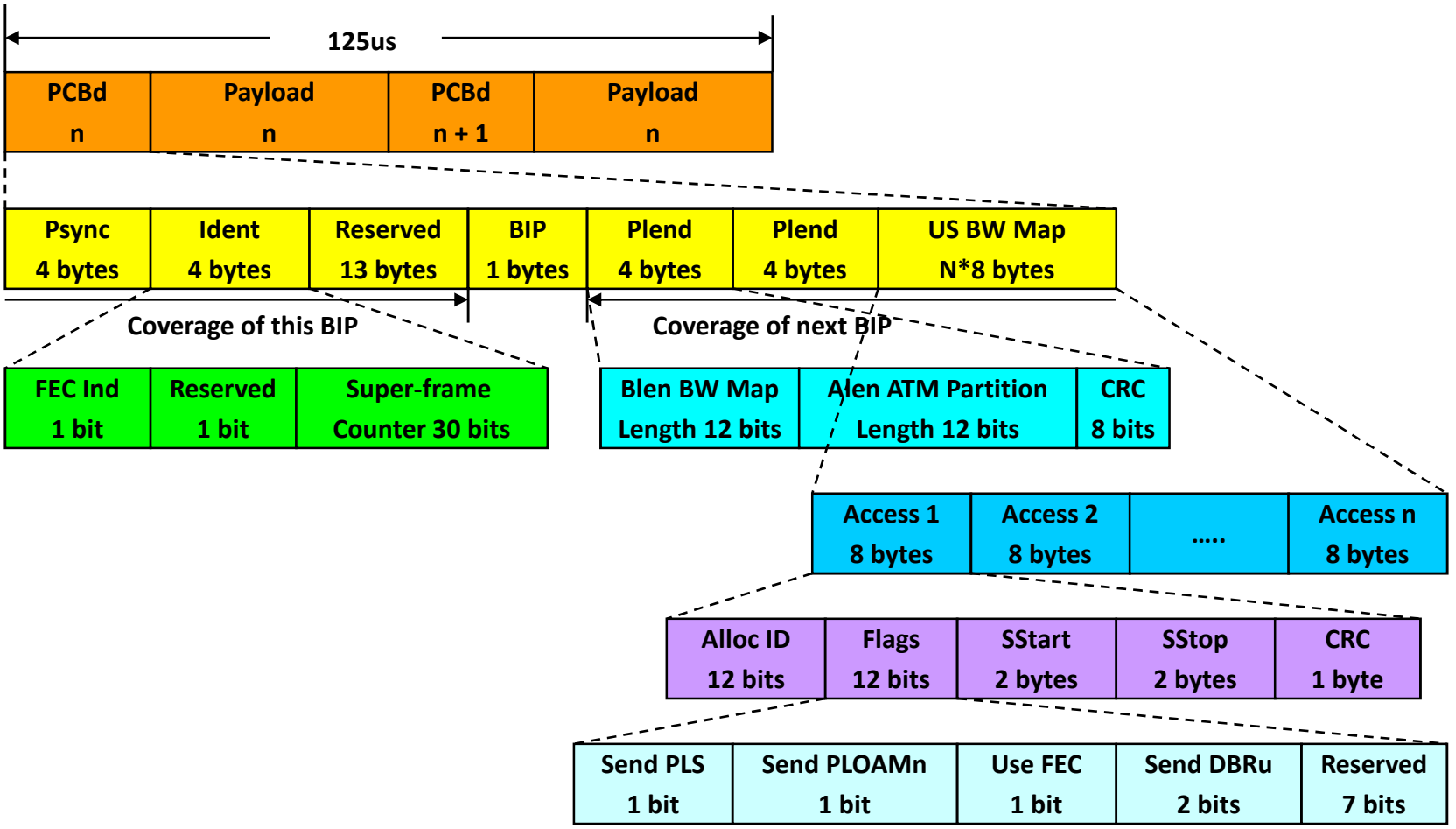
GPON Frame Structure



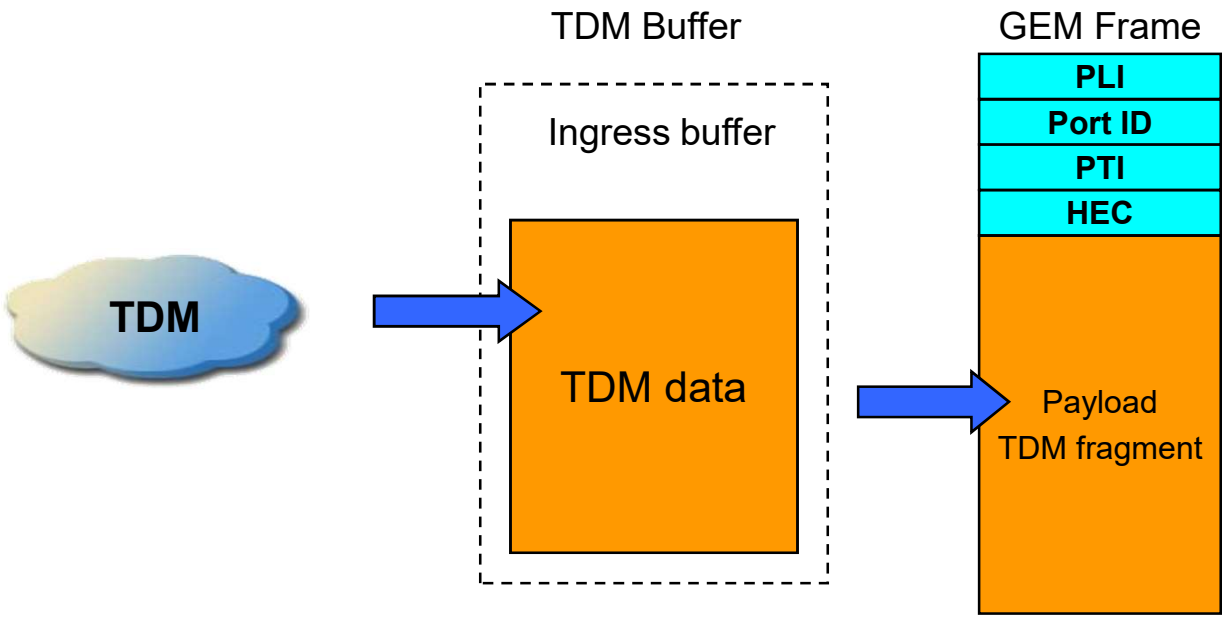
GPON Upstream Frame Structure



GPON Downstream Frame Structure

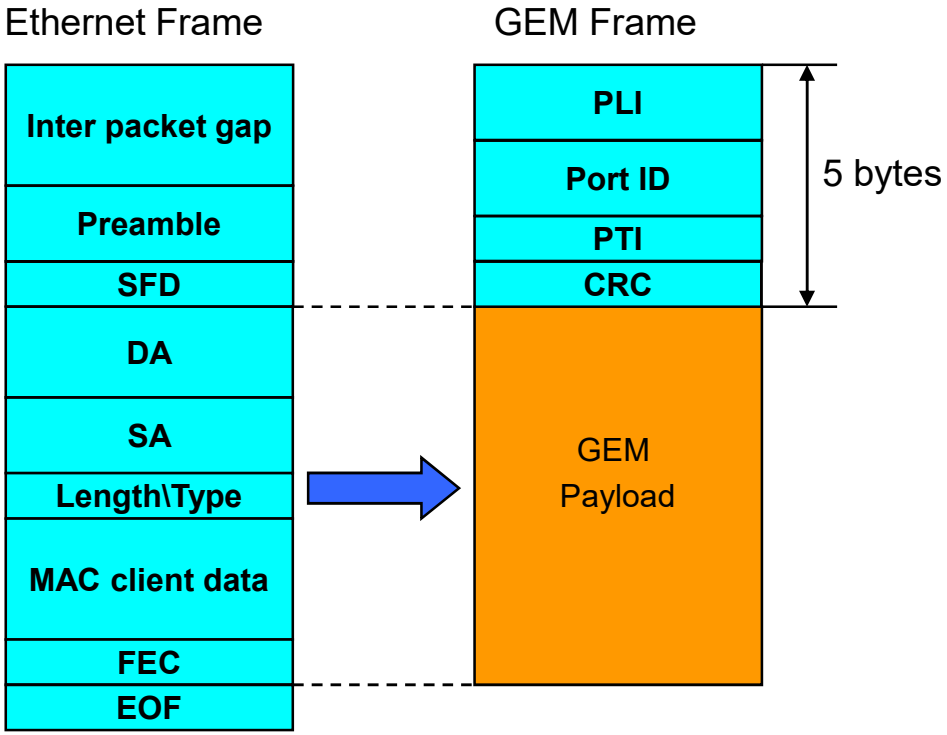


Mapping of TDM Service in GPON



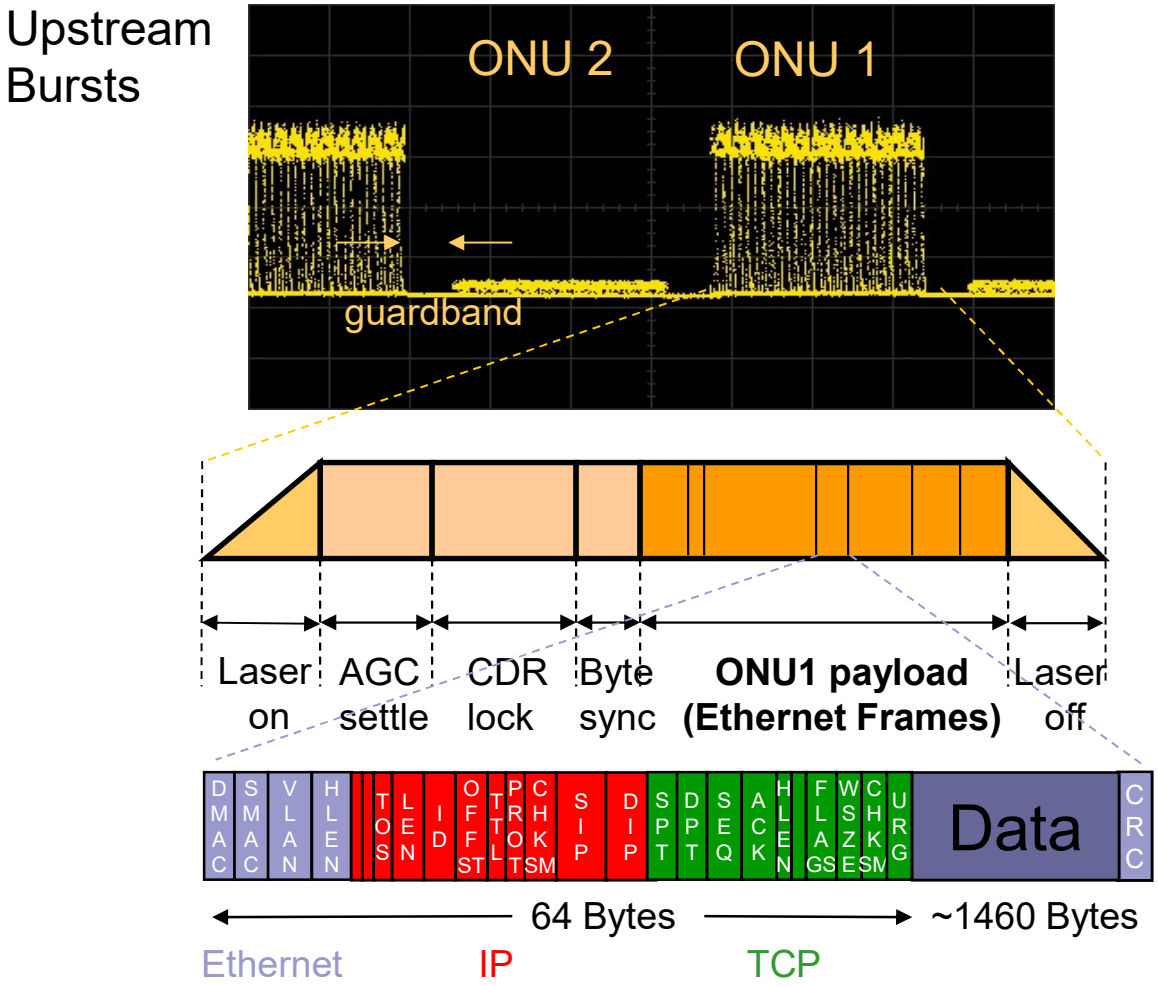
- TDM frames are buffered and queued as they arrive, then TDM data is multiplexed in to fixed-length GEM frames for transmission.
- This scheme does not vary TDM services but transmit TDM services transparently.
- Featuring fixed length, GEM frames benefits the transmission of TDM services .

