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GPON and XGPON

(Gigabit Passive Optical Network and 10 Gigabit Passive Optical Network)

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Fiber to The Home (FTTH)

Introduction

- When optical fiber from a central point is installed and used directly to individual buildings such as residences, apartment buildings and businesses so that unprecedented high-speed Internet access is provided, it is called FTTH.
- Another name given to FTTH is Fiber to The Premises (FTTP).
- The available connection speeds to the computer users has increased using FTTH as compared to that provided by many other technologies used.

(contd...)

Introduction

- Up to 100 Mbps of connection speed is promised by FTTH which is 20-100 times faster as compared to that provided using a cable modem or DSL connection.
- The only disadvantage of FTTH is its high installation cost.
- New cable sets have to be installed in FTTH over the last links from existing optical fiber cables to individual users.

Need for FTTH

- There are number of advantages of FTTH over copper, such as:
  - Large capacity of carrying information
  - Easily upgradeable
  - Easy to install
  - Fully symmetric services are allowed
  - Less cost of operation and maintenance
  - Long distance coverage

(contd...)

Need for FTTH

- Strong, flexible, and reliable
- Small diameter and lightweight cables
- Safe and secure
- Electromagnetic interference (EMI) immunity
- Lower handling cost

Services Provided by FTTH

- Download speed of 10 Mbps.
- 1 Mbps for VoIP and video-conference
- 2 Mbps for music on demand, multimedia contents
- Online gaming at 1 Mbps
- Speed for SD digital TV is 3 Mbps
- Speed for HD digital TV is 8 Mbps
- 16 Mbps for additional TV channels

FTTH Terminologies

- Differential Fiber Distance
  - The difference in the distance between the nearest and the farthest Optical Network Unit/Optical Network Terminal from the Optical Line Termination is called Differential Fiber Distance.
  - The maximum differential fiber distance in GPON is 20 kms.
  - Hence, the size of the ranging window has been affected.
  - It is according to the ITU-T G.983.1.

(contd...)

FTTH Terminologies

- Logical Reach
  - The maximum distance covered for a particular transmission system is called logical reach.
  - It is the maximum distance between ONU/ONT and OLT without considering the physical layer limitation.
  - The maximum logical reach in GPON is 60 kms.

(contd...)

FTTH Terminologies

- Mean Signal Transfer Delay
  - The average of delay values of the upstream and downstream between the reference points is called mean signal transfer delay.
  - The round-trip delay measurement and then divide by 2 determines this value.
  - Only those services are accommodated by GPON in which a maximum mean signal transfer delay of 1.5 ms is required.

(contd...)

FTTH Terminologies

- Optical Access Network (OAN)
  - An access network towards the network side is called optical access network.
  - It is also known as Service Network Interface (SNI).
  - OLT's uplink ports are connected to L2 Switch Ring of access network.
  - All other in-between components are considered as a part of OAN.

(contd...)

FTTH Terminologies

- Optical Distribution Network (ODN)
  - Optical Distribution Network constitutes all passive components from the PON Port of OLT to the PON Port of ONT towards downstream side in a PON Technology.
  - This category includes splitter and ODF/FDMS.

(contd...)

FTTH Terminologies

- Optical Line Termination (OLT)
  - The various network interfaces are provided to PON by a Central Office (CO) equipment.
  - The multiple ONTs are served by one OLT through downstream transmission (from OLT to ONT) by PON.
  - TDMA is used for upstream traffic (from ONT to OLT).
  - PON system may be either symmetrical or asymmetrical.

(contd...)

FTTH Terminologies

- Optical Network Termination (ONT)/ Optical Network Unit (ONU)
  - An ONT is a Customer Premises Equipment by which user interfaces are provided to the customers.
- Service
  - It is a frame structure name or a general name used as a network service required by the operators.

(contd...)

FTTH Terminologies

- Physical Reach
  - The maximum physical distance achieved for a particular transmission system i.e. between ONU/ONT and the OLT is called physical reach.
  - There are two options for physical reach in GPON i.e. 10 km and 20 km.

(contd...)

FTTH Terminologies

- Bit Rate
  - The transmission speeds of more than or equal to 1.2 Gbps is aimed by GPON.
  - The two transmission speed combinations are identified by GPON such that
    - 1.2 Gbps upstream, 2.4 Gbps downstream
    - 2.4 Gbps upstream, 2.4 Gbps downstream

(contd...)

FTTH Terminologies

- Split Ratio
  - It signifies the splitting of optical power and bandwidth.
  - A need for increased power budget is created by a larger split ratio that can support the physical reach.
  - For physical layer, the realistic value of split ratios are up to 1:64.
  - The split ratios of upto 1:128 are considered by the TC layer.

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FTTN, FTTC, FTTD

FTTN

- To provide cable telecommunication services for multiple destinations, Fiber to The Node (FTTN) is used.
- The broadband connection and other data services are provided by the FTTN through a common network box, known as a node.
- It is also called Fiber to The Neighbourhood.
- The ability of the system for delivering the data over fiber optic lines which are more efficient is the main benefit of FTTN.

(contd...)

FTTN

- The copper or other types of wire are used to achieve the last mile service from the node to an individual destination.
- In order to deliver data to multiple users, coaxial or twisted-pair cable is often used by FTTN systems.

FTTC

- The direct installation and use of optical fiber cable to the curbs near homes or any business environment is called FTTC.
- This acts as a replacement for plain old telephone service (POTS).
- High bandwidth has been provided by such wiring.
- The last-mile service is provided by FTTC by using the existing coaxial or twisted-pair infrastructures.

(contd...)

FTTC

- Carrying high-speed signals using suitable wires at short distances is the basic idea of this technology.
- The broadband service delivery such as high speed internet is also allowed by FTTC.
- The signal between the customer and the cabinet are transmitted by using high-speed communication protocols.
- The type of protocol used and the distance between the customer and the cabinet changes the data rates accordingly.

Advantages of FTTC

- The existing copper line has been used without any need of digging a new lead-in conduit to run a line into the premises.
- The end-user premises have reverse-powered DPU's due to which the expenses for the designing and implementation of new physical connections to the power grid are saved.
- Both of these advantages save the significant time and money.

Need for FTTC

- It is deeper into the network as compared to FTTN.
- Due to use of existing lead-in, the complex and expensive process is not involved to take fiber to the premises.
- As compared to FTTP, the driving cost of fiber to the premises from the pit is roughly estimated to be 25% to 30%.
- nbn will be the first operator to launch FTTC which are reverse-powered distribution point-based services.

(contd...)

Need for FTTC

- It is estimated that the FTTC will be launched with VDSL technology by driving fiber deep into the network.
- These areas will be upgraded to new copper acceleration technologies like G.fast or XG.FAST.
- FTTC will be used in the semi-rural areas where deployment of FTTN is expensive as more cost is required while providing connection between the power grid and FTTN cabinet.

FTTD

- When there is a distribution of connections of optical fiber to the individual workstations from the central office, system is called Fiber to The Desk.
- Both bandwidth and security are delivered by this solution to the desk.
- Hence, in simple words, the fiber optic infrastructure extension directly to the locations of the users is FTTD.

Advantages of FTTD

- Security
- Bandwidth and distance
- Lower overall cost
- Future proof

Applications of FTTD

- FTTD can be used for:
  - Mission critical networks, virtual networks, and LAN networks
  - Increasing bandwidth availability
  - Moving large amounts of data at high transmission rates
  - Bringing service to locations where power is limited or unavailable
  - Providing more secure connections
  - Enterprises and Business Campuses

(contd...)

Applications of FTTD

- Banks, Online Brokers and other Financial Institutions
- Healthcare Organizations
- Colleges and Universities
- Local, State, and Federal Governments
- Sports and News Broadcast Agencies

Thanks

Types of Fiber

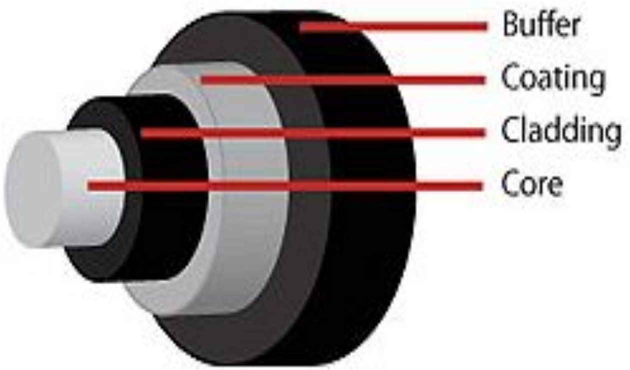
Introduction

- The signals are sent using optical fiber through hair-thin strands made up of glass or plastic fiber.
- There is a guiding of light to the center of fiber which is called the core.
- The cladding is an optical material that surrounds the core and uses optical technique known as total internal reflection to trap the light in the core.
- Ultra-pure glass is used to make the core and the cladding of the fiber.

(contd...)

Introduction

- The primary buffer coating is a protective plastic covering that coats the fiber and protects it from moisture and other damage.
- The fiber is provided with the jacket that provides more protection to the cable as shown in the figure.



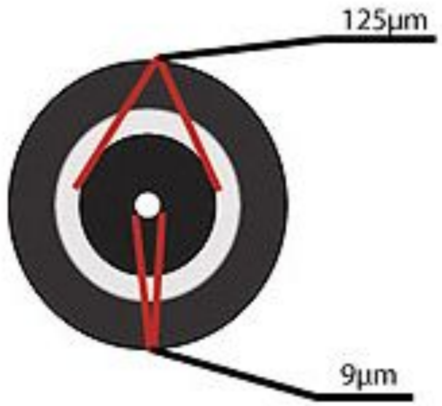
Single Mode Fiber Optic Cable

- The core of single mode fiber optic cable has a small diameter that allows the propagation of only one mode of light through it.
- Hence, there is a decrease in the number of reflections of light when the light passes through the core, attenuation has been lowered and the ability for the signal for further transmission has been created.
- This application requires higher bandwidth and when the signal has to be transmitted to the longer distances.

(contd...)

Single Mode Fiber Optic Cable

- Figure shows that in construction, the single mode fiber is 9/125.
- This implies that the diameter ratio of core to cladding is 9 microns to 125 microns.



Multimode Fiber Optic Cable

- ❑ The core of single mode fiber optic cable has a large diameter that allows the propagation of multiple modes of light through it.
- ❑ Hence, there is an increase in the number of reflections of light when the light passes through the core and the ability for more data to pass through it at a given time has been created.
- ❑ The signal quality over long distances has been reduced due to the high dispersion and attenuation rate with this type of fiber.

(contd...)

Multimode Fiber Optic Cable

- In LANs, for short distance, data and audio/video applications, this application is used.
- RF broadband signals cannot be transmitted over multimode fiber.
- In construction, the multimode fiber is 50/125 and 62.5/125.
- This indicates that the diameter ratio for core to cladding is 50 microns to 125 microns and 62.5 microns to 125 microns.

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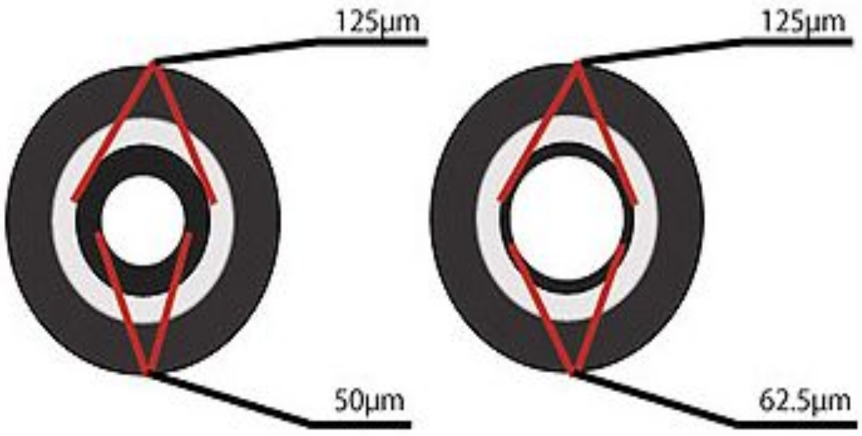
Multimode Fiber Optic Cable

- Figure shows the multimode fiber optic cables with different diameter ratios.



Step-Index Multimode Fiber

- A direct route is followed by some of the light rays while some bounce off the cladding and follow the zigzag path due to the large core of the multimode fiber.
- Hence, the different groups of light rays are caused by these alternate paths due to which they arrive separately at the receiving point.
- The pulse which is an aggregate of different modes, loses its well-defined shape while spreading.

(contd...)

Step-Index Multimode Fiber

- The amount of information that can be sent has been limited due to spacing between the pulses to avoid overlapping.
- This type of fiber suits for transmission of data over short distances.

Graded-Index Multimode Fiber

- It contains a core in which there is a gradual diminishing of the refractive index towards the cladding from the center axis.
- The light rays near the center axis move very slowly as compared to those near the cladding due to high refractive index at the center.
- The travel distance of the graded index fiber is reduced and light in the core curves helically.

(contd...)

Graded-Index Multimode Fiber

- The light at the periphery takes about the same time to arrive at the receiver as that is taken by the slow but straight rays in the core axis due to short path and high speed.
- Hence, less dispersion is suffered by the digital pulse.
- For local-area networks, this type of fiber is basically used.

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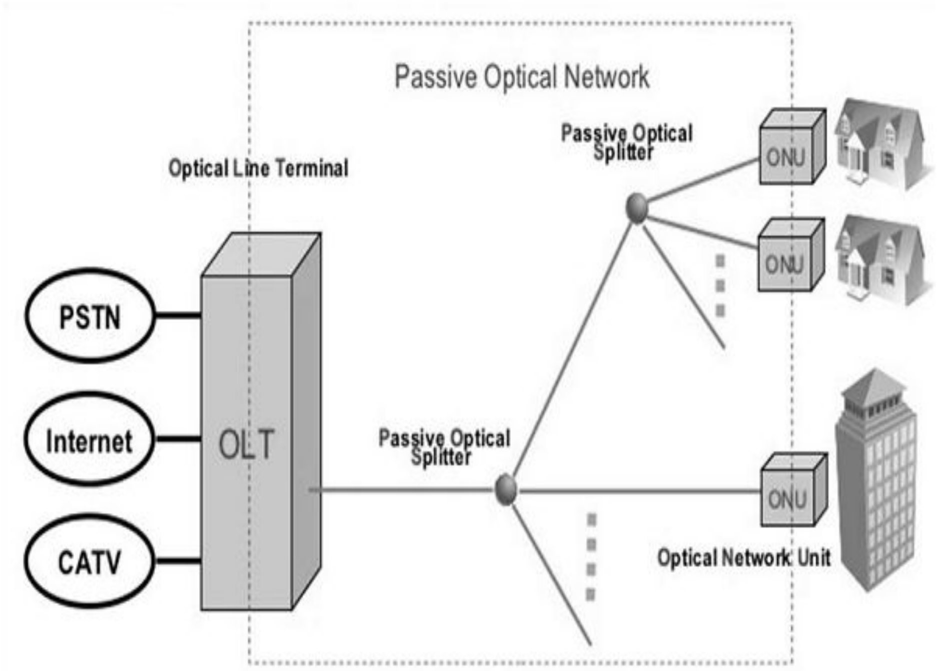
Passive Optical Network (PON)

Introduction

- Passive Optical Network (PON) provides fiber to the end users.
- It has one-to-multiple-point architecture.
- It comprises of Optical Line Terminal (OLT), Optical Network Unit and Passive Optical Splitter as shown in the figure.



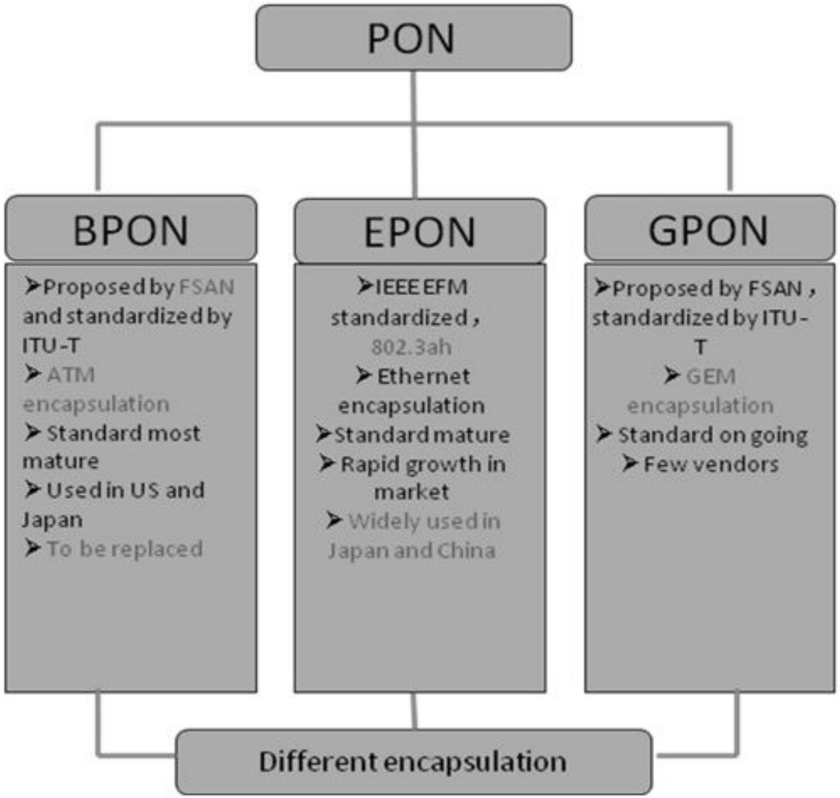
History of PON

- FSAN group initiated the first Passive Optical Network (PON) activity in the mid- 1990s.
- 155 Mbps transmission was covered by the initial standard based on ATM known as the APON/BPON standard.
- There was an enhancement of the standard later on in order to cover 622 Mbps.
- An EPON, an Ethernet based standard, was developed by IEEE in 2001.

(contd...)

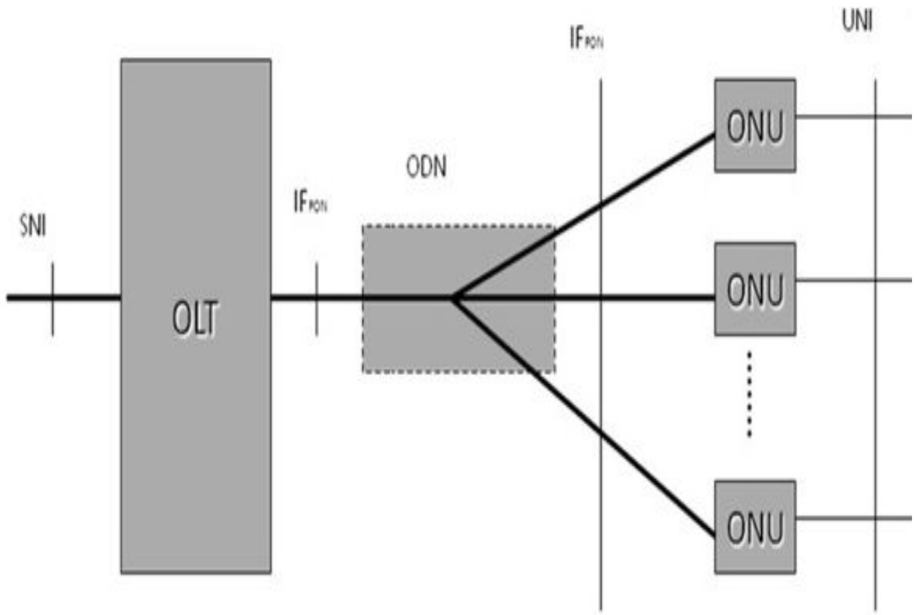
History of PON

- A gigabit speed standard, GPON, was developed by FSAN in 2001 that was ratified by ITU-T.
- Figure shows different PON networks.



Network Architecture

- The network architecture of PON is shown in the figure.
- Here, SNI is Service Node Interface, IFPON is Interface for PON, and UNI is User Node Interface.



