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Implementation of Queue Tree for Network Quality of Service (QoS) Optimization at MIN 3 Pontianak

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Abstract

Optimal network performance is essential to support administrative and learning activities in educational institutions. MIN 3 Pontianak experienced network degradation due to the use of a single bandwidth channel shared by all users, resulting in inefficient traffic management and uneven bandwidth distribution. This study aims to optimize network Quality of Service (QoS) through bandwidth management using the Queue Tree method on a MikroTik router. The research method includes network requirement analysis, traffic classification based on user categories, Queue Tree configuration, and performance evaluation using throughput, latency, jitter, and packet loss parameters. The implementation results show that bandwidth allocation into several service classes, such as examination and teacher classes, improves bandwidth efficiency and minimizes interference among users. QoS testing indicates increased throughput, lower latency, and more stable jitter compared to the previous network condition. Therefore, the Queue Tree method is effective in optimizing network service quality and improving network performance at MIN 3 Pontianak.

***Keywords**: Queue Tree, Quality of Service, Bandwidth Management, QoS, Mikrotik*

1. Introduction

Computer networks play an essential role in supporting communication, data processing, and automation across various sectors of life [1], [2]. In the education sector, internet connectivity has become a primary requirement to support teaching, learning activities, and school administration processes [3]. Stable and reliable network performance is especially critical for computer-based activities such as the Computer-Based National Assessment (ANBK), which requires consistent internet access without interruption.

Madrasah Ibtidaiyah Negeri (MIN 3) Pontianak has utilized internet services to support its learning activities. However, based on interviews and observations, the existing network infrastructure is still relatively simple and has not implemented structured bandwidth management. All devices are connected within a single network without proper traffic control mechanisms, which leads to uneven bandwidth distribution and potential performance degradation when network traffic increases [4].

Furthermore, network usage analysis shows that bandwidth consumption is still shared equally without prioritization of services. This condition results in inefficient bandwidth utilization and reduced Quality of Service (QoS), particularly during peak usage times. In addition, some devices remain connected for long durations without optimal usage, contributing to unnecessary network load and congestion.
These problems become more significant during ANBK implementation, where network stability is crucial and bandwidth must be managed effectively. Limited infrastructure, such as the use of a single access point and diverse connected devices, also contributes to network instability and performance fluctuations [5].

Previous studies indicate that bandwidth management using queuing methods can improve QoS by prioritizing specific traffic types [6]. One widely applied method is Queue Tree on MikroTik, which allows hierarchical bandwidth allocation based on user groups and traffic classification [7],.Several studies have also proven that Queue Tree improves bandwidth efficiency and maintains network stability by distributing resources more fairly and prioritizing essential services [7][8][9].

Therefore, this study proposes the implementation of the Queue Tree method to optimize Quality of Service (QoS) at MIN 3 Pontianak. Network performance will be analyzed using QoS parameters such as throughput, delay, jitter, and packet loss to evaluate improvements after the implementation of this method [10].

2. Theoretical Basis

2.1. Literature Review

Previous studies show that the Queue Tree method is effective for bandwidth management in various network environments, including hotspot networks where it improves fairness and performance [11], comparative studies where it is found more suitable for high-traffic networks than Simple Queue, and implementations combined with Firewall Filtering that enhance traffic control and monitoring in corporate environments [12], while NDLC-based implementations improve throughput and reduce delay under heavy traffic conditions [13], and applications in school and hotspot environments also show better bandwidth distribution and efficiency as well as in ANBK support systems where Queue Tree combined with Mangle Firewall helps prioritize important traffic and improve network stability during exams however most of these studies are still limited to specific environments and do not comprehensively analyze QoS parameters in educational institutions, therefore this study focuses on implementing Queue Tree at MIN 3 Pontianak to evaluate QoS using throughput, delay, packet loss, and jitter before and after implementation.

2.2. Computer Network

A computer network is a collection of several computers that are interconnected with network devices such as cables or wireless, and can exchange information and power supplies with each other.

2.3. Wireless LAN (WLAN)

Wireless LAN (WLAN) or Wireless Fidelity (WiFi) uses new infrastructure and transmission media (in this case radio waves) to send data that travels through a local computer network without cables [14].

