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Komodo National Park fiber optic network design and analysis by considering earthquake epicenter

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Abstract: Labuan Bajo and Komodo National Park (KNP) are the government's agendas in the tourism sector by making the area a premium tourist destination. On that basis, the tourism potential of the region requires infrastructure development to support this plan. One of the critical infrastructures is telecommunications, where the region does not have a direct fiber-optic line. In this paper, the authors propose two scenarios design of fiber-optic networks that also consider the potential for an upward fault earthquake in the northern waters of Labuan Bajo and KNP. The design is analyzed using calculation results of the power link budget, rise time, bit error rate (BER), and Signal to Noise Ratio. The BER value obtained is 5.63×10^{-13}, which is still below the parameter threshold of 10^{-12} with a design that avoids the epicenter of the disaster and a longer route. The SNR value on the longest route (route 7) is 34.69 dB. The SNR value has met the SNR standard, which is 21.5 dB.

Keywords: Bit Error Rate, Power link budget, Rise time analysis, Signal to Noise Ratio

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Introduction

Komodo Island and Rinca Island have been designated as National Parks since 1980 to protect the ancient endemic Komodo in East Nusa Tenggara Province. One area that has experienced a significant design change is the Rinca Island part of Komodo National Park (KNP) in the West Manggarai Regency. This island will be converted into a premium tourist destination with a geopark concept approach [1]. This development is expected to help the management of Komodo Island, which currently reaches Rp 129 billion and only gets Rp 33 billion allocations from the government [2]. The development of KNP is expected to increase government revenue from the tourism sector and increase the income of the surrounding population. Based on data in 2019, the economic potential of tourism value in Labuan Bajo and KNP could reach Rp 2.3 trillion [3].

Developing the area's infrastructure is necessary with the planned development of the Labuan Bajo and KNP areas into premium tourist destinations. One of the crucial infrastructures is a telecommunications infrastructure network. It also supports the government's program to improve telecommunication access in tourist destination areas to increase tourist arrivals [4]. One way is to build a fiber-optic network that has direct access to the area.

The change of the area into a premium tourist destination is expected to require a larger data connection for both the conservation and tourism sectors. Meanwhile, the current condition of the submarine cable shows that no one goes to KNP directly. One thing that needs to be considered in the deployment of submarine cables is the potential for damage to underwater cables caused by underwater earthquakes. Based on BNPB data, the sea area of NTT is an earthquake alert area [5].

The current optical cable network connects Sumbawa Island to NTT with MKCS Cable (Mataram Kupang Cable System) along 1851 Km with 1,041 Km of sea cable and 810 Km of land cable connecting six-station points, namely Mataram, Sumbawa Besar, Raba, Waingapu, and Kupang [6], [7]. However, this MKCS cable had an experience of breaking in 2018 due to the Lombok Earthquake [8]. Repairing the cable requires a lot of money and a long time because the damage occurs under the sea [9]. Several studies have been carried out in designing fiber optic networks in an area such as in [10], which proposed a backbone network for North Sumatra. In [11], a proposed optical network design aims to support 4G technology in Sleman.

Based on the disaster map issued by BNPB in 2020, the KNP and Labuan Bajo location is surrounded by Megathrust and faults. The Rising Back Fault, which is located in the north, is the Alert Zone with a track record of earthquakes and tsunamis occurring in 1992 – 2018, while in the south, there is the Bali – Nusa Tenggara Megathrust which was last recorded by an earthquake in 1977 and is included in the Alert Zone [5]. In 2018-2019 the Labuan Bajo and KNP areas experienced several underwater echoes in the northern part of the waters of Labuan Bajo and West Manggarai [12]–[15].

This paper proposes two scenarios for deploying fiber optic networks in the tourist areas of Labuan Bajo and KNP. The deployment scenario without considering potential underwater earthquake disaster points and deployment scenarios by considering potential aspects of underwater disaster points. The calculation results of the two scenarios will then be compared with the technicalities, impacts, and costs required. This research considers planning flowcharts, location determination and network planning, technical specifications, the power link budget calculation, rise time analysis calculation, signal to noise ratio (SNR), and Bit Error Rate (BER) calculations. Results and Discussions contain power link budget analysis, rise time analysis, SNR and BER analysis, technical analysis, potential risks, and impact estimates, and estimates of cost requirements.

Methodology

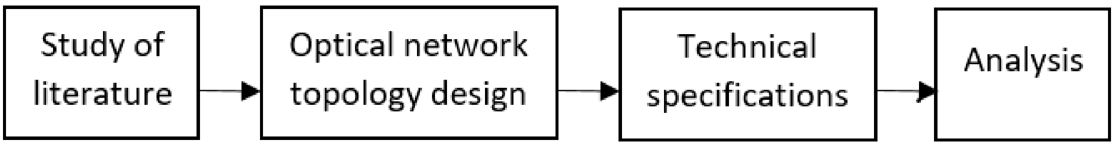

Figure 1. Planning flowchart

Planning Flowchart

The planning flowchart is shown in Figure 1. The planning design of this optical cable deployment will begin with a literature study of the existing Palapa Ring cable system in Sumbawa and East Nusa Tenggara. Its deployment scenario without considering potential underwater earthquake disaster points and deployment scenarios considering potential aspects of underwater earthquake disaster points. Then, we design an optical network topology design to determine the deployment location to determine the necessary cable requirements and deployment scenario without considering aspects of potential underwater earthquake disaster points and deployment scenarios by considering potential aspects of underwater earthquake disaster points. Some researchers consider the need for additional cables with a backup cable of 5% of the distance between points [16]–[18]. After that, we search technical specifications to ensure the devices' specifications used to deploy fiber optic networks, power link budget calculation, rise time analysis calculation, signal to noise ratio (SNR), and Bit Error Rate (BER) calculations. And the last, we analyze:

