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COMPARATIVE ANALYSIS OF NETWORK PERFORMANCE BETWEEN MULTIPROTOCOL LABEL SWITCHING AND SOFTWARE-DEFINED WIDE AREA NETWORK USING QUANTITATIVE EXPERIMENTAL METHODS AT BANK RAKYAT INDONESIA

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Abstract

Bank Rakyat Indonesia's conventional network infrastructure based on MPLS is considered to have limitations in traffic management flexibility, bandwidth capacity, and operational cost efficiency. Therefore, the implementation of SD-WAN has emerged as a solution to improve network performance and optimize service quality. This study aims to comparatively analyze the network performance of MPLS and SD-WAN using a quantitative experimental approach in the environment of BRI. The research method was conducted by applying specific treatments and testing scenarios, such as bandwidth configuration, traffic load simulation, and failover testing, followed by controlled measurements of Quality of Service parameters, including throughput, latency, jitter, packet loss, and bandwidth utilization. The research data were obtained from the Dashboard MONICA and Portal NSO. The experimental results indicate that the implementation of SD-WAN improves network performance, particularly in maintaining latency and jitter stability, reducing packet loss, and optimizing bandwidth utilization under various operational conditions. Furthermore, the cost analysis reveals potential operational cost efficiency compared to conventional MPLS-based networks. Based on the experimental results and quantitative analysis, it can be concluded that SD-WAN implementation is technically and economically effective in supporting the modernization of data communication network infrastructure at BRI.
Keyword: *SDWAN, MPLS, Network, Performance, Comparative*

Abstrak

Infrastruktur jaringan Bank Rakyat Indonesia yang konvensional berbasis MPLS dinilai memiliki keterbatasan dalam fleksibilitas pengelolaan trafik, kapasitas bandwidth, serta efisiensi biaya operasional. Oleh karena itu, penerapan teknologi SD-WAN menjadi salah satu solusi untuk meningkatkan kinerja jaringan dan mengoptimalkan kualitas layanan. Penelitian ini bertujuan untuk menganalisis secara komparatif kinerja jaringan MPLS dan SD-WAN melalui pendekatan eksperimental kuantitatif di lingkungan BRI. Metode penelitian dilakukan dengan memberikan perlakuan dan skenario pengujian tertentu, seperti pengaturan bandwidth, simulasi beban trafik, dan pengujian failover, kemudian mengukur parameter Quality of Service berupa throughput, latency, jitter, packet loss, dan utilisasi bandwidth secara terkontrol. Data penelitian diperoleh dari sistem monitoring Dashboard MONICA dan Portal NSO. Hasil pengujian menunjukkan bahwa implementasi SD-WAN mampu meningkatkan performa jaringan, khususnya dalam menjaga stabilitas latency dan jitter, mengurangi tingkat packet loss, serta mengoptimalkan pemanfaatan bandwidth pada berbagai kondisi operasional. Selain itu, hasil analisis biaya menunjukkan adanya potensi efisiensi biaya operasional dibandingkan

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dengan penggunaan jaringan berbasis MPLS konvensional. Berdasarkan hasil eksperimen dan analisis kuantitatif yang dilakukan, dapat disimpulkan bahwa penerapan SD-WAN efektif secara teknis dan ekonomis dalam mendukung modernisasi infrastruktur jaringan komunikasi data di BRI.
Kata kunci*:* *SDWAN, MPLS, Network, Performance, Comparative*

I. INTRODUCTION

The development of digital services in the banking sector requires a fast, secure, reliable, and stable data communication infrastructure (Dewi & Teknik, 2022). The quality of the data communication network is a key factor in supporting operational activities, financial transactions, and the integration of banking information systems. Herefore, the availability of a high-performance network capable of adapting to the growingdemand for digital sevices is essential (Alfaujianto, Moh., Muttaqi, Fajar, Badriah, 2025). Bank Rakyat Indonesia (BRI) as one of the banks with the largest operational networks in Indonesia, has moe than 6000 branches spread across various regions (Bank Rakyat Indonesia, 2023). All of these brances are connected via data communication neworrk that links branch offices with data centers in Ragunan, Sentul, and Tabanan. To date the network connection BRI's business units has relied on Multiprotocol Label Swiching (MPLS) technology as the primary path, while VSAT, cellular VPN, and fiber optic serve as backup paths (Bank Rakyat Indonesia, 2023).

