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# Link Power Budget and Traffic QoS Performance Analysis of Gigabit Passive Optical Network

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**Abstract.** Data service of telecommunication network is needed widely in the world; therefore extra wide bandwidth must be provided. For this case, PT. Telekomunikasi Tbk. applies GPON (Gigabit Passive Optical Network) as optical fibre based on telecommunication network system. GPON is a point to a multipoint technology of FTTx (Fiber to The x) that transmits information signals to the subscriber over optical fibre. In GPON trunking system, from OLT (Optical Line Terminal), the network is split to many ONT (Optical Network Terminal) of the subscribers, so it causes path loss and attenuation. In this research, the GPON performance is measured from the link power budget system and the Quality of Service (QoS) of the traffic. And the observation result shows that the link power budget system of this GPON is in good condition. The link power budget values from the mathematical calculation and direct measurement are satisfy the ITU-T G984 Class B standard, that the power level must be between -8 dBm to -27 dBm. While from the traffic performance, the observation result shows that the network resource utility of the subscribers of the observed area is not optimum. The mean of subscriber utility rate is 27.985 bps for upstream and 79.687 bps for downstream. While maximally, It should be 60.800 bps for upstream and 486.400 bps for downstream.

## 1. Introduction

Optical fiber telecommunication network system is needed and widely applied in the whole of the world because it provides the widest bandwidth and the highest access rate [1] [4]. Optical fiber is made from purified silicon, so it is not electrical conductor and it is not influenced by electrical interference.

PT. Telkom proceeds to change the access network technology from copper based network to optical fiber based network, because they can not satisfy the need of extra large bandwidth. With optical fiber, PT. Telkom develops triple play services (telephony, internet and cable TV). Even more than triple play, it also develops the services to IP camera service. Therefore, PT. Telkom changes the access network system to the new infrastructure of optical fiber network that is called as GPON (Gigabit Passive Optical Network).

GPON becomes the main choice among several architectures that can be used in FTTx today [8]. GPON and DSL access technology are applied to improve broadband internet penetration [6]. One of the excess of GPON is the passive splitter. With it, the optical fiber cable can be split into other optical fiber branches. There are three main sections of GPON: OLT (Optical Line Terminal), ODN (Optical Distribution Network) and ONT (Optical Network Terminal). OLT services interfacing to local central, multiplexing/de-multiplexing, controller and interfacing to ODN. There are some ODNs in one OLT. ODN services data transmission and distribution from OLT to ONT. The distribution



function of electrical power is applied by splitter to all branch of the network. While ONT services interfacing to ODN and to subscriber terminal [3].

The splitting of optical fiber network system, from OLT, ODN until ONT causes power losses. The power losses of the network system must be observed in order to provide reliable network service, and it is referred to Link Power Budget. Beside that, the performance of optical fiber network system is observed from the traffic QoS (Quality of Service).

The telecommunication network performance measurement is often made and published in many journal. For example, the simulation and evaluation of computer network performance based on data packet size difference [9], Farther more, forecasting for computer network performance with quadratic equation method [10]. In optical fiber network, there are many published papers about the performance evaluation. For example, the analysis of GPON performance that will be implemented in Kosovo [2], the enhancement of GPON performance [7], Farther more, the scheme of time division multiplexing over passive optical networks that is called TDM-PON as a solution in network broadband development [5]. In this research, GPON that is applied by PT. Telkom Regional Division V is observed if it provided a good services to subscribers or not. The comparison of the service standard that is used in this paper is Standard Recommendation of ITU-T G.984.

## 2. Gigabit Passive Optical Network

PON (Passive Optical Network) is point-to-multipoint optical fiber based network that is developed to replace copper based network. It has optical splitter component that has function in data transmission to several terminal. The optical splitter is passive. It doesn't manipulate optical signal. PON is made by FSAN (Full Service Access Network), then it is standardized by ITU-T (A/BPON, GPON) or IEEE (EPON) [4].