1. Power link budget analysis (Power link budget analysis is used to determine whether the power sent along with the information from the transmitter can be received by the receiver or not after passing through the optical cable media at a certain distance)
2. Rise time analysis (Rise time analysis is used to determine the total time required for the system from the initial state to reach a stable state)
3. SNR and BER analysis (BER analysis is a parameter to determine the number of bit errors at the receiver end for each number of data bits sent in a certain time interval. The smaller the BER value in a system, the better the system performance will be. BER can be obtained by using the Q-factor derived from the Signal to Noise Ratio (SNR). SNR is one of the parameters used to determine the performance of a receiver. The higher the SNR, the better the communication quality. SNR is used to determine the ratio of the received signal to noise in the system)

4. Technical analysis (Technical analysis is used to show results of power link budget analysis, rise time analysis, SNR, and BER analysis)
5. Potential risks and impact estimates (Potential risks and impact estimates is used to show technical and non-technical risks)
6. Cost requirements (Cost requirements is used to show parameters, quantity, and price to build KNP fiber-optic network)

Location Determination and Network Planning

1. Scenario 1

The location determination in scenario 1 is based on the current location of the MKCS cable [19] and palapa ring [20] as the starting and ending points of the proposed route. Location determination in scenario 1 is a deployment scenario without considering aspects of potential underwater earthquake disaster points. Deployment scenario without considering aspects of potential underwater earthquake disaster points as shown in Figure 2.

Figure 2. Scenario route 1

The calculation of the distance and total cable length for scenario 1 is shown in Table 1. The total cable length is the sum of the distances with a cable reserve of 5% on each route. Total cable from Soro to Kelapa to Komodo to Pasir Panjang to Labuan Bajo is 162.76 km, where location determination deployment scenario without considering aspects of potential underwater earthquake disaster points.

Table 1. Scenario route 1

No	Route	Distance (km)	Cable Length (km)	Description
1	Sondo to Bima	47.5	49.88	Land cable
2	Bima to Soro	48.3	50.72	Land cable
3	Soro to Kelapa	35.6	37.38	Submarine cable
4	Kelapa to Komodo	55.5	58.28	The longest in submarine cable
5	Komodo to Pasir Panjang	43.8	45.99	Submarine cable
6	Pasir Panjang to Labuan Bajo	20.1	21.11	The shortest in submarine cable
7	Labuan Bajo to Lembor	63.9	67.10	The longest inland cable
8	Lembor to Ruteng	62.1	65.21	Land cable
9	Ruteng to Wangkung	61.2	64.26	Land cable
10	Ruteng to Borong	55.9	58.70	Land cable
11	Borong to Ngada	41.2	43.26	The shortest land cable
12	Ngada to Nagekeo	62.9	66.05	Land cable
13	Nagekeo to Nangaroro	56.2	59.01	Land cable
14	Nangaroro to Ende	43.0	45.15	Land cable
	Total	697.2	732.06	

2. Scenario 2

In scenario 2, the location determination is almost the same as scenario 1. It is based on the location of the MKCS cable [19] and the palapa ring [20] as the starting and ending points of the proposed route. However, there are differences in the deployment of the route on routes 4 and 5; namely, the proposed route is a submarine cable with the deployment avoiding the waters in the northern part of KNP and Labuan Bajo. Deployment scenarios by considering potential aspects of underwater earthquake disaster points as shown in Figure 3.

Figure 3. Scenario route 2

The calculation of the distance and the total cable length for scenario 2 is shown in Table 2. The total cable length is the sum of the distance with a cable reserve of 5% on each route. Total cable from Soro to Kelapa to Komodo to Pasir Panjang to Labuan Bajo is 171.79 km, where location determination scenarios by considering potential aspects of the underwater earthquake disaster.

Table 2. Scenario route 2

No	Route	Distance (km)	Cable Length (km)	Description
1	Sondo to Bima	47.5	49.88	Land cable
2	Bima to Soro	48.3	50.72	Land cable
3	Soro to Kelapa	35.6	37.38	Submarine cable
4	Kelapa to Komodo	57.2	60.06	The longest in submarine cable
5	Komodo to Pasir Panjang	50.7	53.24	Submarine cable
6	Pasir Panjang to Labuan Bajo	20.1	21.11	The shortest in submarine cable
7	Labuan Bajo to Lembor	63.9	67.10	The longest land cable
8	Lembor to Ruteng	62.1	65.21	Land cable
9	Ruteng to Wangkung	61.2	64.26	Land cable
10	Ruteng to Borong	55.9	58.70	Land cable
11	Borong to Ngada	41.2	43.26	The shortest land cable
12	Ngada to Nagekeo	62.9	66.05	Land cable
13	Nagekeo to Nangaroro	56.2	59.01	Land cable
14	Nangaroro to Ende	43.0	45.15	Land cable
	Total	705.8	741.09	

Technical Specification

Bandwidth requirements are calculated in advance to determine the parameters that will be used in network planning. The bandwidth requirement is calculated from the number of residents of the tourist areas of Labuan Bajo and Komodo National Park by the assumption of bandwidth requirements per person (4 Mbps) [21]. The number of people who have the potential to use the internet is in Table 3. From [21], Age 13 to > 60 has potential to use the internet. Region Labuan Bajo has a larger potential to use the internet than Komodo and Pasir Panjang. Region Gorontalo has the largest potential to use the internet. Region Pasir Panjang has the smallest potential to use the internet.

