OBA000100 GPON Fundamentals

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References

- ITU-T 984.1

- ITU-T 984.2

- ITU-T 984.3

- ITU-T 984.4

Objectives

- Upon completion of this course, you will be able to:

    - Describe GPON Network Architecture

    - Outline GPON Basic Concepts

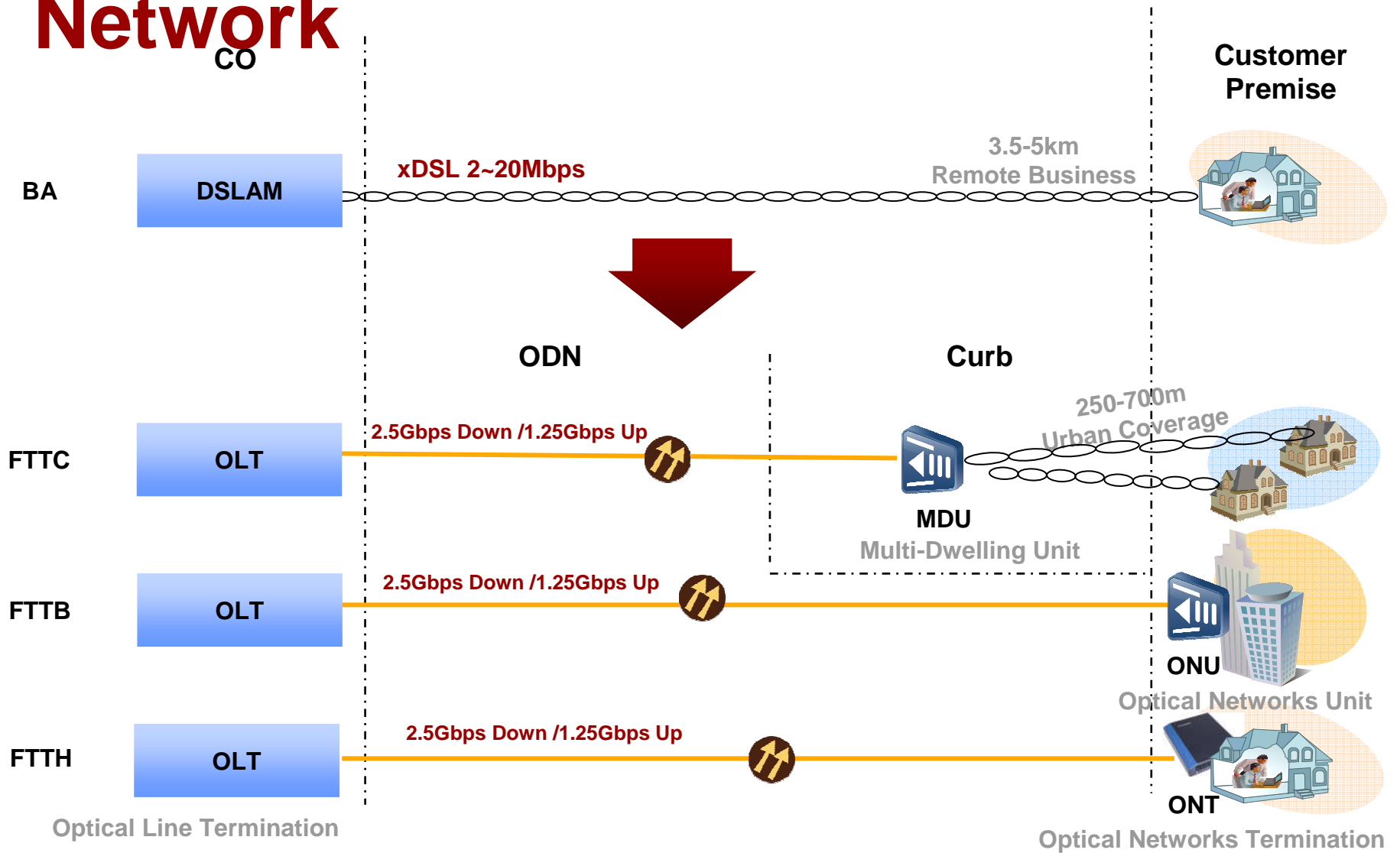   - Outline GPON Applications

Contents

1. Overview of Optical Access Network

2. Basic Concepts of PON

3. GPON Frame Structure

4. GPON Key Technologies

5. GPON Management and Service Provisioning

6. Basic Services over GPON Network

Contents

Architecture of Optical Access Network

CO

Customer Premise

BA — DSLAM

xDSL 2~20Mbps

3.5-5km
Remote Business

ODN | **Curb**

FTTC — OLT

2.5Gbps Down /1.25Gbps Up

250-700m
Urban Coverage

MDU
Multi-Dwelling Unit

FTTB — OLT

2.5Gbps Down /1.25Gbps Up

ONU
Optical Networks Unit

FTTH — OLT

2.5Gbps Down /1.25Gbps Up

ONT
Optical Networks Termination

Optical Line Termination

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What is Optical Access Network?

From the architecture diagram, the optical access network comprises the following scenarios:

1. FTTB scenario

SBU : Single business unit ; providing a comparatively small number of ports such as 10/100/1000BASE-T, RF, and DS1/T1/E1 ports

MTU :Business Multi-tenant unit ; providing a comparatively larger number of ports, including 10/100/1000BASE-T, RF and DS1/T1/E1 ports., VDSL2, and so on.

2. FTTC & FTTCab scenario

MDU : Multi-dwelling unit ;providing a comparatively larger number of ports, including 10/100/1000BASE-T, RF, VDSL2, and so on.

3. FTTH scenario
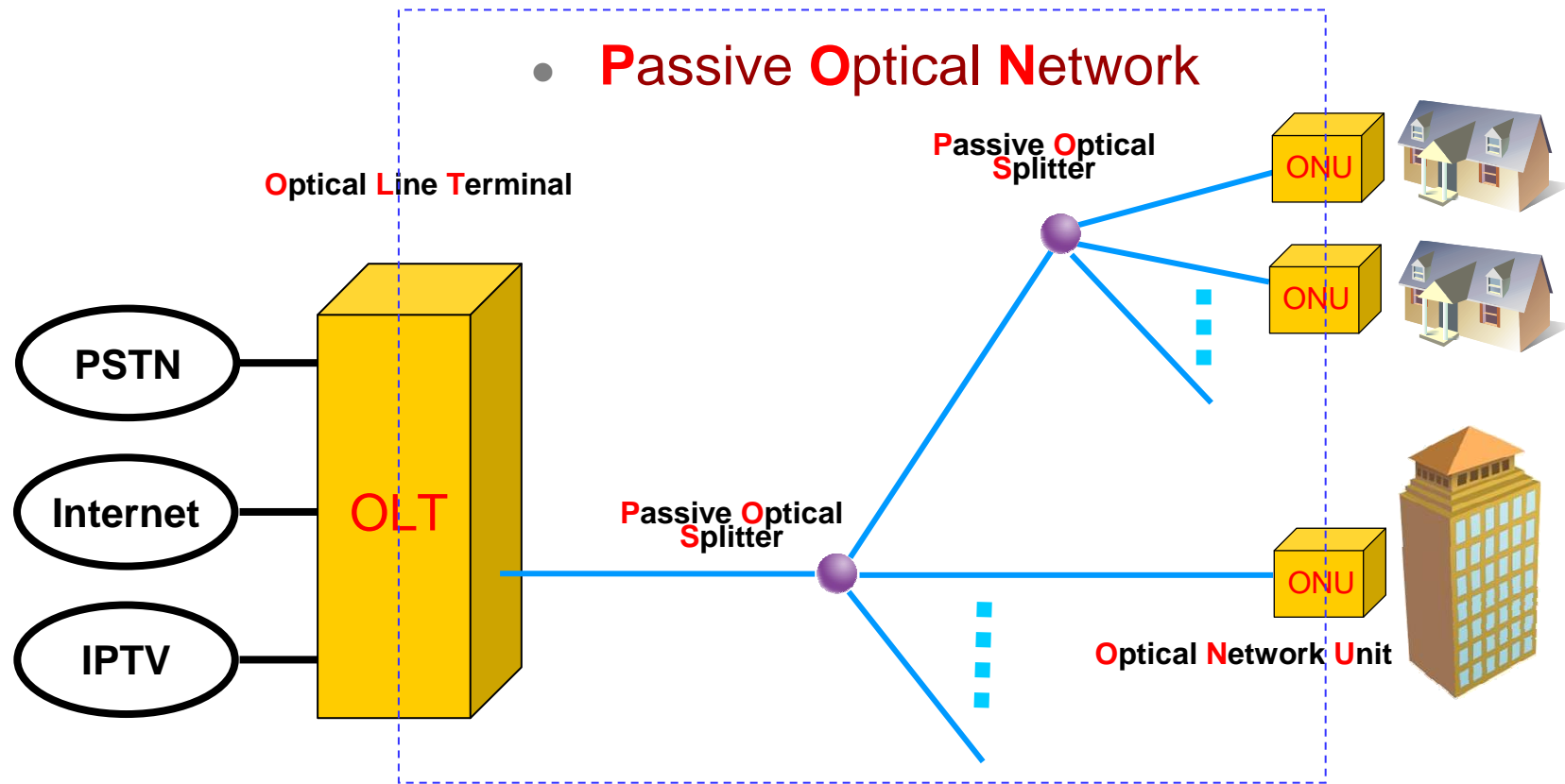
SFU : Single family unit , providing a comparatively small number of ports, including following types: POTS, 10/100/1000BASE-T, and RF.
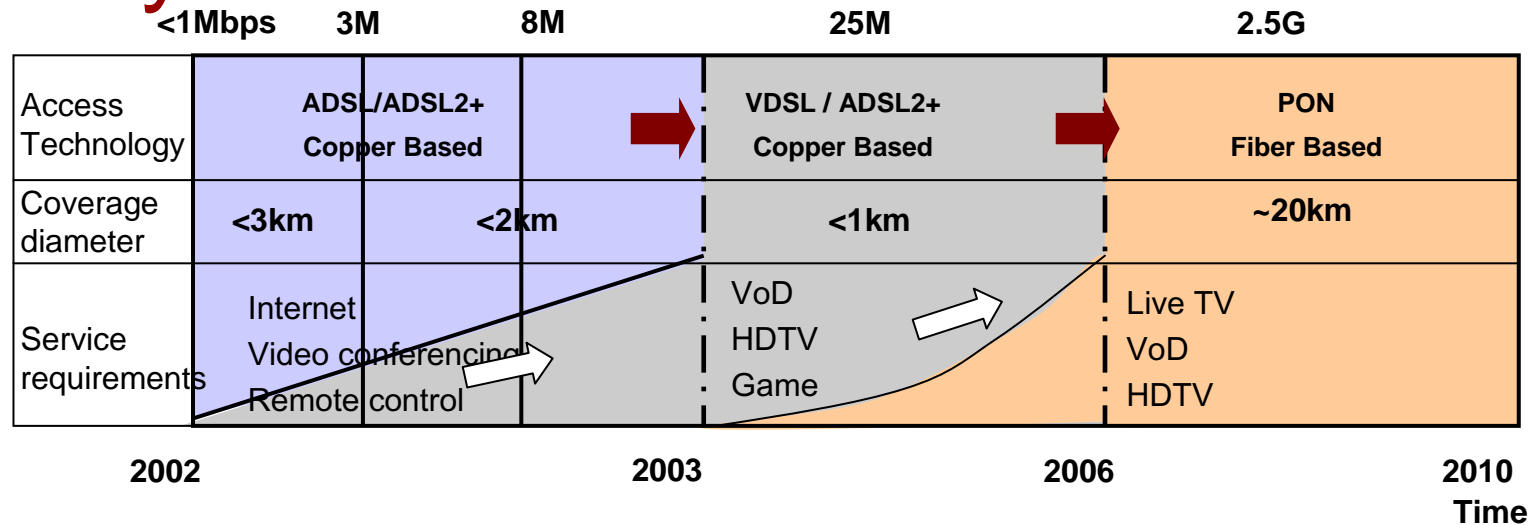
Contents

What is PON?

