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Development of Testing Standardization Regulation of the OLT XG-PON Equipments to Support Broadband Access in Indonesia

Pengembangan Regulasi Standarisasi Pengujian Perangkat OLT XG-PON untuk Mendukung Akses Pita Lebar di Indonesia

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Abstract – This study aims to provide a reference to the technical specifications of the Optical Line Termination (OLT) XG-PON equipment for improving standardization regulations (Perdirjen Postel No. 257 of 2008). The technical specifications tested in this study are the nominal rate capability, wavelength range, and jumbo frame of the OLT XG-PON equipment. The research acquired a reference to the nominal rate using FEC is 8.5 Gbps downstream direction, and 2.5 Gbps upstream direction, upstream wavelength range is 1260-1280 nm and downstream is 1575-1581 nm, and jumbo frame capability is 2000 Bytes.

Keywords: fixed broadband, OLT, standardization regulation, telecommunication management, XG-PON

Abstrak *– Studi ini bertujuan untuk memberikan rujukan spesifikasi teknis perangkat Optical Line Termination (OLT) XG-PON untuk penyempurnaan regulasi standarisasi (Perdirjen Postel No. 257 Tahun 2008). Spesifikasi teknis yang diuji dalam penelitian ini adalah kemampuan nominal rate, rentang panjang gelombang dan jumbo frame perangkat OLT XG-PON. Dari hasil penelitian didapatkan rujukan untuk nominal rate dengan menggunakan FEC adalah 8,5 Gbps arah downstream dan 2,5 Gbps arah upstream, rentang panjang gelombang upstream adalah 1260-1280 nm serta downstream adalah 1575-1581 nm, dan kemampuan jumbo frame sebesar 2000 Bytes.*

Kata Kunci: *manajemen telekomunikasi, OLT, pita lebar tetap, regulasi standarisasi. XG-PON*

INTRODUCTION

Information and Communication Information Technology (ICT) has the potential to drive economic growth and improve the nation's competitiveness and the quality of life of the Indonesian people. Also, Indonesia's strategic location is an opportunity as a center for regional and global ICT traffic. All these advantages invest ICTs become essential to improve people's lives, in addition to their economic role in building new industries, developing new skills, and fostering productivity and competitiveness.

The application of ICT can be realized by using broadband network technology. As broadband becomes increasingly ubiquitous and services and customers become increasingly sophisticated, any country that falls significantly behind in broadband infrastructure, services, and adoption will find economic development more and more difficult (Minehane, 2016).

The deployment of broadband technology in Indonesia has some challenges, and one of them is the topology of the country, which is composed of more than 17,500 islands and span along 6,400 kilometers, thus posing significant obstacles in the development of uniform broadband services. For example, Maluku and Papua, in the east of the country, have the lowest household penetration rates, at only 58 percent of households for mobile (compared to 86 percent nationally), 16 percent for the Internet (compared to 32 percent nationally), and 13 percent for computer ownership (versus 16 percent of households nationally) (Ruddy, 2016).

However, the existence of broadband enables the provision, processing, and distribution of information to be carried out more quickly, efficiently, effectively, transparently and accountably so that the information does not lose value and can even create added value for the community (BAPPENAS, 2014).

Broadband access networks can be divided into fixed access and mobile / radio access solutions where both solutions can skip internet, voice, and video services. In the Asia Pacific, the growth of broadband network technology with the FTTx access method has the most substantial growth, with a CAGR growth rate of 35% during 2012-2020 (Boulay, 2017). FTTx access technology continues to grow until it reaches 82% of the total broadband network technology users in 2022, exceeding cable and DSL technology, as shown in Figure 1.

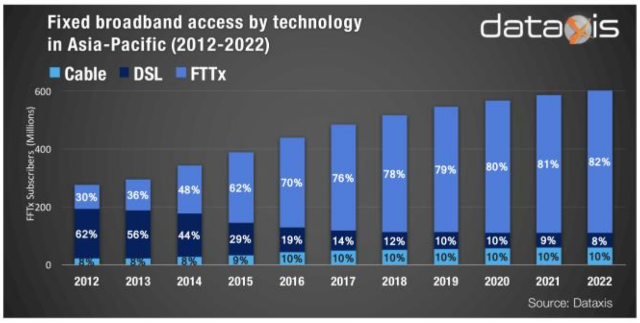

Figure 1 Growth of Fixed Broadband Access Technology in the Asia Pacific (Boulay, 2017)

FTTx, as part of optical fiber technology, also has advantages in terms of speed and the ability to send massive capacity over long distances. Optical fiber is the underlying infrastructure needed by today's internet networks. Optical fiber is the ideal technology for building national and global telecommunications networks (Wang, 2017). Instead of serving a single market (FTTHome), PON technology can address multiple demands (FTTBusiness, FTTWireless, FTTNode) (Effenberger, 2018). These opportunities can be the basis of FTTx implementation to support broadband services in Indonesia.

