Optical Fiber Backbone Network Development Design in East Nusa Tenggara

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***Abstract*—To achieve the Indonesian government's target to provide high-speed Internet networks in all of Indonesia's provinces, the Ministry of Communication and Information Technology carried out the Palapa Ring program, which was divided into three packages. One of the three packages, the Eastern Package, is implemented in East Nusa Tenggara, an area whose implementation still lags behind. Therefore, this paper proposes an optical fiber backbone network in East Nusa Tenggara. This paper is an extended work of the existing East Palapa Ring backbone network. Sixteen land and underwater routes are proposed in this paper. Power link budget and rise-time analyses are performed to determine whether the proposed optical fiber network design can be implemented, and findings show that the proposed network does not exceed the power link and dispersion limitation of 53 dBm and 259.26 ps, respectively. Therefore, the proposed design of the optical fiber networks in East Nusa Tenggara meets requirements.**

***Keywords*—optical fiber; palapa ring; power link budget; rise-time budget**

I. INTRODUCTION

The rapid development of technology has resulted in an increase in data rate. To serve different services with various bandwidths, a transmission system with a good capacity and quality is needed [1]. Accordingly, the Indonesian Ministry of Communication and Information has declared "Broadband/4G dan Efisiensi industri" as one of the priority programs of the Ministry of Communication and Informatics Strategic Plan for 2014–2019. The aim of this program is to improve the quality of communication and information services to support the national development focus of the Indonesian government. The Strategic Plan mandates all the districts and cities in Indonesia to have a broadband telecommunication network with speeds reaching 10 Mbps in rural areas and 20 Mbps in urban areas [2]. To achieve such goals, the Indonesian Ministry of Communication and Information constructed the national Palapa Ring optical fiber backbone network [3].

The national Palapa Ring optical fiber backbone network connects all district capitals in Indonesia through a broadband network. The project is divided into three packages: the Western Package, the Middle Package, and the Eastern Package. A map of the Palapa Ring project deployment is shown in Fig. 1 [4]. Several works on the development of the Palapa Ring network have been conducted in [5], [6],[7], and [8].

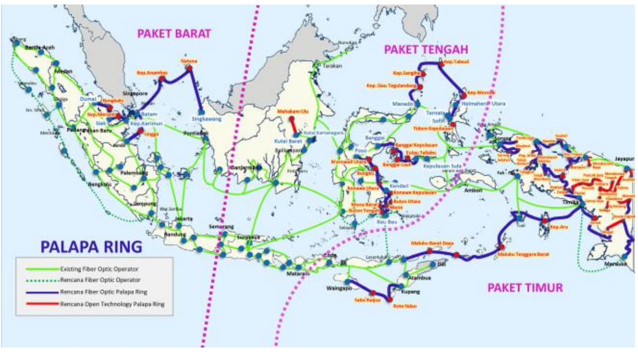

Fig. 1. *Palapa Ring Project Deployment Map [4].*

Given that Indonesia is one of the few archipelagic countries in the world, the construction of its ICT infrastructure, especially in the outskirts, is always an interesting and strategic issue that must be addressed because the national border in the outermost region that deals directly with neighbouring countries often faces issues related to security, disintegration, and nationalism. A survey was conducted on broadband Internet access in the province of East Nusa Tenggara, which is the border between Indonesia and Timor Leste [9]. The results indicate the need to achieve Internet access availability following the needs and conditions of the local community. Another work focused on the development of ICT in the outskirts of the country by the Indonesian Ministry of Communication and Information [10].

The deployment map draft of the Eastern Package Palapa Ring project shows that not all the districts/cities in East Nusa Tenggara are included in the draft deployment map. Therefore, the focus of this research is mainly the design of the development of the Palapa Ring optical fiber backbone network in East Nusa Tenggara, which is not yet connected to the current Palapa Ring network.

This paper is organized as follows: Section I discusses the research background. Section II discusses the design of optical fiber networks in East Nusa Tenggara and performs power link budget and rise-time budget analyses of the proposed design. Section III discusses the analyses. Section IV presents the conclusions.