Table 3. Number of people who have the potential to use the internet

No	Region	Age 13 to >60
1	Komodo	1528
2	Pasir Panjang	1393
3	Gorontalo	5900
4	Wae Kelambu	5392
5	Batu Cermin	4649
6	Labuan Bajo	5742

From Table 3, the total number of people who can use the internet is 24,604 from the age range of 13 to more than 60 years [21], so the total bandwidth requirement is 24,604 x 4 Mbps = 98,416 Mbps = 98.4 Gbps. Table 4 shows the technical parameters. BER, signal encoding, and wavelength are 10^{-12}, NRZ, and 1550 nm, respectively. System Margin is 4 dB. From [22] explained that attenuation (α_f) is used 0.16 dB/km, and chromatic dispersion is used 3 ps/nm.km. From [23] explained that attenuation (α_f) is used 0.16 dB/km, and chromatic dispersion is used 3 ps/nm.km. From [24] explained that transmit power is used 4 dBm, Receiver Sensitivity is used -24 dBm. Transceiver Rise Time has used 28 ps, Spectral Width ($\sigma\lambda$) is used 0.3 nm, Maximum Acceptable Loss is used 28 dB. In Additional loss, Connector Attenuation is used 2 dB/connector. From [25] explained that Dark Current is used 40 nA, M of APD is used 20 dBm, T_eff used 25°C, excess noise figure is used 0.7 nm, FM (Noise Figure) is used 8.14 dB, and Receiver Efficiency is used 85 %.

Table 4. Technical parameters

No	Parameter	Value	Unit
1	Bandwidth	98.4	Gbps
2	BER	10^{-12}	
3	Signal Encoding	NRZ	
4	Wavelength	1550	nm
5	System Margin	4	dB
	Land Optical Fiber Cable (ITU-T G.654.B) [22]		
1	Attenuation (α_f)	0.16	dB/km
2	Chromatic Dispersion (D)	3	ps/nm.km
	Submarine Optical Fiber Cable (ITU-T G.973) [23]		
1	Attenuation (α_f)	0.16	dB/km
2	Chromatic Dispersion (D)	3	ps/nm.km
	Huawei Optix OSN 8800 – TN55TTX [24]		
1	Transmit Power	4	dBm
2	Receiver Sensitivity	-24	dBm
3	Transceiver Rise Time	28	ps
4	Spectral Width ($\sigma\lambda$)	0.3	nm
5	Maximum Acceptable Loss	28	dB
	Additional Loss		
1	Connector Attenuation	2	dB/connector
	Hamamatsu InGaAs APD G8931-04 [25]		
1	Dark Current	40	nA
2	M of APD	20	dBm

3	T_eff	25°	C
4	excess noise figure	0.7	nm
5	FM (Noise Figure)	8.14	dB
6	Receiver Efficiency	85	%

Calculation of Power Link Budget

Power Link Budget analysis is used to determine whether the power sent along with the information from the transmitter can be received by the receiver or not after passing through the optical cable media at a certain distance. Equations (1) and (2) are used to obtain the network's Total Loss value, which will be compared with the maximum allowable loss in the system. Equation (1) is used to calculate Power Link Budget $(\mathrm{P_t})$ which is a power source (P_S) and power receiver (P_r). Equation (2) is used to calculate Power Link Budget $(\mathrm{P_t})$ which the source of power loss comes from cable attenuation $(\alpha_f L)$, connector loss (L_c), loss splices (L_s), and system margins (assuming 4 dB) [26]–[28].

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

$$P_T = \alpha_f L + L_c + L_s + margin\ sistem \quad (2)$$

Calculation of the Rise Time Analysis

Rise time analysis is used to determine the total time required for the system from the initial state to reach a stable state. Equation (3) is used to calculate the time described in equation (4). Equation (4) is used 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 the rise time of the velocity dispersion group (t_{GVD}). Where the value of t_{GVD} is obtained through equation (5) which is the product of the dispersion time of the cable (D), cable length (L), and wavelength width. Equation (6) is used to calculate the maximum rise time dispersion ($t_{max\ sys}$) [26]–[28].

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

$$t_{sys} = \left(t_{tx}^2 + t_{GVD}^2 + t_{rx}^2\right)^{1/2} \quad (4)$$

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

$$t_{max\,sys} = 70\% \times \frac{1}{Data\ Rate} = 259.259 \quad (6)$$

Calculation of Signal to Noise Ratio (SNR) and Bit Error Rate (BER)

BER analysis is a parameter to determine the number of bit errors at the receiver end for each number of data bits sent in a certain time interval. The smaller the BER value in a system, the better the system performance will be. BER can be obtained by using the Q-factor derived from the Signal to Noise Ratio (SNR) which is calculated by Equation (13). Like BER, SNR is one of the parameters used to determine the performance of a receiver. The higher the SNR, the better the communication quality. SNR is used to determine the ratio of the received signal to noise in the system [26]–[28].

$$SNR = \frac{Signal\ Power}{Noise\ Power} \quad (7)$$

Signal Power is the amount of signal power received at the receiver. Equation (7) is the equation for calculating the amount of SNR. Equation (8) is the SNR variables are P_R (power at receiver (W)), η (receiver efficiency (%)), q (electron charge (1.6 x 10^{-19} C)), h (Plank's constant (6.626 x 10^{-34} Js))), v (frequency (Hz)), and M (gain of Avalanche Photodiode (APD)).

$$Signal\ Power = \left(P_R M \left(\frac{\eta q \lambda}{hC}\right)\right)^2 (M)^2 \quad (8)$$

Noise power is the amount of noise in the system, namely thermal noise ($N_{thermal}$), dark current noise (N_{dc}), and shot noise (N_{shot}). Equation (9) is an equation to calculate the amount of noise power in the system.

$$Noise\ Power = N_{thermal} + N_{dc} + N_{shot} \quad (9)$$

The following equations (10), (11), and (12) are used to calculate the amount of thermal noise, dark current noise, and shot noise in the system. T_{eff} is the effective noise temperature (K), k is the Boltzman constant (1.38 x 10^{-23} Joule/k), B is the bandwidth, R is the equivalent resistance (ohms), I_D is the dark current (A), and *F(M)* is noise figure.

