Optical Fiber Network Design in East Nusa Tenggara Based on Palapa Ring Project

Yohanes Galih A.[1], Fetty Amelia[2], Dody Herdianto R.[3], B. Pratiknyo Adi Mahatmanto[4], Catur Apriono[5]
Department of Electrical Engineering
Universitas Indonesia
Depok, West Java, Indonesia
[1]y.galih@ui.ac.id, [2]fetty.amelia@ui.ac.id, [3]dody.herdianto@ui.ac.id, [4]b.pratiknyo@ui.ac.id, [5]catur@eng.ui.ac.id

***Abstract*—Bandwidth capacity and high data rates improvement in Eastern Indonesia become an important aspects in empowering communities that is aimed to facilitating access to information in various sectors. The East Palapa Ring Package project was launched by the Ministry of Communication and Information to meet these needs. The design of optical fiber networks in East Nusa Tenggara Province was carried out in this study to support that project. This province is one of the area that has a high data rates needs especially for the security and tourism sector, because its territory is directly adjacent to other countries and has a high potential of tourism there. A total of 22 routes connecting districts / cities in East Nusa Tenggara were proposed by using Power Link Budget and Rise Time Analysis. From the results, it is known that the Power Loss and Dispersion Time in the proposed network do not exceed the permitted limits, which are 53 dBm and 233.33 ps respectively. Therefore, the proposed optical fiber network is in accordance with the expected and feasible targets to be carried out.**

Keywords—optical fiber network; palapa ring project; link budget analysis; rise time analysis

I. Introduction

The availability of internet access that has not been evenly distributed in several regions in Indonesia is the basis for the government in this case the Ministry of Communication and Informatics to organize the Palapa Ring Project. This project is carried out by connecting broadband internet access via optical fiber network [1]. In addition, Palapa Ring was built to increase the capacity, speed and quality of existing networks along with increasingly rapid technological developments [2]. The project is divided into three packages, namely, the Western, Central, and Eastern regions as shown in Fig 1. The target of the Palapa Ring Project development is in every City and Regency in Indonesia has a data rate speed of 10 Mbps and 20 Mbps in rural areas and urban areas, respectively [3].

The capacity and speed of this data rate is very much needed to support various telecommunications interests in border areas such as ease of internet access for the education sector, economy, defense security, and for the advancement of tourism. As in [4] it is explained that broadband access is needed in areas directly adjacent to other countries such as Indonesia-Papua New Guinea and Indonesia-Timor Leste. This is also in line with other government programs that proclaim the existence of 'information villages' in regions for equitable information with the development of information and communication technology infrastructure and community empowerment in terms of tourism [5]. These reasons are the basis for the selection of the East Nusa Tenggara Province as the design target area for deploying optical fiber networks in the East Package Palapa Ring Project.

Fig. 1. Palapa Ring Project Deployment Map [6].

The design of the previous optical fiber network was also carried out by [7] which connected 29 districts in the North Sumatra area. Analysis of Power Link Budget and Rise Time conducted by Yudiansyah et al. to determine the requirements of optical components so that the specifications of the components used are in accordance with the targets to be achieved. Based on the two analyzes, it was found that the proposed network did not exceed the maximum allowable limit of 32 dB and the maximum dispersion time was 350 ps. In addition, the design of optical fiber networks with DWDM technology was conducted by Fitri in [8] from Makassar to Maumere via underwater route. From the simulation results using OptiSystem, the largest BER value is 5.892 x 10^{-11} which is smaller than the ideal BER standard of 10^{-9}.

The common problem in designing fiber optic networks is the difficult condition of the targeted area because of the routes can through over the mountains, hills, valleys, or the sea. Various studies such as in [9] reported that optical fibers with low loss characteristics capable of reaching long distances have been successfully designed, fabricated and characterized. Yongmin uses a few-mode ring-core fiber type which has ~ 0.3 dB / km loss characteristics and can reach a distance of 25.3 km without repeater.

Another way to minimize the loss arising from the long distance between two nodes can also be used the Raman amplification method. Ibrahim shows that this method utilizes the bidirectional pumped system on the transmitter and receiver to be able to reach a distance up to 400 km without repeaters [10]. In line with that, Mina successfully characterize and demonstrate bidirectional pumped Raman amplification and 1050 km combined wavelength-division and spatial-division multiplexed in the same transmission fiber with a zero-net-gain fiber span [11].

