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Optimization of Computer Network Performance through Traffic Management and Bandwidth Allocation

Dirja Nur Ilham[1*], Muhammad Khoiruddin Harahap[2], Muhammed Saat Talib[3], Arie Budiansyah[4], Rudi Arif Candra[5]
[1,5]Politeknik Aceh Selatan, Indonesia, [2]Politeknik Ganesha Medan, Indonesia, [3]University of Babylon, Iraq, [4]Universitas Syiah Kuala, Indonesia
[1*]dirja.poltas@gmail.com, [2]choir.harahap@yahoo.com, [3]mohammed90.saad1@gmail.com, [4]arie.b@unsyiah.ac.id, [5]rudiarifcandra@gmail.com

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***Corresponding Author**

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ABSTRACT

Computer network performance is highly dependent on effective traffic management and proper bandwidth allocation, especially in network environments with a large number of users and diverse service demands. Uneven bandwidth distribution often leads to degraded service quality, including low throughput, high delay, and increased packet loss. This study aims to analyze and optimize computer network performance through the implementation of traffic management and bandwidth allocation using the **Simple Queue** and **Queue Tree** methods on a MikroTik router. An experimental research approach was employed by comparing network performance before and after the application of bandwidth management mechanisms. The evaluation was conducted based on Quality of Service (QoS) parameters, namely throughput, delay, and packet loss, in accordance with the **TIPHON standard**. The experimental results indicate a significant improvement in network performance after the implementation of Simple Queue and Queue Tree. Throughput increased substantially, while delay and packet loss were considerably reduced, resulting in improved service quality categories. The Simple Queue method effectively ensured fair bandwidth distribution among users by limiting per-user bandwidth usage, whereas the Queue Tree method enhanced performance by prioritizing network traffic based on service types. The combination of these methods successfully minimized bandwidth monopolization, reduced network congestion, and improved overall network stability. Therefore, the implementation of Simple Queue and Queue Tree proves to be an effective solution for optimizing bandwidth utilization and enhancing Quality of Service in computer networks with high user density and heterogeneous traffic characteristics.

INTRODUCTION

The rapid development of information and communication technology has increased the demand for reliable and stable computer networks. Computer networks play a crucial role in supporting data exchange, communication, and information access in educational institutions, offices, and other organizations. As the number of users and internet-based services continues to grow, networks frequently experience performance degradation due to limited bandwidth and uncontrolled data traffic (Stallings, 2018).

A common problem in computer networks is uneven bandwidth usage, where certain users or applications consume excessive bandwidth, resulting in reduced service quality for others. This condition leads to low throughput, increased delay, and high packet loss, which negatively impact user experience. Therefore, effective traffic management and bandwidth allocation mechanisms are required to ensure fairness and maintain optimal network performance (Siregar & Lubis, 2019).

Bandwidth management is a practical solution to address these issues. On MikroTik routers, bandwidth management can be implemented using various methods, including Simple Queue and Queue Tree. Simple Queue is used to limit bandwidth per user, while Queue Tree enables more complex traffic management based on service types and priorities. This study focuses on analyzing the effectiveness of these methods in optimizing computer network performance based on Quality of Service (QoS) parameters (Prayitno & Setiawan, 2018; Putra & Sari, 2020).

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LITERATURE REVIEW

Computer Networks

A computer network is a collection of interconnected devices that communicate and exchange data, information, and shared resources through wired or wireless transmission media. Network performance reflects the ability of the network to deliver data efficiently and reliably, and it is strongly influenced by key parameters such as available bandwidth, achievable throughput, end-to-end delay, and packet loss rate. These parameters collectively determine the quality, responsiveness, and reliability of network services experienced by users (Tanenbaum & Wetherall, 2018; Stallings, 2018).

Network Traffic

Network traffic refers to the volume and pattern of data packets transmitted across a network within a certain period of time, encompassing various types of services such as web browsing, file transfer, video streaming, and real-time communication. When network traffic is not properly controlled, excessive data transmission from specific users or applications can lead to congestion, increased queue length, higher latency, and packet loss, which ultimately degrade overall network performance and user experience. Therefore, proper traffic management is essential to regulate data flow, balance network load, and ensure that each service or application receives network resources proportionally according to its priority level and performance requirements, thereby maintaining stable and efficient network operation (Siregar & Lubis, 2019).