$$N_{thermal} = \frac{4kT_{eff}B}{R} \quad (10)$$

$$N_{dc} = 2qI_D B \quad (11)$$

$$N_{shot} = 2q(P_R \frac{\eta q \lambda}{hC})BM^2F(M) \quad (12)$$

The Q-factor can be used to indicate the minimum SNR ratio required to obtain BER. The Q-factor is a function of OSNR (Optical SNR). Equations (13) and (14) represent the relationship between SNR, Q-factor, and BER. Q is the magnitude of the Q-factor, Pe is the probability of error.

$$SNR = 20\ log\ 2Q \quad (13)$$

$$BER = Pe(Q) = \frac{1}{\sqrt{2\pi}} \frac{e^{-\frac{Q^2}{2}}}{Q} \quad (14)$$

Results and Discussions

Results and discussions contain the Power link budget analysis, rise time analysis, SNR and BER analysis, technical analysis, potential risks and impact estimates, and cost estimates.

Power Link Budget Analysis

Power link budget analysis is the first consideration parameter carried out by calculating the total optical power loss using equations (1) and (2). Table 5. shows the results of calculating the total optical power loss in scenario 1 and scenario 2.
Calculating power link budget use formula from equations (2). Example of calculating power link budget route 1 (Sondo to Bima) in scenario 1 and scenario 2 as below:
Equation (2) is used to calculate Power Link Budget (P_t) which the source of power loss comes from cable attenuation $(\alpha_f L)$, connector loss (L_c), loss splices (L_s), and system margins (assuming 4 dB).

$$P_T = \alpha_f L + L_c + L_s + margin\ sistem$$
$$P_T = 0.16\ \text{dB/km} * 49.88\ \text{km} + 2 * 2\ \text{dB} + 0\ \text{dB} + 4\ \text{dB}$$
$$P_T = 15.98\ \text{dB}$$

Table 5 shows the power link budget calculation for each route for both scenario 1 and scenario 2. Because the difference between scenario 1 and scenario 2 only lies in the deployment of route 4 and route 5, the difference in the calculation value is only on that route. All the power link budget calculation for each route are still below the maximum allowable loss based on the parameters in the proposed design, which is 28 dB.

Table 5. Calculation of power link budget

No	Route	Scenario 1			Scenario 2		
		Cable Loss (dB)	Total Power Loss (dB)	Maximum Allowable Loss (28 dB)	Cable Loss (dB)	Total Power Loss (dB)	Maximum Allowable Loss (28 dB)
1	Sondo to Bima	7.98	15.98	Yes	7.98	15.98	Yes
2	Bima to Soro	8.1144	16.1144	Yes	8.1144	16.1144	Yes
3	Soro to Kelapa	5.9808	13.9808	Yes	5.9808	13.9808	Yes
4	Kelapa to Komodo	9.324	17.324	Yes	9.6096	17.6096	Yes
5	Komodo to Pasir Panjang	7.3584	15.3584	Yes	8.5176	16.5176	Yes
6	Pasir Panjang to Labuan Bajo	3.3768	11.3768	Yes	3.3768	11.3768	Yes
7	Labuan Bajo to Lembor	10.7352	18.7352	Yes	10.7352	18.7352	Yes
8	Lembor to Ruteng	10.4328	18.4328	Yes	10.4328	18.4328	Yes
9	Ruteng to Wangkung	10.2816	18.2816	Yes	10.2816	18.2816	Yes
10	Ruteng to Borong	9.3912	17.3912	Yes	9.3912	17.3912	Yes
11	Borong to Ngada	6.9216	14.9216	Yes	6.9216	14.9216	Yes
12	Ngada to Nagekeo	10.5672	18.5672	Yes	10.5672	18.5672	Yes
13	Nagekeo to Nangaroro	9.4416	17.4416	Yes	9.4416	17.4416	Yes
14	Nangaroro to Ende	7.224	15.224	Yes	7.224	15.224	Yes

Rise Time Analysis

Rise time analysis determines the total time required for the system from the initial conditions to reach a stable condition.

Calculating rise time use formula from equations (4) & (5). Example of calculating rise time route 1 (Sondo to Bima) in scenario 1 and scenario 2 as below:

Equation (4) is used 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 the rise time of the velocity dispersion group (t_{GVD}).

$$t_{sys} = ({t_{tx}}^2 + {t_{GVD}}^2 + {t_{rx}}^2)^{1/2}$$
$$t_{sys} = (28^2 \text{ ps} + 44.89^2 \text{ ps} + \left(\frac{350}{28}\right)^2 \text{ ps})^{1/2}$$
$$t_{sys} = 54.36 \text{ ps}$$

Value of t_{GVD} is obtained through equation (5) which is the product of the dispersion time of the cable (D), cable length (L), and wavelength width.

$$t_{GVD} = D.L.\sigma_\lambda$$
$$t_{GVD} = 3 \text{ ps/nm.km} * 49.88 \text{ km} * 0.3 \text{ nm}$$

$t_{GVD} = 44.89$ ps

Table 6 shows the calculation of the rise time analysis for routes 1 to 14 with a direct comparison between scenario 1 and scenario 2. Similar to power budget analysis, the difference in values is on routes 4 and 5. The total rise time value in the system is greater in scenario 2 for both paths because it has a longer route.