Fiber to the x (FTTx) is a general term for any broadband network architecture that uses optical fiber to replace all or part of the local metal loop cable used for last mile telecommunications. The general term comes from generalizing several optical deployment configurations (Fiber to the Network, Fiber to the Curb/Cabinet, Fiber to the Building, Fiber to the Home). All were starting with FTT but distinguished by the last letter, which is replaced by x in the generalization (Hambali, 2014).

One technology that is part of FTTx is a Passive Optical Network (PON). PON uses optical fibers and passive elements such as splitters and combiners, which make it a cost-effective technology. Traditional copper-based architectures that were quite popular before now are losing popularity because of the emerging bandwidth congestion and security threats (Gupta, Gupta, Kumar, Gupta, & Mathur, 2018). In line with the development of broadband technology, PON can provide optimal solutions for problems such as high data rates, low latency, and others.

Next-Generation PON, which is a development of PON, is present in providing certainty in meeting the increasing bandwidth demand in new access networks. The XG-PON system emerged as one of the most promising candidates to represent the NG-PON paradigm (Dalamagkas, Sarigiannidis, Moscholios, Lagkas, & Obaidat, 2018). It offers STM-64 (10 Gbps) for downstream and STM-16 (2.5 Gbps) for upstream. Asymmetric XG-PON is specified as XG-PON1, while Symmetric XG-PON is also proposed as XG-PON2 (Syambas & Farizi, 2017).

XG-PON has excellent potential with the existence of Quality of Services (QoS) allocation rules through an efficient Dynamic Bandwidth Allocation (DBA) scheme. The XG-PON application includes the implementation of hybrid wireless-optical networks, where XG-PON in the network backhaul and various Long Term Evolution (LTE) radio access networks in the front-haul (Sarigiannidis, Sarigiannidis, Moscholios, & Zwierzykowski, 2017).

In XG-PON, the PON system is required to support strong reciprocal authentication options, and use authentication to protect the integrity of PON management messages and PON encryption keys. This increase makes it difficult for an attacker to disguise himself as ONU or OLT, even if he has access to PON fiber, and also if he can adequately connect his transmission to ONU as a victim (Effenberger, 2011).

The ability of XG-PON that can be applied for broadband network needs is not in line with regulations for XG-PON equipment used in network access in Indonesia. In 2008, the government, through the Directorate General of Post and Telecommunications, issued regulation number 257 regarding the technical requirements of Passive Optical Network (PON) based telecommunications access equipment.

This regulation only explains the technical requirements for Gigabit PON and Ethernet PON technology, thereby the next generation of PON equipment, such as XG-PON, still has zero technical requirements. Therefore, the government is required to update PON technology standards to maintain the quality of telecommunications services in Indonesia.

Based on these problems, this study was conducted to provide an overview of the technical capabilities of XG-PON equipment and to test the technical specifications of XG-PON equipment, especially Optical Line Termination (OLT). The research focuses on technical parameters that change drastically with the existence of XG-PON technology, namely nominal rate, wavelength range, and additional capabilities required on ITU-T G-987, jumbo frame.

This study also examines the extent of nominal rate capability, wavelength range value, and jumbo frames of OLT XG-PON equipment with different brands. The technical specifications discussed in this study is expected to be a reference for the government to update the POSTEL PERDIRJEN 257/DIRJEN/2008 and be a reference in the implementation of equipment certification conducted by telecommunications equipment testing institutions in Indonesia.

RESEARCH METHOD

This research was conducted using a quantitative approach through optical equipment testing laboratory testing at Telkom DDS Bandung. The object of study is the OLT XG-PON equipment from 4 different manufacturers, namely PT. A, PT. B, PT. C, and PT. D with the various number of slots. The card tested was the XG-PON service card only with the consideration that this study would solely focus on the capabilities of the XG-PON technology. In this test, the data obtained from the measurement of nominal rate, wavelength, and jumbo frame from the OLT XG-PON equipment.

Quantitative data collection was done by testing the technical requirements of the OLT XG-PON equipment using the four OLT XG-PON brands. Data obtained from testing electrical requirements (nominal rate and transmission method) as well as jumbo frame performance. Data from the test results are recorded following specified technical parameters.

The technical parameters already have their specifications following data from ITU-T G.987 and equipment specification data. After recording the test results, the data is compared with the value required by ITU-T G.987. If appropriate, the value submitted as a reference for the renewal of POSTEL PERDIRJEN 257/DIRJEN/2008.

Nominal Rate XG-PON

The nominal line rate is the total number of bits that can physically be transferred per unit of time through the communication media. The target standardization of the XG-PON system supports the downstream line rate at 9.95328 Gbps and an upstream rate of 2.48832 Gbps. Split ratio, which is at least 1:256 in XG-PON, is also increasing with increasing bandwidth. This trend depends on several factors. It is related to the modernization of OLT and ONUs, development of passive optical splitters, improvement of transmission parameters of optical fiber on the physical layer, and correction of the Transmission Convergence (TC) Layer over previous versions (Koci, Horvath, Munster, Jurcik, & Filka, 2015).