2.4. Virtual Local Area Network (VLAN)

Virtual Local Area Network (VLAN) is a network technology that enables logical segmentation of a network without depending on physical location, allowing flexible grouping of devices based on organizational needs rather than physical placement [15]. VLAN can be implemented as port-based VLAN, where devices are grouped according to switch ports, or MAC-based VLAN, where grouping is based on device MAC addresses [16]. The main benefits of VLAN include reducing network traffic, simplifying network management, improving scalability, and reducing infrastructure costs by limiting the need for additional routers VLANs operate using VLAN IDs (1–4094), where switches assign ports to specific VLANs and only allow communication within the same VLAN group [15]. Network performance in VLAN can be evaluated using Quality of Service (QoS) parameters such as throughput, delay, jitter, and packet loss to measure efficiency and stability.

2.5. Access Control List (ACL)

Access Control Lists (ACLs) are a critical component of network security. ACLs work by establishing rules that allow or deny data traffic based on specific parameters, such as IP addresses, protocols, and port numbers. With ACLs, network administrators can control access between VLAN network segments, thereby reducing the risk of unauthorized access[16].

2.6. Bandwidth Management

Bandwidth management is the practice of monitoring and controlling data traffic in a computer network to ensure fair and efficient bandwidth allocation for users and applications. Effective bandwidth management helps prevent network congestion and performance degradation. One common solution is the use of MikroTik routers, which provide bandwidth control through queue mechanisms to distribute network resources according to user and application requirements [17].

2.7. Network Devices

Network devices are hardware components used to support communication and data transmission within a network. In this study, the main devices used are the MikroTik Router and Access Point. The MikroTik Router is a networking device that operates using RouterOS and is widely used in various environments, including Small Office/Home Office (SOHO) networks, due to its flexibility, advanced features, and affordability [18]. Meanwhile, an Access Point (AP) is a device that connects wireless devices to a local network using technologies such as Wi-Fi and functions to transmit and receive data between clients and the network [19].

2.8. Network Development Life Cycle (NDLC)

The stages in the Network Development Life Cycle method are: Analysis stage, Design stage, Prototype simulation stage, Implementation stage, Monitoring stage, Management stage

3. Research Methods

3.1. Research Stages

In every research, a description of the process flow is needed, starting from the initial stage to the results, so that the stages in carrying out this research can run in a structured and good manner. The following are the stages that will be used in this research.

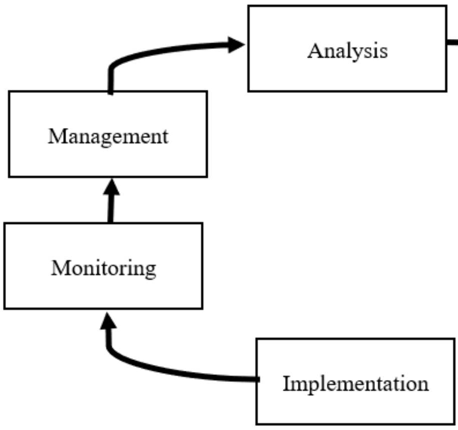

Fig. 1: NDLC method

This study employed the Network Development Life Cycle (NDLC) method, which consists of the analysis stage to identify network problems and requirements, the design stage to create the network topology, the simulation prototype stage using GNS3 to test the network design, the implementation stage involving the configuration of MikroTik, VLANs, SSIDs, and Queue Tree, the monitoring stage to observe network performance and QoS parameters, and the management stage to evaluate and adjust network configurations to maintain optimal service quality.

3.2. Problem Analysis

Problem analysis was conducted through interviews with the school principal and direct observations at MIN 3 Pontianak. The results showed that the existing network infrastructure is still simple, lacks structured bandwidth management and network segmentation, and relies on a single access point, leading to traffic congestion and reduced network performance as the number of users increases.

3.3. Simulation

In the simulation stage, the author conducted initial testing of the network design to ensure that the network topology and configuration could run well before being implemented directly.

3.4. VLAN Implementation

At this stage, VLANs were configured to segment network traffic and optimize bandwidth utilization. Bandwidth management was implemented using the Queue Tree method on MikroTik, while network security was enhanced through MAC Address-based Access Control Lists (ACLs), allowing only registered devices to access the network.

