INFOCOMM MEDIA DEVELOPMENT AUTHORITY

Telecommunications Standards Advisory Committee (TSAC)

Next Generation National Broadband Network (NGNBN)

Optical Fibre Deployment

Part 5 – FTTx Components, Planning and Deployment

IMDA RD OFD – Part 5
Issue 1, 1 October 2016

Info-communications Media Development Authority
Resource Management & Standards
10 Pasir Panjang Road
#10-01 Mapletree Business City
Singapore 117438

Acknowledgement

The Info-communications Media Development Authority (IMDA) and the Telecommunications Standards Advisory Committee (TSAC) would like to acknowledge the following members of the Technical Committee Working Group 1 (TSTC WG1) for their invaluable contributions to the preparation of this Reference Specification:

Chairman: Dr Yeo Yong Kee, A*STAR/I²R

S/N	Organisation	Name
1	A*STAR/Institute for Infocomm Research (I²R)	Dr Chen Jian, Research Scientist
2		Mr Liaw Chin Yi, Senior Research Officer
3		Dr Wang Yixin, Senior Research Scientist
4		Dr Cheng Xiaofei, Senior Research Fellow
5		Dr Park Chul Soo, Research Fellow
6		Dr Rong Weifeng, Research Fellow
7		Dr Shao Xu, Senior Research Fellow
8	BICSI Southeast Asia	Mr Christopher Thiam Boon Kwee, Director RFX Solutions Pte Ltd
9	M1 Limited	Mr Tan Pek Tong, Senior Manager
10	Media Development Authority	Mr Lim Chin Siang, Director (IT & Technologies)
11	National University of Singapore	A/Prof. Yu Changyuan, Assistant Professor
12	Nucleus Connect Pte Ltd	Ms Khor Lay Khim, Senior Manager
13	OpenNet Pte Ltd	Mr Tiong Oon Seng, Project Director
14	Singapore Telecommunications Ltd	Mr Wong Ching Ping, Deputy Director (International Private IP Engineering)
15		Mr Tan Yoke Yin, Deputy Director (Access System Engineering)
16	StarHub Ltd	Mr Tan Yong Teck, Principal Engineer

In addition, IMDA would like to thank Mr Varghese Paulose, A*STAR/I²R for his editorial contributions to this document.

Telecommunications Standards Advisory Committee (TSAC)

TSAC is responsible for the strategic direction, work programmes and procedures for standards-setting, and acts as the advisory body to IMDA in meeting the needs of all stakeholders.

TSAC is supported by a Technical Committee (TSTC) where professional, trade and consumers' interest in information and communications is represented by a wide sector of the info-communications industry, comprising network operators, equipment suppliers and manufacturers, academia and researchers, professional bodies and other government agencies.

TSAC Membership (2009-2011)

TSAC Chairman:

Mr Raymond Lee	Director (Resource Management & Standards), Infocomm Development Authority of Singapore

TSAC Members:

Mr Lim Yuk Min (TSAC Vice-Chairman)	Deputy Director (Resource Management and Standards), Infocomm Development Authority of Singapore
Mr Darwin Ho Kang Ming	Vice President, Association of Telecommunications Industry of Singapore
Mr Lim Chin Siang	Director (IT & Technologies), Media Development Authority
Mr Patrick Scodeller	Chief Technical Officer, M1 Limited
Assoc Prof Li Kwok Hung	Nanyang Technological University, School of Electrical & Electronic Engineering
Prof Ko Chi Chung	National University of Singapore, Department of Electrical & Computer Engineering
Assoc Prof Tham Chen Khong	National University of Singapore, Department of Electrical & Computer Engineering
Mr Simon Smith	Senior Manager Regulatory, Pacnet Internet (S) Ltd
Mr Edwin Lok	Manager (Engineering), Pacnet Internet (S) Ltd
Mr Lee Siak Kwee	Director (Mobile Network Access), Singapore Telecommunications Ltd
Mr Tan Seow Nguan	Director (Network System Engineering), Singapore Telecommunications Ltd
Mr Lim Cheow Hai	Director (Access Engineering), Singapore Telecommunications Ltd
Mr Soh Keng Hock	Director (Private IP Engineering & VAS), Singapore Telecommunications Ltd
Mrs Leong Suet Mui	Principle Technical Executive (Standards Division), Spring Singapore
Mr Peter Cook	Vice President (Network Mobile Technology & Planning Group), StarHub Ltd
Mr Mah Chin Paw	The Institution of Engineers, Singapore, AGM (Guthrie Engineering (S) Pte Ltd

Mr Liang Seng Quee	Deputy Director (Network Infrastructure), Infocomm Development Authority of Singapore
Ms Woo Yim Leng	Senior Manager (Resource Management & Standards), Infocomm Development Authority of Singapore

<u>TSAC Secretariat</u>:

Ms Tay Siew Koon	Manager (Resource Management & Standards), Infocomm Development Authority of Singapore

Contents

Section	Title	Page
1.	Scope	2
2.	Abbreviations	3
3.	FTTx and Passive Optical Network	4
4.	Deployment Scenarios	9
5.	FTTx Network Architecture	11
6.	FTTx Network Design	16
7.	Network Protection Schemes	18
8.	Services and Applications	18
9.	References	20
Annex	Corrigendum / Addendum	21

This Reference Document is a living document which is subject to review and revision.

Reference Documents, Specifications and Guides are informative documents and are not used for approval of customer equipment. They are either one of the following types of documents:

Informative and interim documents on customer equipment standards which are yet to be adopted by network operators; or

Informative documents describing network standards and practices adopted by the public telecommunication networks in Singapore.

FTTx Components, Planning and Deployment

1 Scope

After the fibres of a Passive Optical Network (PON) system are deployed, various performance tests should be performed to ensure that the network meets the functional requirements. The tests can be classified as pre-operation tests and in-service tests, and both are covered in this section, along with commonly used test equipment and optical measurement techniques.

2 Abbreviations

This Reference Specification uses the following abbreviations:

PON	Passive Optical Network
FTTx	Fibre to the x (x can be Curb, Home, etc.)
FTTH	Fibre to the Home
FTTB	Fibre to the Business / Block
FTTC	Fibre to the Curb
FTTN	Fibre to the Neighbourhood
OLT	Optical Line Terminal
CO	Central Office
ONU	Optical Network Unit
ONT	Optical Network Terminal
P2MP	Point-To-Multipoint
P2P	Point-To-Point
EPON	Ethernet Passive Optical Network
GPON	Gigabit Passive Optical Network
LAN	Local Area Network
ATM	Asynchronous Transfer Mode
PSTN	Public Switched Telephone Network
ISP	Internet Service Provider
VOD	Voice On Demand
IPTV	Internet Protocol Television
GEM	GPON Encapsulation Method
ODN	Optical Distribution Network
WDM	Wavelength Division Multiplexer
SC	Standard Connector
LC	Lucent Connector
POTS	Plain Old Telephone Service
PLC	Planar Lightwave Circuit
SDU	Single Dwelling Unit
MTU	Multiple Tenant Unit
FDF	Fibre Distribution Frame
OSP	Outside Plant
NEC	National Electrical Code
OFNP	Optical Fibre Non-conductive Plenum
OFCP	Optical Fibre Conductive Plenum
OFNR	Optical Fibre Non-conductive Riser
OFCR	Optical Fibre Conductive Riser
OFC	Optical Fibre Conductive
OFN	Optical Fibre Non-conductive
FP	Fabry-Perot
DFB	Distributed Feedback
APD	Avalanche Photo Diode
SFP	Small Form Factor Pluggable
XFP	10 Gigabyte Small Form Factor Pluggable
EDFA	Erbium Doped Fibre Amplifier
dB	Decibel

3 FTTx and Passive Optical Network

FTTx is a general term used to describe fibre-based access networks where x could be H(ome) if the fibres are terminated at the home of the subscriber; x could also be B(usiness), if the fibres are terminated at an office building. Besides FTTH and FTTB, FTTC (Fibre-to-the-Curb) and FTTN (Fibre-to-the-Neighbourhood) are also common.

