GPON-Technology

Contents

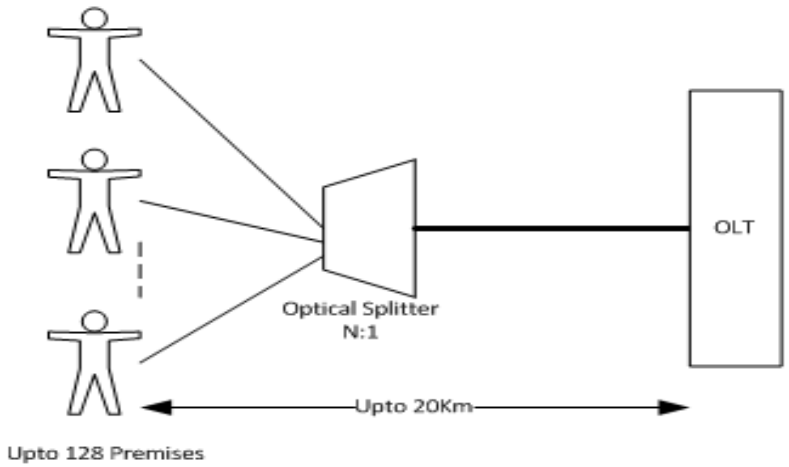
What led to GPON?

- In the late 1990s, the International Telecommunications Union (ITU) created the **APON** standard, which used the Asynchronous Transfer Mode (ATM) for long-haul packet transmission
- Since ATM is no longer used, a newer version was created called the broadband PON, or **BPON** which provided for 622 Mbits/s downstream and 155 Mbits/s upstream
- While BPON may still be used in some systems, most current networks use GPON as it provides 2.488 Gbits/s downstream and 1.244 Gbits/s upstream
- GPON uses optical wavelength division multiplexing (WDM) so a single fiber can be used for both downstream and upstream data.

Introduction

- GPON –Gigabit Passive Optical network
- GPON is a point-to-multipoint access mechanism.
- Its main characteristic is the use of passive splitters in the fiber distribution network, enabling one single feeding fiber from the provider's central office to serve multiple homes and small businesses.
- It mainly consists of three components viz.,
  1. Optical Line Termination (OLT)
  2. Optical Network Unit (ONU) or Optical Network Termination (ONT)
  3. Optical Distribution Network (ODN).
- GPON supports triple-play services, high-bandwidth, long reach etc.
- The differential fiber distance is 20km and the logical reach is 60km.
- It provides 2.5 Gb/s of downstream bandwidth and 1.25 Gb/s upstream divided by the split ratio to each customer delivering a customizable, high capacity fiber network for forms of IP based services.

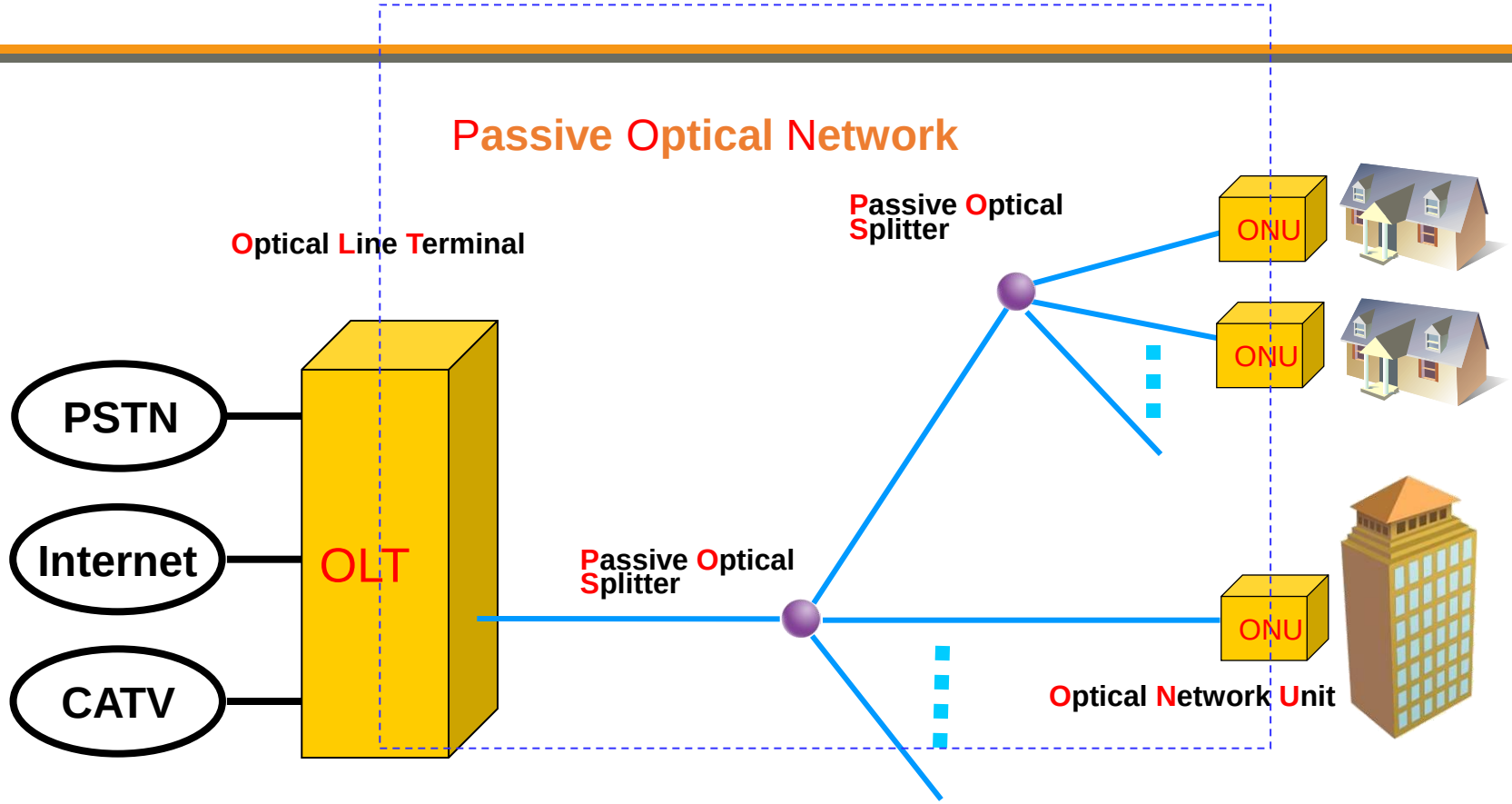
Introduction



A typical GPON architecture

- A single fiber from the OLT runs to a passive Optical Splitter which is located in the user location.
- The Optical Splitter merely divides the optical power into N separate paths to the users. The optical paths can vary between 1 to 128.
- From the Optical Splitter, a single mode (SM) fiber strand run to each user.

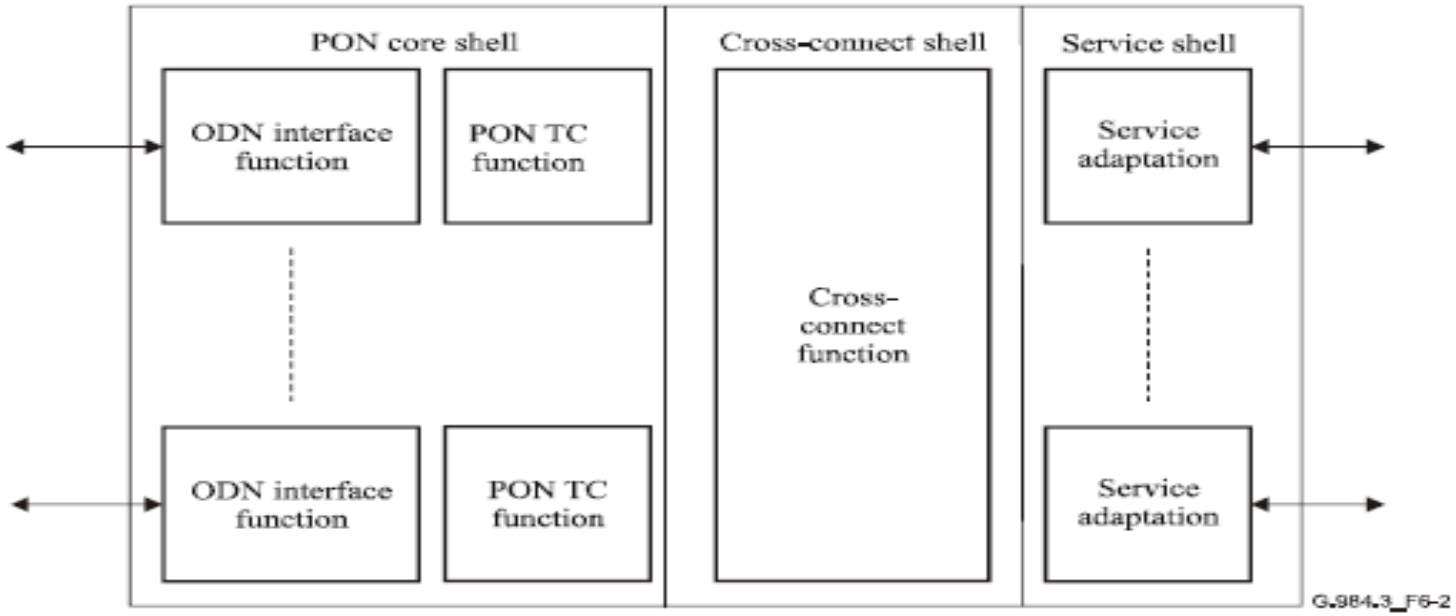
What is PON?