MPLS technology is known for its high level of stability and service level agreement (SLAs). However, as it has evolved, MPLS has begun o face several limitations, particularly in terms of relatively high operating costs, limited bandwidth capacity, and low flexibility in handling data traffic growth. Furthermore, the centralized nature of the MPLS network architecture requires all traffic to pass through a data center, which has the potential to increase latency and reduce bandwidth utilization efficiency (Kamila, Nurul, Suryadi, Amalia, Ismi, Rhamadania, Kustita, Firdhausiah, Salsabilah, 2024). In an effort to address these limitaions, BRI has begun implementing Software-Defined Wide Area Network (SD-WAN) technology. This echnology enables centralized network management by leveraging various connectivity media such as Dedicated Inernet, MPLS, VSAT, and cellular VPN within a single integrated platform. SD-WAN is equipped with application aware routing and dynamic path selection features that allow for automatic selection of communication paths based on network conditions and application requirements(Kamila, Nurul, Suryadi, Amalia, Ismi, Rhamadania, Kustita, Firdhausiah, Salsabilah, 2024). Although the implementation of SD-WAN is believed to enhance network flexibility and efficiency, its performance effectiveness compared to MPLS needs to be demonstrated through measurable and systematic testing. Observational evaluations alone are insufficient to accurately describe the performance differences between the two technologies under various operational conditions(Alfaujianto, Moh., Muttaqi, Fajar, Badriah, 2025). Therefore, a scientific study is needed that employes an experimental approach, spesifically by applying specific treatments and test scenarios to MPLS and SD-WAN networks, such as bandwidth configuration, traffic load simulation, and failover testing. The impact of each pf these treatments on network performance is measured numerically using the parameters of throughput, laency, jitter, packet loss, and bandwidth utilization(Manova et al., 2022). Given these circumstances, this study was conducted to comparatively analyze the performance of Multiprotocol Label Switching (MPLS) and Software-Defined Wide Area Network (SD-WAN) networks within Bank Rakyat Indonesia using a quantitative experimental method. Through direct testing and controlled measurements, it is hoped that an objective, measurable, and verifiable picture of these strengths and limitation of each technology can be obtained to serve as a basis for decision-making in the development of the company's network infrastructure.

II. THEORETICAL STUDIES

Muliprotocol Label Switching (MPLS) is a data communication network technology that uses a label-switching mechanism to speed up the transmission of data packets between network nodes (Shaik, 2021). This technology operates at the layer between layer 2 (Data Link) and Layer 3 (Network) in the OSI reference model, which is why it is often reffered to as "Layer 2.5" technology. Using this labeling system, MPLS is able to route traffeic based on predefined paths, known as Label-Switched Paths (LSPs). In practice, every data paket entering the MPLS network is assigned a header label by a Label Edge Routers (LSRs) along he communication path without he need to read the destination IP address at each hop. This process speeds up data transmission while enabling more pprecise implementation of Quality Service (QoS) policies (Shaik, 2021). Software-Defined Wide Area Network (SD-WAN) is a software defined networking technology ha connects various network location efficiently by separating the control plane from the data plane(12). SD-WAN enables network administrators to centrally manage monitor, and optimize data traffic using dynamic and adaptive policies without the need for manual configuration on each branch device. Technically, SD-WAN works by creating an overlay network layer on top of various physical connectivity media (underlay networks), such as dedicated internet, MPLS, VSAT, and cellular VPNs (Dudczyk

& Sergiel, 2025). The SD-WAN Controller is a key component in a software-Defined Wide Area Network (SD-WAN) architecture that serves as the network's control and orchestration center. The controller serves to separate the control plane from the data plane, so that network decision-making is centralized, while data transmission continues to take place on the physical network device. This separation provides flexibility, scalability, and ease of network management, especially for organizations wih many brances and complex connectivity needs. In principles, an SD-WAN controller provides a centralized management mechanism that allows network administrators to configure, monitor, and enforce prolicies comprehensively through a single platform. This approach reduces the need for manual configuration on each device, improves policy consistency, and minimizes the potential for configurarion erros that often occur in traditional network systems. The controller ensures tha these security policies are applied uniformly across all device (Kamila, Nurul, Suryadi, Amalia, Ismi, Rhamadania, Kustita, Firdhausiah, Salsabilah, 2024). As a result, all company locations adhere to the same security standards, reducing the risk of vulnerabilities arising from manual and inconsistent configurations.