Mapping of Ethernet Service in GPON

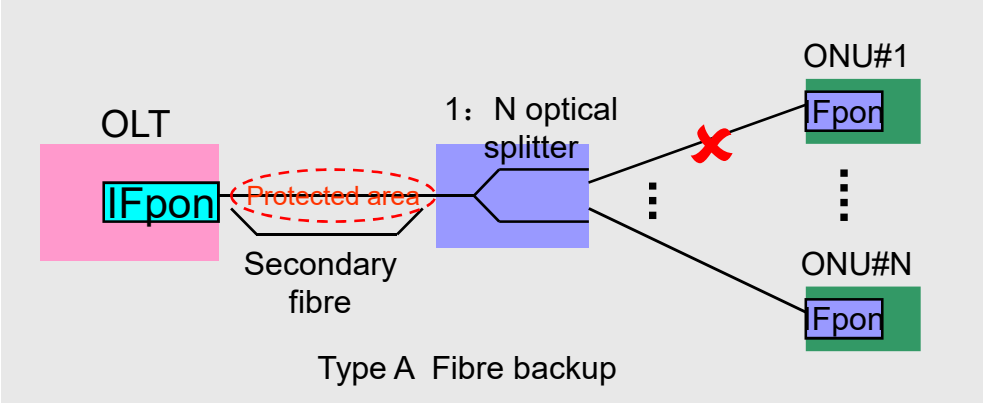


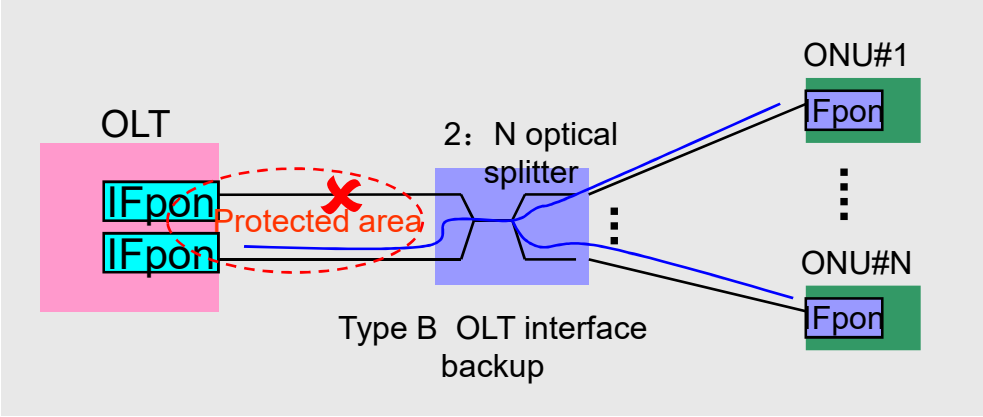
- GPON system resolves Ethernet frames and then directly maps the data of frames into the GEM Payload.
- GEM frames automatically encapsulate header information.
- Mapping format is clear and it is easy for devices to support this mapping. It also boasts good compatibility.

Efficiency of Ethernet Service in GPON



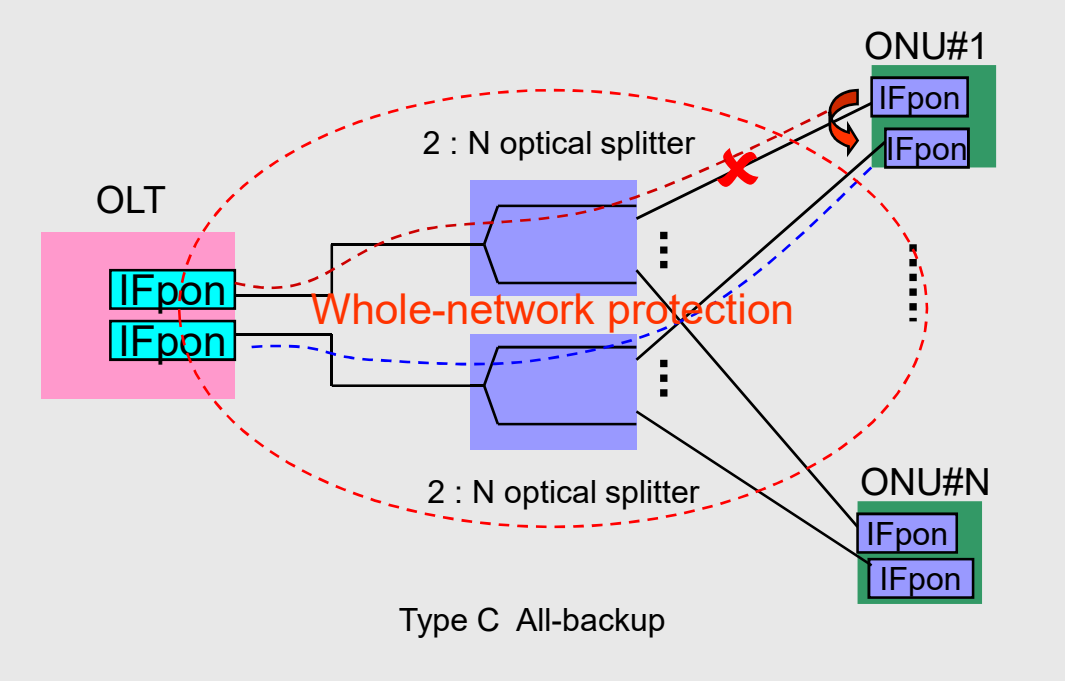
GPON Network Protection Mode





- No backup on devices.
- When the primary fibre fails, the services on the fibre transfers to the secondary fibre.
- Service outage occurs, and the outage duration depends on the time of line recovery.
- When the disconnection occurs to the line from splitter to ONU, service outage will occur and no backup happens.
- OLT provides two GPON interfaces.
- This type protects the primary fibre. When the primary fibre fails, the services on the fibre transfers to the secondary fibre.
- The protected objects are restricted to the fibre from the OLT to the ONU and boards of the OLT. For faults occur to other parts, no protection is provided. With potential security problems, it cannot satisfies customer's requirements.
- Fault location fails.

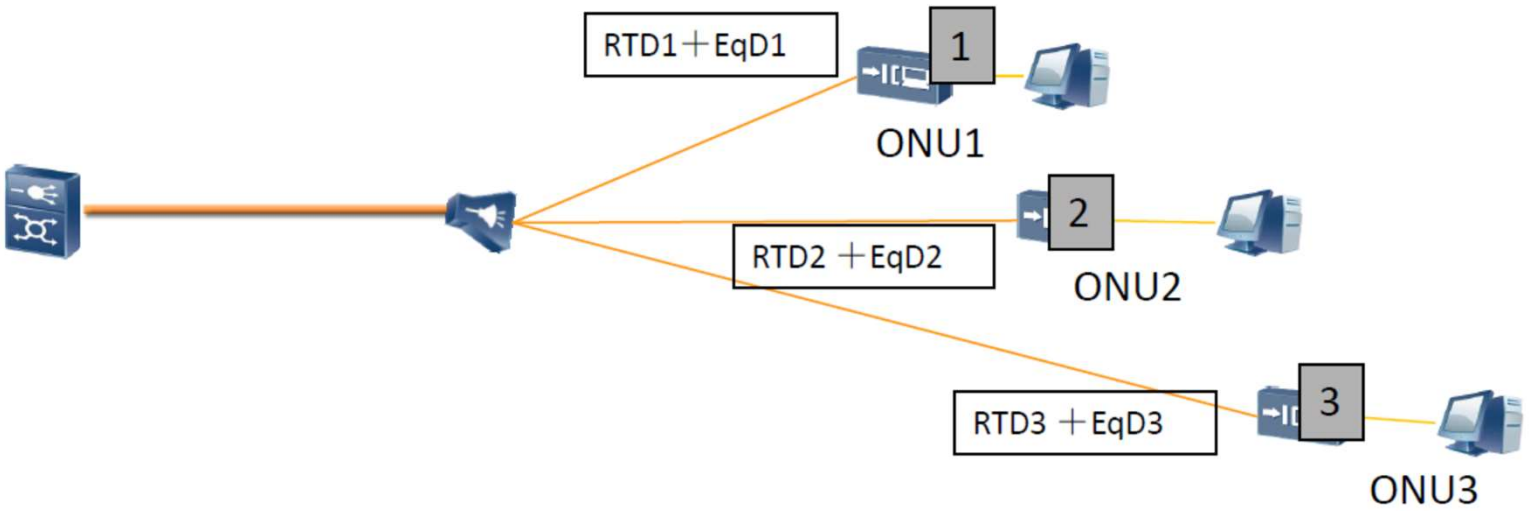
GPON Network Protection Mode



- Both the OLT and the ONT provides two GPON interfaces. GPON interfaces on the OLT work in 1:1 mode.
- This type is a kind of whole-network protection. Two routes are provided between OLT and ONU, ensuring recovery of various faults.
- When the primary PON port on the ONU or user line fails, ONU automatically transfers services to the secondary PON port. In this way, services goes upstream through the secondary line and secondary port on the OLT. Basically, service outage will not occur.
- It is complex to realize it and not cost-effective.
- One port stays at idle state all the time, causing low bandwidth utilization.

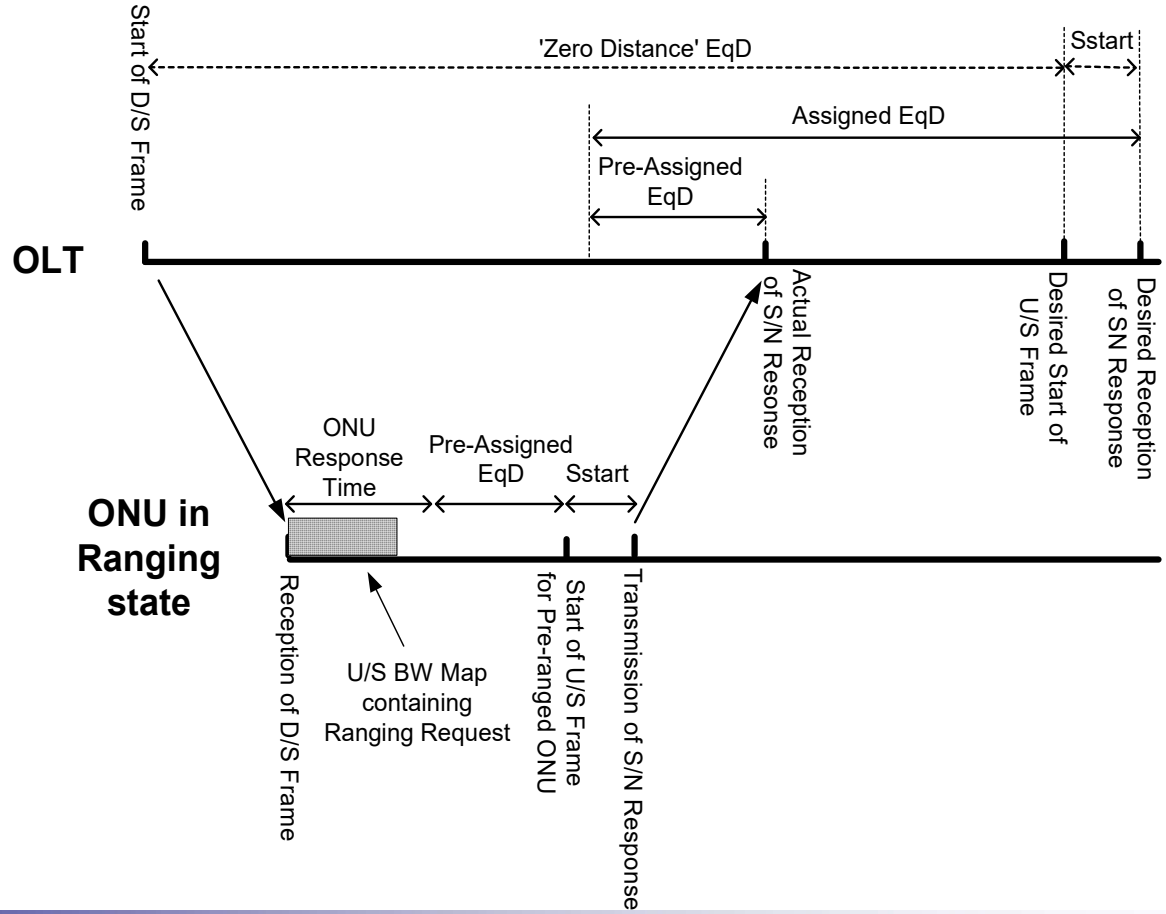
GPON Ranging (and Equalization Delay)

- OLT obtains the Round Trip Delay (RTD) through ranging process, then specifies suitable Equalization Delay (EqD) so as to avoid occurrence of collision of upstream cells sent from different ONUs, in optical splitters.