- **P**assive **O**ptical **N**etwork

Passive **O**ptical **S**plitter

Optical **L**ine **T**erminal

OLT

PSTN

Internet

IPTV

Passive **O**ptical **S**plitter

ONU

ONU

ONU

Optical **N**etwork **U**nit

- PON is a kind of passive optical network featuring one-to-multiple-point architecture;
- PON is short for Passive Optical Network ;
- PON consists of Optical Line Terminal (OLT), Optical Network Unit (ONU) and Optical Distribution Network(ODN).

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Why GPON?

	<1Mbps	3M	8M	25M	2.5G
Access Technology	ADSL/ADSL2+ Copper Based			VDSL / ADSL2+ Copper Based	PON Fiber Based
Coverage diameter	<3km	<2km		<1km	~20km
Service requirements	Internet Video conferencing Remote control			VoD HDTV Game	Live TV VoD HDTV

2002   2003   2006   2010

Time

- **GPON（Gigabit-capable Passive Optical Networks）**

- GPON supports :

  - Triple - play service

  - high-bandwidth

  - long-reach (up to 20 km)

- GPON is the choice of large carriers in the international market.

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GPON Principle----Data Multiplexing

- GPON adopts Wavelength Division Multiplexing (WDM) technology, facilitating bi-direction communication over a single fiber.

1490nm

ODN

OLT

1310nm

ONU/ONT
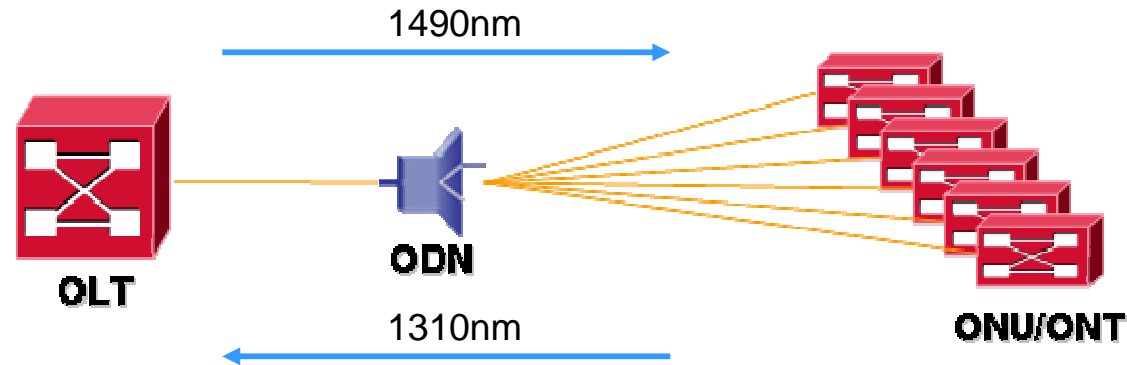
- To separate upstream/downstream signals of multiple users over a single fiber, GPON adopts two multiplexing mechanisms:
  - In downstream direction, data packets are transmitted in a broadcast manner;
  - In upstream direction, data packets are transmitted in a TDMA manner.

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GPON Principle----Downstream Data
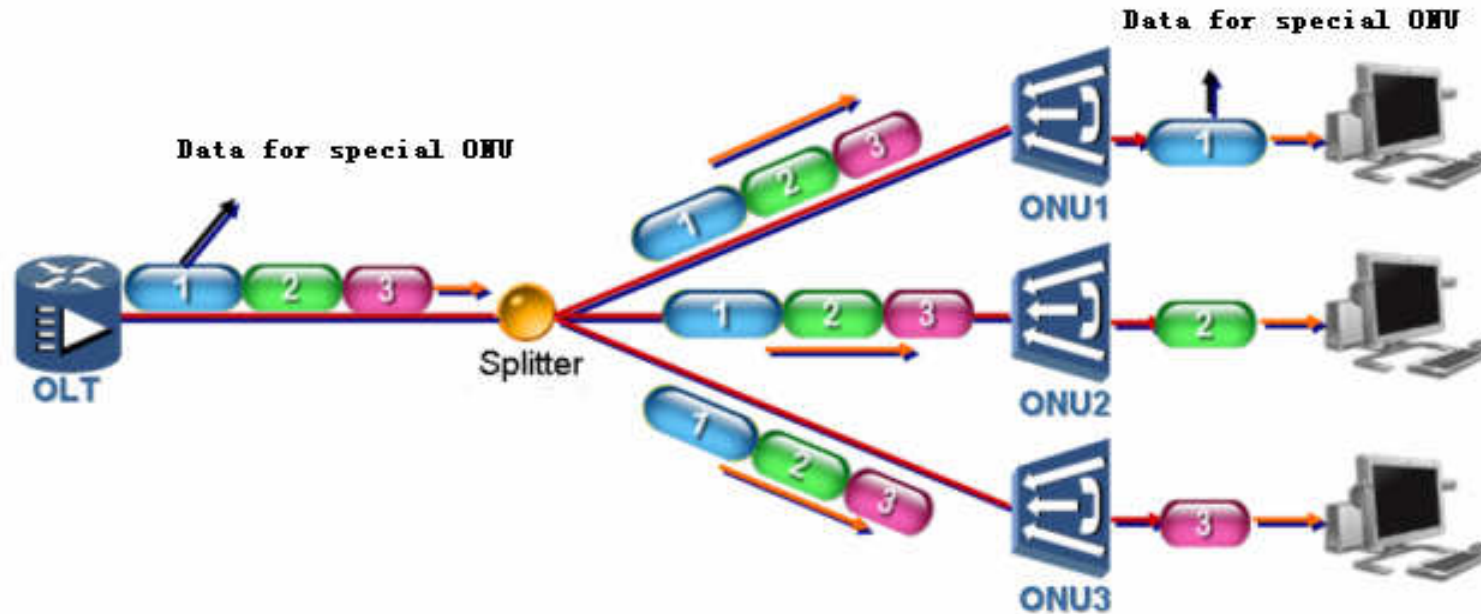
- Broadcast mode

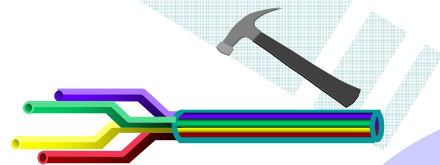# GPON Principle----Upstream Data
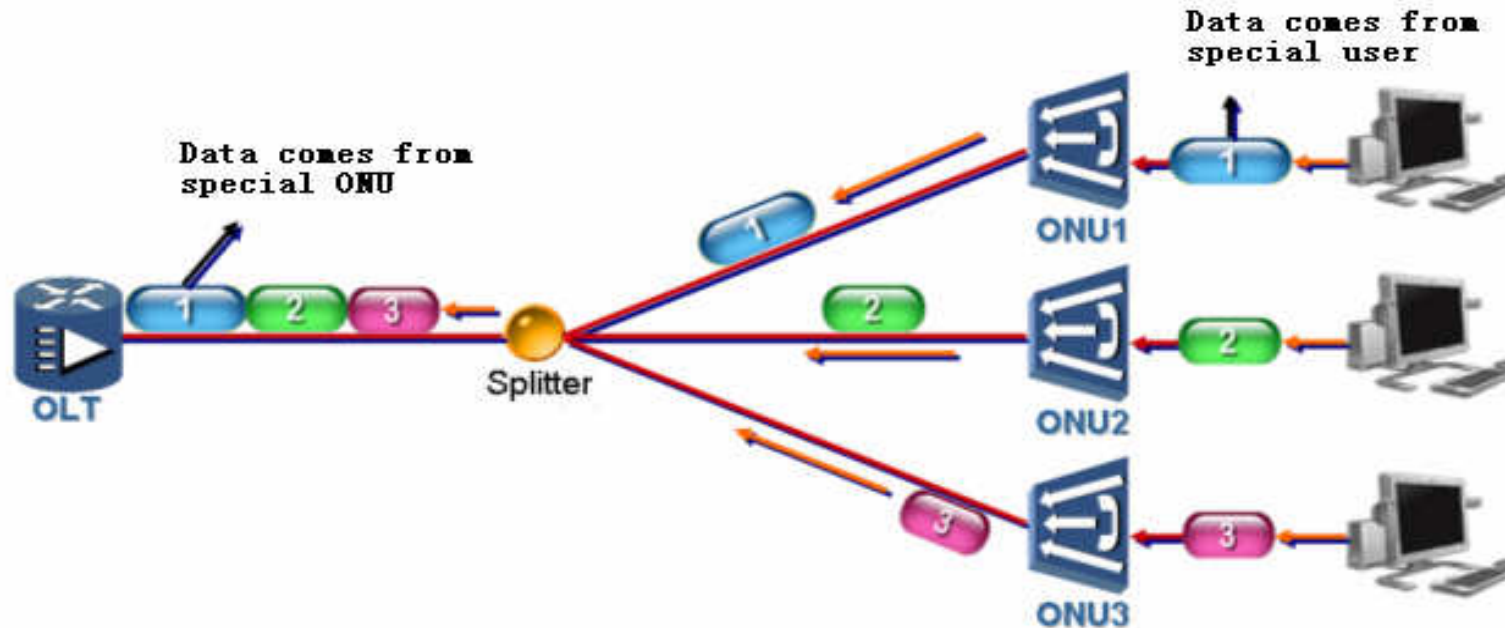
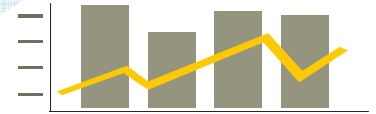- TDMA mode

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

**Simple development process
Powerful compatibility**
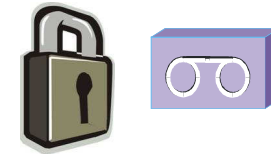
ITU-T G-984.1/2/3/4

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

ITU-T G.984.4

- OMCI message format
- OMCI device management frame
- OMCI working principle

Basic Performance Parameters

Upstream	Downstream
Rate(Gbps) 0.15552	Rate(Gbps) 1.24416
0.62208	1.24416
1.24416	1.24416
0.15552	2.48832
0.62208	2.48832
1.24416	2.48832
2.48832	2.48832