3.5. Monitoring

The monitoring stage was conducted after network implementation to evaluate network performance by collecting traffic data and Quality of Service (QoS) parameters, including throughput, packet loss, delay, and jitter, using Wireshark. The results were used to assess the effectiveness of VLAN implementation and Queue Tree-based bandwidth management.

3.6. Management

The management stage was carried out based on the monitoring results to evaluate VLAN and bandwidth management configurations, ensuring optimal network performance. The evaluation results were used to adjust bandwidth allocation, improve traffic management, and maintain stable network service quality at MIN 3 Pontianak.

4. System Analysis and Design

Detailed submission guidelines can be found on the journal web pages. All authors are responsible for understanding these guidelines before submitting their manuscript.

4.1. System/Network Analysis

System/network analysis was conducted to determine the requirements of the proposed network system by implementing VLAN-based segmentation on the WLAN. This segmentation enables bandwidth management and allocation using the Queue Tree method to optimize internet usage, while network performance is evaluated through Quality of Service (QoS) analysis to achieve better and more reliable WLAN performance at MIN 3 Pontianak.

4.2. System/Network Implementation Design Process

The study implemented VLAN-based network segmentation and Queue Tree bandwidth management at MIN 3 Pontianak through network topology design, GNS3 simulation, MikroTik configuration, VLAN and Queue Tree implementation, and QoS analysis based on throughput, packet loss, delay, and jitter parameters.

4.3. Data Analysis Design

Data analysis was conducted by evaluating different bandwidth limits on WLAN devices and measuring network performance using QoS parameters, namely throughput, packet loss, delay, and jitter, to determine the effectiveness of VLAN implementation and bandwidth management.

5. Results and Testing

In this section you should present the conclusion of the paper. Conclusions must focus on the novelty and exceptional results you acquired. Allow a sufficient space in the article for conclusions. Do not repeat the contents of Introduction or the Abstract. Focus on the essential things of your article.

5.1. Research Implementation

This study implemented a Virtual Local Area Network (VLAN) to segment the network and applied bandwidth management to improve internet distribution efficiency and service quality. Network performance was then evaluated using the Quality of Service (QoS) method under different user-load conditions to analyze the improvement in network service quality at MIN 3 Pontianak.

5.2. Unit Testing Implementation Design

At this stage, the entire configuration to be tested on the MIN 3 Pontianak network is designed. Unit testing focuses on ensuring each network component operates according to the scenario before conducting the overall test. The following sub-chapters will explain MikroTik router settings, Access Point settings, VLAN creation, and the implementation of Queue Tree for bandwidth management.

5.3. VLAN Testing

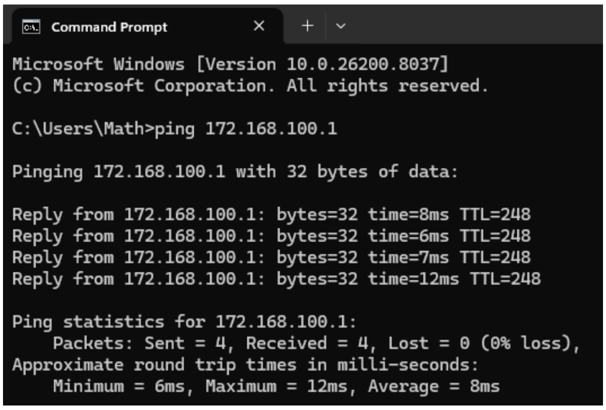
```
Command Prompt
Microsoft Windows [Version 10.0.26200.8037]
(c) Microsoft Corporation. All rights reserved.

C:\Users\Math>ping 172.168.100.1

Pinging 172.168.100.1 with 32 bytes of data:

Reply from 172.168.100.1: bytes=32 time=8ms TTL=248
Reply from 172.168.100.1: bytes=32 time=6ms TTL=248
Reply from 172.168.100.1: bytes=32 time=7ms TTL=248
Reply from 172.168.100.1: bytes=32 time=12ms TTL=248

Ping statistics for 172.168.100.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 6ms, Maximum = 12ms, Average = 8ms
```

Fig. 2: Testing between VLAN 100

Figure 2 shows that if it is in VLAN 100, then the device can get ping from the IP address 172.168.100.1 which is in VLAN 100.