III. RESEARCH METHODS

The method used in this study is a quantitative experimental method, which involves applying a specific treatment to the research subjects and then systematically measuring the effects of that treatment in the form of numerical data that can be statistically analyzed (Dewi & Teknik, 2022). This method aims to identify causal relationships between independent and dependent variables through controlled testing. In the context of computer network research, the quantitative experimental method is used to test network system performance based on measurable technical parameters, such as throughput, latency, jitter, and packet loss (Alfaujianto, Moh., Muttaqi, Fajar, Badriah, 2025). Controlling variables aims to minimize the influence of external factors on the research results (5). In this study, network performance was measured based on Quality of Service (QoS) parameters, namely latency, jitter, packet loss, throughput, and bandwidth utilization. Each parameter was calculated using the following formulas:

1. Latency (Delay) Calculation

Latency is the delay time required for a data packet to travel from the sender to the receiver.

Formula for Average Latency:

$$\boldsymbol{Latency_{avg} = \frac{\sum_{i=1}^{n} D_i}{n}}$$

Description:

D_i = delay time of the i-th packet (ms)

n = number of packets observed

2. Jitter Calculation

Jitter is the variation in delay time between consecutively received packets.

Jitter Formula:

$$\boldsymbol{Jitter} = \frac{\sum_{i=1}^{n-1} |\, D_{i+1} - D_i \,|}{n-1}$$

Description:

D_i = delay of the i-th packet (ms)

D_(i+1) = delay of the next packet

n = number of packets

3. Packet Loss Formula

Packet loss indicates the percentage of packets lost during transmission.

Packet Loss Formula:

$$\boldsymbol{PacketLoss}(\%) = \frac{P_{send} - P_{receive}}{P_{send}} \times 100\%$$

Description:

P_send = number of packets sent

P_receive = number of packets received

4. Throughput Calculation

Throughput indicates the amount of data successfully transmitted within a given unit of time.

Throughput Formula:

In bits:

Throughput = Total Data (bits) / Transmission Time (seconds)
or as an equation:
Throughput = (Total Data (bits)) ÷ (Transmission Time (seconds))
In bytes:
Throughput = (Total Data (bytes) × 8) / Transmission Time (seconds)
or as an equation:
Throughput = (Total Data (bytes) × 8) ÷ (Transmission Time (seconds))

Notes:

Total Data = the amount of data successfully transmitted

Transmission Time = the time it takes to send data

5. Bandwidth Utilisation Formula:

Bandwidth utilization indicates the degree to which link capacity is being used.

Bandwidth Utilization Formula:

$$\boldsymbol{Utilisasi}(\%) = \frac{\boldsymbol{Throughput}}{\boldsymbol{Bandwidth\ Maksimum}} \times \mathbf{100}\%$$

6. Calculation of the Daily Average of Parameters

To calculate the daily average:

$$\boldsymbol{Nilai_{harian}} = \frac{\sum_{i=1}^{m} X_i}{m}$$

Notes:

X_i = parameter value for each hour/period

m = number of periods in a day

7. Calculation of the 95th Percentile (P95) Bandwidth

Used to determine the peak traffic value.

