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ANALYSIS OF GPON CAPACITY BY HYBRID SPLITTING-RATIO BASE ON CUSTOMER SEGMENTATION FOR INDONESIAN MARKET DURING THE COVID-19 PANDEMIC

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Abstract

During the Covid-19 pandemic, the impact on internet demand is very high throughout the world. In Indonesia, through a survey conducted, broadband users recorded 175 million people or equivalent to 64 % of the population. Based on field observations, the Passive Optical Network (PON) port utility in the Optical Line Terminal (OLT) is presently below 75 %, as opposed to the initial value, which was more than 95 % [1]. Furthermore, it was also found that more than 80 % of IndiHome customers use a maximum bandwidth of 20 Mbps with majority using 10 Mbps, which is very ineffective, especially related to network capacity. Generally, passive Optical Distribution Network (ODN) devices are not optimally used, therefore this research aims to determine the optimization level of the FTTH network by maximizing the available infrastructure capacity. This process was carried out by increasing the associate ratio of 1:32 to 1:64 while taking into account the Optical Line Terminal (OLT) capacity factor and the standard link budget with schemas A, B and C used to obtain adequate efficiency. Scheme A consists of a 1:2 passive splitter in the Optical Distribution Cabinet (ODC) & 1:32 at the Optical Distribution Point (ODP). Scheme B consists of a 1:4 (ODC) & 1:16 (ODP) passive splitter, while scheme C consists of a 1:8 (ODC) & 1:8 (ODP) passive splitter intended for the use of different customer area types. The result showed an increase in network capacity from 32 to 64 per PON port while taking into account the technical quality of the Link Budget. In conclusion, to ensure this solution functions properly, both simulation and direct measurement tests are carried out using the existing network.

Keywords: Optimize, GPON, ODC, ODP, PON, OLT, FTTH, Splitter, Link Budget, Bandwith.

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1. Introduction

Broadband technology is an important aspect of human life used by individuals, small-scale businesses and large companies to carry out various daily activities [1]. During the Covid-19 pandemic, there were changes or shifts in the configuration of broadband technology utilization from offices, campuses, schools, and public places to housing, residence, and settlements.

As the fourth largest market in the world, which increased by 7 % from the previous year with the addition of 298 million people, Indonesia is an important broadband market [2]. Similar survey showed that broadband users recorded 175 million people, which is equivalent to 64 % of the population. Furthermore, there was an increase of 17 % from the same period in the previous year [3]. This increase in demand is one of the keys to accelerating the evolution of broadband technology, starting from communication networks via copper cable media for telephone services to now high-speed wide area networks via fiber optic media. The fiber optic transmission method, which uses light to transfer information from the sender to the receiver, was chosen due to its wide bandwidth [4].

IndiHome, a Telkom product is the main player in fixed broadband with a market share of 84 %, while other players are 16 % which is divided into First Media, My Republic, MNC Play, and Biznet with its growth shown in **Fig. 1**.

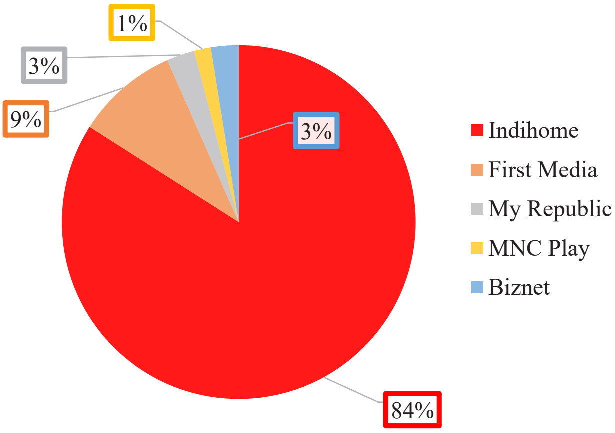

Fig. 1. Market Share (Indihome vs others) [5]

IndiHome has experienced stable growth from 2019 to present, as shown in **Fig. 2**. This growth is in accordance with the implementation of government policies related to studying and working from home due to the pandemic.

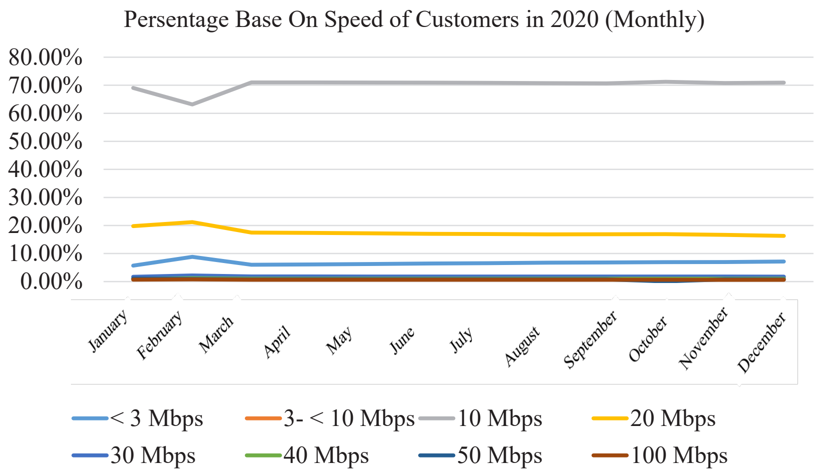

Fig. 2. Indihome customer growth [5]

A Fiber to the Home (FTTH) network consisting of active and passive devices need to be deployed as the infrastructure for IndiHome. The active devices on the FTTH network consist of OLT and ONT on the Central Office and customer sides. **Fig. 3** shows the distribution of OLTs with a total of 148.134 ports in the normal and critical categories. According to studies, the normal and critical categories occur when traffic passing through the port does not pass and exceeds 70 % of the total capacity, respectively. For example, in regional 3, normal and critical ports are 4.782 (99 %) and 0.06 %.

Based on the above conditions, all regional above 99 % are still categorized as normal, therefore traffic passing through the port can still be increased. Currently, one OLT port is intended to serve up to 32 customers. Therefore, the existing FTTH network (IndiHome) still has the ability to increase its traffic by using one OLT port to serve more than 32 customers.

Fig. 4, 5 show the percentage of customers with PT Telkom's network availability.

In 2020, most customers had network speeds of 10–20 Mbps (80 %), as opposed to the expected initial design of 50 Mbps and 100 Mbps.

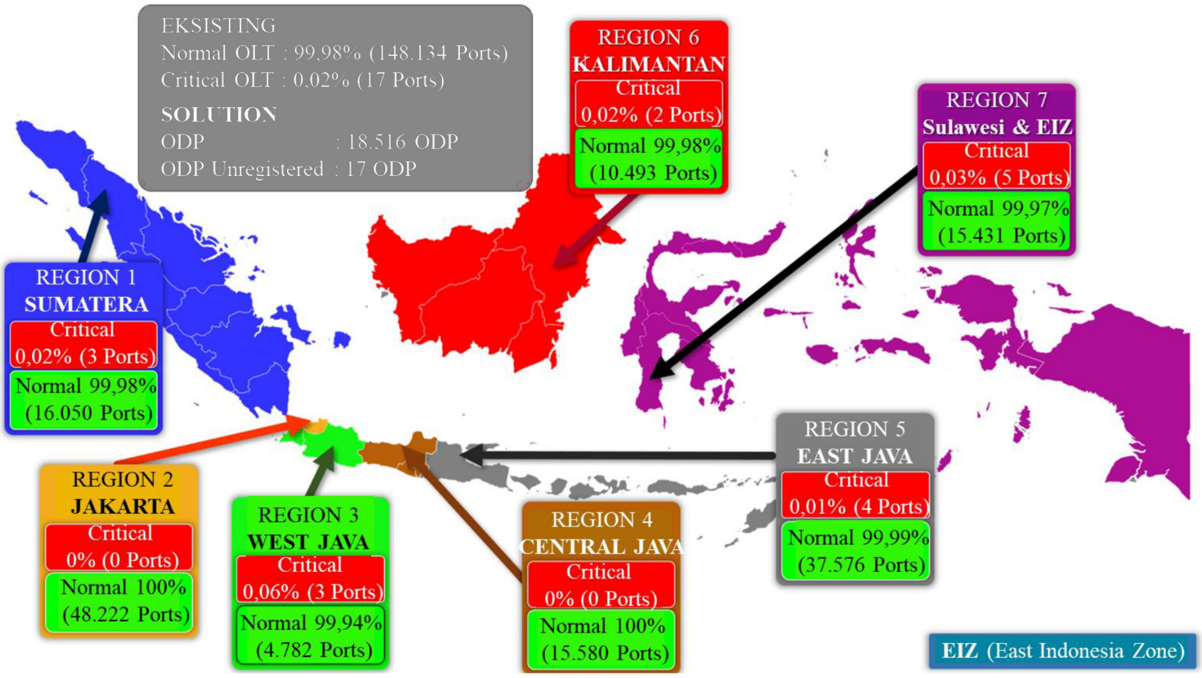

Fig. 3. OLT distribution [5]