- 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 Passive Optical Splitter.

OLT (Optical Line Terminal)

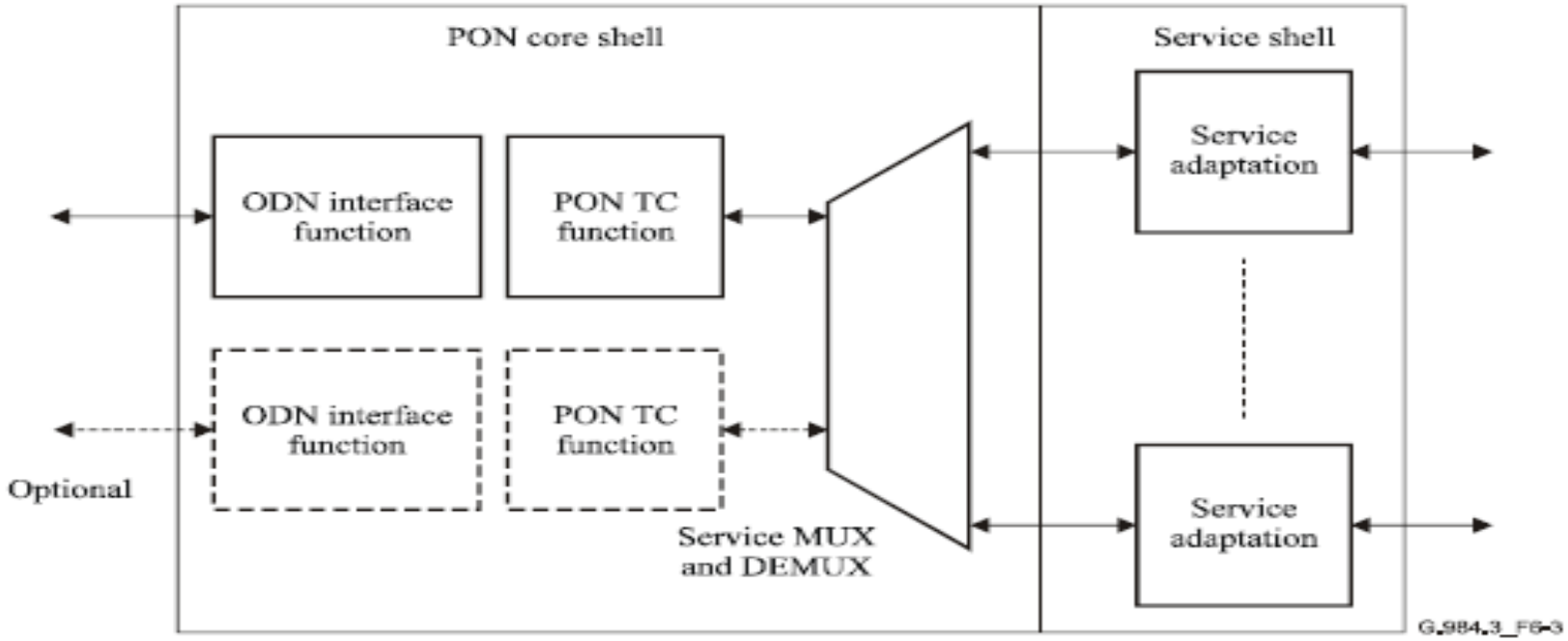
- It consists of three main parts:
  - Service port interface function
  - Cross-connect function
  - Optical distribution network (ODN)interface



OLT functional block diagram

ONU (Optical Network Unit)

- ONU building block is similar to that of OLT's.
- The cross-connect section is omitted.
- Service MUX and DEMUX is specified to handle traffic.



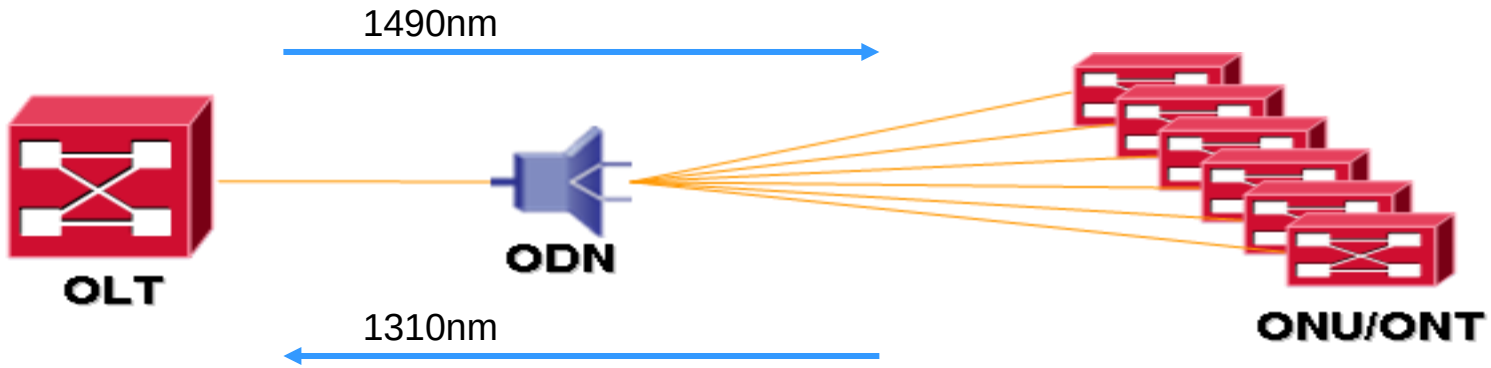
ONU functional block diagram

ODU (Optical Distribution Unit)

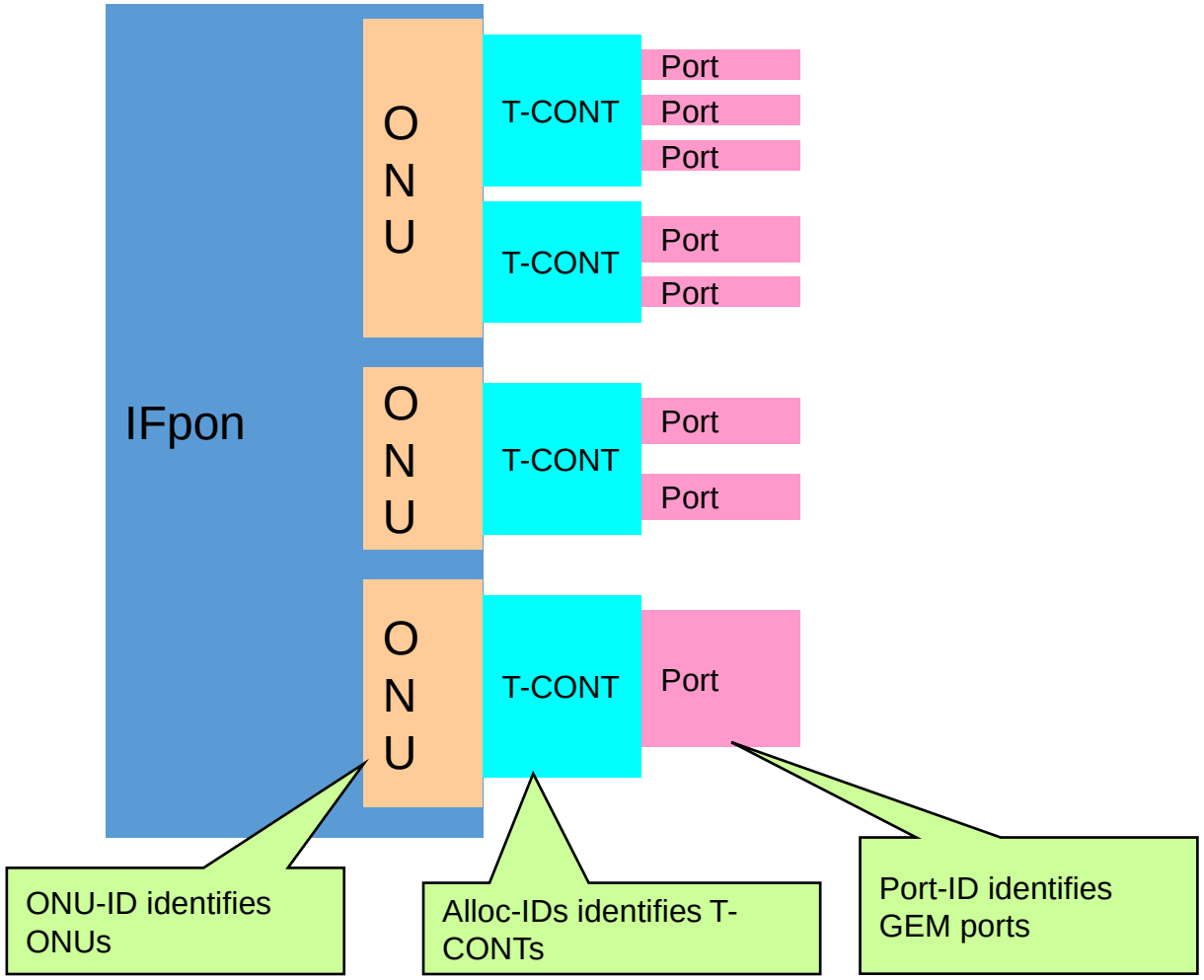
- This provides the optical transmission medium for the physical connection of the ONUs to the OLTs.
- ODU consists of passive optical elements:
  - Single mode optical fiber and cable.
  - Optical fiber ribbons and ribbon cables.
  - Optical connectors.
  - Passive branching components
  - Passive optical attenuators
  - Splices