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Network Architecture

- It consists of an optical line terminal (OLT), optical network units (ONUs) or optical network terminals (ONTs) and the optical distribution network (ODN).
- OLT is a central office node, ONUs/ONTs are theuser nodes, and ODNs are the fibers and splitters between them.
- The interface between the core network of a PON and a service provider is provided by an OLT.

(contd...)

Network Architecture

- These include:
  - IP traffic over Fast Ethernet, Gigabit Ethernet, or 10 Gigabit Ethernet
  - Standard TDM interfaces such as SDH/SONET
  - ATM UNI at 155–622 Mbps
- The PON is terminated by ONT/ONU that acts as interfaces to the user.
- These include:
  - voice or voice over IP

(contd...)

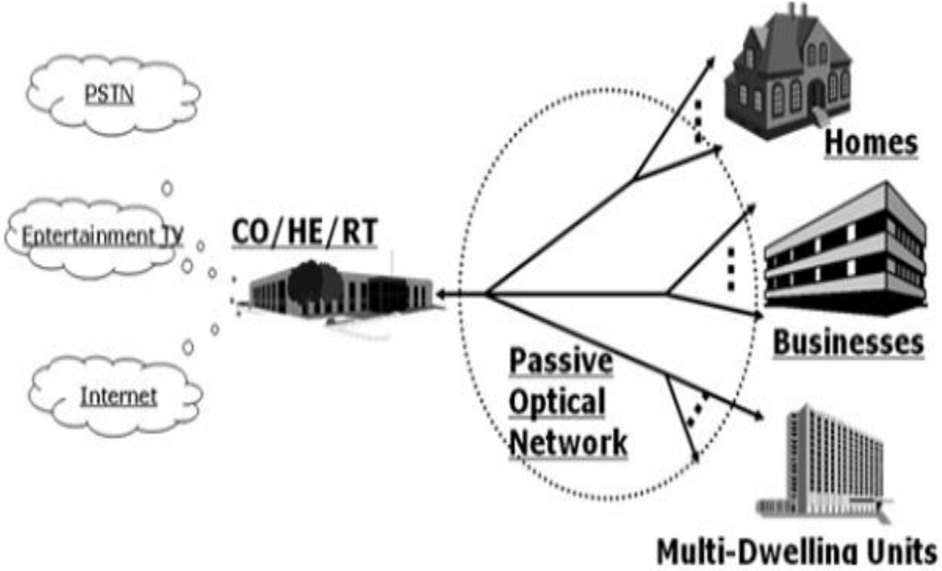
Network Architecture

- video,
- Telemetry

- The functions of ONU are separated into two parts:
  - The ONU towards the user
  - Network termination equipment (NTE)

PON Access Network

- Triple plays (voice, video, & data) services are provided by the cost effective optical fiber based access system of PON for the customers of both the business and the residential.
- Figure shows the PON topologies.



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PON Access Network

- Depending on the customer distribution profile, PON used different types of topologies.
- The connection between ONT and PON can be of any type as long as:
  - Optical budget is met from ONT to OLT & vice-versa
  - Specification of maximum differential distance is met between different ONTs.
  - Allowable range of fiber length from ONT to OLT
  - Limit of maximum number of ONTs cannot exceed.

Passive Modules in PON

- WDM Coupler
- 1 × N Splitter
- Optical fiber and cable
- Connector
- ODF/Cabinet/Subrack

Active Modules in PON

- In OLT
  - Laser transmitter (1490 nm)
  - Laser receivers (1310 nm)
  - For CATV application
  - Laser amplifier (1550 nm)
  - EDFA for amplifying video signal

(contd...)

Active Modules in PON

- In ONU
  - X`Power/Battery for ONU
  - Laser transmitter (1310 nm)
  - Laser receivers (1490 nm)
  - Receivers for CATV signal (1550 nm)

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Gigabit Passive Optical Network (GPON) I

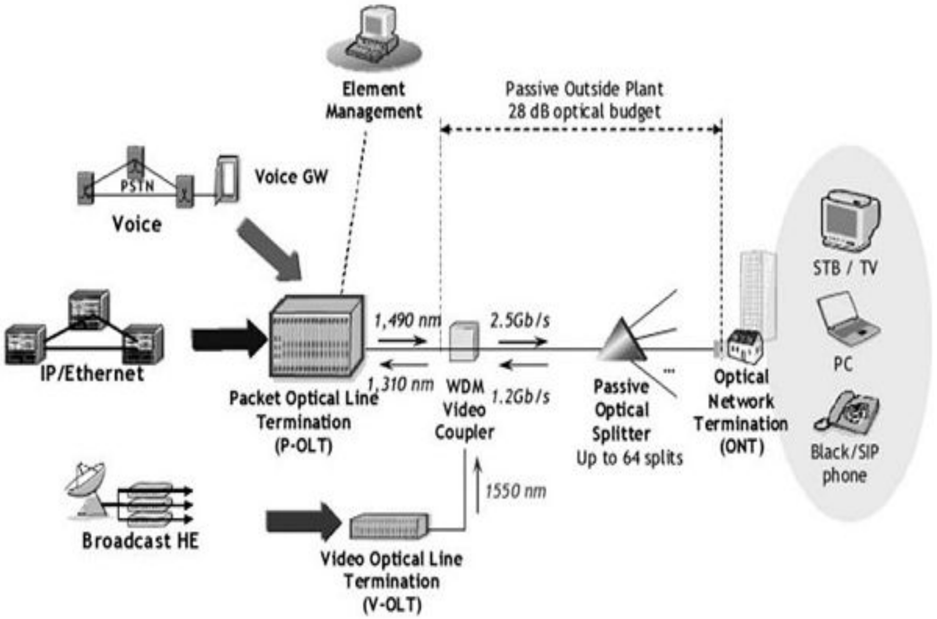
Introduction

- An Optical System for the Access Networks is called GPON (Gigabit Passive Optical Networks) which is based on G.984 series of ITU-T specifications.
- With a 28dB optical budget, a 20 km reach is provided by it by using class B+ optics with 1:32 split ratio.

(contd...)

Introduction

- Figure shows the typical GPON system.



(contd...)

Introduction

- The following rates are supported by GPON:
  - 155 Mbps upstream, 1.24416 Gbps downstream
  - 622 Mbps upstream, 1.24416 Gbps downstream
  - 1.24416 Gbps upstream, 1.24416 Gbps downstream
  - 155Mbps up, 2.48832 Gbps downstream
  - 622 Mbps up, 2.48832 Gbps downstream
  - 1.24416 Gbps up, 2.48832 Gbps downstream
  - 2.48832 Gbps up, 2.48832 Gbps downstream

(contd...)

Introduction

- Both ATM and GEM encapsulation is supported by GPON.
- Both native TDM and Data are supported by GEM (GPON Encapsulation Method).

GPON Features

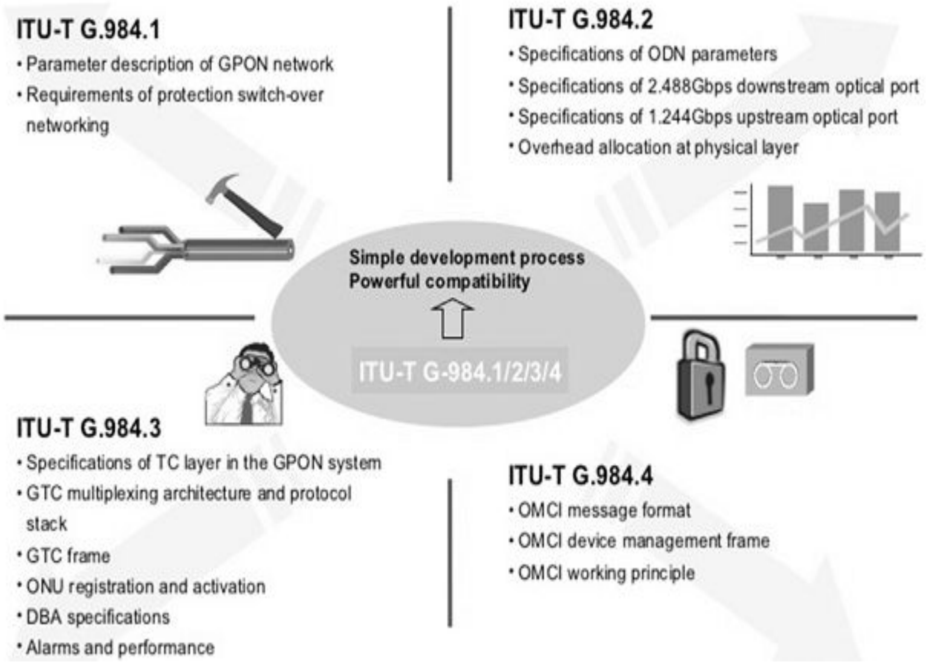
- Downstream transmission
  - 2.4 Gbps
  - BW for one ONT is sufficient for supplying multiple HDTV signals
  - QOS allows to delay sensitive traffic (voice)
- Upstream transmission
  - 1.24 Gbps
  - Guaranteed minimum BW can be
  - Heavy users are assigned with unused time-slots
  - QoS allows to delay sensitive traffic (voice)

Need for GPON

- Triple Play services are supported
- The high-bandwidth transmission is supported by it so that the bandwidth hurdle of the access over twisted pair cables can be broke down.
- The network nodes can be reduced.
- The service coverage of upto 20 km can be supported.

GPON Standards

- The previous BPON specifications are used to build GPON standards.
- The specifications are:
  - G.984.1 – This document describes the Gigabit-Capable Passive Optical Network general characteristics.



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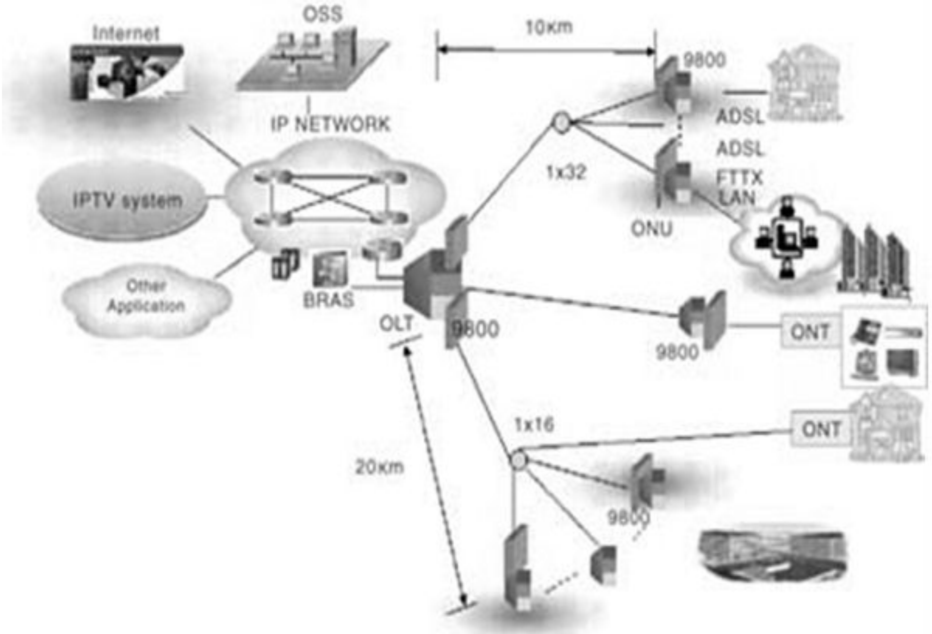
GPON Standards

- G.984.2 – This document describes the Gigabit-Capable Passive Optical Network Physical media-Dependent layer specification.
- G.984.3 – This document describes the Gigabit-Capable Passive Optical Network Transmission Convergence Layer Specification.
- G.984.4 – This document describes the Gigabit-Capable Passive Optical Network ONT Management and Control Interface Specification (OMCI).

GPON Architecture

- The multiple ONTs are served by the GPON OLT through the PON port.
- TDM is used for downstream transmission i.e., from OLT to ONT and TDMA is used for upstream transmission i.e., from ONT to OLT.



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GPON Architecture

- There may be symmetrical or asymmetrical PON system.
- A one-way distributive service can be supported by using PON and fiber infrastructure, eg. Video at a different wavelength.

GPON Physical-Media Dependent Layer

- The physical layer specification of the GPON system is G.984.2.
- The areas addressed by the physical layer are:
  - Optical performance in terms of data rate
  - The class of optical fiber components
  - The timing and control of the optical power
  - Forward error correction

(contd...)

GPON Physical-Media Dependent Layer

- An optical system has one of the basic requirement of providing components with sufficient capacity so that the optical signal can be extended to the expected range.
- On the basis of power and sensitivity, there are three categories or classes of components, such as:
  - Class A optics: 5 to 20dB
  - Class B optics: 10 to 25dB
  - Class C optics: 15 to 30dB

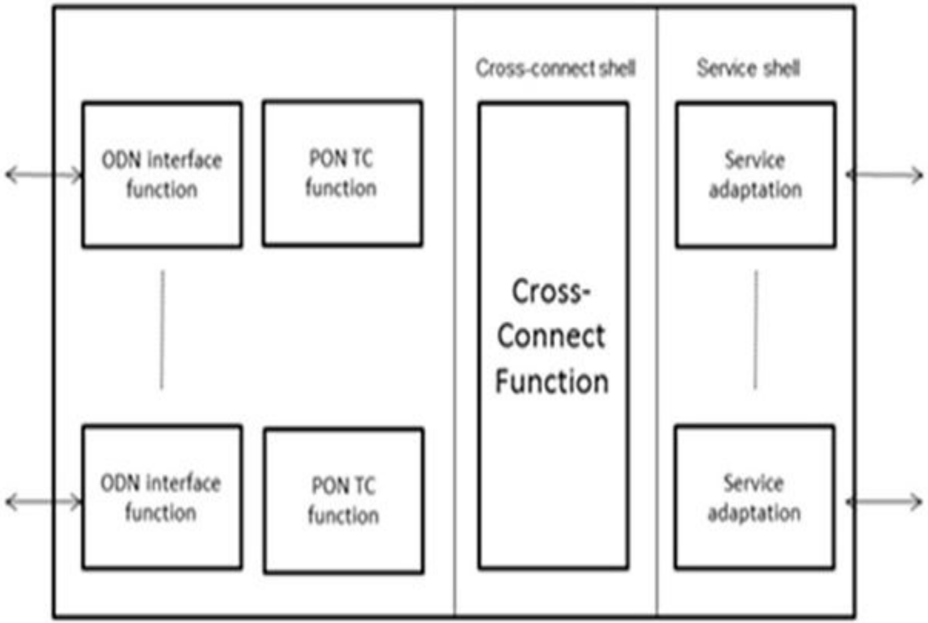
Optical Line Terminal (OLT)

- The service node interface (SNI) (typically 1 Gbps and/or 10 Gbps Ethernet LAN interfaces) is provided by the OLT towards the core network.
- GPON is controlled by the OLT.
- There are three major parts of OLT, such as:
  - Service port interface function
  - Cross-connect function
  - Optical distribution network (ODN) interface

(contd...)

Optical Line Terminal (OLT)

- Figure shows the functional block diagram of OLT.



PON Core Shell

- There are two parts of the core of the PON, i.e.,
  - ODN interface function
  - PON TC function
- OAM, media access control, framing, DBA, delineation of protocol data unit (PDU) for the cross-connect function and the ONU management are included in the PON TC function.

(contd...)

PON Core Shell

- Cross-connect shell – A communication path is provided between the PON core shell and the service shell by this shell.
- Service shell – The translation between service interfaces and the TC frame interface of the PON section is provided by this shell.

ONU/ONT

- A single PON interface is used with the Optical Network Unit (ONU) for operation or maximum two interfaces are also used for link protection purposes.
- If out of these fibers one is cut then other fiber is used to access the ONU and is known as PON protection or Link Protection.
- In link protection, the link is protected as well as the traffic is aggregated so it is also known as link aggregation.

(contd...)

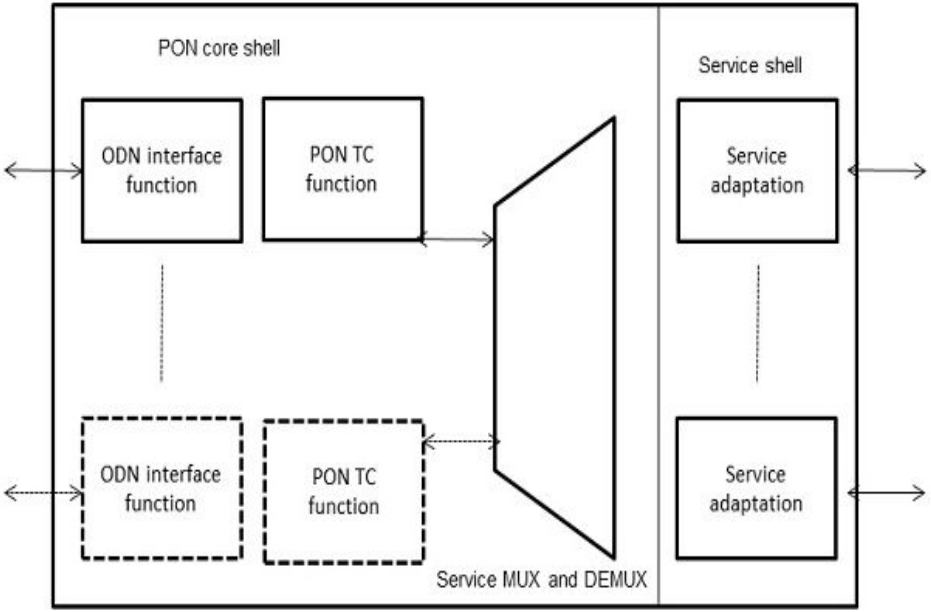
ONU/ONT

- the Customer devices are connected to the PON side by using the service MUX and DEMUX function.
- For single subscriber use, Optical Network Terminal (ONT) is designed and for multiple subscriber use, Optical Network Unit (ONU) is designed.
- The PON can be shared by up to 128 ONTs or ONUs by using splitters.

(contd...)

ONU/ONT

- Figure shows the functional block diagram of ONU/ONT.



ONU/ONT Interfaces

- There are many user-network interface ports of optical network terminal (ONT) to connect to the OLT at uplink side for SNI.
- Four FE/GE ports are there towards UNI i .e.
  - UNI Ports for Residential ONT
  - UNI ports for a business ONT
- The GPON fiber is terminated by the optical network unit (ONU) and for multiple subscribers there are much more user network interface (UNI).

(contd...)

ONU/ONT Interfaces

- UNI interface can be ADSL2+, VDSL2, Power Line, MoCA or HPNA.
- There may not a direct connection of UN UNI to a CPE equipment of subscriber according to the interface ports type.
- The network termination (NT), placed at the final location of the subscriber, is used to connect the UN UNI.
- The subscriber CPE equipment, such as a PC, Wireless Router, Telephone, IP Video Set-Top Box, or Set-Top Box, RF Video, and so on is terminated by NT.

(contd...)

ONU/ONT Interfaces

- the function of an ONU and an NT is combined by an ONT into a single device.
- Hence, the ONT becomes the most cost effective solution by combining these two so that GPON services are provided to local and single-family, small, and medium enterprises.
- A more appropriate solution,when CAT-5 copper cable is laid, is served by ONU for on campus clients as students, hostels, schools, colleges, hospitals, or corporate offices.