Referring to the Palapa Ring Project map, it is known that for the East Package only one city and four districts in the East

Nusa Tenggara province are connected with optical fiber networks, even though there are a total of 22 Regencies and Cities in the province. As in our previous paper, we also conducted a power link and rise time analysis for 16 routes in East Nusa Tenggara [12]. Therefore, in this paper we proposed the more details of 22 routes that connected via in-land and submarine cable.

II. SYSTEM DESIGN

The design of optical fiber networks generally starts from determining the target to be achieved, for example bandwidth and data rates. Next step is the calculation of how far the optical fiber will be installed, and then determining the components to be used in the network until the specifications of each component are obtained. In this paper there are several component specifications that we obtain directly from the PIC of Eastern Package of Palapa Ring Project that we contacted via Telegram. These components include the types of optical fiber cables and transceiver modules used.

A. Technical Specification

In optical fiber backbone network design, several parameters are needed to determine the QoS (Quality of Service) that will be achieved from that network. This parameter refers to the product specifications to be used, such as the type of transceiver, optical fiber cable, and an amplifier. Based on the interviews with PIC Project East Palapa Ring Package, we obtained several specifications of components used in the project such as the type of optical fiber cable and transceiver module used. Details of the parameters of the optical fiber cable and the type of transceiver are shown in Table I.

TABLE I. GENERAL PARAMETERS OF OPTICAL COMMUNICATION SYSTEM

Parameter	*Value*	*Unit*
Data Rate	2.7	Gbps
BER	10^{-12}	-
Signal Encoding	NRZ	-
Wavelength	1550	Nm
System Margin	4	dB
Optical Fiber Cable (ITU-T G.654.B) [13]		
Attenuation (α_f)	0.175	dB/Km
Chromatic Dispersion (D)	3	ps/nm.Km
Huawei Optix OSN 8800 [14] - TN55TTX [15]		
Transmit Power	4	dBm
Receiver Sensitivity	-24	dBm
Transceiver Rise Time	28	ps
Spectral Width (σ_λ)	0.3	nm
Maximum Acceptable Loss	28	dB
Additional Loss		
Connector Attenuation	2	dB/connector
Splice Attenuation	0.2	dB/splice

In this paper we use an optical cable which complied to ITU-T G.654.B standard that has an advantage in distance that can be reached up to 100 km without repeaters. This cable also has a low loss characteristic which is equal to 0.175 dB/km. This part was very important because in this design the distance between districts is far, so that the loss of the cable must be as small as possible. In addition, from the transceiver side there is also a need of large transmit power with low receiver sensitivity. These characteristics is a reason for choosing TN55TTX Transceiver products in the design of optical fiber backbone networks.

B. Proposed Optical Network Design

The East Nusa Tenggara province consists of 1 city and 21 regencies spread over seven different islands. The location between the regencies separated by the sea certainly requires special handling in deploying optical fiber networks. Therefore, in this design two types of optical fiber networks are distinguished, namely in-land network and submarine network.

Table II shows the routes that connect the district along with the distance from each other. The additional assumption of cable length used by 5% that is calculated from the distance between districts. The asterisk on the distance column states that the routes along through the sea. Fig. 2 shows the distribution of districts in East Nusa Tenggara Province and the proposed optical fiber networks both in-land and submarine networks. The blue and orange colours show the in-land paths and submarine paths, respectively. For the deployment of optical fiber over submarine networks there are additional fiber lines that connect the districts to the submarine ports in the seafront, such as in Belu, Alor and Lembata.