1.24416 Gbit/s up, *2.48832 Gbit/s* down is the mainstream speed combination supported at current time.

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Basic Performance Parameters

Maximum logical reach	60 km
Maximum physical reach	20 km
Maximum differential fibre distance	20 km
Split ratio	1：64/up to1：128

The distance between nearest and farthest ONTs

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GPON Network Model Reference
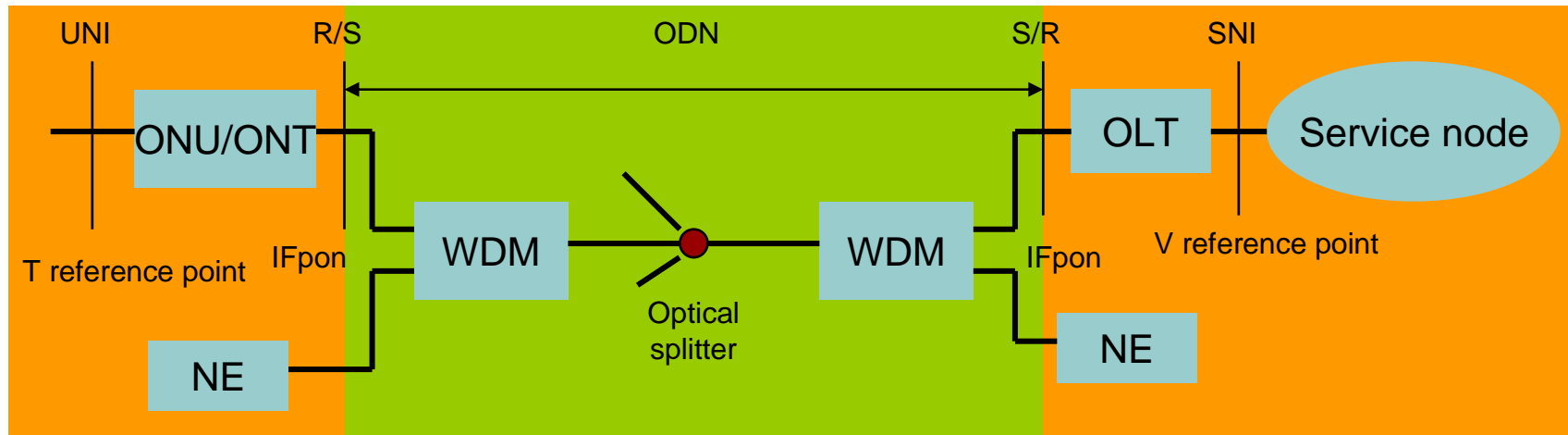
ONU   Optical Network Unit

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 Multiplexing Architecture
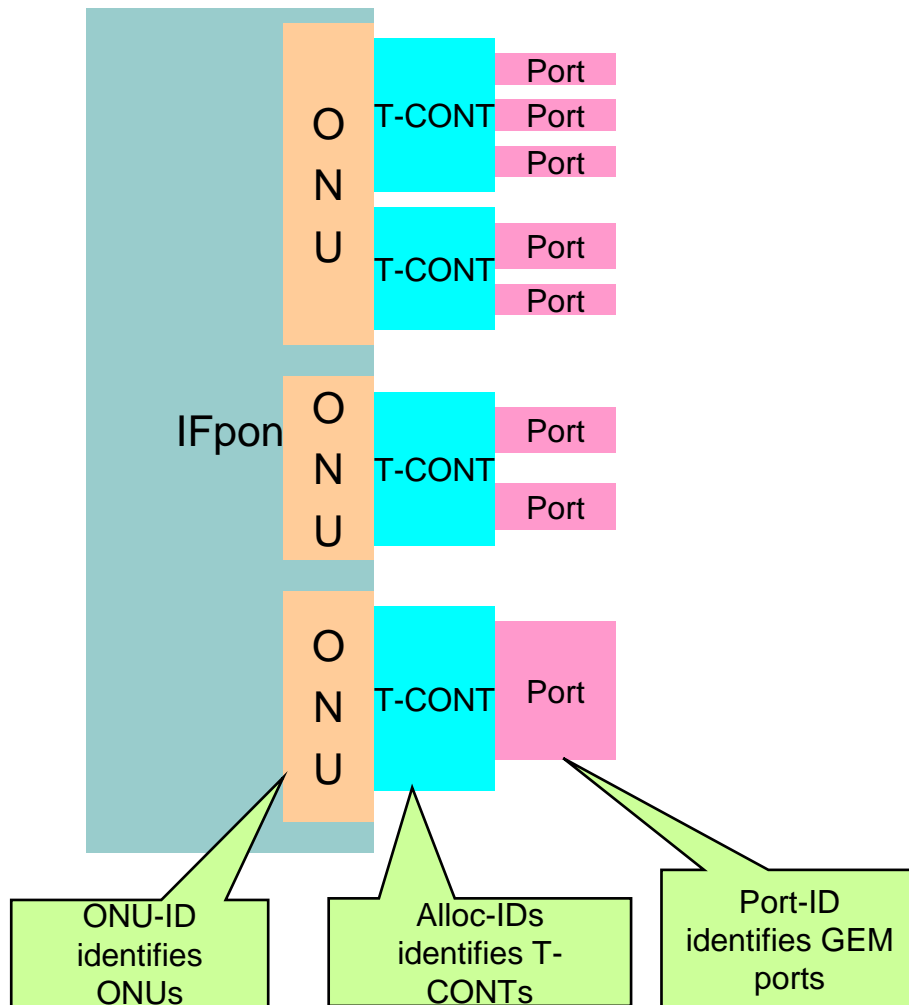
- GEM Port: the minimum unit for carrying services.

- T-CONT: Transmission Containers is a kind of buffer that carries services. It is mainly used to transmit upstream data units. T-CONT is introduced to realize the dynamic bandwidth assignment of the upstream bandwidth, so as to enhance the utilization of the line.

- IF pon: GPON interface.

- Based 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 Multiplexing Architecture
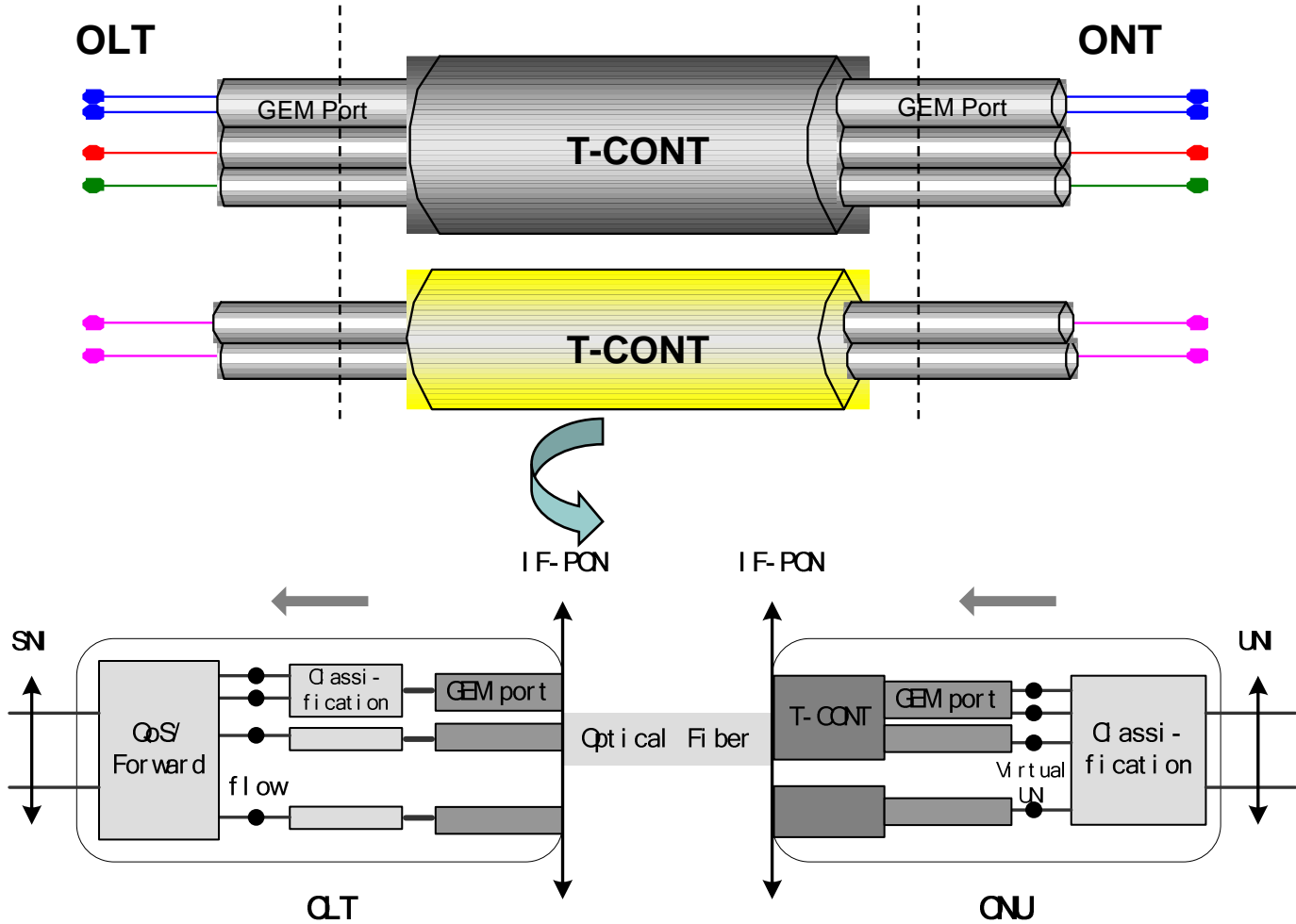
GPON Frame Structure
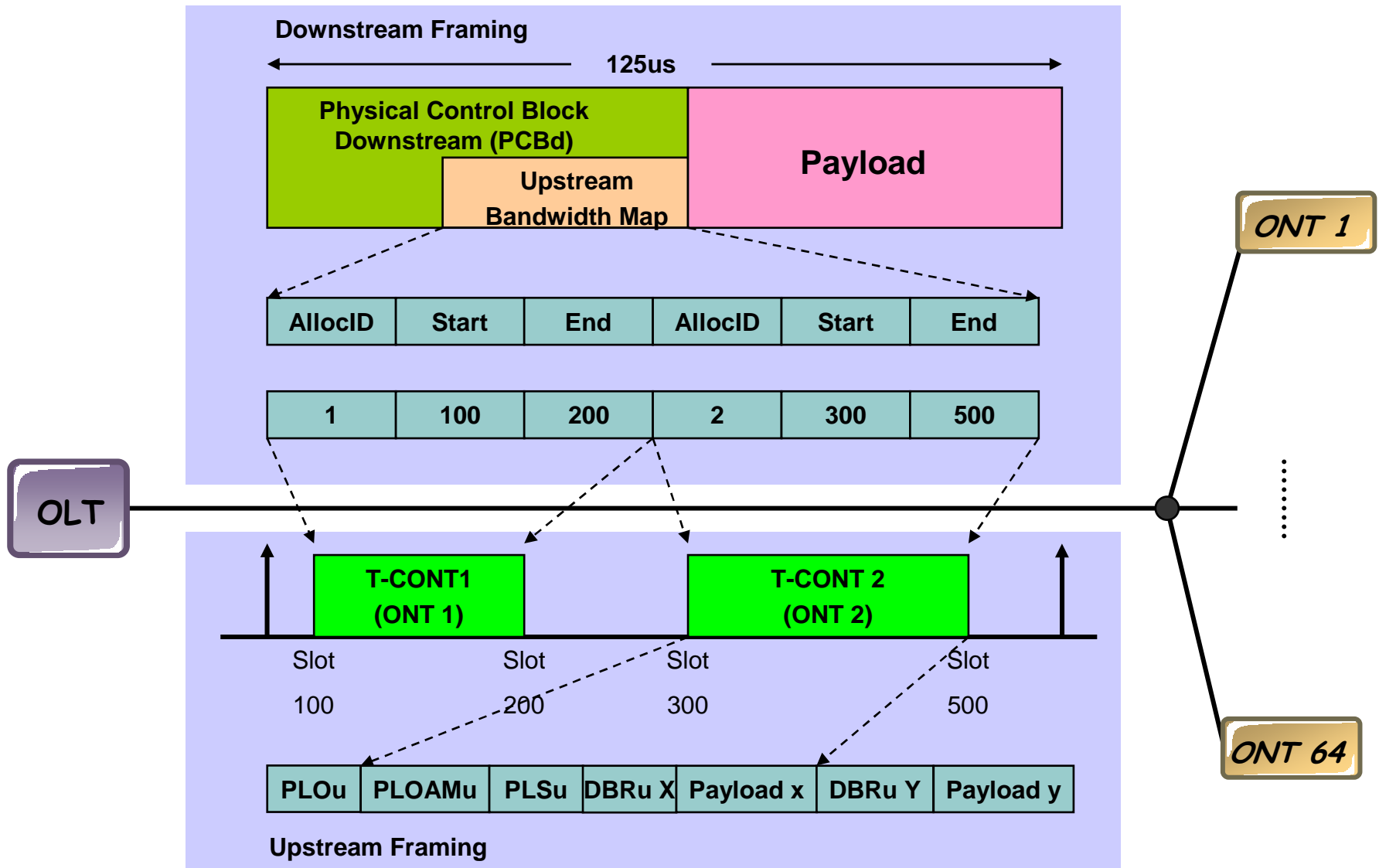
GPON Upstream Frame Structure