P95 Formula:

Sort the data from smallest to largest

Determine the position:

$$\boldsymbol{P95} = \mathbf{0,95} \times (\boldsymbol{N} + \mathbf{1})$$

Take the value at that position

Note:

N = number of data points

Calculation Example

Packet Loss Example

Packets sent = 10,000

Packets received = 9,980

$$\boldsymbol{PacketLoss} = \frac{\mathbf{10000 - 9980}}{\mathbf{10000}} \times \mathbf{100}\% = \mathbf{0,2}\%$$

Throughput Example

Data transmitted = 500 MB

Time = 100 seconds

$$\boldsymbol{Throughput} = \frac{\mathbf{500 \times 8}}{\mathbf{100}} = \mathbf{40}\ \boldsymbol{Mbps}$$

Example of Utilization

Bandwidth = 50 Mbps

Throughput = 40 Mbps

$$\boldsymbol{Utilisasi} = \frac{\mathbf{40}}{\mathbf{50}} \times \mathbf{100\%} = \mathbf{80\%}$$

To ensure objective and accurately comparable test results, this study employed controlled variables. These variables were controlled to ensure that any differences in the results were truly attributable to the differences in the network technologies being tested—namely,

IV. RESEARCH RESULTS

Preliminary network testing was conducted as an initial step in this study to obtain an initial overview of the performance of Multiprotocol Label Switching (MPLS) and Software-Defined Wide Area Network (SD-WAN) before conducting further analysis. This testing aimed to identify the performance characteristics of each network technology under controlled conditions and to serve as a basis for developing subsequent test scenarios. The preliminary testing was conducted using a quantitative experimental method by implementing several testing schemes in stages. Each testing scheme was carried out under relatively similar operational conditions to ensure consistency in the measurement results. The first phase of testing was conducted on a network that uses Multiprotocol Label Switching (MPLS) as the primary data communication path. The testing aimed to determine the baseline performance of the MPLS network under normal operational conditions. The MPLS testing involved monitoring the MPLS network for 60 business days, collecting data via the MONICA Dashboard and the NSO Portal, and processing the data using Python. The parameters tested were latency, jitter, packet loss, throughput, and bandwidth utilization. The results of the MPLS testing are shown in Table 4.

Table 4. MPLS Test Result

Parameter	Minimum	Maximum	Average	SLA BRI	Analysis
Latency (ms)	15	32	22,4	≤ 2000	Latency values are low and stable. The average latency indicates a fast network response time and remains well below the established SLA threshold.
Jitter (ms)	0,4	2,1	1,3	≤ 2000	The jitter value is very low and consistently below 2 ms, indicating very low delay variation and good network stability.
Packet Loss (%)	0,0	0,2	0,05	< 30	The packet loss rate is very low (<0.1%), indicating that data transmission is highly reliable.

Throughput (Mbps)	4,2	6,1	5,4	-	Throughput is relatively limited because it is constrained by the available MPLS link bandwidth.
Utilisasi Bandwidth (%)	65	88	76	-	Bandwidth utilization was quite high (>70%), indicating that most of the link capacity was used during the testing process.

The second phase of testing was conducted on a network that had implemented an Internet-based SD-WAN architecture. The testing phases included monitoring the SD-WAN network for 60 business days, collecting data via the MONICA Dashboard and the NSO Portal, and processing the data using Python. The results of the SD-WAN testing are shown in Table 5.

Table 5. SD-WAN Test Result

Parameter	Minimum	Maximum	Average	SLA BRI	Analysis
Latency (ms)	15	32	22,4	≤ 2000	Latency levels are relatively low and stable, indicating fast network response times and falling well below the established SLA thresholds.
Jitter (ms)	0,4	2,1	1,3	≤ 2000	The jitter value is very small and consistent, indicating low delay variation, which ensures that data communication quality remains stable.
Packet Loss (%)	0,0	0,2	0,05	< 30	The packet loss rate is very low (<0.1%), indicating high network reliability during data transmission.
Throughput (Mbps)	4,2	6,1	5,4	-	Throughput is relatively limited because the bandwidth capacity of the MPLS network is determined by the services being used.
Utilisasi (%)	65	88	76	-	Bandwidth utilization was quite high (>70%), indicating that most of the network capacity was used during the testing process.

The third phase of testing was conducted by enabling MPLS and SD-WAN simultaneously. The testing scenarios included monitoring the MPLS and SD-WAN networks for 60 business days, collecting data via the MONICA Dashboard and the NSO Portal, and processing the data using Python. The results of the multipath testing are shown in Table 6.