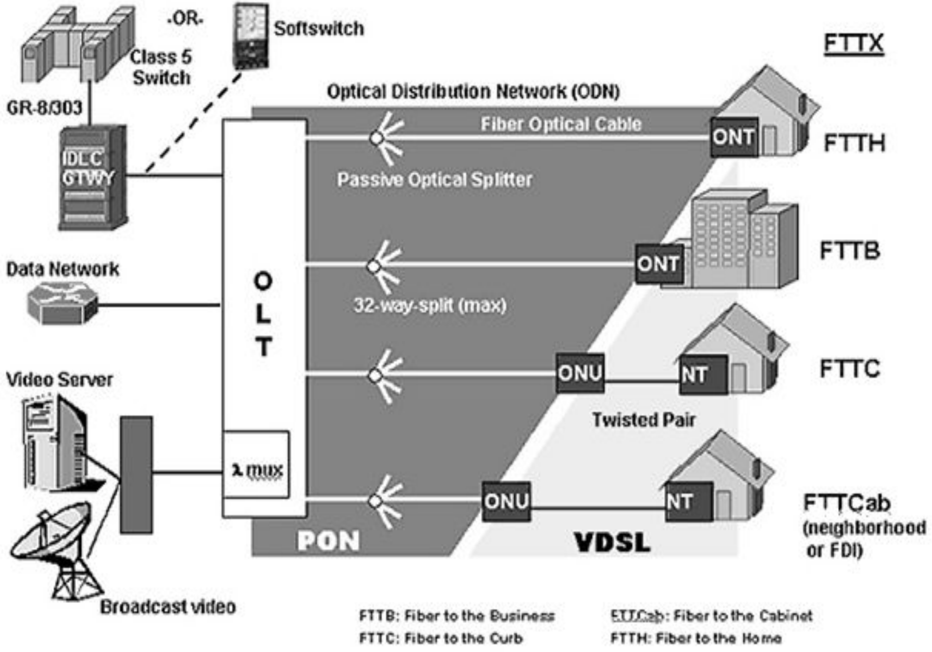
Optical Distribution Network

- A single mode optical fiber and cable; the optical fiber ribbon cables, splices, optical connectors, passive optical splitters and passive branching components are consisted in the GPON ODN.
- The single fiber is divided into multiple fibers by using the ODN optical splitters that will connect to different buildings and individual homes.
- The location of the splitters can be anywhere in the ODN, from the Central Office (CO)/ Local Exchange (LE) to the customer premises and the size may be variable.

(contd...)

Optical Distribution Network

- The splitters are denoted by [n:m], where ‘n’ is the number of input (towards OLT) = 1 or 2, and ‘m’ is the number of outputs (towards ONT) = 2,4,8,16,32,64.
- Figure shows the typical ODN.



GPON Encapsulation Method (GEM)

- The GPON transmission convergence layer has the data transport scheme called GEM.
- A connection-oriented, variable-length framing mechanism is provided by it to transport data services over the passive optical network (PON).
- GEM is designed to not to be dependent on the the type of the service node interface at the OLT as well as the types of UNI interfaces at the ONUs.

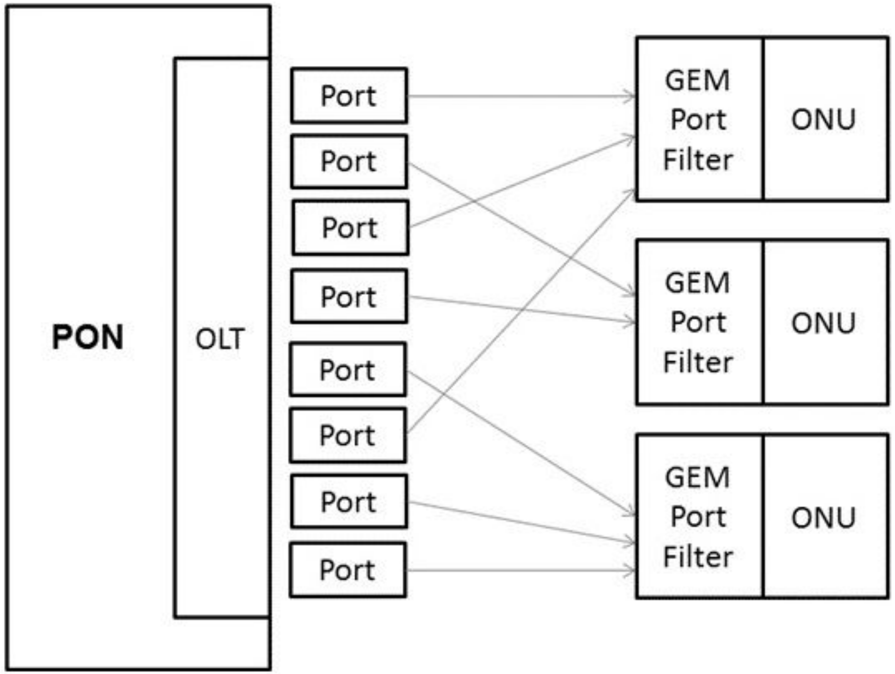
Downstream Traffic

- There is a centralization of the traffic multiplexing functions for downstream traffic in OLT.
- The GEM frames are identified by the GEM Port-ID, which is a 12-bit number assigned to the individual logical connections by the OLT.
- GEM frames are belonged to different logical connections of downstream.
- The downstream GEM frames are filtered by each ONU on the basis of their GEM Port-IDs.

(contd...)

Downstream Traffic

- Figure shows the downstream traffic i.e. from OLT to ONU/ONT.



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Gigabit Passive Optical Network (GPON) II

Upstream Traffic

- The OLT granted upstream transmission opportunity or bandwidth allocation to the traffic bearing entities within the ONU.
- The allocation IDs (Alloc-IDs) identifies the traffic-bearing entities which is a 12-bit number assigned by the OLT to an ONU so that a traffic-bearing entity can be identified.
- Within the ONU, upstream bandwidth allocations are received by it.
- There is a multiplexing of the bandwidth allocations to different Alloc-IDs in time.

(contd...)

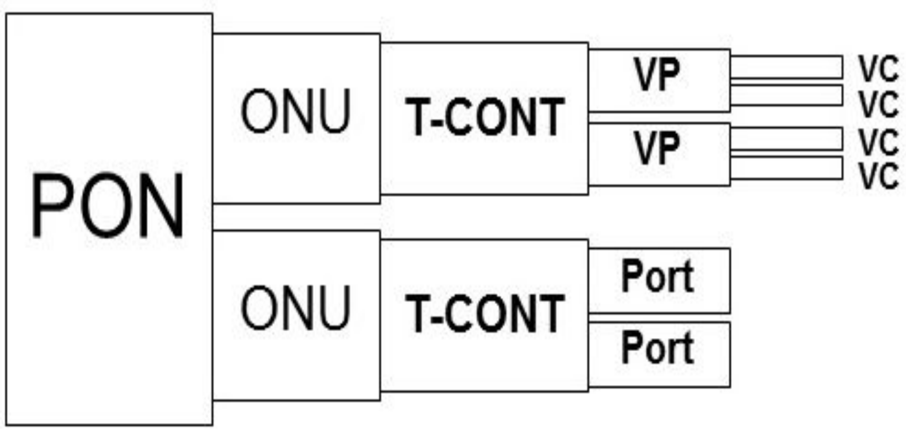
Upstream Traffic

- The GEM Port-ID can be used by the ONU as a multiplexing key within each bandwidth allocation so that the GEM frames belonged to different upstream logical connections can be identified.
- A group of logical connections is represented by a Transmission container (T-CONT) which is an ONU object.
- To assign upstream bandwidth on the PON, it acts as a single entity.
- There is a carrying of service traffic to different GEM ports and then to different T-CONTs on the basis of the mapping scheme.

(contd...)

Upstream Traffic

- There can be a flexible mapping between the GEM port and the T-CONT.
- A GEM Port is corresponding to a T-CONT or multiple GEM Ports are corresponding to the same T-CONT.



(contd…)

GPON Transmission Convergence Layer (GTC)

- The protocol suite of GPON contains a protocol layer positioned between the physical media dependent (PMD) layer and the G-PON clients.
- GTC framing sub-layer and GTC adaptation sub-layer is combined to compose the GTC layer.
- The GTC payload, arrives at all the ONUs, carries the GEM frames in the downstream direction.
- The frames are extracted by the ONU framing sub-layer.

(contd...)

GPON Transmission Convergence Layer (GTC)

- The frames are filtered by the GEM TC adapter on the basis of their 12-bit Port-ID.
- The GEM client function allows the only frames with the appropriate Port-IDs.
- One or more T-CONTs are carried by the GEM traffic in the upstream direction.
- The transmission associated with the T-CONT is received by the OLT.

(contd…)

GPON Transmission Convergence Layer (GTC)

- There is a forwarding of the frames to the GEM TC adapter and then to the GEM client.
- GTC Layer Framing
  - The duration of the downstream frame is 125 microseconds and its length is 38880 bytes.
  - It corresponds to 2.48832 Gbit/s data rate in the downstream.
  - The physical control block downstream (PCBd) and the GTC payload section are consisted in the downstream GTC frame.

(contd...)

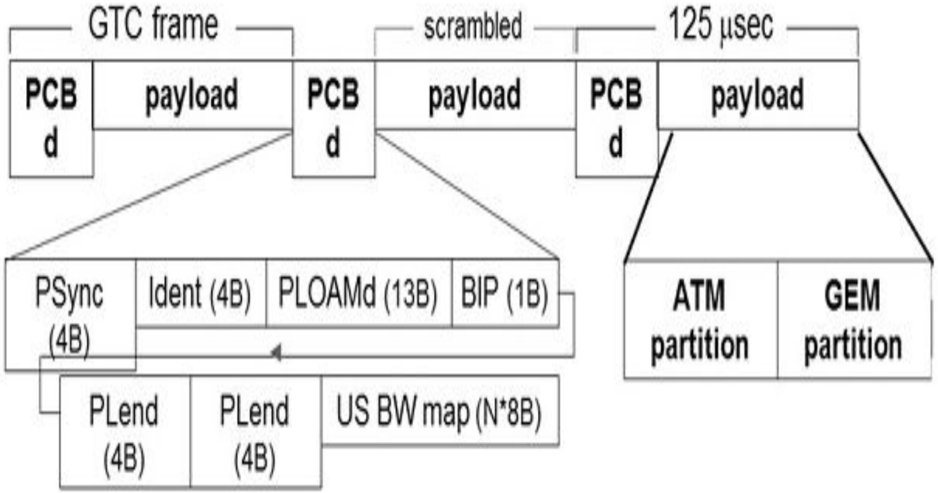
GPON Transmission Convergence Layer (GTC)

- The length of GPON Transmission Convergence frames is 125 Msec always i.e. 19440 bytes/frame for 1244.16 rate and 38880 bytes/frame for 2488.32 rate.
- The Physical Control Block downstream and payload are consisted in each frame of GTC.
- Information about sync, OAM, DBA, and so on is contained in the PCBd.

(contd...)

GPON Transmission Convergence Layer (GTC)

- Either ATM and GEM partitions or both are there in a payload.
- Figure shows the GTC frame.
- The duration of the upstream frame of the GTC is 125 µs.



(contd...)

GPON Transmission Convergence Layer (GTC)

- In GPON system, the size of the upstream GTC frame is 19,440 bytes with uplink of the 1.24416 Gbit/s.
- Number of transmission bursts receiving from one or more ONUs are contained in each frame of upstream.
- An upstream physical layer overhead (PLOu) section is contaied in each upstream transmission burst.

(contd...)

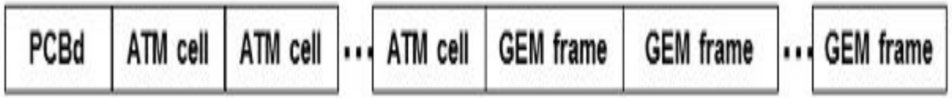
GPON Transmission Convergence Layer (GTC)

- The individual Alloc-IDs has allocation of one or more bandwidth allocation intervals.
- The common time reference is provided by the downstream GTC frame for the PON and provides the common control signaling for upstream.

(contd...)

GPON Payloads

- There are two sections of payload of GTC, such as:
  - ATM partition
  - GEM partition
- ATM partition
  - The PCBd is specified as Alen (12 bits).



(contd...)

GPON Payloads

- The number of 53B cells are specified by Alen in the ATM partition.
- There is no ATM partition if Alen = 0.
- There is no GEM partition if Alen = payload length/53
- GTC frame is aligned with ATM cells.
- In ATM header, ATM cells based on VPI are accepted by ONUs.

(contd...)

GPON Payloads

- GEM partition
  - Frames delineated with GEM can have variable length unlike ATM cells.
  - The GEM partition contains any number of GEM frames.
  - GEM frames are accepted by ONUs on the basis of 12b Port-ID in GEM header.

(contd...)

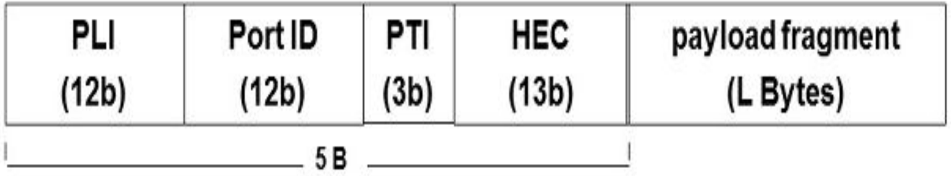
GPON Encapsulation Mode

- The inefficiency because of the ATM cell tax was a common complaint against BPON.
- GEM and ATM are similar.
- It has HEC-protected header with a constant size.
- The variable length frames helps to avoid large overhead.
- Any packet type and even TDM can be supported by GEM, so it is generic.

(contd...)

GPON Encapsulation Mode

- Fragmentation and reassembly can also be supported by GEM.
- GEM is GFP based and the following fields are contained in the header:
  - Payload Length Indicator
  - Port ID



(contd...)

GPON Encapsulation Mode

- Payload Type Indicator
- Header Error Correction field

(contd...)

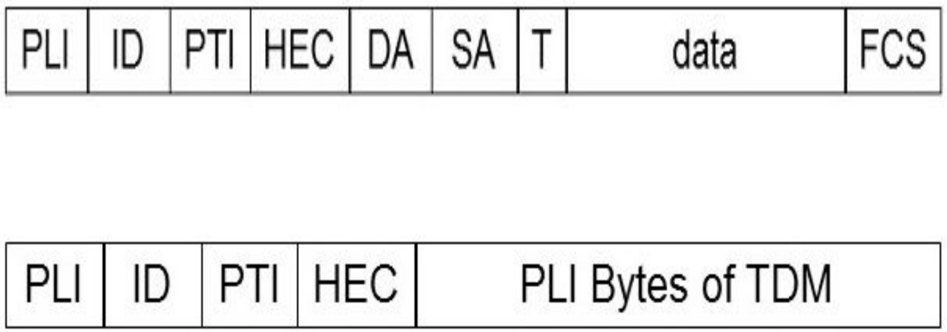
Ethernet/TDM over GEM

- When Ethernet traffic is transported over GEM:
  - Encapsulation of only MAC frame (no preamble, SFD, EFD)
  - Fragmentation of MAC frame
- When TDM traffic is transported over GEM
  - There is a polling of TDM input buffer every 125 Msec.
  - Insertion of TDM PLI bytes into payload field.
  - There is a variation in the length of the TDM fragment by ± 1 Byte because of frequency offset.

(contd...)

Ethernet/TDM over GEM

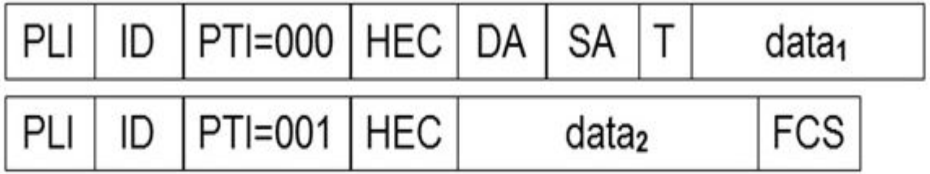
- ❑ 3 msec round trip latency.
- ❑ Figure shows Ethernet and TDM over GEM, respectively.



(contd...)

Ethernet/TDM over GEM

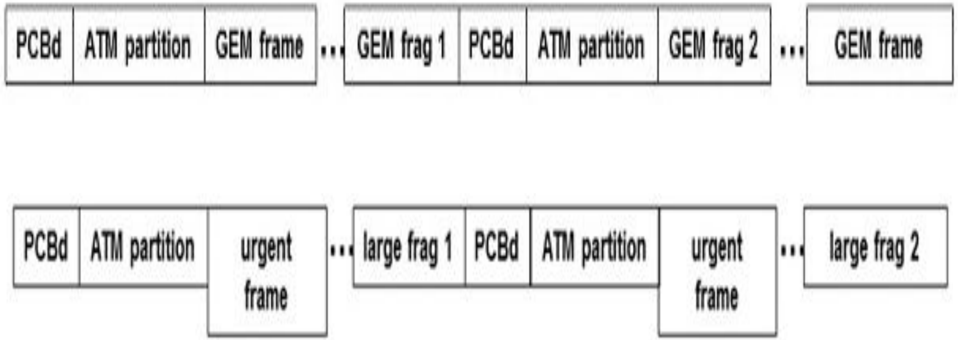
- GEM can fragment its payload.
- Figure shows the un-fragmented Ethernet frame.
- The fragmented Ethernet frame is shown in the second figure.



(contd...)

Ethernet/TDM over GEM

- ❑ Because of the following two reasons the payloads are fragmented by the GEM:
  - ❑ Reason 1 – GTC frame is not straddled by GEM frame.
  - ❑ Reason 2 – For delay-sensitive dataGEM frame may be pre-empted.



(contd...)

GPON Encryption

- In the counter mode, AES-128 is used to encrypt OLT.
- There is an encryption of payload only.
- There is an alignment of encryption blocks to the GTC frame.
- OLT and all ONUs share the counter as follows:
  - 46b = 16b intra-frame + 30 bits inter-frame.
  - Intra-frame counter increments every 4 data bytes.
  - Reset to zero at beginning of DS GTC frame.

(contd...)

GPON Encryption

- A unique symmetric key is agreed by the OLT and each ONU.
- ONU is asked by OLT for a password.
- ONU is informed by OLT about the precise time to start using new key.

(contd...)

QoS

- The QoS is treated explicitly by GPON.
- For time-sensitive applications, QoS is facilitated by constant length frames.
- Transmission containers are of 5 types, such as:
  - Type 1 – fixed BW.
  - Type 2 – assured BW.
  - Type 3 – allocated BW + non-assured BW.

(contd...)

QoS

- ❑ Type 4 – best effort.
- ❑ Type 5 – superset of all of the above.

❑ Several PON-layer QoS features are added by GEM such as:

- ❑ Large number of low-priority frames are pre-empted by using the fragmentation.
- ❑ The queuing algorithms are used PLI - explicit packet length.
- ❑ Congestion indications are carried by PTI bits.

(contd...)

Thanks

Gigabit Ethernet Passive Optical Network (GEPON) I

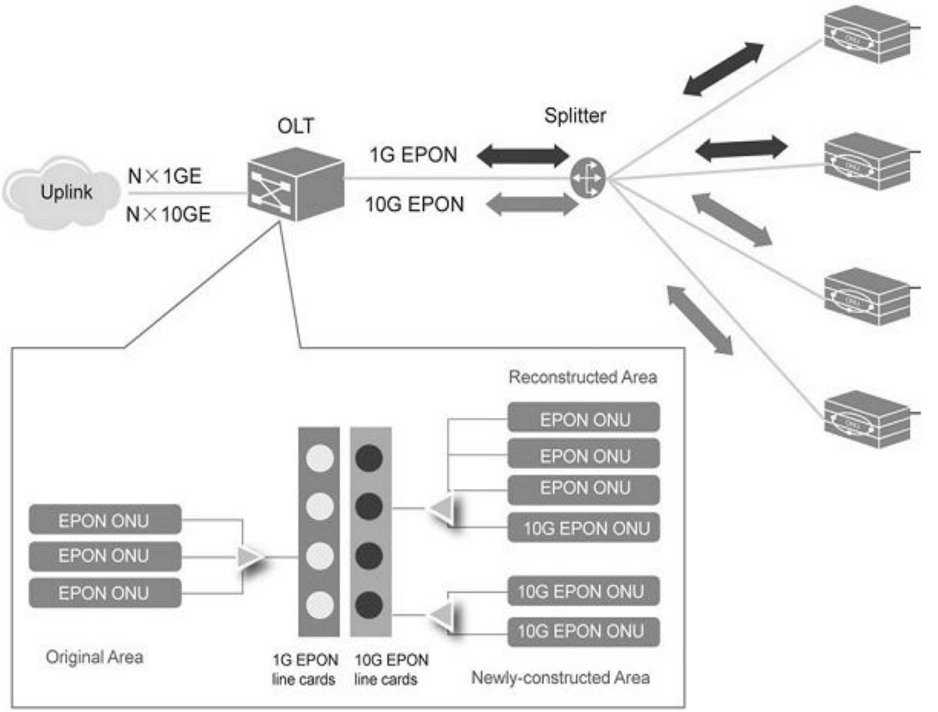
Introduction

- A new type of optical access network technology is GEPON (Gigabit Ethernet Passive Optical Network) that relies on point-to-multipoint architecture and a variety of services are provided over Ethernet by using passive optical fiber transmission.
- It is also known as EPON (Ethernet Passive Optical Network).
- In this, the data is encapsulated with Ethernet and 1 Gbps to 10 Gbps capacity can be offered.

