Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control
Journal homepage: http://kinetik.umm.ac.id
ISSN: 2503-2267
Vol. 9, No. 1, February 2024, Pp. 45-56

BGP dynamic routing protocol: a QoS Analysis for TCP and UDP

Nur Miswar*[1], Herman[1], Imam Riadi[2]
Master Program of Informatics, Universitas Ahmad Dahlan, Yogyakarta, Indonesia[1]
Department of Information System, Universitas Ahmad Dahlan, Yogyakarta, Indonesia[2]

Article Info
Keywords:
Border Gateway Protocol, Quality of Service, Transmission Control Protocol, User Datagram Protocol, Dynamic Routing

Article history:
Received: September 12, 2023
Accepted: December 22, 2023
Published: February 28, 2024

Cite:
N. Miswar, Herman, and I. Riadi, "Performance Analysis of BGP Dynamic Routing Protocol using QOS for TCP and UDP Services", KINETIK, vol. 9, no. 1, Feb. 2024. Retrieved from https://kinetik.umm.ac.id/index.php/kinetik/article/view/1852

*Corresponding author.
Nur Miswar
E-mail address:
nur2007048016@webmail.uad.ac.id

Abstract
The Border Gateway Protocol (BGP) is commonly used for TCP and UDP services, but it poses challenges in terms of Quality of Service (QoS) analysis. Parameters like throughput, packet loss, delay, and jitter are crucial for assessing network service quality. This study aims to analyze the performance and influence of the BGP routing protocol on TCP and UDP services using QoS parameters. The research used a GNS3 network simulation to conduct multiple packet transmission tests for TCP and UDP protocols, lasting 15, 30, and 60 seconds; and monitored using Wireshark. For TCP services, the average QoS index value is 3.75, categorizing the quality as "Good". The tested network topology and routing configuration exhibit reliable performance, providing good throughput, low packet loss rates, minimal delays, and stable jitter. Similarly, UDP services demonstrate "Good" performance with an average QoS index of 3.75. The BGP routing protocol in the tested network topology ensures high-quality service with good delivery speed, low packet loss rate, minimal delay, and stable jitter. Overall, the study concludes that the BGP routing protocol effectively provides satisfactory QoS for TCP and UDP services. This research contributes to understanding network performance and optimizing routing protocols for improved telecommunications services. The findings highlight the significance of routing protocols in facilitating efficient data transmission on the Internet, reinforcing the importance of QoS analysis for enhancing service quality.

1. Introduction

The Internet is now an integral part of daily life, serving crucial functions in business, education, entertainment, and communication [1]. This extensive internet usage leads to increased traffic, demanding efficient data transmission [2]. Routing protocols are essential for connecting internet networks, managing traffic, and ensuring precise data transmission [3],[4]. By optimising paths, these prevent congestion and failures [5]. Routing protocols fall into two categories: static and dynamic. Static routing involves manual setup, while dynamic routing adapts to changes [6]. Dynamic protocols update routing tables as needed, especially valuable in complex networks [7], [8]. Routers collaborate to find optimal paths for data transmission [9].

Border Gateway Protocol (BGP) is a dynamic routing protocol widely used by ISPs to exchange routing data between AS (Autonomous Systems) [10]. Operating at the OSI model's layer 3, BGP efficiently manages routing between ASes, guided by routing policies and metrics [11], [12]. Meanwhile, Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are vital transport protocols in computer networks, crucial for application and service data transmission. Quality of Service (QoS) parameters like throughput, packet loss, delay, and jitter significantly impact TCP and UDP performance [13]. BGP's influence on these parameters necessitates careful configuration of routing policies and metrics to align with TCP and UDP service needs [14], [15], [16]. Ongoing network monitoring and adaptive BGP adjustments are essential for optimal network performance, ensuring efficient application and service functionality [10], [17].

However, despite its fundamental importance, BGP presents a spectrum of challenges that confront network professionals in today's networking milieu. The escalating scale and diversity of internet traffic, coupled with the evolving requirements for QoS across various applications utilizing TCP and UDP, pose significant hurdles [18]. Ensuring optimal QoS for diverse traffic types traversing BGP-managed networks becomes increasingly intricate and vital [19]. Contemporary networking environments grapple with multifaceted challenges pertaining to BGP. Amidst the escalating volumes of internet traffic, the intricacies of ensuring efficient QoS for TCP and UDP traffic present formidable hurdles

[20]. Ensuring optimal QoS for TCP, known for its reliability and congestion control, and UDP, favored for its low-latency and simplicity, within the framework of BGP introduces complexities demanding meticulous analysis and strategic solutions [21].

Previous research has addressed several pertinent issues concerning the BGP. Manzoor et al. [22] compared BGP, EIGRP, and OSPF using GNS3. The experiment employed a network of five directly connected routers to evaluate packet delay, throughput, and network convergence. Results showed OSPF excelled in packet delay, while EIGRP performed better in terms of throughput and convergence. Monita et al. [23] explored multimedia services in SDN (Software Defined Networks) utilizing both internal and external routing protocols, including BGP. Their research demonstrated that increased background traffic led to diminished throughput due to network congestion, resulting in reduced data transfer rates. Another study by Ramadhan et al. [24], delved into QoS assessment by implementing the SIP protocol and G.711 codec with BGP routing. Utilizing BGP, this research obtained superior QoS values across various bandwidths, outperforming standard-based VoIP networks (ITU-T G.114) in terms of delay, jitter, packet loss, and throughput, as determined through simulation tests conducted multiple times for each bandwidth setting.

Based on previous research, this study seeks to assess how the BGP routing protocol performs in delivering TCP and UDP services, focusing on key QoS metrics like throughput (data transfer speed), packet loss, delay, and jitter (delivery time variation). The anticipated insights aim to be a valuable resource for networking professionals and internet service providers, aiding them in optimizing network performance and enhancing user experiences. By comprehending how BGP operates during the transmission of TCP and UDP, engineers gain the ability to make informed adaptations, potentially enhancing the overall efficiency and reliability of network infrastructure. This knowledge holds the potential to better align the utilization of the BGP routing protocol with the specific requirements of TCP and UDP services across varied networking environments.

2. Research Method

The Researchers designed the Experimental Workflow. The Experimental Workflow involves creating an experimental setup involving the selection of the variables to be monitored, the experimental control system, and the data collection method. The experiment is designed as shown in Figure 1.