Table 6. MPLS dan SDWAN Test Result

Parameter	Minimum	Maximum	Average	SLA BRI	Analysis
Latency (ms)	24	55	34,6	≤ 2000	The latency is slightly higher than that of MPLS, but it

					remains within the SLA limits and is therefore still capable of supporting network operations.
Jitter (ms)	1,2	4,5	2,9	≤ 2000	The jitter value remains in the low range and shows no significant fluctuations in data communication.
Packet Loss (%)	0,1	0,9	0,40	< 30	The packet loss rate remains in the “very good” category because it is below 1%, so data transmission continues to function properly.
Throughput (Mbps)	15,8	48,5	32,7	-	Throughput is higher than with MPLS because SD-WAN utilizes a larger amount of Internet bandwidth.
Utilisasi (%)	45	82	61	-	Bandwidth utilization is more balanced, resulting in more efficient use of network capacity.

Figure I, which shows the daily latency graph, indicates that the average latency of the MPLS network ranges from 15 to 27 ms, while that of SD-WAN ranges from 25 to 45 ms. This shows that MPLS has better latency stability than SD-WAN.

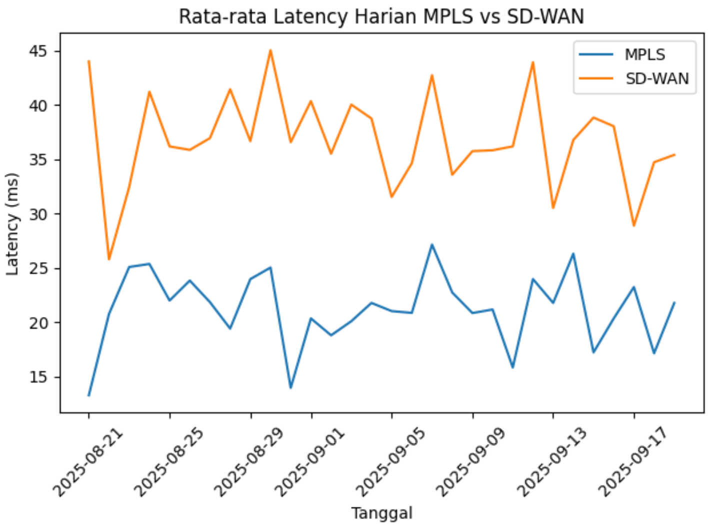

Figure I. Daily Latency Chart

Jitter on MPLS networks is relatively stable at under 2 ms, whereas jitter on SD-WAN networks tends to be more variable, with an average value of about 2–4 ms. The daily jitter graph is shown in Figure 2.

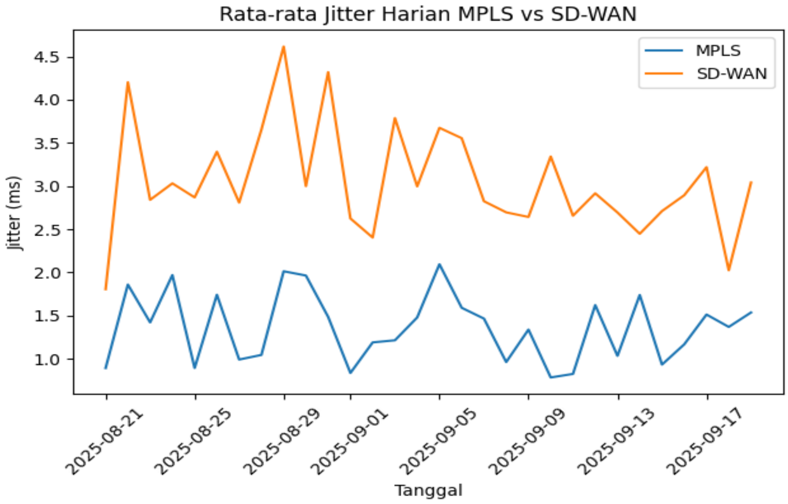

Figure 2. Daily Jitter Chart

SD-WAN network throughput is significantly higher than that of MPLS. The average SD-WAN throughput exceeds 30 Mbps, while MPLS averages only about 5 Mbps. The daily throughput graph is shown in Figure 3. A discussion of the overall network performance comparison can be found in Table 7.