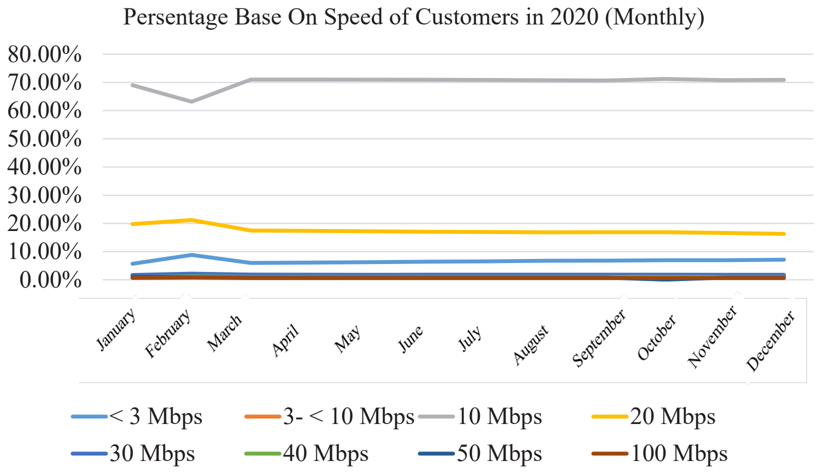

Fig. 4. Percentage number of customers 2020 by monthly [5]

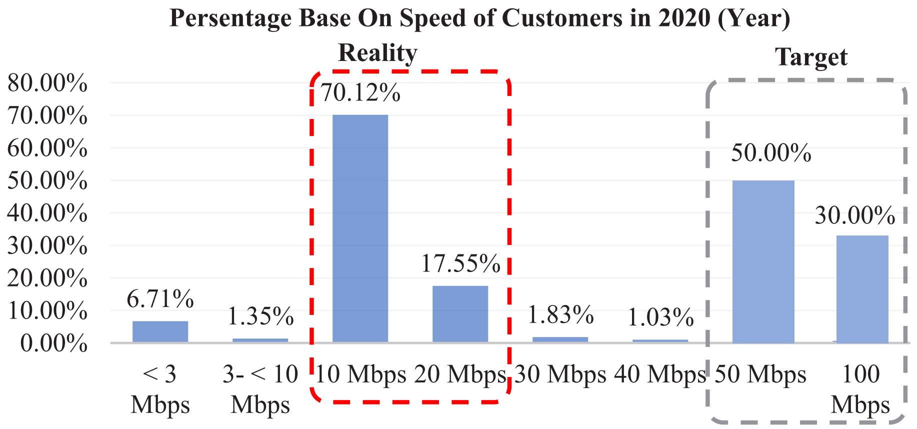

Fig. 5. Percentage number of customers 2020 by year [5]

The main problems associated with the present network are as follows:

1. The majority of IndiHome customers (88 %) still have low speeds (10 Mbps and 20 Mbps).

2. Customers with speeds of 50 Mbps and 100 Mbps are only 1.42 %.

3. There is still low OLT capacity, therefore it needs to be increased.Several possible solutions are proposed in the research [3]. An instance is the 1:64 ratios which failed to display real data in the field. Furthermore [4], failed to provide detailed explanation on the reasons for using a 1:32 and 1:64 splitting ratio.

GPON technology is used to handle 32 to 64 ports according to the splitter used [5]. This research also explains the importance of using 1:32 and 1:64 splitting ratios.

Furthermore, the novelty of this research is to optimize GPON capacity by hybrid splitting-ratio base on customer segmentation for the Indonesian market due to the COVID-19 pandemic as shown in **Fig. 6**.

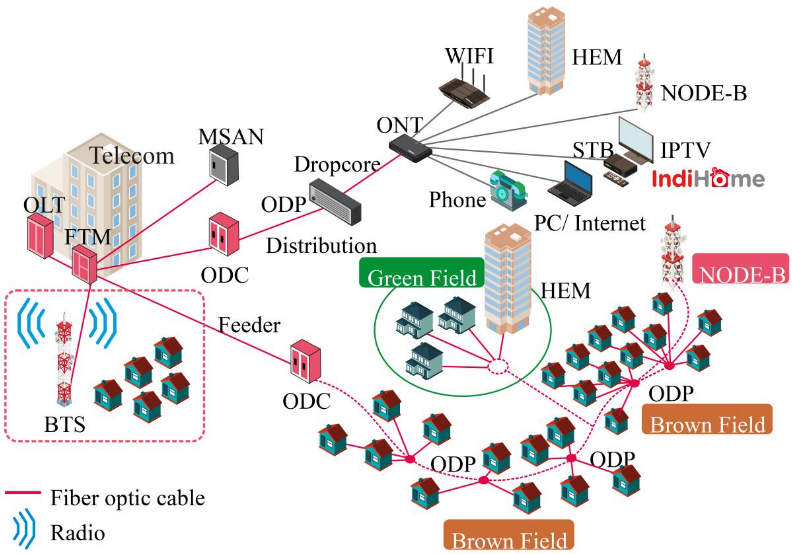

Fig. 6. FTTH Configuration [6]

The details of the contributions and advantages of this research are as follows:

A. It is proposed to carry out 3 schemes in the form of a hybrid splitting-ratio base on customer segmentation area, as follows:

Scheme A: placing 1:2 and 1:32 splitters on ODC and ODP for High rise building (apartment) customers.

Scheme B: placing 1:4 and 1:16 splitters on ODC and ODP for customers in the cluster area (Group).

Scheme C: placing 1:8 and 1:8 splitters on ODC and ODP for dispersed customers.

B. Design data was obtained based on optisystem simulations, Link Budget calculations, and direct measurements in the lab and field.

C. Design data was obtained based on optisystem simulations, Link Budget calculations, and direct measurements in the lab and field.

D. The results of the design, simulation, measurement and implementation proved that the proposed method has been successfully carried out with technical specifications.

E. The main objective of this research is optimizing the installed GPON capacity, in order that it can reduce the inefficiency that occurs.

2. Materials and methods

Gigabit Passive Optical Network (GPON) is one type of active device consisting of Fiber Optic media and used for communication. One of the characteristics of this device is its use for splitters in fiber optic distribution networks.

The Gigabit Passive Optical Network (GPON) is the technology used by IndiHome to distribute services from one point to another. The implemented GPON uses a passive splitter device capable of transmitting services to several Optical Network Terminals (ONT). The operating wavelength used for downstream and upstream are 1480–1500 nm and 1260–1360 nm, respectively [7]. In theory, GPON technology has the capability of serving over 128 customers from 1 port. Based on a 2020 data, the use of OLT ports throughout Indonesia is still not optimal because out of the 148,151 ports, only 17 have a critical status at capacity usage exceeding 80 %. This means that there are still many OLT ports that need to be optimized to meet customer capacity.

The Passive Optical Network is divided into 2, namely the upstream and downstream signals. In the upstream the speed of the data flow is sent from the user to the service provider, while the reverse occurs in the downstream signal. GPON was developed by the ITU-T organization compared to technologies that have a high bit rate and better market dominance.

Furthermore, it uses optical wavelength division multiplexing (WDM) for both downstream and upstream data, which are transmitted at wavelengths of 4900 nm and 1550 nm, respectively [8]. A wavelength of 1550 nm is used for the distribution of TV signals.

Previously 1 OLT port only had the ability to provide services to 32 customers, however, with this solution it is open to 64 customers. By making these additions, the fixed link budget needs to be taken into account. Therefore, based on simulations and direct measurements, the distance suiTable for apartment solutions using mini OLTs installed outside is the main factor.