Table 6. Calculation of the rise time

No	Route	Scenario 1		Scenario 2	
		T_{gvd} (ps)	T_{sys} (ps)	T_{gvd} (ps)	T_{sys} (ps)
1	Sondo to Bima	44.89	54.36	44.89	54.36
2	Bima to Soro	45.64	54.99	45.64	54.99
3	Soro to Kelapa	33.64	45.52	33.64	45.52
4	Kelapa to Komodo	52.45	60.75	54.05	62.15
5	Komodo to Pasir Panjang	41.39	51.51	47.91	56.88
6	Pasir Panjang to Labuan Bajo	18.99	36.07	18.99	36.07
7	Labuan Bajo to Lembor	60.39	67.72	60.39	67.72
8	Lembor to Ruteng	58.68	66.21	58.68	66.21
9	Ruteng to Wangkung	57.83	65.46	57.83	65.46
10	Ruteng to Borong	52.83	61.08	52.83	61.08
11	Borong to Ngada	38.93	49.56	38.93	49.56
12	Ngada to Nagekeo	59.44	66.88	59.44	66.88
13	Nagekeo to Nangaroro	28.32	28.16	28.32	28.16
14	Nangaroro to Ende	21.67	24.63	21.67	24.63

SNR and BER Analysis

SNR and BER are parameters to analyze the number of broken bits during signal transmission on optical fiber.

Calculating SNR & BER use formula from equations (1), (7), (8), (9), (10), (11), (12), (13), & (14). Example of calculating SNR & BER route 1 (Sondo to Bima) in scenario 1 and scenario 2 as below:

Equation (1) is used to calculate Power Link Budget ($\mathrm{P_t}$) which is a power source (P_S) and power receiver (P_r). In this calculation, using equation (1) to get power receiver (P_r).

$$P_T = P_S - P_r$$
$$P_r = P_S - P_T$$
$$P_r = 4\text{ dB} - 15.98\text{ dB}$$
$$P_r = -11.98\text{ dBm}$$

Signal Power is the amount of signal power received at the receiver. Equation (7) is the equation for calculating the amount of SNR. Equation (8) is the SNR variables are P_R (power at receiver (W)), η (receiver efficiency (%)), q (electron charge (1.6×10^{-19} C)), h (Plank's constant (6.626×10^{-34} Js))), v (frequency (Hz)), and M (gain of Avalanche Photodiode (APD)).

$$Signal\ Power = \left(P_R M \left(\frac{\eta q \lambda}{hC}\right)\right)^2 (M)^2$$
$$Signal\ Power = \left(6.34 * (10)^{-5}\text{ W} * 20 * \left(\frac{0.85 * 1.6 * (10)^{-19}\text{ C} * 1.55 * (10)^{-6}\text{ m}}{6.26 * (10)^{-34}\text{ Js} * 3 * (10)^{8}\ m/s}\right)\right)^2 * (20)^2$$
$$Signal\ Power = 8.1 * (10)^{-4}$$

The following equations (10), (11), and (12) are used to calculate the amount of thermal noise, dark current noise, and shot noise in the system. T_{eff} is the effective noise temperature (K), k is the Boltzman constant (1.38×10^{-23} Joule/k), B is the bandwidth, R is the equivalent resistance (ohms), I_D is the dark current (A), and $F(M)$ is noise figure.

$$N_{thermal} = \frac{4kT_{eff}B}{R}$$
$$N_{thermal} = \frac{4 * 1.39 * (10)^{-23} \mathrm{J/K} * 298.15\ \mathrm{K} * 9.84 * (10)^{10}\ \mathrm{Hz}}{50\ \mathrm{Ohm}}$$

$$N_{thermal} = 3.2547 * (10)^{-11}$$

$$N_{dc} = 2qI_DB$$
$$N_{dc} = 2 * 1.6 * (10)^{-19}\ \mathrm{C} * 4 * (10)^{-8}\mathrm{A} * (20)^2 * 9.84 * (10)^{10}\mathrm{Hz} * 20^{0.7}$$

$$N_{dc} = 4.1026 * (10)^{-12}$$

$$N_{shot} = 2q(P_R \frac{\eta q \lambda}{hC})BM^2F(M)$$
$$N_{shot} = 2 * 1.6 * (10)^{-19}\mathrm{C} * \left(6.34 * (10)^{-5}\mathrm{W} * \left(\frac{0.85 * 1.6 * (10)^{-19}\ \mathrm{C} * 1.55 * (10)^{-6}\ \mathrm{m}}{6.26 * (10)^{-34}\ \mathrm{Js} * 3 * (10)^8\ \mathrm{m/s}}\right)\right) * 9.84 * 10^{10}\ \mathrm{Hz} *$$
$$20^2 * 20^{0.7}$$
$$N_{shot} = 1.46 * (10)^{-7}$$

Noise power is the amount of noise in the system, namely thermal noise ($N_{thermal}$), dark current noise (N_{dc}), and shot noise (N_{shot}). Equation (9) is an equation to calculate the amount of noise power in the system.

$$Noise\ Power = N_{thermal} + N_{dc} + N_{shot}$$
$$Noise\ Power = 3.2547 * (10)^{-11} + 4.1026 * (10)^{-12} + 1.46 * (10)^{-7}$$
$$Noise\ Power = 1.46 * (10)^{-7}$$

Signal Power is the amount of signal power received at the receiver. Equation (7) is the equation for calculating the amount of SNR. Equation (8) is the SNR variables are P_R (power at receiver (W)), η (receiver efficiency (%)), q (electron charge (1.6 x 10^{-19} C)), h (Plank's constant (6.626 x 10^{-34} Js))), v (frequency (Hz)), and M (gain of Avalanche Photodiode (APD)). Noise power is the amount of noise in the system, namely thermal noise ($N_{thermal}$), dark current noise (N_{dc}), and shot noise (N_{shot}). Equation (9) is an equation to calculate the amount of noise power in the system.