Bandwidth Management

Bandwidth management is a network control technique used to regulate, allocate, and optimize bandwidth usage in order to ensure efficient, stable, and fair utilization of available network resources. This technique is implemented to prevent bandwidth monopolization by specific users or applications and to maintain consistent service quality across the network. Bandwidth management mechanisms typically include speed limitation to control maximum data rates, traffic prioritization to ensure that critical or latency-sensitive services receive higher priority, and bandwidth allocation based on users, applications, or service types. Through proper bandwidth management, network administrators can improve overall network performance, reduce congestion, and enhance Quality of Service (QoS), particularly in environments with high user density and heterogeneous traffic characteristics (Prayitno & Setiawan, 2018).

Simple Queue

Simple Queue is a bandwidth management method available on MikroTik routers that limits and controls user access speed based on IP addresses, interfaces, or target devices. This method operates by defining minimum bandwidth allocation (limit-at) and maximum bandwidth thresholds (max-limit) for each user, allowing network administrators to regulate bandwidth consumption more effectively. Due to its straightforward configuration and direct per-user control mechanism, Simple Queue is relatively easy to implement and well-suited for small to medium-scale networks. Its application is effective in achieving fair bandwidth distribution, preventing bandwidth monopolization by specific users, and maintaining stable network performance under varying traffic conditions (Apriyanto & Nugroho, 2019).

Queue Tree

Queue Tree is a bandwidth management method on MikroTik routers that enables hierarchical traffic control based on service types, protocols, or traffic priorities. This method operates by classifying traffic packets—commonly through packet marking mechanisms in the firewall—and organizing them into a parent–child queue structure. The parent queue represents the total available bandwidth, while child queues are assigned specific bandwidth limits and priority levels according to service requirements, such as web browsing, video streaming, or real-time communication. Through this hierarchical approach, Queue Tree allows more granular and flexible bandwidth control compared to Simple Queue, particularly in complex network environments with heterogeneous traffic patterns. As a result, Queue Tree is effective in optimizing bandwidth utilization, reducing congestion, and improving Quality of Service (QoS) by ensuring that high-priority and latency-sensitive services receive appropriate network resources (Fauzan & Hidayat, 2020).

Quality of Service (QoS)

Quality of Service (QoS) represents a set of performance parameters used to evaluate the ability of a network to deliver data services reliably, efficiently, and in accordance with user expectations. QoS assessment focuses on quantitative metrics that describe network behavior under specific traffic conditions. Common QoS parameters include throughput, which indicates the effective data transmission rate achieved by the network; delay, which reflects the time required for data packets to travel from source to destination; and packet loss, which represents the percentage of packets that fail to reach their destination due to congestion or transmission errors. These parameters collectively provide a comprehensive view of network performance and service quality. The TIPHON standard is frequently used as

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a reference framework for classifying network service quality levels, as it defines threshold values for each QoS parameter and categorizes network performance into qualitative classes such as Very Good, Good, Fair, and Poor, enabling objective performance evaluation and comparison (Putra & Sari, 2020).

RESEARCH METHODOLOGY

This study employs an experimental research method by implementing bandwidth management on a computer network using Simple Queue and Queue Tree. Network performance is evaluated by comparing conditions before and after the implementation of bandwidth management (Mahendra & Sugiarto, 2024; Nurjanah & Nopiyanto, 2023).

Research Stages

The research stages include problem identification, network requirement analysis, network topology design, Simple Queue implementation, Queue Tree implementation, network performance testing, and result analysis and evaluation (Prasetyo et al., 2024).