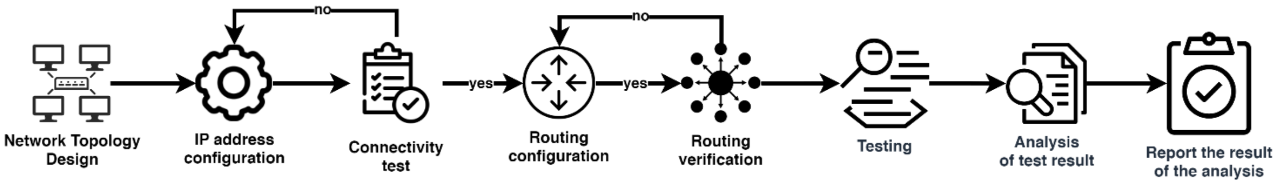


Figure 1. Experimental Workflow

The experimental process in Figure 1 includes several stages: initial network topology design using GNS3 software. GNS3 was chosen for project implementation as it serves as a graphical network emulator, enabling the simulation of a virtual network on a local computer. It supports over 20 different manufacturers' network equipment, facilitating the creation of diverse network setups. Additionally, GNS3 allows the integration of virtual networks with real ones and the inclusion of full computers within the network simulation. Moreover, it offers compatibility with third-party applications like Wireshark for in-depth analysis of network packets [25]. IP address configuration for communication, and verification of point-to-point connectivity through PING commands. After ensuring connectivity, the dynamic routing protocol, specifically BGP, is configured for four AS configurations (AS 1001, AS 2002, AS 3003, and AS 4004). Network quality assessment involves sending TCP and UDP service packets using the "bandwidth-test" command on the router, with test durations of 15, 30, and 60 seconds, repeated five times each with an interval of 10 seconds to obtain the average of each TCP and UDP service. Wireshark captures data transmission during testing, Wireshark can examine data packets in real time. It indicates that the Wireshark application can track and point out all data packets that enter and exit the interface set by the previous user [26], allowing for the analysis of QoS network metrics such as throughput, packet loss, delay, and jitter.

QoS is a method for measuring and managing network performance to provide better and planned network services [27] [28]. QoS can be applied to various routing protocols, including BGP. The application of QoS on BGP networks can ensure network services such as throughput, packet loss, delay, and jitter meet the user needs [29]. According to the standardization, TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks) [30], [31] has a rating index for QoS parameters as in Table 1.

Table 1. Rating Index for QoS

Indeks	Percentage (%)	Category
3,8 – 4	95 – 100	Very Good
3 – 3,79	75 – 94,5	Good
2 – 2,99	50 – 74,5	Medium
1 – 1,99	25 – 49,5	Bad

Table 1's QoS Parameter Index categorizes telecommunications service quality with corresponding percentages or value ranges. "Very Good" scores 3.8 - 4 (95 - 100%), "Good" ranges 3 - 3.79 (75 - 94.5%), "Medium" lies at 2 - 2.99 (50 - 74.5%), and "Bad" scores 1 - 1.99 (25 - 49.5%). This framework aids service evaluation and enhancement based on achieved values. Table 2 aligns QoS parameter indexes with the TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks) standard.

Table 2. QoS Parameter Index

Index	Throughput	Packet loss	Delay	Jitter
4	>2,1 Mbps	0 – 2 %	<150 ms	0 ms
3	1200 kbps – 2,1 Mbps	3 – 14 %	150 – 300 ms	0 – 75 ms
2	700 – 1200 kbps	15 – 24%	300 – 450 ms	75 – 125 ms
1	338 – 700 kbps	>25%	>450 ms	125 – 225 ms
0	0 – 338 kbps	-	-	-

Table 2 presents a comprehensive classification of network quality based on key parameters. Throughput, measured in Mbps, reflects data transfer speed, with higher values indicating better quality by assessing successful data transmission within a timeframe [32]. Packet loss, expressed as a percentage, signifies lost data packets during transmission due to various factors, affecting overall network efficiency and application performance [33]. Delay measures latency in data packet transmission, with lower millisecond values indicating superior quality [34], [35]. Jitter characterizes data packet arrival time variation, potentially impacting real-time applications like video conferencing and VoIP calling [36]. Lower jitter values indicate more consistent data packet arrival times, while high jitter can cause audio and video synchronization issues [37]. After finding the network QoS value, then the preparation of a report on the results of the test will be prepared by covering the results of network quality and the conclusions obtained. This report will become documentation that can be used for evaluation, improvement, and further research.

3. Results and Discussion

This section shows the results of the proposed experimental process including the topology design used, IP address configuration and connectivity test, routing configuration, routing verification, testing, and analysis of test results.

3.1 Network Topology Design

Designing a computer network using the BGP routing protocol requires first designing the network topology with GNS3, the application of network topology can provide maximum results if it is in accordance with the conditions of the research site [38], The network topology of this system is shown in Figure 2.

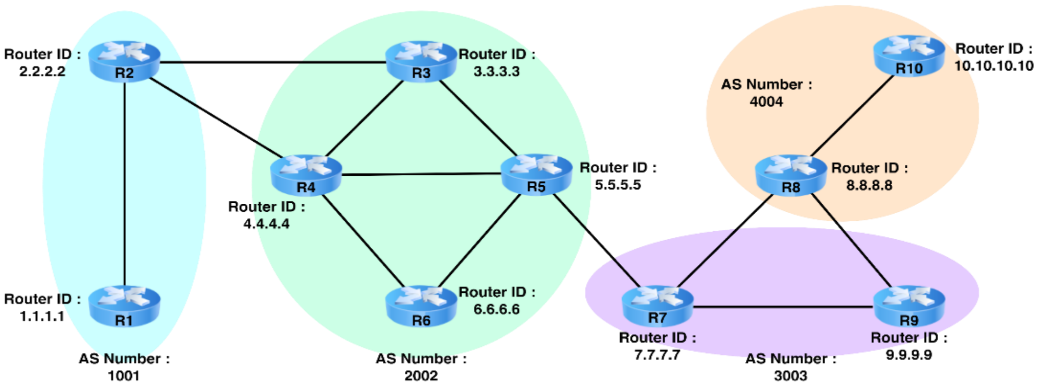


Figure 2. Network Topology Routing Protocol BGP

The topology adopted in this study is a modified version of the framework tested in previous research, which has been customised to investigate the performance of the BGP Dynamic Routing Protocol by focusing on QoS parameters. Previous research [39] has provided a relevant basis for choosing this topology, but the adaptation was made to meet the specific needs of the analysis which includes the evaluation of throughput, delay, packet loss, and jitter in TCP and UDP services along with consideration of the availability of required resources and ease of accessibility, resulting in a suitable environment to test the performance of BGP with QoS in a situation relevant to the existing network scenario.