Upstream Framing

PLI	Port ID	PTI	HEC

GEM header	Frame fragment	GEM header	Full frame	GEM header	Frame fragment

DBA Report	Pad if needed

PLOu	PLOAMu	PLSu	DBRu x	Payload x	DBRu y	Payload y		PLOu	DBRu z	Payload z

ONT A   ONT B

DBA 1,2,4bytes	CRC 1byte

Preamble A bytes	Delimiter B bytes	BIP 1 bytes	ONU-ID 1 bytes	Ind 1 bytes	ONU ID	Msg ID 1 bytes	Message 10 bytes	CRC 1 bytes

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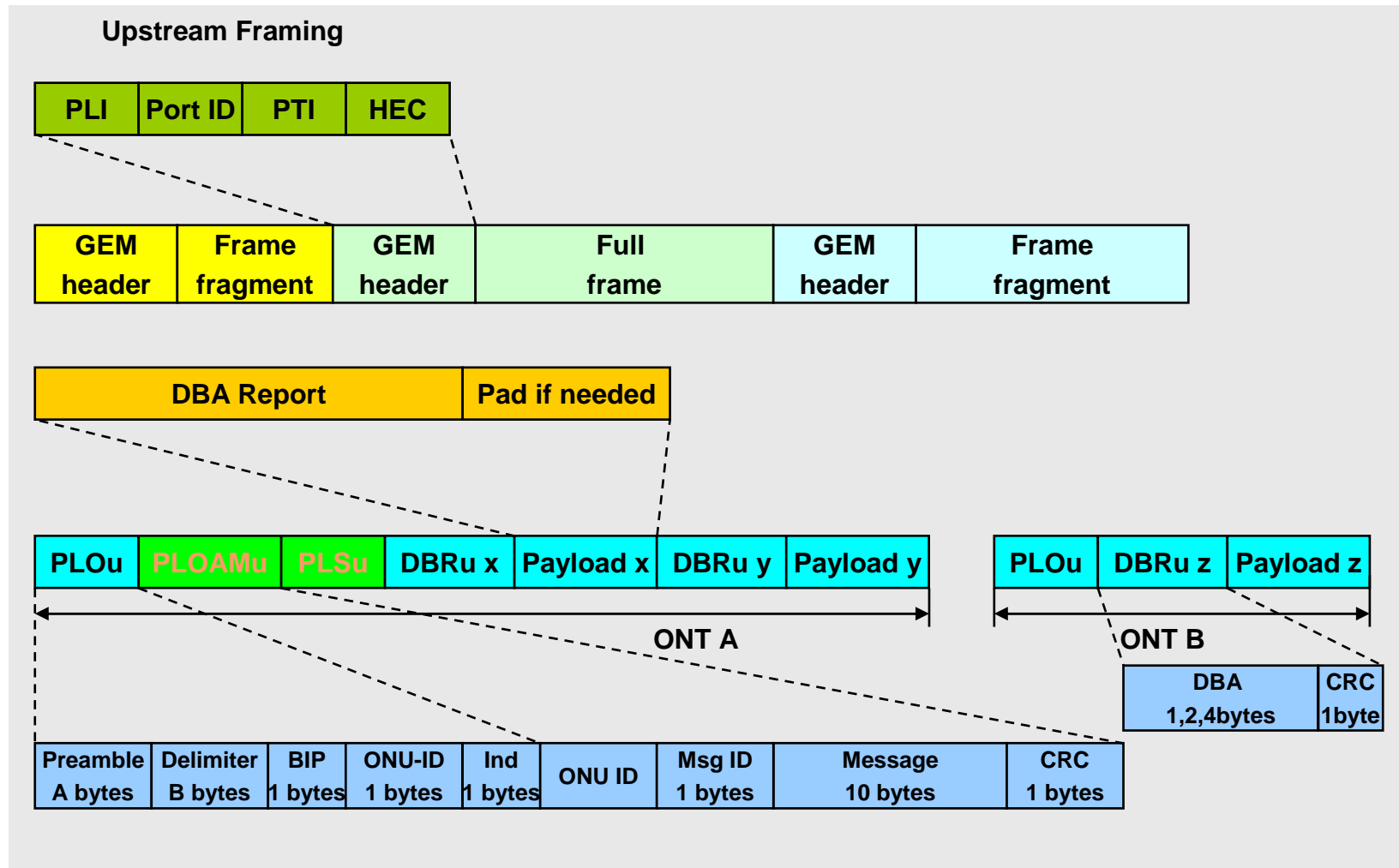
GPON Downstream Frame Structure

Downstream framing

125us

PCBd n	Payload n	PCBd n + 1	Payload n

Psync 4 bytes	Ident 4 bytes	PLOAM 13 bytes	BIP 1 bytes	Plend 4 bytes	Plend 4 bytes	US BW Map N*8 bytes

Coverage of this BIP   Coverage of next BIP

FEC Ind 1 bit	Reserved 1 bit	Super-frame Counter 30 bits

Blen BW Map Length 12 bits	Alen ATM Partition Length 12 bits	CRC 8 bits

Access 1 8 bytes	Access 2 8 bytes	…..	Access n 8 bytes

Alloc ID 12 bits	Flags 12 bits	SStart 2 bytes	SStop 2 bytes	CRC 1 byte

Send PLS 1 bit	Send PLOAMn 1 bit	Use FEC 1 bit	Send DBRu 2 bits	Reserved 7 bits

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Mapping of TDM Service in GPON

TDM Buffer

GEM Frame

Ingress buffer

| PLI |
| Port ID |
| PTI |
| HEC |

TDM

TDM data

Payload
TDM fragment
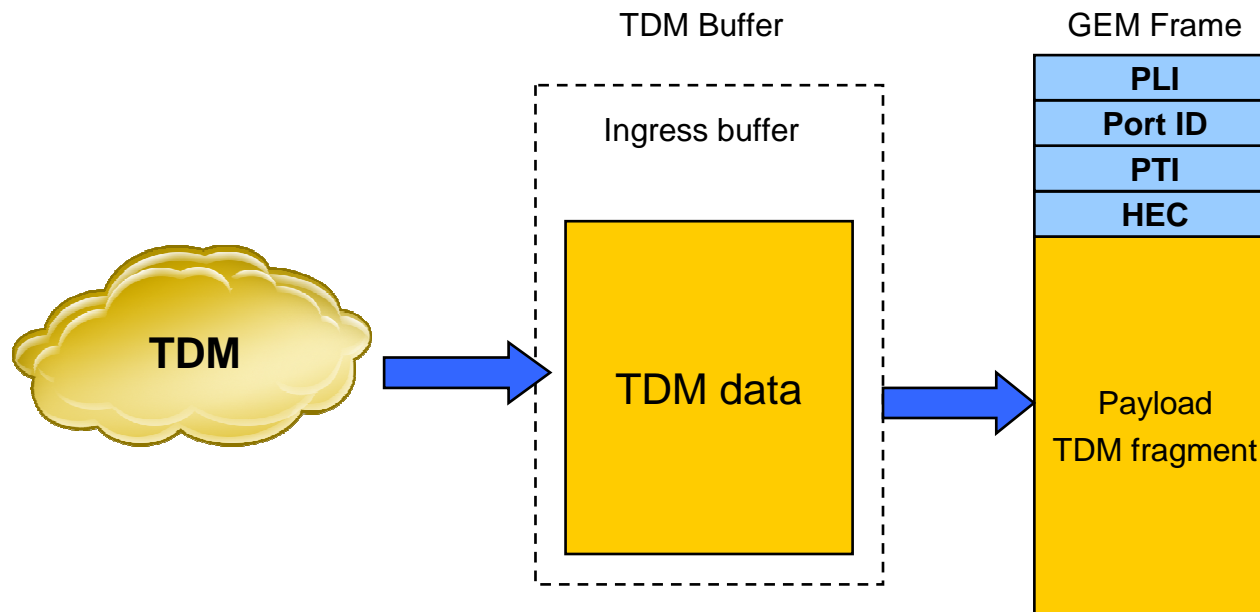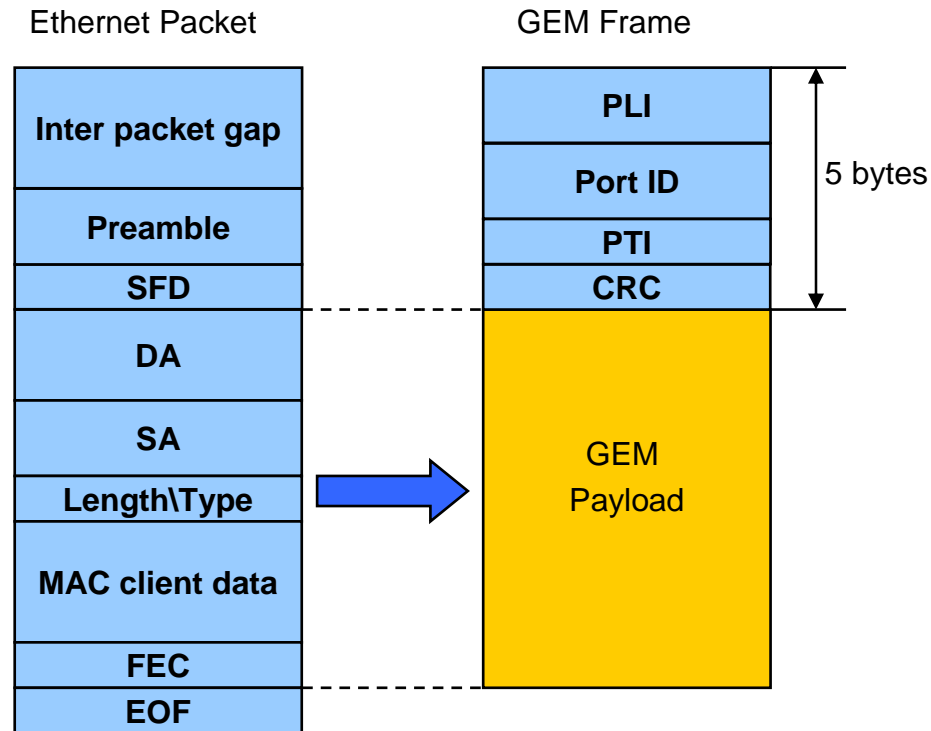
- TDM frames are buffered and queued as they arrive, then TDM data is multiplexed in to fixed-length GEM frames for transmission.