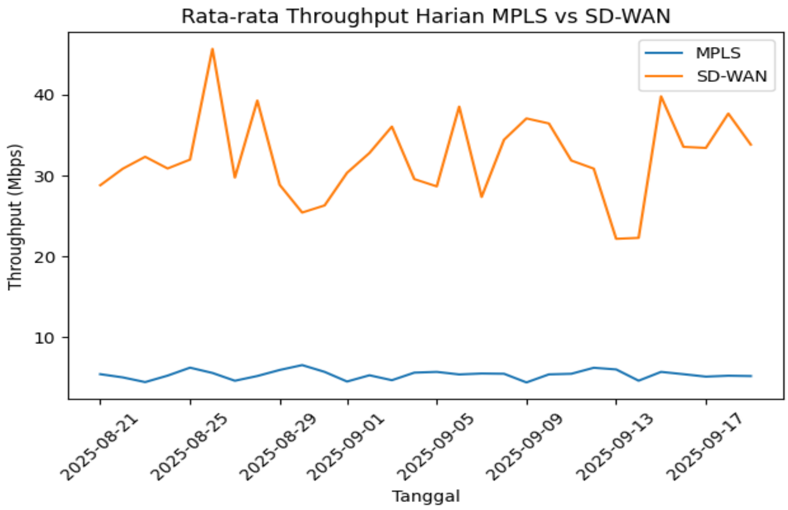

Figure 3. Daily Througput Chart

Table 7. Comparison of MPLS and SD-WAN

Parameter	MPLS	SD-WAN	Hybrid	Analysis
Latency (ms)	22,4	34,6	20,3	MPLS has low latency because it uses private links, while SD-WAN has higher latency due to its reliance on the Internet. However, a hybrid configuration can optimize path selection to achieve the lowest latency.
Jitter (ms)	1,3	2,9	1,8	MPLS jitter is relatively stable, while SD-WAN jitter is more variable due to fluctuations in public network quality. Hybrid solutions can reduce jitter variability through traffic steering mechanisms.
Packet Loss (%)	0,05	0,40	0,03	MPLS has an extremely low packet loss rate. With SD-WAN, packet loss increases slightly

				due to Internet fluctuations, but it remains within SLA limits. The hybrid approach offers the highest level of reliability.
Throughput (Mbps)	5,4	32,7	38,4	SD-WAN and hybrid solutions offer significantly higher throughput than MPLS because they leverage high Internet bandwidth. Hybrid solutions are able to optimally combine the capacity of both links.
Fleksibilitas	Rendah	Tinggi	Sangat Tinggi	MPLS has limited flexibility because it depends on the provider. SD-WAN enables centralized and adaptive configuration. A hybrid approach offers maximum flexibility in network management.

Based on the results of testing and analysis of network performance parameters, the following findings were obtained:

1. Latency

a. The MPLS network has an average latency of 22.4 ms, indicating good stability because it uses private links.

b. SD-WAN has a higher latency of 34.6 ms, which is influenced by Internet network conditions.

c. The hybrid configuration shows the lowest latency value of 20.3 ms, achieved through an automatic best-path selection mechanism.

2. Jitter (Variation in Delay)

a. MPLS has the lowest jitter value of 1.3 ms, making it highly suitable for real-time applications.

b. SD-WAN has a jitter of 2.9 ms, which remains within standard service tolerance limits.

c. The hybrid configuration reduces jitter variation to 1.8 ms through adaptive traffic management.

3. Packet Loss

a. The packet loss rate for MPLS is 0.05%, indicating high network reliability.

b. SD-WAN has a packet loss rate of 0.40%, due to fluctuations in public network quality, but still meets SLA standards.

c. The hybrid solution shows the lowest rate at 0.03%, making it the most reliable configuration for data transmission.

4. Throughput (Data Transmission Capacity)

a. MPLS has a relatively low throughput of 5.4 Mbps, due to bandwidth limitations.

b. SD-WAN shows a significant improvement with a throughput of 32.7 Mbps.

c. The hybrid configuration has the highest throughput at 38.4 Mbps, as it utilizes both paths simultaneously.