(contd...)

Introduction

- The original PON architecture is followed by EPON.
- There is a connection of DTE to the trunk of the tree which is called Optical Line Terminal (OLT) as shown in the figure.



(contd...)

Introduction

- Its location is at the service provider and connected to Optical Network Unit (ONU) which is the DTE branches of the tree whose location is in the subscriber premises.
- In order to achieve the ONU, the passive splitter is used to pass the signals from the OLT and vice-versa.

(contd...)

Ethernet in the First Mile

- Ethernet in the First Mile (EFM), a new study group, began the standardization process that was established in November 2000 and is based on IEEE 802.3ah standard.
- An access to a P2MP topology has been controlled on the basis of Multi-Point Control Protocol (MPCP) which is a function within the MAC control sub-layer.
- The point-to-point (P2P) emulation sub–layer contains the EPON/MPCP protocol.

(contd...)

Ethernet in the First Mile

- The transmission rate of EPON is symmetric 1.25G, distance is 10KM/20KM, and splitter ratio is > 1:32.
- There are many advantages of EPON that are pointed out by the EFM based on Ethernet as core technology that includes
  - Protocols maturity
  - Technology simple
  - Extension flexibility
  - Users' oriented

(contd...)

Ethernet in the First Mile

- The expensive ATM hardware and SONET equipments are chosen by the EPON System so that it becomes compatible to the existing Ethernet network.
- The system structure can be simplified, cost can be decreased and upgrade flexibility can be improved.
- The main focus of equipment vendors is on optimizing the function and practicability.

(contd...)

BPON ATM Systems

- Large IP Frames and variable sizes are consisted in the vast majority of traffic across the access network that makes the BPON ATM based systems very inefficient.
- Therefore, the opportunity has been created to develop pure Ethernet based EPON, QoS of GigE password, and integrating other emerging Ethernet equipment in a cost-effective manner.
- Ethernet has been becoming the ideal transporter for IP traffic over time.

(contd...)

BPON ATM Systems

- After proposing the FSAN members (Quantum Bridge, Al) for an ATM/Ethernet PON solution, Passive Optical Network (GPON) development has began.
- The popularity of Gbps in the IEEE 802.3ah working group is low.
- G.983, the standard of BPON, is used to draw EPON and GPON for the general concepts that work well.
- The version of enhancements is offered by both of then so that better size IP/Ethernet frames can be accommodated at variable rates Gbps.

(contd...)

Concept of EPON

- The concept of EPON has been introduced by EFM by implementing a point-to-multipoint (P2MP) network topology with passive optical splitters.
- The highest bandwidth is offered by the Ethernet point-to-point fiber at a reasonable cost.
- Relatively high bandwidth has been provided by Ethernet Point-to-multipoint fiber at a lower cost.

(contd...)

Concept of EPON

- The extension of the application of Ethernet was the purpose of the IEEE Std 802.3ah in which access subscriber networks were included so that a significant increase in performance was provided while minimizing operation and maintenance equipment costs.
- The range and reach of Ethernet transport has been significantly expanding for the IEEE 802.3ah EFM standard conclusion so that they can be used in the metro networks.

(contd...)

Concept of EPON

- A variety of flexible and cost effective solutions is allowed to service providers by this standard so that broadband Ethernet services are provided in the access and the metro networks.
- A family of technologies is covered by EFM that has different type of media and signaling speed.
- Any IEEE 802.3 defined network topology can be used on the subscriber premises and after that connection is provided to an Ethernet subscriber access network.

(contd...)

Concept of EPON

- Maximum flexibility can be achieved by using different types of topologies in the EFM technology.

(contd...)

IEEE Std 802.3ah

- In IEEE Std 802.3ah, specifications are included for Ethernet access networks of the subscriber and a nominal rate of 1 Gb/s (expandable to 10 Gb/s) has been supported by IEEE Std 802.3ah EPON for each channel.
- The two wavelengths define these:
  - A downstream wavelength
  - For the shared upstream direction between the user devices

(contd...)

IEEE Std 802.3ah

- The full duplex links are supported by EFM to define a full duplex simplified Media Access Control (MAC).
- Ethernet architecture divides The physical layer is divided in a Physical Medium Dependent (PMD), Physical Medium Attachment (PMA), and Physical Coding Sublayer (PCS) by ethernet architecture.
- A P2MP network topology can be implemented by EPON with appropriate extensions to the undercoat and reconciliation sublayer MAC control.

(contd...)

IEEE Std 802.3ah

- This topology has been supported by the optical fiber under layers physical medium dependent (PMD).
- Physical Layer
  - For P2MP topologies, EFM introduced a family of signaling systems has been introduced by EFM for P2MP topologies for the physical layer that are derived from 1000BASE-X.
  - The extensions of the RS, PCS, and PMA are included with an optional forward error correction (FEC) capacity.

(contd...)

IEEE Std 802.3ah

- The characteristics of the interface are mapped with the 1000BASE-X PCS and PMA sublayers.
- The expected services by the undercoat reconciliation are the PMD sublayer, including MDI.
- There is an extension of 1000BASE-X so that other full duplex media can be supported.
- It is required that the consistent environment is there with the PMD level.

(contd...)

IEEE Std 802.3ah

- Medium Load Interface (MDI)
  - The interface between PMD and the physical media.
  - The signals, the physical media, and the mechanical and electrical interfaces are defined by MDI.
- Physical Medium Dependent (PMD)
  - The interface to the transmission medium is provided by the PMD.
  - Depending upon the connected physical medium’s nature, the electrical or optical signals are generated by it.

(contd...)

IEEE Std 802.3ah

- PMD is indicated by D and U suffixes at each end of the link in a PON Ethernet, which transmits in these directions and receives in the opposite direction, i.e., 1000BASE-PX10-D identifies a single downstream PMD and 1000BASE-PX10 U PMD identifies the upstream.
- There can be a simultaneous use of same fibers in both the directions.

(contd...)

IEEE Std 802.3ah

  - ❑ There is a connection of a 1000BASE-PX-U PMD or 1000BASE-PX-D PMD to the appropriate PMA 1000BASE-X and MDI can support them.
  - ❑ There is a combination of PMD with management features so that the access can be provided via the management interface.
- ❑ Physical Medium Attachment (PMA)
  - ❑ The transmission, receipt, clock recovery, and align functions are included in PMA.

(contd...)

IEEE Std 802.3ah

- The PMA provides An independent middle way is provided by PMA for PCS so that the use of a range of bit-oriented physical media series can be supported.
- The codifications bit functions are comprised in the PCS sublayer.
- The Gigabit media independent interface (GMII) is the PCS interface, by which a uniform interface to the Reconciliation sublayer for all implementations of 1000 Mb/s PHY is provided.

(contd...)

IEEE Std 802.3ah

- Gigabit Media Independent Interface (GMII)
  - The interface between the Gigabit MAC layer and the physical layer is referred as the interface GMII.
  - It allows multiple DTE mixed with a variety of implementations from the speed gigabit physical layer.
  - MAC and repeater is included by PCS customers.
  - The Gigabit Media Independent Interface (GMII) precisely defines the PCS interface.

(contd...)

IEEE Std 802.3ah

- The matching of GMII signals is ensured by the Reconciliation sublayer (RS) that defines the service access control medium.
- The independent media is provided by GMII and RS to use an access controller identical media with any type of copper and optical PHY.

❑ Data Link Layer (Multipoint MAC Control)

- The standard was supported by the MAC control protocol.
- There can be implementation and addition of new functions.

(contd...)

IEEE Std 802.3ah

- It is the case of multi-point control protocol (MPCP).
- The Multi-Point Control Protocol defines one of the functions as the management protocol to P2MP.
- The devices of the subscriber are accessed by implementing the multipoint MAC control functionality that contains physical layer devices point to multipoint.
- A point-to-point service is provided by MAC emulation jurisdictions between OLT and the ONU

(contd...)

Thanks

Gigabit Ethernet Passive Optical Network (GEPON) II

MPCP (Multi-Point Control Protocol)

- MPCP is very flexible, easy to implement.
- Five types of messages are used by MPCP where each message is a MAC Control frame and the multiple packet boundaries are reported by ONU/ONT, no delineation overhead has been granted by OLT on a packet boundary.
- The system between an OLT and ONUs associated with a Point-to-Multi-Point (P2MP) PON portion is indicated by MPCP so that the information can be transmitted productively in the upstream heading.

(contd...)

MPCP (Multi-Point Control Protocol)

- The following functions are performed by MPCP:
  - Controls Auto Discovery process.
  - Timeslot/Bandwidth assignment to ONTs.
  - Provides Timing Reference to synchronize ONTs.

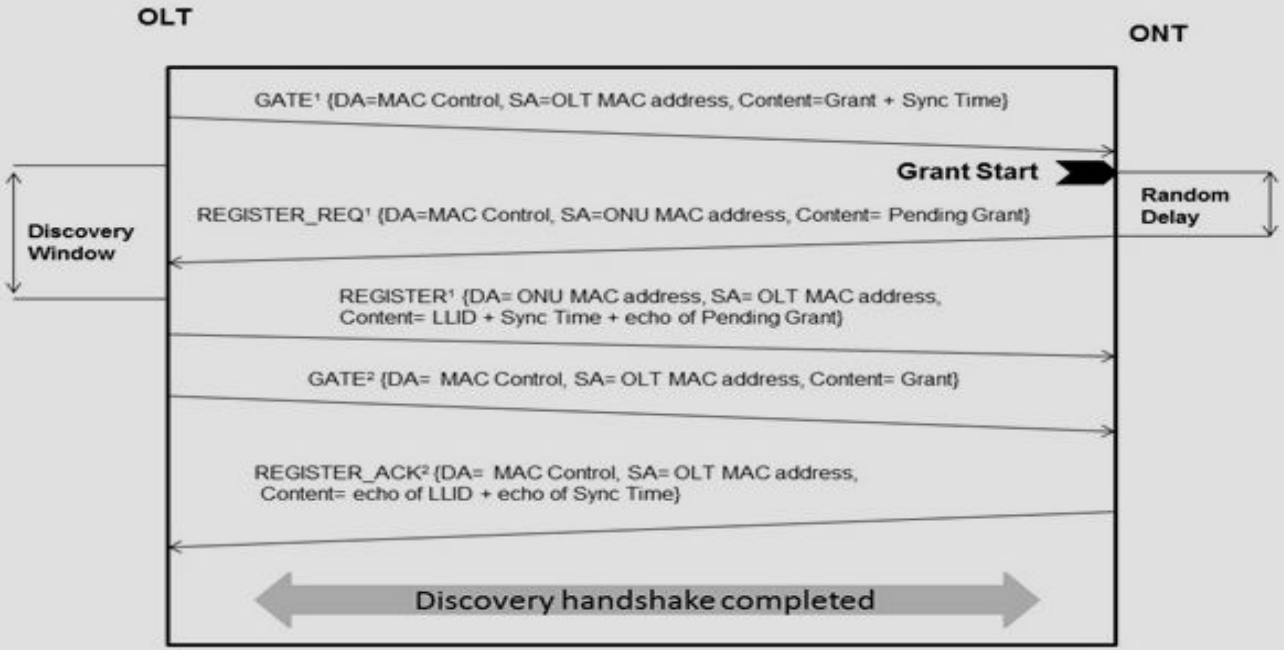
(contd...)

MPCP (Multi-Point Control Protocol)

- Five new MAC control messages introduced by MPCP are:
  - Gate, Report
  - Registered REQ
  - Register
  - Registered ACK
  - Auto Discovery

(contd...)

Message Discovery Sequence Summary



[1] Message sent on broadcast channels
[2] Message sent on unicast channels

DBA EPON

- In EPON, the downstream is indicated by the communication between OLT and ONT, the entire bandwidth is used by OLT to broadcast downstream data towards ONT and on other end, the frames are received by ONT using information available on Ethernet Frames.
- The communication from ONT to OLT is regarded as the upstream that uses single channel communication such that multiple ONTs use one channel which is regarded as data collision.

(contd...)

DBA EPON

- The effective bandwidth allocation scheme is required to avoid this problem by assigning equal resources to ONTs and ensuring the QoS at the same time.
- This scheme is known as Dynamic Bandwidth Allocation (DBA) algorithm.
- The report and gate messages are used by the DBA so that transmission schedule can be built and conveyed to the ONTs.

(contd...)

DBA EPON

- DBA Characteristics
  - Different services are provided by EPON with optimum QoS and effective allocation of bandwidth by using different DBA allocation so that the demand of current and future applications can be easily met.
  - The two different types of DBA algorithms for the EPON are the following:
    - Accommodation of traffic fluctuations.

(contd...)

DBA EPON

- ❑ Provides QoS to different types of traffic.
- ❑ Avoiding Frame Collisions, Managements of Real Time Traffic through QoS and Management of Bandwidth for each Subscriber along with Decrease Delay on Low Priority Traffic.

❑ EPON Frame Format

- ❑ EPON operation is based on the Ethernet MAC and EPON frames are based on GbE frames, but extensions are needed

(contd...)

DBA EPON

- Clause 64
- Clause 65
- They transmit when granted.
- Constant time through MAC stack
- Maintain accurate local time

(contd...)

DBA EPON

- EPON Header
  - Standard Ethernet starts with an essentially content-free 8B preamble
    - 7B of alternating ones and zeros 10101010
    - 1B of SFD 10101011
  - Some of the preamble bytes are overwritten by EPON to hide the new PON header.

(contd...)

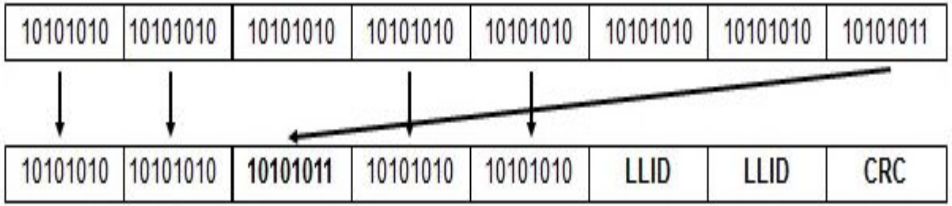
DBA EPON

- The following factors are contained in the LLID field:
  - MODE (1b)
    - Always 0 for ONU
    - 0 for OLT unicast, 1 for OLT multicast/broadcast
  - Actual Logical Link ID (15b)
    - Identifies registered ONUs
    - 7FFF for broadcast

(contd...)

DBA EPON

- CRC protects from SLD (byte 3) through LLID (byte 7).



(contd...)

Security

- Downstream traffic broadcasts to all ONUs, so the reprogramming of ONU is easy for a malicious user and desired frames are captured.
- Upstream traffic has not been exposed to other ONUs, so there is no need of encryption. The fiber-tappers are not considered because any standard encryption method is not provided by EPON, but
  - Can supplement with IPsec or MACsec
  - The proprietary AES-based mechanisms have been added by many vendors.

(contd...)

Security

- Churning mechanism is used by BPON which was a low cost hardware solution (24b key) with several security flaws, such as:
  - Engine was linear - simple known-text attack.
  - 24b key turned out to be derivable in 512 tries.
- Therefore, AES support has been added in G.983.3, which is now used in GPON.

(contd...)

QoS – EPON

- High QoS is required in many PON applications (e.g. IPTV) and QoS is left to higher layers by EPON like:
  - VLAN tags.
  - P bits or DiffServ DSCP.
- In addition to these, there is a crucial difference between LLID and Port-ID
  - There is always 1 LLID per ONU.
  - There is 1 Port-ID per input port - there may be many per ONU.
  - This makes port-based QoS simple to implement at PON layer.

(contd...)

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GPON System Requirements

Introduction

- The development a business case becomes easier if a single network provides all telecommunications services.
- The major steps along the road to convergence are software-defined features, Ethernet, and IP.
- The investment once made is ensured by the contribution of standards and of the network equipment that can be used for a complete range of services for decades to come.

(contd...)

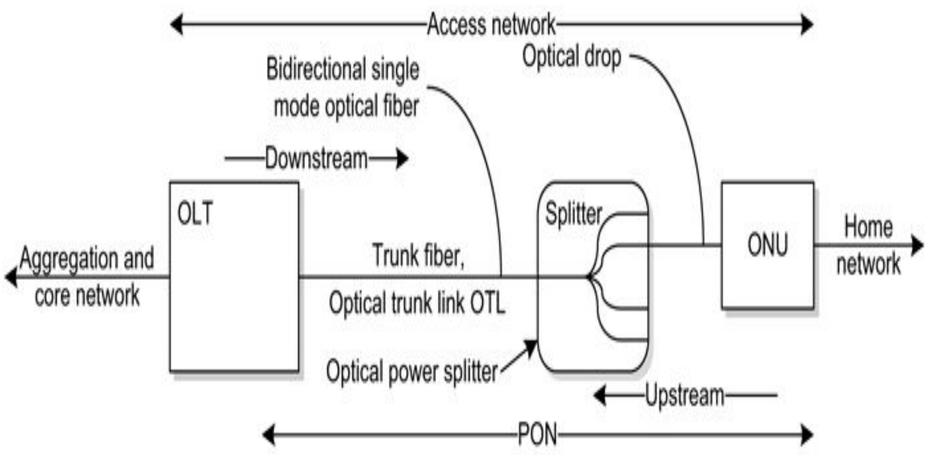
Introduction

- G-PON is designed for delivering any telecommunications service that may be needed, keeping the full-service focus of its FSAN parent.

(contd...)

Physical Layer

- A single-fiber optical network is used to build a G-PON whose topology is a tree as shown in the figure.
- OLT acts as the roots and some number of ONUs are connected at the leaves.



(contd...)

Physical Layer

- At the branching points of the tree, there is splitting of downstream optical power from the OLT.
- An equal fraction of the power is allocated by each split to each branch.
- The achievable reach of a PON is a tradeoff of fiber loss against the division of power at the splitter.
- There is a symmetric power splitter with equal upstream and downstream loss.

(contd...)

Physical Layer

- A continuous downstream signal is transmitted by the OLT for conveying timing, control, management, and payload to the ONUs.
- The master of PON is OLT.
- An upstream capacity allocation plan, typically 1 or 2 ms, has been continuously developed by the OLT on the basis of the service-level commitments and traffic offered by the ONUs and this so-called bandwidth map has been transmitted to the ONUs.

(contd...)

Physical Layer

- When a grant contained in a bandwidth map explicitly given permission to the ONU only then it is permitted to transmit.
- A burst of data upstream is sent by the ONU during its allocated time.
- The notion of a zero reference transmission time has offset by each ONU by a value determined by its round-trip delay, for the bursts to arrive at the OLT at precisely the proper interleaved times.

(contd...)

Physical Layer

- The round-trip delay of each ONU is measured by the OLT during activation and the ONU is programmed with the compensating equalization delay value.
- The discovery of new ONUs is another low-level requirement on a PON.
- A discovery grant is broadcasted periodically by the OLT by which any ONU that is not yet activated on the PON is authorized to transmit its identity.

(contd...)

Physical Layer

- A quiet window, a discovery window, also called a ranging window is opened by the OLT since the round-trip time of a new ONU is unknown.
- The expected fiber distance between the farthest and the nearest ONU determines the size of the discovery window which is called maximum differential reach.

