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Connectivity Revolution: Fiber Optic Network Mapping for Modern Jember

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Abstrak

Kabupaten Jember merupakan tujuan wisata bahari yang populer dengan lima pantai yang masing-masing mengalami peningkatan jumlah pengunjung setiap tahunnya di Kabupaten Jember. Meskipun pantai-pantai ini menjadi favorit dan jumlah pengunjung yang meningkat setiap tahunnya, mereka membutuhkan infrastruktur yang lebih baik untuk mendukung kegiatan pariwisata. Penelitian ini mengevaluasi desain jaringan dengan menggunakan beberapa parameter: power link budget, rise time, Signal to Noise Ratio (SNR), dan Bit Error Rate (BER). Hasil dari penelitian ini menunjukkan bahwa 39 jalur jaringan memenuhi standar perhitungan BER sebesar 10^{-12} dan standar SNR sebesar 21.5 dB.
Kata Kunci — ***Bit Error Rate, Fiber optic network, Power link budget, Rise time analysis, Signal to Noise Ratio.***

Abstract

Jember Regency is a popular marine tourism destination with five beaches, each experiencing an increase in the number of visitors each year in Jember Regency. Although these beaches are favorites and increase visitors annually, they require better infrastructure to support tourism activities. The research evaluated the network design using several parameters: power link budget, rise time, Signal to Noise Ratio (SNR), and Bit Error Rate (BER). The result of this study shows that the 39 network paths meet the BER calculation standard of 10^{-12} and the SNR standard of 21.5 dB.
Keywords — Bit Error Rate, Fiber optic network, Power link budget, Rise time analysis, Signal to Noise Ratio.

I. INTRODUCTION

Digital infrastructure and technological advancements have become essential elements in meeting the needs of modern cities. Jember Regency is located in East Java, where economic growth has accelerated due to infrastructure improvement, especially in areas such as tourism facilities and telecommunication networks [1]. Jember Regency features five popular marine tourism destinations that have continuously grown in visitor numbers. Among these attractions, Watu Ulo Beach, Papuma Beach, and Puger Beach are the second, third, and fourth most-visited beaches. These three beaches are major contributors to tourism and have experienced yearly increases in visitor numbers in the Jember Regency [2].

Tourist visits to Jember Regency grew significantly by 29%. However, tourism infrastructure has not been able to keep up with this growth. The local government has not prioritized infrastructure development for the region's three main beach tourism sites [3]. The government has allocated 57 billion in the 2024 regional budget for infrastructure development in Jember Regency. The plan includes an additional 20 billion expected to go toward marine tourism management[4]. These investments in infrastructure are anticipated to boost the income of residents.

The development of telecommunication networks and other infrastructure is crucial for the coastal areas of Jember Regency, especially as Watu Ulo, Papuma, and Puger beaches are popular tourist destinations. The development of telecommunication infrastructure is in line with the government's initiative to improve connectivity in marine tourism areas that aim to attract more visitors [5][6]. To address this issue, they constructed a fiber opric infrastructure that provides direct connectivity to the Maritime Region.

The fiber optic network in Jember Regency currently only serves three urban sub-districts: Sumbersari, Patrang, and Kaliwates. The network extends to 28 rural sub-districts, spanning approximately 1,550,355 meters with 29,667 electricity poles. The rural; areas include Kalisat, Sukowono, Sumberjambe, Mayang, Silo, Ledokombo, Arjasa, Jelbuk, Pakusari, Jenggawah, Mumbulsari, Ajung, Ambulu, Tempurejo, Wuluhan, Rambipuji, Bangsalsari, Panti, Sukorambi, Balung, Puger, Umbulsari, Kencong, Gumukmas, Jombang, Tanggul, Semboro and Sumberbaru. However, the installation of fiber optic cables and poles in Jember Regency is uncontrolled and unorganized [7]. PLN (state electricity company) conducts 24-hour supervision of the fiber optic network, so government supervision is inadequate [8]. Previous research has suggested developing backbone infrastructure to improve telecommunications connectivity and enable more effective government surveillance, especially in areas with high bandwidth requirements [9].

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According to a 2021 disaster map from BNPB, Jember Regency's marine tourism areas face significant disaster risks due to their proximity to the megathrust zone and active fault lines, making them vulnerable to earthquakes and tsunamis [10]. Puger District serves as a crucial hub for the region's submarine fiber optic network that provides inter-island connectivity [11]. Following several offshore earthquakes measuring between 5.0 and 6.0 magnitude near Jember's southern coast in 2021 [12], the government took steps to enhance the resilience of fiber optic infrastructure across marine tourism zones and districts, both within and beyond Jember Regency's boundaries.