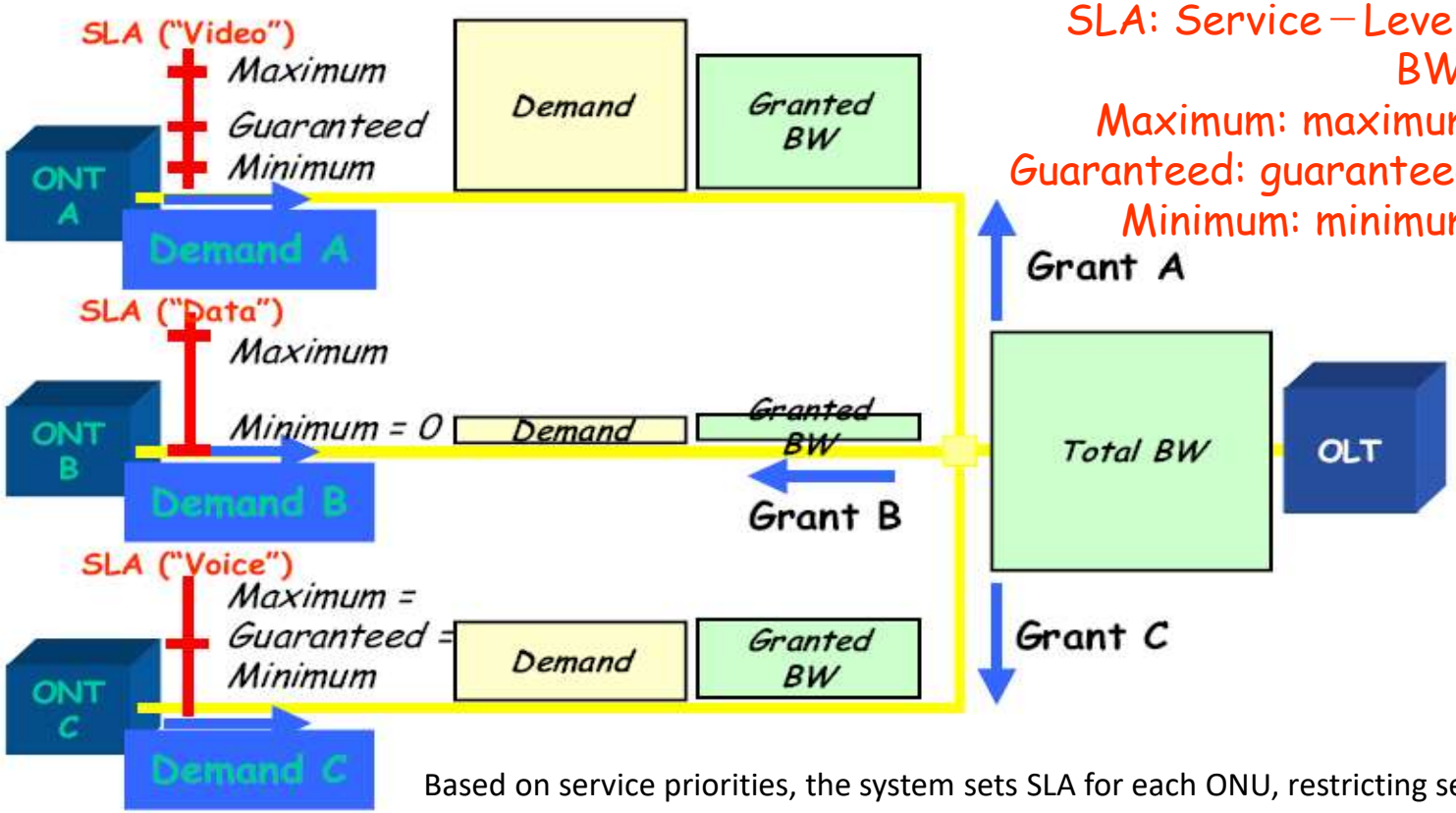
GPON Ranging (and Equalization Delay)

- To acquire the serial number and ranging, OLT needs open a window, that is, Quiet Zone, and pauses upstream transmitting channels on other ONUs.



Dynamic Bandwidth Assignment (DBA)

SLA: Service – Level Agreement
BW: Bandwidth
Maximum: maximum bandwidth
Guaranteed: guaranteed bandwidth
Minimum: minimum bandwidth



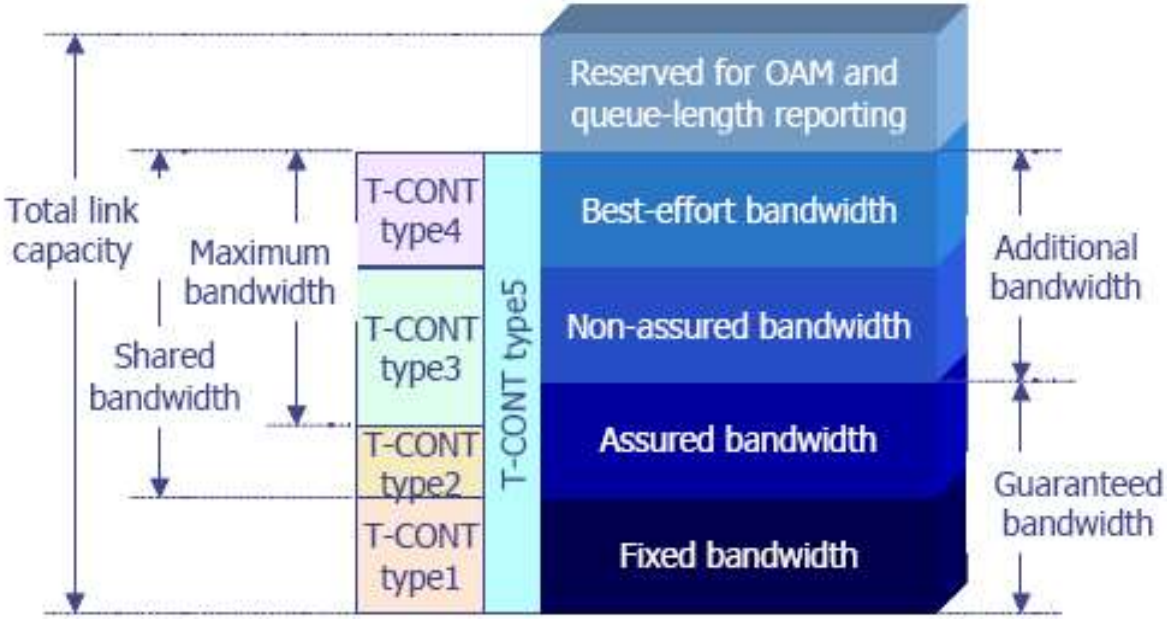
Based on service priorities, the system sets SLA for each ONU, restricting service bandwidth.

The maximum bandwidth and the minimum bandwidth pose limits to the bandwidth of each ONU, ensuring various bandwidth for services of different priorities. In general, voice service enjoys the highest, then video service and data service the lowest in terms of service priority.

OLT grants bandwidth based on services, SLA and the actual condition of the ONU. Services of higher priority enjoy higher bandwidth.

T-CONT Bandwidth Terms

- Transmission Containers (T-CONTs): it dynamically receive grants delivered by OLT. T-CONTs are used for the management of upstream bandwidth allocation in the PON section of the Transmission Convergence layer. T-CONTs are primarily used to improve the upstream bandwidth use on the PON.
- T-CONT type can accommodate 4 traffic types: **F**ixed **B**andwidth, **A**ssured **B**andwidth, **N**on-**A**ssured **B**andwidth and **B**est **E**ffort.
- Five T-CONT types:
  - Type1: FB
  - Type2: AB
  - Type3: AB+NAB
  - Type4: BE
  - Type5: mixed

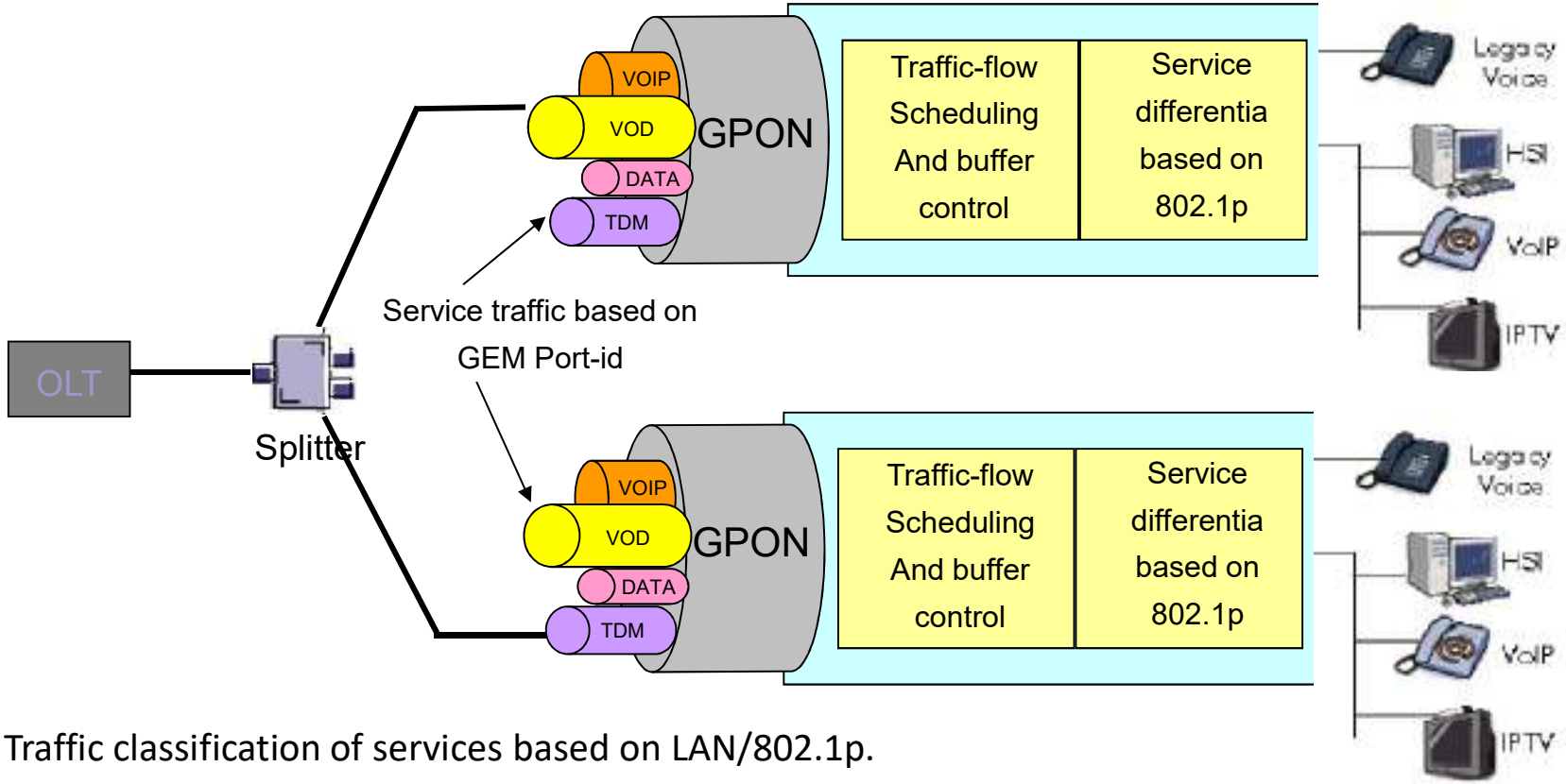


T-CONT Type and Bandwidth

BW Type	Delay Sensitive	Applicable T-CONT types				
		Type 1	Type 2	Type 3	Type 4	Type 5
Fixed	Yes	X				X
Assured	No		X	X		X
Non-Assured	No			X		X
Best Effort	No				X	X
Max.	No			X	X	X

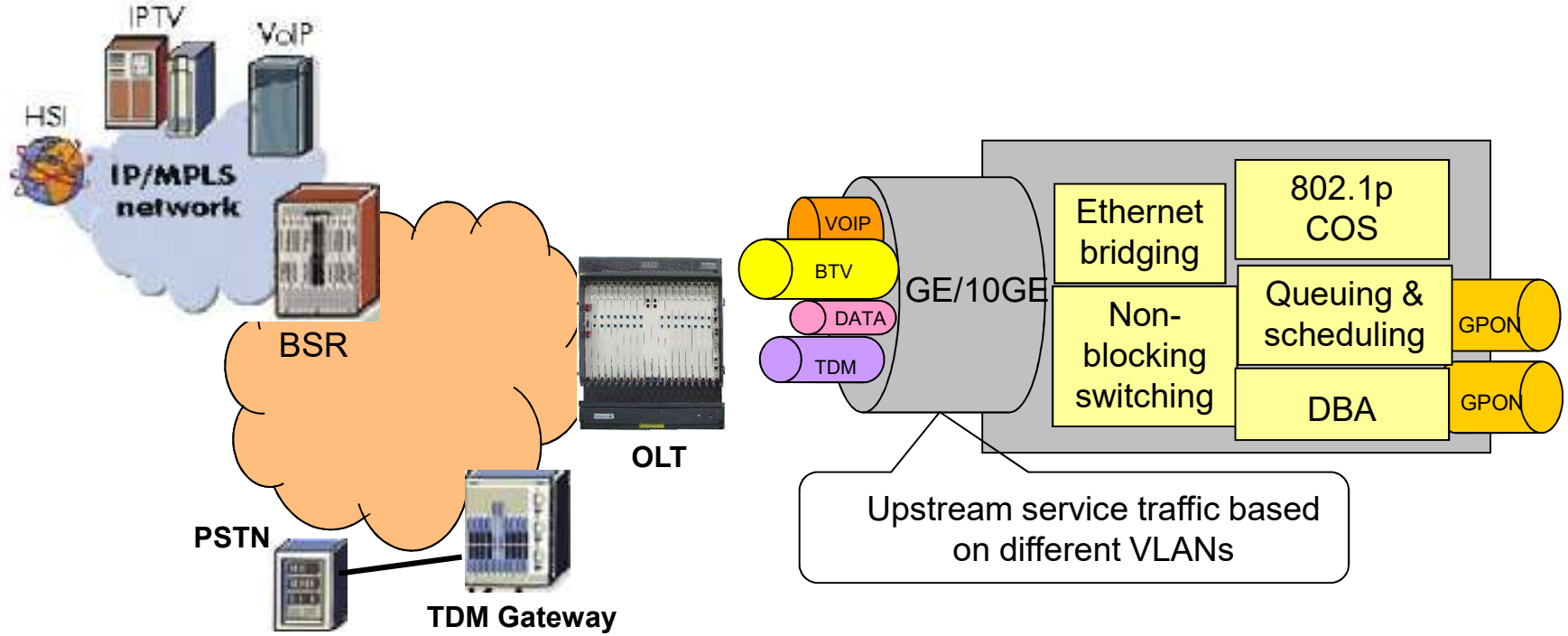
- **Type1 T-CONT** is the fixe bandwidth type and mainly used for services sensitive to time delay and of higher priorities, such as voice services.
- **Type2** and **Type3 T-CONT** is the guaranteed bandwidth type and mainly used for video services and data services of higher priorities.
- **Type4** is of the best-effort type and mainly used for data services (such as Internet and email), and services of lower priorities. These services do not require high bandwidth.
- **Type5** is of the mixed T-CONT type, involving all bandwidth types and bearing all services.

