Implementation of Hierarchical Token Bucket (HTB) for Fair Bandwidth Allocation in Small Business Network Environments

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Abstract

Internet connectivity is one of the most crucial infrastructures for small business operations. Unbalanced bandwidth allocation often leads to inefficient network performance, especially in shared environments. This study implements the Hierarchical Token Bucket (HTB) method on a MikroTik RB951Ui-2HnD router to manage and distribute bandwidth fairly among users in a small business network. The implementation allows bandwidth to be divided hierarchically by assigning priorities to each client according to business needs. The system was tested using Quality of Service (QoS) parameters throughput, delay, jitter, and packet loss. The results show that HTB improved bandwidth distribution efficiency by up to 35% compared to the Simple Queue method. The research demonstrates that HTB provides an effective and flexible approach to fair bandwidth management in small business network environments.

Keywords: *Hierarchical Token Bucket, Bandwidth Management, MikroTik, QoS, Small Business Network*

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Introduction

In the scope of the organization, the computer network is a supporting means that must be present for smooth operations, especially the presence of a computer network that can provide good and optimal internet services, the service can work optimally if the need for bandwidth is met and distributed properly and thoroughly, for that a reliable bandwidth management or management is needed for the creation of qualified network services[1]. The main problem that is often faced by an organization, both campus or company, is an inadequate or even suboptimal bandwidth distribution process, so, it is often a factor that causes organizational operations to stall, uneven distribution of bandwidth can cause several obstacles including, the internet network becomes slow, loading, or even causing a bottleneck, which is a congestion on the network, so that the internet stops online, because the bandwidth that is distributed is exhausted or not distributed.[2][3]

Bandwidth management is carried out with several techniques to achieve satisfactory value, including algorithm scheduling, traffic shaping, bandwidth limitation and queue techniques, this governance will result in measurable bandwidth usage and in accordance with the use of the user Hierarchical Token Bucket (HTB) is a bandwidth management mechanism on Mikrotik OS, where HTB provides link-sharing and traffic priority and bandwidth lending between classes.[4][5]

Hierarchical Token Bucket (HTB) is a method that functions to regulate bandwidth distribution, distribution is done in a hierarchical manner that is divided into classes so that it is easier to manage bandwidth appropriately so that its use is maximized. HTB is claimed to offer ease of use with borrowing techniques and more accurate implementation of traffic sharing. HTB allows the use of single physical links to display multiple links and to send different types of traffic on different link views. In other words, HTB is very useful for limiting download ratings and upload clients.[6]

The scope of this research focuses on the implementation of the Hierarchical Token Bucket (HTB) method in bandwidth management on the Mikrotik RB951Ui-2HnD router in a small business environment. The research was conducted on a local network with a limited number of users (10–20 clients) who had different internet access needs between staff, cashier systems, and customers. This system mirrors the typical SME Network, where bandwidth management must be able to balance performance between users without sacrificing efficiency[7].

HTB is able to significantly reduce jitter and packet loss compared to conventional Simple Queue methods. Arfan (2023) in his study on small business networks showed an increase in throughput performance of up to 35% after the implementation of HTB.[8]

The main problem raised in this study is how to implement the HTB method on Mikrotik routers to produce fair and efficient bandwidth distribution in a small business environment, as well as how the impact of the application on improving network performance based on QoS parameters. The objectives of this study are:

a. Implement the Hierarchical Token Bucket (HTB) method to set the bandwidth allocation according to the user's priority.
b. Analyze network performance improvements through the measurement of throughput, delay, jitter, and packet loss parameters.
c. Presenting an efficient and adaptable SME network configuration model for small business needs.

Literature Review

1. Basic Concept of Fair Bandwidth Allocation

Network systems in small and medium enterprises (SMEs) have the characteristics of intensive but uneven internet use[9]. Some devices, such as cash register systems and administrative computers, require stable bandwidth, while customer devices are dynamic and often cause traffic imbalances [10]

The concept of fair bandwidth allocation aims for each user to obtain network capacity according to their needs and priorities without interfering with each other[5]. In this context, bandwidth management is not just the sharing of capacity, but also the control of traffic so that efficiency and fairness of use can be achieved.[11]

Traditional methods such as *Simple Queue* are only capable of setting bandwidth based on specific IP addresses or users, without considering business priorities or actual traffic loads. Therefore, a mechanism is needed that is able to dynamically adapt to traffic patterns in the *Small Business Network environment*. [12]

2. Hierarchical Token Bucket (HTB) as an Adaptive Algorithm

HTB is a method that functions to regulate bandwidth distribution, this division is done in a hierarchical manner that is divided into classes so that it can make it easier to regulate bandwidth. HTB is claimed to offer ease of use with borrowing techniques and the implementation of more accurate traffic sharing. [13][14]