This research examines approaches to installing fiber optic networks in coastal tourism areas and Jember Regency. The results of this research based on technical aspects include site selection, network design, determination of technical specifications, and various calculations, including power link budget, rise time, signal-to-noise ratio (SNR), and Bit Error Rate (BER).

II. Optical Fiber Network Design

Fig. 1. Scenario`s location setup

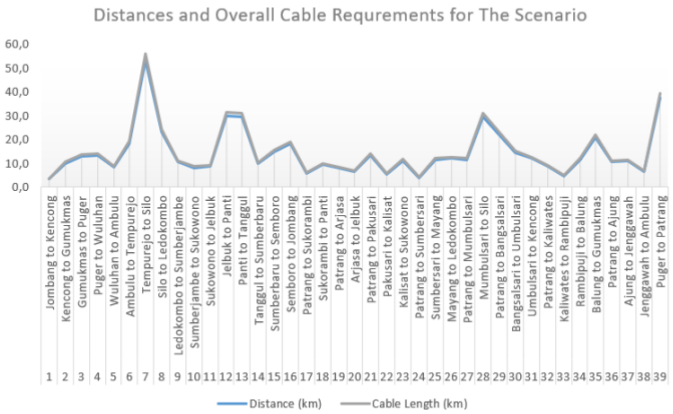

Fig. 2. Distances and Overall Cable Requrements for The Scenario

TABLE I. DISTANCES AND OVERALL CABLE REQUREMENTS FOR THE SCENARIO

No	**Route**	**Distance (km)**	**Cable Length (km)**	**Description**
1	Jombang to Kencong	3.5	3.68	Land cable
2	Kencong to Gumukmas	10.0	10.50	Land cable
3	Gumukmas to Puger	12.9	13.55	Land cable
4	Puger to Wuluhan	13.5	14.18	Land cable
5	Wuluhan to Ambulu	8.4	8.82	Land cable
6	Ambulu to Tempurejo	18.3	19.22	Land cable
7	Tempurejo to Silo	53.3	55.97	Land cable
8	Silo to Ledokombo	23.0	24.15	Land cable
9	Ledokombo to Sumberjambe	10.6	11.13	Land cable
10	Sumberjambe to Sukowono	8.2	8.61	Land cable
11	Sukowono to Jelbuk	8.7	9.14	Land cable
12	Jelbuk to Panti	29.8	31.29	Land cable
13	Panti to Tanggul	29.5	30.98	Land cable
14	Tanggul to Sumberbaru	9.8	10.29	Land cable
15	Sumberbaru to Semboro	14.8	15.54	Land cable
16	Semboro to Jombang	18.1	19.01	Land cable
17	Patrang to Sukorambi	5.9	6.20	Land cable
18	Sukorambi to Panti	9.6	10.08	Land cable
19	Patrang to Arjasa	8.0	8.40	Land cable
20	Arjasa to Jelbuk	6.4	6.72	Land cable
21	Patrang to Pakusari	13.4	14.07	Land cable
22	Pakusari to Kalisat	5.5	5.78	Land cable
23	Kalisat to Sukowono	11.2	11.76	Land cable
24	Patrang to Sumbersari	3.9	4.10	Land cable
25	Sumbersari to Mayang	11.6	12.18	Land cable
26	Mayang to Ledokombo	12.0	12.60	Land cable
27	Patrang to Mumbulsari	11.5	12.08	Land cable
28	Mumbulsari to Silo	29.7	31.19	Land cable
29	Patrang to Bangsalsari	22.0	23.10	Land cable
30	Bangsalsari to Umbulsari	14.4	15.12	Land cable
31	Umbulsari to Kencong	12.0	12.60	Land cable

32	Patrang to Kaliwates	8.6	9.03	Land cable
33	Kaliwates to Rambipuji	4.8	5.04	Land cable
34	Rambipuji to Balung	11.6	12.18	Land cable
35	Balung to Gumukmas	20.9	21.95	Land cable
36	Patrang to Ajung	10.5	11.03	Land cable
37	Ajung to Jenggawah	10.9	11.45	Land cable
38	Jenggawah to Ambulu	6.5	6.83	Land cable
39	Puger to Patrang	37.6	39.48	Land cable
Total		560.9	588.95	

The route`s starting and ending points are determined by the existing location of the MKCS cable [11]. This scenario`s location setup is illustrated in Fig. 1. The fiber optic network in Puger is a branch link from the central fiber optic network in Patrang because the location of the fiber optic network in Puger is the main link for inter-island connectivity from Jember Regency to Jimbaran, Bali. The central fiber optic network is in Patrang based on the submission of the Regent of Jember in the presentation of the work program of the Jember DPRD Secretariat [13]. A clear disaster mitigation or resilience strategy for fiber optic infrastructure is the presence of redundancy in the network design. Operational and maintenance challenges faced by communication networks that is network reliability and uptime, physical infrastructure, security concerns, technology evolution, cost management, and regulatory compliance [6]. The type of fiber optic cable used in single-mode. Patrang as a central node function as a distribution center and signal setting in a fiber optic network. Patrang also has a larger fiber optic capacity than the fiber optic network from the other nodes.

