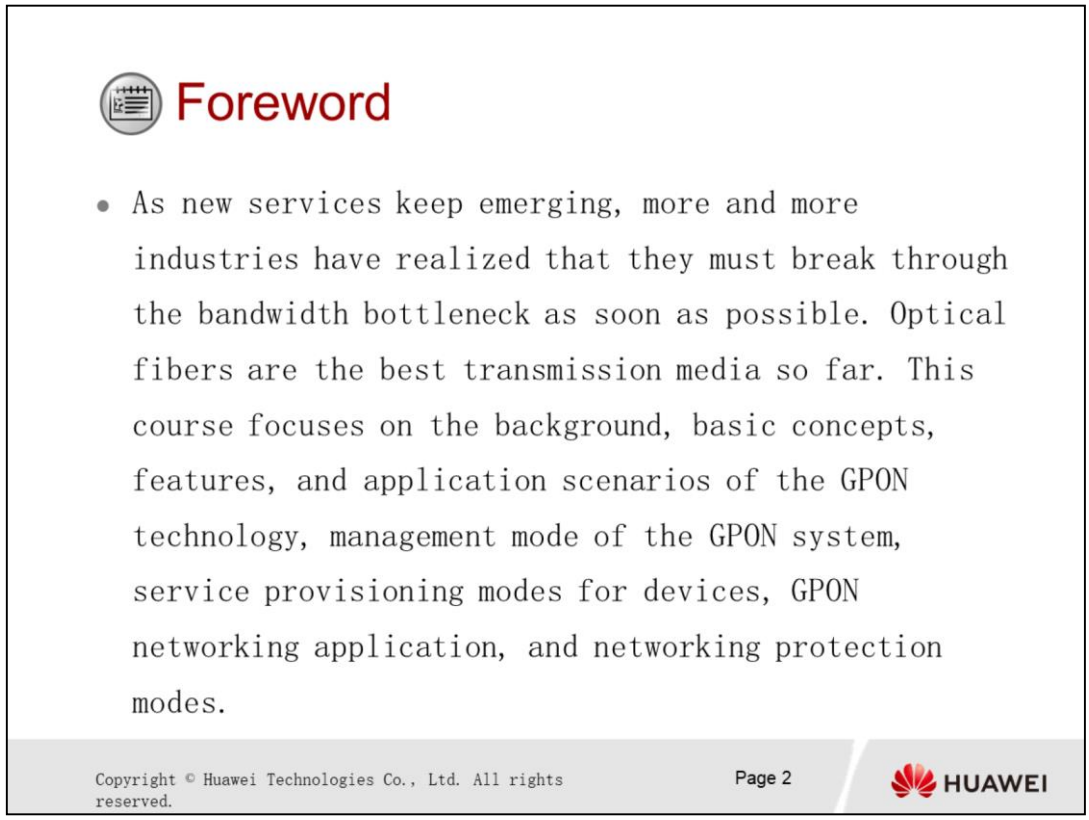
GPON Principles

www.huawei.com

HUAWEI



- GPON: gigabit-capable passive optical network

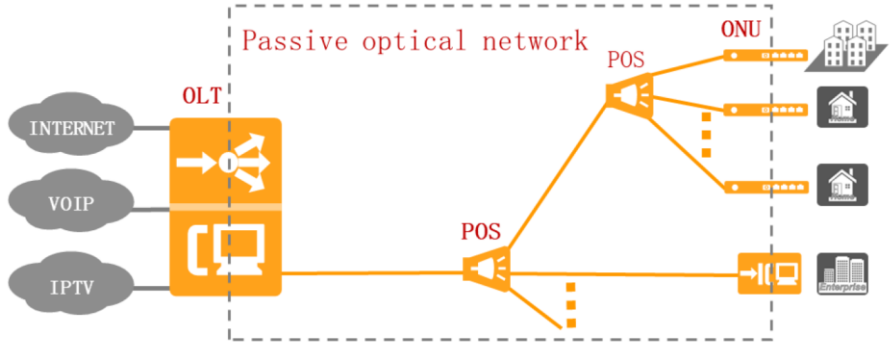
Objectives

- Upon completion of this course, you will be able to:
  - Describe the concept of GPON.
  - Analyze the main protocols of GPON.
  - List the key technologies of GPON.
  - Understand the device management and authentication modes of the GPON system.
  - List GPON networking protection modes.
  - Understand the new trends of the access network technology.

Contents

HUAWEI

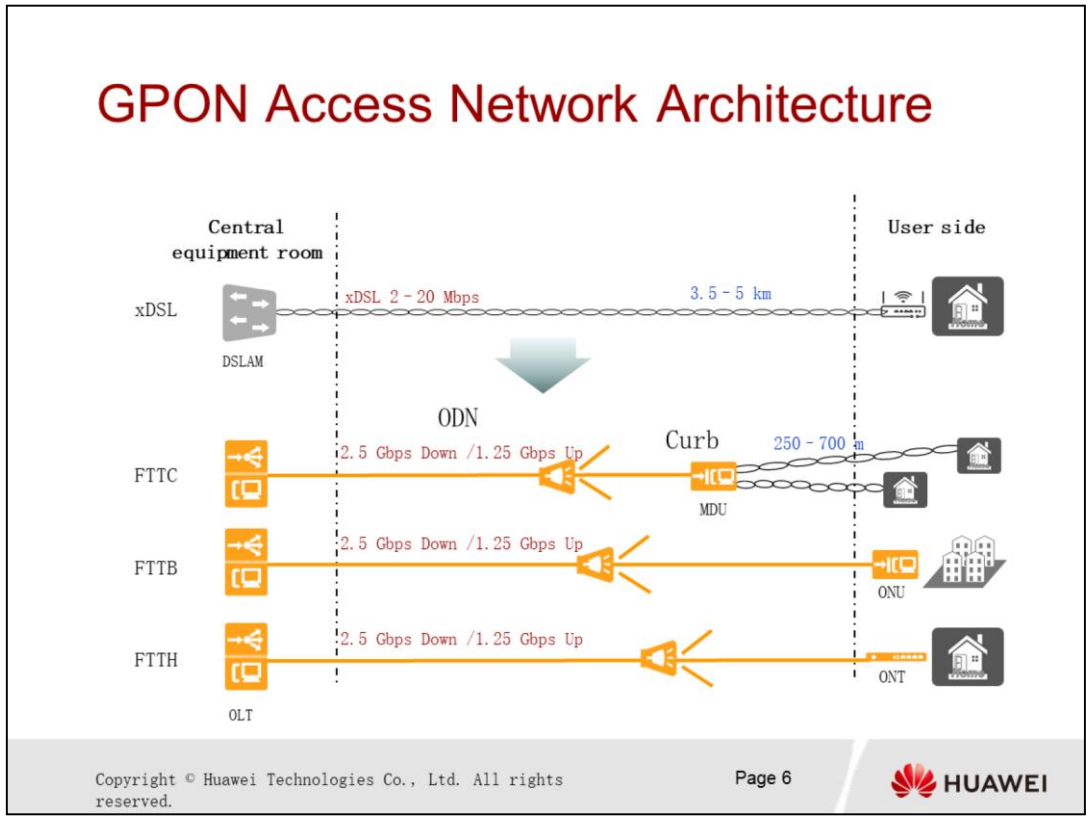
GPON Network Architecture



- PON is a point-to-multipoint (P2MP) passive optical network.
- GPON: gigabit passive optical network
- A PON network consists of the following components:
  - Optical line terminal (OLT)
  - Optical distribution network (ODN) which consists of optical splitters and optical fibers
  - Optical network unit/terminal (ONU/ONT)

HUAWEI

- P2MP: point to multiple point
- POS: passive optical splitter



- FTTC: fiber to the curb
- FTTB: fiber to the building
- FTTH: fiber to the home

Basic Performance Parameters of the GPON Network

Upstream Rate (Gbps)	Downstream Rate (Gbps)
0.15552	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

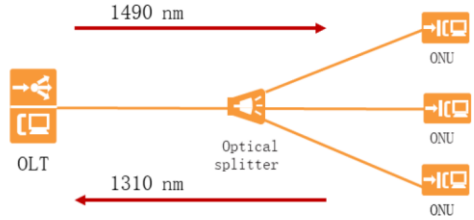
Maximum Logical Distance	60 km
Maximum Physical Transmission Distance	40 km
Maximum Differential Distance	40 km
Maximum Splitter Ratio	1:128

Mainstream rates currently supported and can be upgraded to 10G GPON

HUAWEI

GPON Data Multiplexing Modes

- The GPON implements single-fiber bidirectional transmission using the WDM technology.