XG-PON has a transmission convergence or XG-PON TC layer consisting of three sub-layers, namely: the XG-PON TC service adaptation sub-layer, the XG-PON TC framing sub-layer and the XG-PON TC PHY adaptation sub-layer. The XGTC layer presents on both sides of the OLT and ONU of the XG-PON system. In the downstream, SDU is mapping to PHY layer bitstream with a PHY frame period of 125 µs. As for the upstream, SDUs are assigning to the PHY layer bitstream specific to each ONU in a PHY time burst sequence.

Calculations for the nominal physical rate using the following calculation:

$$Nominal\ Physical\ rate = \frac{total\ physical\ frame\ bytes \times 8\ bit}{125\mu s} \quad (1)$$

Thus, the nominal rate of downstream XG-PON is 9,95328 Gbps at the PHY layer adaptation sublayer using the total number of physical frames is 155520 bytes. Whereas the TC XG-PON framing sublayer consists of the Framing Sublayer (FS) payload and the FS header. At this layer, the Physical Synchronization Blocks (PSB) of 24 bytes and the parity of forwarding Error Correction (FEC) of 32 bytes from 627 codewords have been removed. So the total number of bytes in the FS Frame and FS Burst is 135432 bytes so that the nominal rate is as follows:

$$Nominal\ Framing\ Rate = \frac{total\ XGTC\ frame\ bytes \times 8\ bit}{125\mu s} \quad (2)$$

$$Nominal\ Framing\ Rate = \frac{135432\ bytes\ \times\ 8\ bit}{125\mu s}$$

$$Nominal\ Framing\ Rate = 8{,}667648\ Gbps$$

For upstream, the total number of physical frames is 38880 bytes, and by using formula 1, the nominal rate is 2.48832 Gbit/s. In the XG-PON TC sub-layer, the framing sublayer consists of XGTC Header, several codewords, and XGTC Trailer. Assuming the elimination of Physical Synchronization Blocks (PSB) by 24 bytes and parity from forwarding Error Correction (FEC) by 16 bytes from several codewords and short codewords obtained 36344 bytes in the XGTC frame sublayer. Therefore, the nominal value of the upstream framing rate using the formula 2 equations are as follows:

$$Nominal\ Framing\ Rate = \frac{36344\ bytes \times 8\ bit}{125\mu s}$$

$$Nominal\ Framing\ Rate = 2{,}326016\ Gbps$$

As a note, ITU-T G.987.3 recommends the use of FEC on OLT and ONU; both upstream and downstream services are mandatory. FEC is always active in the downstream direction, while OLT dynamically controls the use of FEC in the upstream direction (ITU, 2010).

For the testing, XG-PON OLT, XGPON ONT, and traffic generator and analyzer are connected according to the configuration in Figure 2. Bidirectional traffic flow is created and sent between OLT and ONT from the traffic generator and analyzer. The received traffic rates evaluated on the traffic generator and analyzer form ports then connected to OLT and ONT. After that, the nominal rate of the XG-PON is compared with the value determined by the standard. The nominal rate of downstream with FEC is 8.6 Gbps, and the nominal rate of upstream with FEC is 2.3 Gbps.

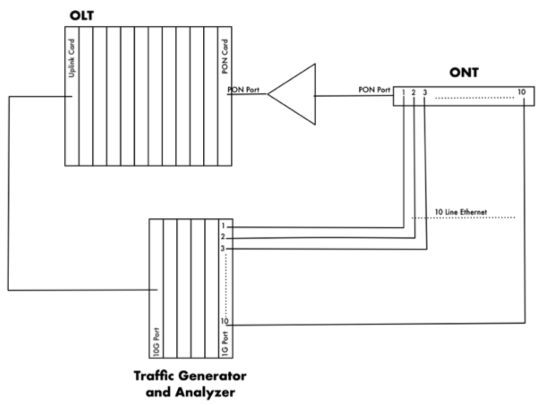

Figure 2 Nominal Rate Testing Configuration

XG-PON Wavelength

Wavelength is the distance between one wave frequency peak and another peak. In other words, the wavelength of the frequency is the distance a wave must travel in one period. Wavelength is usually denoted by the symbol λ (read as Lambda), with the unit measurement in meters (m).

To achieve the backward compatibility and co-existence of GPON and XG-PON systems, the optical wavelengths that selected for XG-PONs were the "O-band" (for the upstream ranging from 1260 to 1280 nm) and the "1577nm" (for the downstream ranging from 1575 to 1580 nm) (Konstadinidis, Sarigiannidis, Chatzimisios, Raptis, & Lagkas, 2014). Figure 4 shows that the XG-PON upstream wavelength range is in the "O-" band. O- the band was selected because the O+ band has higher requirements on filters and is more expensive (Batagelj et al., 2012).