Optical Line Terminal (OLT) provides an interface between the PON system with the data, video, and telephone network service providers. This section links to the service provider's operating system via the Element Management System (EMS). OLT is at STO also known as telephone auto center with a PON system interface provider. Its function is as a converter from an electrical to an optical signal.

Optical Distribution Network (ODN) provides a means of optical transmission from the OLT to the user and vice versa. This transmission uses passive optical components and provides optical transmission equipment between OLT and Optical Network Terminal (ONT) including optical cable, Optical Distribution Cabinet (ODC), and Optical Distribution Point (ODP). ODC is a passive device installed outside the STO, with various capacities depending on needs, namely 96, 144, 288, and 576 cores/ports. Its function is to terminate point of the feeder cable, the base of the distribution cable, and the connection. An optical distribution point is a passive device installed outside the STO [9]. ODP is located outside/inside the room as a distribution and connection cable termination points, and a splitter place.

Optical Network Terminal (ONT) is an active demultiplexing device installed on the customer side to convert optical signals into electrical. The output of the ONT is a telephone, data, internet, and CATV/IP services. Furthermore, it provides an interface between the optical network and the customer [10].

As shown in **Fig. 7**, ONT also uses the FTTx Network Implementation Model (i-ODN) in accordance with the strategic policy to develop an integrated fiber optic distribution network (i-ODN). Fiber ToThe Home (FTTH), Fiber To The Building (FTTB) or High Rise Building (HRB), Fiber To The Mobile (FTTM), Fronthaul or Node B networks, and Fiber To The Area (FTTA) are used for residential, and backhaul customers with an Integrated Fiber Optic Distribution Network.

The limit point for changing drop cables with indoor in the form of OTP is located on the outer wall of the customer's house protected from rain and direct sunlight. The following is a general drawing of the FTTH network configuration. Fiber To The Building (FTTB) is an Integrated Fiber Optic Distribution Network used on high-rise building customers [11]. The limit point for changing distribution cables with FTTB indoor in the form of ODP is located in certain rooms on each floor provided by certain types of building, such as Offices with WiFi, PABx and Internet/Data services, Hotels with WiFi, IPTV and PABx services, Malls with WiFi and EDC services, and Apartments with optional 3 Play services. General or block diagram of FTTB customer configuration with OTP installation is optional according to operational conditions.

Fiber To The Mobile (FTTM) is an Integrated Fiber Optic Distribution Network for approach link, such as backhaul, midhaul, and fronthaul mobile broadband services. FO cable pulling is carried out through FTTH network implementation or direct supply fiber. The limit point for switching Fiber Direct Supply (FCL) cables is through distribution by using multicore scpt 12 cores cables terminated in OTB devices located inside buildings, and shelters/cabinets connected to PTP modules in OLT devices, or Metro Ethernet Access (MEA) devices as shown in **Fig. 4**. FTTA is an integrated fiber optic distribution network that serves customers in an area with a horizontal or multi-story building. The limit point for changing distribution or dropping cables with FTTA is available in the form of ODP, OTP, or OTB according to field conditions located in certain rooms provided by the area manager. Locations included in the FTTA category are customers in the Industrial, education, and business districts. From the building side, the area consists of Landed products, such as Aerial & Underground and HRB.

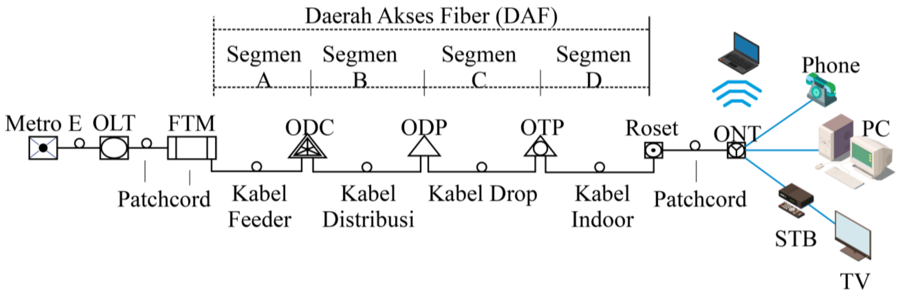

Fig. 7. FTTH architecture [6]

FTTH is one of the implementations used for fiber optic transmission technology, also known as FTTx, which is capable of transmitting data at a fast and sTable bit rate to homes using fiber optic media. The configuration of the fiber access network is the same as in the copper access network, where there are supply segments on the FTTx network, including feeder, distribution, drop, and indoor cables, as well as active devices such as Optical Line Terminals (OLT) and ONT.

OLT is an active device located at the central office that functions as an interface between one or more optical distribution networks. Optical Distribution Frame (ODF) is a device for the initial termination of fiber optic cables. Furthermore, it is also a place of transition from outdoor to indoor cables and vice versa. It is also a fiber optic cable terminated at the Optical Distribution Frame (ODF) and optical distribution cabinet (ODC) which connect the two devices. An optical distribution cabinet (ODC) is a passive optical network device installed in the field.

ODC functions as a termination point for the end of the feeder cable and the base of the distribution cable, from a large capacity (feeder). It is also a place for sharing optical signal information (splitter), and a connection point [12]. Distribution cables are similar to feeder cables, which transmits optical signal information from ODC to ODP. Optical distribution point (ODP) is a final termination device for distribution cables and initial termination on the use of drop cables. ONT is a device that provides interfaces for data, voice, and video. The main function of this ONT is to receive traffic in optical format and convert it into the desired form, such as data, voice, and video [13].

Several issues are related to the design of fiber termination management/optical distribution frame (FTM/ODF). First, FTM/ODF needs to function as fiber optic cable that connects and terminates active devices using OSP. Both FTM special room designs need to be provided with wired access from the OSP and through the chamber. The three FTM rooms need to be separated from the personnel room and equipped with a security system. Fourth, it is necessary to condition the room with AC because the Fiber Monitoring System (FMS) is installed in the FTM. Fifth, for small cities, cable capacity less than 1000 cores are needed without the installation of an E-side ODF. However, it is recommended that the FTM room remains separate from the active device room. Sixth, the FTM room need to be adjacent to the active devices, which is in turn directly connected to the OSP-side ODF port in the FTM room by interconnecting with a patchcord. Seventh, the cable path between the active device and the ODF need to be installed with a separate fiber duct from the power cable tray/wire mesh, cord bundle, grounding cable, or other UTP/PVC cables as a security or protection for the optical cable/patchcord. Eighth, the planned need for optical cores for the next 5–20 years needs to be considered while allocating space for several FTMs [14]. Ninth, in designing the FTM, the layout of the FTM/ODF, Fiber Guide, and the layout of the Tray/Wiremesh need to be considered.

Feeder cable configuration need to have a backup system (Dual Route Preferred), where the internal and external termination at STO is carried out at FTM/ODF and ODC (outdoor/HRB) [15]. In order to supply services other than FTTH (FTTM, FTTB, and FTTA), 1/6 core feeder cable is prepared from the capacity. The configuration of the feeder cable is in the form of Ring, Star, and Bus in accordance to the needs and conditions of the existing field. Ring configuration is used assuming a redundant system is desired and conditions in the field make it possible to create a ring-shaped feeder network. Furthermore, the Star configuration connects all cables from each ODP to the central point as a concentrator, namely ODC. Meanwhile, the Bus configuration is used when field conditions prohibit the use of rings.

Distribution cable is a fiber optic cable that connects ODC and ODP devices [16]. However, this cable is replaced with the Direct Supply Fiber (FCL) system when placing ODC close to the STO supply. The distribution segment configuration includes the following: first, it is the device/infrastructure between ODC and ODP. Second, its installation needs to reach all home-passes with the installation of ODP Poles including ODP Solid for new construction sites. Third, the core reserves are at least 1/6 of the distribution cable capacity and are placed on the last tube number on the distribution cable. Fourth, all types of ODP, such as Pole, Wall, and Pedestal including the Solid need to be installed for the required location according to field conditions. Fifth, it is possible to use Direct Supply Fiber configuration assuming the demand is close to STO or difficulty in performing SITAC ODC [17]. Sixth, in the use of Optical Core in distribution cable, the largest core number is allocated closest to the ODC, therefore, when there is a backup, the spare optical core becomes the smallest. Seventh, the occurrence of ODP Branching, leads to the connection of optical cores according to the needs and the location of the backup on the main cable. Eighth, the existing reserves are used in expanding the main or branching route. Ninth, the distribution cable that comes out of the ODC need to use a cable similar to the diameter of the core and the last termination point (ODP or MDU).