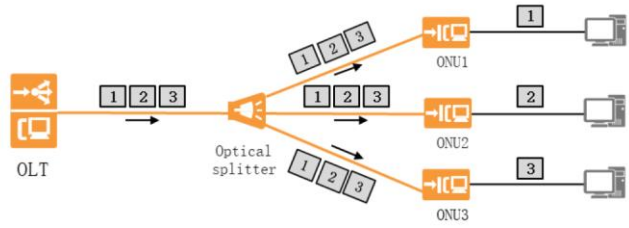


- To separate signals from multiple users on the same optical fiber, the following technologies are used:
  - Broadcast for downstream data streams
  - TDMA for upstream data streams

HUAWEI

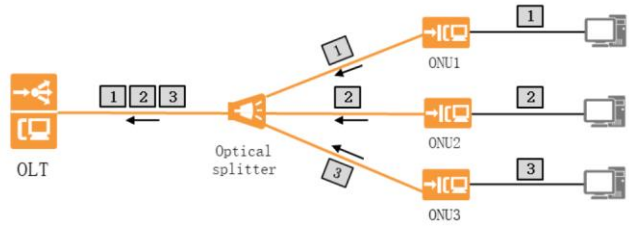
- WDM: wavelength division multiplexing
- TDMA: time division multiple access

GPON Downstream Data



- Broadcast mode: The downstream frame length of the GPON is fixed at 125 μs. Broadcast is used in the downstream direction. All ONUs receive the same data, and the GEM PORTID is used to distinguish the data intended for different ONUs. An ONU receives the data intended for it through filtering.

GPON Upstream Data



- TDMA mode: In the upstream direction of the GPON, data is transmitted in TDMA mode. The upstream link is divided into different timeslots which are allocated to each ONU according to the upstream bandwidth map fields of downstream frames.

Contents

HUAWEI

GPON Standard Protocols

ITU-T G.984.1

- Parameters of the GPON network
- Networking requirements for protection switching

ITU-T G.984.2

- Specifications of the PMD layer
- Specifications of the 2.488 Gbps downstream optical interface
- Specifications of the 1.244 Gbps upstream optical interface
- Physical layer overhead allocation

Simple product development
High compatibility

ITU-T G-984.1/2/3/4/5/6/7

ITU-T G.984.3

- Specifications of the GPON TC Layer
- Introduction to the GTC multiplexing structure and protocol stack
- Introduction to the GTC frame structure
- ONU registration and activation process
- DBA specifications
- Alarms and performances

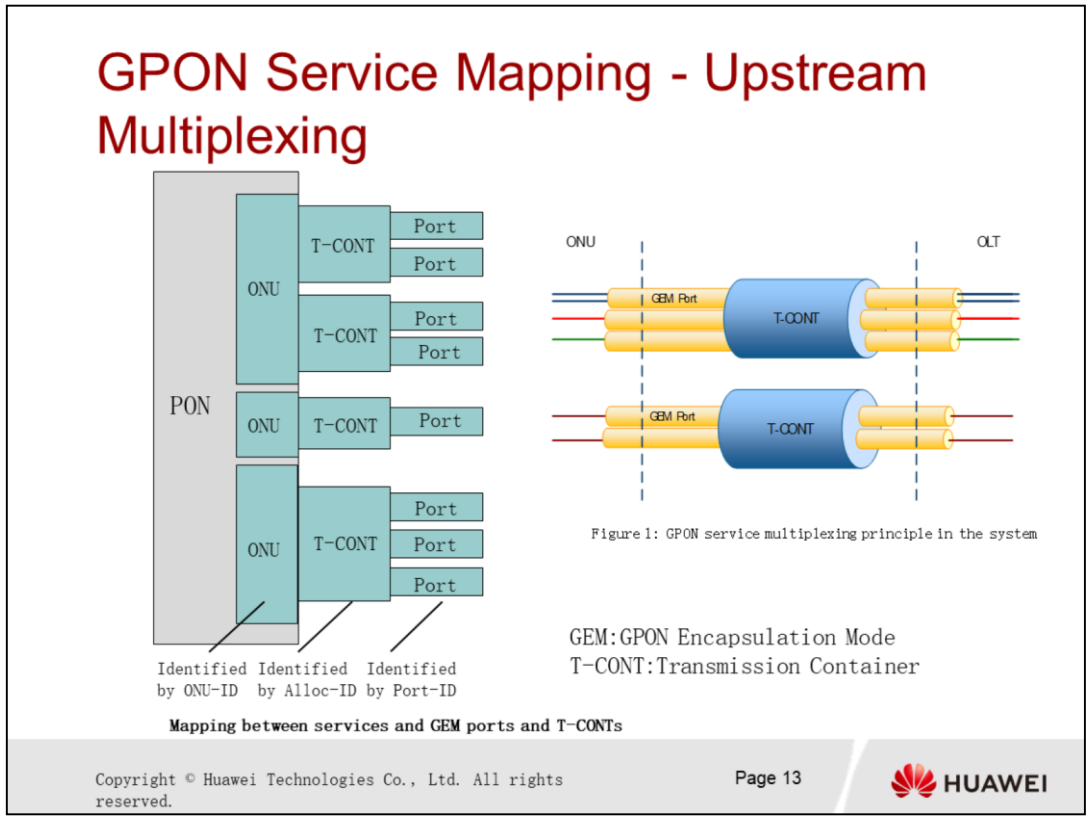
ITU-T G.984.4

- Introduction to the OMCI message structure
- OMCI device management framework
- Introduction to the OMCI implementation principle

ITU-T G.984.5
- GPON wavelength planning

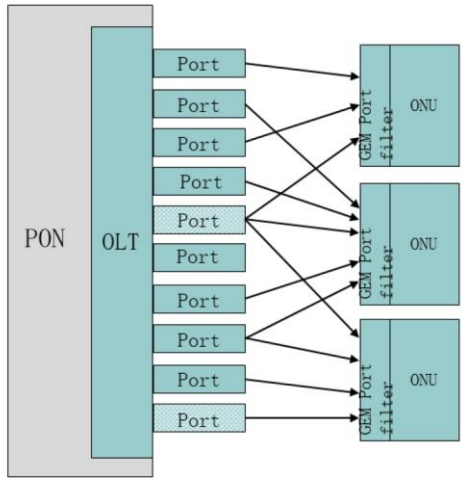
ITU-T G.984.6
- GPON reach extension solution

ITU-T G.984.7
- GPON long reach



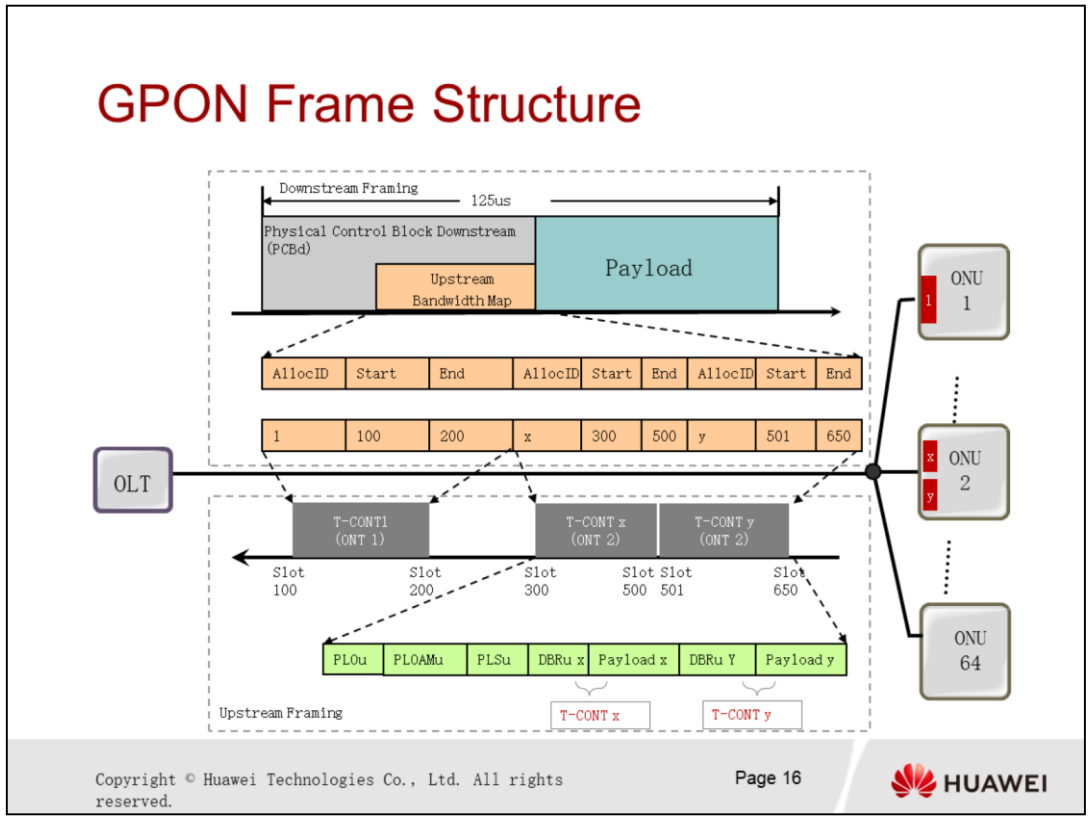
- Basic concepts of GPON
- The GPON encapsulation mode (GEM) frame is the smallest service bearing unit in the GPON technology and is the most basic encapsulation structure. All services are encapsulated in GEM frames for transmission on the GPON line and are identified by GEM ports. Each GEM port is identified by a unique Port-ID, which is globally allocated by the OLT. That is, each ONU/ONT of the OLT cannot use the GEM ports with the same Port-ID. A GEM port identifies the service virtual channel between the OLT and the ONU/ONT, that is, the channel that carries the service stream. The GEM port is similar to the VPI/VCI identifier in the ATM virtual connection.
- T-CONT: The T-CONT is the carrier for services in the upstream direction of the GPON. All GEM ports are mapped to T-CONTs, and the OLT uses the DBA scheduling mode for upstream transmission. A T-CONT is the basic control unit of the upstream service stream in the GPON system. Each T-CONT is uniquely identified by an Alloc-ID which is globally allocated by the OLT. That is, each ONU/ONT of the OLT cannot use T-CONTs with the same Alloc-ID.