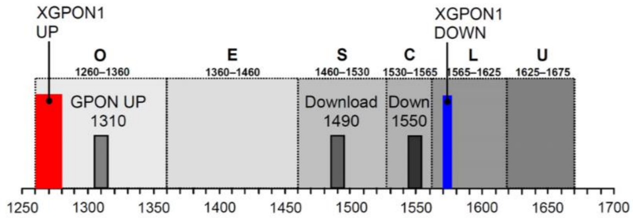

Figure 3 G-PON dan XG-PON Wavelength Allocation (Batagelj et al., 2012)

Note that the downstream window is only 5 nm wide, and require cooling laser sources. It is conceivable that this downstream band could extend beyond 1580 nm for systems that operate on more modern ODN infrastructures, and this could enable optical line termination (OLT) optics suitable for outdoor deployment, or uncooled operation in an indoor implementation. However, such an extension must be small. Otherwise, it complicates the ONU filter design (Effenberger, Mukai, Kani, & Rasztovits-Wiech, 2009).

XG-PON OLT, XGPON ONT, coupler, and optical spectrum analyzer (OSA) are connected according to the configuration in Figure 4 for the downstream, and Figure 5 for the upstream. OLT and ONT are activated and make sure the OLT and ONT signals work. The wavelength values in the downstream and upstream listed on the OSA record to evaluate.

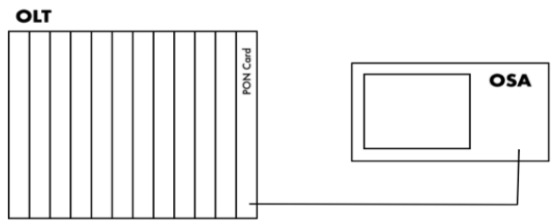

Figure 4 Downstream Wavelength Testing Configuration

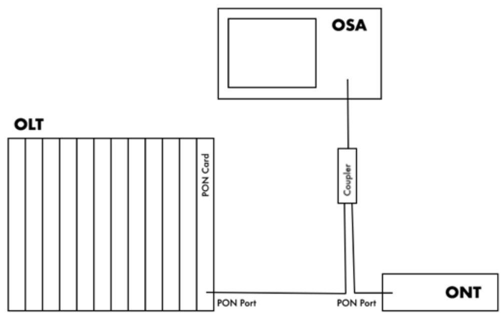

Figure 5 Upstream Wavelength Testing Configuration

XG-PON Jumbo Frame

The widely used technology which is Ethernet is still standardized to use frame size 1518 bytes due to the MTU (maximum transmission unit) is 1500 bytes by default. The Gigabit Ethernet generation has been developed to provide large MTU, but the default is still 1500 bytes (Supriyanto, Sofhan, Fahrizal, & Osman, 2017).

One of the recommendations required of XG-PON technology as part of the service requirements is the jumbo frame. XG-PON technology shall support Ethernet frames having a maximum length of 2000 bytes. Jumbo frames with lengths beyond 2000 bytes and up to 9000 bytes (generally recognized as the upper limit for jumbo frames) should be optionally supported. If jumbo frames beyond 2000 bytes are used for non-delay-sensitive services on the same PON, the delay-sensitive services and packet network synchronization shall not be degraded by jumbo frame transport (ITU, 2016).

Jumbo frames are Ethernet frames that can carry loads of more than 1500 bytes. Conventionally, jumbo frames can carry loads of up to 9000 bytes (Putra, Sukadarmika, & Wirastuti, 2019).

Figure 6 shows that the jumbo frame consists of Header, Payload, and Cyclic Redundancy Check. The largest possible data/payload in a frame is called the Maximum Transmission Unit (MTU). Jumbo Frame is advantageous for applications such as file transfer and Hadoop MapReduce (Prakash et al., 2013).

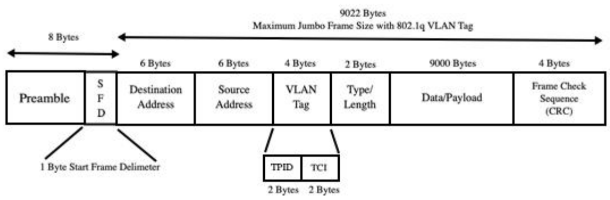

Figure 6 Jumbo Frame 9022 bytes Block Diagram (Putra et al., 2019)

XG-PON OLT, XGPON ONT, and traffic generator and analyzer are connected according to the configuration in Figure 7.

Traffic flow between OLT and ONT is creating with a bandwidth of 1 Gbps. OLT and ONT jumbo frames are set in the amount of 2000 - 9000 MTU depending on the ability of OLT and ONT. Bidirectional traffic is sent from OLT and ONT and make sure the traffic is generally running without frame loss. The traffic packet is checked to ensure the number of jumbo frames.