3.2 IP Address Configuration and Connectivity Test

Following topology design, configuring IP addresses for network devices is pivotal. For the ten routers in this setup, distinct IP addresses, Router IDs, and AS Numbers are assigned. These variables are vital for routing and data exchange among routers. Router ID uniquely identifies each router, while AS Number differentiates within and between AS. For instance, Router R1 has IP 192.168.1.1/24, Router ID 1.1.1.1, and AS Number 1001. Likewise, Router R3 has IP 192.168.2.2/24, Router ID 3.3.3.3, and AS Number 2002. By allocating unique identifiers to routers, effective communication and routing information exchange enables smooth network functionality. The IP address is then set as shown in Table 3. Before the connection is tested by running a point-to-point and traceroute ping test to ensure that the connection is working properly, Figure 3 shows the ping and traceroute test from router R1 to router R10 eth1.

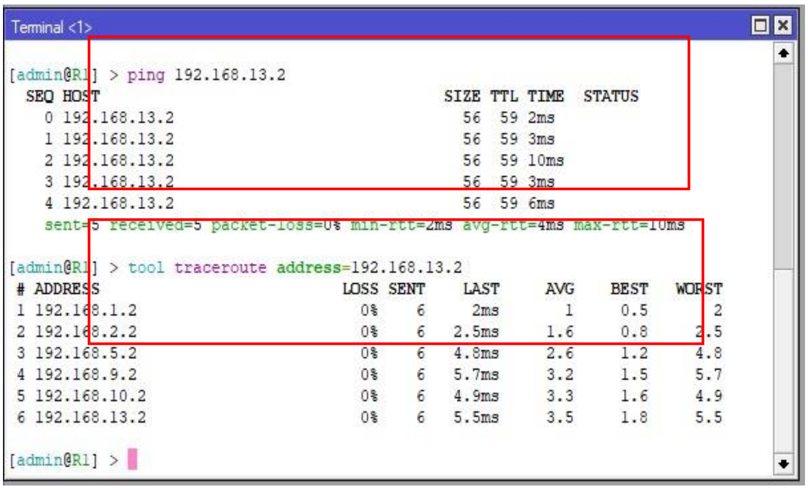


Figure 3. Connectivity Test

Figure 3 shows a successful ping communication between Router R1 to Router R10 eth1. Traceroute also made it to router R10 eth1, in Figure 5 it is shown that there are six hops that must be passed to arrive at the destination IP, namely 192.168.13.2. Table 3 provides a list of router information, including IP addresses, AS numbers, and Router IDs, which aids in configuring and setting up the network correctly.

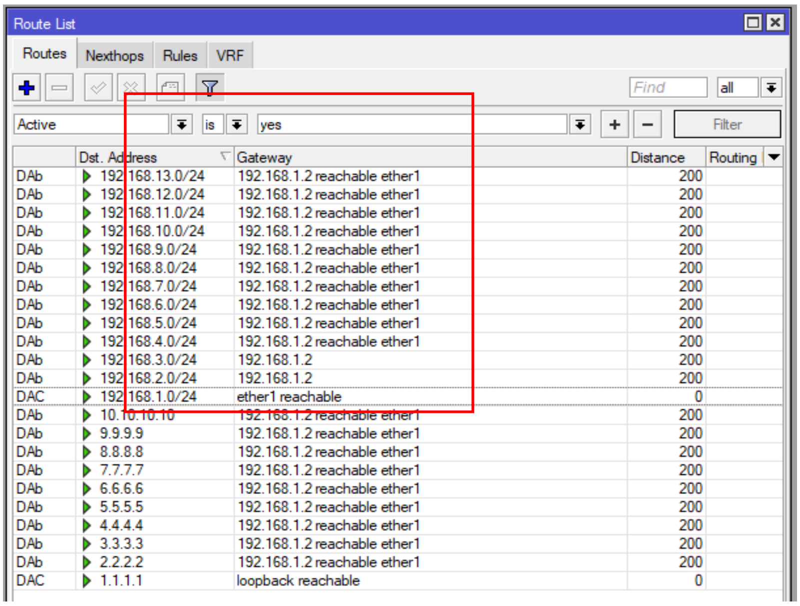
Table 3. Router Information

Router	Int.	Ip Address	Router ID	AS number
R1	Eth 1	192.168.1.1/24	1.1.1.1	1001
R2	Eth 1	192.168.1.2/24	2.2.2.2	
	Eth 2	192.168.2.1/24		
	Eth 3	192.168.3.1/24		
R3	Eth 1	192.168.2.2/24	3.3.3.3	2002
	Eth 2	192.168.4.1/24		
	Eth 3	192.168.5.1/24		
R4	Eth 1	192.168.3.2/24	4.4.4.4	
	Eth 2	192.168.4.2/24		
	Eth 3	192.168.6.1/24		
	Eth 4	192.168.7.1/24		
R5	Eth 1	192.168.6.2/24	5.5.5.5	
	Eth 2	192.168.5.2/24		
	Eth 3	192.168.8.1/24		
	Eth 4	192.168.9.1/24		

Router	Int.	Ip Address	Router ID	AS number
R6	Eth 1	192.168.7.2/24	6.6.6.6	3003
	Eth 2	192.168.8.2/24		
R7	Eth 1	192.168.9.2/24	7.7.7.7	
	Eth 2	192.168.10.1/24		
	Eth 3	192.168.11.1/24		
R9	Eth 1	192.168.12.2/24	9.9.9.9	
	Eth 2	192.168.11.2/24		
R8	Eth 1	192.168.10.2/24	8.8.8.8	4004
	Eth 2	192.168.12.1/24		
	Eth 3	192.168.13.1/24		
R10	Eth 1	192.168.13.2/24	10.10.10.10	

3.3 Routing Configuration and Routing Verification

The next step is to configure BGP routing to enable the exchange of routing information between routers in the network. Furthermore, the routing settings need to be validated by reviewing the routing table on each router involved. The routing table provides a clear picture of the routes chosen for different destination networks. By performing these routing checks, the network can quickly identify any discrepancies and ensure accurate implementation of BGP routing for optimal network performance. The results of routing validation by reviewing the routing table are shown in Figure 4.



	Dst. Address	Gateway	Distance	Routing
DAb	192.168.13.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.12.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.11.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.10.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.9.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.8.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.7.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.6.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.5.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.4.0/24	192.168.1.2 reachable ether1	200	
DAb	192.168.3.0/24	192.168.1.2	200	
DAb	192.168.2.0/24	192.168.1.2	200	
DAC	192.168.1.0/24	ether1 reachable	0	
DAb	10.10.10.10	192.168.1.2 reachable ether1	200	
DAb	9.9.9.9	192.168.1.2 reachable ether1	200	
DAb	8.8.8.8	192.168.1.2 reachable ether1	200	
DAb	7.7.7.7	192.168.1.2 reachable ether1	200	
DAb	6.6.6.6	192.168.1.2 reachable ether1	200	
DAb	5.5.5.5	192.168.1.2 reachable ether1	200	
DAb	4.4.4.4	192.168.1.2 reachable ether1	200	
DAb	3.3.3.3	192.168.1.2 reachable ether1	200	
DAb	2.2.2.2	192.168.1.2 reachable ether1	200	
DAC	1.1.1.1	loopback reachable	0	

Figure 4. Routing Table

Figure 4 shows an example of a network list that can be accessed by router R1. The status referred to in Figure 5, namely 'A' is "Active" indicating the status of the routing table is active, 'D' is "Dynamic" indicating the routing is made dynamically, 'b' is "BGP" indicating the routing protocol used is the routing protocol BGP, 'C' is "Connect" which indicates the status of the routing table connected to the intended interface or address.