II. SYSTEM DESIGN

The design of the Eastern Package Palapa Ring fiber backbone optic network, especially in East Nusa Tenggara, is conducted as follows: First, the Eastern Package Palapa Ring project at present is studied. Data collection is performed among the districts to be connected by optical fiber. Second, the light source and detector to be used to match the expected specifications and targets are selected. Third, power link budget and rise-time budget analyses are performed. Lastly, an analysis is conducted based on the data link budget and rise time to determine whether the proposed optical fiber backbone network development design can be implemented in East Nusa Tenggara.

A. Technical Specification

To design an optical fiber backbone network system in an area, several variables should be known to analyze the power loss budget and rise time, such as the type of transceiver, optical fiber cable, and an amplifier. To reach the end user-required data rate stated in [2], we assume that an initial 2.7 Gbps can be used as the optical fiber backbone data rate. 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	8	dB
Single Mode [11]: ITU-T G.652D [12]		
Attenuation(α_f)	0.22	dB/Km
Dispersion (D)	4	ps/nm.Km
FINISAR FWLF1631R34 [13]		
Maximum Acceptable Loss	24	dB
Transmit Power	3	dBm
Receiver Sensitivity	−21	dBm
Transceiver Rise Time	28	ps
Spectral Width(σ_λ)	0.2	nm
Additional Loss		
Connector Attenuation	2	dB/connector
Splice Attenuation	0.2	dB/splice

B. Proposed Optical Network Design

The districts/cities in East Nusa Tenggara Province included in the present Palapa Ring optical fiber backbone network map draft are Alor District, Belu District, Kupang City, Sabu Raijua District, and East Sumba District. Fig. 2 shows the proposed optical fiber network map.

Fig. 2 describes the proposed optical fiber cable network in East Nusa Tenggara, which is divided into two types of pathways, namely, land lines (straight lines) and sea lines (curved lines). The optical fiber network deployment path that is included in the present Palapa Ring Eastern Package program is marked with a red line, while the proposed additional network is marked with a blue line. We assume that the actual optical fiber length requires an additional 10% of the distance between the district/city capitals. The complete list of optical fiber length, measured in kilometers, is shown in Table II.

TABLE II. FIBER OPTIC NEEDS IN EAST NUSA TENGGARA

Route	***District/city***	***Distance (km)***	***Optical Fiber Length (km)***
1	Kota Kupang–Kabupaten Kupang	37	40.70
2	Waingapu–Sumba Tengah	90	99.00
3	Sumba Barat–Sumba Tengah	38	41.80
4	Sumba Barat Daya–Sumba Barat	31	34.10
5	Atambua–Malaka	42	46.20
6	Atambua–Timor Tengah Utara (TTU)	47	51.70
7	TTU–Timor Tengah Selatan (TTS)	41	45.10
8	Alor–Lembata	147	149.60
9	Lembata–Flores Timur	94	103.40
10	Flores Timur–Sikka	101	111.10
11	Ende–Sikka	45	49.50
12	Nagekeo–Ende	45	49.50
13	Ngada–Nagekeo	36	39.60
14	Manggarai Timur–Ngada	43	47.30
15	Manggarai–Manggarai Timur	26	28.60
16	Manggarai Barat–Manggarai	36	39.60