(contd...)

Layer 2

- The access network exists at layer 2.
- The classification of traffic into VLANs and then forwarding the traffic according to VLAN to the right place with the right QoS is a very substantial part of the hardware, software, and management of a G-PON.
- MAC addresses are less important than VLAN tags at the ONU.
- A large fraction of the traffic is represented by using multicasting anda large part of the revenue derived from a GPON can be yielded.

(contd...)

Layer 2

- There is an interception of a single copy of a multicast signal on the fiber by as many ONUs as need it so the architecture of PON is suited for multicast applications.
- Only the multicast groups, requested by the subscribers, are extracted by each ONU.
- At least an IGMP/MLD snoop function is included in ONU to determine the requested groups at any given time.

(contd...)

Layer 2

- The monitoring transmissions from the subscriber's set-top box (STB) are included in snooping on the basis of which the requested channels are compared by the ONU with a local access control list (ACL).
- The requested content is delivered by ONU immediately without any ado if it is authorized and is already available on the PON.

(contd...)

ONU Types

- Single-Family Unit ONU
  - The most common form of ONU in some markets.
  - Located indoors or out.
  - Subscriber supplies the power.
  - Battery backup may or may not be included.
  - May be owned and managed by the operator or owned by the subscriber.

(contd...)

ONU Types

- Multi-Dwelling Unit ONU
  - Serves a number of residential subscribers.
  - May be deployed in an apartment building, a condominium complex, or at the curbside.
  - Always a part of the telecommunications network.
  - Serves from 8 to 24 subscribers.

(contd...)

ONU Types

- Small-Business-Unit ONU
  - Offers several POTS lines to a small-office customer.
  - Supports a few TDM services.
  - The cellular backhaul unit (CBU) is its variation.
  - Carries traffic between the core network and a radio base station.
  - Multitenant unit (MTU) is also its variation, shared by several small businesses.

(contd...)

Thanks

GPON Network Considerations

Power

- The power for POTS is delivered by the twisted pair in the legacy copper network which is very reliable in most venues.
- The telephone still works during the failure of commercial power.
- The backup power is becoming an option while moving towards mobile telephony.
- The reliable power is still a part of the service offering when a central office or a field site such as a CEV (controlled environment vault) provides POTS.

(contd...)

Power

- It is the responsibility of a subscriber to provide power for an SFU when there is no twisted copper pair in the deployment of SFU.
- An AC power converter unit is used to furnish the ONU but an uninterruptible power supply is also included to provide a backup battery along with converting AC power to DC.
- A typical requirement for lifeline POTS is four to eight hours of battery reserve.

(contd...)

Power

- UPS units for ONUs are installed in a garage or carport in moderate climates where winters are severe so that batteries cannot lose capacity in cold environments.
- The following powering arrangements are seen by the operators:
  - Negotiation of reverse powering, back down the subscribers' copper drops.
  - MDU may reside in a utility equipment room
  - Availability of AC power at a curbside MDU.

(contd...)

Energy Conservation

- In outdoor deployments, heat dissipation is a problem as they are subjected to high ambient temperatures or direct sunlight due to which power is difficult and expensive to provide.
- The additional power is saved by the operator by shutting down functions which are not in use.
- Inactive user network interfaces (UNIs) are easy to power down.
- The energy-saving options are outlined by the ITU-T supplement 45 to the G-PON recommendations but the full maturity came in XGPON.

(contd...)

Energy Conservation

- The two energy conservation modes are defined in XGPON:
  - Dozing
  - Sleeping
- In doze mode, the receiver of the ONU keeps alive at all times.
- IPTV uses this mode as all of the traffic flows downstream.
- In sleep mode, both transmitter and receiver are shut down by the ONU.

(contd...)

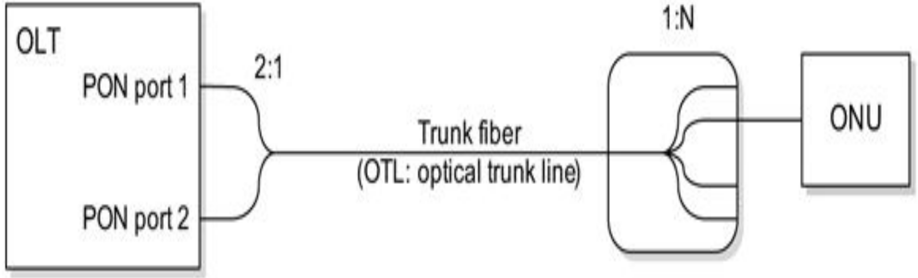
Energy Conservation

- It is required that the ONU responds periodically in both modesso that the OLT can confirm that the ONU is still alive and healthy, and to serve whatever traffic that may arrive.

(contd...)

PON Protection

- OLT port protection is illustrated in the figure.
- The colocated 2:1 splitter is used to connect the trunk fiber to the OLT, at the cost of an additional 3 dB of loss.



(contd...)

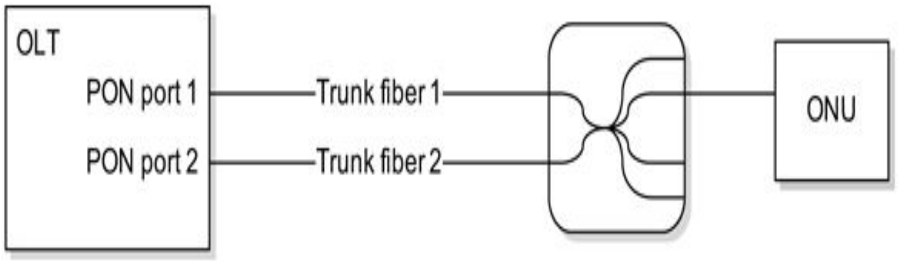
PON Protection

- The upstream signal is received by both OLT ports, but the transmission is done by only one port at any given time.
- The protection switching is triggered by the OLT if one of its ports fails or is unplugged, or if loss of signal is declared by it from all ONUs.
- A 2:N splitter is used at the remote site to protect against cable cuts of the trunk fiber.

(contd...)

PON Protection

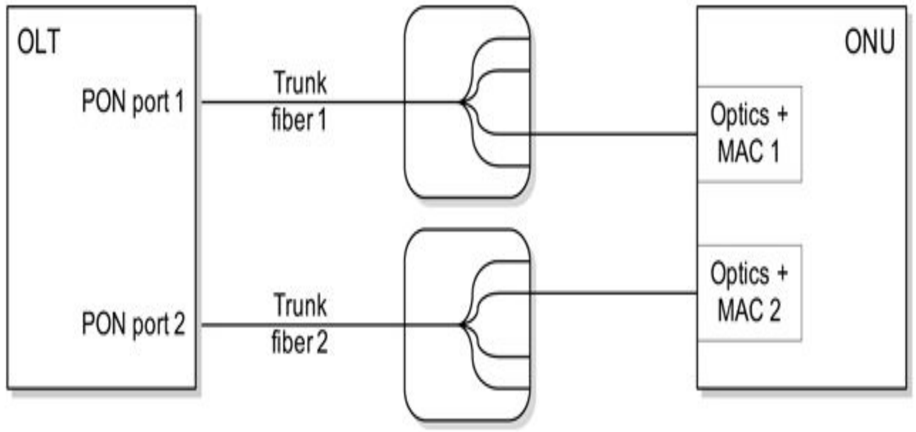
- 3 dB of optical budget is recovered by the layout as shown in the figure.
- To protect against complete OLT failure, the ports on separate OLTs are used.



(contd...)

PON Protection

- An ONU designed for protection by using two optical interfaces is shown in the figure.
- The two MAC interfaces are included in the device so that both PONs can carry traffic at the same time.



(contd...)

Thanks

Optical Layer

Splices

- A permanent joint between two fibers is called a splice.
- The optical cable can be extended or different cable can be joined by using a splice.
- A splice may also be used for repairing the damaged cable.
- In fusion splicing, the fiber ends are melted together with an electric arc or laser pulse.
- A very low-loss but mechanically weak joint is produced using fusion splicing.

(contd...)

Splices

- In mechanical splicing, there is clamping of fiber ends together in a fixture, which is then sealed in a thermoplastic splice closure.
- The structure is filled with gel and insertion losses of 0.5 dB are achieved by which the index of refraction of the fiber core can be matched.

(contd...)

Optical Connectors

- A butt-joint coupling principle is used by the optical connectors in which there is accurate alignment of the ends of the mating fiber.
- A connector comprises a cylinder called a ferrule, with a small hole in the center that precisely matches the fiber cladding diameter.
- The fiber is fixed in the hole with epoxy and the end of the ferrule is polished nearly flat.

(contd...)

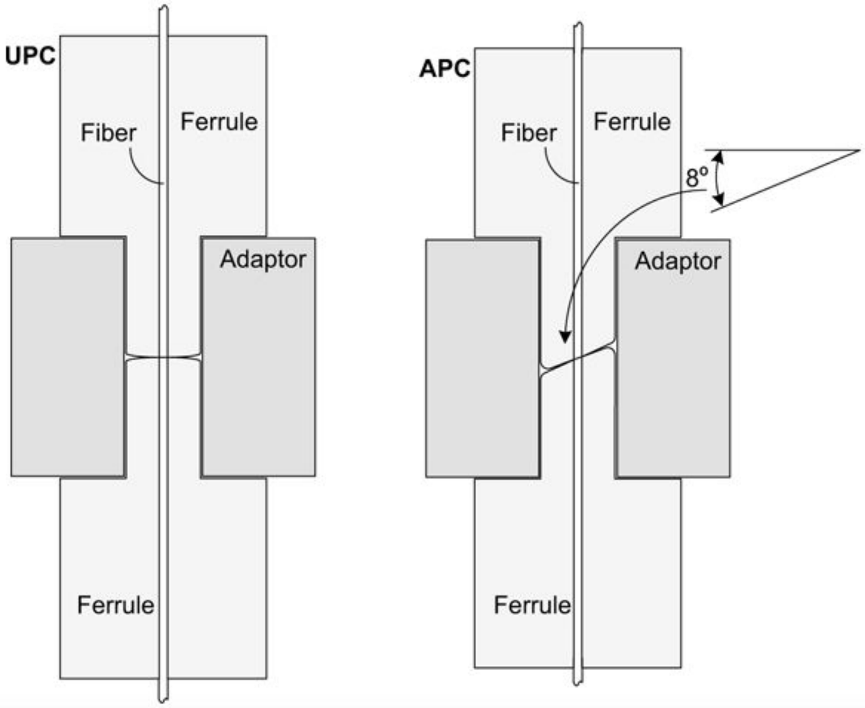
Optical Connectors

- Ceramic is used to make most ferrules because of good strength, low temperature coefficient of expansion, small elasticity coefficient, wear resistance, and dimensional stability of the material during production due to which the exact alignment is achieved that is necessary for low-loss connections.
- Fibers terminated in ferrules are mated in an alignment adaptor, which provides physical contact between end faces.

(contd...)

Optical Connectors

- There is an encapsulation of the ferrules in plastic housings that contains snap-in mechanisms and strain relief boots, the junction of the connector to the fiber is shielded from bending and pulling.
- The SC/UPC (ultra-polished connector) and the SC/APC (angled physical contact) are illustrated in the figure.



(contd...)

Optical Connectors

- The outer plastic housing or the boot is color coded blue for SC/UPC connectors and green for SC/APC connectors.
- The end face geometry is the only difference between UPC and APC connectors.
- The polishing of UPC ferrule and fiber end faces is done at 0 degree whereas the polishing of APC end faces is done at 8 degree.
- The insertion loss is slightly higher in the APC connectors but the return loss is lower.

(contd...)

Optical Connectors

- There is a reflection of light from a UPC connection straight back to the source.
- The reflected light is directed into the cladding in an APC connector where it is dissipated.
- The return loss of the APC is at least –65 dB when a connector is unmated.
- There is a return loss in the neighborhood of –55 dB in open UPC connector.

(contd...)

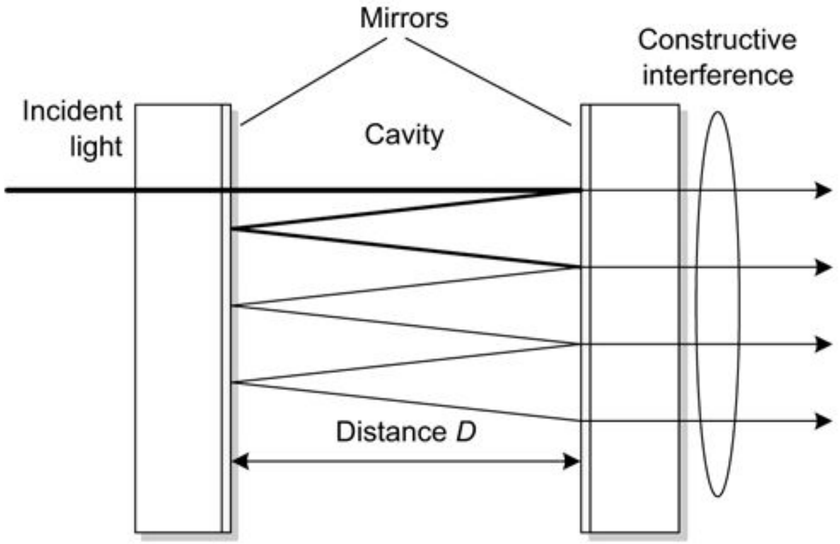
Optical Connectors

- ❑ Mechanical misalignment, either offset or angular, causes loss in a fiber joint or splice.
- ❑ The large insertion and return loss variations are caused by the smallest misalignments with a single-mode fiber.
- ❑ The material, such as dust or oily films, causes loss at a connector.
- ❑ The protection of the ferrules is important when they are not connected and to clean them before mating.

(contd...)

Thin-Film Filters

- Thin-film filters act as optical bandpass filters.
- A narrow wavelength band is transmitted by TFFs while reflecting all other wavelengths.
- The two parallel dielectric surfaces form a cavity in the filter with partially transmissive mirrors on the inner surfaces.



(contd...)

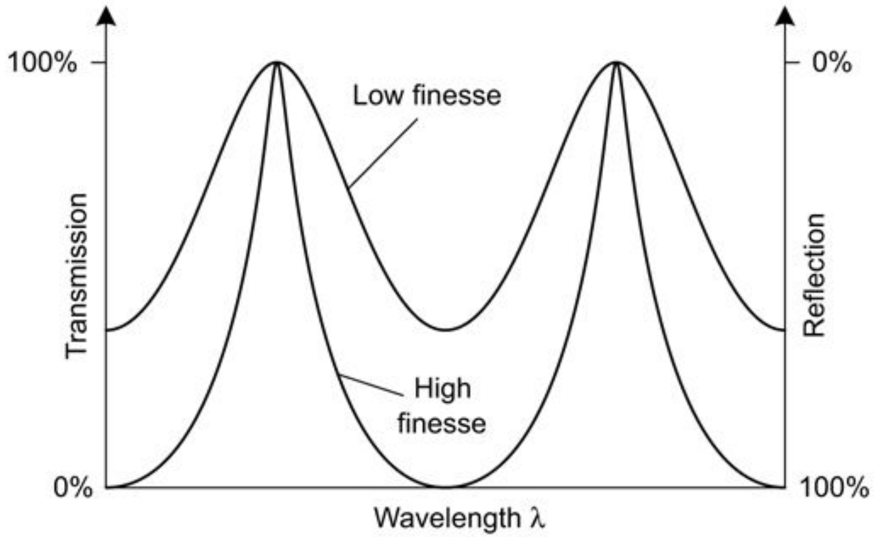
Thin-Film Filters

- The opposite surface is striked by the light passing into the interferometer structure.
- The phase shift depends on the distance D between the inner mirror surfaces.
- The small transmitted fractions interfere constructively for wavelengths equal to 2D, called resonant wavelengths.
- These wavelengths are passed through the cavity filter and all other wavelengths are reflected.

(contd...)

Thin-Film Filters

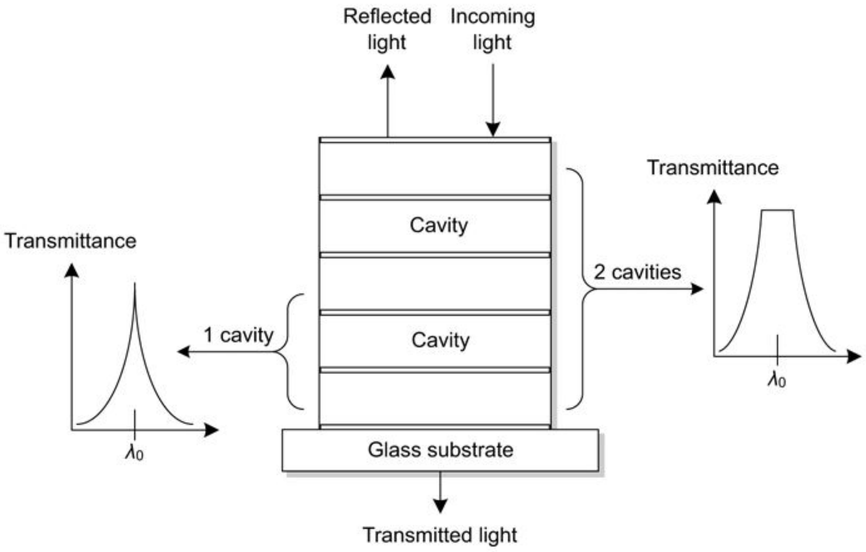
- The reflectivity of the mirrors determines the finesse of a TFF as shown in the figure.
- Finesse is a measure of the sharpness of the filter transfer function.



(contd...)

Thin-Film Filters

- A multilayer TFF structure is shown in the figure.
- The cavities separate the dielectric thin films acting as mirrors which are deposited on a glass substrate.



(contd...)

Thin-Film Filters for wavelength-blocking filter

System	Parameter	Value
G-PON ONU wavelength blocking filter	Passband	1480–1500 nm
	Stopband	1260–1360 nm
		1550–1560 nm
	Transmission loss	<0.04 dB
	Reflection isolation	>20 dB
	Number of layers	4
XG-PON ONU wavelength blocking filter	Passband	1574–1582 nm
	Stopband	1260–1560 nm
		1610–1660 nm
	Transmission loss	<0.05 dB
	Reflection isolation	>35 dB
	Number of layers	6

Diffraction Gratings

- Different wavelengths are combined and separated by using an optical component called diffraction grating.
- A periodic reflective structure splits and diffracts incident multiwavelength light into several monochromatic beams, each wavelength traveling in a different direction.
- The spacing of the grating and the angle of incidence determine the direction of the separated wavelengths.

(contd...)

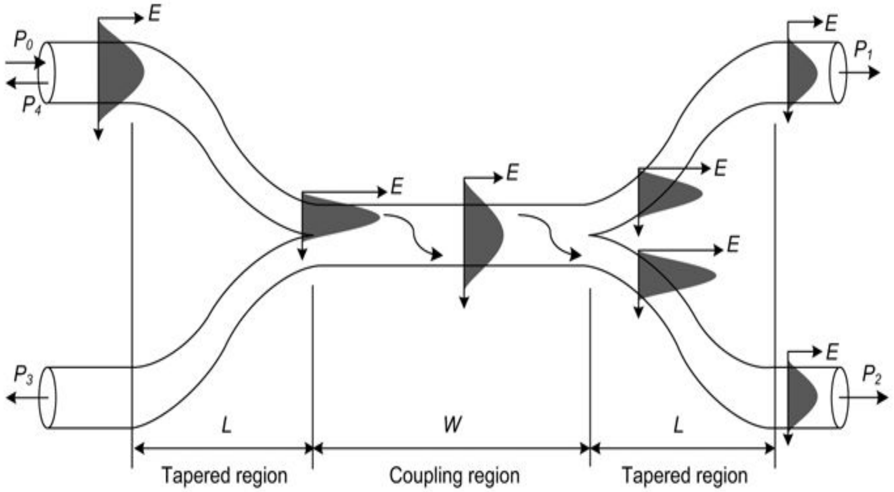
Diffraction Gratings

- Both wavelength separation and combination are possible as grating is fully reciprocal.
- There is a multiplexing of several wavelengths onto a single fiber for transmission but in OLT and ONU transceivers, they must be separated by direction and wavelength which is the important application of grating in GPON.