TABLE II. OPTICAL FIBER NEEDS IN EAST NUSA TENGGARA

Route	*District / city*	*Distance (km)*	*Optical Fiber Length (km)*
1	Kota Kupang – Kab. Kupang	49.6	52.08
2	Kab. Kupang - Kab. TTS	98.6	103.53
3	Kab. TTS - Kab. TTU	73.6	77.28
4	Kab. TTU - Kab. Malaka	63.5	66.68
5	Kab. Malaka - Kab. Belu	58.4	61.32
6	Kab. Belu - Kab. Alor	116.3 67*	192.47
7	Kab. Alor - Kab. Lembata	97.6 93.2*	200.34
8	Kab. Lembata - Kab. Flores Timur	47.1 56.2*	108.47
9	Kab. Flores Timur - Kab. Sikka	163.4	171.57
10	Kab. Sikka - Kab. Ende	140	147.00
11	Kab. Ende - Kab. Nagekeo	108	113.40
12	Kab. Nagekeo - Kab. Ngada	88.1	92.51
13	Kab. Ngada - Kab. Manggarai Timur	150	157.50
14	Kab. Manggarai Timur - Kab. Manggarai	67.6	70.98
15	Kab. Manggarai - Kab. Manggarai Barat	65.3	68.57
16	Kab. Manggarai Barat - Kab. Sumba Tengah	130.8 69.3*	210.11
17	Kab. Sumba Tengah - Kab. Sumba Barat	53.3	55.97
18	Kab. Sumba Barat - Kab. Sumba Barat Daya	41.7	43.79
19	Kab. Sumba Tengah - Kab. Sumba Timur	126	132.30
20	Kab. Sumba Timur - Kab. Sabu Raijua	92.1 142*	245.81
21	Kab. Sabu Raijua - Kab. Rote Ndao	54.4 117*	179.97
22	Kab. Rote Ndao - Kota Kupang	83.4*	87.57

Fig. 2. Proposed Optical Fiber Routes Development Design

C. Power Link Budget

Power Link Budget analysis is used to determine whether the power transmitted along with information from the transmitter can be received by the receiver or not after going through a medium of optical cable over a certain distance. Eq. 1 and 2 are used to obtain the Total Loss value of the network which will be compared with the maximum allowable loss in the system. The source of power loss can come from cable attenuation ($\alpha_f L$), connector loss (L_c), loss splices (L_s), and system margin (4 dB assumption) [1].

$$P_T = P_S - P_R \quad (1)$$

$$P_T = \alpha_f L + L_c + L_s + System\ Margin \quad (2)$$

Table III shows the calculation results of link power budget analysis in each proposed route. In this proposed system, the maximum allowable loss value of 28 dB is used where this value can be exceeded on a route that has distance of more than 106.5 km. Therefore, based on Table III, an amplifier device is needed on routes that exceed the value, namely routes number 6, 7, 8, 9, 10, 11, 13, 16, 19, 20, and 21. From these eleventh routes there were two routes through the sea lanes that require an amplifier that is on route 20 and 21, while others through in-land routes.

TABLE III. POWER LINK BUDGET PARAMETER CALCULATION RESULTS

Route	$\alpha_f L$ (dB)	Loss Splices L_s (dB)	P_T (dB)
1	9.11	0.4	17.51
2	18.11	0.8	26.92
3	13.52	0.6	22.12
4	11.66	0.4	20.07
5	10.73	0.4	19.13
6	21.37	1.0	51.28
	12.31*	0.6	
7	17.93	0.8	52.66
	17.12*	0.8	
8	8.65	0.4	35.78
	10.32*	0.4	
9	30.02	1.4	39.42
10	25.72	1.2	34.93
11	19.84	0.8	28.65
12	16.18	0.6	24.79
13	27.56	1.2	36.76
14	12.42	0.4	20.82
15	11.99	0.4	20.40
16	24.03	1.0	54.37
	12.73*	0.6	
17	9.79	0.4	18.19
18	7.66	0.2	15.86
19	23.15	1.0	32.15
20	16.92	0.8	61.02
	26.09*	1.2	
21	9.99	0.4	48.89
	21.49*	1.0	
22	15.32*	0.6	23.92

D. Rise Time Analysis

Rise Time analysis is used to determine the total time needed by the system from the initial condition to reach a steady state. Equation 3 is a formula to calculate the total rise time (T_{sys}) which is the sum of the rise time of the transmitter (T_{tx}), the rise time of the receiver (T_{rx}) and rise time of the velocity dispersion group T_{GVD}. While the value of T_{GVD} can be obtained using Eq. 4 that is the result of multiplication of the dispersion time of the cable (D), fiber length (L), and spectral width of the transceiver (σ_λ). The value obtained must also be smaller than the allowable maximum dispersion ($t_{max\,sys}$) value of 233.33 ps. Because of this paper uses the NRZ modulation scheme, the calculation of allowable maximum dispersion was obtained by considering data rate (D_r) as shown in Eq. 5.

$$t_{sys} = \sqrt{(t_{tx}{}^2 + t_{GVD}{}^2 + t_{rx}{}^2)} \quad (3)$$

$$t_{GVD} = D.L.\sigma_\lambda \quad (4)$$

$$t_{max\,sys} = 70\% \times \frac{1}{D_r} \quad (5)$$

The calculation results as shown in Table IV state that the product specifications proposed in this paper can be implemented. This can be seen that the value do not exceed the allowed rise time limit.