QoS Mechanism of ONU in GPON



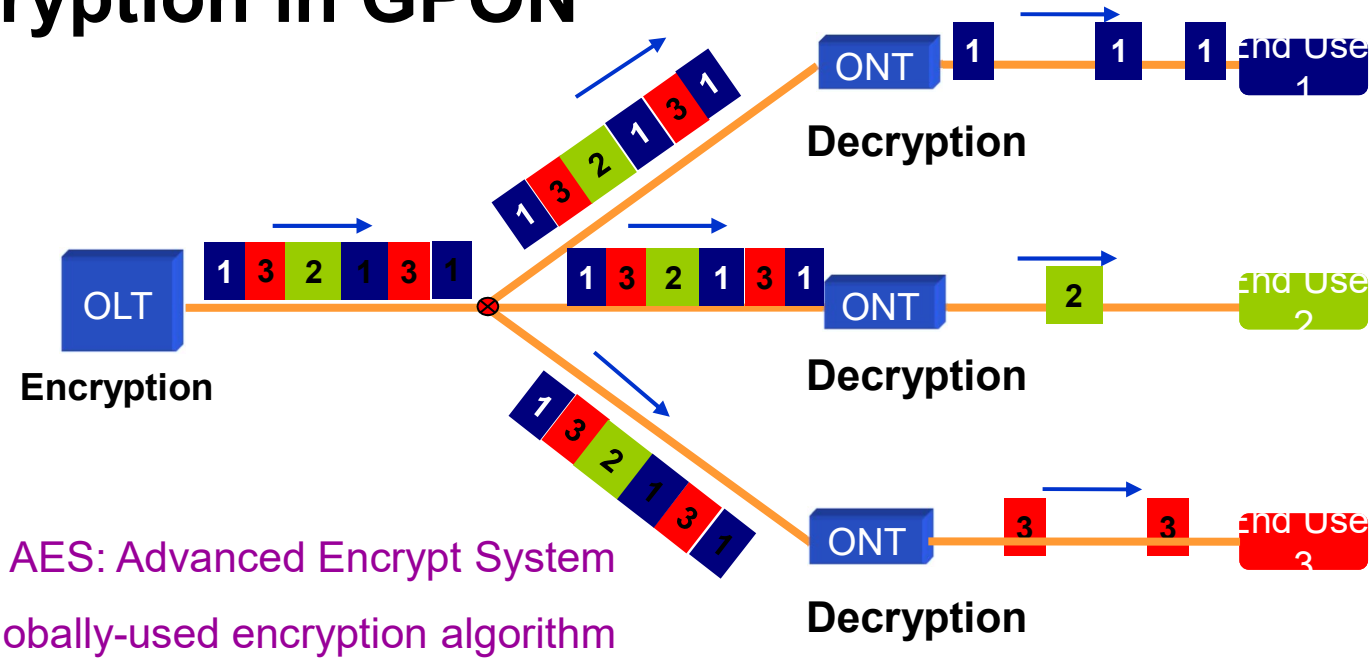
- Traffic classification of services based on LAN/802.1p.
- Service scheduling based on the combination of strict priority (SP) and Weighted Round Robin (WRR) algorithms.
- Service transmission based on service mapping with different T-CONTs, enhancing line utilization and reliability.

QoS Mechanism of OLT in GPON



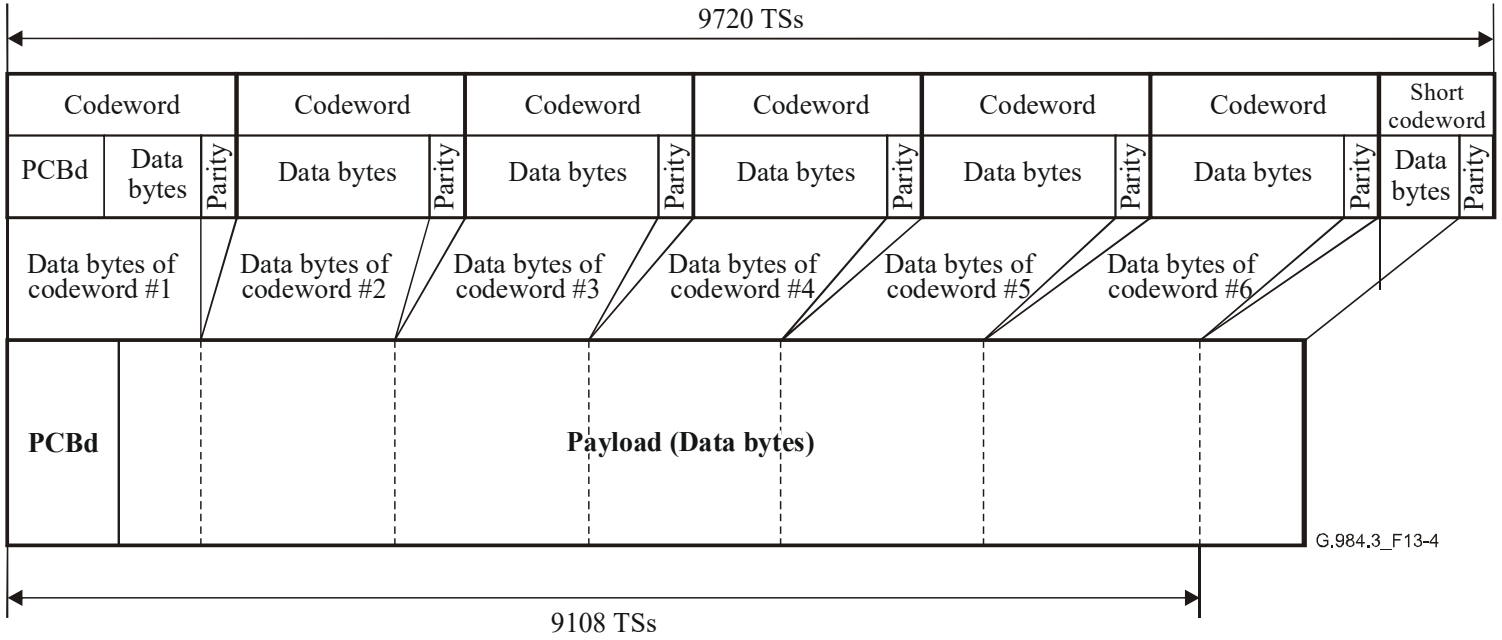
- Traffic classification based on VLAN/802.1p.
- Service scheduling based on combination of strict priority (SP) and Weighted Round Robin (WRR) algorithms.
- DBA algorithm, enhancing uplink bandwidth utilization.
- Access control list (ACL)-based access control on layers above layer-2.

AES Encryption in GPON



- OLT applies Advanced Encryption Standard (AES) 128 encryption.
- GPON supports encrypted transmission in downstream direction, such as AES128 encryption.
- In the case of GEM fragments, only the payload will be encrypted.
- GPON system initiates AES key exchange and switch-over periodically, improving the reliability of the line.

FEC - Forward Error Correction

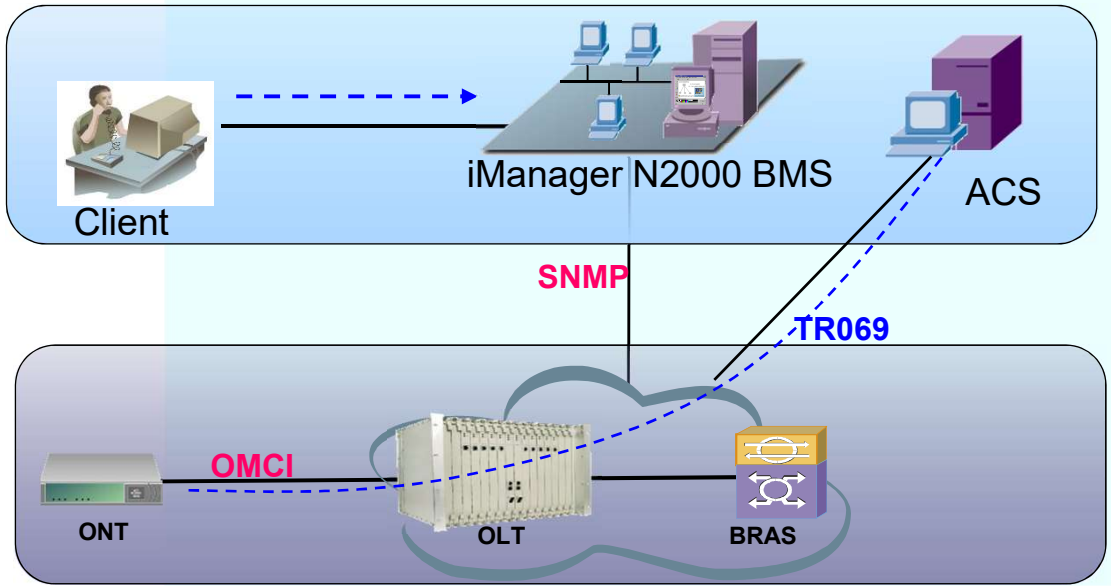


- It is a algorithm based on Reed-Solomon, a Block based code. FEC code comprises fixed-length data block and redundancy bits.
- Applying FEC algorithm on the transmission layer, GPON will drop the error bit rate of the line transmission to 10-15, and avoid retransmission of data.
- GPON supports FEC in the downstream direction.
- Processing of PCBd and Payload improves the transmission quality.

Parameters of GPON Interfaces (Class B+)

Items	Unit	Single fibre
OLT:		**OLT**
•Mean launched power MIN	dBm	+1.5
•Mean launched power MAX	dBm	+5
•Minimum sensitivity	dBm	-28
•Minimum overload	dBm	-8
•Downstream optical penalty	dB	0.5
ONU:		**ONU**
•Mean launched power MIN	dBm	0.5
•Mean launched power MAX	dBm	+5
•Minimum sensitivity	dBm	-27
•Minimum overload	dBm	-8
•Upstream optical penalty	dB	0.5

GPON System Management Mode



- **ONT Plug and Play**
  - Zero configuration
- **ONT Centered Management**
  - ONT remote diagnosis
  - Remote ONT maintenance and management through OMCI
  - Auto configuration and management on ONT through TR069
- **ONT Auto Service Provisioning**

Basic Message Types in GPON Management

Three types OAM message at the physical layer : embedded OAM, PLOAM and OMCI:

- The embedded OAM and PLOAM channels manage the functions of the PMD and the GTC layers. The OMCI provides a uniform system of managing higher (service defining) layers.
- The embedded OAM channel is provided by field-formatted information (such as BW Map, DBRu) in the header of the GTC frame. The functions that use this channel include: bandwidth granting, Dynamic Bandwidth Assignment signalling and so on.
- The OMCI channel is used to manage the service defining layers that lay above the GTC.