(contd...)

Passive Optical Splitters

- The passive power splitter is one of the fundamental components used in GPON in which input optical power is distributed equally to its output ports.
- a fused-fiber design based basic 2:2 splitter is shown in figure.



(contd...)

Passive Optical Splitters

- Two single-mode fibers are pulled, twisted, and melted together over a uniform coupling region.
- There is gradual decrease in the diameter of fiber from the input toward the coupling region where power is exchanged with the second fiber.
- The light is distributed by by the splitter from its input to all outputs in the downstream direction.
- The light paths are combined by the splitter from all ONUs back to the input port in the upstream direction.

(contd...)

Passive Optical Splitters

- The cost of doubling the split ratio is a 3-dB reduction in output power.
- The same loss is suffered by both the upstream and downstream signals even when only single port is connected to the OLT.
- This is a natural consequence of the reciprocity of passive symmetric devices.

(contd...)

Thanks

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GPON Standards and XGPON

G.984

- A standard published by ITU-T for passive optical networks (PON) is G.984 which is commonly known as GPON.
- The last kilometre of Fibre To The Premises (FTTP) services is implemented by using this standard.
- The requirements are put on the optical medium and the hardware by GPON which are used to access it.
- The manner is also defined by GPON where there is conversion of ethernet frames to an optical signal, as well as the parameters of that signal.

(contd...)

G.984

- The single connection bandwidth between the OLT and the ONTs is 2.4 Gb/s down, 1.2 Gb/s up, upto 128 ONTs share that bandwidth using a Time Division Multiple Access (TDMA) protocol which is defined by the standard.
- The error correction (Reed-Solomon) and encryption (AES) protocols are also specified by GPON.
- A protocol for authentication (OHCI) is also defined by the GPON.

(contd...)

The Standards

- In 2003, the ratification of the first version of GPON is done.
- There is expansion and revision of the standard several times since then and the work is still continued on the standard.
- There are seven parts of the most recent version such as:
  - G.984.1: (2008) defines the general characteristics with amendment 1 (2006) and 2 (2008).
  - G.984.2: (2003) defines the layer specification of Physical Media Dependent (PMD) with amendment 1 (2006) and 2 (2008).

(contd...)

The Standards

- G.984.3: defines the layer specification of transmission convergence with amendments 1 (2009), 2 (2009), 3 (2012) and erratum 1 (2010).
- G.984.4: (2008) defines specification of the ONT management and control interface (OMCI) with amendments 1 (2009), 2 (2009), 3 (2010), erratum 1 (2009), corrigendum 1 (2010), and an implementer's guide (2009).

(contd...)

The Standards

- G.984.5: (2014) it is the enhancement Band that co exist on the same medium with future WDM PON technology revised in July, 2018.
- G.984.6: (2008) it is a reach extension with amendments 1 (2009) and 2 (2012).
- G.984.7: (2010) defines long reach.

(contd...)

G.987.1

- G.987.1 is commonly known as 10-Gigabit-capable passive optical network (XG-PON) systems.
- To get simultaneous G-PON and XG-PON working in the transition period the network is installed with a WDM1r combiner/splitter as shown in figure.

(contd...)

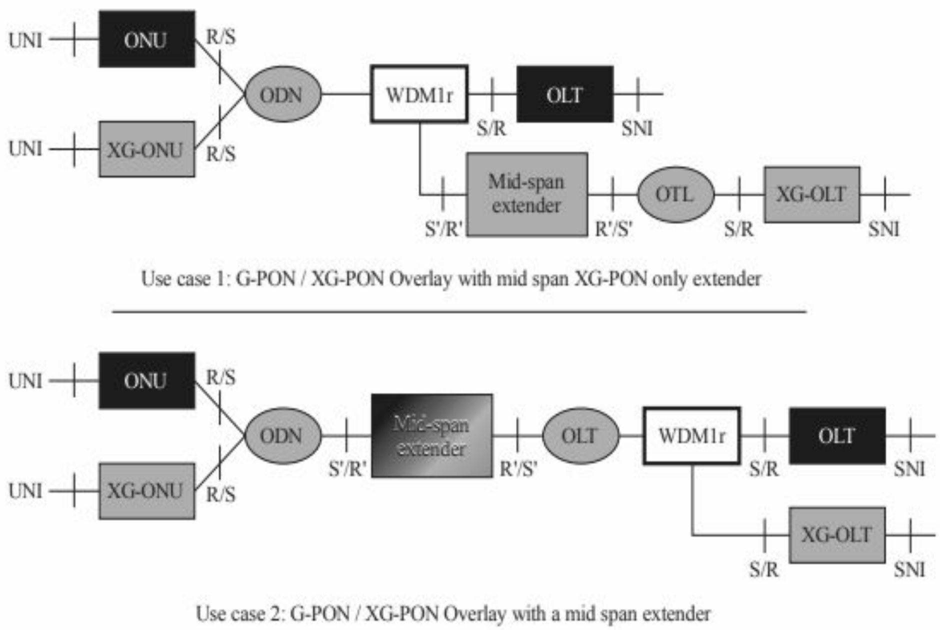
G.987.1

- There may be a use of any coexistence combination of XG-PON.
- Specifically, there is a coexistence of XGPON only with RF video overlay.

(contd...)

RE Architecture Options for XGPON

- The reach extenders are involved in the two main architectures of the XGPON as shown in the figure.



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RE Architecture Options for XGPON

- Providing additional optical budget with normal performances of OLT and ONU is the main goal of using a mid-span RE so that for both distance and split, the use of simultaneous full capability of the technology can be enabled.
- Any change in the requirements of OLT and ONU is not required by the use of such REs.

(contd...)

Maximum/mean Signal Transfer Delay Tolerance

- Those services are accommodated by XGPON in which a maximum mean signal transfer delay of 1.5 ms is required.
- A maximum mean signal transfer delay time of XGPON systems must be less than 1.5 ms between T-V.

(contd...)

Maximum Ethernet Packet Size

- Ethernet frames with a maximum length of 2000 bytes shall be supported by the XG-PON technology.
- XGPON optionally supports the jumbo frames with lengths beyond 2000 bytes and up to 9000 bytes.
- There is no degradation of the delay-sensitive services and packet network synchronization by jumbo frame transport if non-delay-sensitive services use jumbo frames beyond 2000 bytes on the same PON.

(contd...)

Synchronization Features and Quality

- The XG-PON infrastructure and systems are leveraged by the network operators so that high bandwidth can be delivered to mobile cell sites.
- For this accurate synchronization and timing delivery to the cell sites is required.
- The necessary synchronization and timing references are provided by T1 and E1 interfaces that are used for backhaul.
- a high quality timing clock is received by XG-PON OLTs where no T1/E1 interface is available.

(contd...)

Synchronization Features and Quality

- Hence they act as master timing source for the ONUs.
- In order to meet the cell site frequency/phase/time synchronization requirement, the accurate timing/synchronization has been distributed by the ONUs to the cell sites.

(contd...)

QoS and Traffic Management

- The multiple existing and emerging services are supported by XGPON across multiple market segments.
- The simultaneous access has been provided by XGPON to packet-based as well as legacy services.
- An access to carrier-grade metro Ethernet services is also provided by the XGPON.
- Hence, a broad range of QoS characteristics are presented by these varieties of services.

(contd...)

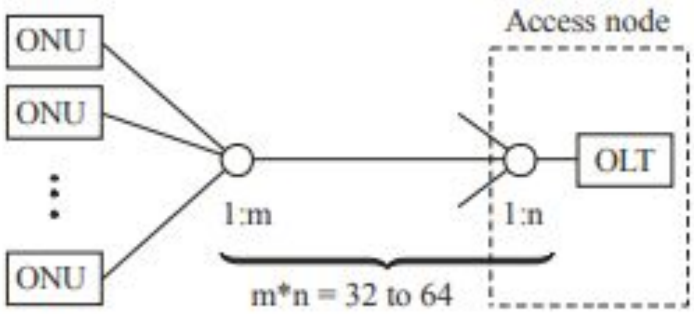
QoS and Traffic Management

- POTS voice quality, TDM services and mobile backhauling applications must be supported by XGPON with guaranteed fixed bandwidth so that the low-delay and low-jitter requirements are met.
- The rate controlled services are supported by the XGPON ONUs with policing and shaping function in addition to the priority based traffic management.

(contd...)

Split Ratio

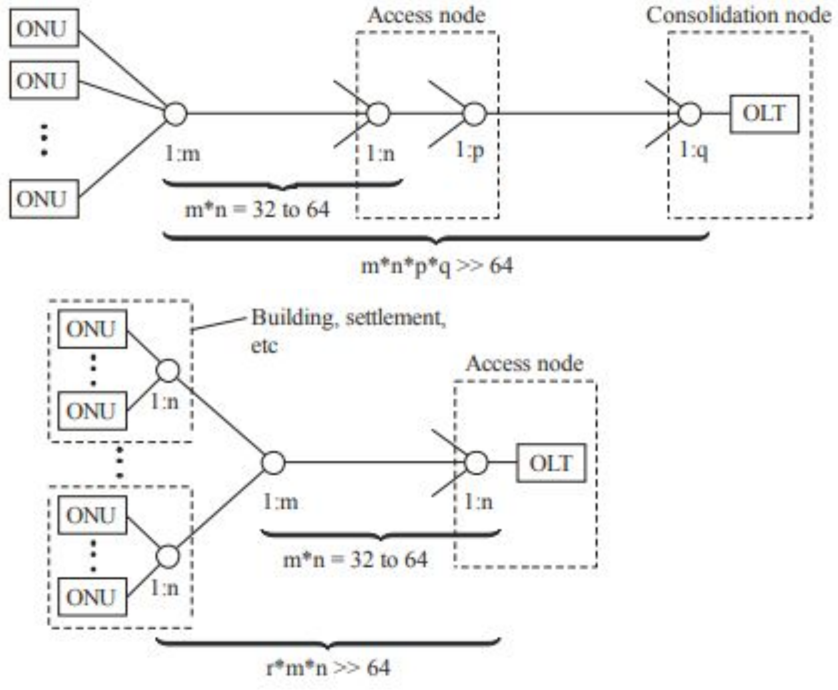
- The minimum requirement for XG-PON 1:64.
- Figure shows the generic splitter deployment of GPONs.
- The split can be extended beyond 1:64 by some network operators so that overall economics of XGPON can be improved compared to GPON.



(contd...)

Split Ratio

- Figure shows that in the backhaul section, PON can be extended due to higher splitter ratio.
- Figure shows the extension of PON towards the end users so that flexible splitter configurations can be provided and variety of deployment scenarios can be efficiently supported.



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Split Ratio

- The loss budget can be increased by using the reach extension and thus a higher split can be realized in the physical layer.

(contd...)

Power Saving and Energy Efficiency

- The use of a backup battery in order to provide the lifeline services when electricity service goes out is the primary objective of the power saving function in access networks.
- Therefore, better energy efficiency shall be supported by the XGPON TC layer.
- The reduction in all time power consumption is the secondary goal.
- Various levels of power saving can be offered by full service mode, dozing mode, and sleep mode during the normal mode of operation.

(contd...)

Authentication/Identification/Encryption

- XG-PON is a shared-medium based system that receives the full data on the same PON by all ONUs.
- There is a standardization of authentication and identification mechanisms in order to protect against impersonation/spoofing.
- ONU serial number or registration ID identification, CPE authentication and a strong authentication mechanism is required.
- To recover from the "sleep" mode, a simple but secure identification method is also necessary while using the power saving function.

(contd...)

Authentication/Identification/Encryption

- There is an encryption of all downstream unicast data with a strong and well characterized algorithm to protect against snooping at the ONUs.
- Therefore, a reliable key exchange mechanism will be provided by XGPON to start an encrypted communication.
- The encryption function shall be optional in the upstream direction.

(contd...)

Dynamic Bandwidth Assignment

- DBA shall be supported by XGPON so that upstream bandwidth can be efficiently shared among the connected ONUs and the traffic-bearing entities within the individual ONUs on the basis of the dynamic indication of their activity.
- The reference model is comprised in the definition of the DBA in which the ideal bandwidth assignment can be specified among the contending upstream traffic-bearing entities under the given conditions of traffic load.

(contd…)

Dynamic Bandwidth Assignment

- The suggested measures of discrepancy is contained by the standard between a DBA implementation and the reference model that allows effective numerical comparison of the DBA implementations.
- The formats of the SR DBA status enquiries and buffer occupancy reports and the associated protocol is specified by the standard so that multi-vendor interoperability can be guaranteed.
- There is a spreading of DBA across several upstream wavelengths in case of overlay XGPONs.

(contd...)

Thanks

Power Budget I

Introduction

- The physical performance of a PON determined by the optical budget in terms of the maximum number of ONUs supported and the reach of the farthest ONU from the OLT.
- A wide range of optical power levels are encountered in GPON applications.
- There may be +5 dBm or more launch powers while it is expected that receivers perform below –30 dBm input powers.

Budget Planning

- ❑ The difference between the minimum launch power at the transmitter and the required minimum power level at the receiver determines the loss budget available for a link that guarantees the necessary quality of transmission.
- ❑ There must be an allocation of the budget to the lossy components so that it can not be exceeded.
- ❑ The receiver overload and damage can be caused by the insufficient attenuation.

(contd...)

Budget Planning

- Each direction has its own budget.
- There are symmetric loss budgets in GPON and XGPON.
- The upstream and downstream budgets are limited by the different factors such as:
  - In upstream
    - There is roughly 0.1 dB/km higher fiber attenuation in the upstream band.

(contd...)

Budget Planning

- There is a lower minimum launch power of the laser at ONU as compared to that at OLT.
- There is a requirement of +2 dBm from the ONU and +14.5 dBm from the OLT in the XGPON.
- A penalty of 2-3 dB is introduced by burst-mode upstream transmission.

(contd...)

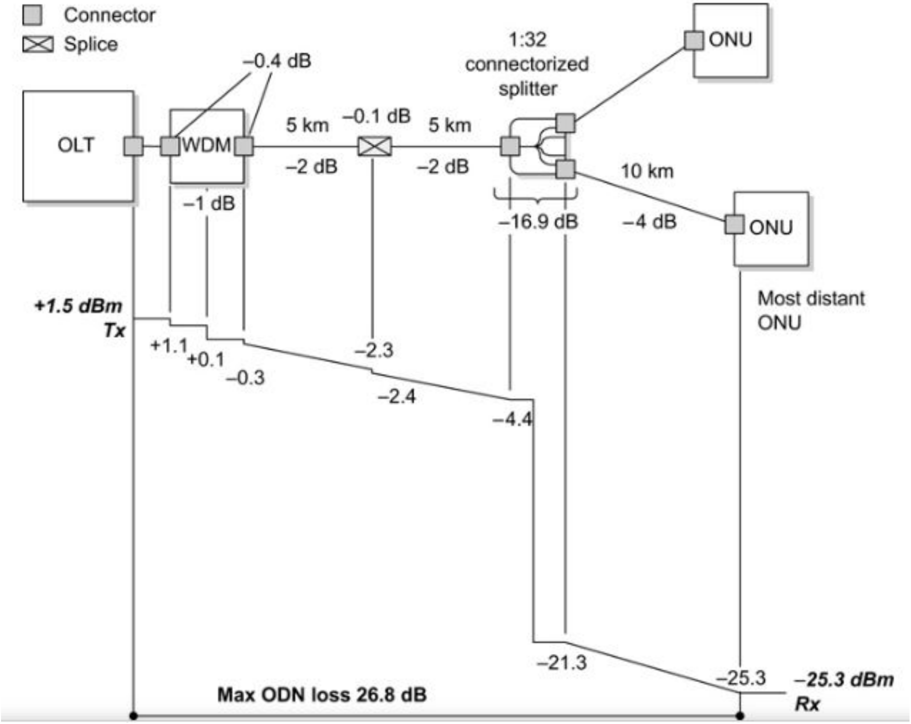
Budget Planning

- In downstream
  - There are higher bit rates.
  - A ratio of 2 in the bit rate of G.984 GPON is regarded as a 3 dB cost and G.987 XG-PON ratio of 4 is worth 6 dB.
  - At 10 Gbps, there is a problem of chromatic dispersion. A spectrally pure OLT transmitter is required to reduce it at a cost.
- There is a simple rule of the reach split ratio i.e. it costs 3.5 dB by doubling the split ratio, which roughly worths 10 km of good fiber.

(contd...)

Budget Planning

- A 28-dB loss budget is good for about 10 km at 1:64 split, 20 km at 1:32, and 30 km at 1:16.
- A graphic view of a budget plan is shown in the figure.
- There is a 26.8 dB loss of the fiber distribution network.The loss does not include the connectors at OLT and ONU.



G.984 GPON Budget Classes

- The three loss budget classes i.e A,B and C, are specified by the initial release of GPON standard G.984.2.
- B+ and C+ are the two additional industry best practice classes.

(contd...)

G.984 GPON Budget Classes

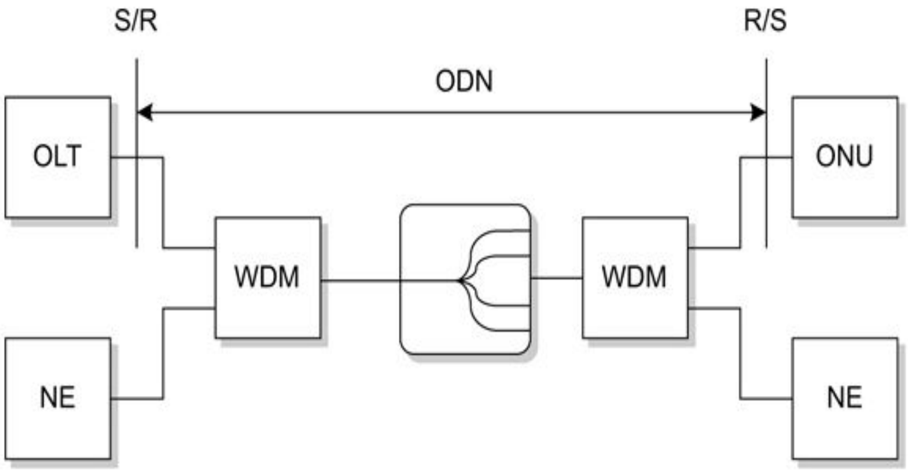
- G.984 GPON Budget Classes are listed in the table:

Link Budget Class	ODN Loss (min–max)	Standard
Class A	5–20 dB	G.984.2 (2003)
Class B	10–25 dB	
Class C	15–30 dB	
Class B+	13–28 dB	G.984.2 Amendment 1 (2006)
Class C+	17–32 dB	G.984.2 Amendment 2 (2008)

(contd...)

G.984 GPON Budget Classes

- A maximum and a minimum value of optical loss defines each class.
- The total bidirectional loss of the ODN is bound by these values which is shown in the figure.



(contd...)

G.984 GPON Budget Classes

- The optical connectors at the OLT and ONU are represented by the reference points.
- Class B+
  - For 1:32 at 20 km, class B was not enough and class C was very expensive for the technology of the time.
  - Hence, 28 dB industry best practice class B+ budget is defined to provide a reach of 20 km with a 32-way split.

(contd...)