TABLE IV. RISE TIME CALCULATION RESULTS

Route	*Total Fiber Length (Km)*	T_{GVD} *(ps)*	T_{SYS} *(ps)*
1	52.08	46.87	102.87
2	103.53	93.18	149.18
3	77.28	69.55	125.55
4	66.68	60.01	116.01
5	61.32	55.19	111.19
6	192.47	109.90	165.90
		63.32	119.32
7	200.34	92.23	148.23
		88.07	144.07
8	108.47	44.51	100.51
		53.11	109.11
9	171.57	154.41	210.41
10	147.00	132.30	188.30
11	113.40	102.06	158.06
12	92.51	83.25	139.25
13	157.50	141.75	197.75
14	70.98	63.88	119.88
15	68.57	61.71	117.71
16	210.11	123.61	179.61
		65.49	121.49
17	55.97	50.37	106.37
18	43.79	39.41	95.41
19	132.30	119.07	175.07
20	245.81	87.03	143.03
		134.19	190.19
21	179.97	51.41	107.41
		110.57	166.57
22	87.57	78.81	134.81

III. ANALYSIS

Based on the Link Power Budget analysis, additional amplifiers are needed in eleven proposed routes so that the transmitted information can reach the receiver with good quality. From Table III the highest total loss of 61.02 dB occurred on route number 20 with a total distance of 245.81 km (92.1 km of in-land routes and 142 km of under-sea routes). Therefore, an amplifier with transmit power of at least 38 dBm is needed so that the maximum allowable loss increases to 62 dB. It makes the total loss in the eleven routes does not exceed the maximum allowable loss.

The specifications of amplifiers that meet these criteria is shown in Table V. Also keep in mind that if we add an amplifier, there will be additional use of connectors on the network so that the total loss will also increase. And for this reason, we have not considered in this paper, so that the product specifications that are already mentioned only limited to the most likely recommendations to be implemented in real environment. One thing for sure is, the optical fiber network that we designed in this paper can provide a comparison of how reliable the Palapa Ring Project being built in East Nusa Tenggara, with the results of theoretical calculations based on Power Link Budget and Rise Time Analysis.

TABLE V. CONSIDERED PARAMETER OF OPTICAL AMPLIFIER

ANVIMUR EYDFA 32X19 [16]	
Optical Input Power (dBm)	-8 ~ +10
Typical Output Power (dBm)	31 ~ 40
Wavelength (nm)	1530 ~ 1565

For information, the entire specification of the products described in this paper has been referred in accordance with the conditions at the Palapa Ring Eastern Package project site. The difference is only in the amplifier because according to the statement from the project's PIC, Palapa Ring Eastern Package Project is not using an amplifier at all. This may happen if the assumptions taken as a margin system, connector loss, or splicer value is not of value assumptions as proposed in this paper. This assumption will determine how the QoS standards to be achieved, whether at the high, medium, or low level. The greater the assumption of estimated loss used, the QoS standard will be even higher and if the assumption of estimated loss taken is small then the QoS will be low too.

IV. CONCLUSION

In this paper, the design of optical fiber backbone network in East Nusa Tenggara was proposed. Based on the analysis (Power Link Budget and Rise Time), the proposed design can be implemented corresponding to the specifications and expected targets. The maximum loss of 61.02 dB occurred in routes number 20 while a minimum loss of 15.86 dB occurred in routes number 18. Eleven routes with details of nine in-land routes and two under-sea routes require amplifiers because the total power loss exceeds the maximum allowable loss. After adding the amplifier, the maximum allowable loss increases to 62 dB so that all the proposed routes meet the target conditions. Based on the rise time analysis, the results show that no proposed routes exceed the maximum allowable dispersion of 233.33 ps. It is proved that the proposed optical fiber backbone network design can be implemented.

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