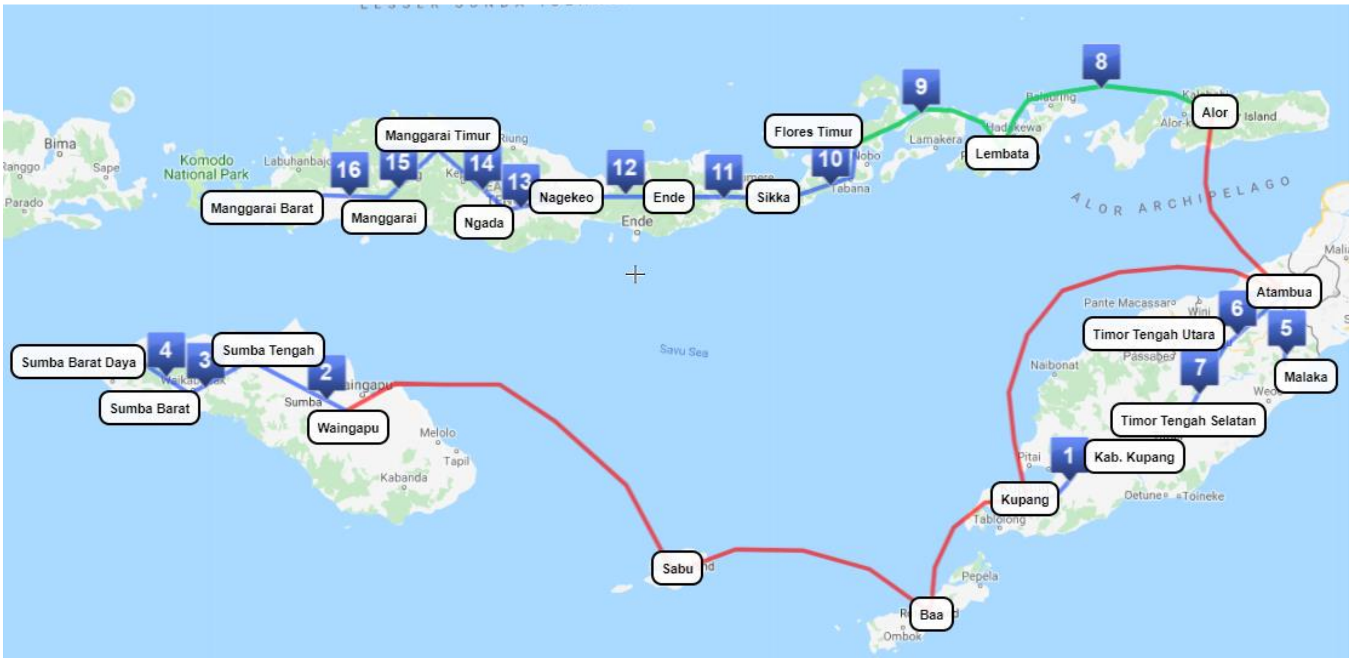

Fig. 2. Proposed optical fiber routes development design

C. Power Link Budget Analysis

To find out if the proposed network can be implemented, the power to be transmitted needs to be analyzed to determine whether it is sufficient to reach the receiver through an optical fiber cable within a certain distance. Therefore, power link budget analysis is used with Equations (1) and (2). Power link budget analysis is conducted to obtain the value of expected loss that is estimated to occur between the optical transmitter and photodetector. Losses occur in the form of cable attenuation ($\alpha_f L$), connector loss (L_c), loss splices (L_s), and system margin [1]

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

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

Calculation results from power link budget analysis are shown in Table III, which shows four routes, namely, route numbers 2, 8, 9, and 10 that require amplifiers. This situation occurred because these four routes have a total loss more than the maximum loss allowed. This condition is caused by the distance on the route being far enough to produce a high attenuation of the optical fiber cable. For example, route number 8, which connects Alor District to Lembata District, spans a distance of up to 147 km, resulting a 35.57 dB attenuation. The solution to this particular problem will be explained in the next section.

TABLE III. RESULT OF LINK LOSS BUDGET PARAMETER CALCULATION

Route	$\alpha_f L$(dB)	Loss Splices L_s(dB)	P_T(dB)
1	8.95	0.20	21.15
2	21.78	0.60	34.38
3	9.19	0.20	21.39
4	7.50	0.20	19.70
5	10.16	0.20	22.36
6	11.37	0.40	23.77
7	9.92	0.20	22.12
8	32.91	1.00	45.91
9	22.74	0.80	35.54
10	24.44	0.80	37.24
11	10.89	0.20	23.09
12	10.89	0.20	23.09
13	8.71	0.20	20.91
14	10.40	0.20	22.60
15	6.29	0.20	18.49
16	8.71	0.20	20.91

D. Rise-Time Analysis

In addition to the power link budget analysis, ris- time analysis is also necessary. Rise-time analysis is used to measure the dispersion limitation in an optical system. Calculations related to rise-time budget can be obtained by using Equation (3), which was derived from [1]. T_{SYS} in Equation (4) is the total rise time of the system, while T_{TX} and T_{RX} is the rise time of the transmitter and receiver, respectively. The rise time of the velocity dispersion group T_{GVD} in Equation (5) is the result of multiplying the dispersion time of the material (D), fiber length (L), and spectral width of the transceiver (σ_λ).