GPON Service Provisioning and Zero Configuration on Terminals

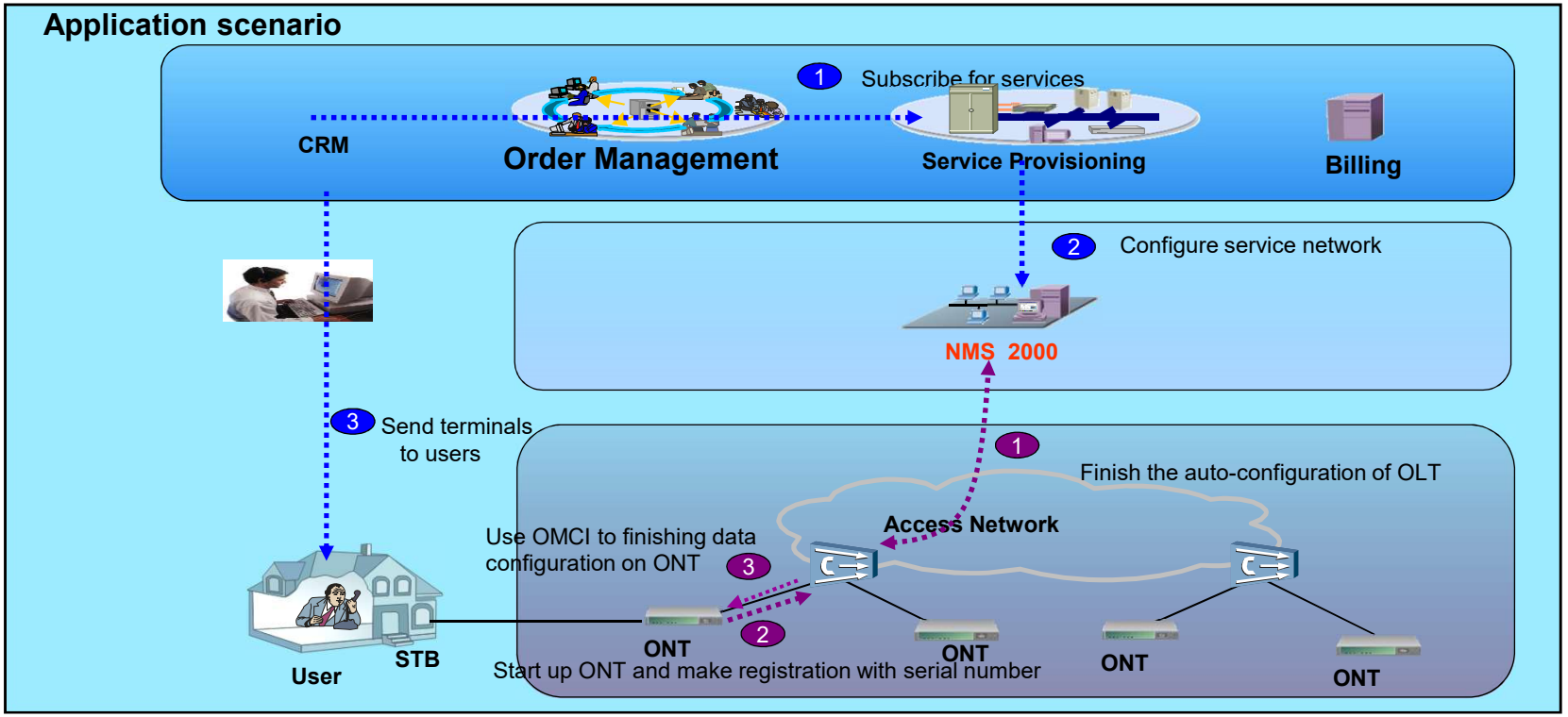
Carriers' nightmare

Initial configurations (such as service system information configuration, data configuration) are required on terminals and then they can be put into use. To finish these configurations, it is not cost-effective to carriers.

Flexible Configuration plan of GPON

GPON supports zero configuration on terminals and plug-and-play of terminals, which is cost-effective.

Application scenario

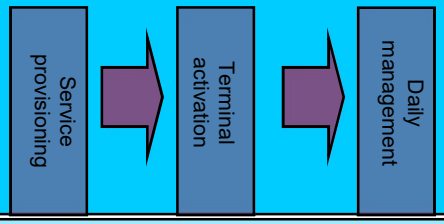


VOIP Service Management Solution in GPON

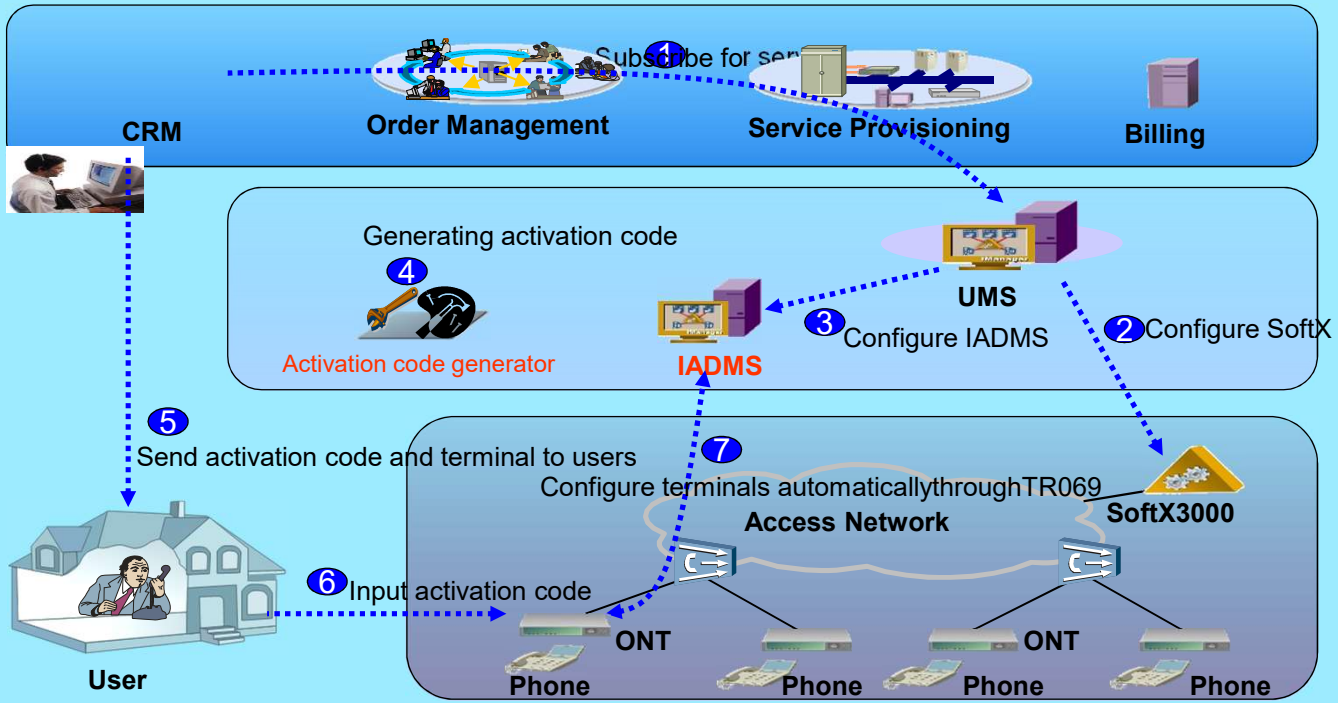
Description

Maintenance personnel use activation code generator to generate terminal activation code (including IADMS IP, PPPoE user name and password). Users input activation code on terminals, terminals register on IADMS upon power-up and the IADMS makes auto-configuration on terminals.

Basic operation and maintenance process



Process and Networking



Basic Services over GPON Network

- Voice
- IPTV
- Triple-play
- TDM
- RF overlay services
- Base station access solution