GPON Service Mapping - Downstream Multiplexing



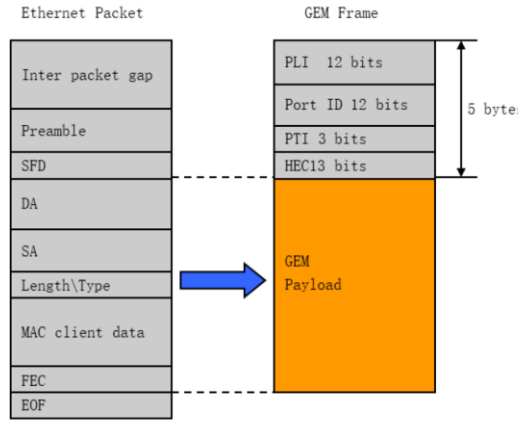
- In the downstream direction, all services are encapsulated into the GEM port in the GPON service processing unit and broadcast to all the ONUs connected to the GPON port. An ONU filters the data according to the GEM port ID, retains only the GEM port belonging to the ONU, decapsulates the service, and then sends the service from the service interface of the ONU to the user equipment.
- A shared GEM port is a multicast GEM port.

HUAWEI



- The OLT uses the Flag field in the Bwmap to indicate whether the PLSu, PLOAMu, or DBRu information is transmitted in each allocation. When setting the transmission period, the OLT scheduler also needs to consider the bandwidth and delay requirements of these auxiliary channels.
- The status information of the PLOu is included in the allocation arrangement. Each time an ONU takes over a PON medium from another ONU, a copy of the new PLOu data must be sent. When an ONU is allocated with two consecutive IDs (the StopTime of one ID is 1 less than the StartTime of the other), the ONU suppresses the sending of the PLOu data to the second Alloc_ID. When the OLT authorizes multiple consecutive Alloc_ID to the ONU, the suppression can occur multiple times. Note that the continuous OLT allocations to the same ONU must have intervals. The allocations must be strictly continuous or for 2 different ONUs.
- User payload data is followed by these overheads during transmission until the position indicated by the StopTime pointer is reached.

Mapping Mode of Ethernet Services in GPON

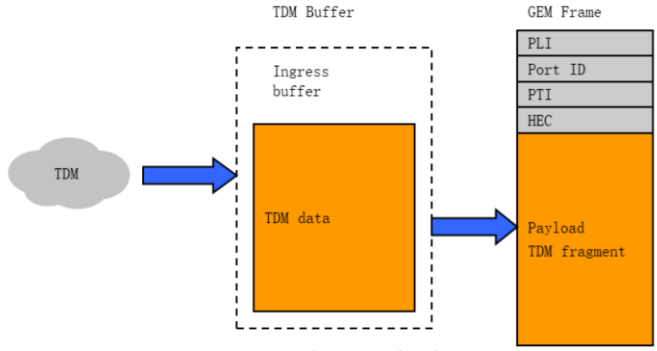


- The GPON system parses Ethernet frames and directly maps the data part to the GEM Payload for transmission.
- A GEM frame automatically encapsulates the header information.
- The mapping format is clear and easy to implemented, and the compatibility is excellent.

HUAWEI

- PLI: payload size, 12 bits. That is, the maximum payload length of each GEM frame is 4095 bytes.
- PORT ID: 12-bit 4096 GEM PORT IDs.
- PTI: 3-bit payload type. The last bit indicates whether the segment is the last segment.
- HEC: 13 bits for header error control.

Mapping Mode of TDM Services in GPON

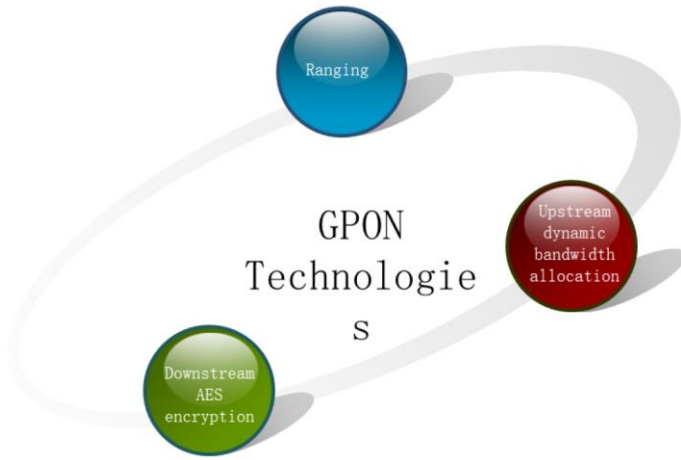


- TDM services are first imported into the buffer for queuing and then multiplexed into GEM frames for transmission in a fixed number of bytes.
- In this mode, the system is not aware of specific TDM services and only transparently transmits data.
- A GEM frame has a fixed length and is beneficial to the transmission of TDM services.

Contents

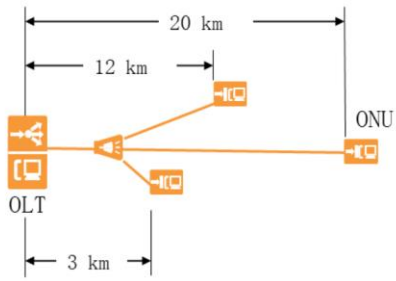
HUAWEI

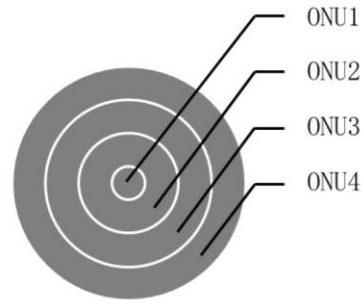
Key GPON Technologies



HUAWEI

Why Ranging Is Required

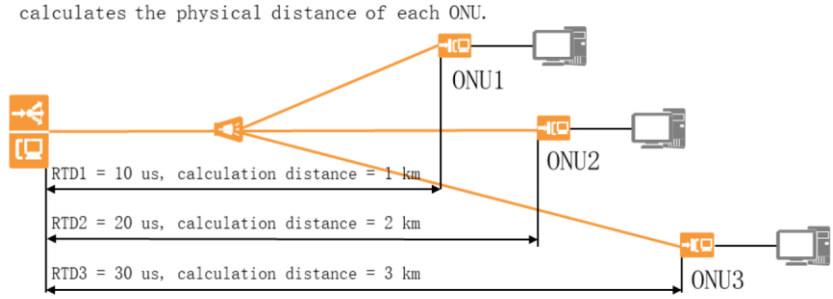




- The distances between ONUs and OLTs are different. The transmission time of optical signals on the optical fiber is different, and the time when the optical signal arrives at each ONU is also different.
- The OLT allocates different timeslots to each ONU to transmit upstream data. How to ensure that each ONU can accurately locate timeslots?
- How to avoid conflicts between upstream data from multiple ONUs and implement frame synchronization?

Ranging Principles

- The ranging process is as follows:
  - The OLT obtains the Round Trip Delay (RTD) of each ONU through ranging, and calculates the physical distance of each ONU.



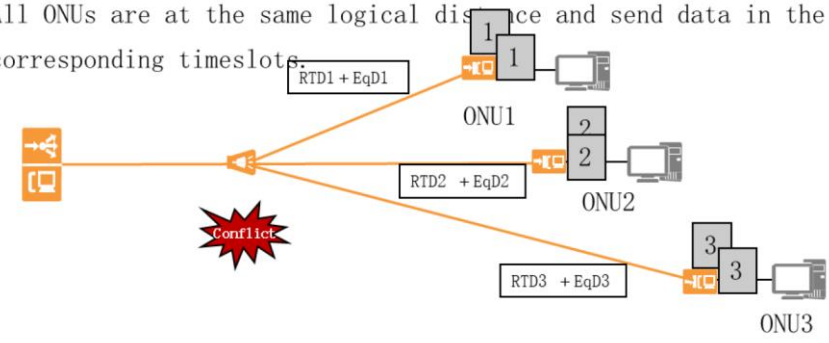
  - Then, the OLT specifies a proper equalization delay (EqD).
  - In the ranging process, a window needs to be opened, that is, quiet zone to suspend the upstream transmission channels of other ONUs. The OLT opens the window by setting BWmap to null without authorizing any timeslot.

HUAWEI

- The PON upstream transmission adopts the TDMA mode. One OLT can be connected to multiple ONUs. The distance between the ONU and the OLT can range from dozens of meters to 20 km. Optical fibers are used to transmit optical signals with a delay of 5 ps per kilometer. Due to the change of the ambient temperature and the aging of the components, the transmission delay is also changing. To realize the TDMA access and ensure that the upstream data of each ONU is inserted into the specified timeslots after data is converted on the public fiber without collision between ONUs, the OLT must accurately measure the distance between each ONU and the OLT, so as to control the moment at which each ONU sends upstream data.
- The OLT obtains the round trip delay (RTD) of each ONU through ranging, and specifies equalization delay (EqD) to ensure that no conflict occurs on the optical splitter when each ONU sends data.
- In the ranging process, a window needs to be opened, that is, Quiet Zone to suspend the upstream transmission channels of other ONUs. The OLT opens the window by setting BWmap to null without authorizing any timeslot.