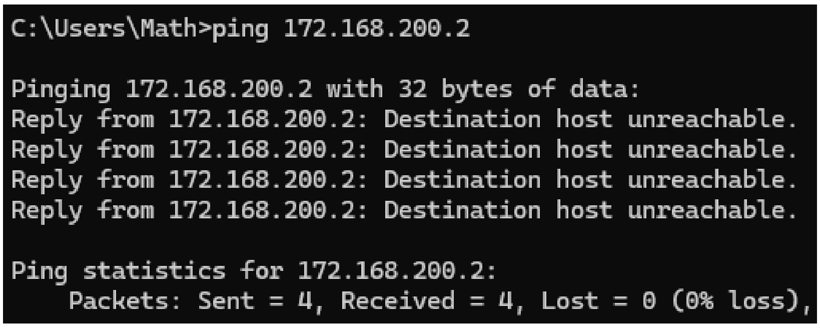
```
C:\Users\Math>ping 172.168.200.2

Pinging 172.168.200.2 with 32 bytes of data:
Reply from 172.168.200.2: Destination host unreachable.
Reply from 172.168.200.2: Destination host unreachable.
Reply from 172.168.200.2: Destination host unreachable.
Reply from 172.168.200.2: Destination host unreachable.

Ping statistics for 172.168.200.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
```

Fig. 3: VLAN 100 Communication Testing with VLAN 200

Figure 3 shows that if you are on VLAN 100 and want to ping the IP address 172.168.200.1 which is on VLAN 200, you won't be able to.

5.4. Testing Scenario

This study evaluated WLAN performance under three scenarios: without VLAN, with VLAN, and with VLAN plus bandwidth limitation on non-priority networks. Testing was conducted with 30 clients (busy condition) and 10 clients (non-busy condition). Network performance was measured using Quality of Service (QoS) parameters, including throughput, packet loss, delay, and jitter, to assess the impact of VLAN and bandwidth management on service quality.

Table 1: Testing Scenarios

No	**Case Skenario Pengujian**	**Kondisi Jaringan**	**Jumlah Client**	**Parameter QoS yang Dianalisis**
1	Case 1 WLAN tanpa VLAN	Sibuk	30 Client	Throughput, Packet Loss, Delay, dan Jitter
2	Case 1 WLAN tanpa VLAN	Tidak Sibuk	10 Client	Throughput, Packet Loss, Delay, dan Jitter
3	Case 2 WLAN dengan VLAN	Sibuk	30 Client	Throughput, Packet Loss, Delay, dan Jitter
4	Case 2 WLAN dengan VLAN	Tidak Sibuk	10 Client	Throughput, Packet Loss, Delay, dan Jitter
5	Case 3 WLAN dengan VLAN + Pembatasan Bandwidth pada jaringan tidak prioritas	Sibuk	30 Client	Throughput, Packet Loss, Delay, dan Jitter
6	Case 3 WLAN dengan VLAN + Pembatasan Bandwidth pada jaringan tidak prioritas	Tidak Sibuk	10 Client	Throughput, Packet Loss, Delay, dan Jitter

5.5. Comparison of Calculation Results Testing

The study analyzed four Quality of Service (QoS) parameters—throughput, packet loss, delay, and jitter—to evaluate network performance and service quality at MIN 3 Pontianak. The results were compared across three scenarios: Case 1 (without implementation), Case 2 (with VLAN implementation), and Case 3 (with VLAN and bandwidth limitation using Queue Tree).