A passive optical network (PON) is a type of FTTx fibre optic network that does not require any active electronics in the field. It is 'passive', because it doesn't need any active devices nor amplification between the Optical Line Terminal (OLT) in the central office (CO) and the Optical Network Unit (ONU) (or Optical Network Terminal (ONT)) at the subscribers' premises. Thus operators can expect savings in operating expenditures as the need for powering and managing active components in the field is no longer necessary.

A PON uses a passive device called an optical power splitter to provide fibre connections to the subscribers' premises using a point-to-multipoint (P2MP) scheme (Figure 1). Another common scheme that can be used to connect the fibres to the subscribers' premises is called point-to-point (P2P). P2P can also be referred to as a star, or direct fibre, or home-run connection.

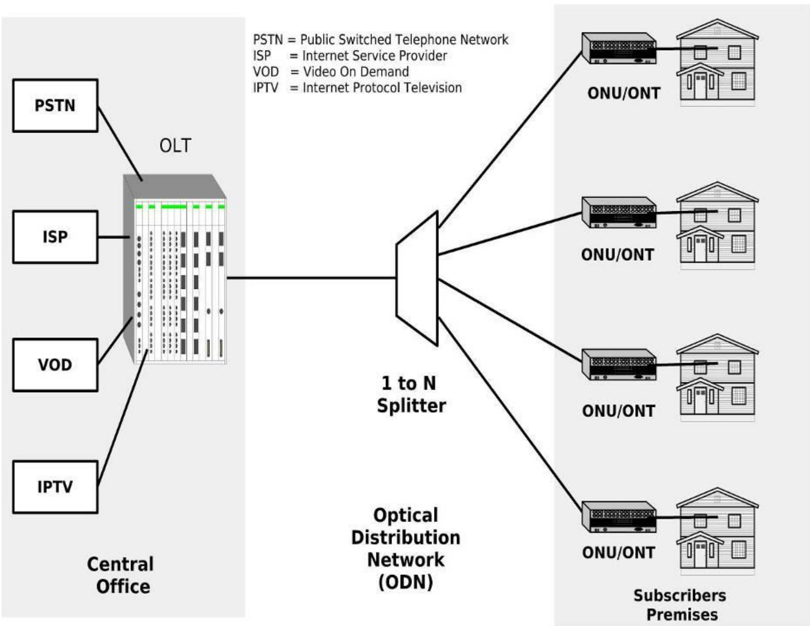

Figure 1: Point-to-multipoint Scheme in PON

In a PON system using the P2MP scheme, each single-mode fibre from the CO typically serves 16 to 32 subscribers, up to 20 km away from the CO. This also means that each port in the OLT can serve 16 to 32 subscribers.

3.1 Passive Optical Network (PON) Types

There are two main types of PON technologies deployed in the field. They are EPON (Ethernet Passive Optical Network) and GPON (Gigabit Passive Optical Network).

EPON is one implementation of Ethernet in the access network. The widespread use of Ethernet in both local area and metro networks makes EPON an attractive option for access networks. As EPON is developed based on Ethernet, it simplifies the interoperability between metro networks and the Ethernet LANs at the subscribers' premises. EPON is standardised as IEEE 802.3ah [1], (a 10 Gigabit/s version of EPON is also available [2]).

GPON is developed to meet the growing demand for higher speeds, longer transmission distances, and higher splitting ratios in the access network. Unlike EPON, which is purely based on Ethernet, GPON is based on both ATM and Ethernet with the introduction of a new encapsulation method for data called GPON Encapsulation Method (GEM). With GEM, GPON can support voice, Ethernet, ATM, leased lines, and wireless applications. GPON is standardised as ITU-T G.984 [3].

Despite the significant differences between EPON and GPON, there is one similarity between them: the downstream data traffic uses the 1490 nm wavelength, the upstream traffic uses the 1310 nm channel, and the analogue video signals are located at 1550 nm.

Table 1 shows the characteristics of EPON and GPON.

Table 1: EPON and GPON Characteristics

Characteristics	EPON	GPON
Standards	IEEE 802.3ah	ITU-T G.984
Protocol	Ethernet	ATM and Ethernet
Transmission Speeds (Mbps)	1244 Upstream, 1244 Downstream	155 to 2488 Upstream, 1244 or 2488 Downstream
Span	10 km	20 km
Maximum number of splits	16 to 32	64

3.2 Optical Line Terminal (OLT)

The optical line terminal (OLT) is one of the most important components in a PON system. It is located in the CO, and is responsible for the transmission and control of the bi-directional data traffic across the optical distribution network (ODN). The ODN is the physical network between the CO and subscribers' premises, and consists of the all the fibres and splitters that run between the OLT and ONTs or ONUs.

In the downstream direction, from the OLT to the ONUs/ONTs, OLT will take in voice, data and video traffic from the service providers through long-haul or metro networks, and then distribute them to all registered ONUs/ONTs through the ODN. In the upstream direction, the OLT receives traffic from the registered ONUs/ONTs.

OLT equipment usually supports multiple PONs. Figure 2 depicts how an OLT can support four different PONs whereby each of them consists of 32 ONTs. Figure 3 shows a commercial OLT system with three OLT cards, each supporting up to two PON systems.