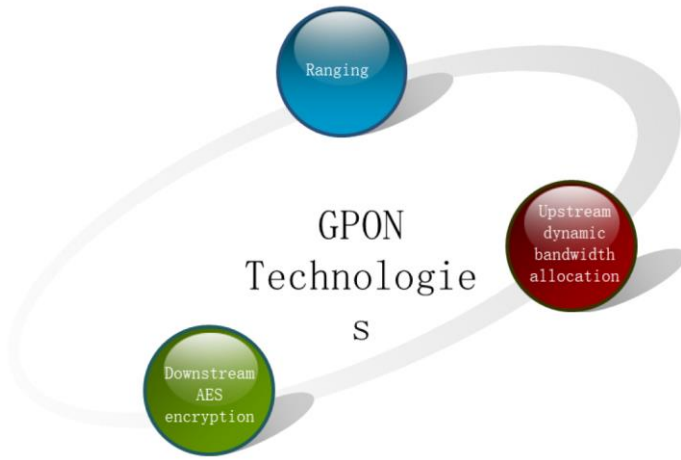
Ranging Result

- Using RTD and EqD, the OLT can ensure that data frames sent by different ONUs are synchronized and do not conflict on an optical splitter.
- All ONUs are at the same logical distance and send data in the corresponding timeslots.



HUAWEI

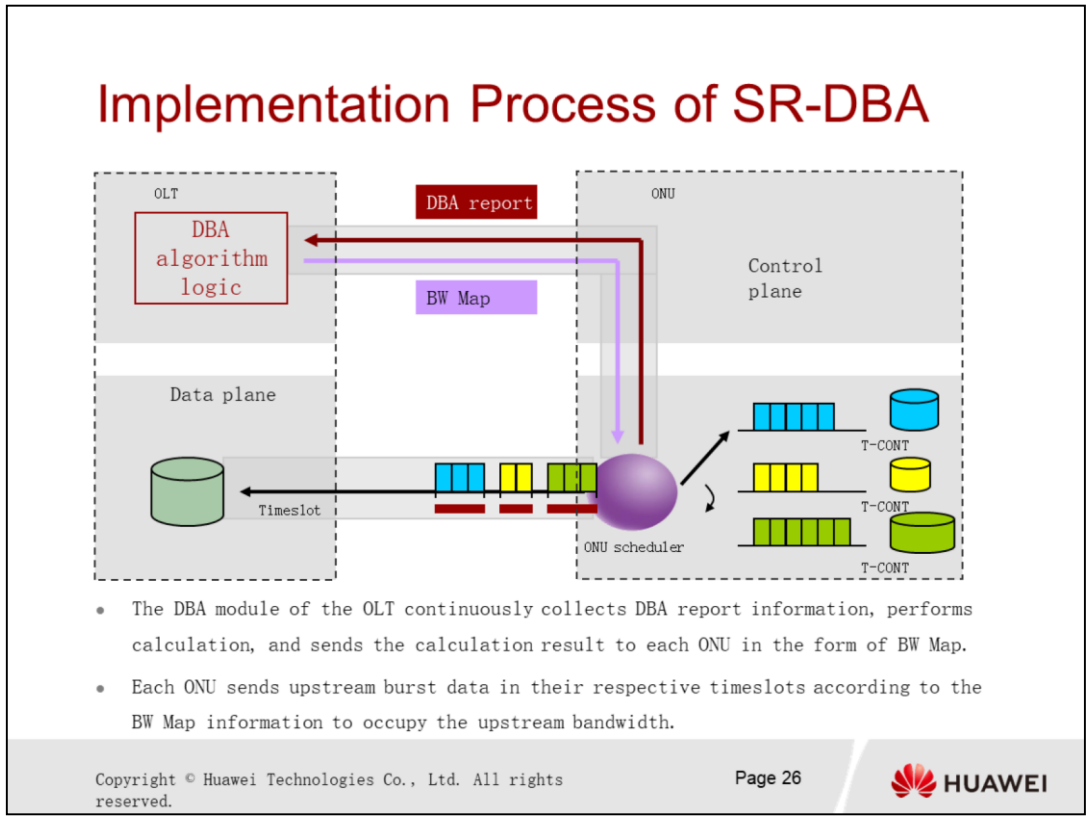
Key GPON Technologies



HUAWEI

Why DBA Is Required

- What Is DBA?
  - Dynamic bandwidth assignment (DBA)
  - DBA can dynamically allocate upstream bandwidth within microseconds or milliseconds.
- Why DBA Is Required?
  - Improve the upstream line bandwidth utilization of the PON ports.
  - Connect more users to the PON ports.
  - Provide users with better services at higher bandwidths, especially for services that have bandwidth bursts.
- DBA working mechanism
  - SR-DBA: status report-DBA
  - NSR-DBA: non status report-DBA



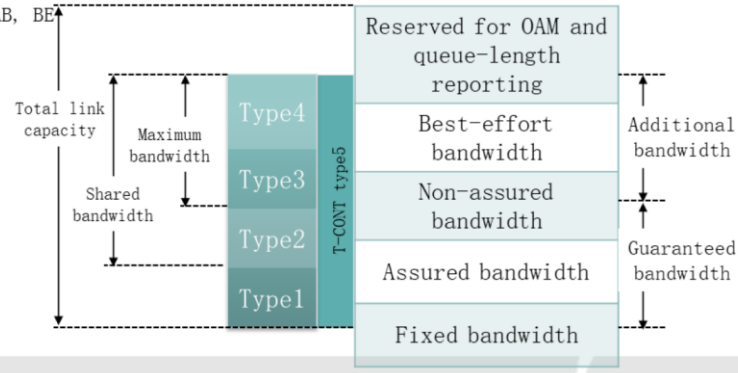
- The GPON system uses the SBA+DBA mode to achieve effective bandwidth utilization.
  - TDM services are configured with a bandwidth through SBA to ensure high QoS.
  - Bandwidths for other services are dynamically allocated through DBA.
  - The implementation of DBA is closely related to the QoS guarantee mechanism.
  - The GPON system supports dynamic bandwidth allocation through status reporting and OLT service monitoring (non-status reporting).
- There are three mechanisms for the GPON to report DBA status:
  - PLOu-State Ind DBA
  - DBRu-Piggy-back DBA
  - Payload DBA
- The implementation mechanism of the DBA function consists of the following parts:
  - The OLT or ONU performs congestion detection.
  - Report the congestion status to the OLT.
  - Update the bandwidth to be allocated by the OLT according to the specified parameters.
  - The OLT sends authorization according to the newly allocated bandwidth

and T-CONT type.

- Manage DBA operations.

DBA Basics - T-CONT

- Transmission containers (T-CONTs): Dynamically receives the authorization from the OLT, manages the upstream bandwidth allocation at the transmission convergence layer of the PON system, and improves the upstream bandwidth in the PON system.
- Bandwidth type
  - FB, AB, NAB, BE
- T-CONT type
  - Type1
  - Type2
  - Type3
  - Type4
  - Type5



HUAWEI

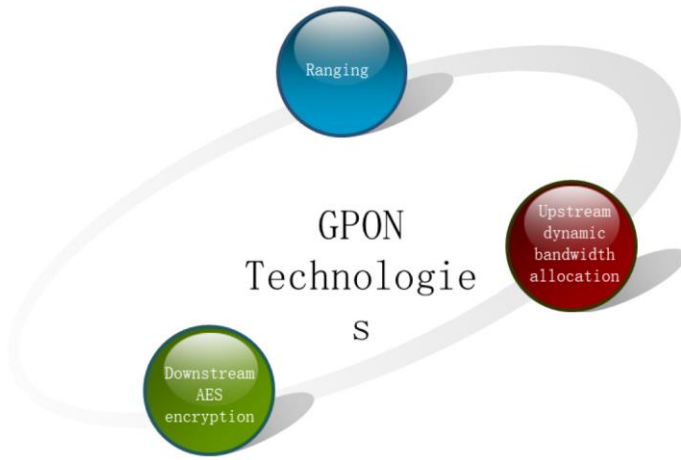
Relationship between T-CONT Types and Bandwidth types

Bandwidth Type	T-CONT Type				
	Type1	Type2	Type3	Type4	Type5
Fixed BW	X	No	No	No	X
Assured BW	No	Y	Y	No	Y
Maximum BW	Z = X	Z = Y	Z > Y	Z	Z ≥ X + Y

- According to service priorities, the system sets the SLA for each ONU and limits the bandwidth of the services.
- The maximum and minimum bandwidths limit the bandwidth of each ONU at extreme conditions to ensure that the bandwidth varies according to the service priorities. Generally, the voice service has the highest priority, followed by video and data services.
- The OLT allocates the bandwidth according to the service, SLA, and actual ONU conditions. The higher the priority is, the higher the bandwidth is.

- T-CONTs are classified into five types. In the upstream service scheduling process, different types of T-CONTs are selected for different types of services. Each T-CONT bandwidth type has specific QoS characteristics. QoS characteristics mainly indicate the bandwidth guarantee, including fixed bandwidth, assured bandwidth, assured/maximum bandwidth, maximum bandwidth, and hybrid mode (corresponding to Type 1 to Type 5 of five T-CONT types).