- This scheme does not vary TDM services but transmit TDM services transparently.

- Featuring fixed length, GEM frames benefits the transmission of TDM services .

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Mapping of Ethernet Service in GPON

Ethernet Packet

| Inter packet gap |
| Preamble |
| SFD |
| DA |
| SA |
| Length\Type |
| MAC client data |
| FEC |
| EOF |

GEM Frame

| PLI |
| Port ID |
| PTI |
| CRC |

5 bytes

GEM
Payload

- 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.

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Contents

GPON Key Technologies-

- Ranging

- DBA

- T-CONT

- AES

- Attenuation

Ranging

- OLT obtains the Round Trip Delay (RTD) through ranging process, then specifies suitable Equalization Delay (EqD) so as to avoid occurrence of collision on optical splitters.

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

OLT

ONU1

ONU2

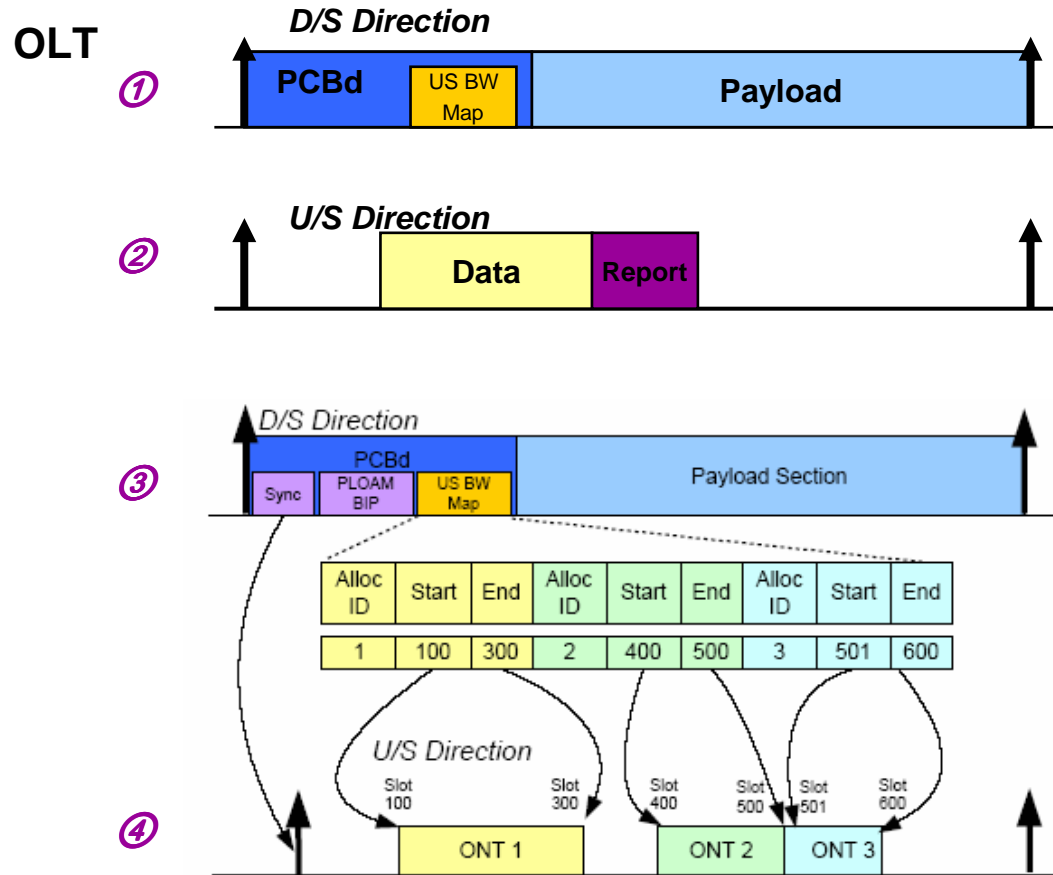**ONU3**
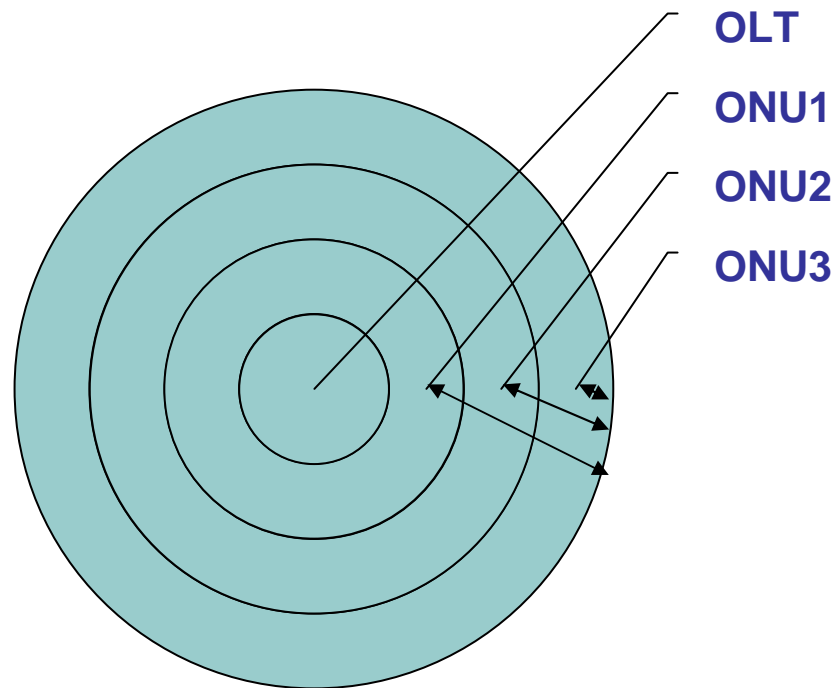
DBA

- What is DBA?

    - DBA, Dynamic Bandwidth Assignment

- Why DBA?

    - It enhances the uplink bandwidth utilization of PON ports.

    - More users can be added on a PON port.

    - Users can enjoy higher-bandwidth services, especially those requiring comparatively greater change in terms of the bandwidth.

- DBA operation modes

    - SR-DBA: status report-DBA

    - NSR-DBA: non status report-DBA

SR-DBA Operation
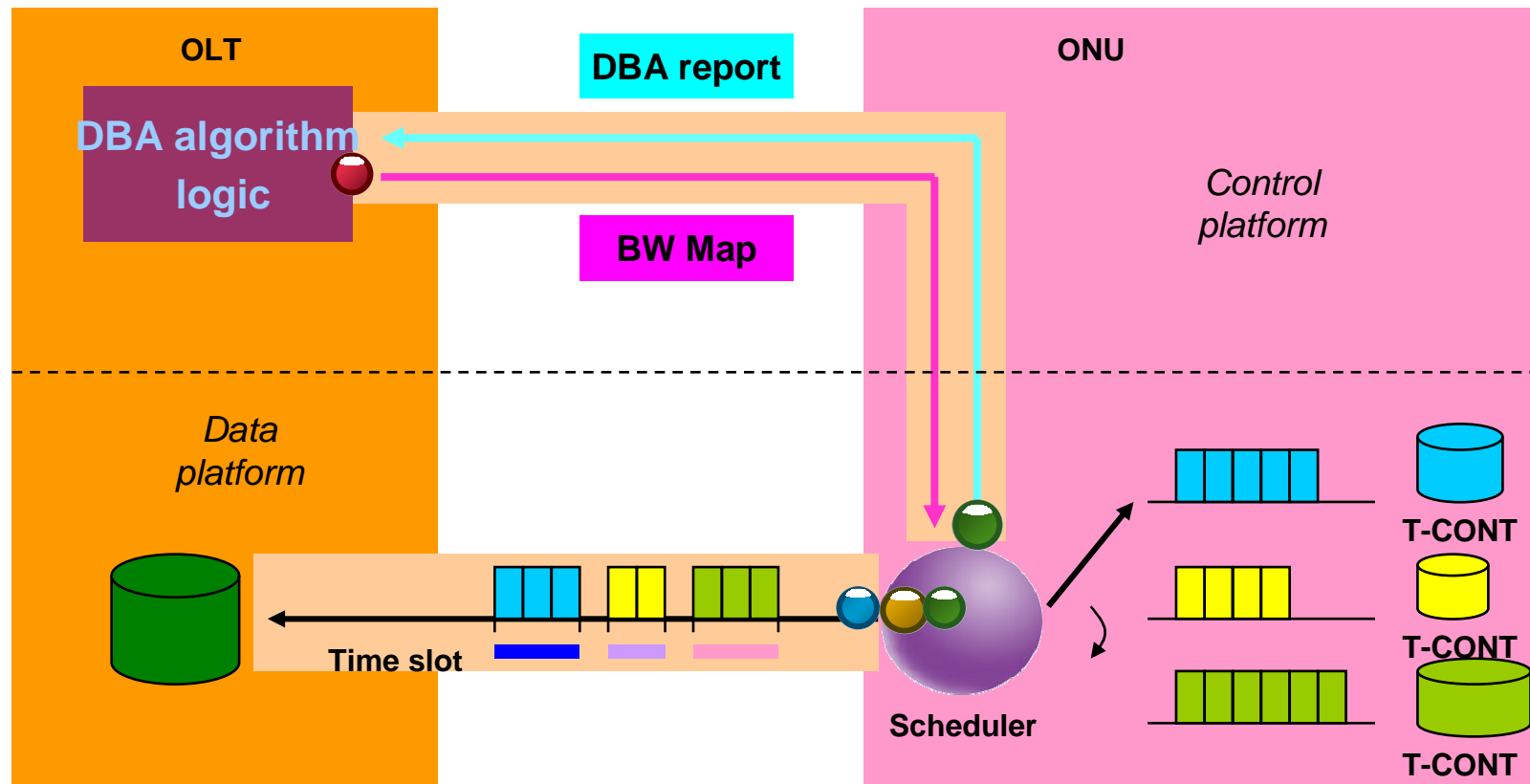
- DBA block in the OLT constantly collects information from DBA reports, and sends the algorithm result in the form of BW Map to ONUs .