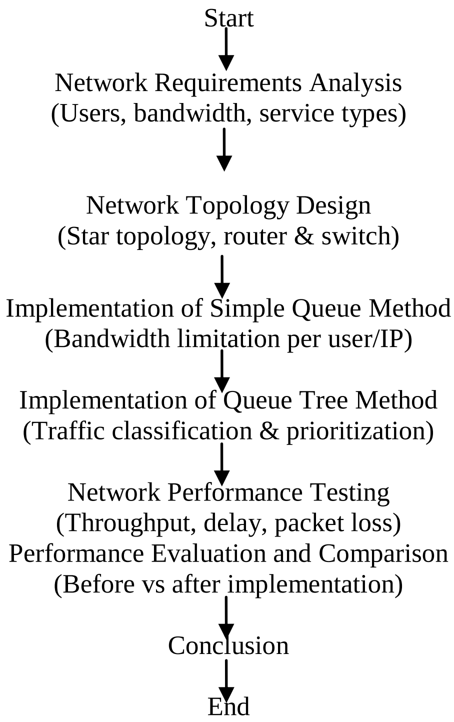

Figure 1. Research Flowchart for Bandwidth Management

As illustrated in **Figure 1**, this study begins with a **network requirements analysis** aimed at identifying the number of active users, the available internet bandwidth capacity, and the types of network services most frequently used, such as browsing, streaming, and data downloading. The next stage involves **network topology design**, in which a star topology is adopted, with the router functioning as the central network management device and switches serving as connectors between user devices. Following the topology design, the **Simple Queue method** is implemented to perform basic bandwidth limitation and allocation based on user or IP addresses. At this stage, each user is assigned minimum (*limit-at*) and maximum (*max-limit*) bandwidth thresholds to ensure fair bandwidth distribution and to prevent bandwidth monopolization by specific users. Subsequently, the **Queue Tree method** is applied to enable more complex and structured traffic management, where network traffic is classified according to service types, such as HTTP, HTTPS, and streaming services. Each traffic class is assigned different priority levels and bandwidth allocations based on its level of importance, utilizing a parent–child hierarchical mechanism that allows more flexible bandwidth control. The final stage, as depicted in **Figure 1**, involves **network performance testing and evaluation**, which is conducted by measuring Quality of Service (QoS) parameters, including throughput, delay, and packet loss. The performance results obtained before and after the implementation of the Simple Queue and Queue Tree methods are then compared to determine the improvement in overall network performance.

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Network Topology

As shown in **Figure 1**, the network topology employed in this study is a **star topology**, in which a MikroTik router functions as the central network management device, while switches are used to interconnect client devices. This topology was selected due to its simplicity, scalability, and ease of management, making it suitable for implementing bandwidth control mechanisms and facilitating efficient bandwidth allocation across client devices (Stallings, 2018).

Quality of Service (QoS) Measurement Parameters

The Quality of Service (QoS) parameters analyzed in this study include throughput, delay, and packet loss, which are widely used to represent network performance and service quality. Measurements were conducted under two conditions, namely before and after the implementation of bandwidth management using the Simple Queue and Queue Tree methods, to objectively evaluate performance improvements (Putra & Sari, 2020; Rudiyanto & Asri, 2025).

Throughput Throughput represents the effective rate of successful data transmission over the network within a specific period of time. It reflects how efficiently the available bandwidth is utilized. Throughput is calculated using the following formula:

Throughput = **Total data successfully received** (bits) / **Total transmission time** (seconds)

Higher throughput values indicate better network performance and more efficient bandwidth utilization.

Delay Delay refers to the time required for a data packet to travel from the source node to the destination node across the network. It includes processing delay, queuing delay, transmission delay, and propagation delay. The average delay is calculated as follows:

Delay = **Total packet transmission time** (seconds) / **Total number of packets received**

Lower delay values indicate faster data delivery and improved network responsiveness, which are especially important for real-time applications.

Packet Loss Packet loss represents the percentage of data packets that fail to reach their destination due to congestion, buffer overflow, or transmission errors. Packet loss is calculated using the following formula:

Packet Loss (%) = (**Number of lost packets / Total packets sent**) × **100%**

Lower packet loss percentages indicate higher network reliability and better Quality of Service.
Based on these calculated values, network performance is then classified according to the TIPHON standard to determine the corresponding service quality category.

RESULTS

QoS Test Results

The QoS measurement results show a clear and consistent improvement in network performance after the implementation of bandwidth management using the Simple Queue and Queue Tree methods. Based on the measurement data, the average throughput increased from **3.2 Mbps before bandwidth management to 5.8 Mbps after implementation**. According to the TIPHON standard, throughput values in this range indicate a transition from the *Fair* category to the *Good* category, reflecting more efficient bandwidth utilization.