1. Throughput

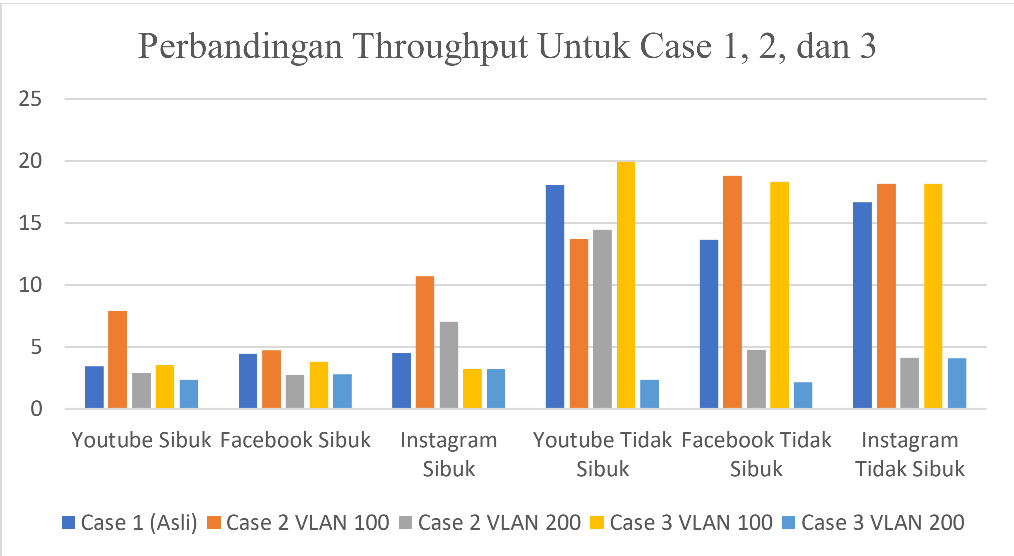

Fig. 4: Throughput Comparison Chart For Case 1, 2, and 3

The results show that VLAN implementation affects throughput, especially under busy network conditions. VLAN 100 maintained stable performance close to Case 1, while VLAN 200 experienced the largest decrease. The implementation of Queue Tree further reduced the throughput of VLAN 200 due to the 5 Mbps bandwidth limitation. Therefore, VLAN without bandwidth limitation provided better throughput performance.

2. Packet Loss

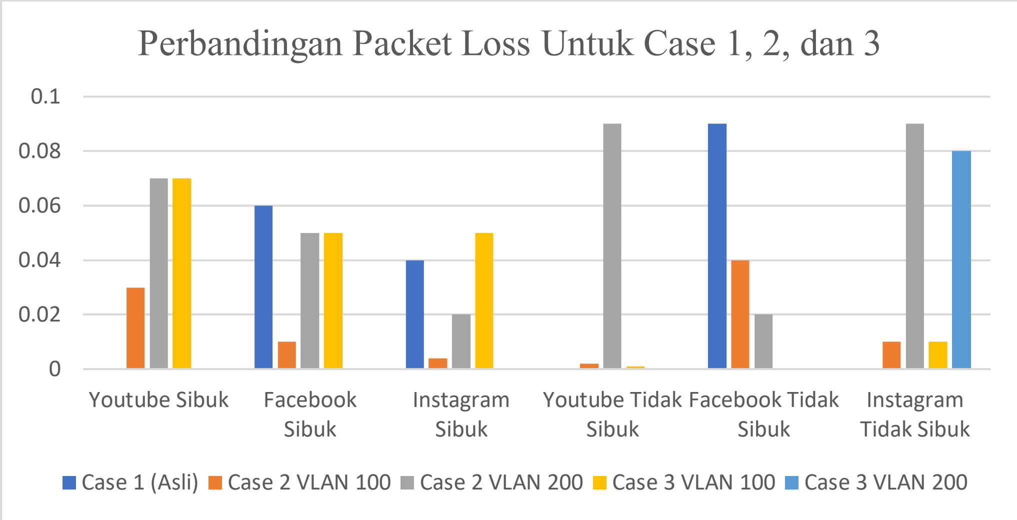

Fig. 5: Pocket Losst Comparison Chart For Case 1, 2, and 3

The results indicate that packet loss remained very low in all scenarios, below 0.1%, showing excellent data transmission quality under both busy and non-busy conditions. The implementation of VLAN and Queue Tree did not significantly increase packet loss. Although VLAN 200 showed a slight increase, especially under busy conditions and with Queue Tree, the values were negligible and had no significant impact on network service quality.