- Based on the BW Map, each ONU sends upstream burst data on time slots specified to themselves and utilizes the upstream bandwidth.

SR-DBA Operation

OLT

D/S Direction

① | PCBd | US BW Map | Payload |

U/S Direction

② | | Data | Report | |

③ D/S Direction

PCBd: Sync | PLOAM BIP | US BW Map | Payload Section

Alloc ID	Start	End	Alloc ID	Start	End	Alloc ID	Start	End
1	100	300	2	400	500	3	501	600

U/S Direction

Slot 100 ... Slot 300 | Slot 400 | Slot 500 | Slot 501 | Slot 600

④ | ONT 1 | | ONT 2 | ONT 3 |

ONT

- Based on the algorithm result of last time, OLT delivers BW Maps in the header of downstream frames.

- Based on the bandwidth allocation information, ONU sends the status report of data currently waiting in T-CONTs in the specified time slots.

- OLT receives the status report from the ONU, updates BW Map through DBA algorithm and then delivers the new BW Map in the next frame.

- ONU receives the BW Map from the OLT and sends data in the specified time slots.

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NSR-DBA Operation

- **NSR-DBA**

  - NSR is an algorithm scheme that realizes DBA. It helps to predict the bandwidth allocated to each ONU based on the traffic from ONUs.

- **Procedure:**

  - Step1: Monitor the number of data packets received by OLT within the specified interval.

  - Step2: Use the result of real time monitoring in step 1 to calculate the utilization rate.

  - Step3: Recognize the congestion status by comparing the utilization rate with the specified limits.

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DBA Working Principle
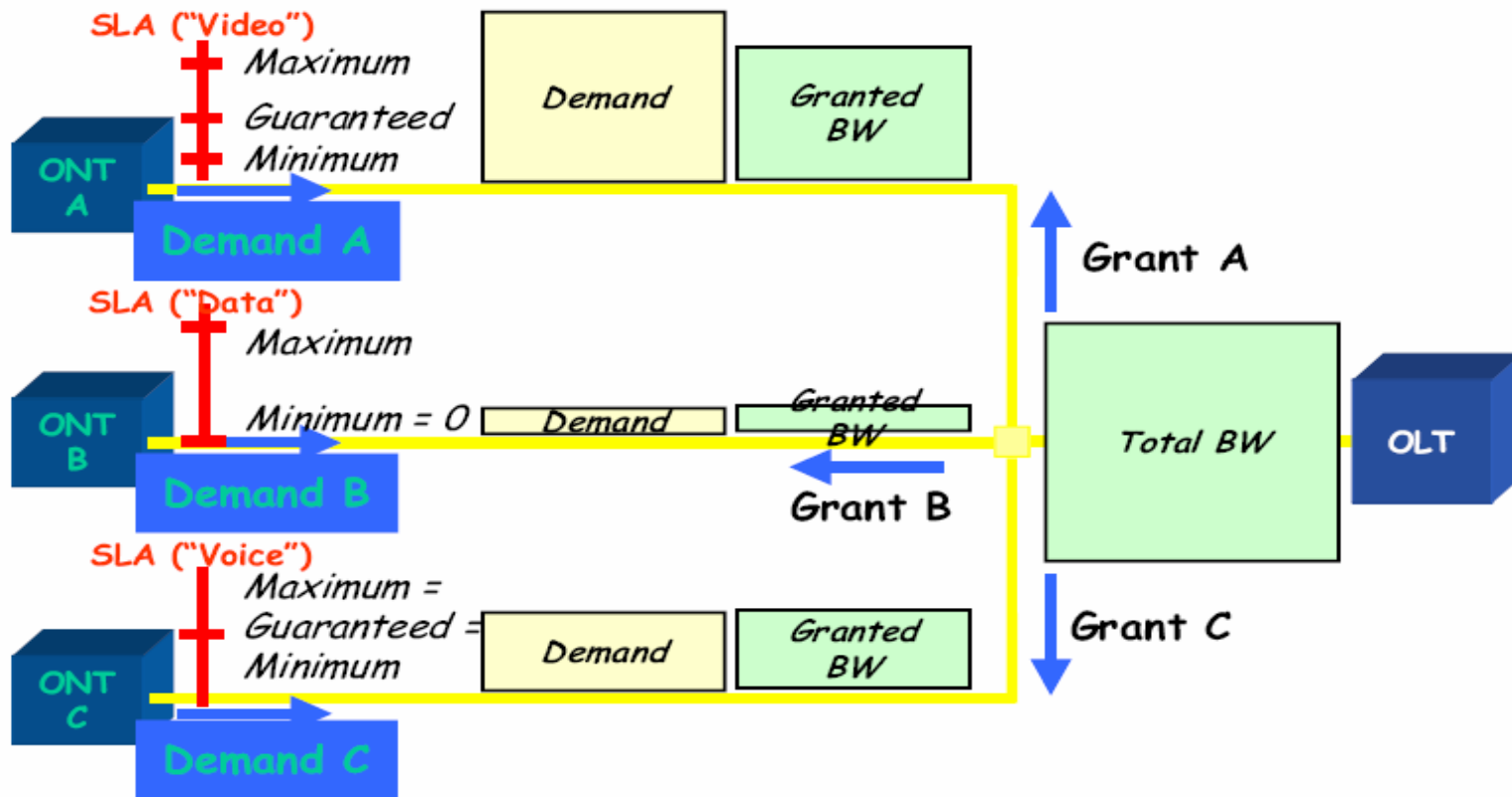
- Based on service priorities, the system sets SLA for each ONU, restricting service bandwidth.
- The maximum bandwidth and the minimum bandwidth pose limits to the bandwidth of each ONU, ensuring various bandwidth for services of different priorities. In general, voice service enjoys the highest, then 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 receives 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 BW type falls into FB, AB, NAB, and BE.

- Five T-CONT types: Type1, Type2, Type3, Type4, and Type5.
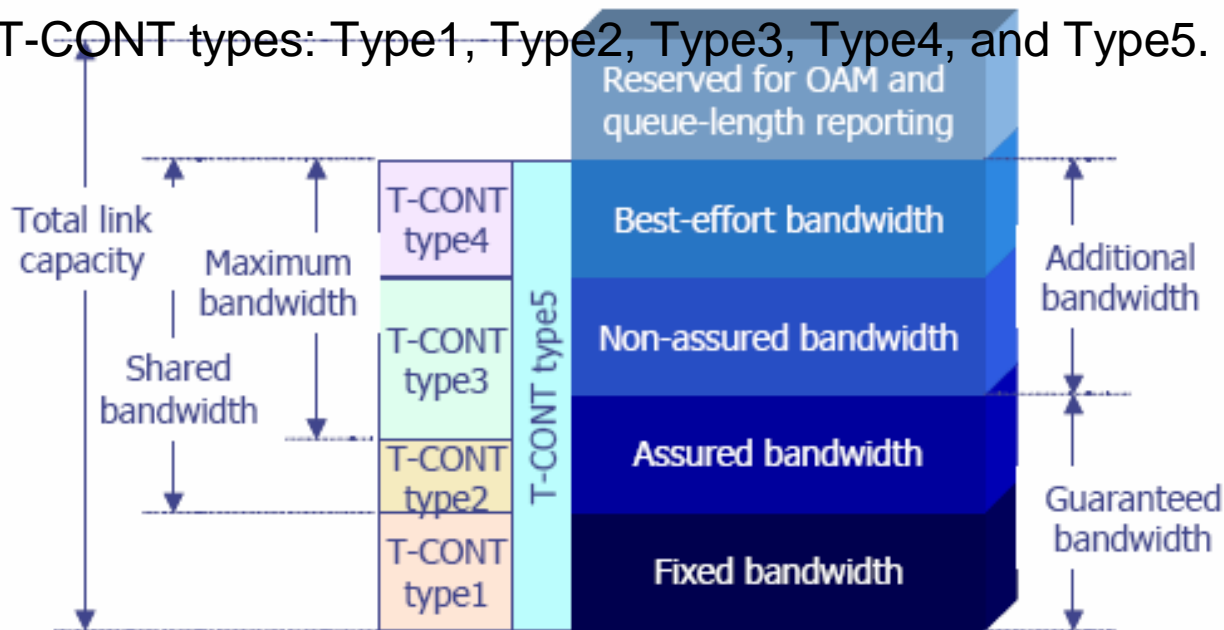
T-CONT Type and Bandwidth Type

| 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

- Type1 T-CONT is of the fixed bandwidth type and mainly used for services sensitive to delay and services of higher priorities, such as voice services.