Key GPON Technologies

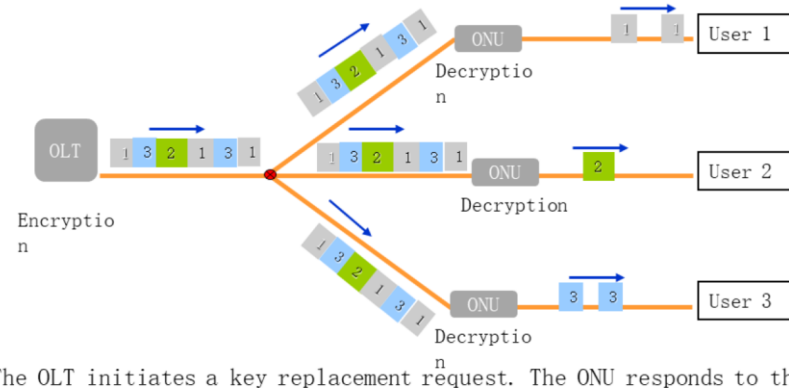


HUAWEI

Why Encryption

- The broadcast technology is used in the GPON downstream direction. On the same PON port, data is the same on the backbone optical fiber and after optical splitting. The data received by each ONU is the same. How to ensure that the data intended for one ONU is not parsed by other ONUs?
- The GPON supports AES128 encryption for downstream broadcast data.
  - Advanced encrypt system (AES) is an international encryption algorithm.
    - Only the payload in a GEM frame is encrypted.
    - The GPON system periodically exchanges and updates the AES key to improve the reliability of the line data.

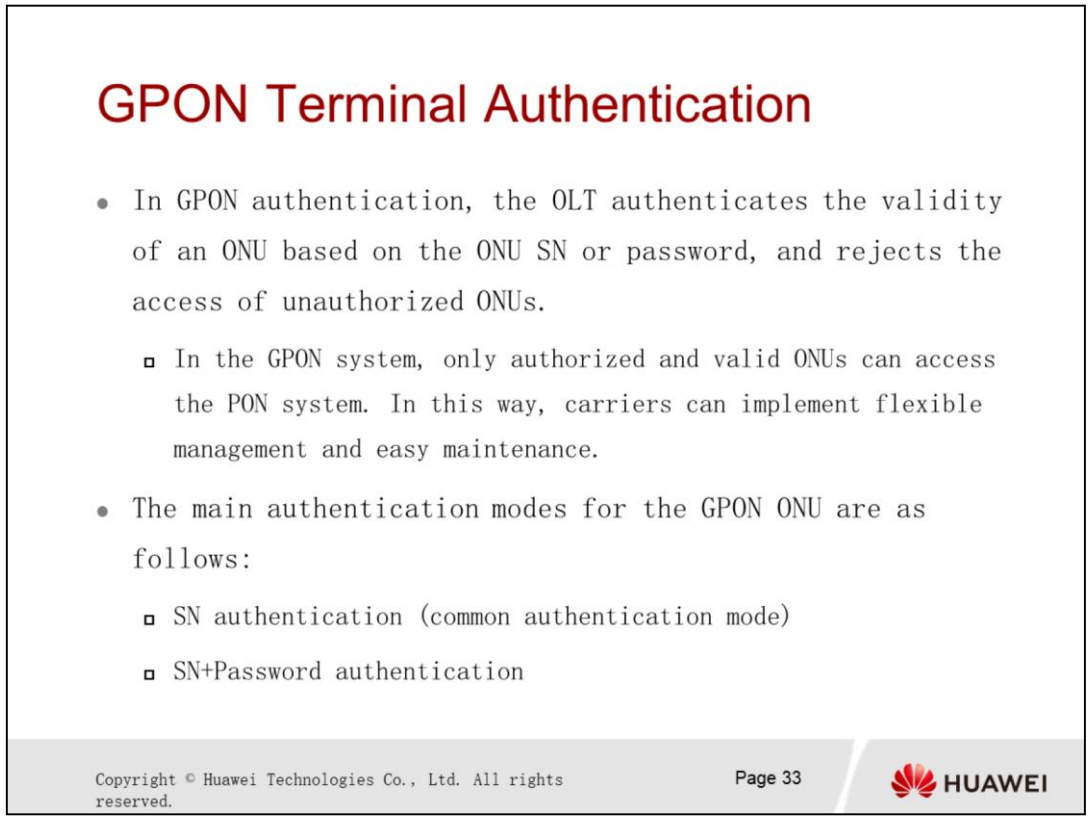
AES Encryption in the GPON system



- The OLT initiates a key replacement request. The ONU responds to the request, generates a new key, and sends the new key to the OLT for three times.
- After receiving the new key, the OLT starts key switching, and notifies the ONU (also three times) of the frame number of the new key by using related commands. The ONU switches the check key in the corresponding data frame.

Contents

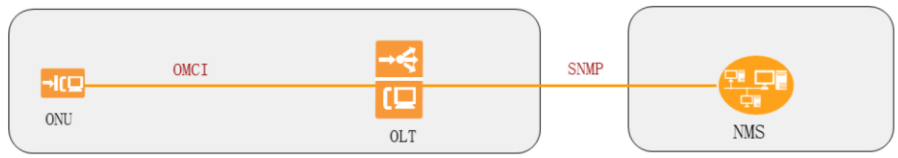
HUAWEI



- SN authentication is an authentication mode in which the OLT matches only the SN of an ONU. The SN+Password authentication mode requires matching both the SN and password at the same time.
- After receiving the sequence code response message from the ONU, the OLT checks whether the ONU with the same SN is online. If an ONU with the same SN is online, the OLT reports an SN conflict alarm is reported to the CLI and NMS. Otherwise, the OLT directly allocates the specified ONU ID to the ONU.
- After the ONU enters the operation state:
  - For the ONU in SN authentication mode, the OLT does not request the password. The OLT directly configures a GEM port for the ONU to carry OMCI messages and enables the ONU to go online. The configuration can be automatically performed by the OLT so that the GEM port carrying OMCI messages is the same as the ONU ID. In addition, the OLT reports an ONU online alarm to the CLI or NMS.
  - For an ONU in SN + password authentication mode, the OLT sends a password request to the ONU and compares the password returned by the ONU with the locally configured password. If the password is the same as the locally configured password, the OLT directly configures a GEM port for the ONU to carry OMCI messages and enables the ONU to go online, and reports an ONU online alarm to the CLI or NMS. If the password is different from the local configuration, a password error alarm is reported to the CLI or NMS. In this case, even if the ONU auto-discovery function is enabled on the PON port, the OLT does not report the ONU auto-discovery, and sends the Deactivate_ONU-ID PLOAM message to deregister the ONU.

GPON Terminal Management Model

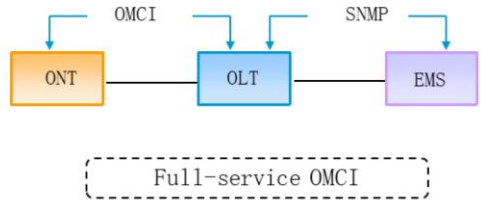
- The GPON system manages ONUs through the OMCI management channel between the OLT and the ONUs.
  - ONU PnP and automatic service provisioning
  - ONUs remote central management



- OMCI: ont terminal management and control interface
- SNMP: Simple Network Management Protocol
- ONU management in the GPON system is implemented through OMCI messages.
  - OMCI messages are mainly used for service layer management and maintenance, such as device hardware capability discovery, alarm maintenance information, and service capability configuration.
  - OMCI is a master-slave management protocol. The OLT is the master device, and an ONU is a slave device. After the ONU completes the registration process, an OMCI channel is established The OLT controls multiple ONUs connected to it through OMCI channels.
  - The OMCI supports offline configuration of ONUs. The ONU does not need to save the configurations locally, which facilitates service provisioning.

Common GPON Terminal Management Modes (1)

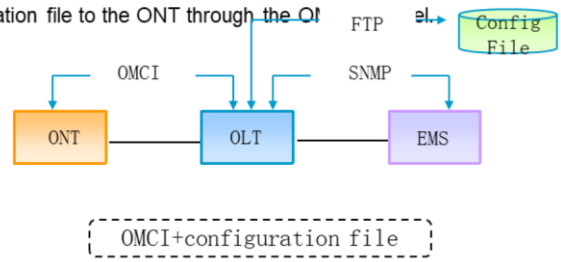
- ONT management mode 1
  - In full OMCI mode, the Internet access service, multicast service, and voice service are all delivered through OMCI.



- EMS: element management system
- Voice services are delivered through the OMCI.

Common GPON Terminal Management Modes (2)

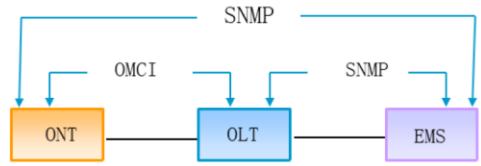
- ONT management mode 2
  - The Internet access service and multicast service are delivered through OMCI.
  - For the voice service, the OLT downloads the XML configuration file from the NMS through FTP.
    - After downloading the configuration file from the NMS, the OLT issues the configuration file to the ONT through the OL



- EMS: element management system
- For the voice service, an XML configuration file is downloaded from the NMS through FTP.
- The OLT downloads the XML configuration file of the voice service from the NMS in FTP mode and delivers the file to the ONT through the OMCI channel to complete the voice service configuration.