GPON is technology that is developed by ITU-T G.984. it uses optical fiber as transmission medium. It uses TDMA (Time Division Multiple Access) in upstream multiple access technique with rate 1,2 Gbps, and uses broadcast technique for downstream with rate 2,5 Gbps. Some level best of GPON are:

1. It supports triple play application (data, voice and video) of FTTx service over one optical fiber core.
2. It can divide bandwidth to 32 ONT
3. It is more simple in cable installation than point-to-point architecture
4. Bandwidth allocation can be managed
5. It has flexibility in information transmission with different bit rate

While some shortage of GPON are :

1. Complexity in layering model
2. Very expensive

## 3. Methodology

Measuring performance is one of the main elements in design, operation and management of the network. Some metrics that is usually used in measuring the network performance are delay, jitter, throughput, blocking probability. There are 3 methods in measuring the network performance [11],

1. Direct measuring (collecting data observation of the existing system). Some advantageous of direct measuring are accurate, precise, detail. But it depends on the tools and needs a lot of time.
2. Simulation (observing over the computer model of the system). Some advantageous of simulation are wider in the problem coverage, time scale management, and independency to existing system. But it has problems especially in sensitivity of the tools, so it needs validation step to the output data.
3. Analysis (making description of the system analytically). Some advantageous of pure analysis are saving the time, and the problem coverage that is wider than direct measuring and simulation. But the result is just approximation conclusion.

The performance of GPON here is observed over link power budget and QoS of the traffic. In the link power budget, the power values are obtained by 2 ways, direct measuring and calculation. The power values from both of direct measuring and calculation are compared. The next step is calculating the MSE (Mean Square Error) and Se (Standard Deviation of Error). Then, the power level quality is compared to standard recommendation of ITU-T G.984 that is enclosed in table 1 and table 2.

The power level calculation follows,

$$P_l = P_i - L_t \quad (1)$$

with,  $P_l$  = Power level  
 $P_i$  = Initial power  
 $L_t$  = Total loss

The calculation of MSE follows,

$$MSE = \left[ \frac{\sum_{i=1}^n e_i^2}{n-2} \right] \quad (2)$$

While the calculation of  $S_e$  is,

$$S_e = \sqrt{MSE} \quad (3)$$

**Table 1.** Link power budget standard system applied in PT. Telkom regional division V

| No                                                             | Parameter                  | Unit | Attenuation<br>Standard (dB) | volume | Total<br>Attenuation (dB) |
|----------------------------------------------------------------|----------------------------|------|------------------------------|--------|---------------------------|
| 1                                                              | Optical fiber cable length | Km   | ≤0,35                        | 17     | 5,96                      |
| 2                                                              | splitter                   |      |                              |        |                           |
|                                                                | 1:2                        | unit | ≤3,70                        |        |                           |
|                                                                | 1:4                        | unit | ≤7,25                        | 1      | 7,25                      |
|                                                                | 1:8                        | unit | ≤10,38                       | 1      | 10,38                     |
|                                                                | 1:16                       | unit | ≤14,10                       |        |                           |
|                                                                | 1:32                       | unit | ≤17,45                       |        |                           |
| 3                                                              | Connector                  |      |                              |        |                           |
|                                                                | SC/UPC                     | unit | ≤0,25                        | 14     | 3,5                       |
|                                                                | SC APC/UPC                 | unit | ≤0,35                        | 2      |                           |
| 4                                                              | Adapter                    |      |                              |        |                           |
|                                                                | SC/PC single mode(blue)    | unit | ≤0,20                        | 7      | 1,4                       |
| 5                                                              | Connection                 |      |                              |        |                           |
|                                                                | in feeder cable            | unit | ≤0,10                        | 5      | 0,5                       |
|                                                                | In distribution cable      | unit | ≤0,10                        | 2      | 0,2                       |
| Maximum total attenuation on theory                            |                            |      |                              |        | 29,19                     |
| Maximum total attenuation of link power budget of GPON class B |                            |      |                              |        | 28                        |