Table I. and Fig. 2. displays the computed distances and overall cable requirements for the scenario. The complete cable length calculation includes a 5% buffer allocation for each pathway and combines all route distances. In Jember, the cables extend across a total distance of 588.95 km.

Network planning parameters are determined by pre-calculating the expected bandwidth needs. These calculations are based on the population count in tourist regions, assuming each person requires 4 Mbps of bandwidth [20]. The potential internet user base consists of 34,678 people, ranging from teenagers (13 years) to seniors (over 60) [14]. Based on a requirement of 4 Mbps per user, the total bandwidth needed would be 138712 Mbps (or 138.712 Gbps) [14].

The technical specifications are detailed in Table II. The system operates at a wavelength of 1550 nm using NRZ signal encoding, with a Bit Error Rate (BER) of 10^{-12} and a system margin of 4 dB. Multiple studies provided various parameters:

1. Research [15] both reported an attenuation (α_f) of 0.16 dB/km and chromatic dispersion of 3 ps/nm.km.
2. Research [16] specified a transmit power of 4 dBm and receiver sensitivity of -24 dBm. It also documented a transceiver rise time of 28 ps, spectral width ($\sigma\lambda$) of 0.3 nm, and maximum acceptable loss of 28 dB. For connectors, each has an attenuation of 2 dB.
3. Research [17] provided several receiver parameters: a dark current of 40 nA, APD gain (M) of 20 dBm, operating temperature (T_eff) of 25˚C, excess noise figure of 0.7 nm, noise figure (FM) of 8.14 dB, and receiver efficiency of 85 %.

A Power Link Budget analysis determines if a signal`s power can successfully travel from transmitter to receiver through an optical cable over a specific distance. This analysis involves calculating the Total Loss in the network using two key equations. The first equation compares the power levels at the source and receiver. Power Link Budget, which measures the relationship between power source and receiver, can be calculated using Equation 1. While the second equation accounts for various sources of power loss – including cable attenuation, connector losses, splice losses, and a system margin (typically set at 4 dB). The Power Link Budget is calculated using Equation 2, which accounts for various sources of power loss including cable attenuation, connector loss, splice loss, and system margins (with assumed value of 4 dB). The total Loss value is then compared against the maximum loss the system can tolerate to determine if the connection is viable [18][19][20].

$$P_T = P_S - P_R \tag{1}$$

$$P_T = \alpha_f L + L_c + L_s + margin\ sistem \tag{2}$$

The rise time measurement tells us how long it takes a system to move from its starting point to a steady state. This total rise time is calculated by adding together three components: the transmitter`s rise time, the receiver`s rise time, and the rise time due to group velocity dispersion. Group velocity dispersion rise time is found by multiplying three factors: the cable`s dispersion coefficient, the length of the cable, and the wavelength range. From these calculations, we can determine the maximum allowable rise time dispersion in the system. The total rise time is calculated through a sequence of equations. First, we determine the timing using Equation 3, which feeds into Equation 4. Equation 4 combines three components to give us the total rise time: the transmitter`s rise time, the receiver`s rise time, and the group velocity dispersion rise time. The group velocity dispersion value comes from Equation 5, which multiplies three factors: the cable`s dispersion time, its length, and the wavelength width. Finally, Equation 6 determines the maximum dispersion rise time. [18][19][20].

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TABLE II. TECHNICAL SPECIFICATIONS

No	***Parameter***	***Value***	***Unit***
1	Bandwidth	138.712	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) [15]			
1	Attenuation (α_f)	0.16	dB/km
2	Chromatic Dispersion (D)	3	ps/nm.km
Huawei Optix OSN 8800 – TN55TTX [16]			
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 [17]			
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	%

$$t_{sys} = (\sum_{i=1}^{N} t_i^{\,2})^{1/2} \tag{3}$$

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

$$t_{GVD} = D.L.\sigma_\lambda \tag{5}$$

$$t_{max\,sys} = 70\% \times \frac{1}{Data\ Rate} \tag{6}$$

Bit Error Rate (BER) measures how many bits are received incorrectly compared to the total bits transmitted during a specific period. System performance improves when BER values are lower. BER can be calculated using the Q-factor, which is derived from the Signal to Noise Ratio (SNR) as shown in the referenced Equation 13. SNR, similar to BER, is a key metric for evaluating receiver performance. It compares the strength of the desired signal against background noise – a higher SNR indicates superior communication quality and system reliability [18][19][20].