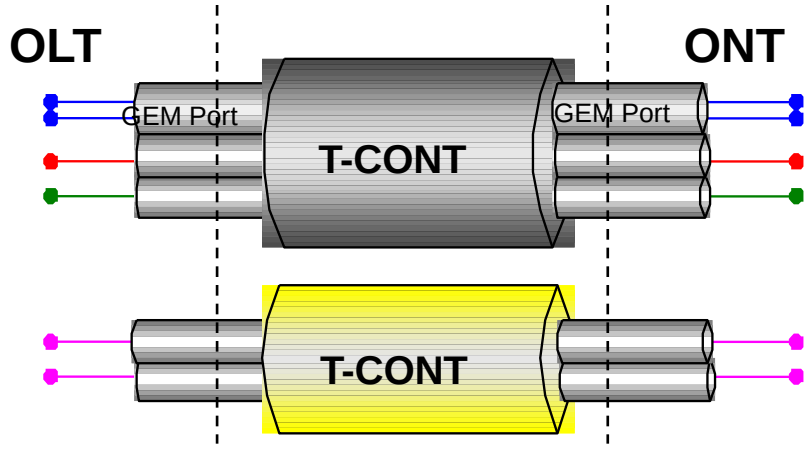
GPON Principle - Data multiplexing

- GPON adopts Wavelength Division Multiplexing (WDM) technology, facilitating bi-direction communication over a single fiber.
- To separate upstream/downstream signals of multiple users over a single fiber, GPON adopts
- two multiplexing mechanism:
  - In downstream direction, data packets are transmitted in a broadcast manner;
  - In upstream direction, data packets are transmitted in a TDMA manner



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.
- 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.

Disambiguation of the concept of frame

- The term "frame" can appear within this recommendation in the following contexts:
  - **User frame**: A service data unit (SDU) of the GTC layer, usually represented by an Ethernet frame.
  - **GEM frame**: A protocol data unit (PDU) of the GTC framing sublayer that consists of a 5-byte GEM header and a variable-length GEM payload.
  - **Downstream GTC frame**: 125-µs interval with well-defined boundaries and fixed, repetitive data format containing the GTC header (PCBd field) and the GTC payload.
  - **Upstream GTC frame**: 125-µs interval with well-defined boundaries containing multiple upstream transmission bursts controlled by the individual BW maps.

Basic Performance Parameters of GPON

- It provides 2.5 Gb/s of downstream bandwidth and 1.25 Gb/s upstream divided by the split ratio to each customer delivering a customizable, high capacity fiber network for forms of IP based services.

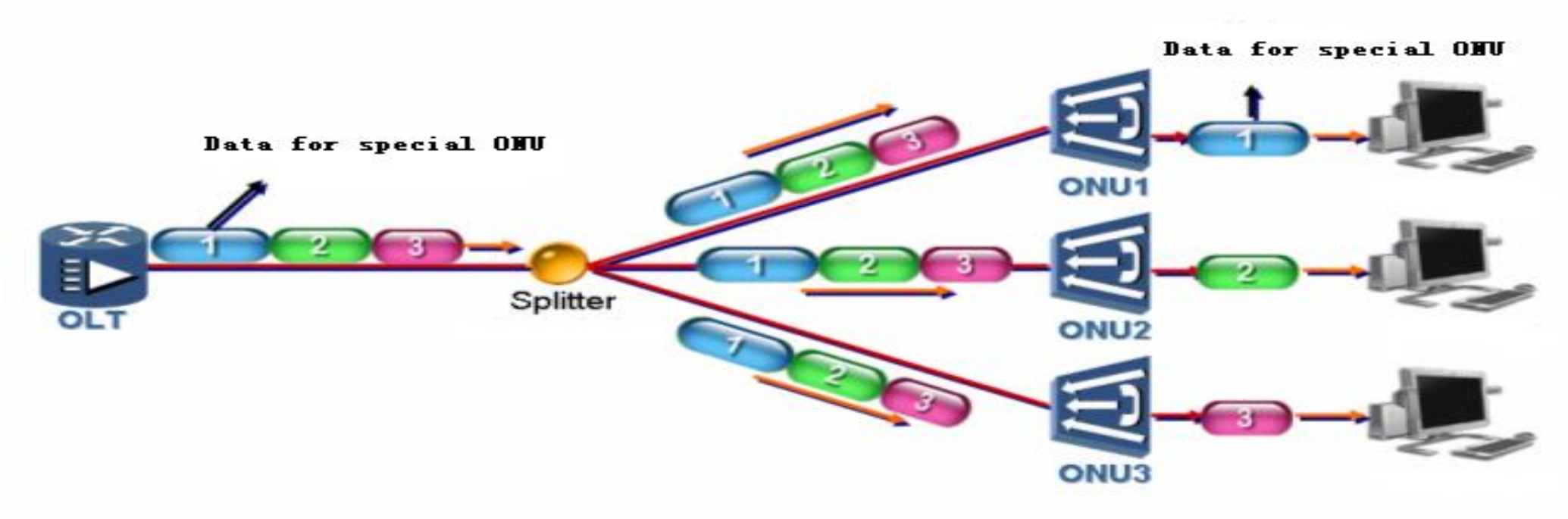
- Maximum logical reach: 60 km

- Maximum physical reach: 20 km

- Maximum differential fiber distance: 20 km

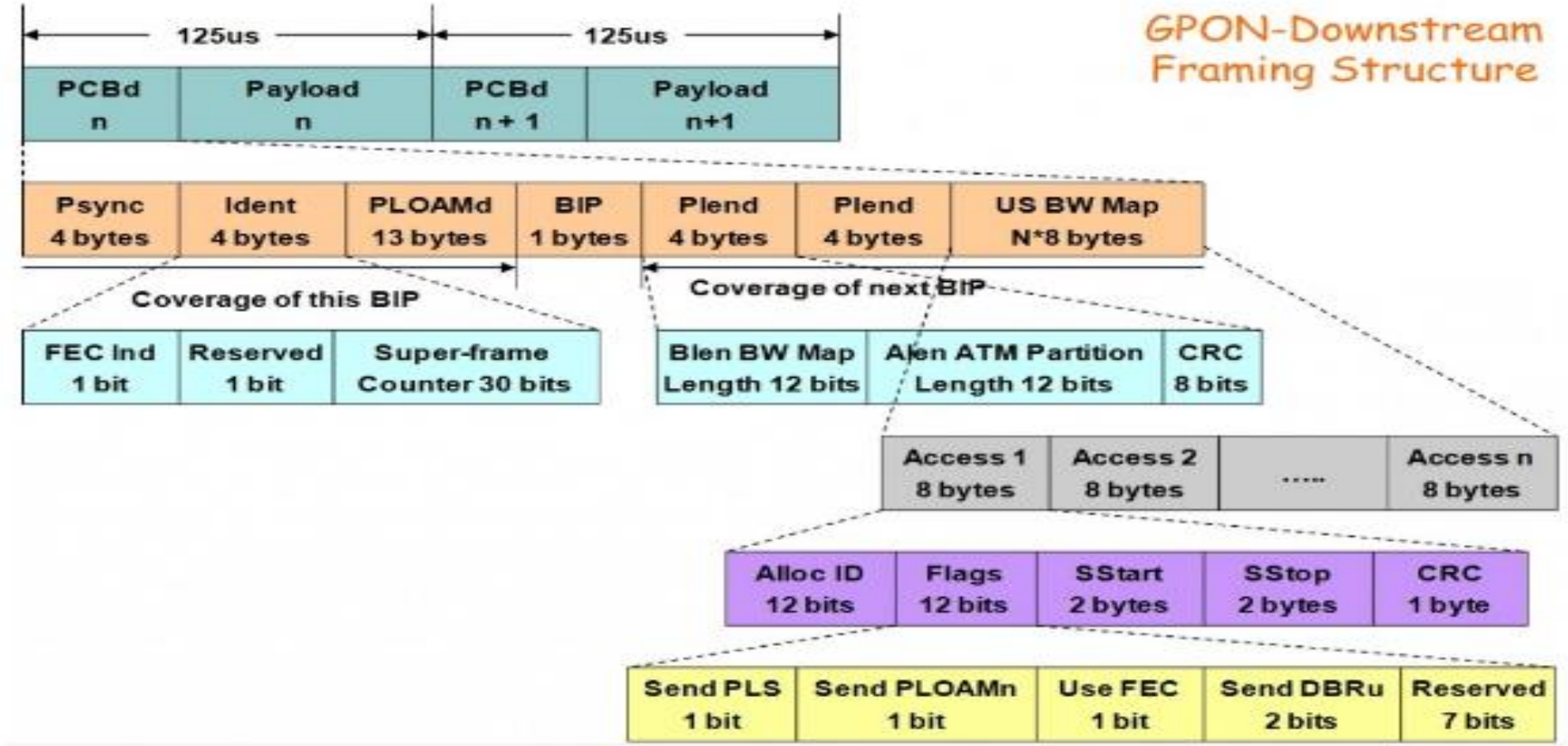
- Split ratio: 1:4, it can be up to1:128

GPON Principle - Downstream Data



- Broadcast mode

Downlink frame structure



Downstream Framing structure

Downlink frame structure

- ***Psync***: Synchronization for olt and onu.(4 bytes)
- ***Ident:*** MSB indicates if FEC is used, 30 LSBs are superframe counter.