Common GPON Terminal Management Modes (3)

- ONT management mode 3
  - The Internet access service, multicast service, TLS service, and voice service of the ONT are all configured by EMS or Telnet.
  - However, the management VLAN and management IP address can be delivered through OMCI. Therefore, such ONTs can be remotely configured and commissioned.



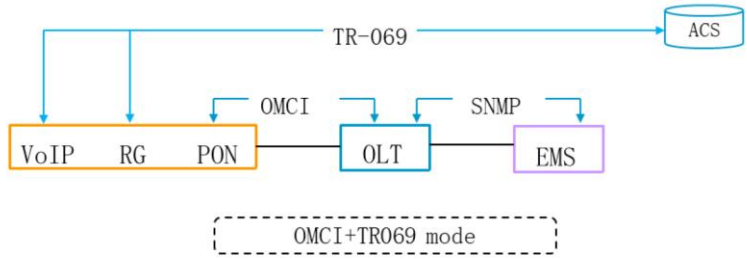
OMCI+SNMP mode

HUAWEI

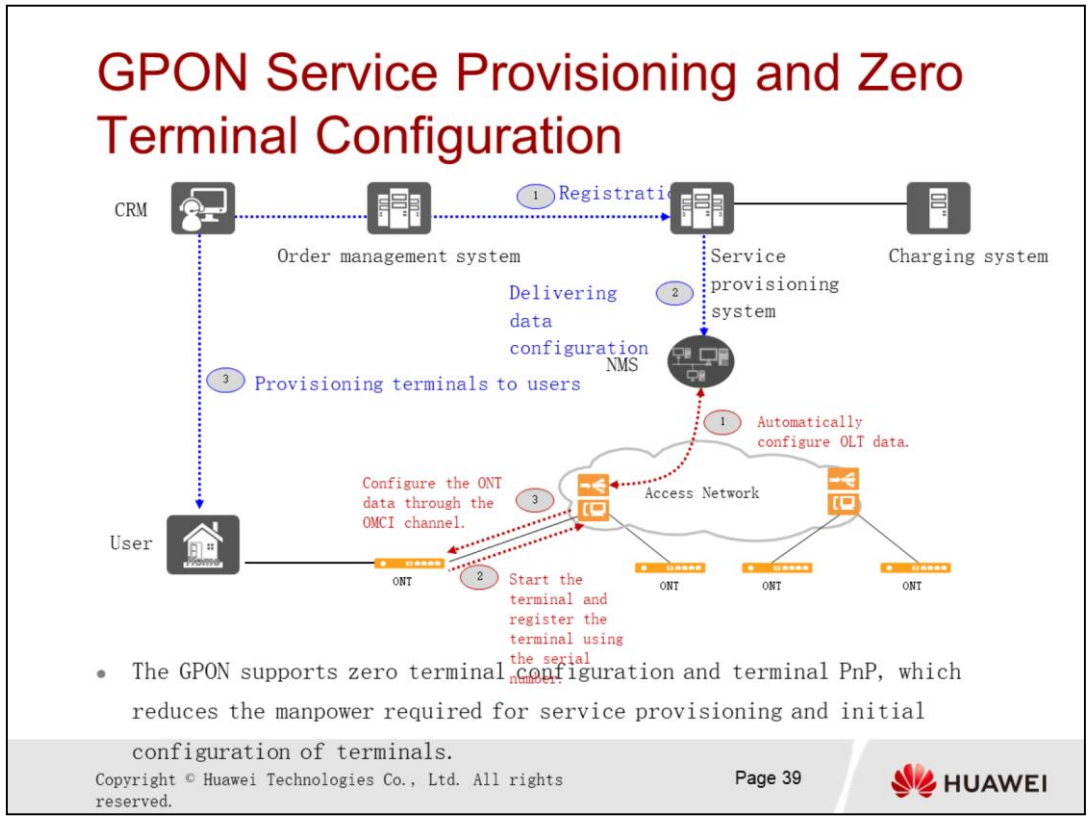
- VLAN: virtual local area network
- MXU services are typically delivered by EMS.

Common GPON Terminal Management Modes (4)

- ONT management mode 4
  - OMCI is still used for configuration, status, performance, and fault management at the PON link layer.
  - IP-based services (for example, Internet access and VoIP services) are managed by ACS in TR-069 mode.



- VoIP, RG, and PON indicate the VoIP service, gateway service (IP services are used as examples), and PON link layer management respectively.



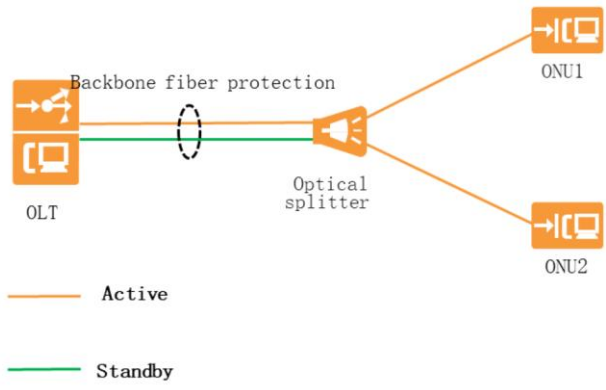
- ONT PnP
  - Zero configuration
- Centralized ONT management
  - ONT remote diagnosis and batch upgrade
  - Remote maintenance and management of the ONT through OAM
- Automatic ONT service provisioning

Contents

HUAWEI

Type B Single-homing Protection

- Type B protection is implemented for different PON ports on the same OLT.

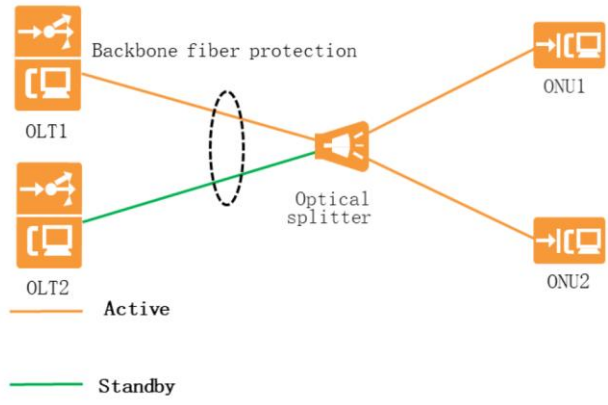


HUAWEI

- Advantages: The networking, OLT/ONU management, and service provisioning are simple.
- Disadvantages: If the OLT is faulty, services are interrupted. Optical fibers are usually laid in the same pipe, and two optical fibers may be disconnected at the same time.
- Application scenario: Protects important services of users, such as enterprise private line access services and base station private line access services.

Type B Dual-homing Protection

- Type B dual-homing protection is implemented for PON ports of two OLTs.

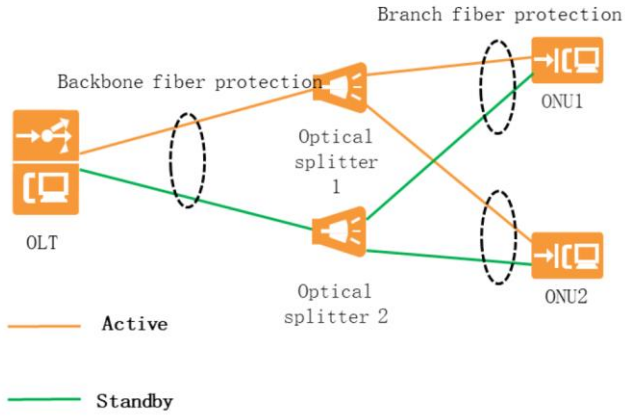


HUAWEI

- Advantages: Two backbone optical fibers are connected to two OLTs to implement remote disaster recovery.
- Disadvantages: The networking is complex, the cost is high, and the OLT configuration is complex.
- Application scenario: Protects important services such as enterprise private line access services and base station private line access services, especially in scenarios where remote disaster recovery is required.