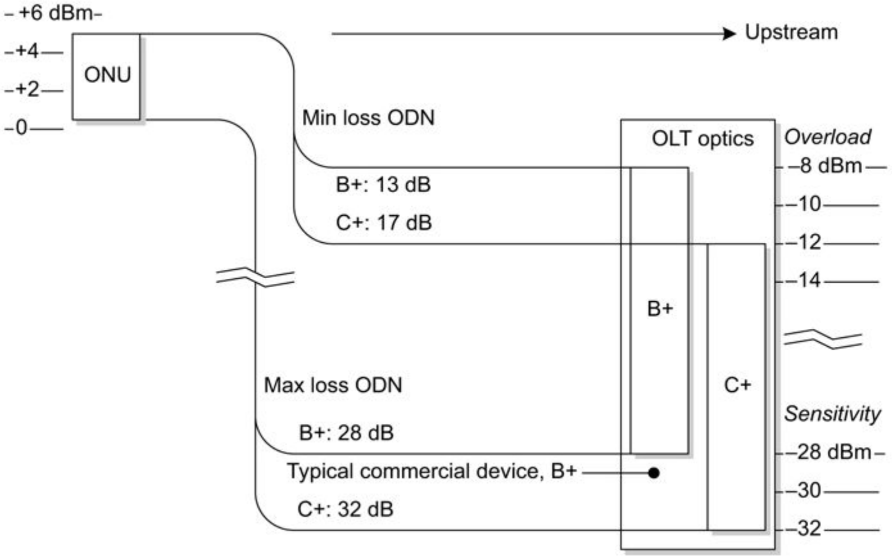
G.984 GPON Budget Classes

- Class C+
  - The extended 32-dB C+ budget class is introduced in 2008 with amendment of G.984.2 so that the following deployment constellations can be supported:
    - 1:16 split at 40 km
    - 1:32 split at 30 km
    - 1:64 split at 20 km

(contd...)

G.984 GPON Budget Classes

- A single-ended upgrade from B+ to C+ is supported by the standard i.e. there is a replacement of OLT optics only.
- The upstream optical budget is shown in the figure that indicates the OLT receiver takes the increased ODN loss and not ONU.



(contd...)

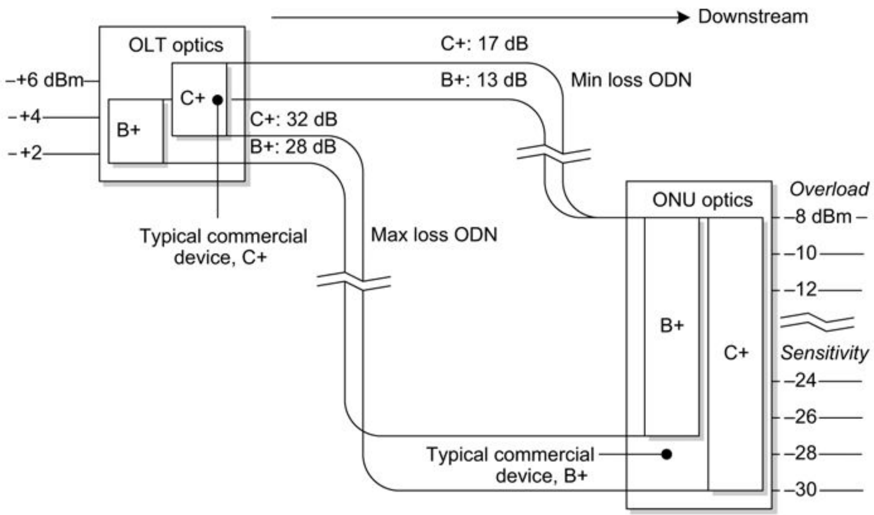
G.984 GPON Budget Classes

- OLT has nontrivial 32 dBm receiver.
- The C+ OLT sensitivity is defined by the standard with an assumption of enabling forward error correction (FEC).
- Byte synchronization and frame alignment is presupposed by the FEC and FEC is of no use if proper recognition of the burst header is not done in the presence of a high bit error rate.

(contd...)

G.984 GPON Budget Classes

- The GPON downstream budget is shown in the figure.
- An additional 3 dB of ONU receiver sensitivity is required.
- 28 dBm is supported by the existing B+ optics which is 2 dB short.



(contd...)

G.984 GPON Budget Classes

- C+ ONU sensitivity is defined by the standard with assumption of enabling FEC, so that satisfactory results can be yielded due to lower optical input power from the same physical B+ receiver.

Thanks

Power Budget II

G.987 XGPON Budget Classes

- G.987 XGPON Budget Classes including two nominal and two extended loss budgets are listed in the table:

Link Budget Class	ODN Loss (min to max)	Standard	Maximum Differential Distance
Nominal 1 (N1)	14–29 dB	G.987.2	
Nominal 2 (N2)	16–31 dB		20 km (DD20)
Extended 1 (E1)	18–33 dB		40 km (DD40)
Extended 2 (E2)	20–35 dB		

(contd...)

G.987 XGPON Budget Classes

- The counterparts of the G.984 GPON B+ and C+ classes are nominal 1 and extended 1 classes.
- A WDM device has additional 1 dB.
- For a large cost difference between N1 and E1 nominal 2 is used which is an intermediate budget.
- The extended 2 budget is used as a target for the components industry.
- It is expected that the OLT needs optical amplification.

(contd...)

G.987 XGPON Budget Classes

- Different dispersion ranges are allowed by specifying two maximum differential distances of 20 km (DD20) and 40 km (DD40) regardless of budget class:
  - 0-400 ps/nm for DD20 downstream, 0-140 upstream
  - 0-800 ps/nm for DD40 downstream, 0-280 upstream
- This means that, in terms of modulated linewidth,a 40-km OLT transmitter must be twice as good as a 20-km transmitter.

(contd...)

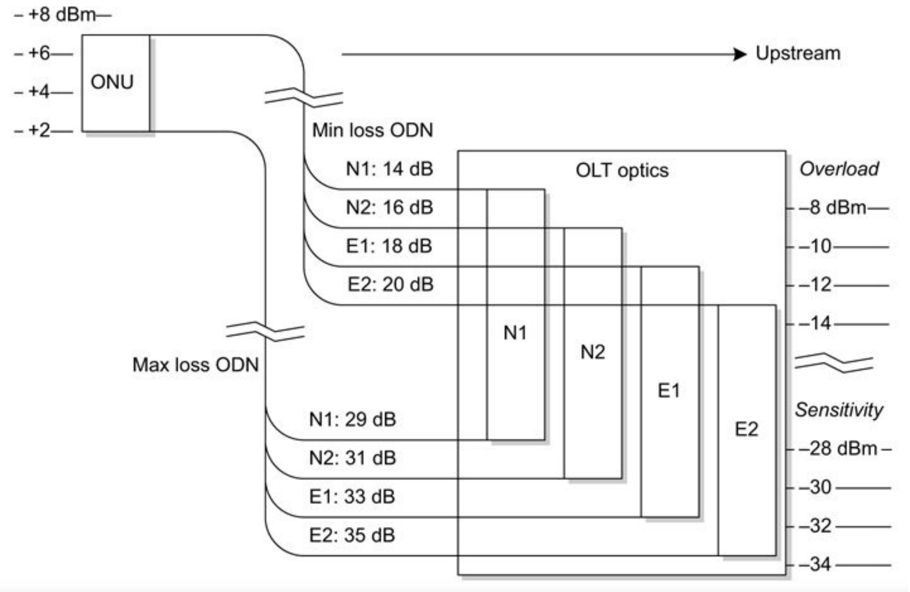
G.987 XGPON Budget Classes

- The XGPON budget of downstream is designed against a BER of 10^{-3}, which is then improved by FEC to 10^{-12}.
- There is a designing of the XGPON budget to a worst-case BER of 10^{-4}, that can be improved by FEC to 10^{-10} in upstream.
- Depending on the actual measured BER, the upstream FEC can be switched on or off by the OLT.

(contd...)

G.987 XGPON Budget Classes

- There can be only +2 dBm upstream transmit power so that the ONU optics remain reasonably inexpensive which is achieved by common uncooled 2.5-Gb/s distributed feedback (DFB) lasers.
- Figure shows the upstream budget for G.987 XGPON.



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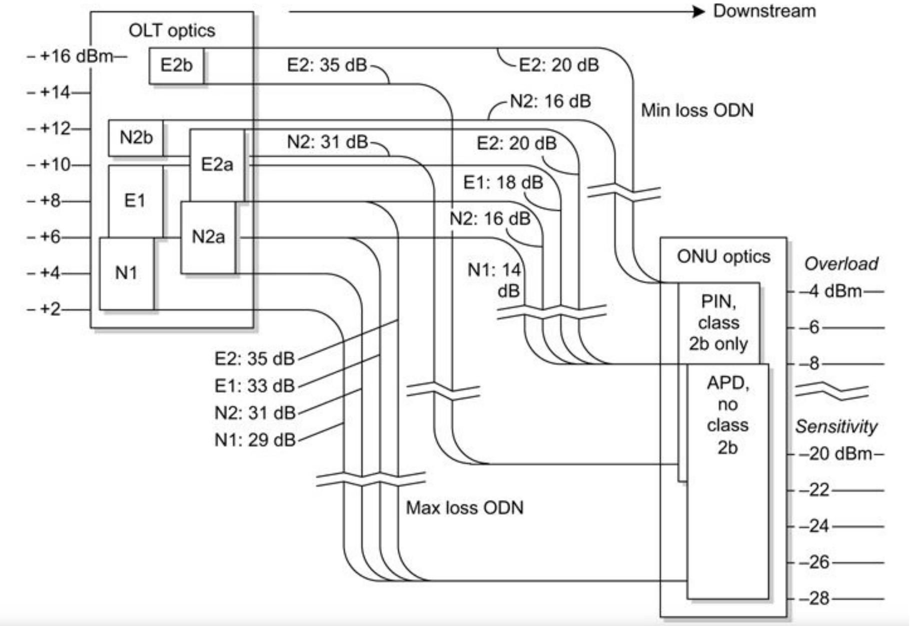
G.987 XGPON Budget Classes

- The downstream budget for G.987 XGPON is shown in the figure.
- The idea of GPON is the minimization of the number of ONUs that must be supported.



(contd...)

G.987 XGPON Budget Classes

- It is impossible to deploy a and b classes together on the same PON as they are not compatible.
- There is a shifting of cost into the OLT so that the reduced ONU receiver sensitivity of the b classes can be compensated.
- The power of a standard DFB laser can be boosted to levels of at least +10.5 and +14.5 dBm for classes N2b and E2b, respectively, by using an optical amplifier at the OLT transmitter.
- The onset of fiber nonlinearities bounds the maximum launch power.

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Management I

Introduction

- The management model of GPON assumes that a logical extension of the OLT is the ONU.
- A logical separation exists inside the ONU when an RG function is included in the ONU that can be managed separately by the operator.
- There occurs coordination between identifiers in the network management databases.
- The GPON systems standard management interface is known as OMCI.

(contd...)

Introduction

- The OLT is allowed by OMCI to perform full fault, configuration, performance, and security functions (FCAPS) at the ONU.
- OMCI is defined in ITU-T recommendation G.988, as amended.
- The information model and the set of messages exchanged across the OMCC are referred to as OMCI.
- The set up as part of discovery process of the ONU is OMCC.

(contd...)

Introduction

- A set of managed entities (MEs) is comprised in the information model in which a list of attributes is included.
- Various actions and notifications are supported by the specific managed entity types.
- A given managed entity type may have zero, one, or many instances depending on its definition.

OMCI Messages

- The OLT initiates the most of the messages which results in simple confirmation from the ONU or an error response by which the reason for command failure is indicated.
- The purpose of other OLT messages is to retrieve information from the ONU.
- The ONU itself initiates the notification messages so that significant events such as alarms, attribute value changes, or test completion, can be signalled.

OMCI Message Structure

- There has been a fixed length of 48 bytes of the default or baseline OMCI message.
- Because only an integer number of attributes may be contained in a message, some limitations are imposed on the size of information model fragments.

(contd...)

OMCI Message Structure

- The format of a baseline message is shown in the table.

Byte Number	Size	Use
1..2	2	Transaction correlation identifier
3	1	Message type
4	1	Device identifier
5..8	4	Managed entity identifier
9..40	32	Message contents
41..48	8	OMCI trailer

(contd...)

OMCI Message Structure

- With variable-length messages of up to 1980 bytes, there defines a set of an extended message.
- The baseline message set is supported by all ONUs and OLTs to initialize in them a backward-compatible way.

(contd...)

OMCI Message Structure

- The extended message format is shown in the table.

Byte Number	Size	Use
1..2	2	Transaction correlation identifier
3	1	Message type
4	1	Device identifier
5..8	4	Managed entity identifier
9..10	2	Message contents length
11..($N-4$)	–	Message contents
($N-3$)..N	4	Message integrity check (MIC)

Management Information Base

- The default MIB is contained in the ONU when it starts up.
- A few fundamental MEs are contained in it for conveying information such as the ONU's serial number, its capabilities, its port configuration, and parameters of its resident software images.
- A number of additional managed entities are automatically instantiated and populated by the ONU depending on its capabilities, and especially on its hardware architecture.

(contd...)

Management Information Base

- The ONU's baseline configuration is expected to be confirmed by the OLT so that its services can be audited and provisioned at ONU initialization.
- All of its configured information, along with non-configured information is represented by the ONU's MIB.
- the ONU's MIB can be uploaded by the OLT at any time to confirm that the ONU is in sync.

ONU Information Model

- A tool to manage ONUs is OMCI in which a model of the ONU is included.
- The concept of MEs is used to build OMCI, each of which is identified by a unique ME type or class enumeration (2 bytes).
- Several aspects of a real ONU are represented by the managed entities of OMCI:
  - Some MEs focus primarily on the ONU as equipment.

(contd...)

ONU Information Model

- Some MEs represent the access network interface (ANI) side of the ONU, that is, the PON interface itself
- Some MEs represent the various kinds of user-network interface (UNI) ports available on ONUs
- ONU interfaces are represented by the previous two categories

ME-Type Definition Template

- ❑ Managed Entity Name
- ❑ Introduction
- ❑ Relationships
- ❑ Attributes
- ❑ Actions
- ❑ Notifications
- ❑ Supplemental Material

OMCI Attributes

- Managed Entity Identifier
- Simple Attribute Types
- Table Attributes
- Extended Table Rows

OMCI Actions

- Get
- Set
- Create, Delete
- Get Next
- Test

Thanks

Management II

OMCI Notifications

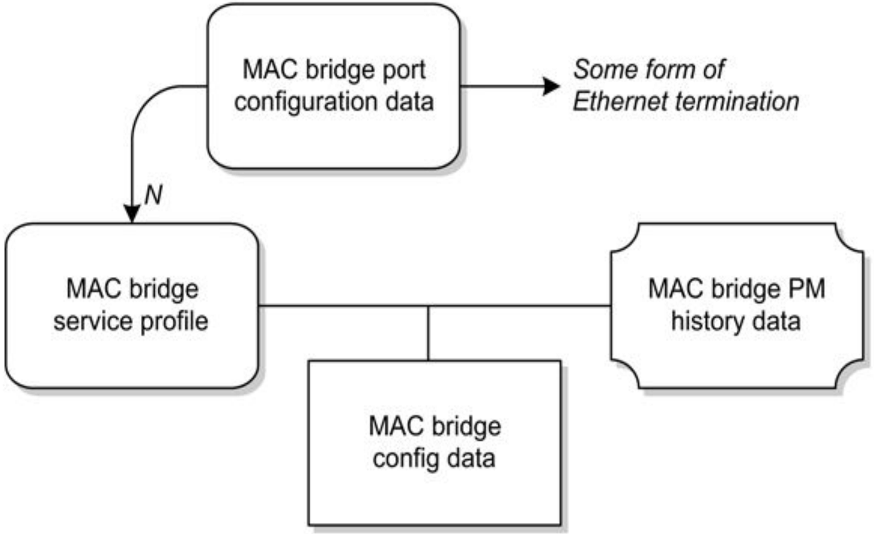
- Attribute Value Change Notifications
- Alarms
- Threshold Crossing Alerts

OMCI State Model

- The following pair of states appears in quite a number of OMCI-managed entities:
  - Administrative State
  - Operational State

OMCI Graphical Conventions

- The graphical conventions of G.988 are shown in the figure.
- The managed entity instances are represented by the rounded boxes that are created and deleted by the OLT while MEs are represented by square boxes that are created by the ONU itself.



(contd...)

OMCI Graphical Conventions

- Pointers are used to relate MEs to one another which are shown as arrows with a quantifier.
- Any number of ports are used to model a MAC bridge.
- A pointer attribute is included in each MAC bridge port managed entity instance.
- Identical ME IDs are used to relate the MEs implicitly shown by lines without arrows.

ONU-G, ONU2-G, and ONU-E MEs

- The ONU is modelled by these MEs.
- Some of the ONU's basic characteristics are defined by them.
- OMCI has a limit of 16 attributes per ME type due to which GPON defines only two attributes.
- Available attributes include:
  - Vendor ID, Serial Number
  - Version, Equipment ID, Vendor Product Code

(contd...)

ONU-G, ONU2-G, and ONU-E MEs

- Battery Backup
- ONU Survival Time
- Traffic Management Attributes
- System Uptime
- States
- Registration Credentials

(contd...)

ONU-G, ONU2-G, and ONU-E MEs

- Some specialized functions are supported by the ONU-G MEalong with the usual get and set actions, such as:
  - Reboot
  - Test
  - Synchronize Time
- A variety of problems are signalled by declaring alarms by ONU ME:
  - Equipment failure, ONU self-test failure

(contd...)

ONU-G, ONU2-G, and ONU-E MEs

- Powering alarm
- Battery missing, battery failure, battery low
- Physical intrusion
- DG ONU manual power off
- Temperature yellow, temperature red
- Voltage yellow, voltage red

Cardholder, Circuit Pack and Port Mapping Package MEs

- The ONU is modelled as a chassis by this family of MEs with replaceable circuit packs (cards) that can be plugged into cardholders (slots).
- There is a modelling of an integrated ONU as a set of virtual slots and circuit packs.
- A slot is allowed to be empty, to be preprovisioned, to be equipped with the right or the wrong circuit pack, or to accept whatever circuit pack is plugged in by the cardholder ME attributes and actions.

(contd...)

Cardholder, Circuit Pack and Port Mapping Package MEs

- ARC is supported by the cardholders.
- The instances of the necessary MEs are created automatically by the ONU when a card is preprovisioned, or when a plug-and-play slot is equipped with a suitable card.
- In addition with supporting queues, schedulers, T-CONTs, possibly software images, etc., ANI or UNI ports are also included in them.
- The pack-specific MEs are automatically destroyed by the ONU when a circuit pack is deleted from a slot by management action.

Equipment Extension Package ME

- This managed entity is automatically instantiated by the ONU.
- The external sense points that can be wired up to arbitrary sensors are supported by the ONU by using equipment extension package.
- A change in a sense point is reported by the ONU as an alarm.
- The interpretation of the report depends on the OLT or the EMS.
- The manager is allowed to control ONU outputs by the same ME.

Equipment Protection Profile ME

- The equipment protection is supported by this ME.

ONU Power-Shedding ME

- The ONU may or may not know whether AC power has failed, or to put it another way, whether it is operating on its backup battery depending on its design.
- If it knows, the services are shed by the ONU so that its availability on the backup battery can be prolonged selectively.
- the power-shedding ME can provision each type of service—data, voice, video, etc., with a hold time.

(contd...)

ONU Power-Shedding ME

- If there is an elapse of hold time without AC power recovery, that service is shut down, therefore the availability of higher priority services can be extended.
- If POTS has to be delivered by the ONU, the highest priority is given to the POTS.

ONU Dynamic Power Management Control ME

- G.987.3 defines the energy conservation for XGPON.
- The provisionable intervals by which the ONU's doze and sleep functions can be supported, is provided by this ME.

OLT-G ME

- The type of OLT, to which an ONU is connected, is identified by this ME.
- The respectability has been gained by the OLT-G ME as a parent of the ToD attribute by which the OLT is permitted to specify a date and time stamp that signifies the start of a specified frame count.

ONU Data ME

- Only one attribute, the MIB data sync, is contained in the ONU data ME.
- A long list of actions is supported by the ONU data ME
  - MIB Upload, MIB Upload Next
  - MIB Reset
  - Get All Alarms, Get All Alarms Next

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Management III

Software Upgrade

- The function of software upgrade is supported by the software image ME.
- By default, the ONU is pertained by it as a whole, but if independently maintainable software is contained in circuit packs, they are managed by using the same ME.
- Several such circuit packs download the software in parallel.
- The product code and version fields are included in the attributes of the software image.