  1bit FEC（Forward Error Correction）Ind + 1bit reserve + 30bits Super- frame Counter. (4 bytes)
- ***PLOAMd:*** *carries OAM, ranging, alerts, activation messages, etc. GPON uses PLOAMd as control channel. 1Byte (8bits) ONUid + 1Byte (8bits) message segment + 10Bytes Content body + 1Byte (8bits) CRC checksum bits. (13 Bytes)*
- ***Bip:*** SONET/SDH-style Bit Interleaved Parity of all bytes since last BIP.(1 Byte)
- ***PLend:*** *(4 Bytes)* Transmitted twice for robustness, including three parts:
  - Blen – 12 MSB are length of BW map in units of 8 Bytes
  - Alen – Next 12 bits are length of ATM partition in cells
  - CRC – final 8 bits are CRC over Blen and Alen

Downlink frame structure contd…

- ***US BW map***: The array of Blen 8Bytes structures granting BW to US flow, telling in which time segment the ONT should transmit the data.

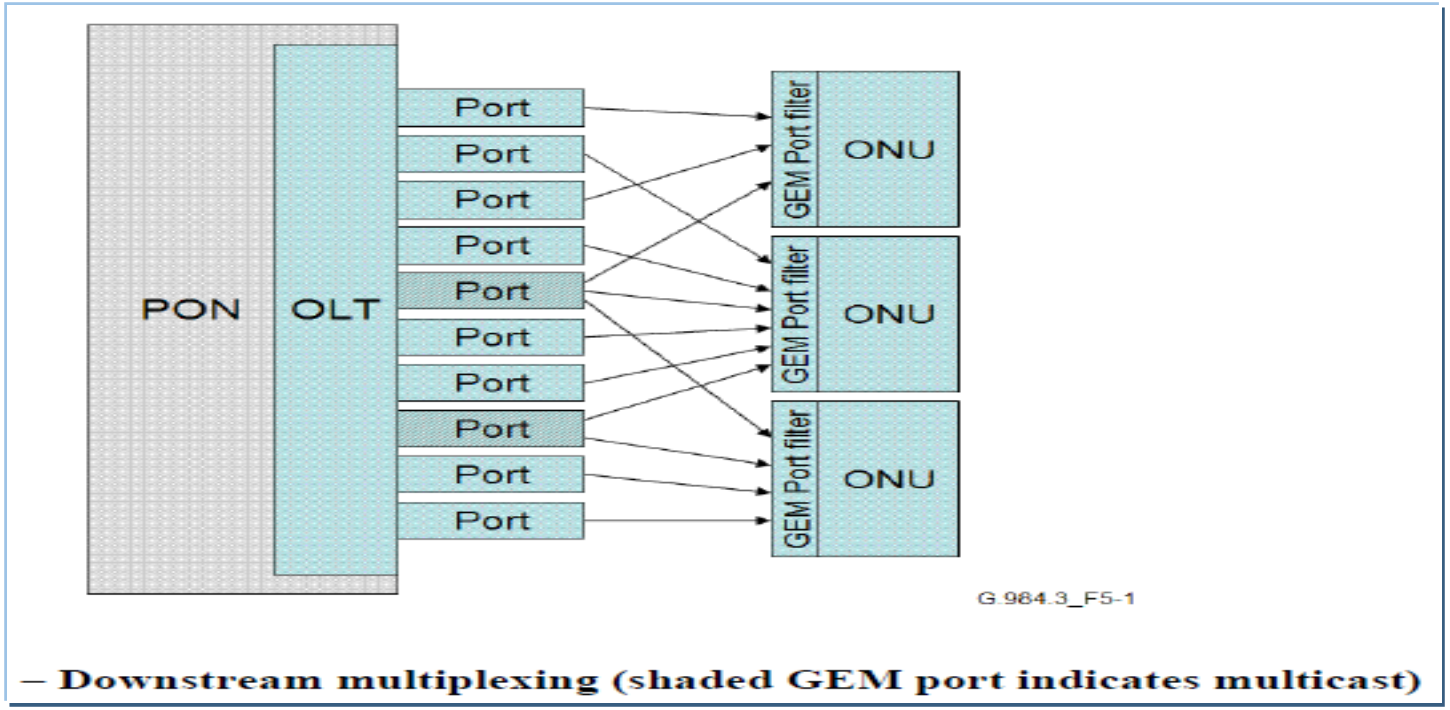
  Each access 8Bytes defines a time message. BWmap is sent by OLT to ONUs, including a list of these fields:

  - **Alloc-id** : ONU allocation IDs
  - **Flags:** Used to indicate the behavior of ONU, such as, next uplink data transmission(PLOAMu, PLSu, DBRu etc).
  - **S-start, S-stop** : start and stop times (16bits fields, in Bytes from beginning of US frame)
  - **CRC** : CRC(cyclic redundancy check) Checksum.

GPON TDM down stream

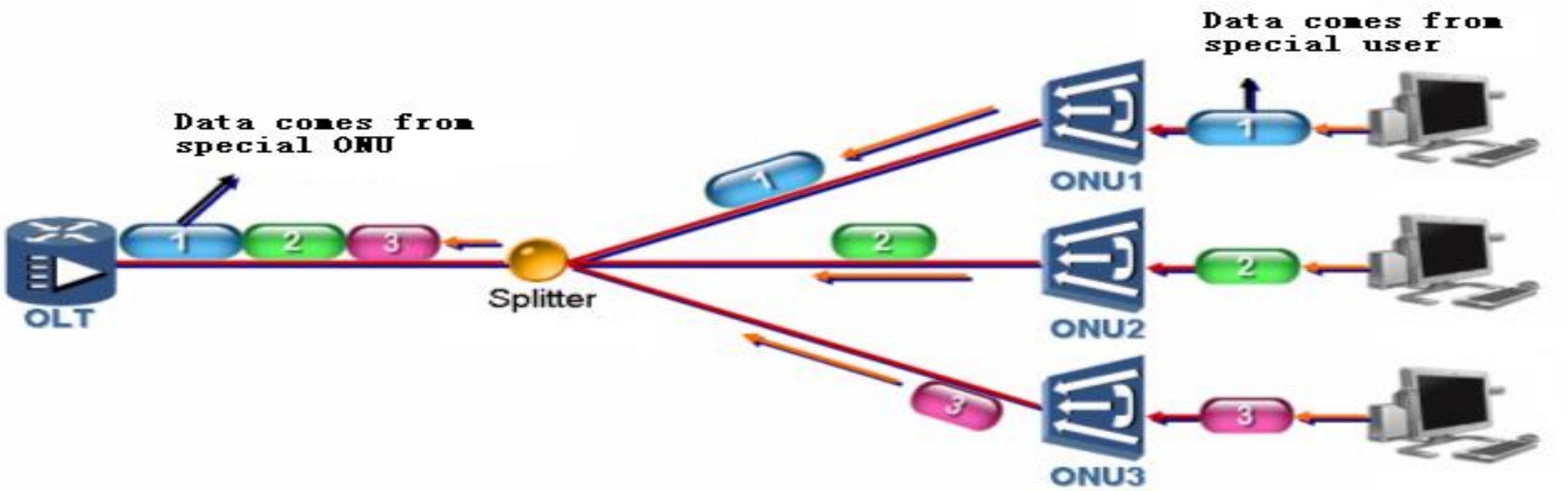
- The OLT multiplexes the GEM frames onto the transmission medium using GEM Port-ID as a key to identify the GEM frames that belong to different downstream logical connections.

- Each ONU filters the downstream GEM frames based on their GEM Port-IDs and processes only the GEM frames that belong to that ONU.



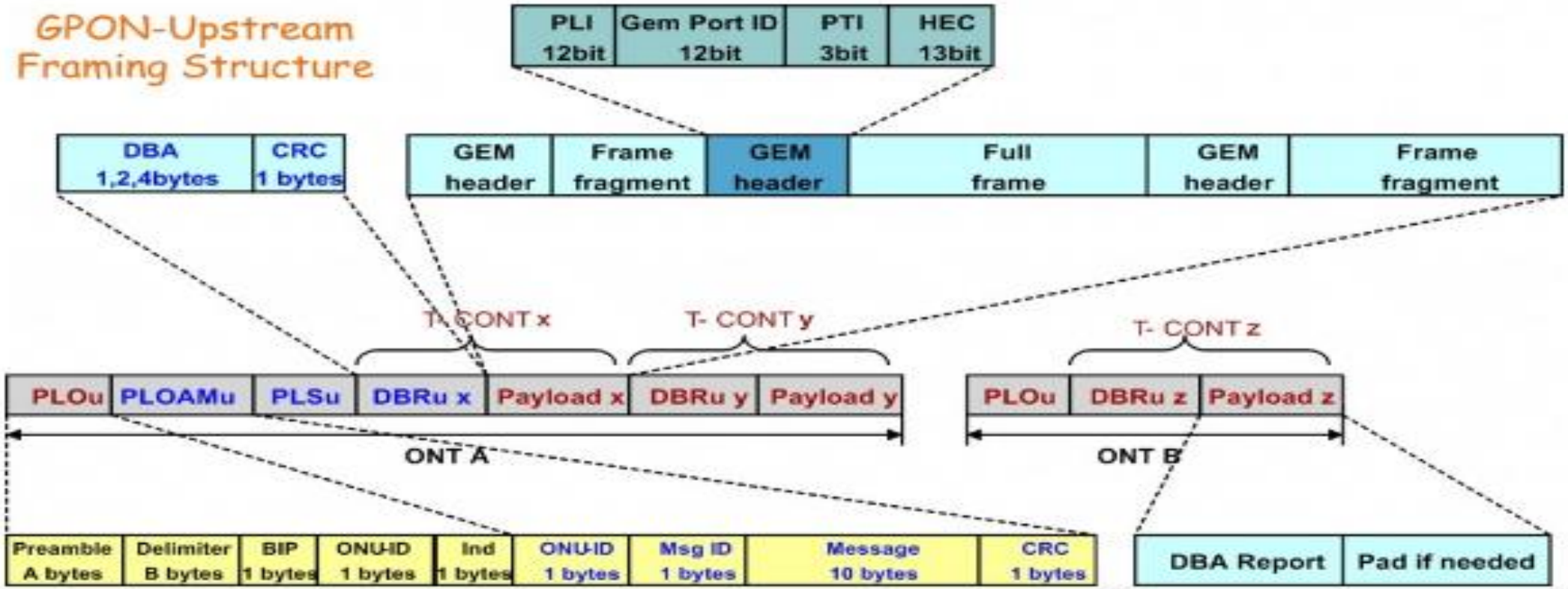
– Downstream multiplexing (shaded GEM port indicates multicast)