5. Bandwidth Utilization

a. MPLS has an average utilization of

b. SD-WAN has a more balanced utilization rate of 61%, reflecting more efficient bandwidth management.

c. The hybrid solution has a utilization rate of 72%, indicating optimal network utilization.

6. Network Management

a. MPLS network management remains limited and heavily dependent on service providers.

b. SD-WAN provides a centralized management system that simplifies configuration and monitoring.

c. Hybrid solutions also use centralized management, ensuring efficient administration.

7. Network Flexibility
a. MPLS has a low level of flexibility because configuration changes require a lengthy process.
b. SD-WAN offers high flexibility in setting network policies.
c. Hybrid solutions provide the highest flexibility through the integration of multiple connectivity media.
8. Operating Costs
a. The operating costs for MPLS are relatively high, at around Rp15.5 million per month.
b. SD-WAN has the lowest costs, at around Rp5.7 million per month.
c. The hybrid solution has moderate costs of Rp9.2 million per month.
9. Feasibility of Implementation
a. MPLS is considered to have limited feasibility for long-term development.
b. SD-WAN is considered highly feasible for supporting digital transformation in the banking sector.
c. A hybrid approach is considered feasible as a transitional solution prior to the full implementation of SD-WAN.
Details of the overall performance differences can be seen in Table 8.

Table 8. Comparison Results for MPLS, SD-WAN, and Hybrid

Parameter	MPLS	SD-WAN	Hybrid
Latency (ms)	22,4	34,6	20,3
Jitter (ms)	1,3	2,9	1,8
Packet Loss (%)	0,05	0,40	0,03
Throughput (Mbps)	5,4	32,7	38,4
Utilization (%)	76	61	72
Management	Limited	Centralized	Centralized
Flexibility	Low	High	Very High
Cost/Month (Rp)	15,5Million	5,7Million	9,2Million
Feasibility	Limited	Highly Recomended	Recomended

V.CONCLUSION

Based on the results of testing, analysis, and discussion conducted on the performance of Multiprotocol Label Switching (MPLS) and Software-Defined Wide Area Network (SD-WAN) networks within the Bank Rakyat Indonesia environment using quantitative experimental methods, several conclusions can be drawn: In terms of latency, the MPLS network exhibits lower and more stable values compared to SD-WAN. However, the hybrid configuration was able to produce the most optimal latency through an adaptive path selection mechanism. In terms of jitter, the MPLS network exhibited better stability. Nevertheless, the jitter in the SD-WAN remained within the service standard’s tolerance limits and did not disrupt banking operations. Based on packet loss measurements, all tested technologies—MPLS, SD-WAN, and the hybrid configuration—exhibited very low packet loss rates and met Bank Rakyat Indonesia’s Service Level Agreement standards. In terms of throughput, SD-WAN and the hybrid network demonstrated significant advantages over MPLS. This is due to greater Internet bandwidth capacity and the ability to dynamically manage traffic. In terms of flexibility and network management, SD-WAN offers key advantages through its centralized management system, application-based policies, and automatic failover mechanisms. Based on an analysis of operational cost efficiency, the use of SD-WAN can significantly reduce network costs compared to MPLS, making it more cost-effective in the long term. A hybrid MPLS–SD-WAN configuration offers the best technical performance; however, a full-scale implementation of SD-WAN is considered more strategic for supporting Bank Rakyat Indonesia's digital transformation. Overall, the implementation of SD-WAN is worthy of being adopted as the primary solution for the development of Bank Rakyat Indonesia's national data communication network because it meets the requirements for performance, flexibility, and cost efficiency. In future research, we hope that the hybrid model can be implemented as a transitional phase before a full migration to an SD-WAN architecture. Additionally, it is necessary to increase the capacity and quality of the Internet network in work units with high traffic to maintain the stability of SD-WAN services. The development of an integrated network performance monitoring and analysis system needs to be continuously improved to support data-driven decision-making. Future research is also expected to examine network security aspects in greater depth, including Zero Trust integration and cloud-based security. Further research could also expand the scope of the study by involving more work units and a longer testing period.

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