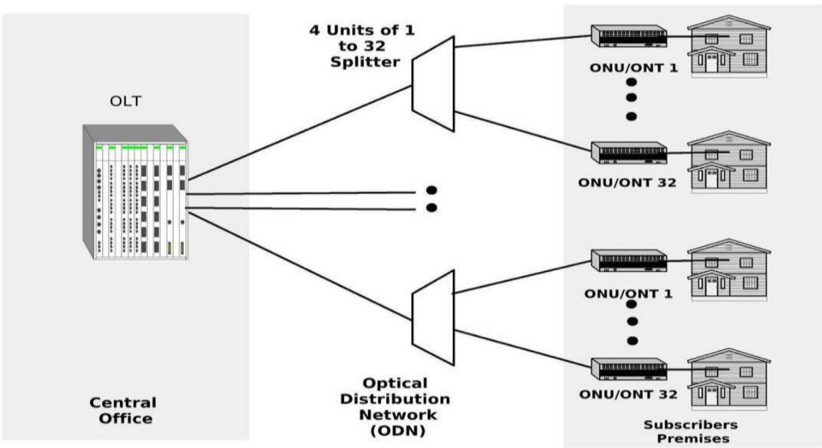

Figure 2: OLT Serving 4 PONs

Figure 3: Optical Line Terminal (OLT) Equipment

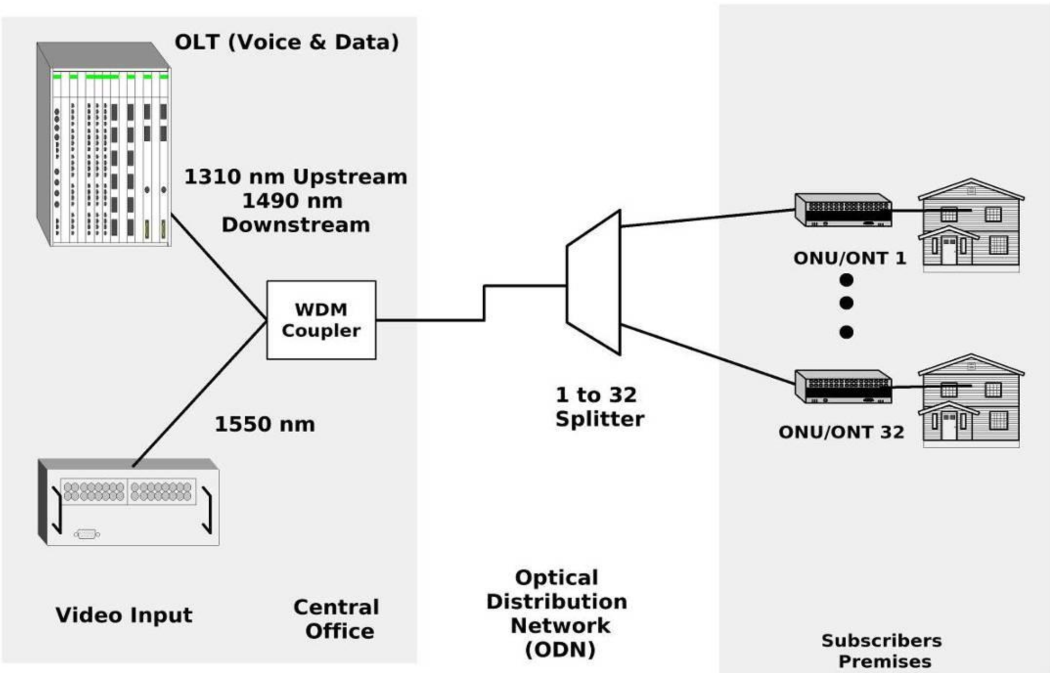

Figure 4: Separate Wavelengths for Downstream, Upstream and Video

A PON uses 1490 nm wavelength for voice and data downstream transmission while the 1310 nm wavelength is used for upstream voice and data transmission. For downstream distribution of analogue video, PON uses a separate wavelength at 1550 nm. Passive WDM couplers are used to combine and separate the wavelength as depicted in Figure 4.

3.3 Optical Network Terminal (ONT) and Optical Network Unit (ONU)

While the OLT is located at the head end of the PON system, the ONT/ONU is a device at the subscribers' premises (Figure 5). In ITU-T Rec. G.984.1 [4], ONT is defined as a single subscriber device, while the ONU is more generic term that could represent a single- or multi-subscriber device. The ONU converts the optical signal in the fibre to electrical form so it can be readily used by subscribers through a television set-top box, personal computer or Ethernet switch. Figure 6 shows how the ONU can be networked to multiple services to the subscribers, and these include Ethernet, telephony (POTS), and video (Video-on-demand or IPTV).

The ONU can be located indoors or outdoors depending on the PON deployment scenario. For an outdoor ONU, an additional enclosure may be required to protect it from the weather or temperature variations.

Figure 5: Indoor ONU
(Courtesy of Aztech Technologies Pte Ltd)

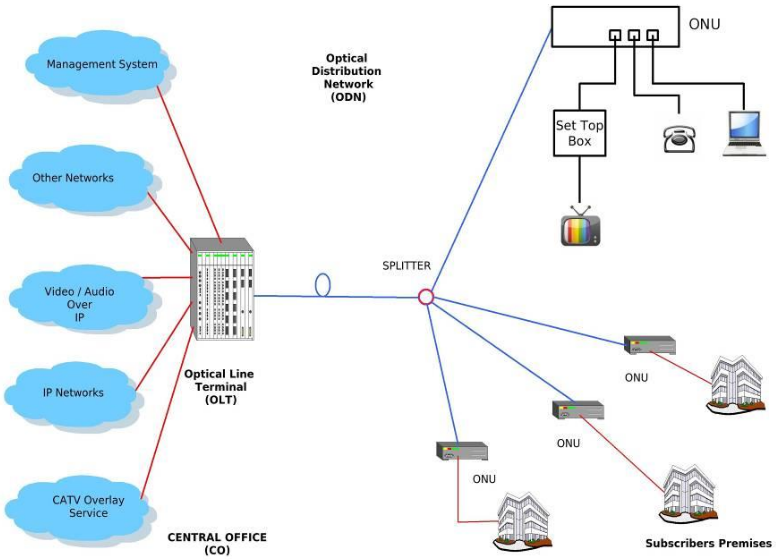

Figure 6: A PON ONU is Used to Provide Multiple Services to the Home

ONU Local Powering System

A standard telephone (POTS) does not need an external power supply to operate as it is powered by the copper-based phone line. Thus in the event of an emergency where there is power outage, the subscriber still can make phone calls.

One of the telecommunications services provided by ONU is telephony. In a PON system, no electrical power is provided to the subscriber's phone through the fibres. Thus to supply an emergency telephone service in the time of power outages, a back-up power supply can be attached to the ONU. Such back-up power supplies can typically provide power to the ONU for up to several hours.

3.4 Optical Fibre Patch Cord

Single-mode fibres are terminated at the subscribers' homes in a FTTH type of deployment. The ONU is then connected to the fibre termination points using single-mode fibre patch cords. Such patch cords usually have SC or LC type connectors for easy handling (see IMDA RS OFD – Part 3 for details on connector types).

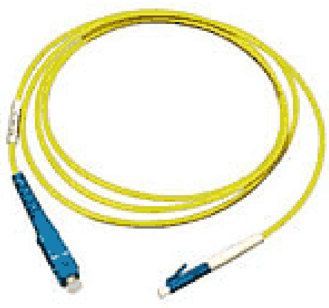

Figure 7: Patch Cord

A service disruption may occur if the patch cord is not properly installed or maintained. Commonly encountered problems include excessive bending, patch cord breakage or accumulation of dirt particles on the fibre endfaces. They result in high optical power losses and the ONU will not be able to communicate with the OLT. One of the preventive measures to counter excessive bending is to use a bend-tolerant fibre. (Please refer to IMDA RS OFD – Part 2 for more information.)

3.5 Optical Power Splitter

Optical power splitters are passive devices and they are used in PON to distribute optical signals to every subscriber. In general, a PON splitter is designed to divide the input optical power equally to all output ports. The two technologies that are commonly used to realise commercial splitters are: planar lightwave circuit (PLC) technology or fused-fibre coupler technology (Figure 8). Splitters are available in 1x4, 1x8, 1x16 or 1x32 configurations.

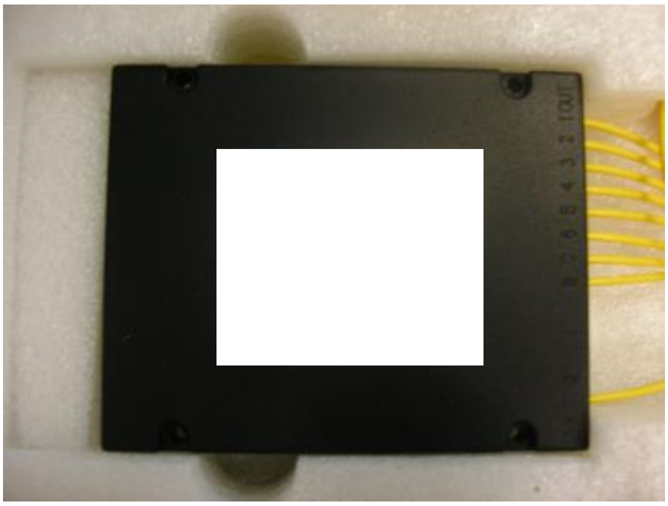

Figure 8: Commercial 1 X 8 Optical Splitter

PLC-based optical splitters are popular for PON because they are highly reliable components that exhibit stable operation over wide temperature and wavelength ranges. Typical specifications are listed below:

Table 2: Performance Specifications of PLC-based Splitters

Temperature Range	-40 deg C to 85 deg C
Wavelength Range	1280nm to 1650nm
Typical insertion loss of 1 x 8 Splitter	10.5dB
Typical insertion loss of 1 x 32 Splitter	18dB
Typical insertion loss variation for 1 x 8 Splitter	+/- 1.0dB (max)
Typical insertion loss variation for 1 x 32 splitter	+/- 2.2dB (max)

Optical splitters are housed in enclosures to protect them from the environment, and sealed enclosures are required for below-surface installations to prevent water ingress.