**Table 2.** OLT Transceiver and ONT receiver recommendation of ITU-T G984

| OLT Recommended Operating Conditions  |      |     |      |      |
|---------------------------------------|------|-----|------|------|
| Parameter                             | Min  | Typ | Max  | Unit |
| Storage Temperature                   | -40  |     | 85   | °C   |
| Operating Case Temperature            | 0    |     | 70   | °C   |
| Relative Humidity                     | -40  |     | 85   | °C   |
|                                       | 5    |     | 95   | %    |
| Power Supply Voltage                  | 3.15 | 3.3 | 3.45 | V    |
| Power Supply Current                  |      |     | 500  | mA   |
| OLT Transmitter Optical Specification |      |     |      |      |

|                                            |      |      |         |
|--------------------------------------------|------|------|---------|
| Average Output Power                       | 1.5  | 5    | dBm     |
| Centre Wavelength                          | 1480 | 1490 | 1500 nm |
| Spectral Width                             |      | 1    | nm      |
| <b>ONT Receiver Optical Specifications</b> |      |      |         |
| Receiver sensitivity                       |      | -27  | dBm     |
| Receiver Overload                          | -8   |      | dBm     |
| Wavelength of Operation                    | 1260 | 1310 | 1360 nm |

The second step of observing the GPON performance is calculating the traffic QoS. The parameter that is used to measure the QoS in this paper is utility rate (bps). The utility rate  $r_u$  defines a number of bits proceeded (bits utility)  $b$  during the observation time  $t_o$ .

$$r_u = \frac{b}{t_o} \quad (4)$$

The raw data of bits utility is obtained from I-Booster of PT. Telkom. It contains upstream and downstream utility bit and observation time. Furthermore, the value of utility rate is compared to the maximum bit rate recommended by ITU-T G.984 (1,2 Gbps for upstream and 2,4 Gbps for downstream). The data is obtained in Semolowaru Elok, Manyar, Surabaya.

#### 4. Results and Discussion

From the previous explanation, the GPON performance in this research is evaluated from two schemes, the link power budget and the traffic QoS. The results of link power budget observation are shown in table 3.

The error standard deviation of power level on ODC  $S_{e.pl.ODC}$  is low (0,665 dBm). It means that the power level value of the calculation  $P_{L.ODC}$  and power level value of measurement  $P'_{L.ODC}$  have almost same value. So do the error standard deviation of the attenuation loss on ODC  $S_{e.l.ODC}$  (1,555 dBm). It means that the attenuation loss value of the calculation  $L_{ODC}$  and the attenuation loss value of measurement  $L'_{ODC}$  have almost same value too.

**Table 3.** The link power budget

| <b>Link power budget on OLT</b>     |                |             |
|-------------------------------------|----------------|-------------|
| Initial power of OLT                | $P_i$          | 5 dBm       |
| Power level of OLT                  | $P_{L.OLT}$    | 5 dBm       |
| <b>Link power budget on ODC</b>     |                |             |
| Power level of the calculation      | $P_{L.ODC}$    | -5,235 dBm  |
| Power level of the measurement      | $P'_{L.ODC}$   | -4,767 dBm  |
| MSE of the power level              | $MSE_{pl.ODC}$ | 0,442 dBm   |
| $S_e$ of the power level            | $S_{e.pl.ODC}$ | 0,665 dBm   |
| Attenuation loss of the calculation | $L_{ODC}$      | 9,135 dBm   |
| Attenuation loss of the measurement | $L'_{ODC}$     | 8,038 dBm   |
| MSE of the                          | $MSE_{l.ODC}$  | 2,418 dBm   |
| Attenuation loss                    |                |             |
| $S_e$ of the Attenuation Loss       | $S_{e.l.ODC}$  | 1,555 dBm   |
| <b>Link power budget on ODP</b>     |                |             |
| Power level of the calculation      | $P_{L.ODP}$    | -16,188 dBm |