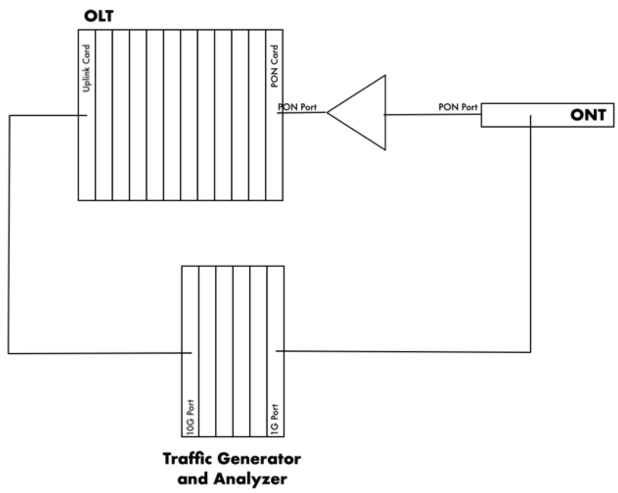

Figure 7 Jumbo Frame Testing Configuration

RESULT AND DISCUSSION

Standardization Regulation of the PON Devices in Indonesia

The Government of Indonesia issues a regulation for the technical requirements of access equipment based on passive optical network (PON) as outlined in PERDIRJEN No. 257 of 2008. The PON definition in this regulation is an optical fiber-based broadband access network architecture that uses passive optical equipment so that it can use in a point-to-multipoint configuration.

This regulation refers to the ITU-T G.984 series standard with Gigabit PON (G-PON) and IEEE 802.3ah technology, which is often called Ethernet PON (E-PON). GPON technology has a traffic rate of 2.488 Gbps downstream at a wavelength of 1490 nm and a traffic rate of 1,244 Gbps upstream at a wavelength of 1310 nm. Whereas E-PON has symmetrical traffic rate capability between upstream and downstream with 1.25 Gbps. The PON equipment whose technical requirements in this regulation are OLT, ODN, and ONU/ONT, following Figure 8.

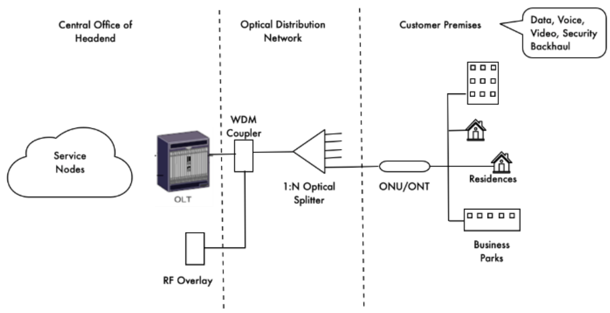

Figure 8 Passive Optical Network Public Service Architecture (DEPKOMINFO, 2008)

Table 1 OLT G-PON Specification (DEPKOMINFO, 2008)

No.	Technical Requirement	Specification
1.	**General Requirements**	
a.	Interface	• Ethernet Interface • FE (Electrical/optical) • GE (Electrical/optical) • 10G (Optional) • T1/E1 Interface (Optional) • RF video overlay (Optional)
b.	Power Supply	-48 ± 10%
c.	Environmental Condition	Temperature = 5~ 40^0 C Humidity = 5 ~ 85%
2.	**Electrical Requirements**	
a.	Bit rate	
	Upstream	1244,16 Mbps
	Downstream	2,488,32 Mbps
b.	Transmission Method	
	Downstream	1490 nm
	Upstream	1310 nm
3.	**Signaling Requirements**	
a.	Mean launced power max	OLT = +1,5 s/d +5 dBm
b.	Min sensitivity	OLT = -28 dBm
c.	Min overload	OLT = -8 dBm
d.	Maximum -20 dB Width	OLT = 1 nm
e.	Minimum SMSR	30 dB
f.	Distance Range OLT-ONU/ONT	0 ~ 20 Km with 28 dB optical power budget clas B+ ITU-T G.984.2
4.	**Performance Requirements**	
a.	Ethernet service functionality	VLAN based service QoS support (IEEE 802.1q / d / p) which configured to pass VLANs 1 to 4096 with variations: • VLAN Access • VLAN Trunking • VLAN Tagging
b.	Link Aggregation	The equipment shall support at least 2 GbE ports, which can be aggregated into a single logical link using standard link aggregation. When some ports in the group link aggregation fail, then the switch function of the other ports is not interrupted by the failing port.
c.	Multicasting (IGMP proxy & snooping)	The equipment shall be capable of at least 256 multicast groups and be able to run well on each ODN interface
d.	QoS	The equipment shall have a packet clarification function for the service class (CoS) following the priorities that apply based on: • VLAN ID-based • Based on 802.10-bit min 4 priority • Mapping DSCP to 802.1p
e.	Bandwidth Control Management	The equipment shall support the rate limit function for each service that can be set at least 1 Mbps with granularity not exceeding 1 Mbps, and the error accuracy must be less than 10%
f.	Security	The equipment shall have a security mechanism to protect data packets from interference by applying the following minimum standards: • 802.1x port-based security • DHCP relay and relay agent option 82 for the authentification radius • Restrictions on broadcast, multicast and MAC address flooding
g.	Resiliency	• Modular equipment shall equip with a redundancy system for the main modules, namely: processor control module, up-link, and power supply. • Compact equipment shall equip with a redundancy power supply system
h.	Layer 3 Function	Transparency support for layer 3 routing protocols and optional for multicast routing using PIM-SM / SSM (Protocol Independent Multicast-Sparse Mode / Single Source Multicast)
5.	**NMS Requirements**	• Minimum NMS management system functions shall meet the requirements of the features of fault management, configuration management, performance management, and security management • OLT equipment shall have a standard interface to an NMS with a minimum SNMP protocol version 1.0 or web-based and a minimum FE (100 Base-T) physical interface and a local console. • The equipment shall provide a standard northbound interface API (Application Program Interface) and sufficient documentation about the NMS interface and its functionality to facilitate the integration of the NMS into the operator's Operating Support System (OSS).
6.	**Electromagnetic Compatibility (EMC) Requirements**	The equipment shall meet the EMC specifications set out in separate Regulations.