For detailed information of performance specification and test methods (mechanical and environmental) that can be applied to optical splitters, please consult ITU-T L. 37 [5]. For a more general introduction on the deployment of splitters in PON, please refer to ITU-T L.52 [6] (Deployment of Passive Optical Network). This document includes descriptions on various configurations of PONs as well as other optical components used in such networks. (Please refer to IMDA RS OFD – Part 2 for more information on the tests and installation of PON components.)

4 Deployment Scenarios

In an FTTx network, the fibre can be terminated at the users' premises or a block of apartments. The deployment scenario depicted in Figure 1 is for FTTH, where the optical fibre is laid all the way to the subscribers' premises. In some scenarios, fibre optics may be terminated at a place or node close to groups of subscribers, and this decision depends on many factors such as whether the deployment is a green field deployment or not. Some common deployment scenarios are listed below.

4.1 FTTH (Fibre-to-the-Home)

FTTH is a deployment scenario where the fibres are being laid from the CO to every single house or apartment. A house or a home is usually occupied by a family, and it is frequently referred to as a single dwelling unit (SDU). The FTTH scenario is depicted in Figure 9.

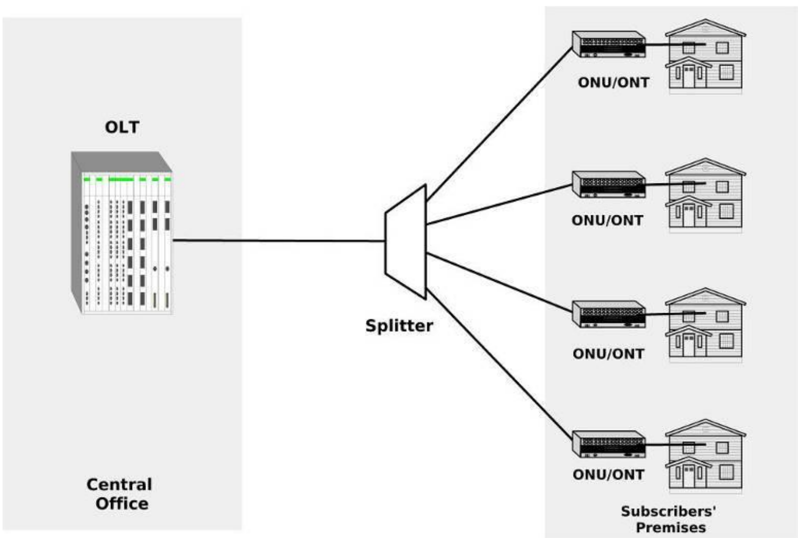

Figure 9: Fibre-to-the-Home

4.2 FTTB (Fibre-to-the-Block)

FTTB is used to describe a scenario where the fibre is laid directly from the CO to an office/private apartment building with multiple business tenants or homes. Such tenants or apartment units are frequently described by the term Multiple Tenant Unit (MTU). The FTTB scenario is depicted in Figure 10. It is common for the ONT to be connected to an Ethernet switch and this can be used to network all the tenants within the same building. The advantage of FTTB is that existing copper LAN wirings in the building do not have to be replaced by fibres.

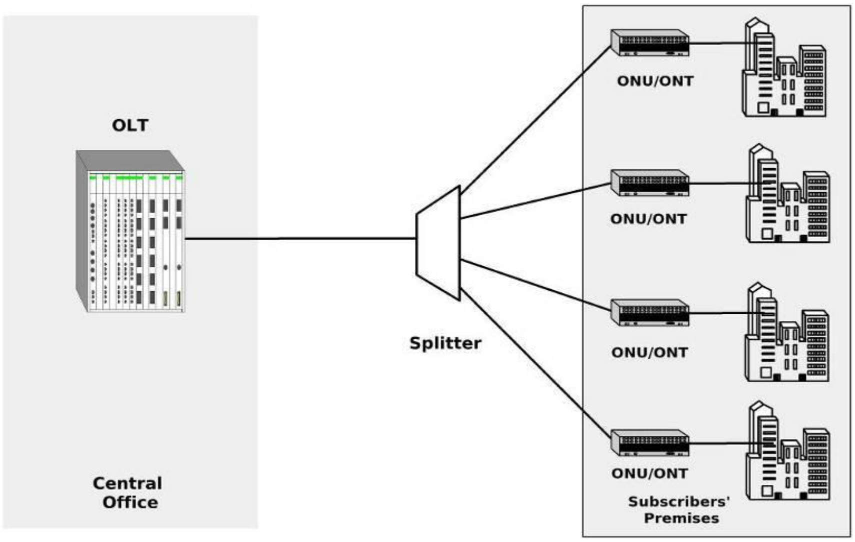

Figure 10: Fibre-to–the-Block (FTTB)

4.3 FTTC (Fibre-to-the-Curb)

FTTC is a deployment scenario where fibre is laid from the CO to an ONU or ONT that is located within 300 m from office building or home. Connection to the subscribers will be through some other types of transmission medium such as twisted pair copper or coaxial cable. The FTTC scenario is depicted in Figure 11.

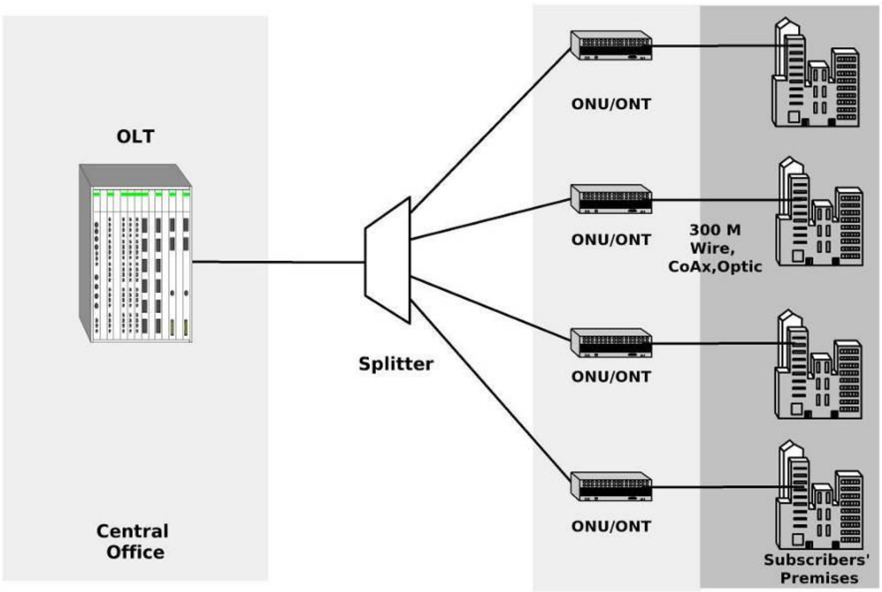

Figure 11: Fibre-to-the-Curb (FTTC)

4.4 FTTN (Fibre-to-the-Neighbourhood)

FTTN is a deployment scenario where fibre from the CO is terminated at a communication switch located within 1 km from office buildings/homes (depicted in Figure 12). With FTTN, one can use the existing coaxial or twisted pair infrastructure to provide the final physical connection to the end users. Thus, significant deployment costs can be saved.