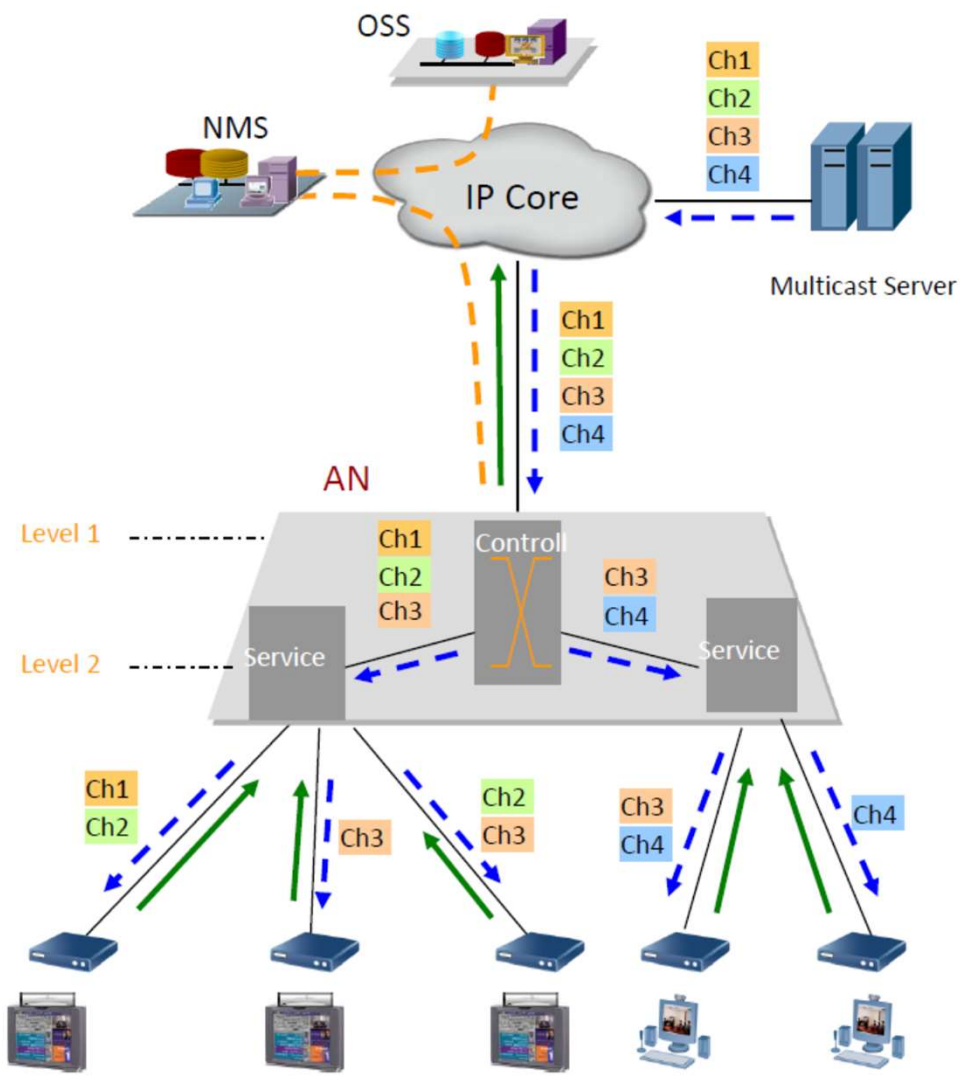
IPTV Solution

Multicast stream

IGMP report

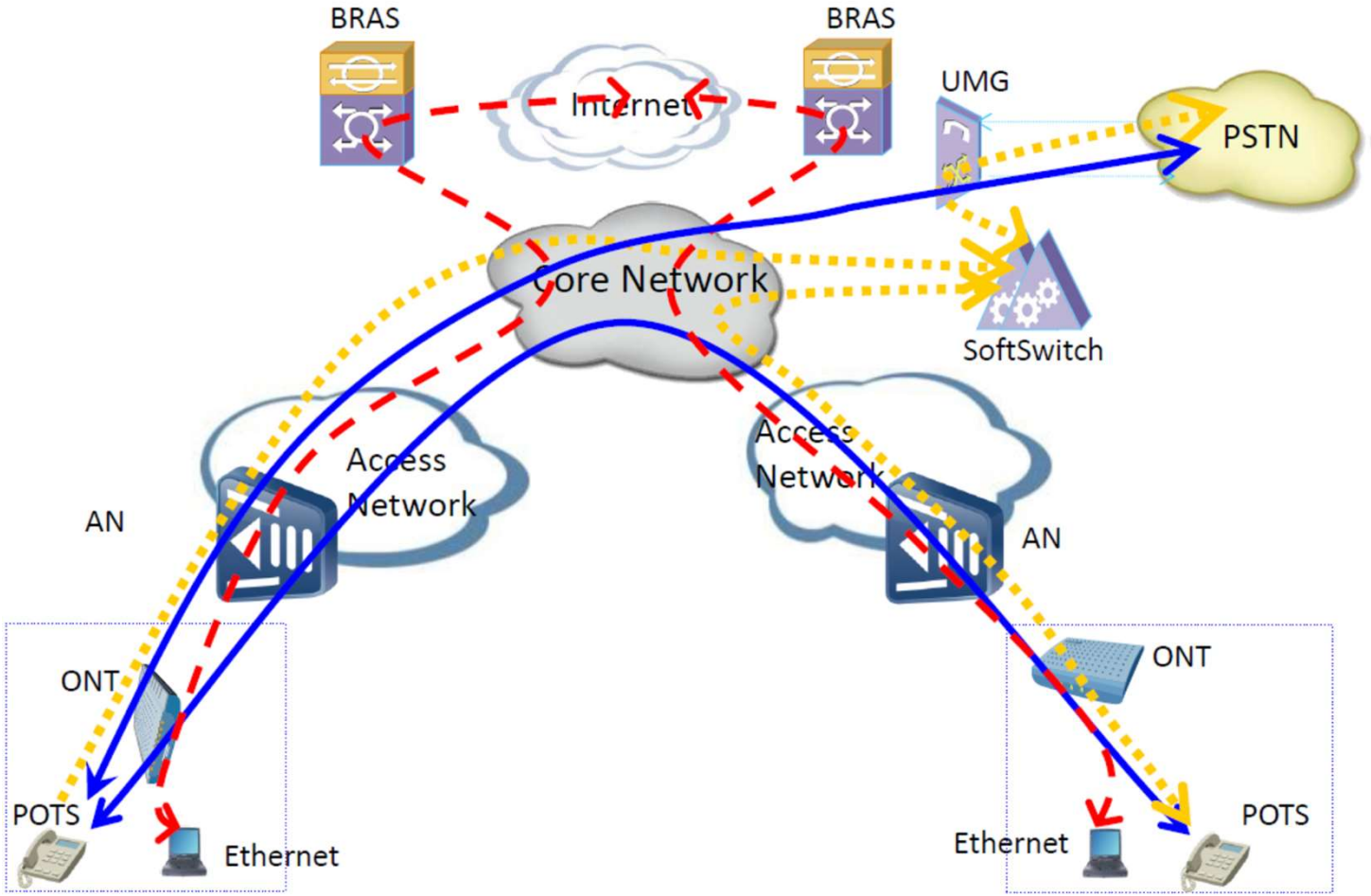
Ch1
Ch2
Ch3
Ch4

IP group: 1~4



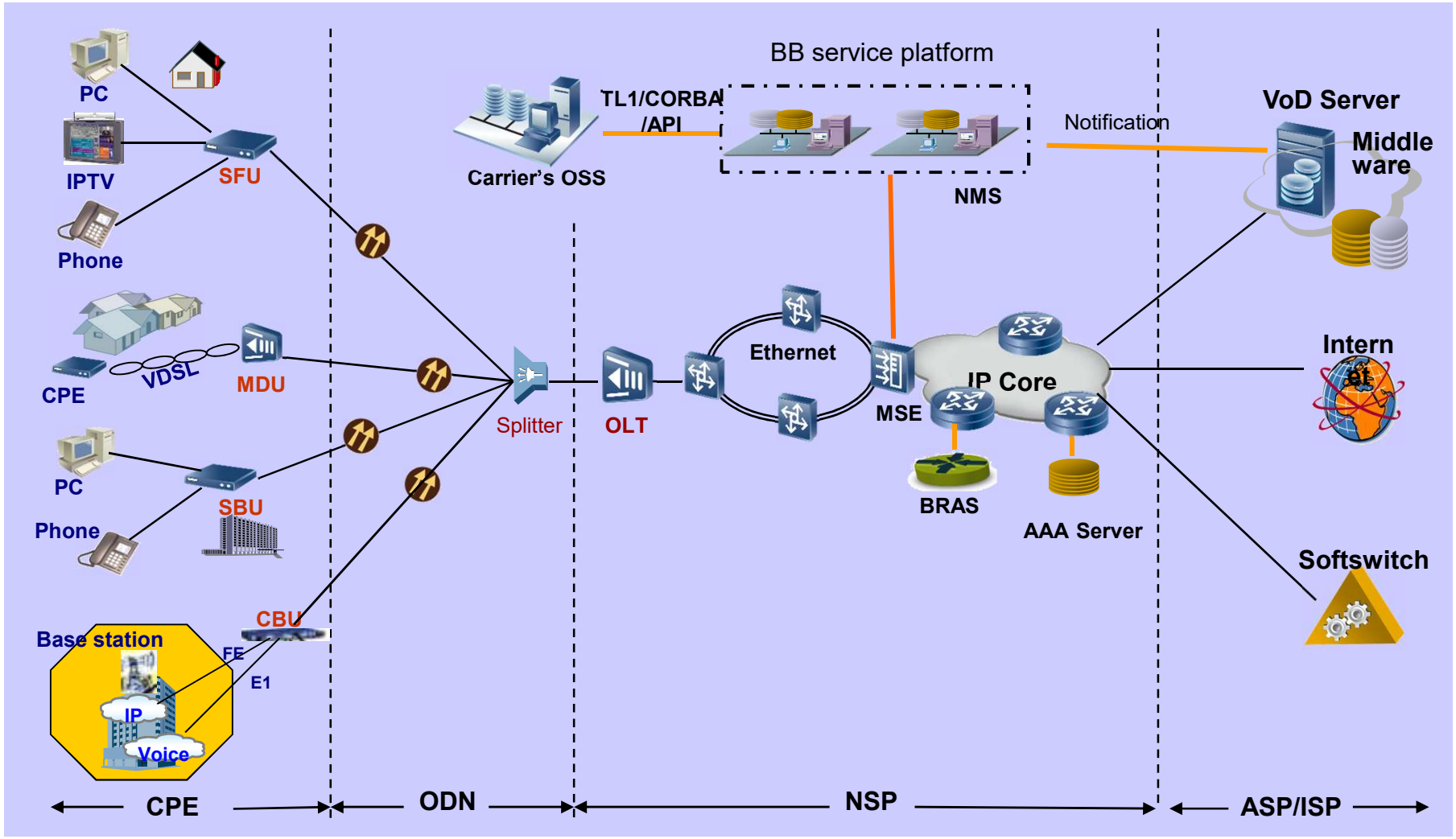
Optical Access Network

Voice + High-Speed Internet Solution



Optical Access Network

Triple Play Service Application in GPON



Triple Play Service Application in GPON

- Triple play means that the VoIP, IPTV, and Internet services are transmitted over one cable to the ONT/ONU through the OLT in a centralized manner.
- OLT is able to sense services, facilitating flexible VLAN switching.
- Services go upstream to the IP network through different VLANs

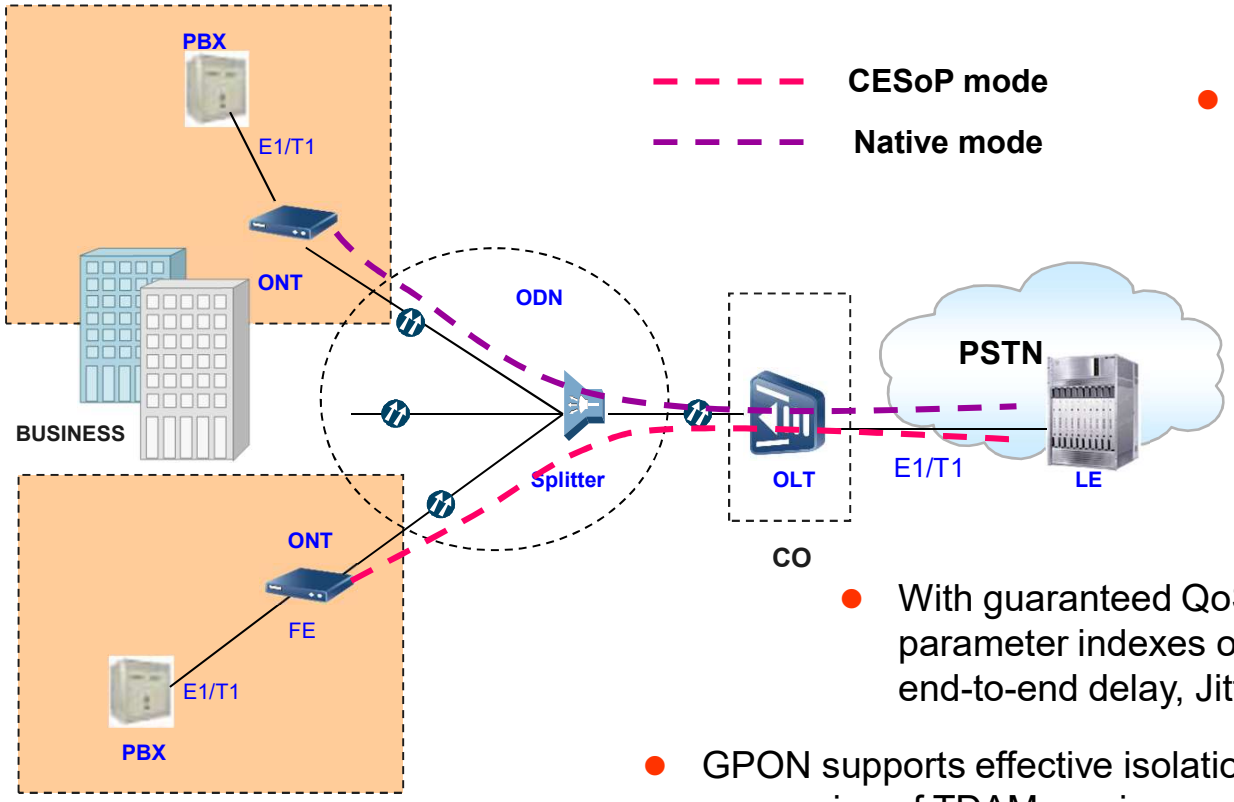
- **Triple play service classification**
  - The ONU maps three types of services to three different GEM ports according to the VLAN ID, 802.1p value, or physical port and then the service packets are sent to the OLT for processing.
  - After receiving the packets from the GEM port, the OLT converts them into the data flow, labels the data flow with a certain service VLAN, and then sends the labeled data flow to the upper layer device.

Triple play main concern

The main concern of triple play is how to handle different priorities of different services in an user port, and to reduce the mutual effect to the lowest level.

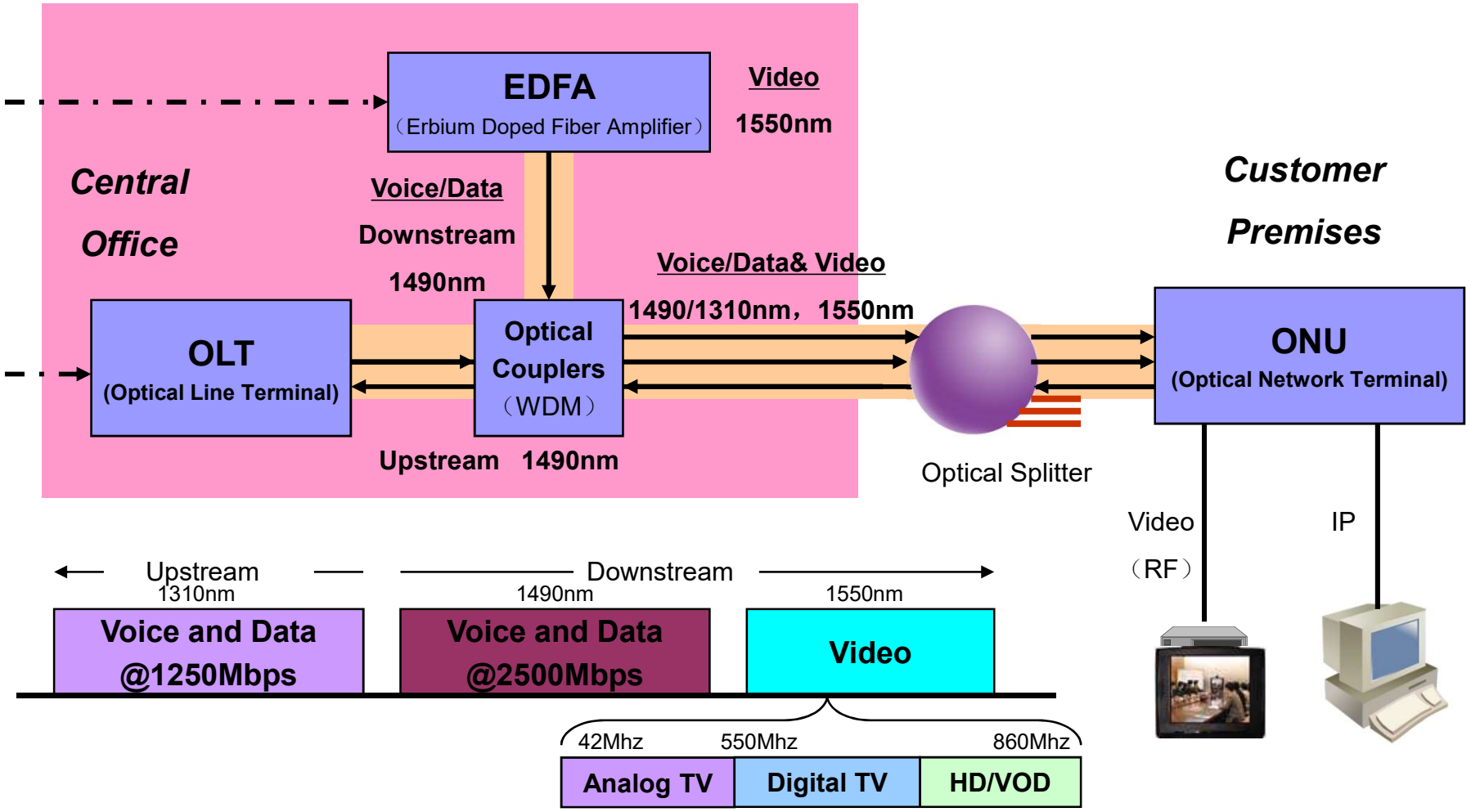
- **VoIP service**
  - Because the bandwidth and delay of the VoIP service are low, the priority of the VoIP service is the highest among the triple play services.
- **IPTV service**
  - Because the bandwidth occupied by the IPTV service is relatively high, and the bit error ratio/packet loss ratio is relatively low, the priority of the IPTV service is lower than that of the VoIP service, but is higher than that of the Internet access service.
- **High-speed Internet access**
  - Because common Internet access services, such as web browsing, require neither a strong real-time performance nor a low packet loss ratio, the priority of the high-speed Internet access service is the lowest among the triple play services.