GPON Principle - Upstream Data



- TDMA mode

Upstream(US) frame format



GPON Upstream Framing structure

Upstream(US) frame format

- There are 4 different US overhead types:
- **PLOu**: Physical Layer Overhead upstream
  - always sent by ONU when taking over from another ONU
  - contains preamble and delimiter (lengths set by OLT in PLOAMd)

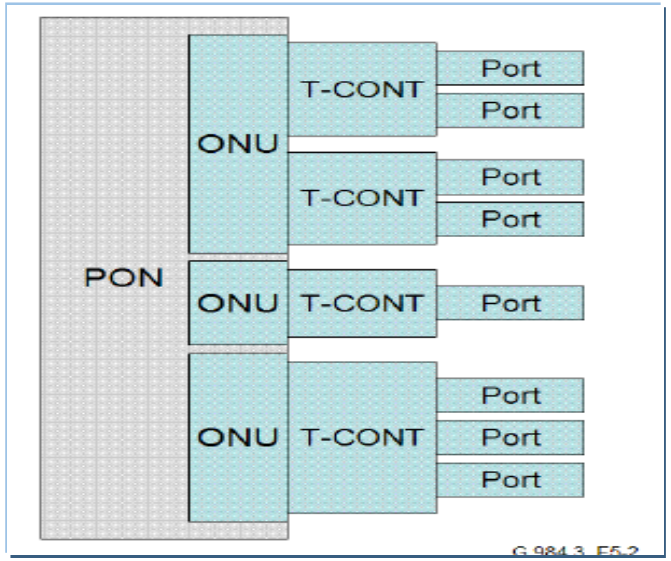
  BIP (1B), ONU-ID (1B), and Indication of real-time status (1B)
- **PLOAMu**: PLOAM upstream (13B) – messaging with PLOAMd
- **PLSu**: Power Levelling Sequence upstream (120B)
  - used during power-set and power-change to help set ONU power so that OLT sees similar power from all ONUs
- **DBRu**: Dynamic Bandwidth Report upstream
  - sends traffic status to OLT in order to enable DBA computation
- **Payload**： Payload data, may be a data frame or DBA status report， Payload=（DBA Report+Pad）/（Gem Header+Gem Frame)

GPON TDM Up stream

- The OLT grants upstream transmission opportunities, or *upstream bandwidth allocations, to the traffic-bearing* entities within the subtending ONUs.

- Upstream bandwidth allocations are identified by their allocation IDs (Alloc-IDs). >The bandwidth allocations to different Alloc-IDs are multiplexed.

- Within each bandwidth allocation, the ONU uses the GEM Port-ID as a multiplexing key to identify the GEM frames that belong to different upstream logical connections.



GEM

- GEM（GPON Encapsulation Mode) delineated frames may have any length, any number of GEM frames may be contained in the GEM partition.
- ONUs accept GEM frames based on 12b Port-ID in GEM header
  - GEM is generic – any packet type (and even TDM) supported
  - GEM supports fragmentation and reassembly

- GEM（**G**PON **E**ncapsulation **M**ode） is based on GFP, and the header contains the following fields:
  - **PLI**: Payload Length Indicator – payload length in Bytes
  - **Port ID** : Identifies the target ONU
  - **PTI**: Payload Type Indicator (GEM OAM, congestion/fragmentation indication)
  - **HEC**: Header Error Correction field (BCH(39,12,2) code+ 1b even parity)

GPON Transmission Convergence (GTC)

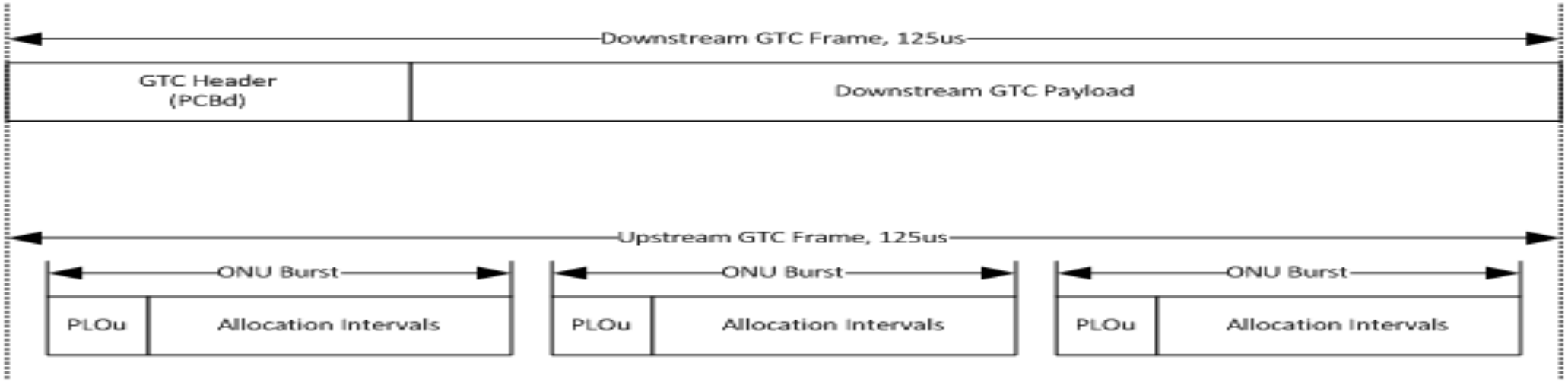


Figure 3. GTC Layer Framing

- GPON TC layer is equivalent to Data Link layer of OSI model.
- It specifies GPON frame format, the media access control protocol, OAM processes and information encryption method.

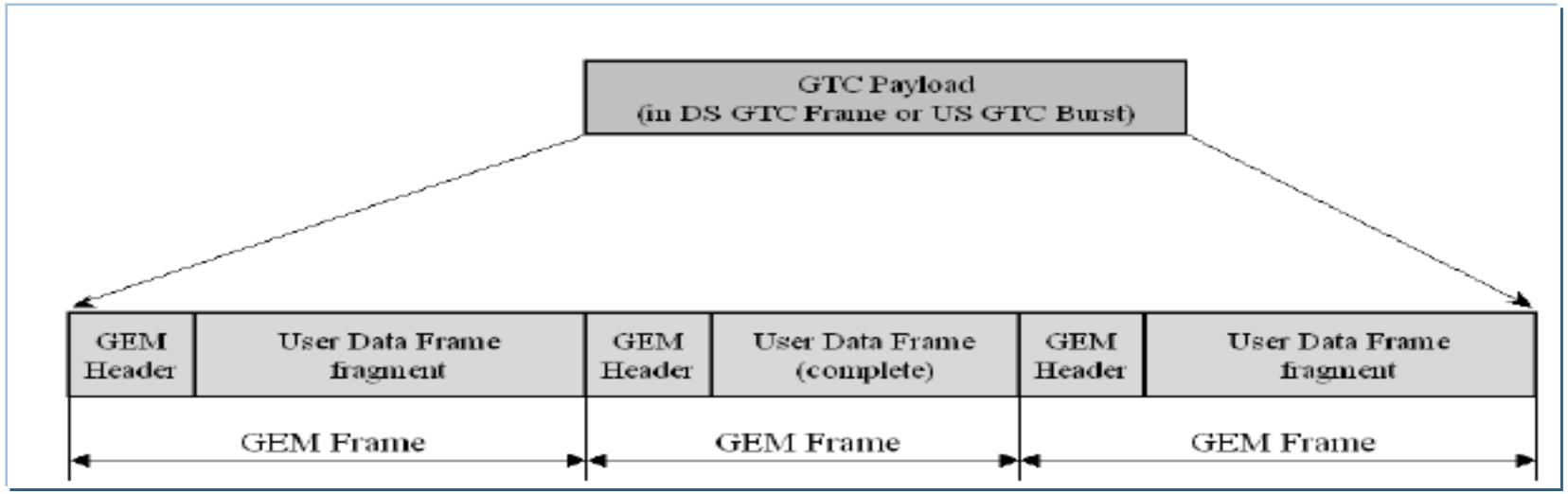
GPON Transmission Convergence (GTC) contd…

- The downstream GTC frame consists of the physical control block downstream (PCBd) and the GTC payload section.
- The upstream GTS frame contains multiple transmission bursts.
- Each upstream bursts consists of the upstream physical layer overhead (PLOu) section and one or more bandwidth allocation intervals associated with a specific ALLOC_ID.
- The downstream GTC frame provides the common time reference for the PON and common control signaling for the upstream.

Mapping of GEM frames into GTC payload

- GEM traffic is carried over the GTC protocol in transparent fashion. The GEM protocol has two functions:
    1. To provide delineation of the user data frames
    2. To provide the port identification for multiplexing.

- Note that the term 'user data frames' denotes frames either going to or coming from a user.