(contd...)

Software Upgrade

- The three additional attributes are used to get the current status of the image:
  - Is Valid
  - Is Active
  - Is Committed

(contd...)

Software Upgrade

- A number of specialized actions are supported by the software image ME to upgrade software:
  - When an ONU is to be upgraded, it is ensured by the OLT that the ONU is active on the committed image and addresses itself to the other image.
  - The new image is downloaded by the OLT.
  - The OLT asks the ONU for validating the new image and storing it in nonvolatile memory.

(contd...)

Software Upgrade

- The new image is activated by the OLT without having committed it.
- A command is committed to a new image by the OLT when all goes well and the previous image is decommitted automatically.

❑ Start Download, Download Section

- A only 31 bytes, referred to as section, are downloaded by the baseline OMCI message set at a time, a bit more detail is involved to download an image.

(contd...)

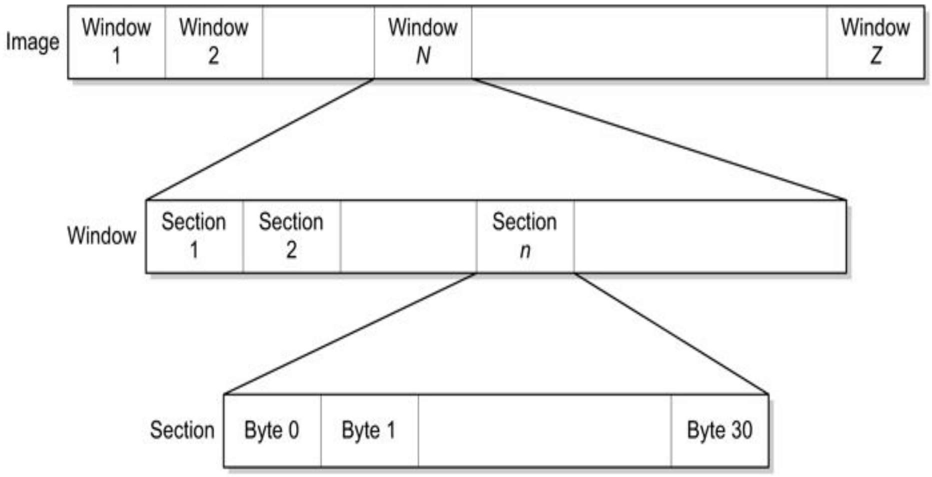
Software Upgrade

- There is a grouping of up to 256 sections into window whose size has been negotiated between ONU and OLT at the starting of the process.
- A sequence number is included in each section that starts at zero with each window.
- It is expected that the sections, sequentially numbered from zero, are received by the ONU in each window.

(contd...)

Software Upgrade

- There is a failure in receiving of one or more sections if error in download occurs.
- Figure shows the software image structure for download.



(contd...)

Software Upgrade

- End Download
  - The end download command is sent by the OLT after downloading all windows of the image and hence, the ONU validates the image and stores it in nonvolatile memory.
  - When the validation and persistence of an image is acknowledged by the ONU, the OLT can go ahead and activate, then commit the image.

(contd...)

Software Upgrade

- Software Upgrade, Vendor-Specific Use
  - Those managed entity IDs are reserved for software management of the ONU or its circuit packs that match actual or virtual slots (cardholders).
  - This is a small part of the 2-byte ME ID space.
  - As vendor software and operator practices are used to build it, cases are there so that other purposes use the download-activate-commit process.

(contd...)

Software Upgrade

- The nonreserved ME ID address space can be used for vendor-specific functions by deploying OMCI.
- The bulk upload or restoration of ONU MIBs as files is one of its important use case.
- If a file contains an MIB, scratch can be used to archive, analyze, modify and construct it in some remote location.

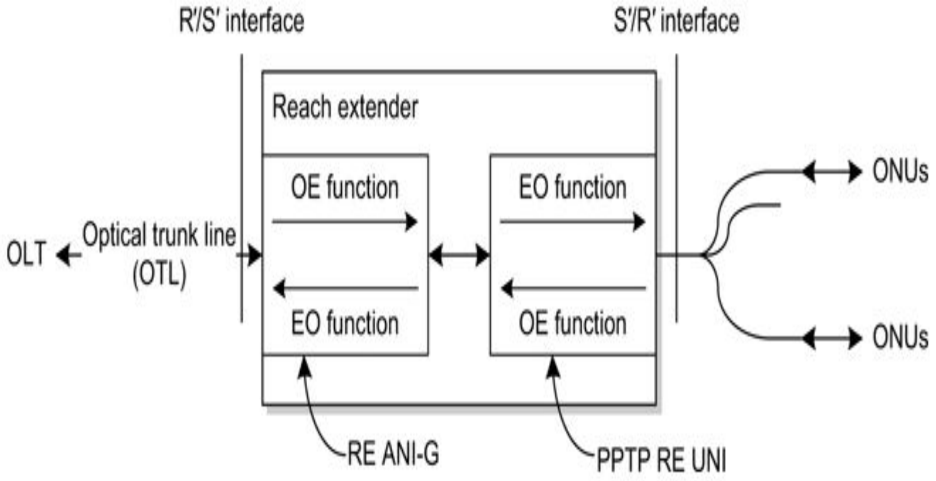
Reach Extender Management

- G.984.6 defines the reach extension for GPON and G.987.4 for XGPON.
- A reach extender is remote equipment whose location is not necessarily the remote power splitter due to which the effective optical budget of the PON can be increased.
- The reach of the ODN can be extended by the extra budget that can increase the split ratio, or both.
- OEO and OA are two simple reach extender architectures.

(contd...)

Reach Extender Management

- The case when OEO is employed in both directions is shown in the figure.
- The RE ANI-G and the physical path termination point RE UNI are the pertinent OMCI MEs.
- The transceiver at the R′/S′ interface is modelled by the RE ANI-G.



(contd...)

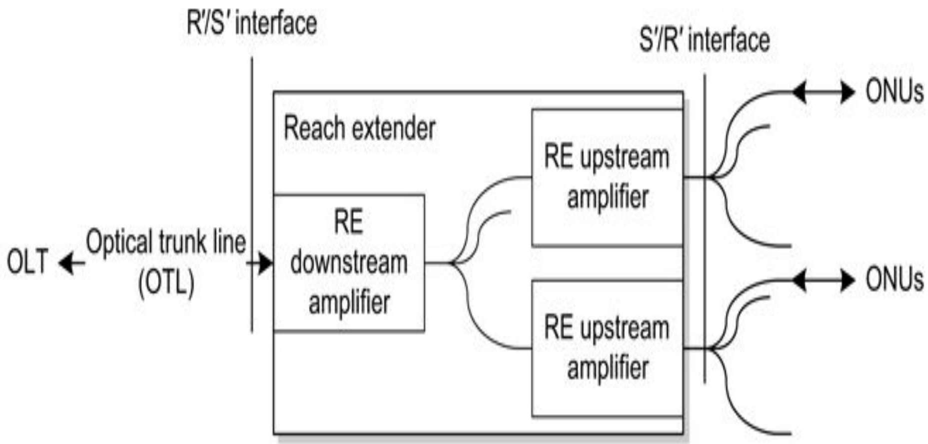
Reach Extender Management

- One of the PONs extended by an RE is used for the RE's own management channel.

(contd...)

Reach Extender Management

- The figure shows a reach extender using optical amplification (OA) in both directions.
- There is a possibility that the ONU side have one or more optical amplifiers.



(contd...)

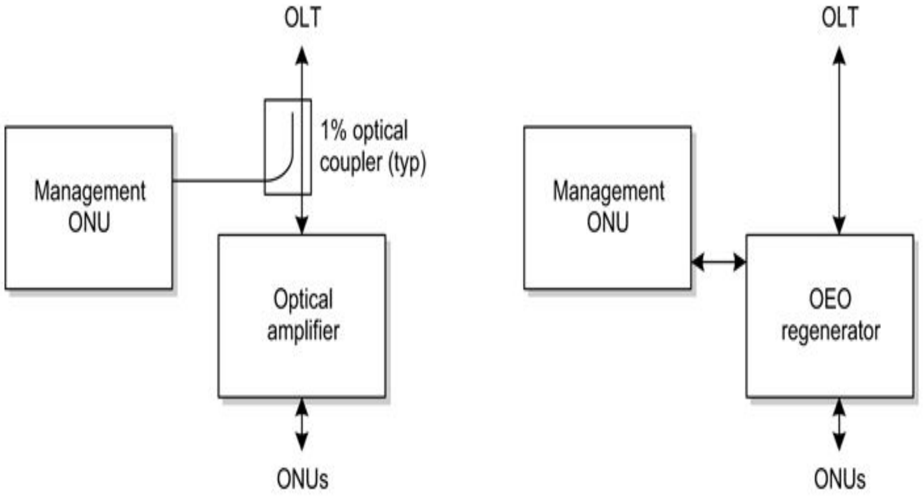
Reach Extender Management

- The RE upstream and downstream amplifiers are the pertinent OMCI managed entities.
- Hybrid RE architectures are possible in which one direction is electrically regenerated while the other direction is optically amplified.

(contd...)

Reach Extender Management

- Figure shows that a logical ONU function contained in the RE performs the management of the RE.



(contd...)

Reach Extender Management

- If the OLT side of RE has an optical amplifier, the trunk fiber is used to feed the management ONU function through a tap that drains off only a very small amount of light, typically 1% and reverse action in the upstream.

Thanks

Services

Introduction

- Each telecommunications operator has its own service model.
- The two standards streams define the common aspects of the system requirements:
  - ITU-T G.987.1
  - Broadband Forum

The MAC bridge

- Ethernet frames are accepted by a MAC bridge on one port and replicates them to all other ports.
- The source MAC addresses of incoming frames are learned by a MAC bridge and thereafter outgoing frames are forwarded only to ports where the pertinent destination addresses are connected.

(contd...)

The MAC bridge

- If two or more ports have connected two bridges directly or indirectly, there is a risk that the frames could be forwarded by them to each other forever.
- Therefore, a spanning tree protocol (STP) can be implemented by the bridges to avoid this.
- STP may be rapid STP (RSTP) or multiple STP (MSTP).

(contd...)

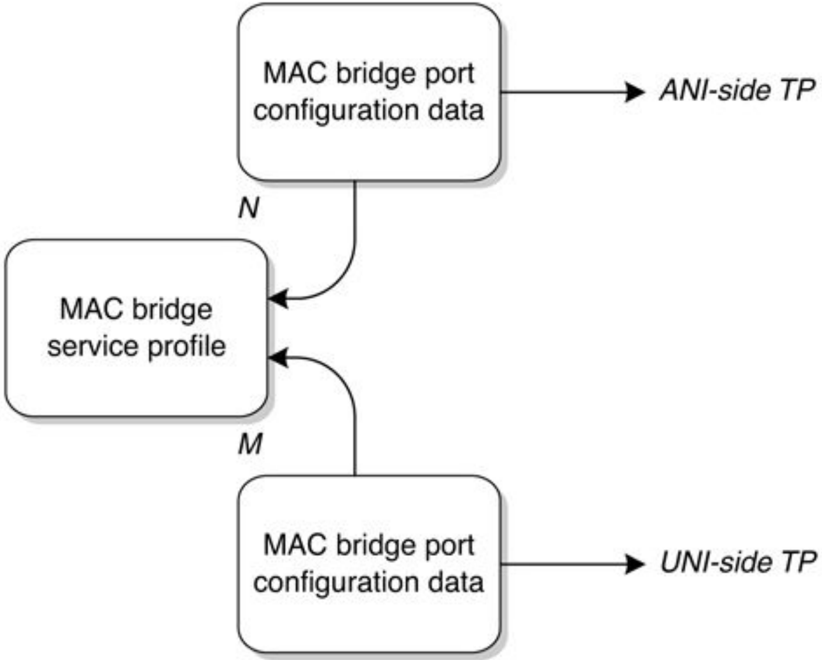
The MAC bridge

- The forwarding loops can be recognized and broken by the bridges through STP by disabling one of the links that would otherwise close the loop.
- The multicast frames are replicated onto several ports based on control actions by using MSTP.
- The MAC bridges are aware of VLANs and a VID is 12 bits long.

(contd…)

The MAC bridge

- Figure shows the basic MAC bridge configuration model in OMCI.



(contd...)

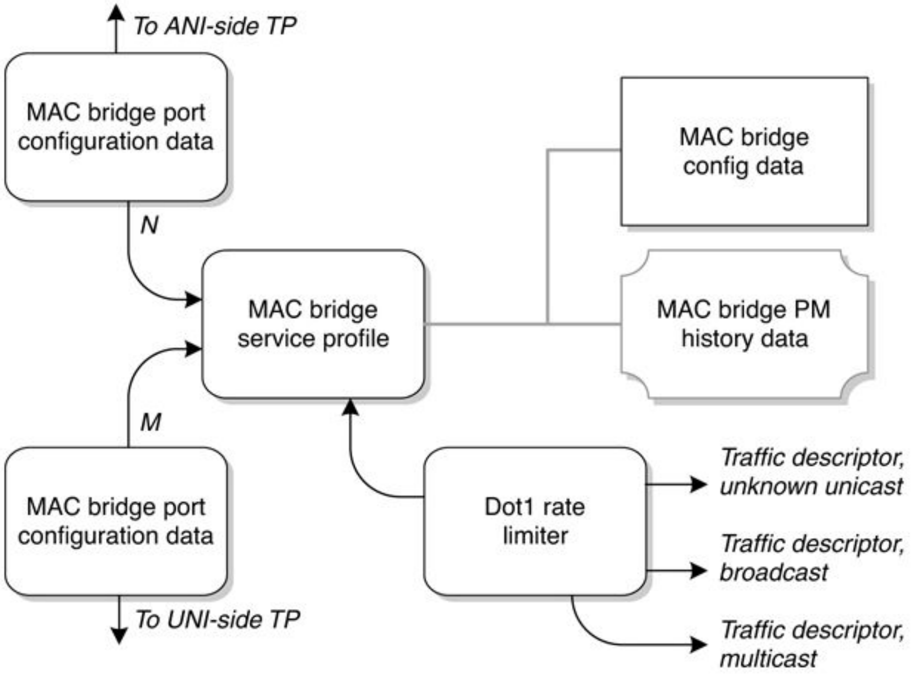
The MAC bridge

- MAC Bridge Service Profile
  - The bridge is modelled by this ME.
- MAC Bridge Port Configuration Data
  - An instance of this ME models each port of the MAC bridge.
  - A pair of pointers is included in it, one is to link to the MAC bridge service profile, the other to connect with a subscriber-side (UNI) of one kind or another, or to a PON-side (ANI) termination point.

(contd...)

The MAC bridge

- Figure shows several additional MEs that can be associated with a MAC bridge.



(contd...)

The MAC bridge

- MAC Bridge Configuration Data
  - The ONU automatically instantiate this ME when the MAC bridge service profile is created.
  - It is a read-only ME in which the MAC address of the bridge is contained.
- Dot I Rate Limiter
  - A dot I rate limiter is created by the OLT help protect the network from some forms of DoS attacks.

(contd...)

The MAC bridge

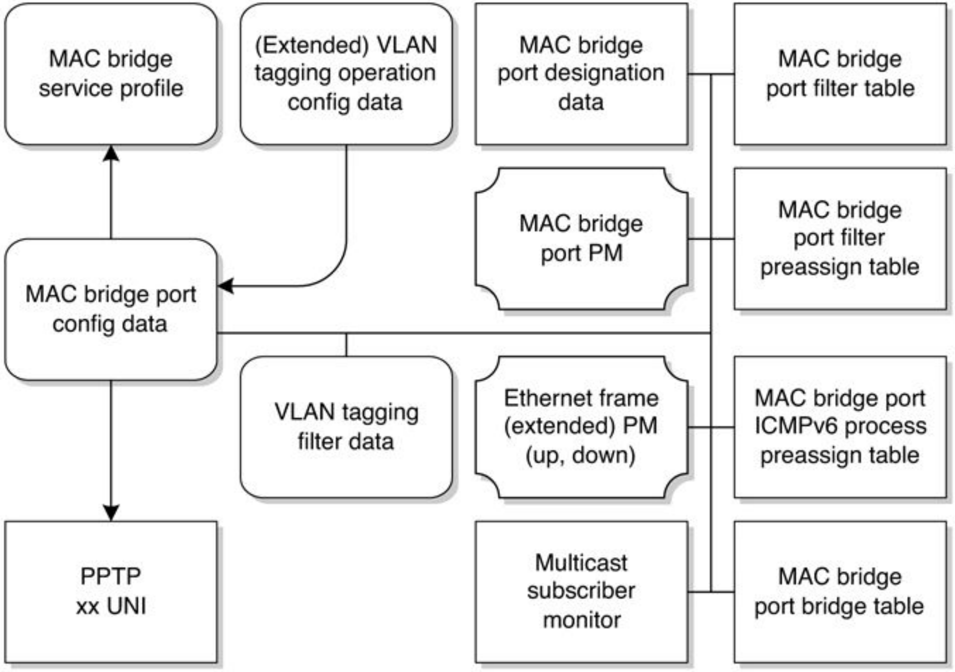
- The amount of upstream traffic can be restricted by the rate limiter.
- The classification of data is as follows:
  - Unicast traffic with an unknown destination address
  - Broadcast traffic
  - Multicast traffic

- MAC Bridge Performance Monitoring History Data
  - A MAC bridge PM ME may be created by the OLT.
  - The ME ID of both MAC bridge PM and service profile is same.

(contd...)

The MAC bridge

- The discarded MAC address learning entries are counted by this particular ME.
- Figure shows the MAC bridge port adjunct MEs.
- Only one of the VLAN tagging operation MEs can perform VLAN tagging.



(contd...)

The MAC bridge

- It defines the two forms of Ethernet PM out of which the extended PM is more flexible but complex.

- MAC Bridge Port Filter Table Data
- MAC Bridge Port Filter Preassign Table
- MAC Bridge Port ICMPv6 Process Preassign Table
- MAC Bridge Port Bridge Table Data
- MAC Bridge Port Designation Data

(contd...)

The MAC bridge

- Ethernet Frame PM
- GEM Interworking Termination Point
- GEM Port Network CTP

Downstream Quality of Service

- The downstream QoS is largely localized to functions within the OLT, or to functions within the ONU.
- The ONU's UNI necessary management model is supported by OMCI and is a set of downstream priority queues.
- The flow of all the data traffic is through the broadband remote access server or broadband network gateway.

Upstream Quality of Service

- It is assumed by the information model ONU-centric OMCI that there is localization of all upstream traffic congestion points at the ANI which is the PON interface.
- This model is approximated by the ONU vendor.
- Some number of GEM ports (flows) are mapped in the T-CONT, a specific traffic class.
- One or more T-CONTs are supported by each ONU.

(contd...)

Upstream Quality of Service

- An upstream frame is deemed to be green when it arrives if it can be added to the committed bucket or if enough tokens are there in the committed bucket to pay for it.
- It is tried against the peak bucket if it does not fit into the committed bucket.
- The frame is marked yellow if it fits and otherwise marked red which are discarded.

(contd...)

Upstream Quality of Service

- Setting the depth of the priority queue is another QoS tuning mechanism.
- It would appear that all of the memory available for queuing should be used which is probably not the right strategy.
- The traffic is increasingly get delayed as a queue fills up.
- The service may deteriorate or even become unusable at some point due to the additional delay.

(contd...)

Upstream Quality of Service

- The packet is lost in case of real-time or semi-real-time traffic if it is delivered too late.
- Hence, the priority queue is set to signal PAUSE frames to the incoming streams when occupancy threshold is reached.
- There is 4 bytes (XG-PON) or 1 byte (G-PON) granularity of a capacity allocation.

(contd...)

Upstream Quality of Service

- The responsibility of ONU is enqueueing of traffic in one or more queues feeding each T-CONT so that the queue backlog can be reported with T-CONT granularity when requested by the OLT and when permission is granted for transmission of the upstream traffic according to the provisioned queuing disciplines.

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