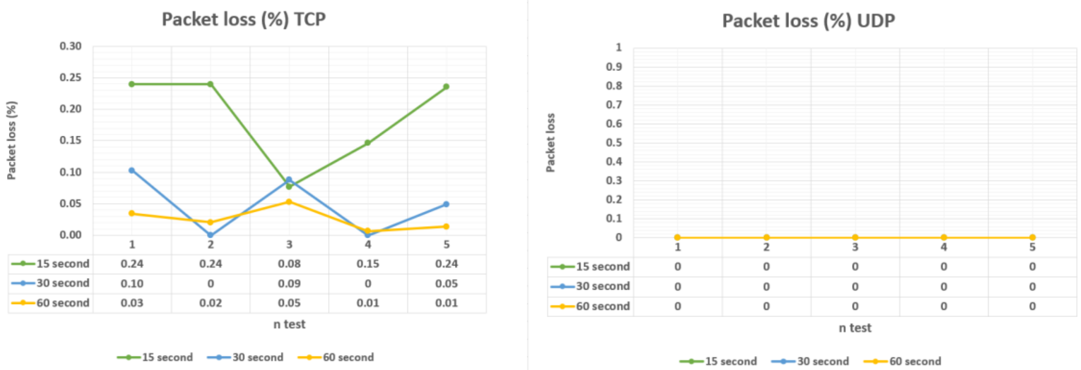
3.4 Testing TCP and UDP

After successfully verifying routing, the next step is to carry out a test scenario for sending TCP and UDP packets from R1 to R10. The testing and data collection process is carried out by sending TCP packets first from Router R1 to Router R10 using the "Bandwitdh-Test" tool on the router and using Wireshark software to capture data flow, testing was carried out for 3 sessions, each session was carried out 5 times to get an average, the time per each session was 15, 30, and 60 seconds. after testing by sending TCP packets, continued with UDP testing by doing the same thing as TCP. each TCP and UDP test will be monitored by wireshark software. BGP dynamic routing testing of TCP and UDP services to obtain QoS parameter information such as throughput, packet loss, delay, and jitter. The test results for the BGP routing protocol Throughput (kbps) parameter for TCP and UDP service is in Figure 5.

(a) (b)

Figure 5. (a) TCP Throughput Graphics and (b) UDP Throughput Graphics

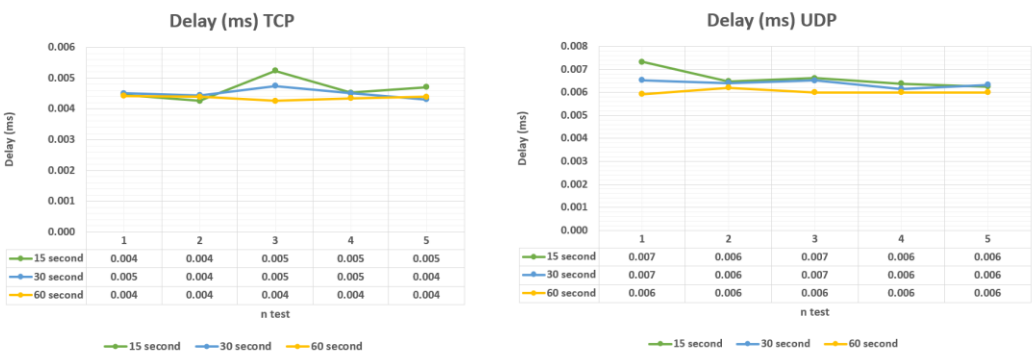
Figure 5 (a) presents BGP routing protocol throughput (kbps) outcomes for TCP services, with average throughputs of 1624.80 kbps (15s), 1848.01 kbps (30s), and 1962.18 kbps (60s). Similarly, to Figure 5 (b), UDP services' average throughputs were 1678.88 kbps (15s), 1787.55 kbps (30s), and 1914.10 kbps (60s). The graph increases with measurement time, although the difference in average throughput at 15, 30, and 60 seconds is not highly significant. The throughput values also exhibit consistency, with a narrow range at each time interval. Furthermore, the results of packet loss measurements are shown in Figure 6.



(a) (b)

Figure 6. (a) TCP Packet Loss and (b) UDP Packet Loss Graphics

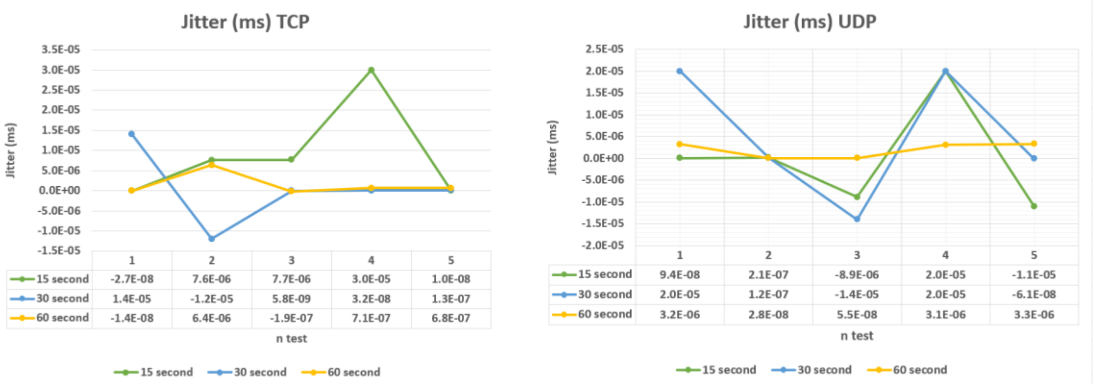
Figure 6 (a) shows minimal packet loss with the BGP routing protocol in TCP services, averaging 0.19%, 0.05%, and 0.03% over 15, 30, and 60 seconds, respectively. In Figure 6 (b), the BGP routing protocol exhibits zero packet loss in UDP services throughout the tests, consistently recording 0% loss. Wireshark analysis confirms this, highlighting BGP's reliability. Furthermore, the results of testing the BGP routing protocol delay parameters for TCP and UDP services are listed in Figure 7.