T-CONT

- Transmission container (T-CONT) is a service carrier in the upstream direction in the GPON system.
- All GEM ports are mapped to T-CONTs. Then service streams are transmitted upstream by means of OLT's dynamic bandwidth allocation (DBA) scheduling.
- T-CONT is the basic control unit of the upstream service stream in the GPON system.
- Each T-CONT is identified by Alloc-ID. The Alloc-ID is allocated by the GPON port of the OLT, and the T-CONTs used by ONUs connected to the same GPON port of OLT cannot have the same Alloc-IDs
- There are five types of T-CONT :
  - Type-1
  - Type-2
  - Type-3
  - Type-4
  - Type-5

T-CONT

- Type 1:
  - The fixed bandwidth is reserved for specific ONUs or specific services on ONUs. It cannot be used by other ONUs even if no upstream service streams are carried on the specific ONUs.
  - It applies to services that are sensitive to service quality. The services can be TDM or VoIP services.

- Type 2:
  - The assured bandwidth is available at any time required by an ONU. When the bandwidth required by the service streams on the ONU is smaller than the assured bandwidth, the system can use the DBA mechanism to allocate the remaining bandwidth to services on other ONUs.
  - Because DBA is required, this type provides a less real-time performance compared with the fixed bandwidth.

T-CONT

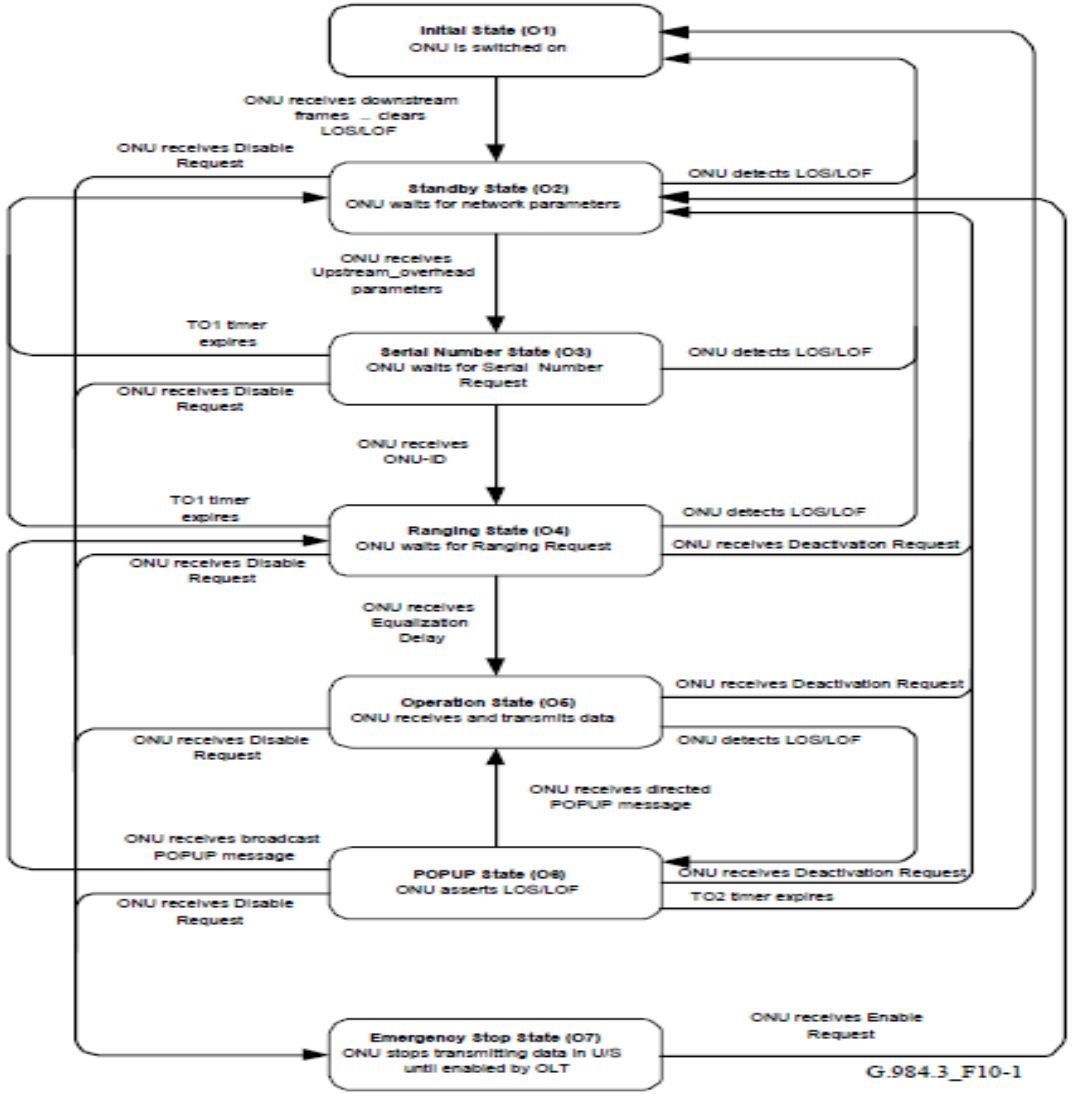
- Type 3:
  - This type is the combination of the assured bandwidth and maximum bandwidth. The system assures some bandwidth for subscribers and allows subscribers to preempt bandwidth. However, the total used bandwidth cannot exceed the maximum configured bandwidth.
- Type 4:
  - This type is the maximum bandwidth that can be used by an ONU, fully providing the bandwidth required by the ONU.
- Type 5:
  - This type is the combination of the fixed, assured, and maximum bandwidth.

    (Currently not supported)

ONU Activation

- It has 3 phase:
  - **Parameter learning**- ONU is in passive state acquiring the operating parameters to be used in the upstream transmission
  - **Serial number acquisition**- OLT discovers new ONU by its serial number and assigns an unique ONU-ID.
  - **Ranging**- equalization delay (EqD) is given to each ONU based on the RTD(round time delay)

ONU Activation



ONU Identifier

- ONU-ID is the 8-bit identifier that the OLT assigns to an ONU during the ONU's activation using the PLOAM messaging channel.
- The ONU-ID is unique across the PON and remains valid until the ONU is powered off, deactivated by the OLT, or moves itself into an inactive state

The following table presents the semantics of the ONU-ID values.

ONU-ID	Designation	Comment
0..253	Assignable	Assigned by OLT at ONU activation; used to identify the sender of an upstream burst or a PLOAMu, and to address PLOAMd.
254	Reserved	Should not be assigned, as it conflicts with the Alloc-ID usage.
255	Broadcast/unassigned	Broadcast address in PLOAMd; unassigned ONU in PLOAMu.

Allocation Identifier (ALLOC_ID)

ALLOC_ID is a 12-bit number that the OLT assigns to an ONU to identify a traffic-bearing entity that is a recipient of upstream bandwidth allocations within that ONU. This traffic-bearing entity is also called T-CONT.

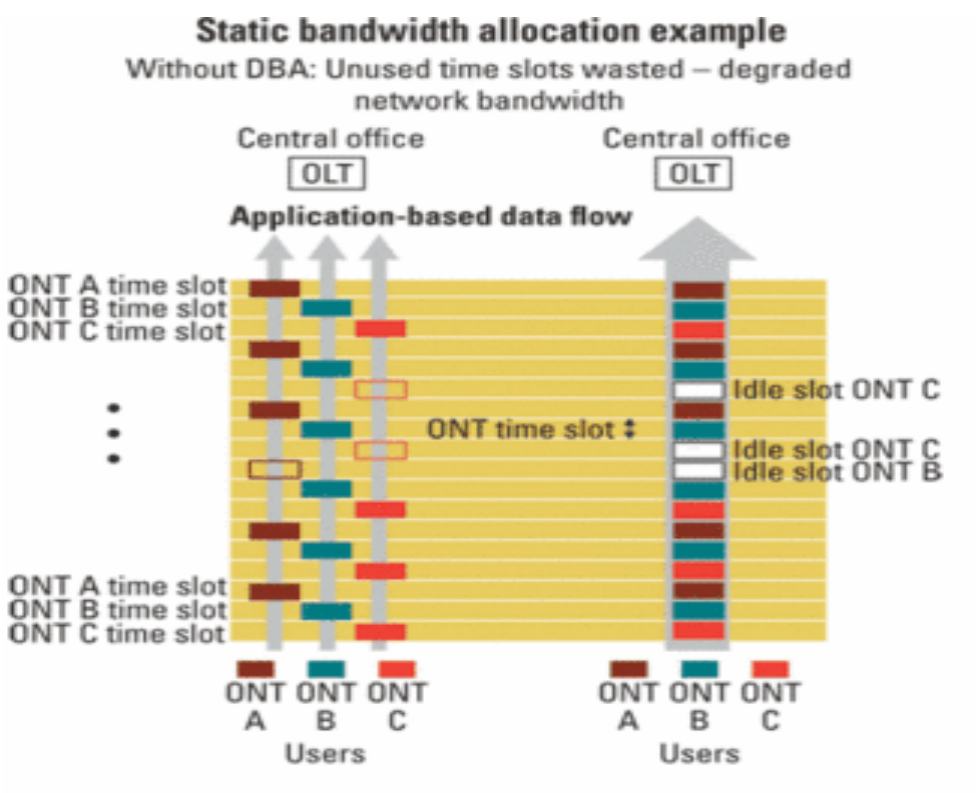
Each ONU is assigned a default ALLOC_ID which is equal to that ONU's ONU-ID, and may be assigned additional ALLOC_IDs as per OLT's discretion.