TDM Service Solution in GPON

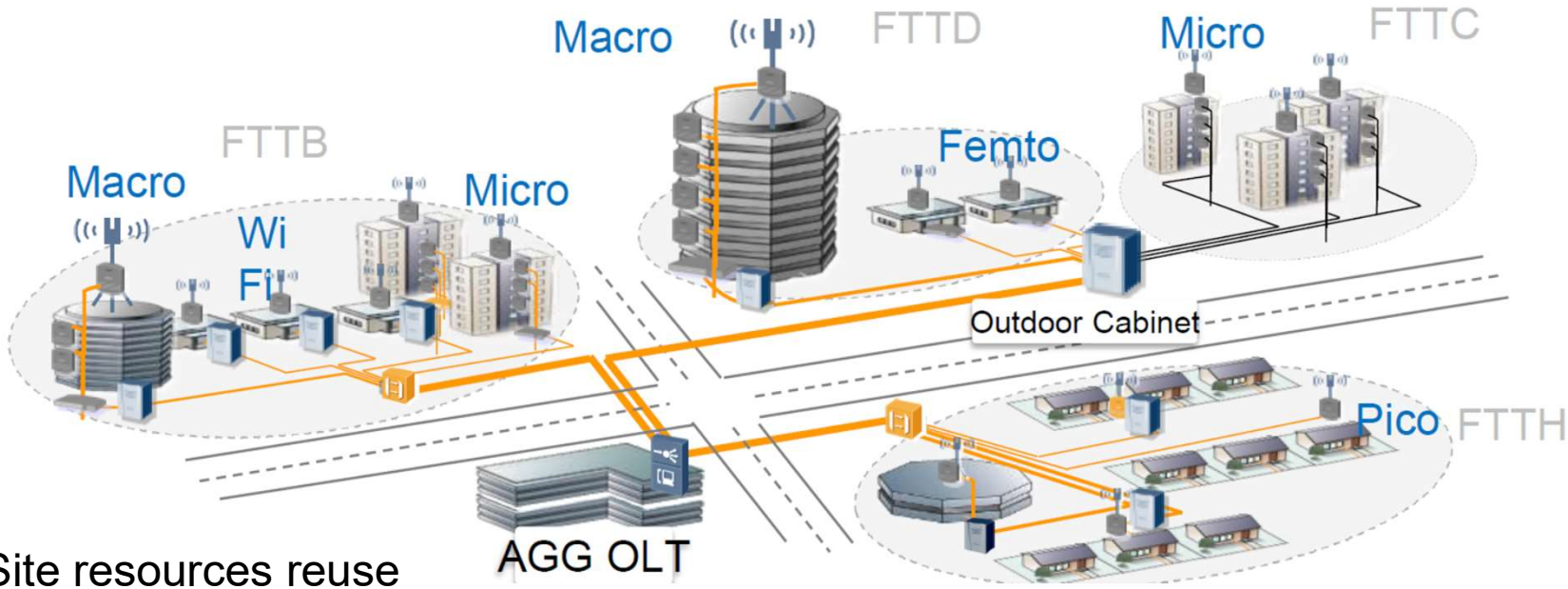


- With fixed upstream/downstream frame structure, periodic multiframes are transmitted in GPON line. So, GPON can transmit TDM service with first-born advantage.
- With guaranteed QoS, GPON ensures the parameter indexes of TDM service, such as end-to-end delay, Jitter and error bit rate.
- GPON supports effective isolation and higher-priority processing of TDAM service.

RF Overlay Service Solution in GPON



Base station access solution - FTTM



- Site resources reuse

Only FTTX can completely supply site and power resources in the range of 20~30 meters. Realize higher MBB bandwidth and capacity with intensive, comprehensive, and multiple coverage.

- Pipeline resources reuse

The last paragraph FTTX network pipeline resources (copper, fiber, CAT5, etc) can be used in small cell backhaul

- Bandwidth resources reuse

Advantage in bandwidth: reuse existing ODN network, can smooth evolution to 10G PON; With the development of Vectoring and G.fast technology, twisted pair can reach 500MB even 1000MB in the future.

Base station access solution

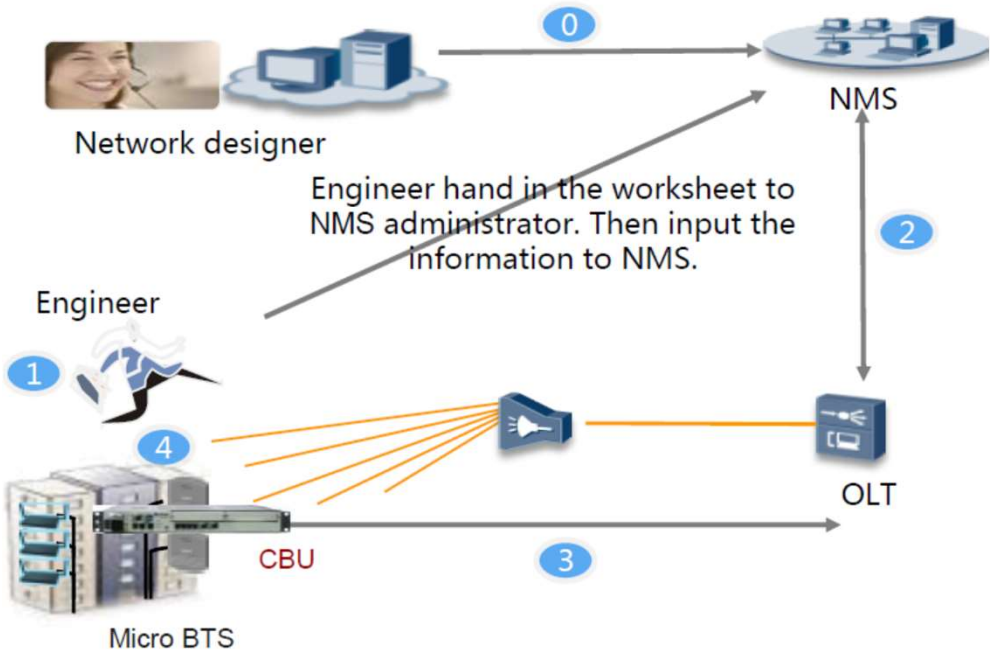
Steps:

0. Network designer finish network design, then put the configuration onto NMS. The configurations include no authentication policy, ONU profiles, OLT profiles

1. Engineer go to the small sell site to install small cell and ONU. Plug in the GPON fiber and power on the device

2. OLT find ONU online, then inform NMS automatically. NMS find this ONU matches the no authentication policy, then download the configuration to the OLT automatically.

3. OLT send command to ONU and active the service

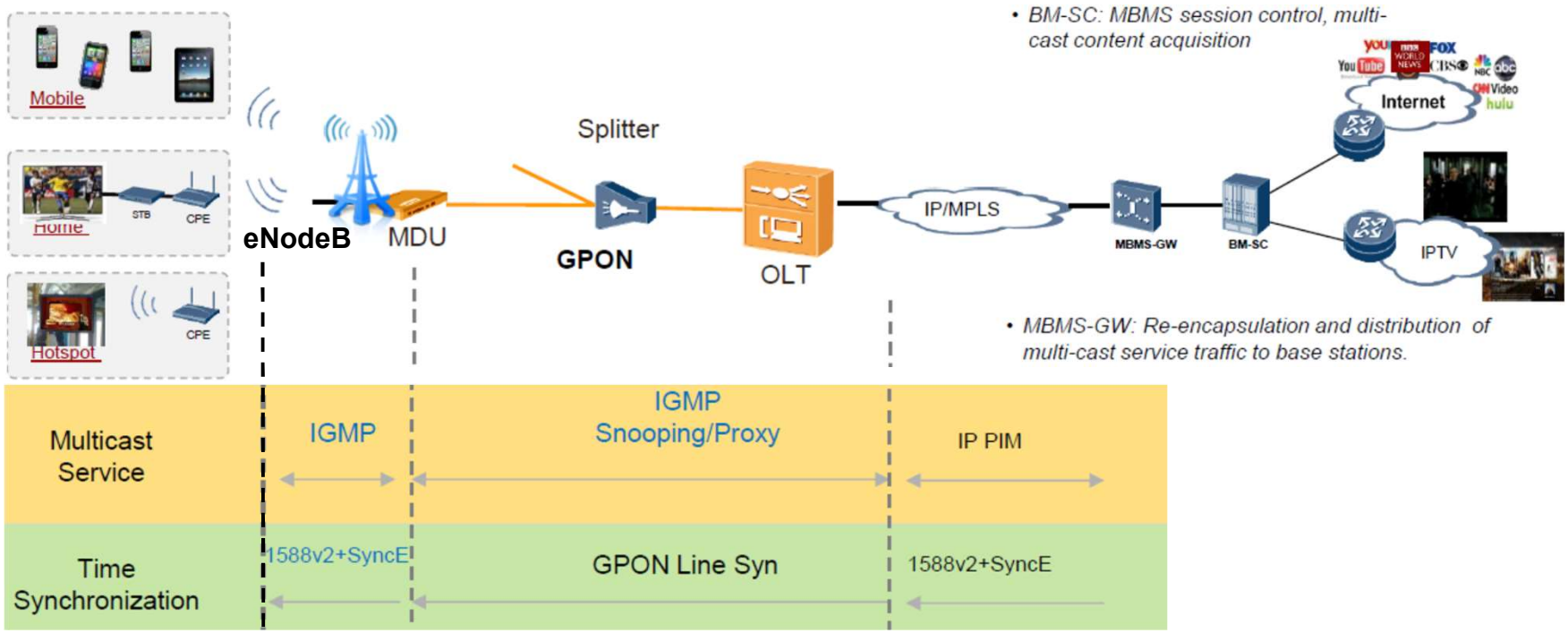


4. After about 5-10 mins Engineer check the Small Cell work normal, then copy the SN of ONU and the site location to worksheet. Then finish the installation.

- Plug and Play without authentication and configuration;
- High efficiency for service provision.
- Plug and play for ONU . No GPON service configuring needed on site.
- Network designer need to design the all the ONUs to same configuration

Optical Access Network

FTTM Supports LTE eMBMS & VoLTE new Services



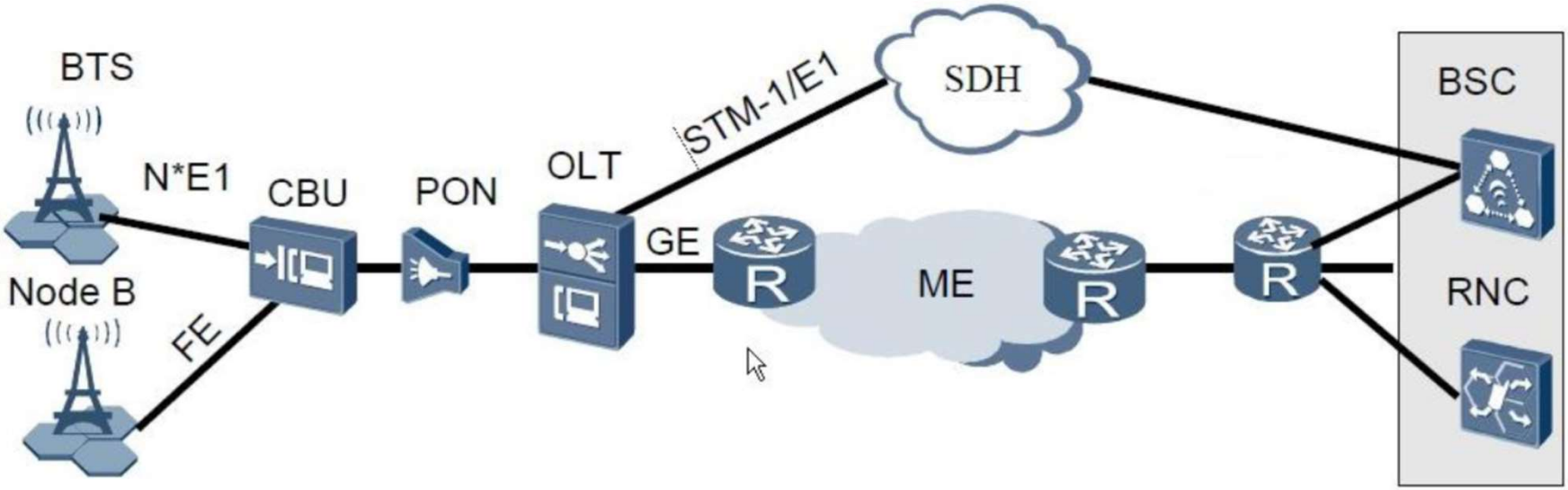
- The eMBMS provides a solution to delivery very hot video content to UEs by broadcasting. The future video service mode might be Sparse OTT + Dense eMBMS.
- LTE eMEMS service require supporting multicast transport and time synchronization. GPON solution can fully match these two requirements.

Base station access solution

Wireless system	Frequency sync. required	Phase sync. required
GSM	0.05ppm	NA
WCDMA	0.05ppm	NA
TD-SCDMA	0.05ppm	+/-1.5us
CDMA2000	0.05ppm	+/-3us
WiMax FDD	0.05ppm	NA
WiMax TDD	0.05ppm	+/-0.5us
LTE FDD	0.05ppm	NA
LTE TDD	0.05ppm	+/-1.5us

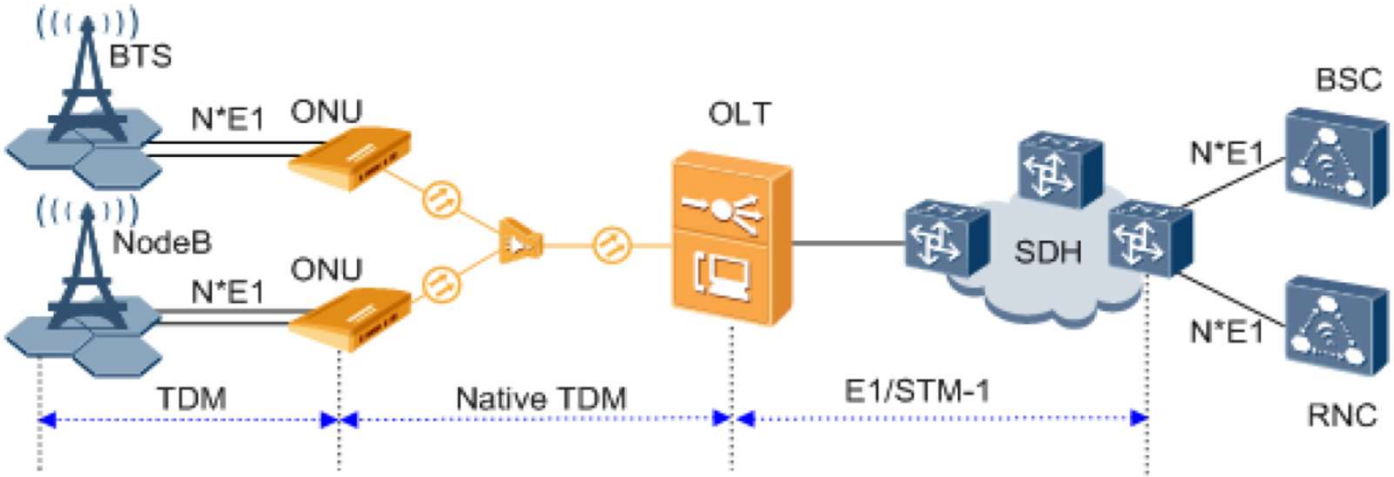
Base station access solution

- Full-service carriers hope to carry 2G and 3G voice and mobile data services on a unified ME network. The carriers expect to use abundant PON resources to carry mobile services on an integrated platform.