The distribution cable deployment pattern is carried out with underground and above-ground installations, using the duct system designed for housing/HRBs that have prepared SPBT in locations with high broadband. Furthermore, the deployment of distribution cables uses the Microduct system and is carried out at the housing location of the HRB, as well as an area that allows the use of Microduct. In the Above Ground Installation, an aerial system is used for housing in the Brown Field area and optimization of existing pole. Furthermore, 3 standards are used in the deployment of distribution cables. First, for the duct system in housing, the depth of distribution cable deployment is similar to the drop cables while considering the regulations of the regional developer and the local city planning service. Second, the type of cable used is SCPT (single-core single tube). Third, the distribution capacity is 8–24 cores and the cable type is G.652D using the duct and aerial systems. Subsequently, the drop cable is a fiber optic that connects the ODP and OTP devices placed at the customer's house. In general, the implemented cable refers to the ITU-T. G657 which consists of 2 standard types, namely Loosetube and Ribbon.

The following attributes, need to be considered for the drop cable configuration. First, the stripper segment needs to be connected from the ODP to OTP port at a maximum length of 150 meters. Second, the termination of drop cables on ODP and OTP need to use a Splice On Connector (SOC) or pre-connectorized drop cables in accordance with applicable standards. Third, the drop cable used above ground with a capacity of 2 or 1 core, need to use a barrier or cable amplifier with a messenger in the middle [18]. The drop cable used is in accordance with applicable standards. Fourth, Polyvinyl Chloride (PVC) or High-Density Polyethylene (HDPE) pipes need to be used for cable protection for fiber optic installations for road crossing routes. Fifth, there are 2 models of drop cable channel installation, namely by using aerial or underground drop cables. Sixth, the installation of underground cable channels need to use a direct planting or ripping system using HDPE pipe protectors.

Based on the location, these indoor cable designs are grouped into the customer's house (IKP) and the High Rise Building (IKG/HRB). The indoor cable design in the customer's house is a fiber optic cable that connects the OTP device to the Rosette. Meanwhile, the indoor cable design in High Rise Buildings (IKG/HRB) is a fiber optic cable that connects the ODP device to the Rosette, with optional installation process.

Some of the attributes that need to be considered for indoor cable configuration in the customer's house are that it starts from OTP to Rosette using the Patchcord of G.657, capable of protecting the cable Tray. It is covered by a pipe when installed with a planting system. However, when using a transparent indoor cable with a patch system, the pipe does not need to be protected with a cable tray. This is because the connectors at both ends of the cable need to be carried out by splice on connector (SOC) or Fast Connector, and terminated to the OTP device and Rosette. Meanwhile, the connection from Rosette with ONT does not use Patchcord type SC-UPC because the path or entry point for indoor cables from OTP into the house creates special paths or uses the existing holes, such as air vents to guarantee safety. The determination of indoor cable routes as well as the placement of Rosettes, ONT, and Client Premises Equipment (CPE) needs to be coordinated and approved by the customer [19]. The analysis in this research is carried out by calculating the link budget to determine the ability of these parameters to fulfill the basic quality requirements of network connections. The link budget calculation is carried out to determine the suitability of the power with the sensitivity of the receiver.

Table 1 shows the comparison results between the use of bandwidth capacity per PON port with 1:32 and 1:64 splitting based on Telkom customer data. In 1 port of OLT, 43 %, 48 %, 3 %, 1 %, 3 %, and 1 % customers subscribed to 10 Mbps, 20 Mbps, 30 Mbps, 40 Mbps, 50 Mbps, and 100 Mbps, respectively.

Table 1
Bandwidth Usage Comparison

EXISTING BANDWIDTH CAPACITY				PROPOSED BANDWIDTH CAPACITY			
Service Type	**%**	**Subscribers**	**BW**	**Service Type**	**%**	**Subscribers**	**BW**
10 Mbps	43	12	120 Mbps	10 Mbps	43	28	280 Mbps
20 Mbps	48	14	280 Mbps	20 Mbps	48	30	600 Mbps
30 Mbps	3	2	60 Mbps	30 Mbps	3	2	60 Mbps
40 Mbps	1	1	40 Mbps	40 Mbps	1	1	40 Mbps
50 Mbps	3	2	100 Mbps	50 Mbps	3	2	100 Mbps
100 Mbps	1	1	100 Mbps	100 Mbps	1	1	100 Mbps
Total BW			700 Mbps	Total BW			1.180 Mbps
Residual BW			1.788 Mbps	Residual BW			1.308 Mbps

This research aims to increase the capacity of the splitter from 32 to 64 customers using 3 scenarios. The first is scheme A where ODC and ODP have 1:2 and 1:32 passive splitters suiTable for use in apartment areas, office buildings, and hotels, due to its efficiency and effectiveness in device installation, which does not require a lot of space. The second is scheme B where ODC and ODP have 1:4 and 1:16 passive splitters suiTable for densely populated housing complex with large areas. The third is scheme C where ODC and ODP have 1:8 each of passive splitters suiTable for use in small and medium cluster areas that are not too densely populated.

As a novelty, this research proposes optimizing GPON capacity by hybrid splitting-ratio base on customer segmentation for the Indonesian market at the COVID-19 pandemic. It is proposed to carry out 3 schemes in the form of a hybrid splitting-ratio base on customer segmentation, namely: Scheme A: 1:2 and 1:32 splitters of ODC and ODP are put in configuration A as shown in **Fig. 8**, with the calculation result of the average power transmission generated at 28 dBm. Therefore, it is suiTable for high-rise building and apartment area customers.

Scheme B:1:4 and 1:16 splitters of ODC and ODP are put in configuration B as shown in **Fig. 9**. The calculation result of the average power transmission generated at the transmitter is 28 dBm, therefore, it is suiTable for high-rise building customers.

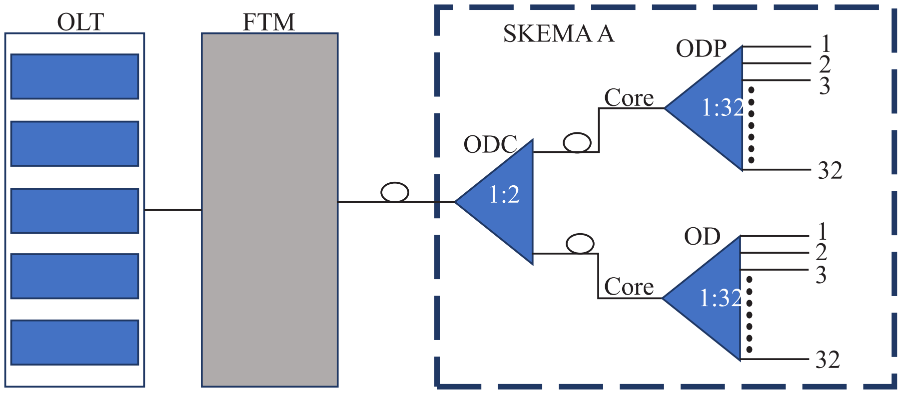

Fig. 8. Trial Configuration of Scheme A [6]

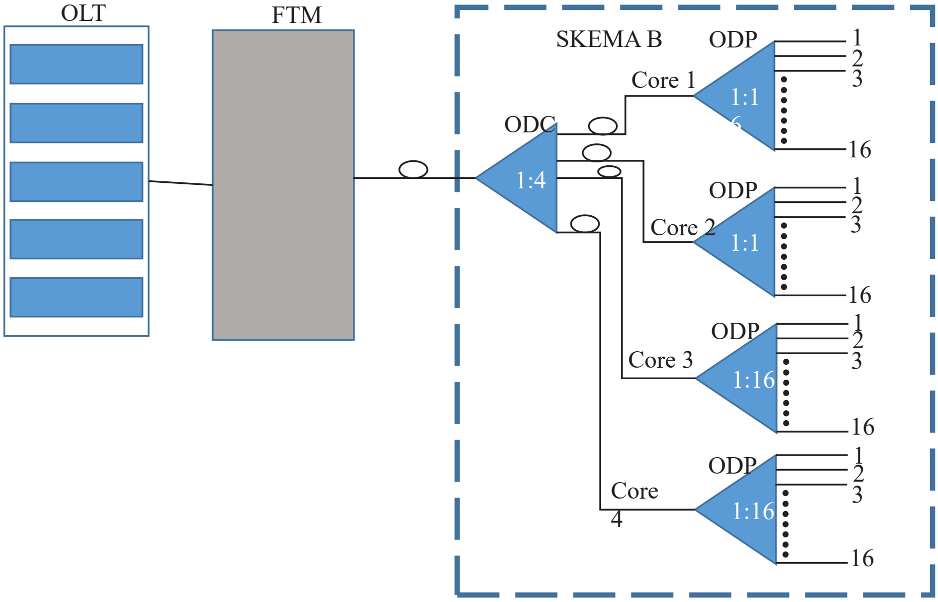

Fig. 9. Trial Configuration of Scheme B [6]

Scheme C: 1:8 splitters each of ODC and ODP are put in configuration C as shown in **Fig. 10** the calculation result of the average power transmission generated at the transmitter is 28 dBm, therefore it is intended for scattered customers.