$$SNR = \frac{Signal\ Power}{Noise\ Power}$$
$$SNR = 10 * \log \frac{Signal\ Power}{Noise\ Power}$$
$$SNR = 10 * \log \frac{8.1 * (10)^{-4}}{1.46 * (10)^{-7}}$$
$$SNR = 37.44$$

The Q-factor can be used to indicate the minimum SNR ratio required to obtain BER. The Q-factor is a function of OSNR (Optical SNR). Equations (13) and (14) represent the relationship between SNR, Q-factor, and BER. Q is the magnitude of the Q-factor, Pe is the probability of error.

$$SNR = 20\ log\ 2Q$$
$$Q = (10)^{\frac{(\frac{SNR}{20})}{2}}$$
$$Q = (10)^{\frac{(\frac{37.44}{20})}{2}}$$
$$Q = 8.63$$
$$BER = Pe(Q) = \frac{1}{\sqrt{2\pi}} \frac{e^{-\frac{Q^2}{2}}}{Q}$$

$BER = Pe(Q) = \frac{1}{\sqrt{2\pi}} \frac{e^{-\frac{8.63^2}{2}}}{8.63}$

$\mathrm{BER} = 1.94 * (10)^{-17}$

Tables 7 and 8 show the calculation of SNR and BER for routes 1 to 14 in scenario 1 and scenario 2. Similar to power budget analysis and rise time analysis, the difference in values is on routes 4 and 5. BER values in the longest route (route 7) are 5.69 x 10^{-13}. The BER value has met the proposed BER standard, which is 10^{-12}. The SNR value on the longest route (route 7) is 34.69 dB. The SNR value has met the SNR standard, which is 21.5 dB [28].

Table 7. SNR and BER for scenario 1

No	Route	Scenario 1				
		Pr (dBm)	Q	SNR	BER	BER standard (10^{-12})
1	Sondo to Bima	-11.98	8.63	37.44	1.94 x 10^{-17}	Yes
2	Bima to Soro	-12.11	8.56	37.31	3.47 x 10^{-17}	Yes
3	Soro to Kelapa	-9.98	9.68	39.44	1.13 x 10^{-21}	Yes
4	Kelapa to Komodo	-13.32	7.99	36.10	4.38 x 10^{-15}	Yes
5	Komodo to Pasir Panjang	-11.36	8.95	38.06	1.18 x 10^{-18}	Yes
6	Pasir Panjang to Labuan Bajo	-7.38	11.25	42.05	7.36 x 10^{-29}	Yes
7	Labuan Bajo to Lembor	-14.74	7.36	34.69	5.69 x 10^{-13}	Yes
8	Lembor to Ruteng	-14.43	7.49	34.99	2.14 x 10^{-13}	Yes
9	Ruteng to Wangkung	-14.28	7.56	35.14	1.29 x 10^{-13}	Yes
10	Ruteng to Borong	-13.39	7.96	36.03	5.62 x 10^{-15}	Yes
11	Borong to Ngada	-10.92	9.17	38.50	1.46 x 10^{-19}	Yes
12	Ngada to Nagekeo	-14.57	7.44	34.85	3.32 x 10^{-13}	Yes
13	Nagekeo to Nangaroro	-13.44	7.93	35.98	6.77 x 10^{-15}	Yes
14	Nangaroro to Ende	-11.22	9.01	38.20	6.28 x 10^{-19}	Yes

Table 8. SNR and BER for scenario 2

No	Route	Scenario 2				
		Pr (dBm)	Q	SNR	BER	BER standard (10^{-12})
1	Sondo to Bima	-11.98	8.63	37.44	1.94 x 10^{-17}	Yes
2	Bima to Soro	-12.11	8.56	37.31	3.47 x 10^{-17}	Yes
3	Soro to Kelapa	-9.98	9.68	39.44	1.13 x 10^{-21}	Yes
4	Kelapa to Komodo	-13.61	7.86	35.81	1.25 x 10^{-14}	Yes
5	Komodo to Pasir Panjang	-12.52	8.37	36.90	1.87 x 10^{-16}	Yes
6	Pasir Panjang to Labuan Bajo	-7.38	11.25	42.05	7.36 x 10^{-29}	Yes
7	Labuan Bajo to Lembor	-14.74	7.36	34.69	5.69 x 10^{-13}	Yes
8	Lembor to Ruteng	-14.43	7.49	34.99	2.14 x 10^{-13}	Yes
9	Ruteng to Wangkung	-14.28	7.56	35.14	1.29 x 10^{-13}	Yes
10	Ruteng to Borong	-13.39	7.96	36.03	5.62 x 10^{-15}	Yes
11	Borong to Ngada	-10.92	9.17	38.50	1.46 x 10^{-19}	Yes
12	Ngada to Nagekeo	-14.57	7.44	34.85	3.32 x 10^{-13}	Yes
13	Nagekeo to Nangaroro	-13.44	7.93	35.98	6.77 x 10^{-15}	Yes
14	Nangaroro to Ende	-11.22	9.01	38.20	6.28 x 10^{-19}	Yes

Technical Analysis

The total power loss in both scenarios ranges from 11.38 to 18.74 dB, and the power received in both scenarios has a range of -7.38 to -14.74 dBm. The power loss value is still below the maximum value of the total power loss allowed by the parameters specified in the system. Based on the power link budget calculation, both scenarios are in line with expectations.

In Rise Time analysis, the Maximum Rise Time allowed is 259.29 ps. In both scenarios, no route exceeds the maximum allowed value. The total rise time value in the system is greater in scenario 2 for both paths because it has a longer route.

SNR is calculated on each route. It is to show the smallest SNR value against other routes. The smallest SNR value is on route 7 from Labuan Bajo to Lembor, with a value of 34.69 dB for both scenario 1 and scenario 2. This value is still above the SNR value that meets the SNR standard of 21.5 dB [28] so based on the SNR calculation in both scenarios according to the author's expectations.