Meanwhile, the average delay decreased from **145 ms to 78 ms**. Referring to TIPHON delay classification, a delay below 100 ms is categorized as *Good*, whereas delays between 100–300 ms fall into the *Fair* category. This reduction demonstrates a significant improvement in network responsiveness and packet delivery efficiency.

In addition, packet loss was significantly reduced from **3.5% to 0.8%**. Based on the TIPHON standard, packet loss values below 1% are classified as *Very Good*, while values between 1–5% are categorized as *Fair*. This improvement indicates enhanced network reliability and reduced congestion after bandwidth management implementation. Overall, the explicit comparison between measured QoS values and TIPHON thresholds confirms that the applied Simple Queue and Queue Tree methods successfully improved network service quality across all evaluated parameters (Nurjanah & Nopiyanto, 2023).

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Table 1. QoS Measurement Results Before and After Bandwidth Management

QoS Parameter	Condition	Average Value	Unit	QoS Category
Throughput	Before Bandwidth Management	3.2	Mbps	Fair
	After Bandwidth Management	5.8	Mbps	Good
Delay	Before Bandwidth Management	145	ms	Fair
	After Bandwidth Management	78	ms	Good
Packet Loss	Before Bandwidth Management	3.5	%	Fair
	After Bandwidth Management	0.8	%	Very Good

Throughput Results

The observed increase in throughput demonstrates that bandwidth allocation became more evenly distributed among users after the implementation of bandwidth management. **Based on TIPHON classification**, the improvement in throughput values indicates a transition from the *Fair* category to the *Good* category, reflecting more efficient bandwidth utilization and improved service quality. The implementation of Simple Queue prevented bandwidth domination by individual users, while Queue Tree optimized traffic handling based on service priorities, resulting in more effective use of available network resources (Apriyanto & Nugroho, 2019; Lestari, 2025).

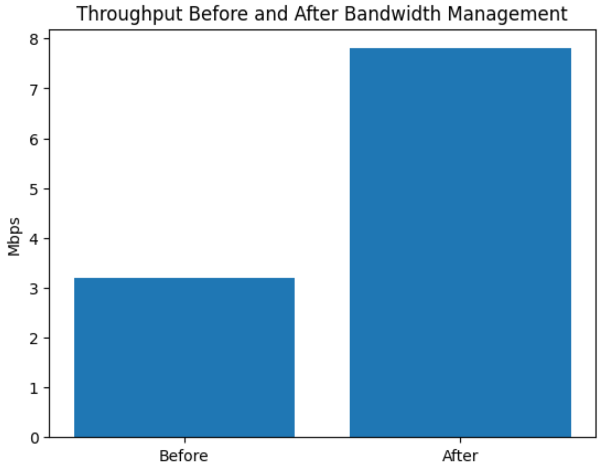

Figure 2. Grafik Throughput Before and After Bandwidth Management

Delay Results

A significant reduction in delay reflects improved packet scheduling and reduced congestion within the network. Based on TIPHON classification, the measured delay values fall within the Good category, indicating faster packet delivery and enhanced network responsiveness. Traffic prioritization through the Queue Tree mechanism ensures that latency-sensitive services receive higher priority, thereby improving the performance of real-time and interactive applications such as video conferencing and online communication (Siregar & Lubis, 2019).