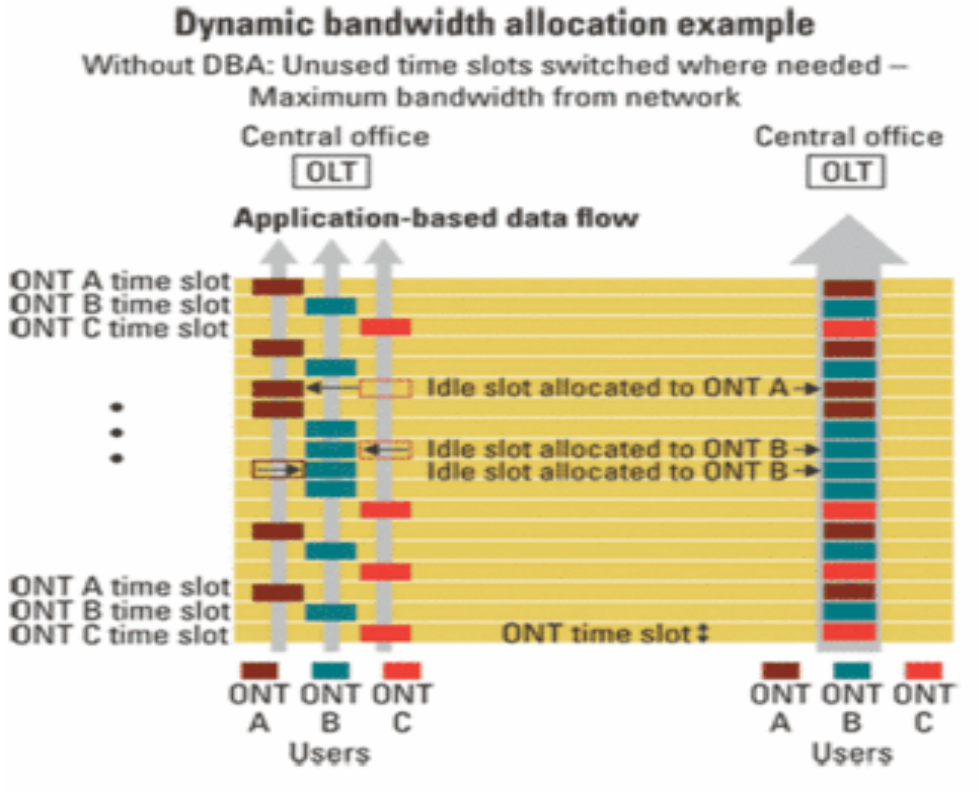
Alloc-ID	Designation	Comment
0..253	Default	Default Alloc-ID, which is implicitly assigned with and is equal to the ONU-ID.
254	Broadcast	Used by OLT in a serial number request allocation structure to indicate that any ONU executing the serial number acquisition phase of the activation procedure may use this allocation to transmit a serial number response.
255	Unassigned	May be used by the OLT to indicate that a particular allocation structure should not be used by any ONU.
256..4095	Assignable	If more than a single Alloc-ID is needed for an ONU, the OLT assigns additional Alloc-IDs to that ONU by selecting a unique number from this range and communicating it to the ONU using the Assign_Alloc-ID PLOAM message.

Dynamic Bandwidth Allocation

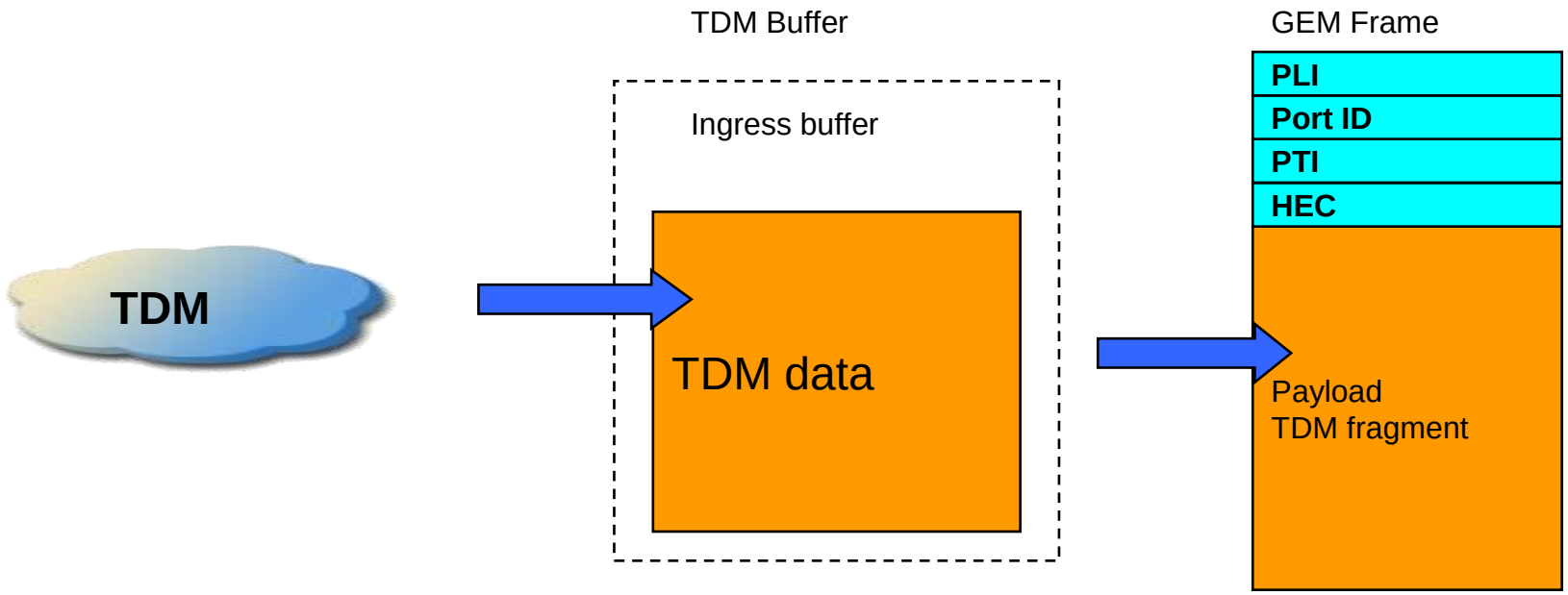
- MANs and WANs have relatively stationary BW requirements due to aggregation of large number of sources.
- But each ONU in a PON may serve only 1 or a small number of users.
- So BW required is highly variable.
- It would be inefficient to statically assign the same BW to each ONU
- So PONs assign dynamically BW according to need.
- The need can be discovered
  - by passively observing the traffic from the ONU
  - by ONU sending reports as to state of its ingress queues
- The goals of a Dynamic Bandwidth Allocation algorithm are
  - maximum fiber BW utilization
  - fairness and respect of priority
  - minimum delay introduced

Dynamic Bandwidth Allocation



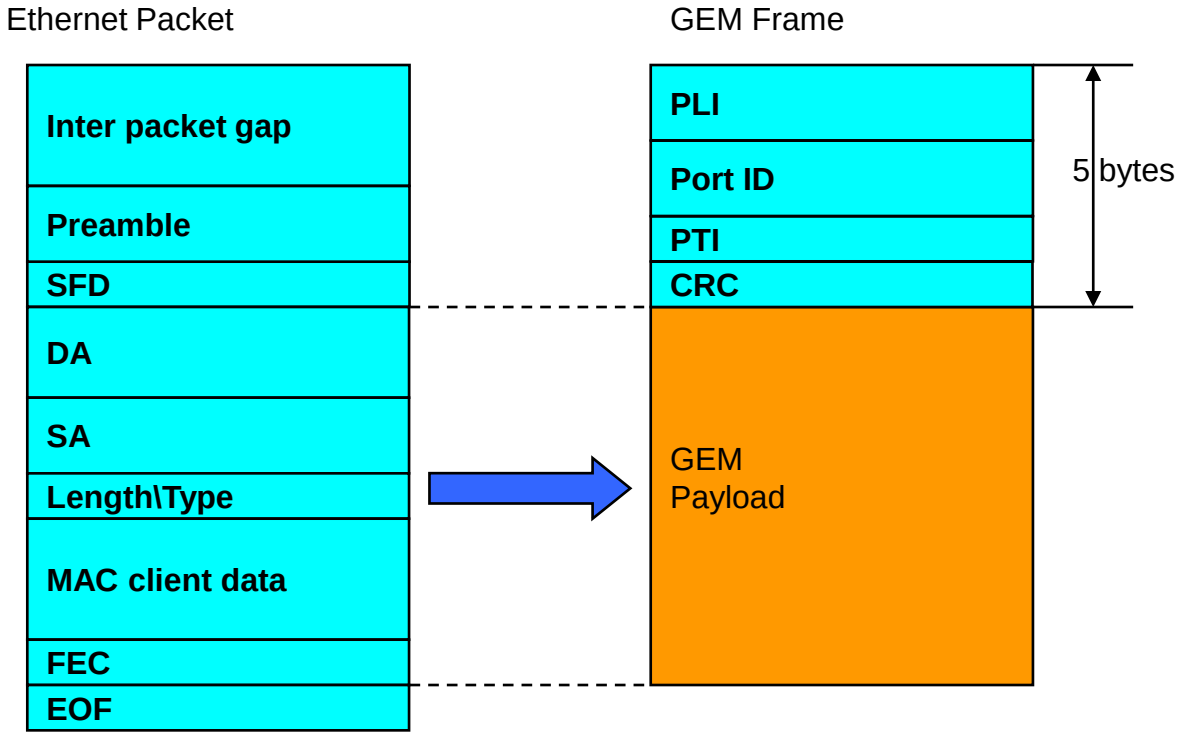


Mapping of TDM Service in GPON



- 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.