The scope of the technical requirements of regulation number 257 of 2008 includes (1) General Requirements; (2) Electrical Requirements; (3) Performance Requirements; (4) NMS requirements; and (5) EMC Requirements. General requirements for OLT G-PON equipment consist of physical interface requirements, the ability of the power supply, and the ability of the equipment's environmental conditions (temperature and humidity) to operate normally.

For electrical requirements, PERDIRJEN No. 257 of 2008 requires packet framing to use as GEM Frame. Besides, PON equipment regulation requires several interface parameters and optical signals for single fiber in the downstream and upstream service directions with the details in Table 1. Electrical requirements also test the ability of the OLT range to ONU/ONT, the ability of the splitter ratio, and the power budget.

Performance requirements that must be met by PON equipment are Ethernet service capabilities, which include VLAN capabilities, Link Aggregation, Multicasting, and QoS. OLT equipment must also support Bandwidth Control, Security, Resiliency, and Layer 3 functions. While NMS requirements address the capabilities of management functions of NMS, OLT supports interface standards to NMS and support for open standard northbound interface API (Application Program Interface). Another requirement that must be fulfilled by PON equipment is the Electromagnetic Compatibility (EMC) requirements.

ITU-T Recommendation for XG-PON Technology

Recently, XG-PON technology is one of the developed PON networks. XG-PON is a technology recommended by ITU in 2010 using the TDM method for downstream and TDMA for upstream. XG-PON is a subclass of NG-PON1. This standard offers 10 Gbit/s downstream and 2.5 Gbit/s upstream speed, but target distance and split ratio did not increase much. Research in this area continues the job of bringing even better P2MP technology (Batagelj et al., 2012).

ITU gives standardization recommendations for XG-PON in ITU-T G.987 with various series. In this recommendation, XG-PON is defined as part of a PON system that supports a nominal transmission rate of 10 Gbit / sec at least in one direction and applies the set of protocols specified in the ITU-T G.987.x series Recommendations (ITU, 2012).

ITU gives the recommendations for the XG-PON standard outlined in several G.987 series. In G.987.1, ITU recommends service requirements, physical layer requirements, system-level requirements, operational requirements, and resilience and protection for ODN. The G.987.2 series recommendations related to flexible access networks using optical fiber technology. The focus is mainly on network support services with bandwidth requirements ranging from voice services to data running up to 10 Gbps, including broadcast services. This recommendation explains the characteristics of the PMD (Physical Media Dependent) layer of the optical access network with the ability to transport various services between the user-network interface and the service node interface (ITU, 2010).

In the next series, G.987.3 describes the transmission convergence (TC) layer both in layers and functions, the encapsulation method of XG-PON, PLOAM messaging channels, OLT and ONU timing relationships, security functions, performance monitoring, and error monitoring, and ONU power management. The last recommendation is G.987.4 regarding the extension range, which involves increasing the overall fiber length and splitting ratio.

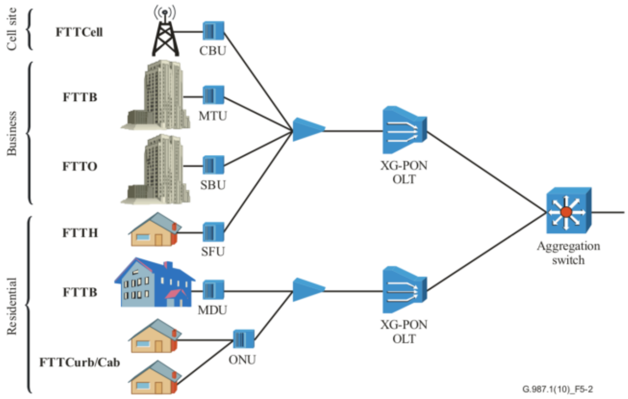

Figure 9 XG-PON Network Scenario (ITU, 2016)