- Type2 and type3 T-CONT is of 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
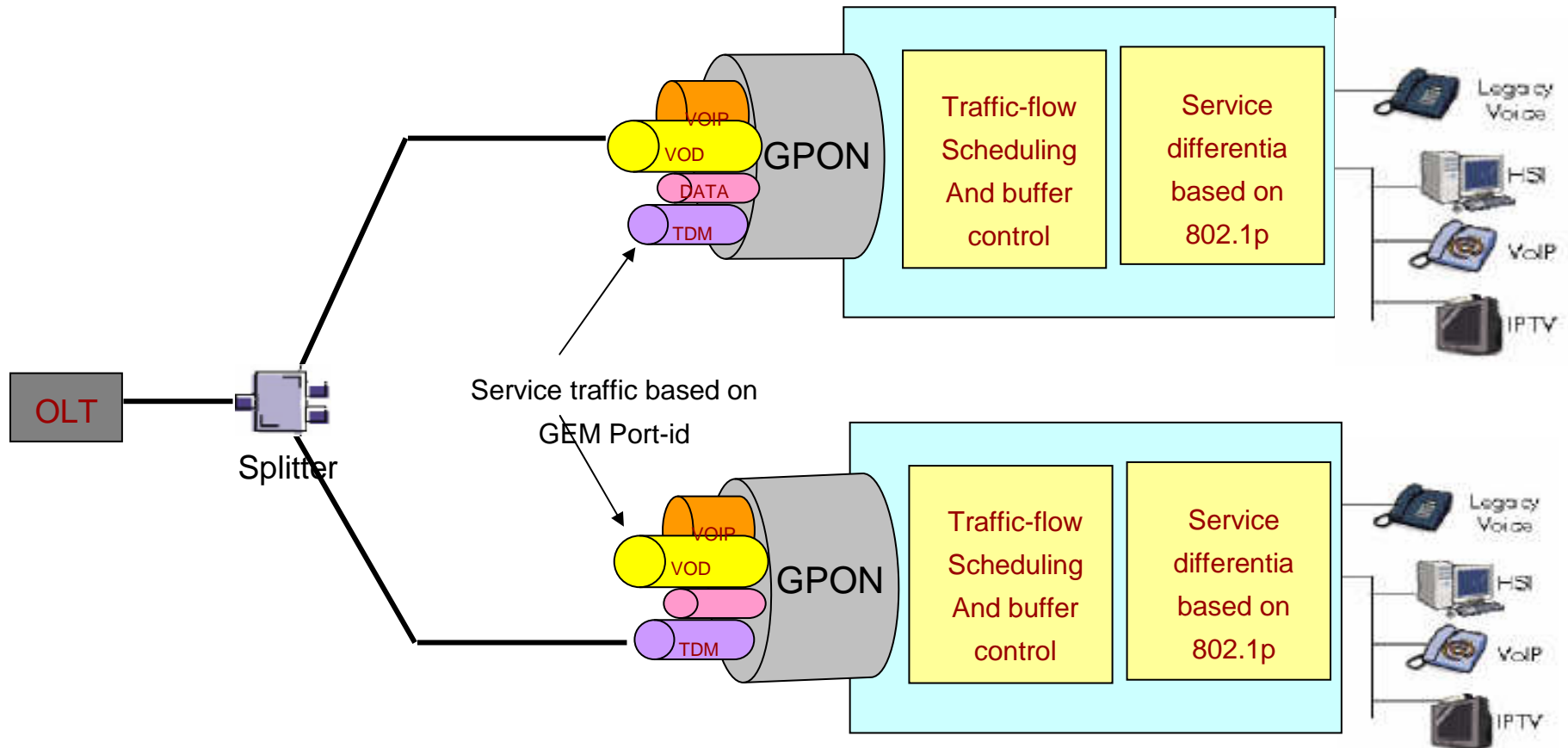
- Traffic classification of services based on LAN/802.1p.
- Service scheduling based on the combination of strict priority (SP) and Weighted Round Robin (WRR) algorithms.
- Service transmission based on service mapping with different T-CONTs, enhancing line utilization and reliability.

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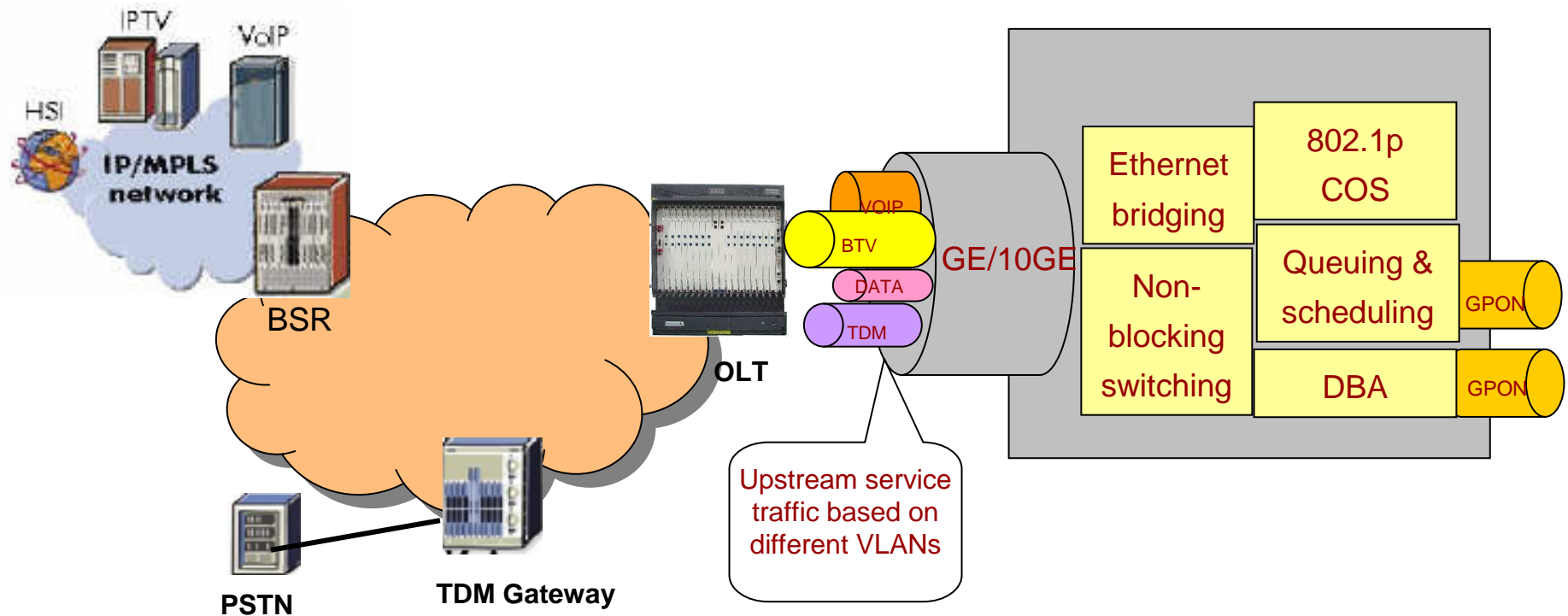
- Traffic classification based on VLAN/802.1p.
- Service scheduling based on combination of strict priority (SP) and Weighted Round Robin (WRR) algorithms.
- DBA algorithm, enhancing uplink bandwidth utilization.
- Access control list (ACL)-based access control on layers above layer-2.

AES Encryption in GPON
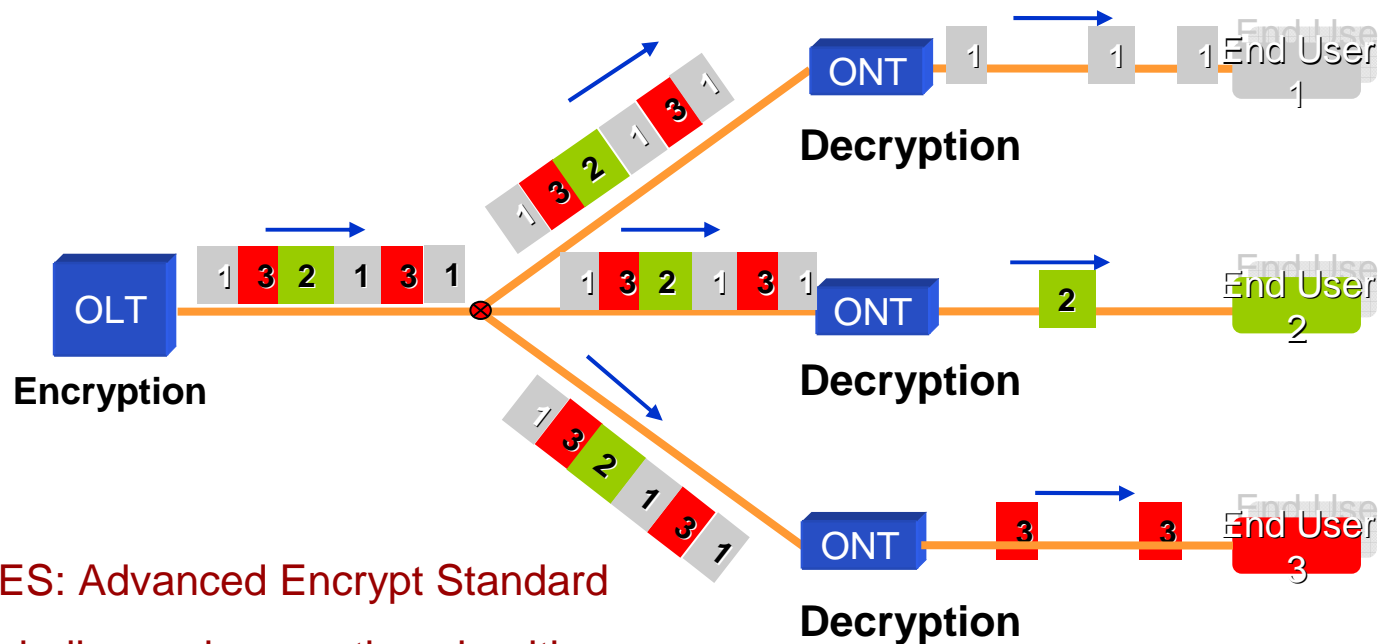
AES: Advanced Encrypt Standard

A globally-used encryption algorithm

- 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.

Fibre Attenuation and Power Budget

- ➢ Fibre attenuation relates to the fibre length

- ➢ The attenuation of fibre splicing point is

- ➢ generally less than 0.2dB

- ➢ Other factors may cause attenuation, such

- ➢ as fibre bending

About 0.35 dB per km for 1310,1490nm

Huawei's OLT and ONU 28 dB (Class B+)

Table G.984.2 – Classes for optical path loss

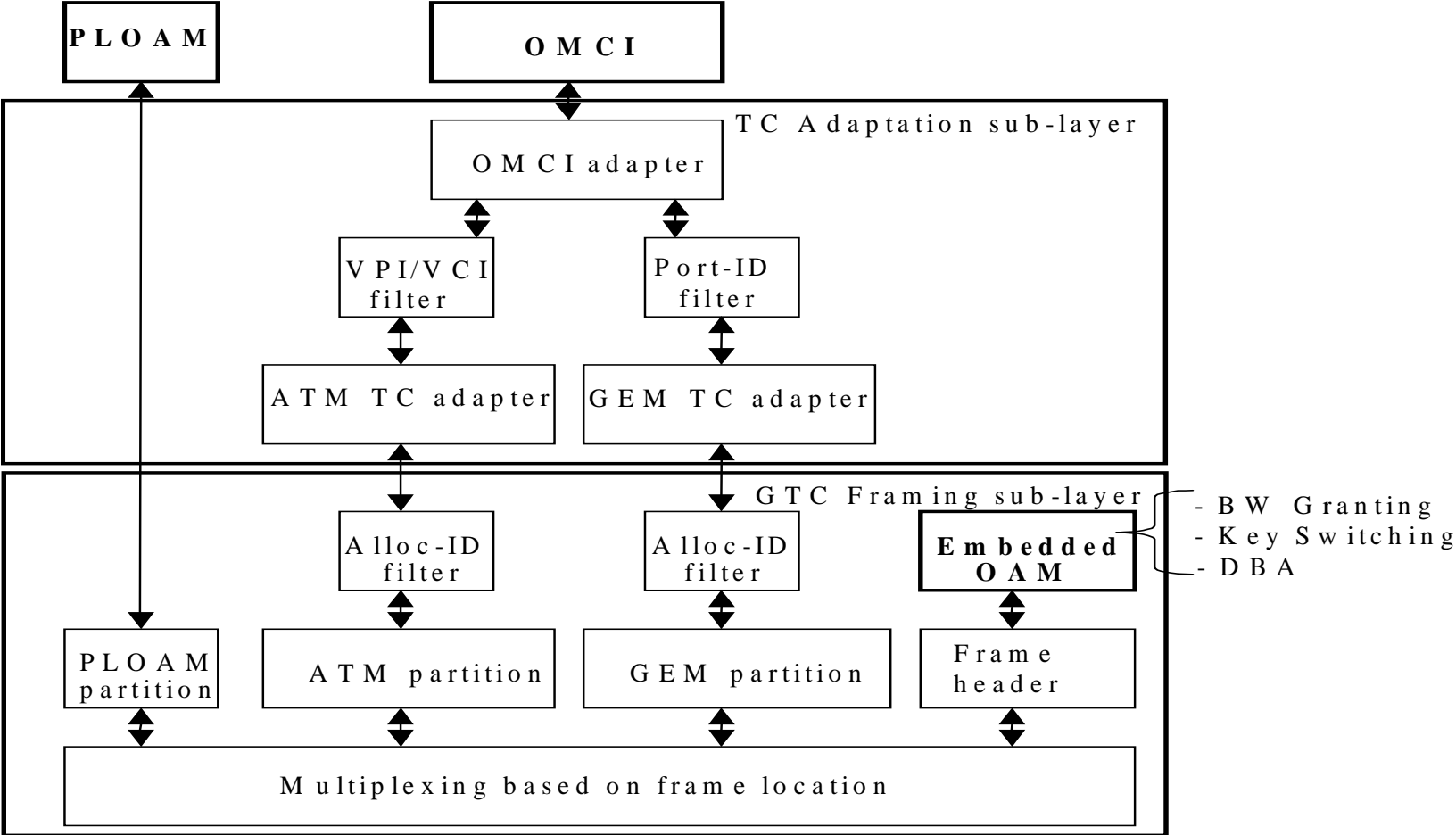|	Class A	Class B	Class B +	Class C
Minimum loss	5 dB	10 dB	13 dB	15 dB
Maximum loss	20 dB	25 dB	28 dB	30 dB
NOTE – The requirements of a particular class may be more stringent for one system type than for another, e.g. the class C attenuation range is inherently more stringent for TCM systems due to the use of a 1:2 splitter/combiner at each side of the ODN, each having a loss of about 3 dB.				