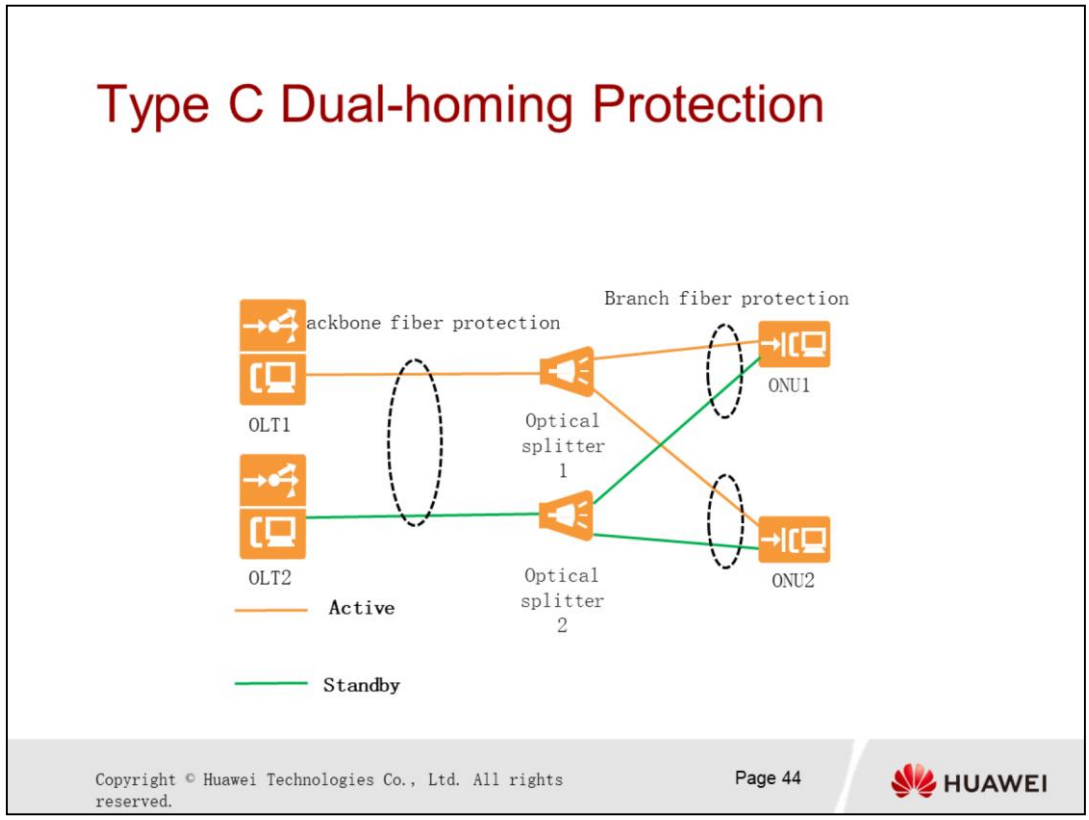
Type C Single-homing Protection

- Type C protection is similar to ring protection implemented for the OLT, ONU, and optical splitter.



HUAWEI

- Advantages: The networking and OLT/ONU management is simple.
- Disadvantages: If the OLT is faulty, services are interrupted. Optical fibers are usually laid in the same pipe, and two optical fibers may be disconnected at the same time.
- Application scenario: Protects important services of users, such as enterprise private line access services and base station private line access services.

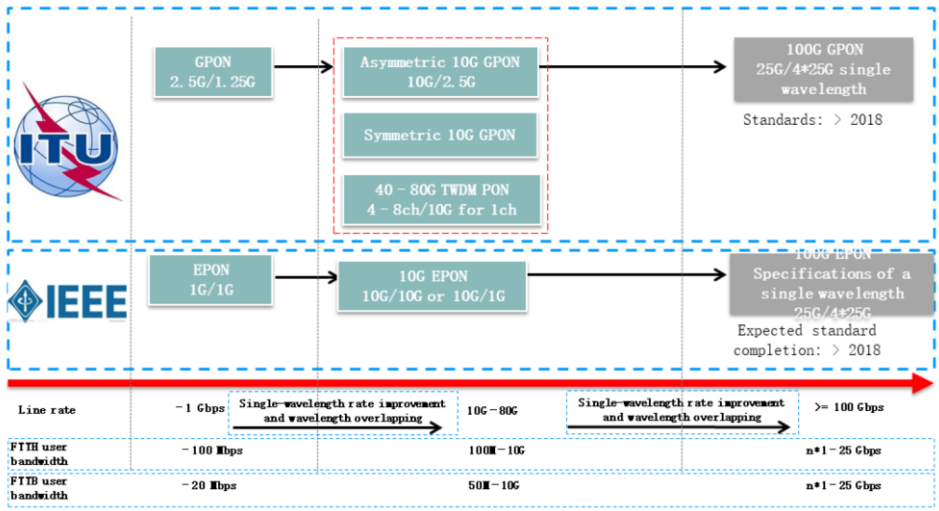


- In dual-homing networking, the two PON lines between the ONUs and two OLTs are in the active/standby state and cannot forward packets at the same time.
- Advantages: When the upstream link of the OLT or OLT is faulty, services can be switched to the other OLT.
- Disadvantages: The networking is complex, the cost is high, and the ONU management is complex.
- Application scenario: Protects power supply as well as enterprise private line access services and base station private line access services.

Objectives

- GPON Network Architecture
- GPON Protocol Analysis
- Key GPON Technologies
- Management and Service Provisioning Modes of the GPON System
- GPON networking protection
- Access Network Technology Evolution

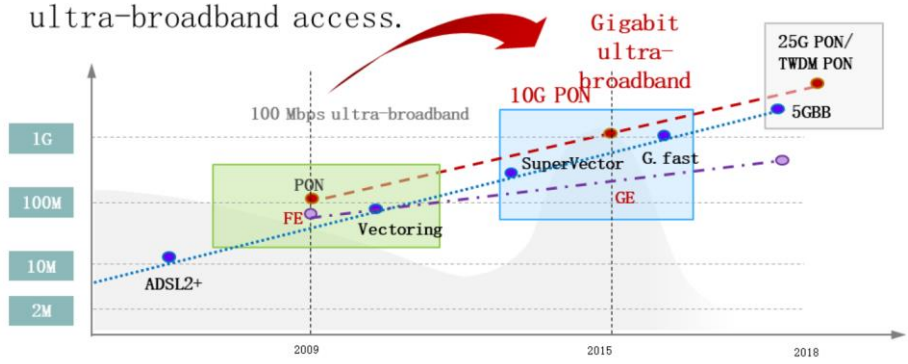
PON Standard Evolution Direction



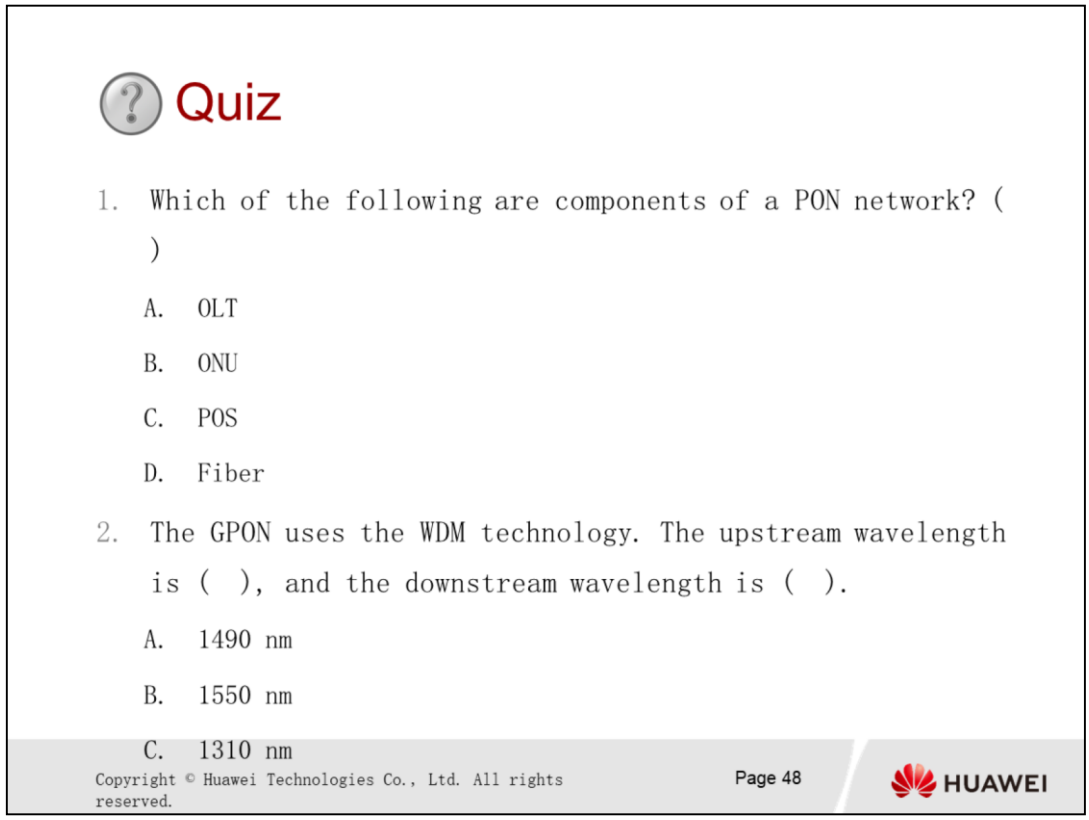
HUAWEI

10G PON: Best Technical Choice for Gigabit Ultra-Broadband Access

- Multiple media support gigabit ultra-broadband access, and FE interfaces are evolving to GE interfaces.
- 10G PON is the best technical choice for gigabit ultra-broadband access.