3. Delay

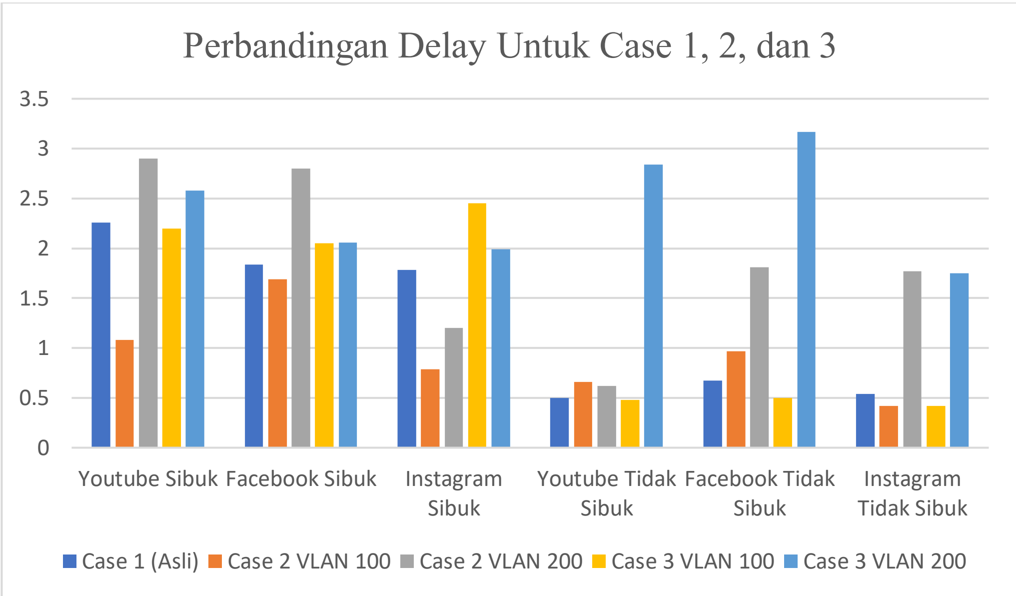

Fig. 6: Delay Comparison Chart For Case 1, 2, and 3

VLAN 100 maintained stable delay values similar to Case 1 under both busy and non-busy conditions, indicating minimal impact on packet transmission delay. In contrast, VLAN 200 showed a significant increase in delay, especially under busy conditions and after applying Queue Tree with bandwidth limitation. Therefore, VLAN 200 combined with Queue Tree significantly increased network delay, while VLAN 100 maintained good delay performance.

4. Jitter

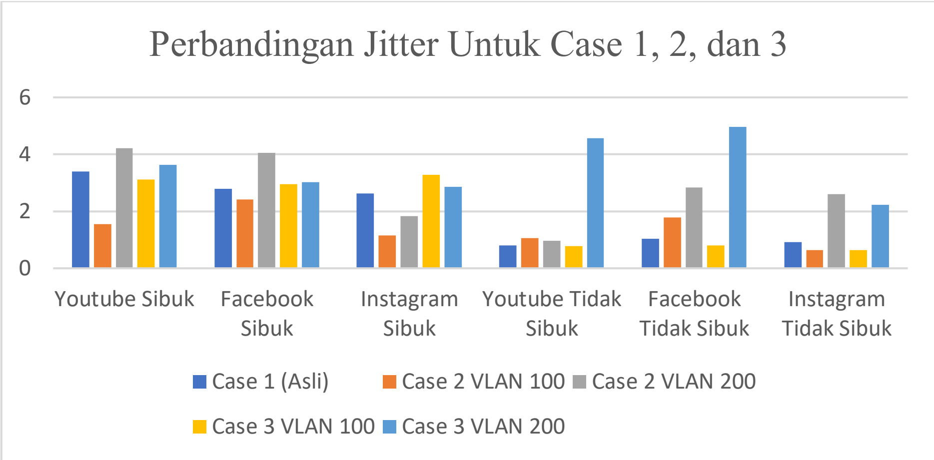

Fig. 7: Jitter Comparison Chart For Case 1, 2, and 3

Based on the test results, VLAN 100 maintained relatively stable jitter values with no significant changes from Case 1 under both busy and idle conditions, indicating good delay variation stability. In contrast, VLAN 200 experienced a noticeable increase in jitter, particularly during busy conditions. The implementation of Queue Tree in Case 3 increased packet queuing on VLAN 200, resulting in higher jitter. Therefore, VLAN 100 demonstrated more stable performance, while the combination of VLAN 200 and Queue Tree significantly increased network jitter.

6. Conclusion

The implementation of Queue Tree at MIN 3 Pontianak successfully optimized bandwidth management by providing structured and controlled bandwidth allocation, effectively managing traffic priorities while maintaining acceptable QoS performance despite slight decreases in throughput and increases in delay and jitter on limited networks, and it is recommended to continuously optimize Queue Tree configurations, increase bandwidth capacity or implement load balancing, and perform regular network monitoring to maintain network stability and service quality.

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