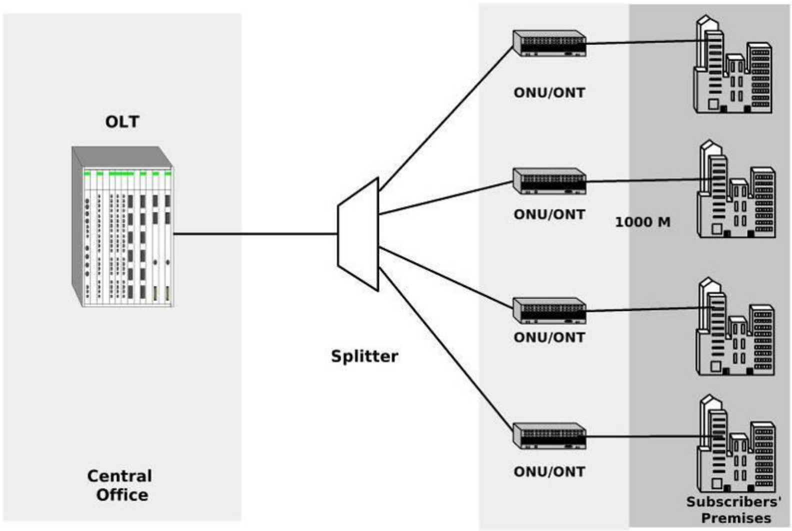

Figure 12: Fibre-to-the-Neighbourhood

5 FTTx Network Architecture

5.1 Central Office Equipments and Cabling Layout

Figure 13 shows a typical cabling network in the CO. The main equipment in the CO consists of the OLT, fibre distribution frame (FDF) and fibre entrance cabinet. The fibre starts at the OLT and is connected to the FDF by an optical patch cord. Feeder cables from OSP (OutSide Plant) are terminated at the fibre entrance cabinet, which could be wall mounted or installed in an equipment rack. Intra-facility cables are then spliced to the OSP feeder cable at the fibre entrance cabinet and they connect the feeder cable to the FDF. The OLT and OSP can then be connected via a short patch cable (or cross connect patch cord) on the front of FDF.

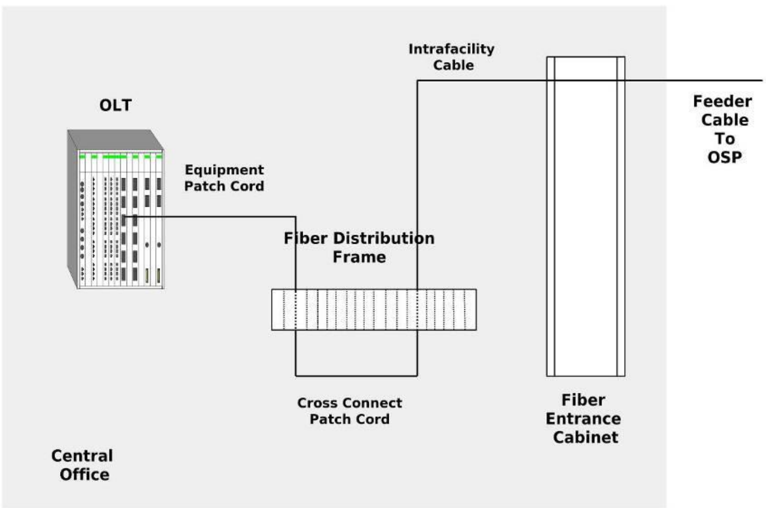

Figure 13: Central Office Cable Layout

5.2 Central Office's WDM Coupler Location

Video transmission, one the components in the FTTx triple-play services, occupies a separate wavelength channel (1550 nm). A WDM coupler in the CO is used to combine this video overlay wavelength with the other wavelengths (1310 nm for upstream and 1490 nm for downstream). Figure 14 shows the placement of a WDM coupler at the OLT rack. OLT and Video output is attached to WDM coupler input while an intra-facility path cord is used to connect the WDM coupler output to the FDF. The fibre distribution frame is a fibre organiser that can store fibre pigtails and cables. ITU-T L.50 [7] contains more information on the requirements and performance of FDFs.

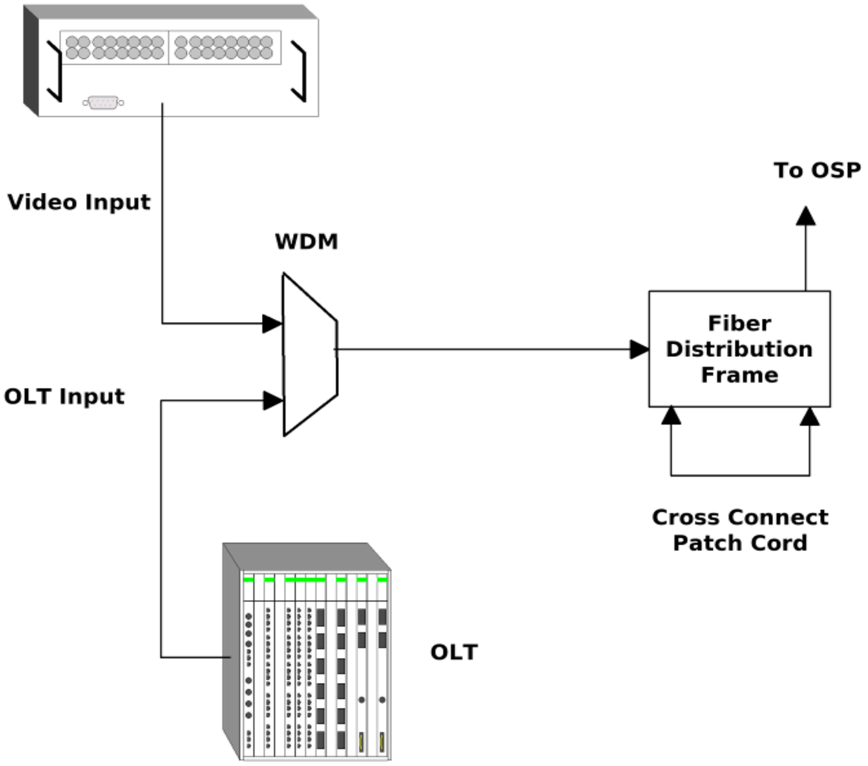

Figure 14: WDM Coupler at the OLT Rack

5.3 Central Office Cable Requirement

The fibre optic cables used in the CO should be marked and installed correctly based on their intended usage. The most important factor for fibre optic cables installed indoors is their fire and smoke rating. The National Electrical Code (NEC) [8] used in the United States defines flame ratings for fibre optic cables, and the Underwriters' Laboratories (UL) develops the test procedures.

There are three different building regions identified by the NEC:

1. Plenum: This includes empty space within walls, space under floors, or above drop ceilings. UL-certified (UL-910) plenum cables are marked OFNP (Optical Fibre Non-conductive Plenum) or OFCP (Optical Fibre Conductive Plenum).

2. Riser: Riser cables certified by the UL-1666 riser fire test method are marked OFNR (Optical Fibre Non-conductive Riser) or OFCR (Optical Fibre Conductive Riser).

3. General purpose: This includes all other regions on the same floor that are not of the plenum or riser type. This type of fibre optic cable cannot be used in riser or plenum without being housed in fireproof conduits. It is marked as OFN (Optical Fibre Non-conductive) or OFC (Optical Fibre Conductive) and certified by the UL-1581 vertical-tray fire test.

Please refer to National Electrical Code (NFPA70) and Underwriter's Laboratories for more information on flame ratings and testing procedures on fibre optics.

5.4 Feeder Cable

A feeder cable is the cable that links the central office and the optical splitters in the outside plant (OSP) distribution cabinet. Generally one feeder fibre is connected to a splitter, which in turn will serve up to 32 homes/premises. As an example, if there are 800 premises, the total number of feeder cables required will be at least 25 if each PON contains 32 subscribers. Usually extra fibres in the feeder cable will be planned for redundancy purposes as well as for future expansion.

5.5 Outside Plant (OSP) Distribution Cabinet and Distribution Section

The OSP distribution cabinet is where all the splitters are located. It will also serve as the termination point of the feeder cable in the field. From the OSP distribution cabinet, fibres are run to individual premises and there is a wide range of distribution mechanisms. The main elements in the distribution section are distribution cables, access terminals or enclosures, and drop cables. Figure 15 shows that 32 distribution fibres leave the OSP distribution cabinet and are distributed to the users' premises using drop cables from the access terminals.