$$SNR = \frac{Signal\ Power}{Noise\ Power} \tag{7}$$

The signal power represents the strength of the signal when it reaches the receiving end. The Signal to Noise Ratio (SNR) can calculated using equation 7. In Equation 8, SNR is determined by several factors: P_R represents the power detected at the receiver, η shows how efficiently the receiver operates, q is the charge of an electron, h stands for Planck`s constant, v indicates the frequency, and M represents how much the Avalanche Photodiode amplifies the signal [18][19][20].

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

The system`s noise power encompasses various noise sources including thermal, dark current, and shot noise. This total noise power can be quantified using Equation 9 [18][19][20].

$$Noise\ Power = N_{thermal} + N_{dc} + N_{shot} \tag{9}$$

Thermal noise, dark current noise, and shot noise in system can be determined using Equation 10, 11, and 12. These calculations involve several parameters: The Boltzman constant, the effective noise temperature, the bandwidth, the equivalent resistance, the dark current, and the noise figure [18][19][20].

$$N_{thermal} = \frac{4kT_{eff}B}{R} \tag{10}$$

$$N_{dc} = 2qI_D B \tag{11}$$

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

The quality factor (Q-factor) helps determine the lowest Signal to Noise Ratio (SNR) needed to achieve a specific Bit Error Rate (BER). This Q-factor depends on the Optical Signal to Noise Ratio (OSNR). The mathematical connection between SNR, Q-factor, and BER is shown in equation 13 and 14, where represents the Q-factor`s magnitude and Pe indicates the error probability. BER calculation standard of 10^{-12} and the SNR standard of 21.5 dB [18][19][20].

$$SNR = 20\log 2Q \tag{13}$$

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

III. RESULTS AND DISCUSSION

To calculate the power link budget between Jombang and Kencong, we use the formula shown in Equation 2. This equation accounts for various power losses. Including cable attenuation $(\alpha_f L)$, connector losses (L_c), splice losses (L_s), and system margins (which we assume to be 4 dB).

$P_T = \alpha_f L + L_c + L_s + margin\ sistem$

$P_T = 0.16\ \text{dB/km} * 3.68\ \text{km} + 2 * 2\ \text{dB} + 0\ \text{dB} + 4\ \text{dB}$

$P_T = 8.59\ \text{dB}$

The rise time calculation combines formulas from Equations 4 and 5. To illustrate this, let`s look at the rise time calculation for the path between Jombang and Kencong. The total rise time (t_{sys}) determined using Equation 4, which adds together three components: the transmitter rise time (t_{tx}),

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receiver rise time (t_{rx}), and group velocity dispersion rise time (t_{GVD}).

$$t_{sys} = ({t_{tx}}^2 + {t_{GVD}}^2 + {t_{rx}}^2)^{1/2}$$
$$t_{sys} = (28^2 \text{ ps} + 3.31^2 \text{ ps} + \left(\frac{350}{28}\right)^2 \text{ ps})^{1/2}$$
$$t_{sys} = 30.84 \text{ ps}$$

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.

$$t_{GVD} = D.L.\sigma_\lambda$$
$$t_{GVD} = 3 \text{ ps/nm.km} * 3.68 \text{ km} * 0.3 \text{ nm}$$
$$t_{GVD} = 3.31 \text{ ps}$$

Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER) are metrics used to evaluate data transmission errors in optical fiber networks. To determine these values, calculations are performed using a series of equations from 1 through 14. Let`s look at a specific case study between Jombang and Kencong. The first step involves using Equation 1 to determine the Power Link Budget (P_t) which analyses the relationship between transmitted power at source (P_S) and received power at destination point (P_r). In this analysis, Equation 1 specifically helps calculate the power at the receiver end (P_r).

$$P_T = P_S - P_r$$
$$P_r = P_S - P_T$$
$$P_r = 4 \text{ dB} - 8.59 \text{ dB}$$
$$P_r = -4.59 \text{ dBm}$$