Types of services in GPON

- The Fiber to the Home can be best supported with GPON technology as it best supports triple play (voice, video, data) services.
- It can provide the following services:
  - HSI (High Speed Internet)
  - VoIP (voice over IP)
  - IPTV
  - WiFi
  - VBES

VoIP

- **What is Voice over IP?**

  Voice over Internet Protocol (VoIP) technology lets you use the Internet to make and receive telephone calls.

- **What is Voice over IP?: The Range of Services**

  VoIP is available in a wide range of services. Some basic, free VoIP services require all parties to be at their computers to make or receive calls. Others let you call from a traditional telephone handset or even a cell phone to any other phone.

- **What is Voice over IP?: Equipment**

  For VoIP, you need a broadband Internet connection, plus a traditional phone and an adapter; a VoIP-enabled phone; or VoIP software on your computer.

- **What is Voice over IP?: Security and Service Quality**

  Most consumer VoIP services use the Internet for phone calls. But many small businesses are using VoIP and unified communications on their private networks. That's because private networks provide stronger security and service quality than the public Internet.

IPTV

- IPTV system is based around a set top box or an equivalent such as a computer
- This receives the incoming data and re-assembles the data packets and decodes them to provide the required output for passing on to a television or other form of screen for viewing
- There are two basic ways in which the material for IPTV can be handled. It can be sent out as broadcast or "multicast" material to many users simultaneously or it can be used to provide video-on-demand where the material is sent to just one subscriber who has requested that particular item
- The core for any IPTV system is the operator's central distribution center. Here the material is assembled and encoded
- Once encoded, the video stream is split into packets, so that it can enter the IP network system and routed to the relevant destination or destinations
- The video streams consisting of these packets then travel from the center of the network to outlying local exchanges and routing centers before being routed on to the individual subscribers
- It is typically at these local centers that where authentication, channel change requests, billing and video-on-demand requests are handled.

IPTV contd…

Channel selection

- One important aspect of multicasting is the ability of the system to be able to select the required channel and change it as required.
- In order that vast amounts of data are not set to the set top box, or any other form of IP receiver, one a single channel is sent to a given receiver.
- Channel selection is accomplished by using a special protocol known as IP Group Membership Protocol (**IPGMP**). This is a communications protocol used to manage the membership of Internet Protocol multicast groups
- It is used by IP hosts and adjacent multicast routers to establish multicast group memberships
- When a local routing center receives a request to receive multicast data or to change from one channel to another, it checks to ensure that the user is authorized to connect to the channel and then it directs its routers to add the particular user to its distribution list
- In this way only the channels that are being used are routed to the receiver, and this saves enormous amounts of data.

IPTV contd…

Unicast/Video on demand

- In order that users can connect to a video on demand service a different set-up is needed
- The local server operates in a fashion that enables single streams of data to be drawn off as required and it is controlled using a different protocol to that used for multicasting is used
- Known as Real Time Streaming Protocol, RTSP, it controls the data stream and allows DVD-style control over the media stream, enabling the user to play, pause and stop the programme being watched.

WiFi

- Wi-Fi stands for Wireless Fidelity. It is a technology for wireless local area networking with devices based on IEEE 802.11 standards.
- Wi-Fi compatible devices can connect to the internet via WLAN network and a wireless **access point** abbreviated as AP.
- Every WLAN has an access point which is responsible for receiving and transmitting data from/to users.
  IEEE has defined certain specifications for wireless LAN, called **IEEE 802.11** which covers physical and data link layers.
- There are two general types of Wi-Fi transmission
  1. DCF (Distributed Coordination Function)
  2. PCF (Point Coordination Function)

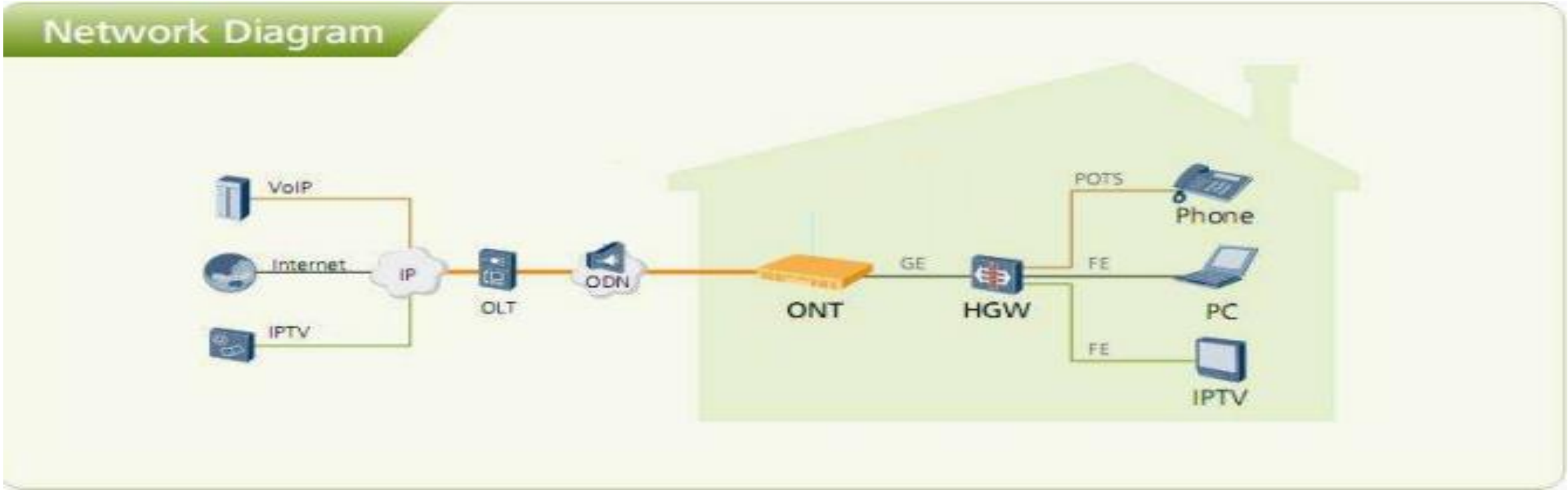
DCF is Ethernet in the air. It employs a very similar packet structure, and many of the same concepts.

PCF, it is a polling, token-ring type communcation system. It isn't much used.

VBES

- VBES works similar to HSI
- Instead of just using one VLAN here we can use up to 10 VLANS

An application of GPON



In this example an ONT is connected in a villa and it support HSI, IPTV and VOIP.
A single ONT will provide all the mentioned services to the customers.

Limitations

- GPON provides 2.5 Gb/s downstream and up to 1.25 Gb/s upstream capacity and hence systems struggle with providing 100 Mb/s service and certainly cannot cope with Gb/s rates at all.
- Costly, due to the number of components involved and the fact they require a greater number of street cabinets.

What next?? – NGPON1

- NG PON1/XGPON delivered performance that was at least four times better than GPON
- It provided for 10 Gb/s downstream and a range of upstream speeds including the possibility of 10Gb/s
- But NG PON1 faced the following limitations

1. Costly because operators had to buy completely new equipment
2. Relied on TDM technology, which allocates time slots on an optical signal to individual users

NGPON2

- NGPON2 is relatively simple
- It involves stacking multiple NGPON1 systems on a fiber network, using time and wavelength division multiplexing (TWDM) techniques to ensure they work together.
- This combines multiple signals onto a single optical fiber by using the different wavelengths (i.e. colours) of laser light, and then splits transmission into time slots, in order to further increase capacity.
- Main advantages of NGPON2 are

1. **Cost effective-** it can co-exist with existing GPON
2. **High speed-** minimum of 40 Gb/s downstream capacity & 10 Gb/s total upstream capacity

(can be doubled to provide 80 Gb/s downstream and 20 Gb/s upstream in the "extended" NGPON2)

3. **Symmetrical upstream/downstream capacity-** For business users with data mirroring and similar requirements, a symmetric implementation will be provided giving 40/40 and 80/80 Gb/s capacity respectively.

Quiz

- The differential reach between ONTs is
  a)60km b)20km c)40km d)30km
- The maximum splitter ratio can be
  a)1:4 b)1:100 c)1:128 d)1:64
- The fiber mode used in GPON is _____
- Downstream bandwidth is
  a)2.5Gbps b)1.25Gbps c)2.25Gbps d)1.5Gbps
- Upstream Bandwidth is
  a)2.5Gbps b)1.25Gbps c)2.25Gbps d)1.5Gbps
- Psync has _____ bytes
- Wavelength of Upstream traffic is _____
- Each ONT is assigned a unique _____
  a) ONU-ID b) allocation ID c) Gem port ID d) none

ACRONYMS

- **PON**- Passive Optical Network
- **GPON**- Gigabit Passive Optical Network
- **ONT**- Optical Network Terminal
- **OLT**- Optical Line Terminal
- **ONU**- Optical Network Unit
- **ODN**- Optical Distribution Network
- **HSI**- High Speed Internet
- **VoIP**- Voice Over IP
- **IPTV**- Internet Protocol Television
- **WiFi**- Wireless Fidility
- **RTD**- Round Trip Delay
- **WAN**- Wide Area Network
- **MAN**- Metropolitan Area Network
- **TDM**- Time Division Multiplexing
- **PSTN**- Public Switched Telephone Network
- **NGPON**- Next Generation PON
- **WDM**- Wavelength Division Multiplexing
- **GEM**- GPON Encapsulation Mode
- **GTC**- GPON Transmission Convergence
- **OAM**- Operation Administration & Maintenance

Reference

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Thank You