The design data is obtained based on optisystem simulation and Link Budget calculation. Meanwhile, experimental measurement in the laboratory is carried out to validate the values.

Attenuation contributor is contributed through the Splitter, Splicing, Cable, and Adapter (Coupler) methods where each of these devices produces different attenuation.

Formula:

$$P_t = P_S - P_R = LC + SL + CL + PSL + \text{Link Loss Margin},$$

P_t – power transmitter (optical source output power); P_s – power source; P_r – power receiver (detector receive power sensitivity); LC – loss connector (loss connector); SL – splice loss; CL – cable loss; PSL – passive splitter loss; Link Loss Margin – 5 dB.

The measurement results show that schemes A, B, and C have simulation of 1:2, 1:4 and 1:8 in ODP and 1:32, 1:16 and 1:8 in ODC. Furthermore, the average transmission power generated at the dBm transmitter is in accordance with **Table 2**.

This design is simulated with optisystem software to test its feasibility, through (ONT), the ratio of the signal shape to the receiver and sender as well as the eye diagram of each receiver.

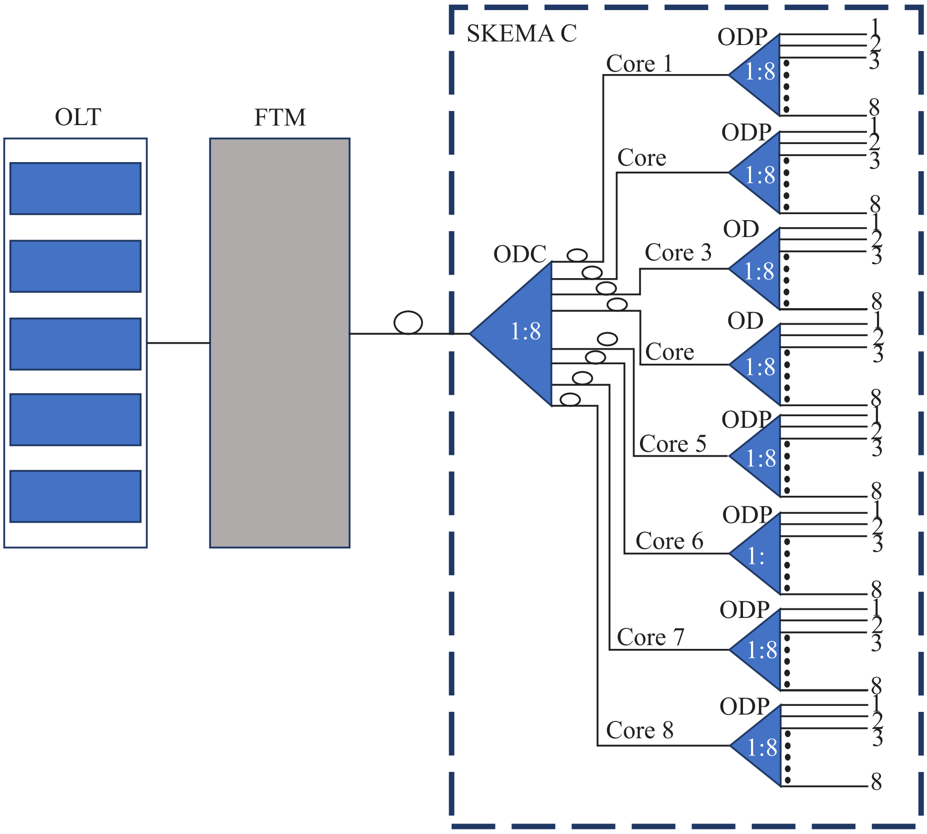

Fig. 10. Trial Configuration of Scheme C [6]

Table 2
Calculation results of Scheme A, B and C

No.	Description		Unit	Standard Attenuation (dB)	Scheme A: Splitter Schematic 1:2 & 1:32		Scheme B: Splitter Schematic 1:4 & 1:16		Scheme C: Splitter Schematic 1:8 & 1:8	
					Vol	Total Attenuation (dB)	Vol	Total Attenuation (dB)	Vol	Total Attenuation (dB)
1	Feeder Cable & Distribution Cables		Km	0.7	4	2.8	3	2.1	3	2.1
2	Splitter		Pcs	4.2	1	4.2	1	7.8	2	22.8
			Pcs	18.6	1	18.6	1	15	–	–
3	Connector	SC/UPC	Pcs	0.25	8	2	8	2	8	2
4	Splicing	Cable/Feeder: 1 Splicing/3 km	Pcs	0.1	1	0.1	1	0.1	1	0.1
5		FO cable splicing with pigtail	Pcs	0.1	5	0.5	5	0.5	5	0.5
Total attenuation + tolerance					28		28		28	

The link budget is the calculation of all the power gains and losses experienced by the communication signal in the telecommunication system from the transmitter, via a communication medium such as radio waves, cable, and optical fiber, to the receiver. This signal gives the received power from the transmitter, after attenuation the transmitted signal due to propagation, and the antenna with feedline gain and losses, passes through the process. The link budget is a design aid, calculated during the design of the communication system to determine the received power, to ensure that information is received clearly with an adequate signal-to-noise ratio. Randomly varying channel gains such as fading are calculated by adding some margin, which is dependent on the severity of the anticipated effect. The amount of margin needed can be reduced by using mitigation techniques such as antenna diversity or frequency hopping.

In this research, two types of simulations were carried out, namely using the optisystem and the manual link budget calculation simulation. The optisystem described the network design starting from the OLT or Central Office using a Tx (Optical Transmitter) at a frequency of 1310 nm and a power of 1.5 dBm with an additional attenuation of 0.25 dB. The connection is continued to the ODC using a feeder cable with a cable length of 5 km. The ODC uses a passive splitter and proceeds to ODP using distribution cable, in this distribution segment there are 2 connectors. There are 3 schemes, namely scheme A using 2 1:8 splitters both in ODC and ODP, scheme B using 1:4 splitters in ODC and 1:16 in ODP, and scheme C using 1:2 splitters in ODC and 1:32 in ODP.

The first simulation scheme is carried out in **Fig. 11**, namely the installation of passive splitters 1:2 and 1:32 split ratios in ODC and ODP. Starting from TX as an OLT incorporated in the active device, it is connected to one connector then to the bundle core, EA (Equipment Access), and connector 2. Furthermore, it is connected using a patch core to connector 3 OA (Outsite Access). Subsequently, by using feeder cable 1 (3 km), this is connected to feeder cable 2 (2 km), connector 4, and power splitter 1 1:2 (ODC). Moreover, it is reconnected to connector 5 to the distribution cable (3 km) and to passive splitter 2 1:32 (ODP). Next, it is connected to connectors 6 and 7 using a drop core and then to a rosette/connector 8. Then, it is connected to OTP/connector 9 using an indoor cable and connector 10 using a patch core. Finally, it is connected to RX as an ONT.