As shown in Figure 9, the implementation of XG-PON consists of the following components:

a) OLT (Optical Line Termination). Optical Line Termination is a component of a fiber optic cable network that is connected to a backbone network (uplink) and connected to several ODN (downlink). OLT is part of a network element in an optical access network based on ODN by providing services to customers through ODN (downlink) and providing an interface to the service node (uplink). OLT has management and maintenance functions for ODN, ONU, and ONT. OLT must be able to deliver voice, data, and video services from service providers to customers.

b) ONU (Optical Network Unit). Optical Network Unit is active equipment that is part of the XG-PON subsystem that functions as an interface on the customer side with a PON network that still adds/requires an additional network termination (NT) on the customer's side such as a modem.

c) ONT (Optical Network Terminal). Optical Network Termination is a piece of active equipment that is part of the XG-PON subsystem. It functions as an interface on the customer side with a PON network that is positioned directly at the customer's position that acts as an endpoint, end equipment of the ODN (Optical Distribution Network) distribution.

d) ODN (Optical Distribution Network). Optical Distribution Network is part of point-to-multipoint optical fiber infrastructure. ODN located between OLT and ONT / ONU with the tree topology of the optical fiber in the access network. ODN equipped with a power splitter or wavelength splitter, filters, or other passive optical equipment. The ODN class on XG-PON consists of Nominal 1 (N1), Nominal 2 (N2), Extended 1 (E1), and Extended 2 (E2) with differences in their respective power budget values.

OLT XG-PON Nominal Rate Testing Result

The nominal rate test results shown in Figure 10 show that all OLT tested using FEC for upstream and downstream traffic. The nominal rate of the downstream for OLT Brand B and brand D has a value below the result of calculation formula 2, which is 8.667648 Gbps. In contrast, the nominal rate test results for upstream direction for OLT Brand A and OLT brand B have a value below the result of calculation formula 2, which is 2.326016 Gbps.

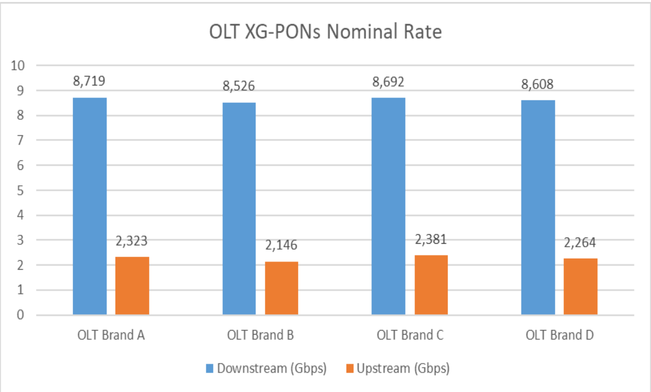

Figure 10 Nominal Rate Test Results for 4 OLT XG-PON Equipment Brands

XG-PON OLT Equipment Wavelength Test Results

The results of the upstream wavelength testing for 4 brands of OLT XG-PON equipment, as shown in Figure 11, informs that the wavelength values of the 4 OLT brands are within the recommended range of ITU-T 987 which is 1260-1280 nm. As for the downstream direction, the 4 OLT brands have wavelengths that are still in the range of 1575-1581 nm according to recommendations from ITU-T.

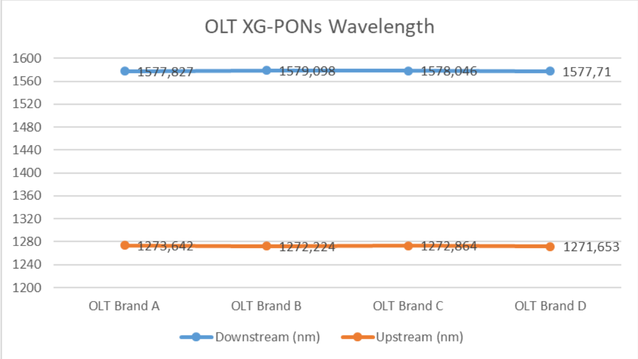

Figure 11 Wavelength Test Results for 4 OLT XG-PON Equipment Brands

Jumbo Frame Testing Results for OLT XG-PON Equipment

Figure 12 presents the ability of jumbo frames for four brands of OLT equipment with various slots has different values. OLT brands A and D have a jumbo frame capability of 2000 Bytes, which is the minimum value recommended by ITU-T G.987. Whereas OLT brands B and C have jumbo frame capability above the optional value recommended by ITU-T G.987, which is 9000 bytes.