$$t_{sys} = \left(\sum_{i=1}^{N} {t_i}^2\right)^{1/2} \quad (3)$$

$$t_{sys} = ({t_{tx}}^2 + {t_{GVD}}^2 + {t_{rx}}^2) \quad (4)$$

$$t_{GVD} = D.L.\sigma_\lambda \quad (5)$$

$$t_{\max sys} = 70\% \times \frac{1}{Data\ Rate} \quad (6)$$

Table IV clearly shows which route can be implemented or not by comparing the T_{SYS} value with the maximum allowable dispersion value, whose formula is given in Equation (6). This paper uses NRZ modulation type with a maximum allowable rise-time value of 70% of the bit period.

TABLE IV. RESULT OF RISE TIME PARAMETER CALCULATION

Route	Total Fiber Length (Km)	T_{GVD}(ps)	T_{SYS}(ps)
1	40.70	32.56	51.26
2	99.00	79.20	88.54
3	41.80	33.44	51.82
4	34.10	27.28	48.08
5	46.20	36.96	54.16
6	51.70	41.36	57.25
7	45.10	36.08	53.57
8	161.70	129.36	126.06
9	103.40	82.72	91.70
10	111.10	88.88	97.30
11	49.50	39.60	56.00
12	49.50	39.60	56.00
13	39.60	31.68	50.71
14	47.30	37.84	54.77
15	28.60	22.88	45.73
16	39.60	31.68	50.71

III. ANALYSIS

On the basis of Table III, route 2 (Waingapu–Sumba Tengah), route 8 (Alor–Lembata), route 9 (Lembata–Flores Timur), and route 10 (Flores Timur–Sikka) shows that the total loss experienced by the transmitter has a value that is greater than the allowable loss. As a result, the information being carried cannot be read by the receiving system. Therefore, a special modification is needed for these four routes, namely, the addition of optical amplifiers [14]. The specifications of the optical amplifier in question and the updated version of the total loss because of the addition of the amplifier (P'_T) are shown in Tables V and VI, respectively. The use of an amplifier would require an extra pair of connectors, which would result in an estimated attenuation of about 4 dB.

TABLE V. OPTICAL AMPLIFIER PARAMETER CONSIDERATION

MEDALLION 7110 SERIES CATV EYDFA [14]		
Optical Input Power	−10 ~ +12	dBm
Typical Output Power	27–31	dBm

The configuration of the optical amplifier in this paper is placed after the optical source, as seen in Fig. 3, because of routes 8 and 9, which are underwater routes that do not allow the use of amplifiers in the middle of the lane.

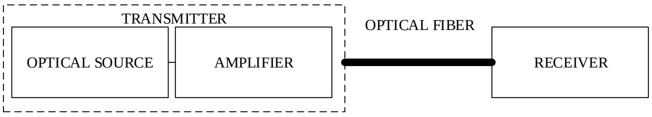

Fig. 3. Amplifier-added system

After the amplifier is added on the transmitter side, the output power of the transmitter becomes 29 dBm, then the maximum allowable loss parameter increases to 53 dB. Just like before, we compare each element of the P_T in Table III with the new value of the maximum allowable loss parameter, which is 53 dB. No element in P_T exceeds 53 dB, which means that the proposed system can be implemented.

TABLE VI. UPDATED LINK LOSS BUDGET CALCULATION

Route	District	P_T (dBm)	P'_T (dBm)
2	Waingapu–Sumba Tengah	34.38	38.38
8	Alor–Lembata	45.91	49.91
9	Lembata–Flores Timur	35.54	39.54
10	Lembata–Flores Timur	37.24	41.24

IV. CONCLUSION

The proposed design of the optical fiber backbone network in East Nusa Tenggara can be implemented according to specifications and expected targets. The experienced total loss in the system has a maximum value of 49.91 dBm and a minimum 18.49 dBm. The maximum allowable loss value of 53 dBm is not exceeded with the help of an optical amplifier in four routes. In the rise-time analysis, the maximum allowable dispersion of 259.26 ps, and no proposed route exceeds that value, thereby indicating that the proposed design meets the required dispersion limitation.

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