The receiver measures the incoming signal strength, known as Signal Power. To determine the Signal-to-Noise Ratio (SNR), we use Equation 7. The components of the SNR calculation in Equation 8 include: the power measured at the receiver (P_R) in Watts, the efficiency of the receiver (η) as a percentage, the charge of an electron (q) which is 1.6 x 10^{-19} Coulombs, Plank's constant (h) at 6.26 x 10^{-34} Joule-seconds, the frequency (v) in Hertz, and the Avalanche Photodiode`s gain factor (M).

$$Signal\ Power = \left(P_R M \left(\frac{\eta q \lambda}{hC}\right)\right)^2 (M)^2$$
$$Signal\ Power = \left(3.48 * (10)^{-4} \text{ W} * 20 * \left(\frac{0.85 * 1.6 * (10)^{-19} \text{ C} * 1.55 * (10)^{-6} \text{ m}}{6.26 * (10)^{-34} \text{ Js} * 3 * (10)^8 \, m/s}\right)\right)^2 * (20)^2$$
$$Signal\ Power = 2.44 * (10)^{-2}$$

The following Equation 10 until 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.

$$N_{thermal} = \frac{4kT_{eff}B}{R}$$
$$N_{thermal} = \frac{4 * 1.39 * (10)^{-23} \text{J/K} * 298.15 \text{ K} * 1.39 * (10)^{11} \text{ Hz}}{50 \text{ Ohm}}$$
$$N_{thermal} = 4.58 * (10)^{-11}$$

$$N_{dc} = 2qI_D B$$
$$N_{dc} = 2 * 1.6 * (10)^{-19} \text{ C} * 4 * (10)^{-8} \text{A} * (20)^2 * 1.39 * (10)^{11} \text{Hz} * 20^{0.7}$$
$$N_{dc} = 5.78 * (10)^{-12}$$

$$N_{shot} = 2q(P_R \frac{\eta q \lambda}{hC}) B M^2 F(M)$$
$$N_{shot} = 2 * 1.6 * (10)^{-19} \text{C} * \left(3.48 * (10)^{-4} \text{W} * \left(\frac{0.85 * 1.6 * (10)^{-19} \text{ C} * 1.55 * (10)^{-6} \text{ m}}{6.26 * (10)^{-34} \text{ Js} * 3 * (10)^8 \frac{\text{m}}{\text{s}}}\right)\right) * 1.39 * 10^{11} \text{ Hz} * 20^2 * 20^{0.7}$$
$$N_{shot} = 1.13 * (10)^{-6}$$

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.

$$Noise\ Power = N_{thermal} + N_{dc} + N_{shot}$$
$$Noise\ Power = 4.58 * (10)^{-11} + 5.78 * (10)^{-12} + 1.13 * (10)^{-6}$$
$$Noise\ Power = 1.13 * (10)^{-6}$$

The receiver measures the incoming signal strength, known as Signal Power. To determine the Signal-to-Noise Ratio (SNR), we use Equation 7. The components of the SNR calculation in Equation 8 include: the power measured at the receiver (P_R) in Watts, the efficiency of the receiver (η) as a percentage, the charge of an electron (q) which is 1.6 x 10^{-19} Coulombs, Plank's constant (h) at 6.26 x 10^{-34} Joule-seconds, the frequency (v) in Hertz, and the Avalanche Photodiode`s gain factor (M). 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.

$$SNR = \frac{Signal\ Power}{Noise\ Power}$$
$$SNR = 10 * \log \frac{Signal\ Power}{Noise\ Power}$$
$$SNR = 10 * \log \frac{2.44 * (10)^{-2}}{1.13 * (10)^{-6}}$$
$$SNR = 43.34$$

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). Equation 13 and 14 represent the

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relationship between SNR, Q-factor, and BER. Q is the magnitude of the Q-factor, Pe is the probability of error.

$$SNR = 20\,log\,2Q$$

$$Q = (10)^{\frac{(\frac{SNR}{20})}{2}}$$

$$Q = (10)^{\frac{(\frac{43.34}{20})}{2}}$$

$$Q = 12.12$$

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

$$BER = Pe(Q) = \frac{1}{\sqrt{2\pi}}\frac{e^{-\frac{12.12^2}{2}}}{12.12}$$

$$\text{BER} = 2.53 * (10)^{-33}$$

The initial analysis focused on calculating the cumulative optical power loss, which was determined using Equation 1 and 2 as part of the power link budget assessment. The final calculations for total optical power loss in the scenario are presented in Table III and Fig. 3. The results demonstrate that all routes maintain power link budget values below the maximum allowable loss of 28 dB, as specified in the design parameters.