BER System is calculated on each route. This parameter aims to show the smallest BER value for other routes. The largest BER value is on route 7 from Labuan Bajo to Lembor with a value of 5.69×10^{-13} for both scenario 1 and scenario 2. This value is still below the BER value specified in the system parameters, 10^{-12}, based on the BER calculation for both scenarios according to expectations.

Potential Risks and Estimated Impacts

In planning this network, it is estimated that the potential risks, such as a fiber cut due to construction work on land or anchors in submarine cables, can be overcome by splicing but increasing processing time costs. In addition, it should be noted that the presence of splices will increase the loss that needs to be recalculated. In addition, there are non-technical risks related to administration such as material costs, taxes, user fees, and human resources that need to be considered in the deployment plan.

Estimated Cost

Table 9. and Table 10. show the results of calculating the estimated cost in scenario 1 and scenario 2. The list of items needed in both scenarios includes rack server, sfp module, patch cord, 48 core fiber optic cable, 48 joint port closure, installation cable pulling, and OSN of each node (Huawei). In scenario 1, the required cost is around Rp 675,559,025,000 while in scenario 2, the cost is around Rp 683,884,685,000.

Table 9. Estimated cost in scenario 1

No	Parameter	Quantity	Unit Price (Rp)	Total (Rp)
Data Center Device				
1	Rack Servers (units)	15	8,650,000	129,750,000
Fiber Optic Network Device				
1	SFP Modules (units)	45	5,335,000	240,075,000
2	Patch cord (unit)	100	35,000	3,500,000
Fiber Optic Material				
1	Fiber optic cable 48 Cores (meters)	732,060	18,000	13,177,080,000
2	Joint Closure 48 port	6	230,000	1,380,000
3	Cable pulling installation (meters)	732,060	904,000	661,782,240,000
4	OSN each node - Huawei Price (unit)	15	$ 1,000	225,000,000
Total (Rp)				675,559,025,000

Table 10. Estimated cost in scenario 2

No	Parameter	Quantity	Unit Price (Rp)	Total (Rp)
Data Center Device				
1	Rack Servers (units)	15	8,650,000	129,750,000
Fiber Optic Network Device				
1	SFP Modules (units)	45	5,335,000	240,075,000
2	Patch cord (unit)	100	35,000	3,500,000
Fiber Optic Material				
1	Fiber optic cable 48 Cores (meters)	741,090	18,000	13,339,620,000
2	Joint Closure 48 port	6	230,000	1,380,000
3	Cable pulling installation (meters)	741,090	904,000	669,945,360,000
4	OSN each node - Huawei Price (unit)	15	$ 1,000	225,000,000
Total (Rp)				683,884,685,000

Conclusion

Both scenarios have total power loss and power received with the same value range. The difference in values is only on routes 4 and 5. The total cable deployment in scenario 2 is longer than scenario 1 because the planned deployment route avoids earthquake-prone areas. Scenario 2 is expected to be more disaster-resistant based on the selected deployment location. So it is expected to minimize the cost of restoration. The value of the Rise Time analysis in both scenarios is that no route exceeds the allowed value So that both scenarios can be applied. By considering technical aspects and risks, it is expected that the construction of fiber optic networks in the Labuan Bajo and KNP areas can provide increased bandwidth needs for residents and travelers. The BER value on the longest path is 5.69×10^{-13}. The BER value has met the proposed BER standard, which is 10^{-12}. Based on the calculation of the system's feasibility, the proposed route in scenario 1 and scenario 2 has the feasibility for deployment. But what needs to be considered is the deployment location where scenario 2 has a deployment route that avoids disaster-prone areas even though it impacts higher initial deployment costs. This condition will reduce the risk of catastrophic cable breakage resulting in higher repair costs.

References

[1] N. F. Azzahro, "Sulap Pulau Rinca TN Komodo, Serupa Dengan 'Jurassic Park' Sebagai Destinasi Wisata Premium - Lingkar Kediri," 2020. [Online]. Available: https://lingkarkediri.pikiran-rakyat.com/nasional/pr-67877155/sulap-pulau-rinca-tn-komodo-serupa-dengan-jurassic-park-sebagai-destinasi-wisata-premium?page=2. [Accessed: 22-Nov-2020].

[2] CNN Indonesia, "Wisata Pulau Komodo Dibanderol Rp14 Juta Buat Turis Asing," 2019. [Online]. Available: https://www.cnnindonesia.com/ekonomi/20191115145650-92-448699/wisata-pulau-komodo-dibanderol-rp14-juta-buat-turis-asing. [Accessed: 22-Nov-2020].

[3] I. A. Pribadi, "Bernilai Rp2,3 triliun, potensi penerimaan Labuan Bajo belum optimal - ANTARA News," 2019. [Online]. Available: https://www.antaranews.com/berita/1203556/bernilai-rp23-triliun-potensi-penerimaan-labuan-bajo-belum-optimal. [Accessed: 22-Nov-2020].

[4] Kristantyo Wisnubroto, "Sinyal 4G Menguat di Pulau Komodo | Indonesia.go.id," 20-Nov-2020. [Online]. Available: https://indonesia.go.id/ragam/pariwisata/ekonomi/sinyal-4g-menguat-di-pulau-komodo. [Accessed: 22-Nov-2020].

[5] BNP2TKI, "Laporan kinerja tahunan BNPB (Yearly report of BNPB)," 2019.

[6] "Telkom Bangun Backbone Serat Optik Mataram-Kupang," 2009. [Online]. Available: https://nasional.kompas.com/read/2009/11/30/13121962/Telkom.Bangun.Backbone.Serat.Optik.Mataram-Kupang. [Accessed: 22-Nov-2020].