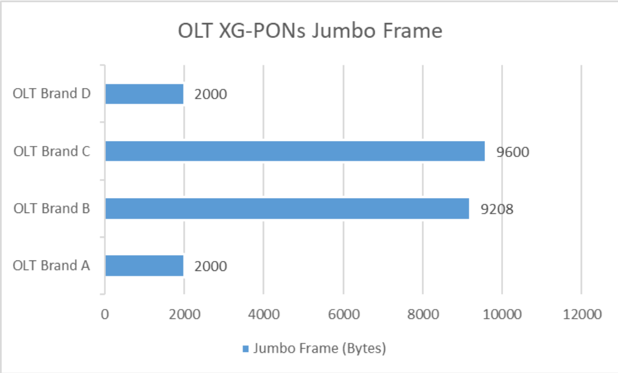

Figure 12 Jumbo Frame Test Results for 4 OLT XG-PON Equipment Brands

Discussion of OLT XG-PON Equipment Testing Results

From the tests of four OLT XG-PON brands with various numbers of slots, the following results were obtained, as presented in Table 2.

Table 2 Test Results for Nominal Rate, Wavelength and Jumbo Frame

Item Test	OLT Brand A	OLT Brand B	OLT Brand C	OLT Brand D
1.Nominal Rate				
Downstream (Gbps)	8,719	8,526	8,692	8,608
Upstream (Gbps)	2,323	2,146	2,381	2,264
2. Wavelength				
Downstream (nm)	1577,827	1579,098	1578,046	1577,71
Upstream (nm)	1273,642	1272,224	1272,864	1271,653
3. Jumbo Frame (Bytes)	2000	9208	9600	2000

From data in Table 2, the nominal rates result from OLT brand A and OLT Brand B are below the value in formula 2 calculation for both upstream and downstream. These happened might be due to the capability of OLT and ONT equipment, the ability of the equipment to make error corrections, and the attenuation of the transmission media. Therefore, the proposed nominal rate for the technical requirements of the downstream OLT XG-PON equipment is 8.5 Gbps, and the upstream direction is 2.1 Gbps. It is with the consideration that the OLT XG-PON equipment is still working and can deliver data, voice, and video services.

For wavelength values, four OLT XG-PON equipment brands can work with wavelengths that meet the requirements of ITU-T G.987. It proves that the OLT XG-PON equipment in the market has been able to pass the wavelength in the range of 1260-1280 nm for the upstream and 1575-1581 nm for the downstream so that the wavelength value recommended by ITU-T G.987 can be used as a reference in determining the wavelength requirements. Besides, the result shows that OLT XG-PON has wavelength capability around 1577 nm for downstream and 1270 nm for upstream.

As for the jumbo frame capability, the four OLT brands tested have diverse capabilities. The difference in jumbo frame capability can be caused by OLT equipment specification or ONT equipment specification. However, this capability is still in the range of ITU-T G.987 recommendation with mandatory and optional jumbo frame size, which is 2000 to 9000 bytes. Consequently, for the design of jumbo frame size, technical requirements shall use mandatory recommendations from ITU-T G.987, which is 2000 bytes.

Recently, the Director-General of Post and Telecommunications Regulation No. 257 / DIRJEN / 2008 concerning Technical Requirements of Passive Optical Network (PON) Access Telecommunication Tools and Equipment only presents technical requirements for G-PON and E-PON technology. It has limited capability for transmission rates. G-PON has the ability of 2.5 Gbps for downstream and 1.25 for upstream, while E-PON has only 1.25 Gbps for downstream and upstream.

Thus, for the development of XG-PON technology new regulation, the value of the nominal rate specification using FEC is 8.5 Gbps for downstream and 2.1 Gbps for upstream. Also, the updated regulation needs to add the XG-PON wavelength range requirements for the upstream is 1260-1280 nm, and the downstream is 1575-1580 nm. Another requirement that needs to be added is the ability of the XG-PON jumbo frame with a minimum value of 2000 bytes. The lowest value of the test results is taken with consideration; the value can accommodate all the capabilities of the device.

CONCLUSION

This study provides several significant findings. First, FTTx technology is still growing to support the implementation of fixed broadband networks. It is an opportunity for the government, regulators, and operators to utilize PON technology in Indonesia. For example, the use of XG-PON to meet the needs of broadband services for residential, business, and cellular network providers.

Secondly, from testing the technical specifications of Optical Line Termination (OLT) equipment, several parameters need to be added in the regulation of the technical standardization of the Passive Optical Network (PON). First, the XG-PON nominal rate with FEC is 8.5 Gbps (downstream) and 2.1 Gbps (upstream); Second, the wavelength range of XG-PON is 1260-1280 nm (upstream) and 1575 -1580 nm (downstream); and Third, the XG-PON jumbo frame capability is 2000 bytes.

By adding the standardization parameters for testing OLT XG-PON equipment, it significantly supports the quality of the broadband technology deployment in Indonesia. The government, as the supervisor for the quality of telecommunications services in Indonesia, is expected to be able to make updates to the regulation of the PERDIRJEN POSTEL no. 257 of 2008. The updated regulation will be part of the success of the Indonesia Broadband Plan and encourages Indonesian

ICTs to contribute optimally in enhancing the nation's competitiveness.

Hopefully, there are additional parameters for OLT devices in further research. Also, the next study can be extended to ONT or ODN devices. So, the government will get a lot of recommendations to develop the XG-PON equipment specification standard in Indonesia.

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