(a) (b)

Figure 7. (a) TCP Delay and (b) UDP Delay Graphics

Figure 7 (a) displays the delay (ms) measurements for TCP services with the BGP routing protocol, revealing average delays of 0.005 ms, 0.005 ms, and 0.004 ms over 15, 30, and 60 seconds, respectively. For UDP services utilizing the BGP routing protocol in Figure 7 (b), the average delays during the same durations are impressively low, measuring at 0.007 ms, 0.006 ms, and 0.006 ms. Figure 8 shows a graph of the average delay in BGP routing protocol measurements for TCP and UDP services. Figure 7 (a) shows a minor variation in average delay across different time scenarios using the BGP routing protocol for TCP services, indicating its efficient performance with low delay. A smaller delay ensures faster response times and data transmission, ensuring network efficiency and quality of service. Figure 7 (b) reveals a consistent trend of low average delay with longer measurement times for UDP services, demonstrating the BGP routing protocol's reliability and efficiency in facilitating high-speed UDP packet transmission within the network topology. Furthermore, the results of Jitter measurements are shown in Figure 8.



(a) (b)

Figure 8. (a) TCP Jitter, (b) TCP Jitter Graphics

Figure 8 presents jitter measurements (in ms) for both TCP and UDP services utilizing the BGP routing protocol. Jitter results vary across different time intervals. For TCP in Figure 8 (a), the average jitter is 1.4E-05 ms at 15 seconds, 1.4E-05 ms at 30 seconds, and 1.4E-05 ms at 60 seconds. Meanwhile, UDP in Figure 8 (b) exhibits an average jitter of 8.1E-08 ms at 15 seconds, 5.2E-06 ms at 30 seconds, and 1.9E-06 ms at 60 seconds. Figure 8 (a) displays a jitter graph indicating relatively minor fluctuations during measurement, signifying consistent TCP service packet delivery via the BGP routing protocol. These small fluctuations indicate robust network stability with low variation in packet delivery time. Meanwhile, Figure 8 (b) shows that the 60-second measurement exhibits a milder slope compared to the 15 and 30-second measurements, suggesting increased stability with longer durations. Shorter measurement times display more significant jitter variations. This graph provides a visual representation of BGP protocol route jitter characteristics for UDP packet services across different timeframes.

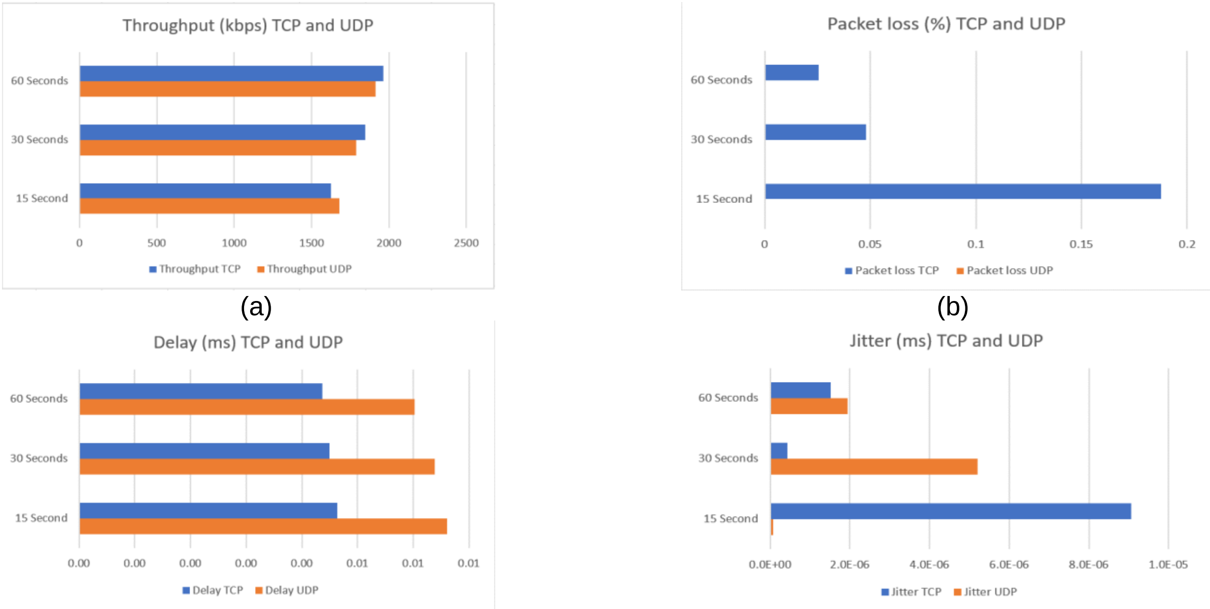
The next stage is the average yield of each parameter adjusted to the QoS rating index. Table 8 shows the average QoS index values for TCP services.

Table 4. The Average Value of the TCP Service QoS Index

Parameter	TCP			UDP		
	15 Second	30 Second	60 Second	15 Second	30 Second	60 Second
Throughput (kbps)	1624.80	1848.01	1962.18	1678.88	1787.55	1914.10
Index	3	3	3	3	3	3
Packet loss (%)	0.19	0.05	0.03	0	0	0
index	4	4	4	4	4	4
Delay (ms)	0.005	0.005	0.004	0.007	0.006	0.006
index	4	4	4	4	4	4
Jitter (ms)	9.1E-06	4.3E-07	1.5E-06	1.8E-07	5.2E-06	1.9E-06
index	4	4	4	4	4	4
Index averages	3.75	3.75	3.75	3.75	3.75	3.75

Table 8 represents the quality of service (QoS) measurement results for the TCP and UDP protocols during different time intervals of 15 seconds, 30 seconds, and 60 seconds. The results show excellent quality of service, with high throughput, low packet loss rate, minimal delay, and stable jitter, for both protocols. Although there were fluctuations in some parameters, such as throughput and delay, the values remained within an excellent range. The stable average index of 3.75 illustrates the consistency of the quality of service throughout the test, indicating that the network can transfer data efficiently and reliably under various situations and different time intervals.

The results of BGP performance analysis on TCP and UDP services for each of the throughput, packet loss, delay, and jitter parameters, graphically viewed are shown in Figures 9 (a), (b), (c), and (d).