Parameters of GPON (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
ONU:		ONU
Mean launched power MIN	**dBm**	0.5
Mean launched power MAX	**dBm**	+5
Minimum sensitivity	**dBm**	-27
Minimum overload	**dBm**	-8

Contents

Control and Management Plane

PLOAM

OMCI

TC Adaptation sub-layer

OMCI adapter

VPI/VCI filter

Port-ID filter

ATM TC adapter

GEM TC adapter

GTC Framing sub-layer

- BW Granting
- Key Switching
- DBA

Alloc-ID filter

Alloc-ID filter

Embedded OAM

PLOAM partition

ATM partition

GEM partition

Frame header

Multiplexing based on frame location

GPON Management

- OAM message at the physical layer falls into three types: **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.
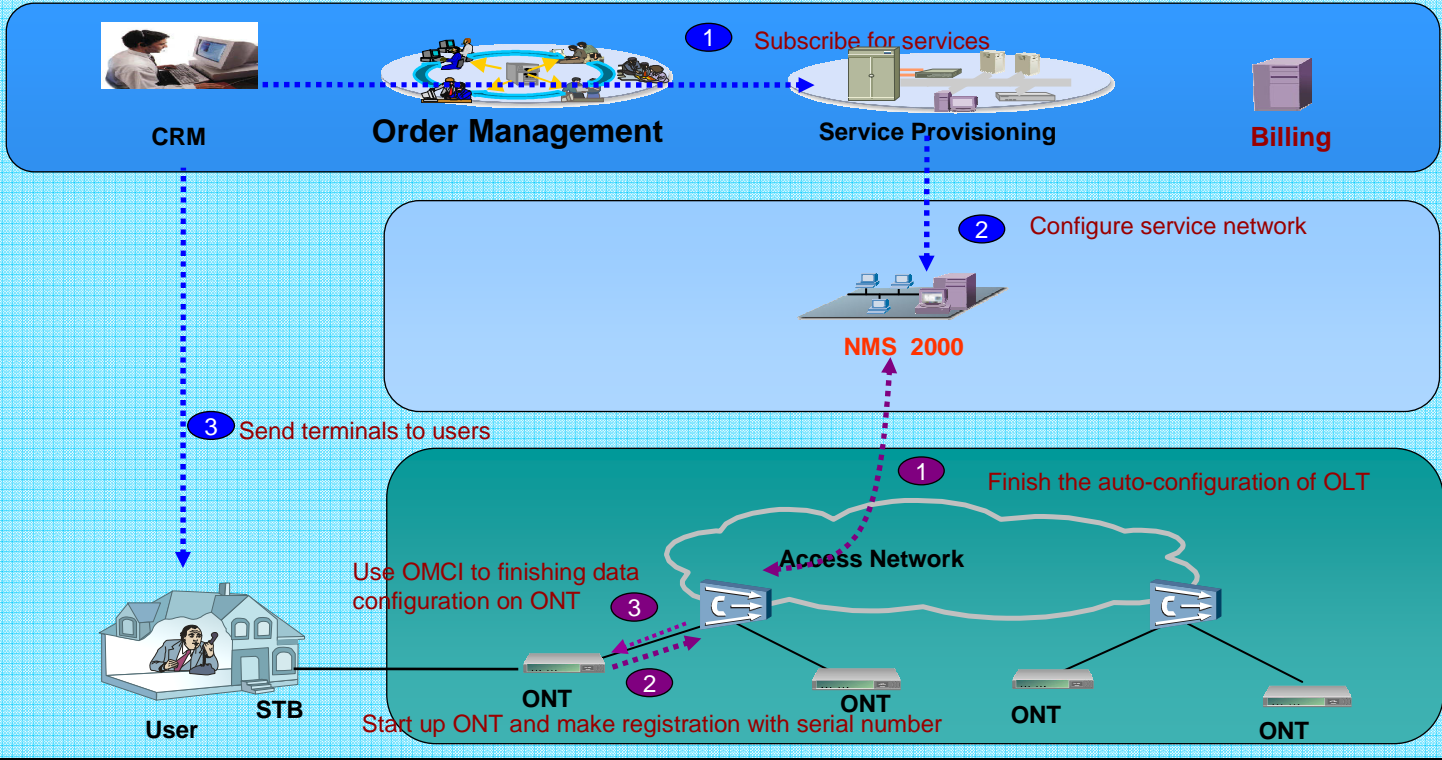
GPON Service Provisioning

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

1 Subscribe for services

CRM   **Order Management**   **Service Provisioning**   **Billing**

2 Configure service network

NMS 2000

3 Send terminals to users

1 Finish the auto-configuration of OLT

Access Network

Use OMCI to finishing data configuration on ONT

3

User   **STB**   **ONT**   **ONT**   **ONT**   **ONT**

2 Start up ONT and make registration with serial number
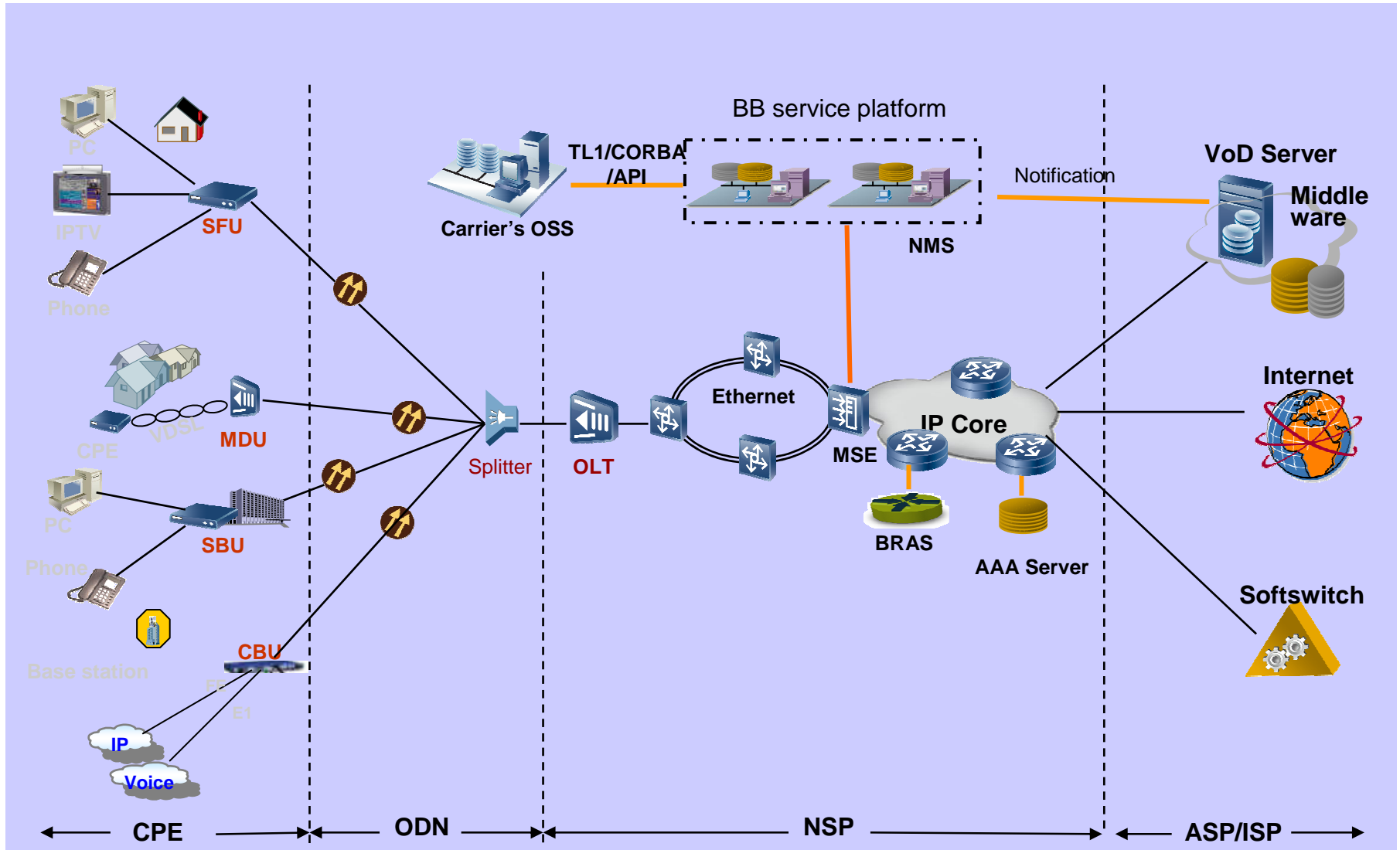
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1. Basic Concepts of PON

2. Overview of Optical Access Network

3. Analysis of GPON Standards

4. GPON Key Technologies

5. GPON Management and Service Provisioning

6. **Basic Services over GPON Network**

Triple Play Solution in GPON

Questions

- GPON network architecture?

- Describe DBA operation mode?

- Describe GPON service provisioning?

Summary

- In this presentation, we introduced GPON basic concept ,architecture ,and principle.

- We also discussed about GPON service provisioning and application.

Thank you

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