The analysis of rise time calculates how long it takes a system to stabilize from its starting state. The rise time is determined using calculations based on Equation 4 and 5, with the results for different route scenarios presented in Table IV and Fig. 4. Signal to Noise Ratio (SNR) and Bit Error Rate (BER) are metrics used to evaluate data corruption during optical fiber transmission. These parameters can be determined using mathematical expressions presented in Equation 1 and 7 through 14. The Signal to Noise Ratio (SNR) and Bit Error Rate (BER) calculations for the routes are presented in Table V. The results of this study show that 39 sub-district routes in Jember Regency networks meet the BER calculation standard of 10^{-12} and SNR standard of 21.5 dB. The longest route based on the sub-district distance scenario in Jember Regency, namely Tempurejo to Silo, reaches 55.97 km with a BER calculation of 2.22×10^{-13} and SNR of 34.98 dB. The shortest route based on the sub-district distance scenario in Jember Regency, namely Jombang to Kencong, reaches 3.5 km with a BER calculation of 2.53×10^{-33} and SNR of 43.34 dB.

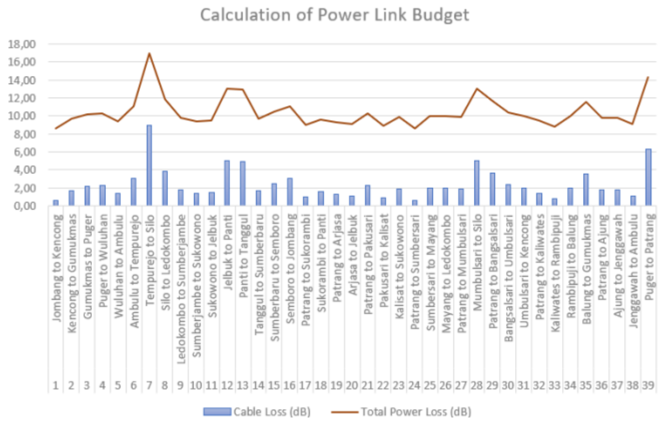

Fig. 3. Calculation of Power Link Budget

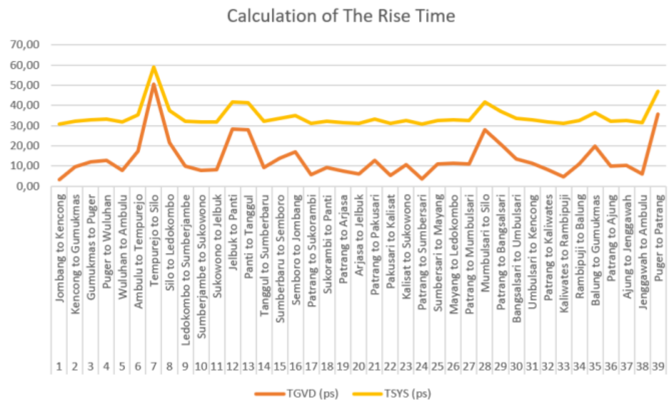

Fig. 4. Calculation of The Rise Time

TABLE III. CALCULATION OF POWER LINK BUDGET

No	Route	Cable Loss (dB)	Total Power Loss (dB)	Maximum Allowable Loss (28 dB)
1	Jombang to Kencong	0.59	8.59	Yes
2	Kencong to Gumukmas	1.68	9.68	Yes
3	Gumukmas to Puger	2.17	10.17	Yes
4	Puger to Wuluhan	2.27	10.27	Yes
5	Wuluhan to Ambulu	1.41	9.41	Yes
6	Ambulu to Tempurejo	3.07	11.07	Yes
7	Tempurejo to Silo	8.95	16.95	Yes
8	Silo to Ledokombo	3.86	11.86	Yes
9	Ledokombo to Sumberjambe	1.78	9.78	Yes
10	Sumberjambe to Sukowono	1.38	9.38	Yes
11	Sukowono to Jelbuk	1.46	9.46	Yes