(a) (b) (c) (d)

Figure 9. TCP and UDP Graphics, (a) Throughput TCP and UDP Graphics, (b) Packet loss TCP and UDP Graphics, (c) Delay TCP and UDP Graphics, (d) Jitter TCP and UDP Graphics

The graphical image in Figure 9 shows comparison of performance parameters between TCP and UDP in the use of BGP routing at three different measurement sessions (15 seconds, 30 seconds, and 60 seconds), Figure 9 (a) shows that for throughput parameters both TCP and UDP show an increase in throughput over time, with TCP starting from the 15 second session having an average value of 1624.80 kbps, the 30 second session having an average value of 1848. 01 to 60 seconds session having an average value of 1962.18 kbps, and UDP from 15 seconds session having an average value of 1678.88 kbps, 30 seconds session having an average value of 1787.55 to 60 seconds session having an average value of 1914.10 kbps. both TCP and UDP services on BGP routing show index value 3 according to TIPHON standardisation, indicating comparable performance in terms of throughput. Although both have increased, TCP throughput at 60 seconds is slightly higher than that of UDP.

As for the Packet loss parameter in Figure 9 (b), the TCP service decreases as the time session increases. Measurement of TCP services on BGP routing when the time session is 15 seconds having an average value of 0.19%, when the time session increases to 30 seconds it decreases with an average of 0.05% and decreases again when the time session increases to 60 seconds with an average of 0.03%. In contrast to TCP, UDP services remain stable at 0% throughout the measurement time session. TCP and UDP services on BGP routing show an index value of 4 according to TIPHON standardisation, indicating a very low packet loss rate.

Then the delay parameter in Figure 9 (c), TCP and UDP services show a low and stable delay, with TCP in the 15-second and 30-second sessions having an average value of 0.005 ms, and the 60-second session having an average value of 0.004 ms. For UDP services, the 15-second session having an average of 0.007 ms, and for 30-second and 60-second sessions having an average value of 0.006 ms. Both TCP and UDP services have an index value of 4 according to TIPHON standardisation, showing consistency in low delay times.

Jitter conditions in Figure 9 (d) on TCP and UDP services against the BGP routing protocol show low jitter with small value fluctuations throughout the measurement time. Jitter measurements on TCP services during the 15 second session showed an average of 9.1E-06 ms, when the 30 second session showed an average of 4.3E-07 ms, when the 60 second session showed an average of 1. 5E-06 ms, while the jitter measurements on the UDP service during the 15 second session showed an average of 1.8E-07 ms, during the 30 second session showed an average of 5.2E-06 ms, during the 60 second session showed an average of 1.9E-06 ms. Both TCP and UDP services against the BGP routing protocol show an index of 4, which indicates that both TCP and UDP show low jitter values, although there are small fluctuations over time.

With a constant index value of 3.75 for both TCP and UDP services, it can be concluded that TCP and UDP services have comparable performance overall under the influence of BGP routing according to TIPHON standardisation with a category of "Good". Although there are minor differences in some parameters, in general they both exhibit stability, good throughput, and low packet loss rates, making them reliable services in the use of BGP routing.

Based on the results of this study which has a method approach and data processing techniques used in the research of E.P Saputra et al [40], it can be compared that the research on the topic of QoS analysis of Wireless Internet Network Performance has the same four QoS parameters tested, namely Throughput, packet loss, and delay, the average QoS index value is 2. 9 which means that the Quality of Service from the test is in the "medium" category based on TIPHON standardisation, while in this study using the same four parameters, the average QoS index value is 3.75 for TCP and UDP services on dynamic routing BGP, which means that the Quality of Service from the test is in the "Good" category. Furthermore, in the research of A. C. Nurcahyo et al [41], using the same four QoS parameters with the topic of bandwidth management, the average QoS index value is 3.75 which is categorised as "Good" based on TIPHON standards, another study [42] which discusses the comparison of the performance of interior gateway protocol routing on virtual private networks with the same QoS parameters, obtains an average index of 3.25 which means it has a good index value according to TIPHON standards.

4. Conclusion

Based on the measurement results, network performance for the TCP and UDP protocols both in terms of throughput, packet loss, delay, and jitter are good and stable. The quality of TCP service on the BGP routing protocol is categorized as "Good" according to the TIPHON standards with an average QoS index of 3.75. Likewise, UDP services perform very well by TIPHON standards with an average QoS index of 3.75, indicating a high level of quality of service. This shows that the policy configuration and routing metrics implemented in the BGP experiment were effective. Continuous monitoring and adjustments are made to ensure optimal network performance and efficient functioning of applications and services. This study aims to deepen the understanding of how BGP affects the quality of TCP and UDP services in terms of data transfer rates, packet loss rates, delays, and variations in data transmission time. Further studies can be conducted to analyze the effect of other factors, such as network topology and network capacity, on network performance and service quality. Research can also be expanded into more complex network environments with more realistic scenarios and implementation of network optimization and solutions in real-world implementations.

As per TIPHON standards with an average QoS index of 3.75, highlight the importance of effective routing configuration policies and metrics. The implications go beyond these test results, including the need for continuous monitoring and adaptation to maintain optimal performance, as well as emphasising the importance of standards as guidelines for quality-of-service evaluation in complex network environments. In addition, these results underscore the room for further research involving additional factors such as network topology, capacity, and optimisation solutions in the context of real-world implementations. This indicates that while BGP provides impressive results, further research is needed to deepen the information on how computer networks can be optimised under increasingly complex conditions.

References

[1] W. Saputra and F. Suryawan, “Implementasi VLAN dan Spanning Tree Protocol Menggunakan GNS 3 dan Pengujian Sistem Keamanannya,” *Khazanah Informatika*, vol. 3, no. 2, pp. 64–72, 2017. https://doi.org/10.23917/khif.v3i2.5311

[2] M. A. K. Qalbi and I. Riadi, “Optimalisasi Jaringan Wireless Menggunakan Quality of Serfice (QoS) dan Algoritma Hierarchical Token Bucket (HTB),” *Jurnal Sarjana Teknik Informatika*, vol. 7, no. 2, pp. 7–13, 2019. http://dx.doi.org/10.12928/jstie.v7i2.15812

[3] D. I. Mudhoep, Linawati, and Oka Saputra, “Kombinasi Protokol Routing OSPF dan BGP dengan VRRP, HSRP, dan GLBP,” *Jurnal Nasional Teknik Elektro dan Teknologi Informasi*, vol. 10, no. 1, pp. 1–10, Feb. 2021. https://doi.org/10.22146/jnteti.v10i1.942

[4] S. Iqbal, K. N. Qureshi, N. Kanwal, and G. Jeon, “Collaborative energy efficient zone-based routing protocol for multihop Internet of Things,” *Transactions on Emerging Telecommunications Technologies*, vol. 33, no. 2, Feb. 2022. https://doi.org/10.1002/ett.3885

[5] A. A. Aouiz, S. B. Hacene, and P. Lorenz, “Channel Busyness Based Multipath Load Balancing Routing Protocol for Ad hoc Networks,” *IEEE Netw*, vol. 33, no. 5, pp. 118–125, Sep. 2019. https://doi.org/10.1109/MNET.2019.1900036