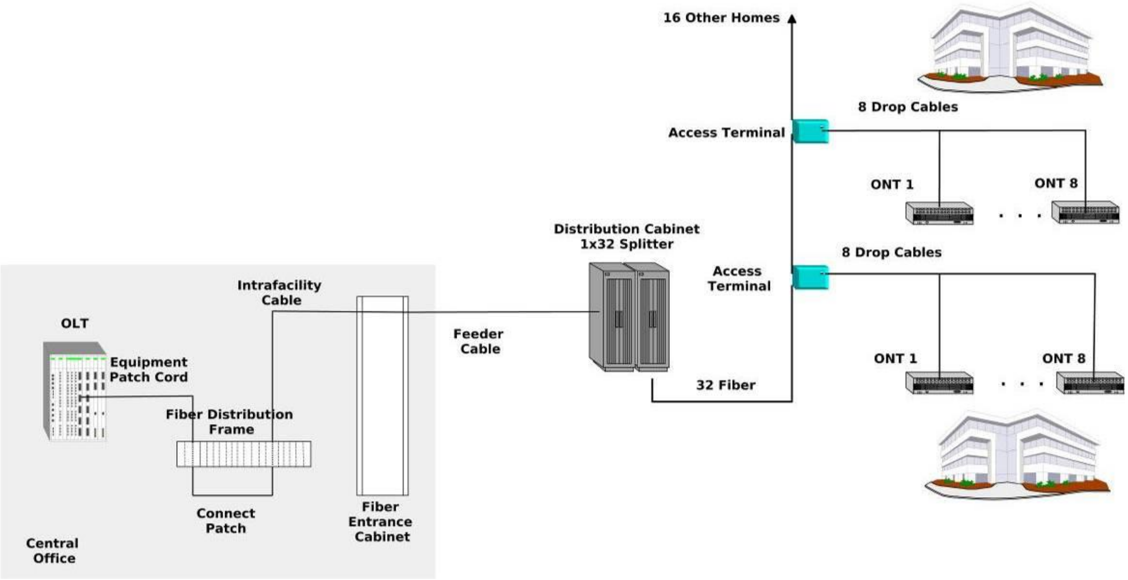

Figure 15: Distribution of Fibres in the ODN

5.6 Active and Passive Optical Components in OLT and ONU

Wavelength Division Multiplexer (WDM)

A Wavelength Division Multiplexer (WDM) is a passive device that combines different optical wavelengths from two or more fibres into one common fibre. WDM can also be used to separate a group of optical wavelengths in a common fibre into different output fibres.

Each input port of a WDM module is designed to pass a particular optical wavelength. For example, if there are two input channels at 1310 nm and 1510 nm, the WDM will combine these wavelengths and couple them into a single output fibre. At the opposite end of the transmission network, a corresponding WDM is used to demultiplex the 1310 nm and 1510 nm optical wavelengths into two separate fibres. In a PON system, WDMs are found in the OLT and ONT (Figure 16).

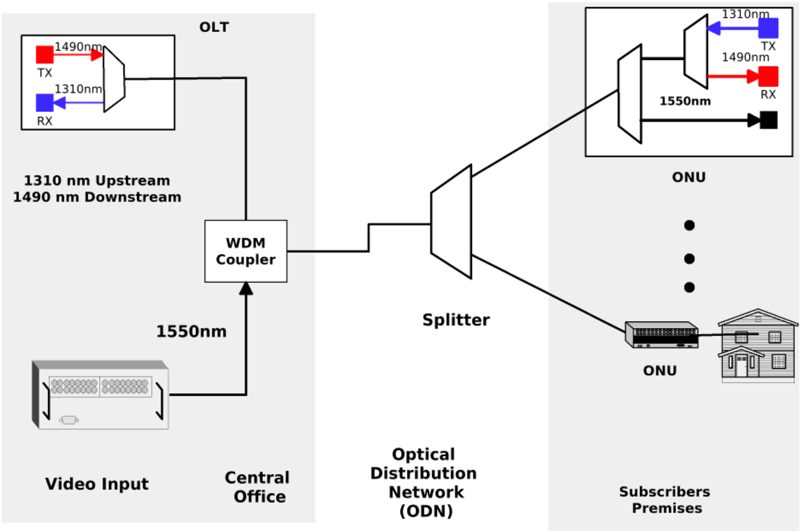

Figure 16: The Location of WDMs in a PON System

Please refer to ITU-T Recommendation G.671 [9], Transmission Characteristics of Passive Optical Components, for more detailed information with regards to specifications and various test methods for WDM.

Optical Attenuator

Both OLT and ONU consist of optical transceivers that are used to convert optical signals to electrical signals and vice versa. The photodetector is a component in the optical transceiver. Its primary function is to receive optical signals and convert them to electrical signals. Photodetectors can be easily damaged if the power of the input optical signal is too high. An optical attenuator is used to reduce the optical power received at the photodetector if the optical link does not have sufficient loss.

Figure 17: An Optical Attenuator in the Form of an Optical Fibre SC-SC Adapter

Attenuators should not be placed at the transmitter end of the fibre because back reflections caused by the attenuator into the transmitter may affect transmitter operation. ITU-T L.31 [10] describes the main features of optical attenuators in terms of types, field of application and configurations. The document also contains test methods and performance specifications that are applicable to optical attenuators. Please refer to Telcordia GR-910 [11] for more information on reliability tests.

Optical Transceiver

An optical transceiver is a component in the ONU that converts optical signals to electrical signals and vice versa. It comprises a laser source, an optical receiver and other electronics circuits such as amplifiers.

1. Laser Source

Generally there are two main types of laser used in PON: Fabry-Perot (FP) laser and Distributed-Feedback (DFB) laser. Both are semiconductor-based laser diodes. FP and DFB lasers do not need laser cooling to maintain their temperature, which in turn reduces the power requirement, cost of manufacturing, and size of the PON transceivers. The modulation speed limit of the laser source in GPON is 2.5Gbit/s.

2. Optical Receivers

The main component in the optical receiver is a photo diode. The photo diode converts the light signal that it receives into an electric signal. Like the laser source, the photo diode is semiconductor-based. The most common photo diode is PIN photo diode, which is very stable and highly reliable. Another type is called avalanche photo diode (APD), which internally multiplies the primary signal photo current before it enters the input circuitry of the electrical post-amplifier. The APD is more sensitive to low optical powers compared to the PIN photo diode. This property makes it attractive for PONs with high splitting ratios.

3. Transceiver Package

Manufacturers have developed special transceiver packages to support PON. The transceiver package includes the laser source, the receiver and optical multiplexer all in one small form factor package. Popular PON transceiver packages are SFP (Small Form Factor Pluggable), XFP (10 G Small Form Factor Pluggable), and XENPAK.

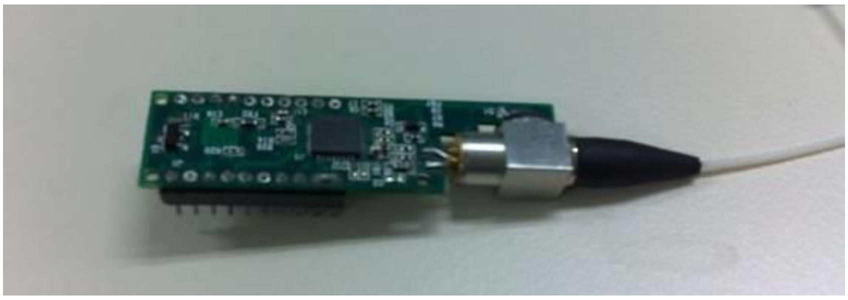

Figure 18: A GPON Transceiver without External Metal Enclosure (Courtesy of A*STAR Institute for Infocomm Research)

Optical Amplifier

An optical amplifier is a device used to amplify optical signals. In a wavelength-division multiplexed fibre link, the optical amplifier can amplify a band of optical wavelengths, not just one. It is important to note that any signal distortion introduced in the fibre link will be passed through the optical amplifier, and each amplifier will introduce additional noise during the amplification process. This, in turn, will limit the number of optical amplifiers deployed in the fibre optic link.