12	Jelbuk to Panti	5.01	13.01	Yes
13	Panti to Tanggul	4.96	12.96	Yes
14	Tanggul to Sumberbaru	1.65	9.65	Yes
15	Sumberbaru to Semboro	2.49	10.49	Yes
16	Semboro to Jombang	3.04	11.04	Yes
17	Patrang to Sukorambi	0.99	8.99	Yes
18	Sukorambi to Panti	1.61	9.61	Yes
19	Patrang to Arjasa	1.34	9.34	Yes
20	Arjasa to Jelbuk	1.08	9.08	Yes
21	Patrang to Pakusari	2.25	10.25	Yes
22	Pakusari to Kalisat	0.92	8.92	Yes
23	Kalisat to Sukowono	1.88	9.88	Yes
24	Patrang to Sumbersari	0.66	8.66	Yes
25	Sumbersari to Mayang	1.95	9.95	Yes
26	Mayang to Ledokombo	2.02	10.02	Yes
27	Patrang to Mumbulsari	1.93	9.93	Yes
28	Mumbulsari to Silo	4.99	12.99	Yes
29	Patrang to Bangsalsari	3.70	11.70	Yes
30	Bangsalsari to Umbulsari	2.42	10.42	Yes
31	Umbulsari to Kencong	2.02	10.02	Yes
32	Patrang to Kaliwates	1.44	9.44	Yes
33	Kaliwates to Rambipuji	0.81	8.81	Yes
34	Rambipuji to Balung	1.95	9.95	Yes
35	Balung to Gumukmas	3.51	11.51	Yes
36	Patrang to Ajung	1.76	9.76	Yes
37	Ajung to Jenggawah	1.83	9.83	Yes
38	Jenggawah to Ambulu	1.09	9.09	Yes
39	Puger to Patrang	6.32	14.32	Yes

TABLE IV. CALCULATION OF THE RISE TIME

No	**Route**	**T_{gvd} (ps)**	**T_{sys} (ps)**
1	Jombang to Kencong	3.31	30.84
2	Kencong to Gumukmas	9.45	32.09
3	Gumukmas to Puger	12.19	33.00
4	Puger to Wuluhan	12.76	33.21
5	Wuluhan to Ambulu	7.94	31.67
6	Ambulu to Tempurejo	17.29	35.20
7	Tempurejo to Silo	50.37	58.97
8	Silo to Ledokombo	21.74	37.59
9	Ledokombo to Sumberjambe	10.02	32.26
10	Sumberjambe to Sukowono	7.75	31.63
11	Sukowono to Jelbuk	8.22	31.75
12	Jelbuk to Panti	28.16	41.63
13	Panti to Tanggul	27.88	41.44
14	Tanggul to Sumberbaru	9.26	32.03
15	Sumberbaru to Semboro	13.99	33.70
16	Semboro to Jombang	17.10	35.11
17	Patrang to Sukorambi	5.58	31.17
18	Sukorambi to Panti	9.07	31.98
19	Patrang to Arjasa	7.56	31.58
20	Arjasa to Jelbuk	6.05	31.25
21	Patrang to Pakusari	12.66	33.18
22	Pakusari to Kalisat	5.20	31.10
23	Kalisat to Sukowono	10.58	32.44
24	Patrang to Sumbersari	3.69	30.88
25	Sumbersari to Mayang	10.96	32.56
26	Mayang to Ledokombo	11.34	32.69
27	Patrang to Mumbulsari	10.87	32.53
28	Mumbulsari to Silo	28.07	41.57
29	Patrang to Bangsalsari	20.79	37.05
30	Bangsalsari to Umbulsari	13.61	33.55
31	Umbulsari to Kencong	11.34	32.69
32	Patrang to Kaliwates	8.13	31.72
33	Kaliwates to Rambipuji	4.54	31.00
34	Rambipuji to Balung	10.96	32.56
35	Balung to Gumukmas	19.75	36.47
36	Patrang to Ajung	9.92	32.23
37	Ajung to Jenggawah	10.30	32.35
38	Jenggawah to Ambulu	6.14	31.27
39	Puger to Patrang	35.53	46.93

TABLE V. SNR AND BER

No	**Route**	**Pr (dBm)**	**Q**	**SNR**	**BER**	**BER standard (10^{-12})**
1	Jombang to Kencong	-4.59	12.12	43.34	2.53×10^{-33}	Yes