[6] A. G. Biradar, “A Comparative Study on Routing Protocols: RIP, OSPF and EIGRP and Their Analysis Using GNS-3,” in *2020 5th IEEE International Conference on Recent Advances and Innovations in Engineering, ICRAIE 2020 - Proceeding*, Institute of Electrical and Electronics Engineers Inc., Dec. 2020. https://doi.org/10.1109/ICRAIE51050.2020.9358327

[7] D. Ramphull, A. Mungur, S. Armoogum, and S. Pudaruth, “A review of mobile Ad hoc NETwork (MANET) protocols and their applications,” in *Proceedings - 5th International Conference on Intelligent Computing and Control Systems, ICICCS 2021*, Institute of Electrical and Electronics Engineers Inc., May 2021, pp. 204–211. https://doi.org/10.1109/ICICCS51141.2021.9432258

[8] A. N. Hameed, S. A. Alabady, and M. A. Thanoon, “Performance analysis and evaluation of distance vector and link state routing protocols over a large area networks,” *Telkomnika (Telecommunication Computing Electronics and Control)*, vol. 20, no. 6, pp. 1189–1199, Dec. 2022. https://doi.org/10.12928/TELKOMNIKA.v20i6.22211

[9] V. Bhardwaj and N. Kaur, “SEEDRP: a Secure Energy Efficient Dynamic Routing Protocol in Fanets,” *Wirel Pers Commun*, vol. 120, no. 2, pp. 1251–1277, Sep. 2021. https://doi.org/10.1007/s11277-021-08513-0

[10] K. R. Naina, “AMPLE: A New Method of Adaptive Multi-Topology Border Gateway Protocol (MT-BGP) Traffice Engineering System Based on Virtual Routing Topologies,” *Global Journal of Engineering Science and Researches*, vol. 6, no. 5, 2019. https://doi.org/10.5281/zenodo.3174803
[11] A. A. Malik, A. Riaz, H. U. R. Kayani, and W. Azeem, “Analysis of Border Gateway Protocol, Its Types and Measures to Avoid Risk,” *LGU Research Journal for Computer Sciences & IT*, vol. 3, no. 3, pp. 3–9, 2019. https://doi.org/10.54692/lgurjcsit.2019.030379
[12] K. Ishaq, A. Abid, K. Abid, Q. Ali, and M. Ijaz, “Factor Influencing the Convergence Time in Border Gateway Protocol (BGP),” *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 2, pp. 5269–5272, Dec. 2019. https://doi.org/10.35940/ijitee.B7582.129219
[13] H. Babbar and S. Rani, “Performance Evaluation of QoS metrics in Software Defined Networking Using Ryu Controller,” in *IOP Conference Series: Materials Science and Engineering*, IOP Publishing Ltd, Jan. 2021. https://doi.org/10.1088/1757-899X/1022/1/012024
[14] S. Bentacur, M. F. Bon, G. G. Sena, C. Rattaro, and I. Brugnoli, “Flow-based QoS forwarding strategy: a practical implementation and evaluation,” in *2020 Seventh International Conference on Software Defined Systems (SDS)*, 2020, pp. 279–279. https://doi.org/10.1109/SDS49854.2020.9143901
[15] S. Bentancur, M. Fernández Bon, G. G. Sena, C. Rattaro, and I. Brugnoli, “Flow-based QoS forwarding strategy: a practical implementation and evaluation,” *IEEE 2020 Seventh International Conference on Software Defined Systems (SDS)*, 2020. https://doi.org/10.1109/SDS49854.2020.9143901
[16] I. Brugnoli, M. F. Bon, D. Mazzuco, G. G. Sena, C. Rattaro, and S. Bentancur, “Tunnelless SDN overlay architecture for flow based QoS management,” in *2021 24th Conference on Innovation in Clouds, Internet and Networks and Workshops, ICIN 2021*, Institute of Electrical and Electronics Engineers Inc., Mar. 2021, pp. 62–69. https://doi.org/10.1109/ICIN51074.2021.9385539
[17] H. Alotaibi, S. Li, and M. A. Gregory, “Utilising SDNto Counter BGP Convergence Delays,” *IEEE 2019 29th International Telecommunication Networks and Applications Conference (ITNAC)*, 2019. https://doi.org/10.1109/ITNAC46935.2019.9078017
[18] N. Mishra and S. Pandya, “Internet of Things Applications, Security Challenges, Attacks, Intrusion Detection, and Future Visions: A Systematic Review,” *IEEE Access*, vol. 9. Institute of Electrical and Electronics Engineers Inc., pp. 59353–59377, 2021. https://doi.org/10.1109/ACCESS.2021.3073408
[19] G.-M. Lee, C.-W. Lee, and B.-H. Roh, “QoS Support Path Selection for Inter-Domain Flows Using Effective Delay and Directed Acyclic Graph in Multi-Domain SDN,” *MDPI Electronics*, vol. 11, no. 14, Jul. 2022. https://doi.org/10.3390/electronics11142245
[20] A. Kumar, P. V. S. Srinivas, and A. Govardhan, “A Multipath Packet Scheduling Approach based on Buffer Acknowledgement for Congestion Control,” in *Procedia Computer Science*, Elsevier B.V., 2020, pp. 2137–2146. https://doi.org/10.1016/j.procs.2020.04.231
[21] Z. Ashraf, A. Sohail, and M. Yousaf, “Performance Analysis of Network Applications on IPv6 Cloud Connected Virtual Machine,” *International Journal of Computer Network and Information Security*, vol. 11, no. 12, pp. 1–9, Dec. 2019. https://doi.org/10.5815/ijcnis.2019.12.01
[22] A. Manzoor, M. Hussain, and S. Mehrban, “Performance Analysis and Route Optimization: Redistribution between EIGRP, OSPF & BGP Routing Protocols,” *Comput Stand Interfaces*, vol. 68, Feb. 2020. https://doi.org/10.1016/j.csi.2019.103391
[23] V. Monita, I. D. Irawati, and R. Tulloh, “Comparison of Routing Protocol Performance on Multimedia Services on Software Defined Network,” *Bulletin of Electrical Engineering and Informatics*, vol. 9, no. 4, pp. 1612–1619, Aug. 2020. https://doi.org/10.11591/eei.v9i4.2389
[24] E. Ramadhan, A. Firdausi, and S. Budiyanto, “Design and analysis QoS VoIP using routing Border Gateway Protocol (BGP),” in *2017 International Conference on Broadband Communication, Wireless Sensors and Powering, BCWSP 2017*, Institute of Electrical and Electronics Engineers Inc., Jan. 2018, pp. 1–4. https://doi.org/10.1109/BCWSP.2017.8272556
[25] B. Korniyenko, L. Galata, and L. Ladieva, “Research of Information Protection System of Corporate Network Based on GNS3,” in *IEEE International Conference on Advanced Trends in Information Theory (ATIT)*, 2019, pp. 244–248. https://doi.org/10.1109/ATIT49449.2019.9030472
[26] N. Hildayanti and I. Riadi, “Forensics Analysis of Router On Computer Networks Using Live Forensics Method,” *International Journal of Cyber-Security and Digital Forensics*, vol. 8, no. 1, pp. 74–81, 2019. http://dx.doi.org/10.17781/P002559
[27] A. R. Maulana, Walidainy Hubbul, Irhamsyah Muhammad, Fathurrahman, and Akhyar, “Analisis Quality of Service (QoS) Jaringan Internet Pada Website e-Learning Universitas Syiah Kuala Berbasis Wireshark,” *KITEKTRO: Jurnal Komputer, Teknologi Informasi, dan Elektro*, vol. 6, no. 2, pp. 27–30, 2021. https://doi.org/10.24815/kitektro.v6i2.22284
[28] A. Yudhana, I. C. Kurniawan, I. Anshori, and I. Mufandi, “Performance evaluation of communication methods on electric wheelchairs as assistive technology for persons with disabilities,” *International Journal on Smart Sensing and Intelligent Systems*, vol. 15, no. 1, pp. 1–18, Jan. 2022. https://doi.org/10.2478/ijssis-2022-0016
[29] E. K. Putra and S. Patra, “Implementasi Routing Protokol Border Gateway Protocol (BGP) pada Rouer Mikrotik RB 2011 di Kabupaten Solok Selatan,” *Jurnal Teknoif Teknik Informatika Institut Teknologi Padang*, vol. 9, no. 2, pp. 97–103, Oct. 2021. https://doi.org/10.21063/jtif.2021.v9.2.97-103
[30] “Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); General aspects of Quality of Service (QoS),” Valbonne, France, 1999.
[31] A. Charisma, A. D. Setiawan, G. M. Rahmatullah, and M. R. Hidayat, “Analysis Quality of Service (QoS) on 4G Telkomsel Networks In Soreang,” in *IEEE 13th International Conference on Telecommunication Systems, Services, and Applications (TSSA)*, 2019, pp. 145–148. https://doi.org/10.1109/TSSA48701.2019.8985489
[32] A. Ahad, M. Tahir, and K. L. A. Yau, “5G-based smart healthcare network: Architecture, taxonomy, challenges and future research directions,” *IEEE Access*, vol. 7, pp. 100747–100762, 2019. https://doi.org/10.1109/ACCESS.2019.2930628
[33] A. A. W. Aisyah, H. Pujiharsono, and M. A. Afandi, “Sistem Monitoring dan Kontrol Pakan Budidaya Ikan Lele menggunakan NodeMCU berbasis IoT,” *Journal of Telecommunication, Electronics, and Control Engineering (JTECE)*, vol. 4, no. 2, pp. 108–116, Jul. 2022. https://doi.org/10.20895/jtece.v4i2.533
[34] S. Aminah, “Manajemen Bandwidth dalam Mengoptimalkan Penggunaan Router Mikrotik terhadap Pelayanan Koneksi Jaringan,” *Jurnal Informatika Ekonomi Bisnis*, vol. 4, no. 3, pp. 102–106, Sep. 2022. https://doi.org/10.37034/infeb.v4i3.144
[35] R. S. Hadikusuma, H. G. Sitindjak, and M. H. Assubhi, “Analisis Quality of Service (QoS) Jaringan Provider Tri Melalui Drive Test di Purwakarta,” *Barometer*, vol. 6, no. 2, pp. 387–394, 2021. https://doi.org/10.35261/barometer.v6i2.5205
[36] S. Pawar *et al.*, “Security and QoS (Quality of Service) Related Current Challenges in IoT,” *SSRG International Journal of Electronics and Communication Engineering*, vol. 10, no. 4. Seventh Sense Research Group, pp. 9–20, Apr. 01, 2023. https://doi.org/10.14445/23488549/IJECE-V10I4P102
[37] A. Ginanjar and K. A. Santoso, “Analisis Perbandingan Performance Video Streaming dengan Metode Routing Protocol Open Shortest Path First Routing Information Protocol, Intermediate System-Intermediate System,” *Jurnal Kajian Teknik Elektro*, vol. 6, no. 1, pp. 38–45, 2021. https://doi.org/10.52447/jkte.v6i1.5727
[38] S. Budin and I. Riadi, “Traffic Shaping Menggunakan Metode HTB (Hierarchical Token Bucket) pada Jaringan Nirkabel,” *Buletin Ilmiah Sarjana Teknik Elektro*, vol. 1, no. 3, pp. 144–152, Dec. 2019. https://doi.org/10.12928/biste.v1i3.1100