HUAWEI



- Answer:
  1. ABCD
  2. CA

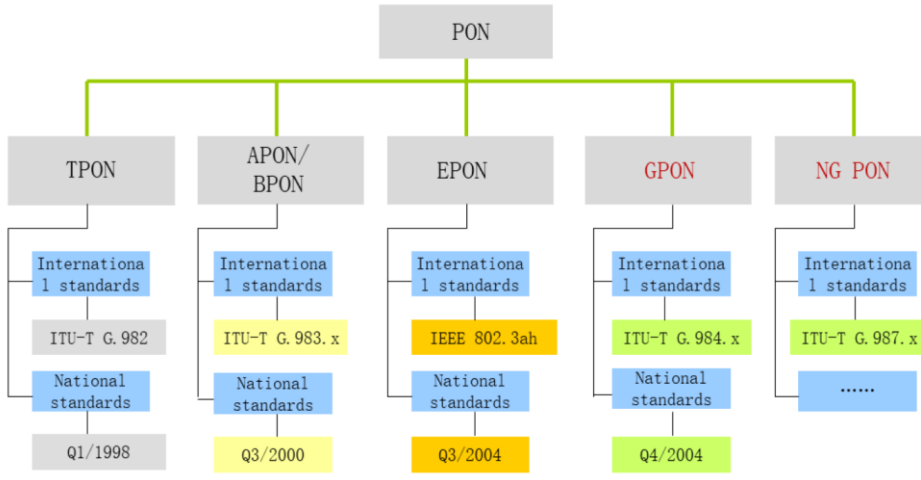
Summary

- The copper access xDSL technology has a contradiction between distance and bandwidth. The access network trend is fiber-in and copper-out, and GPON has become the mainstream access technology.
- The GPON system consists of the OLT, ODN, and ONU.
- The OLT registers and activates the ONU by identifying the SN or password.
- Data is transmitted between the OLT and ONU through GEM ports.
- The OLT manages and delivers configurations to an ONU through the OMCI channel.
- The GPON system supports the Type B/C protection modes.

Thank You

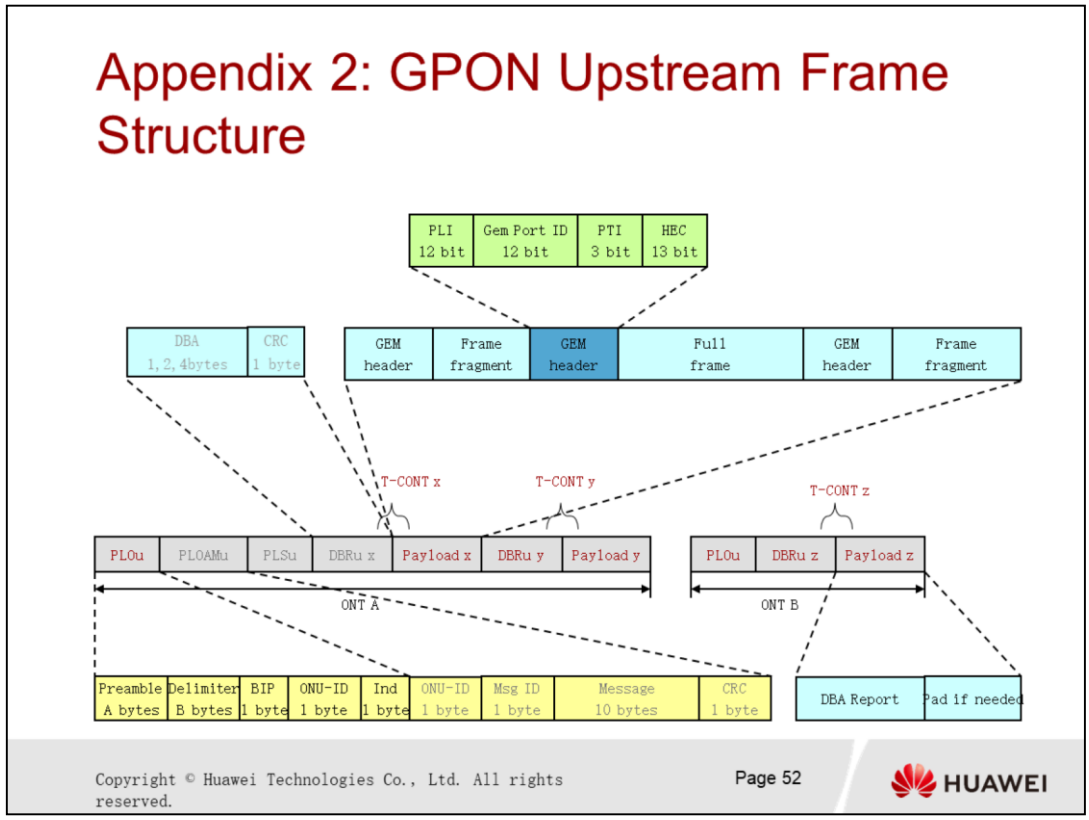
www.huawei.com

Appendix 1: PON Technology Standards

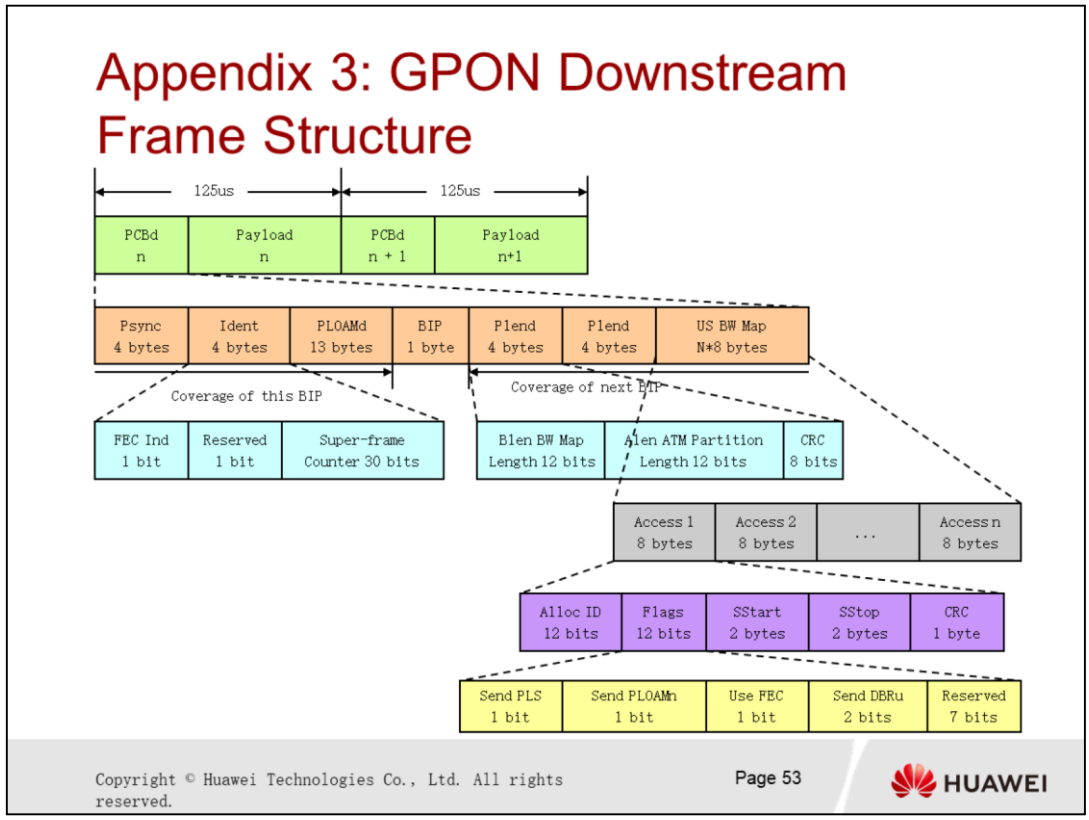


HUAWEI

- The 3 most important access technologies in the PON field are APON, EPON, and GPON.



- PLOu: This is a physical control header and is used to locate, synchronize, and mark the data of an ONU.
- PLOAMu: This is a physical layer OAM message of the upstream data and is mainly used to report management messages such as the maintenance and management status of the ONU.
  - (This field is not contained in each frame. Whether to send the frame is determined by the FLAG indicator of the previous downstream frame.)
- PLSu: Indicates the power level sequence which is used by the ONU to adjust the optical power of the optical port.
  - (This field is not contained in each frame. Whether to send the frame is determined by the FLAG indicator of the previous downstream frame.)
- DBRu: It is mainly used to report the status of the T-CONT and apply for the bandwidth for the next transmission to complete dynamic bandwidth allocation for ONUs.
  - (This field is not contained in each frame. Whether to send the frame is determined by the FLAG indicator of the previous downstream frame.)
- Payload: The data payload can be a data frame or a DBA status report.
  - Payload = (DBA report + Pad)/(GEM header + GEM frame)



- A GPON downstream frame consists of the PCBd + Payload.
  - A downlink frame is fixed at 125 uS at the frequency of 8000 Hz.
  - In 2.488 G downstream transmission, the downstream frame length is 38880 bytes.
- PCBd: This is a physical control block which implements frame synchronization, positioning, and bandwidth allocation.
  - (The length varies depending on the number of timeslots allocated this time.)
- Payload: The same as the GEM frames in the upstream frames, it bears the upper-layer PDU.
- Psync: Indicates physical-layer synchronization information which is used for synchronization between the OLT and the ONU. The value is fixed to 0xB6AB31E0.
- Idnet: Identifier domain
  - FEC: forward error correction
  - Reserved
  - SFupeFrame: Indicates a jumbo frame.
- PLOAMd: This is a physical layer OAM message for downstream data (defines N

types of messages. For details, see the G.984 standard.)

- BIP: Parity check is performed on all bytes between the BIP fields of two frames for bit error monitoring.