2	Kencong to Gumukmas	-5.68	11.38	42.25	1.59×10^{-29}	Yes
3	Gumukmas to Puger	-6.17	11.07	41.76	5.60×10^{-28}	Yes
4	Puger to Wuluhan	-6.27	11.01	41.66	1.14×10^{-27}	Yes
5	Wuluhan to Ambulu	-5.41	11.56	42.52	2.04×10^{-30}	Yes
6	Ambulu to Tempurejo	-7.07	10.51	40.86	2.57×10^{-25}	Yes
7	Tempurejo to Silo	-12.95	7.49	34.98	2.22×10^{-13}	Yes
8	Silo to Ledokombo	-7.86	10.04	40.07	3.25×10^{-23}	Yes
9	Ledokombo to Sumberjambe	-5.78	11.32	42.15	3.37×10^{-29}	Yes
10	Sumberjambe to Sukowono	-5.38	11.58	42.55	1.57×10^{-30}	Yes
11	Sukowono to Jelbuk	-5.46	11.53	42.47	3.01×10^{-30}	Yes
12	Jelbuk to Panti	-9.01	9.40	38.93	1.73×10^{-20}	Yes
13	Panti to Tanggul	-8.96	9.43	38.98	1.34×10^{-20}	Yes
14	Tanggul to Sumberbaru	-5.65	11.41	42.29	1.23×10^{-29}	Yes
15	Sumberbaru to Semboro	-6.49	10.87	41.45	5.20×10^{-27}	Yes
16	Semboro to Jombang	-7.04	10.53	40.89	2.07×10^{-25}	Yes
17	Patrang to Sukorambi	-4.99	11.84	42.94	7.26×10^{-32}	Yes
18	Sukorambi to Panti	-5.61	11.43	42.32	9.56×10^{-30}	Yes
19	Patrang to Arjasa	-5.34	11.61	42.59	1.21×10^{-30}	Yes
20	Arjasa to Jelbuk	-5.08	11.79	42.86	1.43×10^{-31}	Yes
21	Patrang to Pakusari	-6.25	11.02	41.68	1.01×10^{-27}	Yes
22	Pakusari to Kalisat	-4.92	11.89	43.01	4.19×10^{-32}	Yes
23	Kalisat to Sukowono	-5.88	11.25	42.05	7.11×10^{-29}	Yes
24	Patrang to Sumbersari	-4.66	12.08	43.28	4.48×10^{-33}	Yes
25	Sumbersari to Mayang	-5.95	11.21	41.98	1.16×10^{-28}	Yes
26	Mayang to Ledokombo	-6.02	11.17	41.92	1.89×10^{-28}	Yes
27	Patrang to Mumbulsari	-5.93	11.22	42.00	1.03×10^{-28}	Yes
28	Mumbulsari to Silo	-8.99	9.41	38.94	1.59×10^{-20}	Yes
29	Patrang to Bangsalsari	-7.70	10.14	40.24	1.20×10^{-23}	Yes
30	Bangsalsari to Umbulsari	-6.42	10.91	41.51	3.28×10^{-27}	Yes
31	Umbulsari to Kencong	-6.02	11.17	41.92	1.89×10^{-28}	Yes
32	Patrang to Kaliwates	-5.44	11.54	42.49	2.65×10^{-30}	Yes
33	Kaliwates to Rambipuji	-4.81	11.97	43.13	1.59×10^{-32}	Yes
34	Rambipuji to Balung	-5.95	11.21	41.98	1.16×10^{-28}	Yes
35	Balung to Gumukmas	-7.51	10.25	40.42	3.95×10^{-24}	Yes
36	Patrang to Ajung	-5.76	11.33	42.17	2.98×10^{-29}	Yes
37	Ajung to Jenggawah	-5.83	11.29	42.10	4.90×10^{-29}	Yes
38	Jenggawah to Ambulu	-5.09	11.78	42.84	1.64×10^{-31}	Yes
39	Puger to Patrang	-10.32	8.72	37.61	9.09×10^{-18}	Yes

IV. CONCLUSION

Jember Regency has 5 marine tourism destinations, with Watu Ulo Beach, Papuma, and Puger as the main tourist attractions. Tourist visits increased by 29%, but the infrastructure has not been able to keep up with this growth. The government allocated 57 billion in the 2024 Regional Budget for insfrastructure development, with 20 billion focused on marine tourism management.

Jember`s marine tourism areas are located in disaster-pone zone (earthquakes and tsumanis). Puger District plays an important role as a hub for underwater fiber optic networks. After several earthquakes measuring 5.0 – 6.0 in 2021, the government improved the resilience of fiber optic infrastructure. A clear disaster mitigation or resilience strategy for fiber optic infrastructure is the presence of redundancy in the network design.

This research examines the approach to fiber optic network installation in coastal tourism areas and Jember Regency, taking into account technical aspects such as site selection, network design, technical specifications, and various technical calculations (power link budget, rise time, SNR, and BER).

The results of this study show that 39 sub-district routes in Jember Regency networks meet the BER calculation standard of 10^{-12} and SNR standard of 21.5 dB. The longest route based on the sub-district distance scenario in Jember Regency, namely Tempurejo to Silo, reaches 55.97 km with a BER calculation of 2.22×10^{-13} and SNR of 34.98 dB. The shortest route based on the sub-district distance scenario in Jember Regency, namely Jombang to Kencong, reaches 3.5 km with a BER calculation of 2.53×10^{-33} and SNR of 43.34 dB.

Future research can take into account SWOT analysis so that it can provide a comprehensive view; facilitate decision making; be flexible and simple; increase organizational awareness; encourage strategic thinking; be cost-effective; and improve performance.

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