The Erbium Doped Fibre Amplifier (EDFA), which is the most commonly used amplifier, can amplify optical signal by 35 dB in 1530 to 1580 nm bands. There are two types of EDFA amplifiers, single pump and dual pump. Typical amplifier gains are 17dB for the single-pump and 35 dB for the dual-pump. (Figure 19 shows the design of a single-pump EDFA).

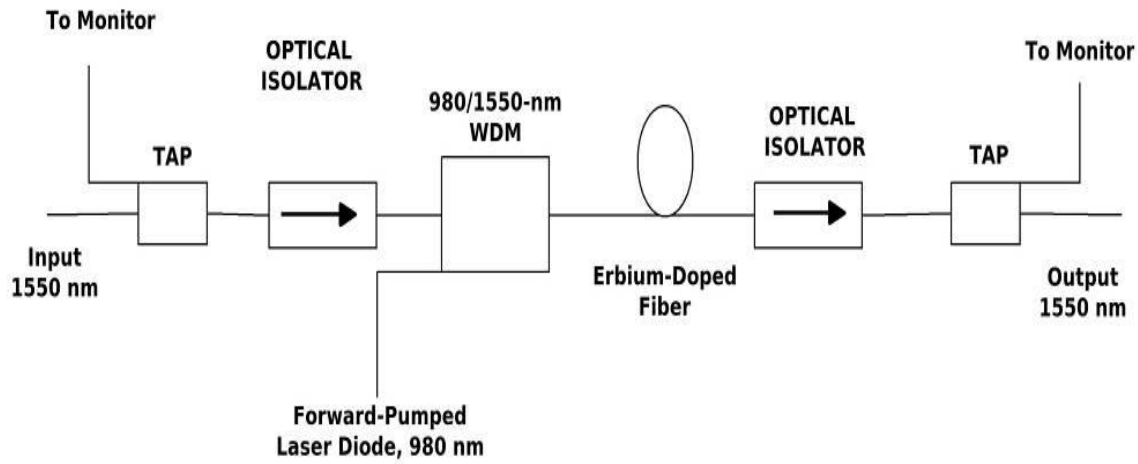

Figure 19: Design of a Single-pump EDFA

In an EDFA, a pump laser source at 980 nm or 1480 nm constantly provides optical light that excites the erbium ions in the doped fibre to a higher energy state. When the optical signal propagates through the doped fibre, it interacts with the excited erbium ions. This causes the erbium ions to return to their relaxed state and in the process releasing high-energy photons with the same wavelength and signal characteristics as the photons of the input signal. Therefore, the incoming optical signal is amplified.

EDFA amplifiers can be classified as post-amplifier, line amplifier and pre-amplifier. The post-amplifier (postamp) configuration places the amplifier at the optical signal source (in the central office), where it will amplify the signal before it is transmitted to the outside plant fibre. The line amplifier (Lineamp) is placed at the midspan of the fibre link, where weak optical signals need to be amplified. Note that this type of amplifier is typically not used in a PON because it requires active electronics in the field. The pre-amplifier is located at the receiver end of the fibre link, just before the optical transceiver. However, the EDFA pre-amp is not used in the ONU as it is too expensive. Instead, a very sensitive photodetector known as an avalanche photodiode (APD) is used to detect very weak optical signals.

When working with optical amplifiers, caution should be exercised, since their output can be harmful to the eye. Equipment should be turned off before disconnecting any fibre link. The amplifier should be turned on only when all the fibre connections are installed. Powerful optical amplifiers may incorporate a safety lock that turns off the laser optical output if the fibre link is broken or disconnected. For detailed description on the generic characteristics of optical amplifiers, please refer to ITU-T Rec. G.662 [12]. This document contains descriptions on the characteristics of power amplifiers, pre-amplifiers, line amplifiers, optical amplified transmitters and optically amplified receivers.

6 FTTx Network Design

6.1 System Margin

Degradation of the optical signal could occur in an optical link due to many factors such as:

a. Dimming of the light source over time
b. Ageing components in the link
c. Splices/Connectors

To compensate for these factors, extra decibels are added to the optical power link budget. ITU-T Rec. G.957 [13] specifies that a system margin from 3.0 to 4.8 dB should be allowed between the transmitter and the receiver.

6.2 Link Power Budget Calculation

When performing a link power budget calculation, the first component to take into account is the optical fibre attenuation. Determining the optical fibre attenuation is not quite straightforward since it depends on the wavelength. For PON network, there are three wavelengths that one should consider: 1310, 1490 and 1550 nm.

Figure 20 shows that the optical power attenuation, in an optical fibre, at a wavelength of 1310 nm is approximately 0.3dB/km. In contrast, the attenuation at 1550 nm is about 0.2dB/km.

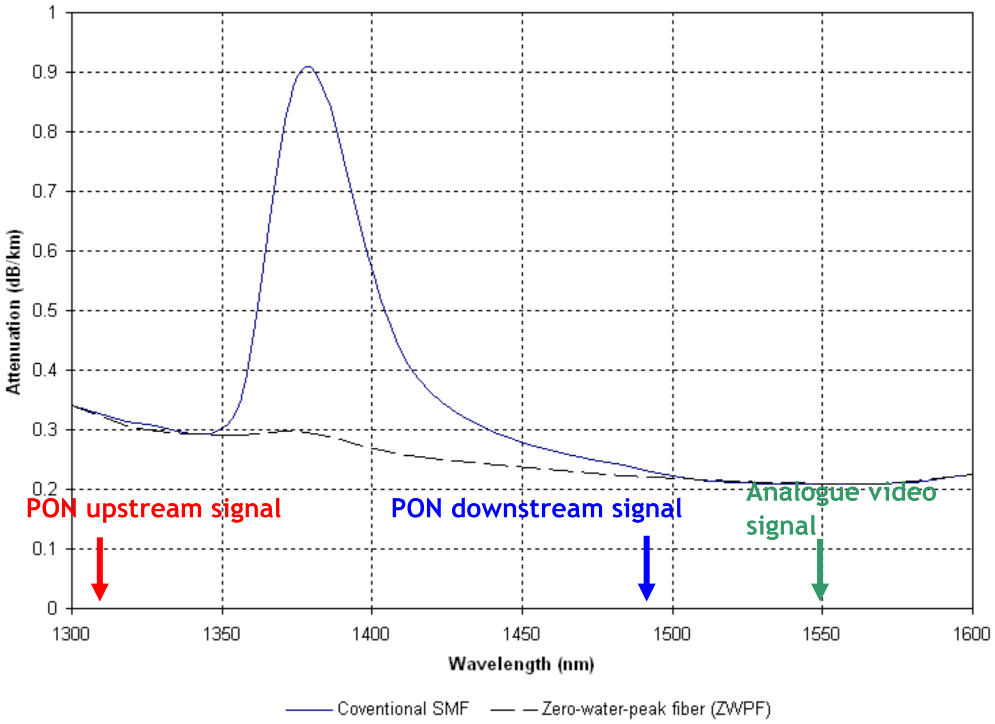

Figure 20: Optical Fibre Attenuation as a Function of Wavelength

An example is used to illustrate the link budget calculation for a GPON-based FTTH network with a maximum link length of 15 km (Figure 21).