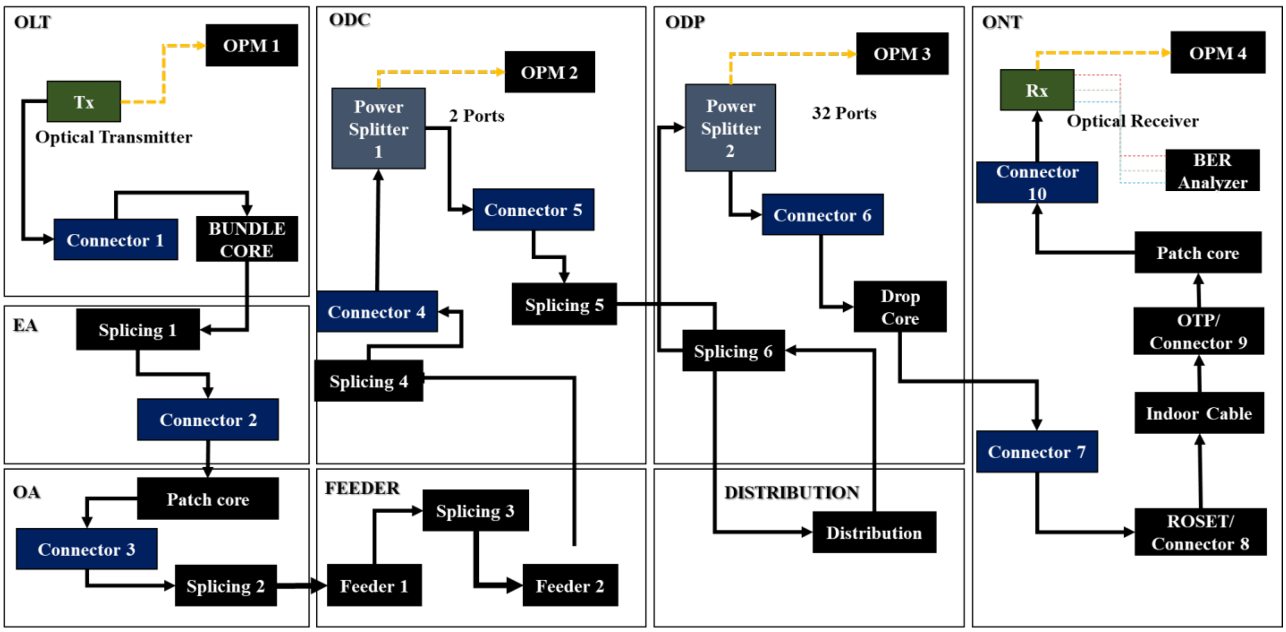

Fig. 11. Schematic A 1:2 (ODC) and 1:32 (ODP) Simulation.

The first simulation scheme is carried out in **Fig. 12** by installing passive splitters in ratios of 1:4 and 1:16 in ODC and ODP, respectively. Starting from TX as an OLT that is incorporated in the active device, it is connected to one connector, then to the bundle core, and to EA (Equipment Access). Furthermore, it is connected to connectors 2 and 3 using patch core and 3 OA (Outsite Access). Moreover, by using feeder cable 1 (3 km), it is connected to feeder cable 2 (2 km) and 4 using power splitter 1 at a ratio of 1:4 (ODC). This is reconnected to connector 5 to the distribution cable (3 km) then reconnected to passive splitter 2 at 1:16 (ODP). Subsequently, it is connected to connectors 6 and 7 using drop core as well as to rosette/connector 8. Furthermore, it is connected to OTP/connector 9 using an indoor cable and then to 10 using a patch core. Lastly it is connected to RX as ONT with a difference from schematic A, namely the splitter and the attenuation results.

The first simulation scheme is carried out in **Fig. 13**, namely the installation of a passive splitter ratio of 1:8 each in ODC and 1 ODP. This starts from TX as an OLT that is incorporated in the active device, with 1 connector used connect the bundle core and EA (Equipment Access) then to connector 2. Furthermore, it is connected using a patch core to connector 3 OA (Outsite Access). Using feeder cable 1 (3 km), it is connected to feeder cable 2 (2 km) and to connector 4 then to power splitter 1 1:8 (ODC). Moreover, it is reconnected to connector 5 and to distribution cable (3 km) then to passive splitter 2 1:8 (ODP). Subsequently, it is connected to connectors 6 and 7 using a drop core and then to a rosette/connector 8. Next, it is connected to OTP/connector 9 using an indoor cable and then to connector 10 using a patch core. Finally, it is connected to RX as an ONT. There is a difference between schematic A and B, namely the splitter and the attenuation results.

From the three schemes above, the variables that determine the results of the simulation are obtained as shown in **Table 3.**