[39] I. R. Julia, H. B. Suseno, L. K. Wardhani, D. Khairani, K. Hulliyah, and A. T. Muharram, “Performance Evaluation of First Hop Redundancy Protocol (FHRP) on VRRP, HSRP, GLBP with Routing Protocol BGP and EIGRP,” in *2020 8th International Conference on Cyber and IT Service Management, CITSM 2020*, Institute of Electrical and Electronics Engineers Inc., Oct. 2020. https://doi.org/10.1109/CITSM50537.2020.9268799

[40] E. P. Saputra, A. Saryoko, M. Maulidah, N. Hidayati, and S. Dalis, “Analisis Quality of Service (QoS) Performa Jaringan Internet Wireless LAN PT. Bhineka Swadaya Pertama,” *Jurnal Sains dan Manajemen*, vol. 11, no. 1, pp. 13–21, 2023. https://doi.org/10.31294/evolusi.v11i1.14955

[41] A. C. Nurcahyo, L. Firgia, and Y. Mustaqim, “Implementasi dan Analisis Metode Hierarchical Token Bucket pada Manajemen Bandwidth Jaringan (Studi Kasus : Jaringan Rektorat Institut Shanti Bhuana),” *JIFOTECH (Journal of Information Technology)*, vol. 1, no. 2, pp. 41–49, 2021. https://doi.org/10.46229/jifotech.v1i2.200

[42] I. Nurhaida, D. W. P. Pratama, R. A. M. Zen, and H. Wei, “Interior Gateway Protocol Routing Performance Comparison of The Virtual Private Network Based on Multi Protocol Label Switching and Direct-Link Backup,” *SINERGI*, vol. 24, no. 1, pp. 1–10, Dec. 2019. https://dx.doi.org/10.22441/sinergi.2020.1.001