[7] Masnun, "TELKOM BANGUN BACKBONE SERAT OPTIK MATARAM-KUPANG - ANTARA News Mataram - Berita NTB Terkini," 2009. [Online]. Available: https://mataram.antaranews.com/berita/6775/telkom-bangun-backbone-serat-optik-

mataram-kupang. [Accessed: 22-Nov-2020].
[8] Andina Librianty, "Telkom: Penyambungan Kabel Laut Putus Akibat Gempa Lombok Rampung Bulan Ini - Tekno Liputan6.com," 2018. [Online]. Available: https://www.liputan6.com/tekno/read/3626866/telkom-penyambungan-kabel-laut-putus-akibat-gempa-lombok-rampung-bulan-ini. [Accessed: 22-Nov-2020].
[9] "Perbaikan Kabel Laut Putus Biayanya Bisa Lebih dari Rp50 Miliar - Nawacita," 2019. [Online]. Available: https://nawacita.co/index.php/2019/08/15/perbaikan-kabel-laut-putus-biayanya-bisa-lebih-dari-rp50-miliar/. [Accessed: 22-Nov-2020].
[10] Yudiansyah, P. Dewi Mariyam, A. P. Aji, N. Chisnariandini, and C. Apriono, "Design of land optical fiber backbone communication network in North Sumatera," in *2018 International Conference on Information and Communications Technology (ICOIACT)*, 2018, pp. 915–918.
[11] Firdaus, R. A. I. Asyari, and E. Indarto, "Optical network design for 4G long term evolution distribution network in sleman," *Proc. - 2016 Int. Semin. Appl. Technol. Inf. Commun. ISEMANTIC 2016*, pp. 332–335, 2017.
[12] Sriwidiah Rosalina, "Manggarai Barat NTT Diguncang Gempa Bumi 6,8 SR - Alagraph.com," 2015. [Online]. Available: https://www.alagraph.com/berita/detail/manggarai-barat-ntt-diguncang-gempa-bumi-68-sr. [Accessed: 22-Nov-2020].
[13] "Gempa Hari Ini: Gempa M 4.1 Guncang Manggarai Barat Kamis Siang (21/2/2019), Kedalaman 142 Kilometer - Halaman all - Tribunnews.com," 2019. [Online]. Available: https://www.tribunnews.com/section/2019/02/21/gempa-hari-ini-gempa-m-41-guncang-manggarai-barat-kamis-siang-2122019-kedalaman-142-kilometer?page=all. [Accessed: 22-Nov-2020].
[14] "BREAKING NEWS: Gempa Bumi 5,1 SR Guncang Labuan Bajo, Tak Berpotensi Tsunami - Pos Kupang," 2019. [Online]. Available: https://kupang.tribunnews.com/2019/01/12/breaking-news-gempa-bumi-51-sr-guncang-labuan-bajo-tak-berpotensi-tsunami. [Accessed: 22-Nov-2020].
[15] Andi Mohammad Ikhbal, "Gempa 5,0 SR Guncang Manggarai Barat NTT, Tak Berpotensi Tsunami," 2013. [Online]. Available: https://regional.inews.id/berita/gempa-5-0-sr-guncang-manggarai-barat-ntt-tak-berpotensi-tsunami. [Accessed: 22-Nov-2020].
[16] A. Yohanes Galih, F. Amelia, R. Dody Herdianto, B. Pratiknyo Adi Mahatmanto, and C. Apriono, "Optical fiber network design in east nusa tenggara based on palapa ring project," *2019 Int. Conf. Inf. Commun. Technol. ICOIACT 2019*, pp. 212–216, 2019.
[17] D. H. Rachmat, Y. G. Adhiyoga, F. Amelia, and C. Apriono, "Optical Fiber Backbone Network Development Design in East Nusa Tenggara," vol. 2, pp. 36–39, 2019.
[18] B. P. A. Mahatmanto, A. S. Nasution, R. Madina, and C. Apriono, "Design and Analysis of Optical Fiber Network for Railway Communication Lines," pp. 267–271, 2020.
[19] "Submarine Cable Map," 2020. [Online]. Available: https://www.submarinecablemap.com/#/. [Accessed: 22-Nov-2020].
[20] "BAKTI - Palapa Ring," 2018. [Online]. Available: https://www.baktikominfo.id/id/layanan/list-service/palapa_ring-384. [Accessed: 22-Nov-2020].
[21] BPS Kab. Manggarai Barat, *Kecamatan Komodo Dalam Angka 2020*. BPS Kabupaten Manggarai Barat, 2020.
[22] ITU, "G.654 : Characteristics of a cut-off shifted single-mode optical fibre and cable." [Online]. Available: https://www.itu.int/rec/T-REC-G.654/en. [Accessed: 22-Nov-2020].
[23] ITU, "G.973 : Characteristics of repeaterless optical fibre submarine cable systems." [Online]. Available: https://www.itu.int/rec/T-REC-G.973/en. [Accessed: 22-Nov-2020].
[24] Huawei, "Huawei TN55TTX. TTX Specifications," 2018. [Online]. Available: http://support.huawei.com/ hedex/pages/EDOC100015294031189461/01/EDOC1000152940311 89461/01/resources/help/wdm/ngwdm/hd/tri/ttx/ttx_specification.html. [Accessed: 22-Nov-2020].
[25] Hamamatsu, "InGaAs APD Photoreceivers," vol. 125. pp. 1–4, 2019.
[26] G. Keiser, *Optical Fiber Communication 3rd Edition*. New York, NY, USA: Springer-Verlag, 2000.

[27] G. P. Agrawal, "OPT 428 Optical Communication Systems – Agrawal Research Group." University of Rochester, Rochester-New York, 2007.
[28] A. J. Maulana, "Perencanaan Desain Jaringan Metro FTTH di Universitas Indonesia," Universitas Indonesia, 2012.