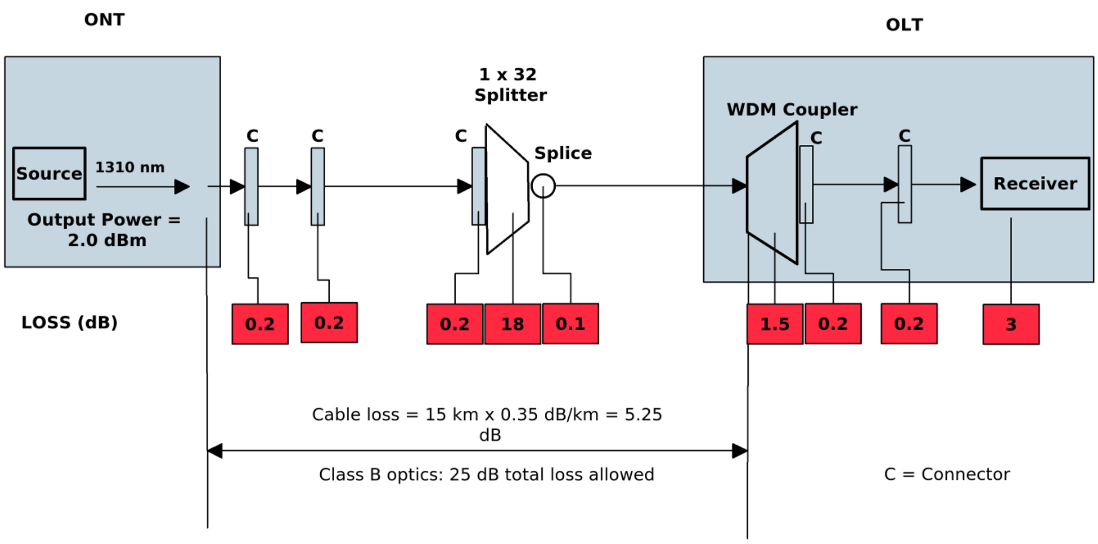

Figure 21: Optical Power Losses in 1310nm GPON FTTH Link

In the ITU-T G.984 [3] recommendation on GPON, there are three classes of attenuation permitted between the OLT and the ONU:

Class A: 5 to 20 dB
Class B: 10 to 25 dB
Class C: 15 to 30 dB

For the purpose of illustration, class B attenuation range with maximum permitted attenuation of 25dB is selected. If the ONT output power is +2dBm and the OLT detector sensitivity is -30dBm, then the total link power budget is 32dB.

	Insertion Loss	System Margin
(A) Initial power budget		32 dB
(B) WDM coupler loss (1 x 1.5 dB)	1.5 dB	
(C) Central-office patch cord loss	0.4 dB	
(D) OLT receiver power penalty	3.0 dB	
(E) Power available for class B link = A - B - C - D		27.1 dB
(F) Power splitter loss (1 x 32)	18 dB	
(G) Splice loss (1 x 0.1 dB)	0.1 dB	
(H) Connector loss (3 x 0.2 dB)	0.6 dB	
(I) Cable attenuation (15 km x 0.35 dB/km)	5.25 dB	
Remaining power margin = E - F - G - H - I		3.15 dB

The system margin of 3.15 dB, based on the calculation, is sufficient for implementation.

7 Network Protection Schemes

Network protection schemes discuss how to ensure PON survivability and implement network protection. There are three types of basic network protection scheme. ITU-T Recommendation G.983.5 [14] describes the functions needed to extend ITU-T Rec. G.983.1 [15] to enable survivability and network protection enhancements for delivering very reliable services.

Type A scheme has an extra feeder cable from the CO to the splitter, so that, in the event of the main feeder cable's failure, it will be able to switch to the spare feeder cable. However, the ranging procedure of the OLT needs to be done after switchover occurs.

Type B scheme has an extra feeder cable with extra OLT. While one OLT is designated as active, the other one will serve as a hot standby. If the active fibre is broken or the active OLT fails, the hot standby set will take over.

Type C scheme is called a fully redundant back-up PON Network, which can protect against fibre failures in the feeder, distribution or drop cables and against OLT and ONT failures.

8 Services and Applications

FTTx offers a standard mix of traffic types referred to as triple play. They are voice, video and data. Traditionally subscribers must connect to three different networks and service providers for their phone services, video broadcast and the Internet. With FTTx, all of these traffic types can be integrated into a single fibre network using different wavelengths.

A triple play service can include IP telephony, video on demand (VOD), IPTV, interactive games, telepresence, video conferencing, and externally monitored home security. In order for the subscribers to be able to use these services, service providers typically need to offer bandwidths of 50 to 100 Mbps.

Service / Application	Typical Bandwidth
Internet Access	6 Mbps
HDTV	10 Mbps
SDTV	2 Mbps
Internet VOD	1 Mbps
Video Conferencing	1 Mbps
Home Security Monitoring	2 Mbps
IP Phone	0.1 Mbps

Figure 22: Bandwidth Requirements for Various FTTx Services

There are two ways for the subscriber to receive video services. The first is through video over IP, where the contents are digitised and streamed/broadcast using data channel (1490 nm). The second is through the use of separate video overlay wavelength (1550 nm) as shown in Figure 4.

9 References

[1] **IEEE 802.3AH-2004.** CSMA/CD Access Method & PHY Specifications Amd: Media Access Control Parameters, Physical Layers, & Mgmt Parameters for Subscriber Access Networks. Jan 1, 2004.

[2] **IEEE Std 802.3AV-2009.** Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications; Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks. 30 Oct 2009

[3] **ITU-T G.984.** Gigabit-Capable Passive Optical Networks (GPON). Mar 1, 2008.

[4] **ITU-T G.984.1.** Gigabit-Capable Passive Optical Networks (GPON): General Characteristics - Study Group 15. Mar 1, 2008.

[5] **ITU.T L.37.** Optical Branching Components (Non-Wavelength Selective) - Study Group 6. Feb 1, 2007.

[6] **ITU.T L.52.** Deployment of Passive Optical Networks (PON). May 1, 2003.

[7] **ITU.T L.50.** Requirements for Passive Optical Nodes: Optical Distribution Frames for Central Office Environments - Study Group 6. Nov 1, 2003.

[8] **NFPA 70.** National Electrical Code (NEC). 2008.

[9] **ITU-T G.671.** Transmission Characteristics of Optcial Components and Subsystems - Study Group 15. Jan 1, 2009

[10] **ITU-T L.31.** Optical Fibre Attenuators - Series L: Construction, Installation and Protection of Cables and Other Elements of Outside Plant - Study Group 6. Oct 1, 1996.

[11] **Telcordia GR-910.** Generic Requirements for Fibre Optic Attenuators. Dec 1998.

[12] **ITU-T G.662.** Generic Characteristics of Optical Amplifier Devices and Subsystems - Study Group 15. Jul 1, 2005.

[13] **ITU-T G.957.** Optical Interfaces for Equipments and Systems Relating to The Synchronous Digital Hierarchy - Study Group 15. Mar 1, 2006.

[14] **ITU-T G.983.5.** A Broadband Optical Access System With Enhanced Survivability - Study Group 15. Jan 1, 2002.

[15] **ITU-T G.983.1 .** Broadband Optical Access Systems Based On Passive Optical Networks (PON) - Study Group 15. Mar 16, 2006.

Annex

Corrigendum / Addendum

Changes to IDA RD OFD - Part 5 Issue 1 Rev 1, May 2011			
Page	**RS Ref**	**Items Changed**	**Date of Issue**
		The IDA RD OFD - Part 5 Issue 1 Rev 1 (May 2011) has been re-issued as the IMDA RD OFD - Part 5 Issue 1 (Oct 2016)	1 Oct 2016

Changes to IDA RD OFD - Part 5 Issue 1, Jul 10			
Page	**RS Ref.**	**Items Changed**	**Effective Date**
–	–	Change of IDA's address at cover page to Mapletree Business City.	1 May 11