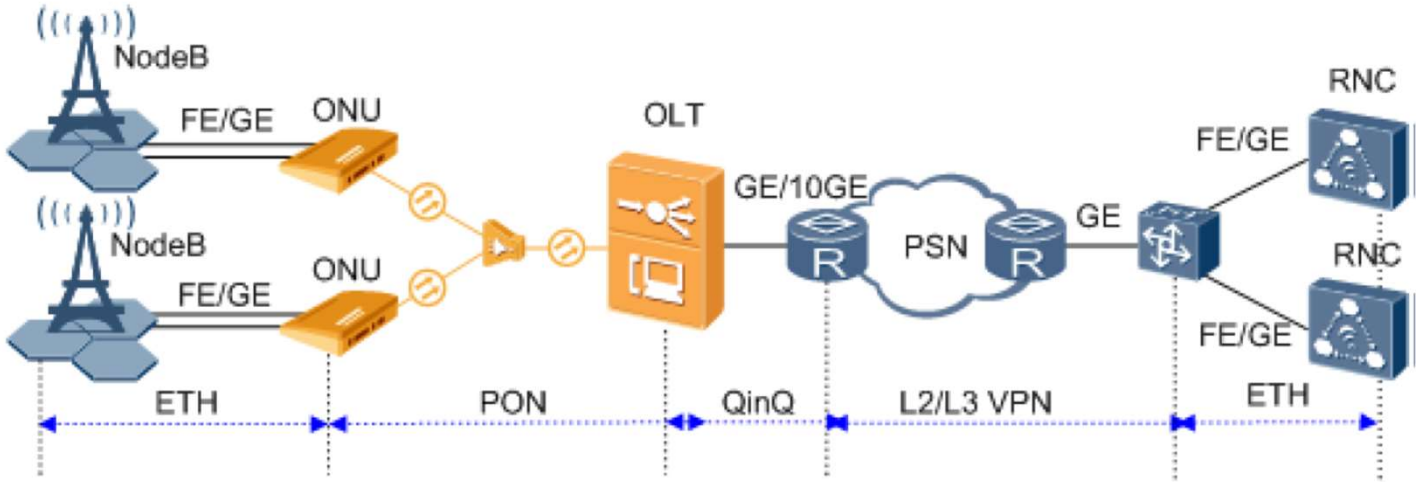


Base station access solution

- .TDM

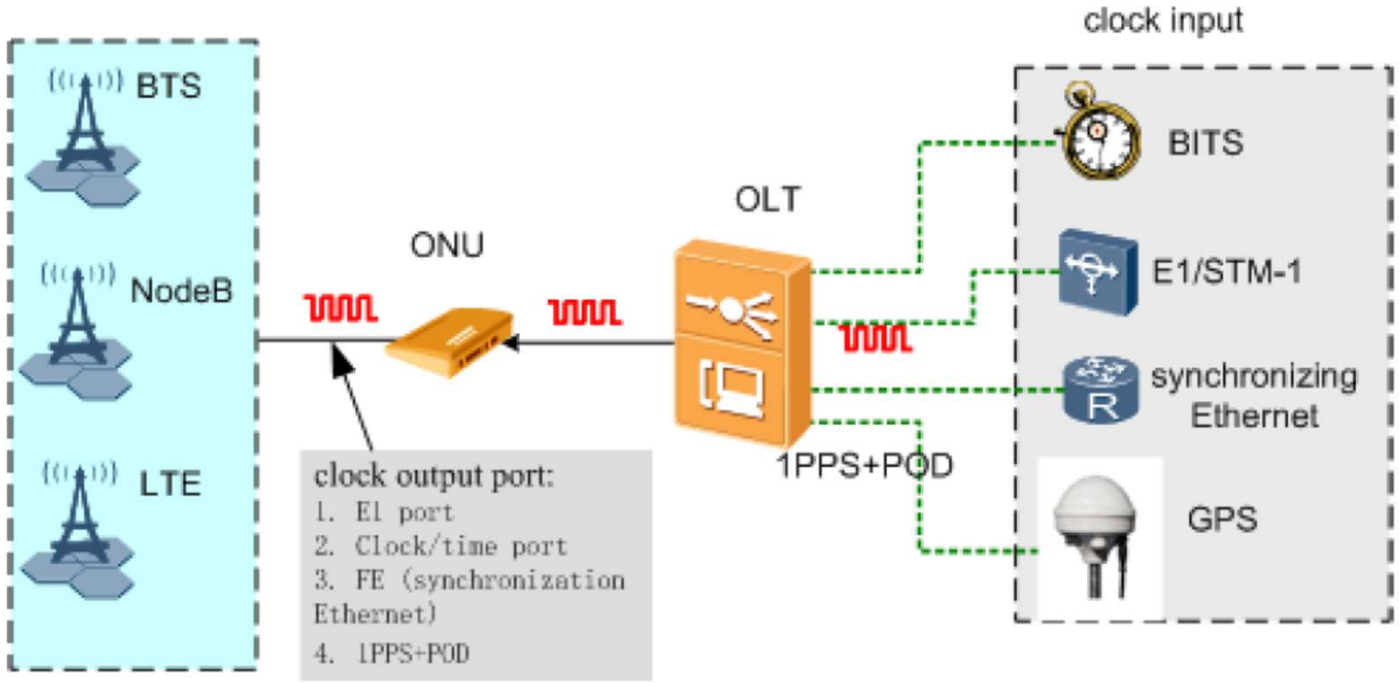


- Ethernet



Base station access solution - Clock

- In wireless technologies, clocks of different base transceiver stations (BTSs) must be the same and must meet precision requirements. Otherwise, abnormalities such as call interruption and one-way audio may occur.
- The OLT can obtain the clock signal as shown in the picture below:



New GPON technologies.

- FSAN divides next generation PON into two stage:
  - NGA1 is based on TDMA PON, and the rate is 10Gbps。
  - Now NGA2 is under discussion, such as 40G PON, WDM PON, OFDM,

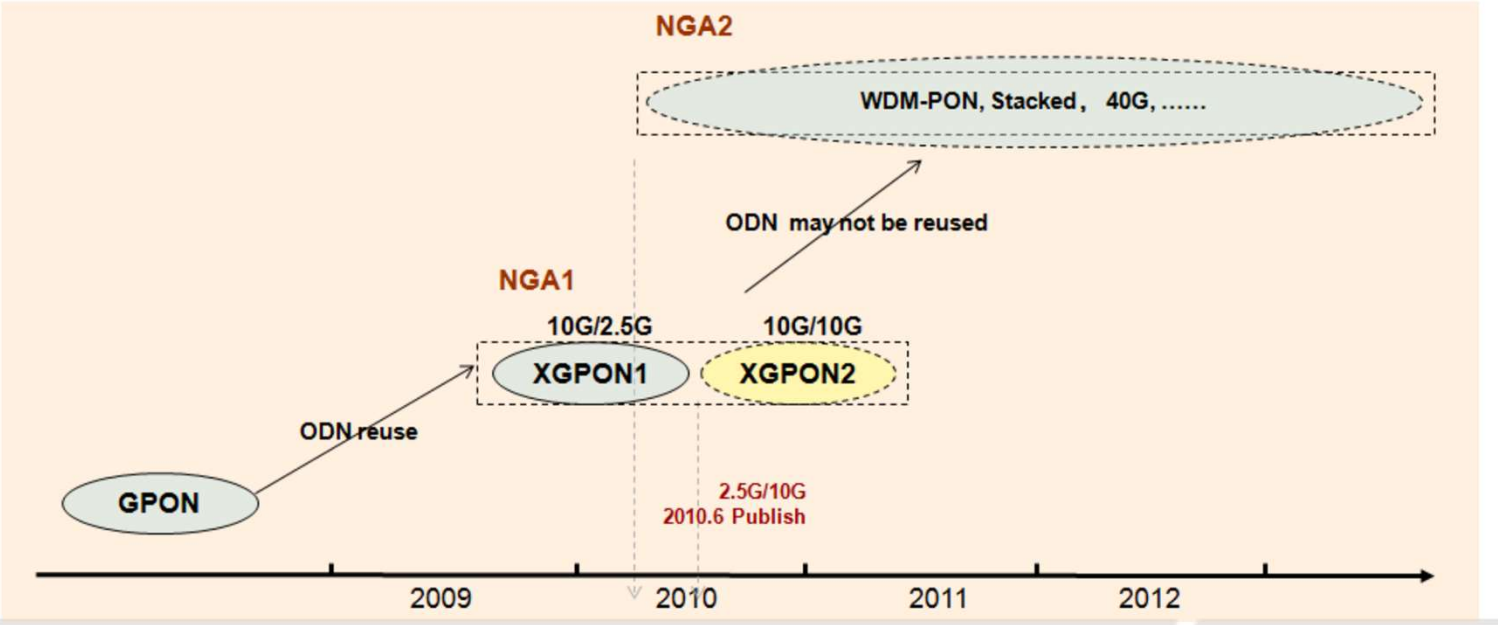
10G PON Specifications:

	10G GPON
bandwidth	10G DS/2.5G US
Wave Length	DS1575-1580nm / US 1260-1280nm
Transmission Technique	DS WDM US WDMA
Optical Power Budget	N1 : 29 N2 : 31 E : 33 or 35
Max Reach	20km（1 : 64）
Splitting Ratio	≥64
US Modulation Method	NRZ
Efficiency	US : 88.4% DS : 78%
Effective Bandwidth	US : 2.2G DS : 7.72G

New GPON technologies.

The Development of 10G GPON（2）

- ITU NGA1 XGPON1: Asymmetric 10G GPON : G.987.1&G.987.2 ; G.987.3&G. 988 published in 2010.6.
- ITU NGA1 XGPON2: Symmetric 10G GPON: XGPON2 may be crossed, and the migration of XGPON1 may direct to NGA2.
- ITU NGA2: start discussion from 2010 Q1.



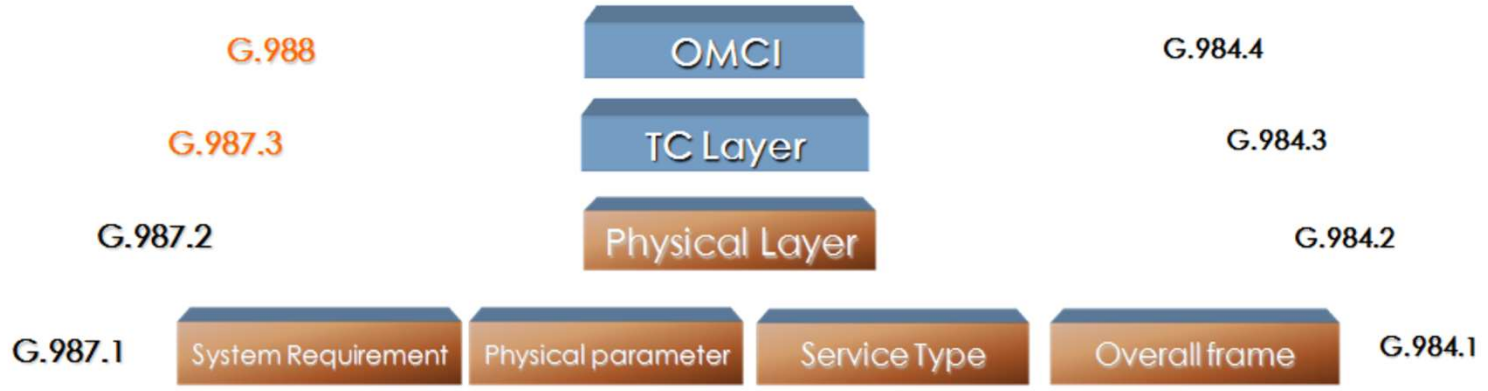
New GPON technologies.

The Development of 10G GPON（3）

XG-PON1 adopts the asymmetric technology, 10G/2.5G 10G GPON

- G.987x is based on **G.984x, complies with G.984.**
- G.987x inherits all the service scenario of GPON.
- G.987x adopts the same management mechanism with GPON, which is easy to upgrade the OSS.

- G.987.1, G.987.2: 2009.10.;
- G.987.3, G.988(G.OMCI): 2010.6..



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