|                                                      |                |                |
|------------------------------------------------------|----------------|----------------|
| Power level of the measurement                       | $P'_{L.ODP}$   | -5,238 dBm     |
| MSE of the power level                               | $MSE_{pl.ODP}$ | 42,798 dBm     |
| $S_e$ of the power level                             | $S_{e.pl.ODP}$ | 6,547 dBm      |
| Attenuation loss of the calculation                  | $L_{ODP}$      | 11,358 dBm     |
| Attenuation loss of the measurement                  | $L'_{ODP}$     | 8,929 dBm      |
| MSE of the                                           | $MSE_{L.ODP}$  | 6,167 dBm      |
| Attenuation loss                                     |                |                |
| $S_e$ of the                                         | $S_{e.L.ODP}$  | 2,483 dBm      |
| Attenuation loss                                     |                |                |
| Power level on ODP output recommended by ITU-T G.984 |                | $\leq -28$ dBm |

The error standard deviation of power level on ODP  $S_{e.pl.ODP}$  (6,547 dBm) is higher than  $S_{e.pl.ODC}$ . The power level value of the calculation  $P_{L.ODP}$  and power level value of measurement  $P'_{L.ODP}$  have different value relatively. It means that the accuracy level of the power level of the calculation value and the measurement value are worse than the value in ODC. So do the error standard deviation of the attenuation loss on ODP  $S_{e.L.ODP}$  (2,483 dBm). It is higher than the value in ODC. It means that the accuracy level of the attenuation loss of the calculation value and the measurement value are worse than the value in ODC. This condition can be analyzed,

1. The values of calculation involves maximum values. So, it causes the error standard deviation value is higher than the measurement value.
2. The quantity of splitting points from OLT to ODP is greater than from OLT to ODC. So, it causes the error standard deviations of ODP ( $S_{e.L.ODP}$  and  $S_{e.pl.ODP}$ ) are greater than the error standard deviations of ODC ( $S_{e.L.ODC}$  and  $S_{e.pl.ODC}$ ).

The GPON performance from link power budget is good, because the ODP power level value of calculation ( $P_{L.ODP} = -16,188$  dBm) and measurement ( $P'_{L.ODP} = -5,238$  dBm) are better than the value of ITU-T G.984 standard recommendation ( $\leq -28$  dBm).

The second evaluation of GPON performance in this paper is about traffic QoS. The result of measurement and calculation of that can be analyzed as follow,

1. The mean of upstream utility rate of each subscriber is 27.985 bps. Whereas the maximum mean of upstream utility rate of that should be 60.800 bps. It means that the upstream network utilization of each subscriber is only 46%.
2. The mean of downstream utility rate of each subscriber is 79,687 bps. Whereas the maximum mean of downstream utility rate of that should be 486.400 bps. It means that the downstream network utilization of each subscriber is only 16%.
3. The mean total of upstream utility rate of all subscriber in one line ONT is 1.119.405 bps. It means that the mean total of upstream utility rate of all subscriber in one line OLT is for about 5 Mbps. Whereas the maximum upstream utility rate of one OLT according to ITU-T G.984 standard recommendation should be 1,2 Gbps. This data shows that the utility of the network resource is too low and it should be developed.
4. While, the mean total of downstream utility rate of all subscriber in one line ONT is 3.185.462 bps. It means that the mean total of downstream utility rate of all subscriber in one line OLT is for about 13 Mbps. Whereas the maximum downstream utility rate of it according to ITU-T G.984 standard recommendation should be 2,4 Gbps. It means lack of subscriber and utilization.

## 5. Conclusion

Some conclusions of the research are :

1. The error or the difference between calculation value and measurement value of the power level and the attenuation loss in ODP is greater than in ODC, because of the number of splitting points in ODP is also greater than in ODC, beside the effect of the maximum values that is used in calculation.
2. The GPON performance from link power budget is good, because the ODP power level value of calculation ( $P_{L,ODP} = -16,188$  dBm) and measurement ( $P'_{L,ODP} = -5,238$  dBm) are better than the value of ITU-T G.984 standard recommendation ( $\leq -28$  dBm).
3. The number of subscriber in OLT for the case of this research is too small, and the network utilization is also too low. So the recommendation for PT. Telkom Regional Division V is to increase the subscriber quantity especially in Semolowaru Elok, Manyar of Surabaya.

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