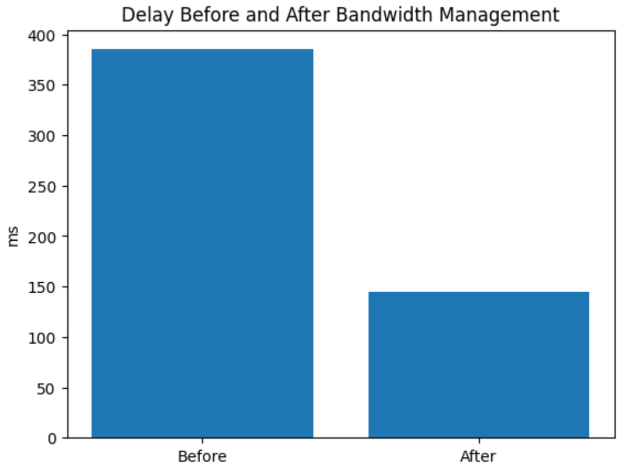

Figure 3. Grafik Delay Before and After Bandwidth Management

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Packet Loss Results

The reduction in packet loss indicates improved network reliability and stability following the implementation of bandwidth management. Based on TIPHON classification, packet loss values below 1% are categorized as Very Good, demonstrating that network congestion and packet drops were effectively minimized. Controlled queuing mechanisms and balanced traffic flow reduce buffer overflow and transmission errors, leading to a more stable and reliable Quality of Service (QoS) (Putra & Sari, 2020).

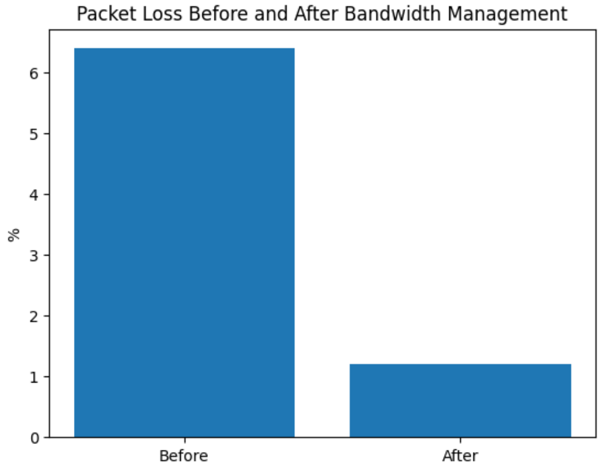

Figure 4. Grafik Packet Loss Before and After Bandwidth Management

DISCUSSION

Discussion of Throughput Performance

As illustrated in **Figure 2** and summarized in **Table 1**, the observed increase in throughput reflects the effectiveness of the implemented bandwidth management mechanisms. The **Simple Queue** method successfully limits per-user bandwidth usage, ensuring fair bandwidth distribution, while the **Queue Tree** method prioritizes network traffic based on service types. This combined approach prevents bandwidth monopolization by specific users and optimizes overall bandwidth utilization, resulting in improved network efficiency and higher throughput values.

Discussion of Delay Performance

The significant reduction in delay, as shown in **Figure 3**, demonstrates that structured traffic prioritization effectively minimizes packet waiting time within network queues. By assigning higher priority to latency-sensitive services, the **Queue Tree** mechanism ensures faster packet processing and transmission. This improvement is particularly crucial for real-time and interactive applications, such as video conferencing and online communication, which require low latency to maintain acceptable service quality.

Discussion of Packet Loss Performance

The decrease in packet loss values presented in **Table 1** indicates improved network reliability following the implementation of bandwidth management. Controlled queuing mechanisms and reduced congestion allow packets to be transmitted more consistently with fewer drops. These results suggest that the applied methods effectively regulate traffic flow and enhance network stability, thereby contributing to better overall **Quality of Service (QoS)**.

Overall Discussion

Overall, the integration of Simple Queue for user-based bandwidth allocation and Queue Tree for service-based traffic prioritization proves to be an effective strategy for optimizing computer network performance. This combined approach significantly improves throughput while simultaneously reducing delay and packet loss, making it suitable for networks with diverse traffic characteristics. **Based on TIPHON classification, the overall QoS improvement achieved in this study confirms that the implemented bandwidth management mechanisms successfully elevate network service quality from moderate to high performance levels in a standardized and measurable manner.**

CONCLUSION

This study concludes that computer network performance can be effectively optimized through traffic management and bandwidth allocation using the **Simple Queue** and **Queue Tree** methods. The experimental results indicate a significant improvement in throughput, accompanied by substantial reductions in delay and packet loss, thereby enhancing overall network service quality. The integrated application of user-based bandwidth limitation and

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service-based traffic prioritization promotes fairness, improves network stability, and ensures more efficient bandwidth utilization. Consequently, these methods are highly recommended for network environments with a large number of users and diverse service requirements, particularly those requiring reliable and consistent Quality of Service (QoS)

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