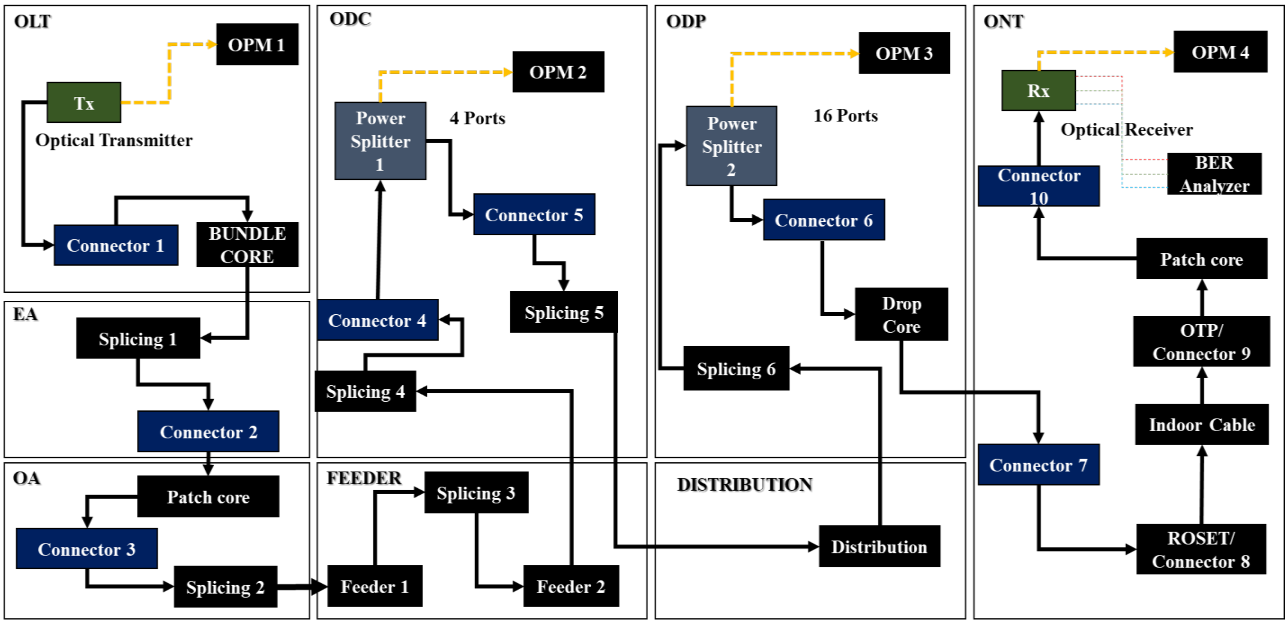

Fig. 12. Schematic B 1:4 (ODC) and 1:16 (ODP) Simulation

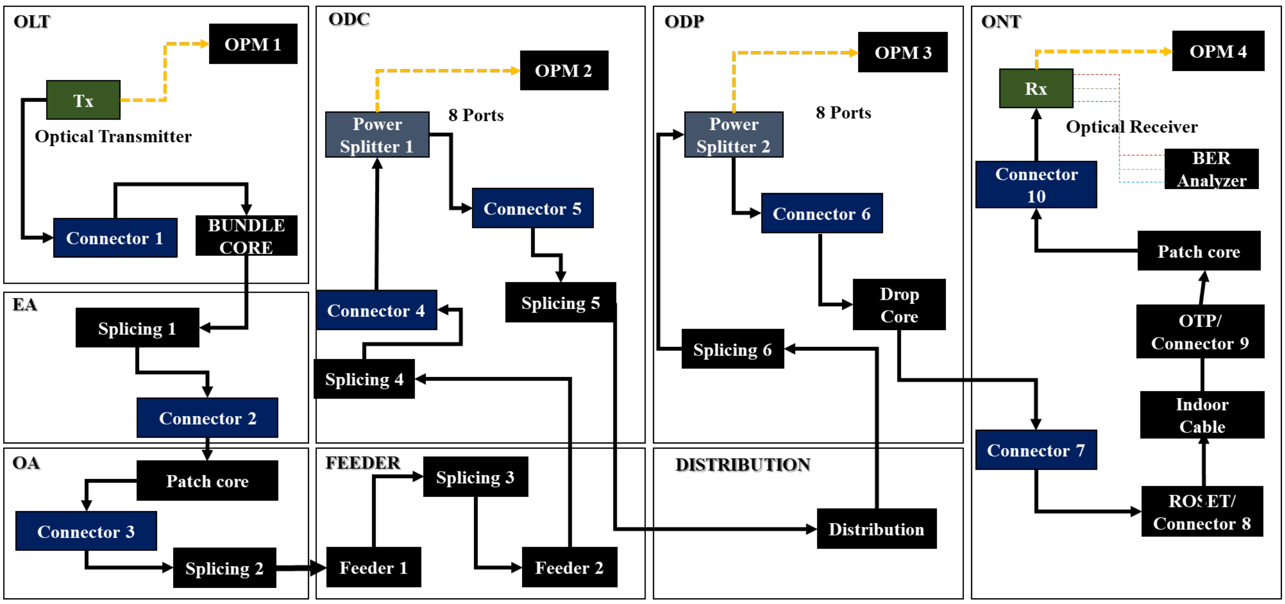

Fig. 13. Schematic C 1:8 (ODC) and 1:8 (ODP) Simulation

Table 3
Simulation Variables

Parameter	Value	Unit
Wavelengh	1490	Nanometer
Connector	0.25	dB
Passive splitter 1:2	4	dB
Passive splitter 1:4	7.25	dB
Passive splitter 1:8	10.38	dB
Passive splitter 1:16	15	dB
Passive splitter 1:32	18.6	dB
Splicing	0.1	dB
Patch core	0.35	dB/km
Distribution cable	0.35	dB/km
Feeder cable	0.35	dB/km
Indoor cable	0.35	dB/km
Roset	0.25	dB
OLT	5	dBm
ONT (Maks)	28	dBm
Bundle core	20	Meter
Drop core	0.35	dB/km

The measurement results show that in schematic A the simulation in ODP an ODC are in the ratios of 1:2 and 1:32, with an average power transmission of 28 dBm generate at the transmitter as shown in **Table 4**. Furthermore, the measurement results show that in schematic B the simulation in ODP and ODC are in the ratios of 1:4 and 1:16 with an average power of 28 dBm generated at the transmitter. Moreover, in schematic C the simulation in ODP and ODC are 1:8 respectively, with an average transmission of 28 dBm, generated at the transmitter.

Table 4
Simulation results

No.	Description		Unit	Standard Attenuation (dB)	Scheme A		Scheme B		Scheme C	
					Splitter Schematic 1:2 & 1:32		Splitter Schematic 1:4 & 1:16		Splitter Schematic 1:8 & 1:8	
					Vol	Total Attenuation (dB)	Vol	Total Attenuation (dB)	Vol	Total Attenuation (dB)
1	Feeder Cable & Distribution Cables		Km	0.7	4	2.8	3	2.1	3	2.1
2	Splitter		Pcs	4.2	1	4.2	1	7.8	2	22.8
			Pcs	18.6	1	18.6	1	15	–	–
3	Connector	SC/UPC	Pcs	0.25	8	2	8	2	8	2
4	Splicing	Cable/Feeder: 1 Splicing/3 km	Pcs	0.1	1	0.1	1	0.1	1	0.1
5		FO cable splicing with pigtail	Pcs	0.1	5	0.5	5	0.5	5	0.5
Total attenuation + tolerance					28		28		28	

Before carry out the installation work, it is necessary to prepare materials. The materials needed for installation at each segments of passive optical networks shown in **Table 5**.

Table 5
List of Material [20, 21]

Patchcord	UTP Cable	PVC Cable	Coaxial Cable
Terminal Material			
Optical Distribution Frame ODC with Splitter	ODP With Splitter	OTP	Rosette FO
Cable Material			
1. FO Duct G.652.G cable 2. FO Aerial G.652.G cable 3. FO ABC cable G.652.G	1. FO Duct G.652.G cable 2. FO Aerial G.652.G cable 3. FO ABC cable G.652.G	1. FO Duct G.652.G cable 2. FO Aerial G.652.G cable 3. FO ABC cable G.652.G	1. Drop FO Indoor G.657A
Cable Groove Material			
1. Subduct if in Duct 2. HDPE if Borring Rojok 3. Micro Duct if ABS 4. Iron I Concrete Pole for Aerial 5. PVC Pipe for Crossing 6. Galvanized Pipe for Boring / Bridges	1. HDPE if Borring Rojok 2. Micro Duct if ABS 3. Iron I Concrete Pole for Aerial	1. PVC 20 mm for SPBT 2. HH/Pit 3. Micro Duct if ABS 4. Iron I Concrete Pole for Aerial 5. Duct Cable	1. PVC 20 mm 2. Micro Duct if ABS 3. Duct Cable
Material Accessories			
1. Cable connecting tool 2. Splitter 1> 4 3. Pathcord 4. Connector 5. Pole Accessories	1 Cable extension tool 2. Splitter·1:8 3. Connector 4. Pole accessories	1. Connector 2. Cable Clamps 3. Pole strap 4. Drop Clam Hook 5. Pole Accessories	1. Connector 2. Cable Clamps

3. Results and discussion

A pilot implementation (trial) was carried out at the STO Ketintang office location, Surabaya to ensure direct field configuration. The choice of location in Surabaya is because the STO covers 3 schemes at once. **Fig. 14** shows a regional plan implementing Scheme A using a 1:8 splitter in ODC and 1:8 in ODP.

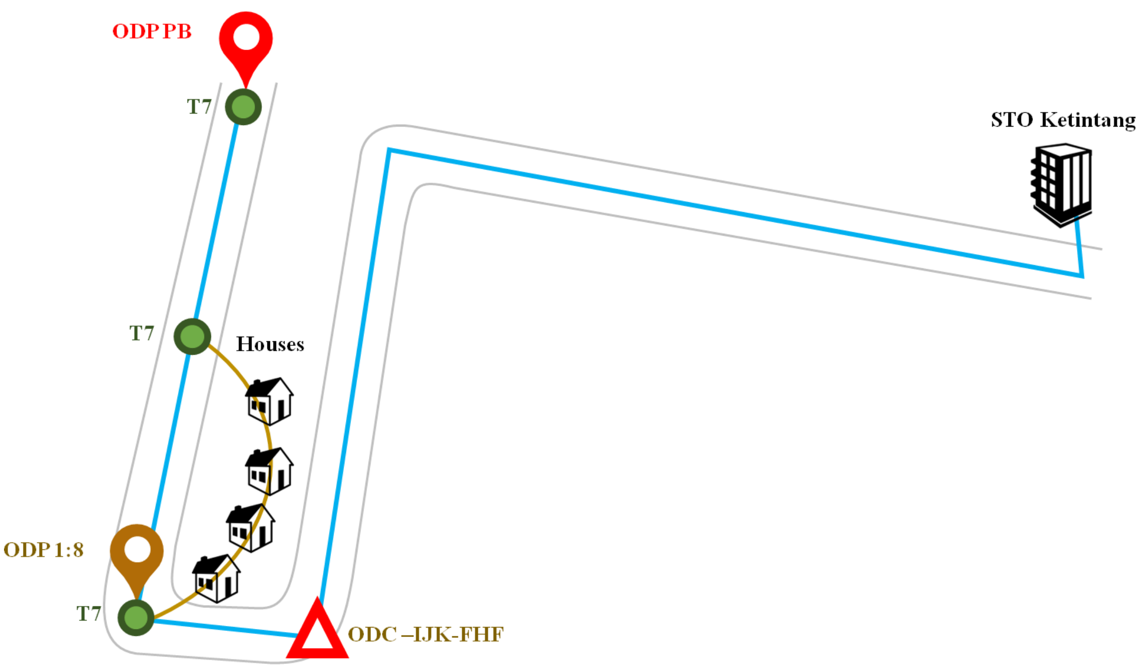

Fig. 14. Schematic A using 2 splitters 1:8 in both ODC and ODP

Fig. 15 shows a regional plan implementing Scheme B using 1:4 and 1:16 splitters in ODC and ODP.

Fig. 16 shows the implementation of Scheme C using 1:2 and 1:31 splitters on ODC and ODP, respectively on a case in an apartmen.

Fig. 17–19 show the tools and materials when taking measurements in the field.

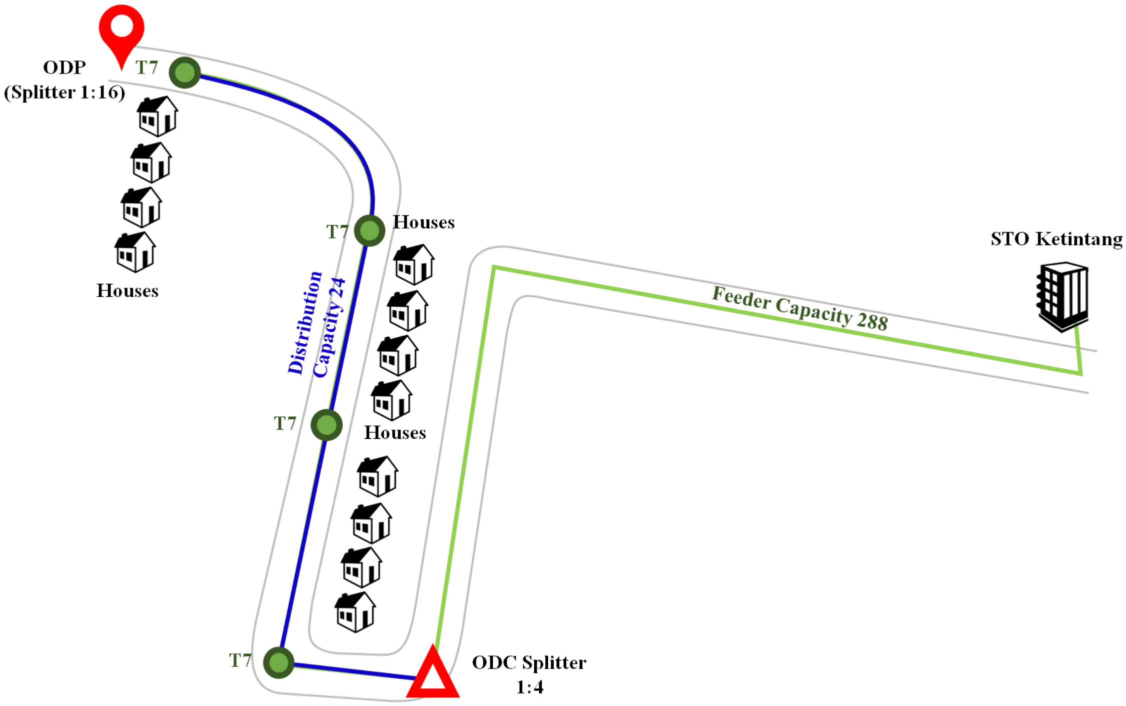

Fig. 15. Schematic B using a 1:4 splitter at ODC and 1:16 at ODP

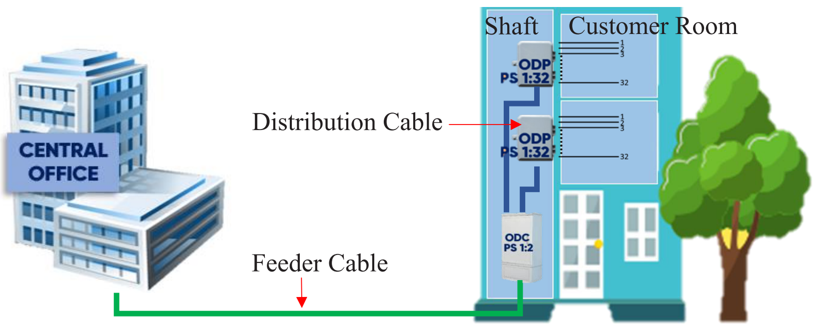

Fig. 16. Schematic C using a 1:2 splitter at ODC and 1:32 at ODP

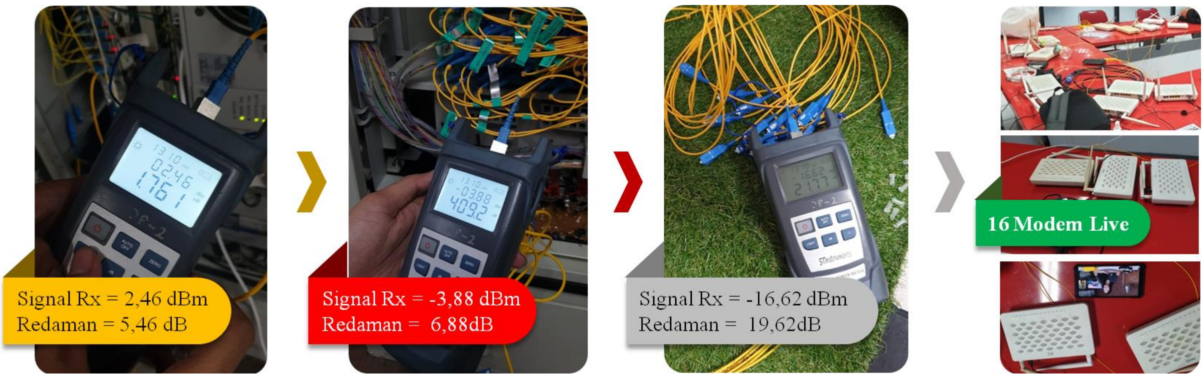

Fig. 17. Evidence of power signal and attenuation measurement

Fig. 18. Evidence of the measurement and testing process

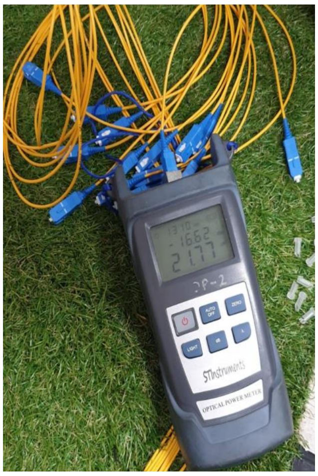

Fig. 19. Evidence of measuring power signal and attenuation at splitter 1:64

The 1:64 splitter test was carried out in the FA room by referring to the schemes A and B with ODC values of 1:8 and 1:4 and ODP of 1:8 and 1:16, respectively. Meanwhile, Scheme C was not used to carry out this test because there were no existing cases in the field.

This research conducted a series of tests from FTM, ODC, and ODP, with a Rx power signal of 2.46 dBm at OLT at an attenuation of 5.46 dB, –3.88 dBm with attenuation of 6.88 dB in ODC, and –26.62 dBm with attenuation of 27.62 dB on ODP.

The test results explained that the 1:64 splitter test in FA is an alternative that is still within the permissible attenuation tolerance limits and the bandwidth speed is still stable. Therefore, it can be concluded that the 1:64 splitter can be implemented for customers.

The limitations of this study are related to the equipment that needs to be prepared because it is related to operations. So in doing the test will have an impact on the customer directly. Thus the solution used is with a limited scope.

For future development, it can be used not only for GPON technology but also for Next GPON. While the use case can be extended not only to fixed broadband but can be implemented for 5G technology. In addition, the policy was also developed to be easy to implement.

4. Conclusions

This research optimized the GPON capacity by maximizing the available bandwidth and the maximum capability of GPON devices. To further strengthen the research on bandwidth capacity, a simulation was carried out to increase the number of customers, which obtained the following results:

1. It is possible to increase the customer capacity from 32 per PON port to 64.
2. The increase in the number of customers to 64 per PON port, is also possible in terms of bandwidth (the remaining 1,308 Mbps).
3. The use of a 1:64 splitter is also available on the link budget side with a maximum attenuation of 28 dB due to the following scenarios:
   – Scheme A with a distance of 4.2 km;
   – Scheme B with a distance of 3.4 km;
   – Scheme C with a distance of 3.2 km.
4. Three methods were used to maximize the installation in the field, namely A, B, and C. Scheme A places 1:2 and 1:32 splitters at ODC and ODP for High rise building (apartment) customers. Meanwhile, scheme B places 1:4 and 1:16 splitters on ODC and ODP for customers in the cluster area and scheme C places 1:8 splitters each on ODC and ODP for dispersed customers. In conclusion, the solution proposed in this research can be taken because it meets both the bandwidth capacity and link budget.

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