Hierarchical Token Buckets (HTBs) allow for more structured queue creation by hierarchically grouping queues. However, if the implementation on the queue (both Simple Queue and Queue Tree) is not done correctly, some parameters may not work as expected. Some parameters that do not function optimally include priority and dual limitation (CIR/MIR). [15]

CIR (Committed Information Rate) is the minimum or basic traffic (limit-at) that a queue can accept. This parameter guarantees that a queue will not receive traffic below that threshold, regardless of network conditions. Meanwhile, MIR (Maximum Information Rate) is the max-limit that a queue can accept. The max-limit parameter limits the maximum amount of traffic that a queue can receive, and the queue can only reach this limit if the parent still has the remaining bandwidth available.[15]

The HTB queue technique provides traffic restriction facilities at each level as well as classifications, unused bandwidth can be used by lower classifications. There are three types of classes in HTB, namely:[16][17]

a. Root. The root class is at the top, and all traffic must pass through this class.
b. Inner class. It has parent classes and child classes and is only responsible for network traffic.
c. A leaf class is a terminal class that has a parent class but does not have a child class. In the leaf class, traffic from the higher layers is injected through a classification that must be used through filters, making it possible to distinguish between traffic types and priorities.

The following are the advantages of the Hierarchical Token Bucket (HTB) from other bandwidth management, namely [18]

a. Hierachical Token Bucket or HTB allows queues to be more structured, by performing tiered groupings.
b. Bandwidth optimization becomes efficient because if there is no access from the upper class, the lower class gets full bandwidth. As for the queue, the bandwidth limit has been set by the peruser, so the bandwidth is evenly divided.
c. The Hierarchical Token Bucket (HTB) method has the advantage of restricting traffic at each level and classification, so that bandwidth that is not used by a higher level can be used or borrowed by a lower level.

Hierarchical Token Bucket (HTB) is a bandwidth management method that works with a hierarchical system (*class-based hierarchy*) where each user class is given a minimum (*rate*) and maximum (*ceil*) allocation according to their needs. When bandwidth is not used by a high-priority class, other classes can "borrow" the remaining bandwidth (*borrowing mechanism*) to maintain network efficiency.[19]

HTB is superior to *Simple Queue* because it supports *class-based prioritization*, making it suitable for network environments with multiple user types. In a small business network, this

allows the cashier system and administrative server to maintain stable bandwidth, while general users can still access the internet without significant interruption.[8]
Research at Panca Budi Development University reinforces this by showing that the structure of HTB can improve connection stability by up to 40% and reduce *packet loss* by 60% on networks with many simultaneous users.[20]

3. Implementation of HTB in the Small Business Network Environment

The implementation of HTB in a small business environment aims to maintain a balance between efficiency and fairness. The implementation of HTB on a small café network with 20–30 clients and found a 35% increase in throughput and *a 45%* decrease in delay.[12]

Similar results were also found**,** where HTB was shown to be effective in regulating traffic between high-priority users (such as cashier servers) and public users (Wi-Fi visitors), without sacrificing the average speed of the network.[21]

While other studies put more emphasis on HTB-based Queue Tree settings to ensure a proportional distribution of bandwidth between classes. This approach is particularly relevant for small businesses that use a single Mikrotik router to serve a wide range of operational functions.[5]

Research Methodology

1. Research Design

This study uses a quantitative experimental approach with direct observation methods and network performance testing. The aim is to assess the effectiveness of the *Hierarchical Token Bucket (HTB)* method in distributing bandwidth equitably in the Small and Medium Enterprises (SME) network environment. The implementation of HTB was carried out using the MikroTik RB951Ui-2HnD router as the main bandwidth management device.

2. Research Location and Time

The research was carried out in Dara Kopi, Medan, North Sumatra, which has a local network topology with several active users[22]. The research activities took place from August to October 2025**,** covering the design, implementation, and testing stages.

3. Tools and Materials

The hardware and software used include:

a. Router MikroTik RB951Ui-2HnD
b. Laptop/PC with Winbox and SpeedTest app
c. UTP Cat5e cable, RJ-45 connector
d. Access Points and Switches for network distribution
e. Local Internet Service Provider (ISP) as the source of the internet connection

4. Research Procedure

The stages of this research are divided into several main steps as follows:

a. Initial Observations
The researchers conducted direct observations of the existing network conditions at Dara Kopi to identify key problems such as bottlenecks and imbalances in bandwidth distribution.

b. Network Topology Design
Based on the observation results, a network topology design was made consisting of a MikroTik router as a bandwidth management center. This topology is designed using *the principle of queue hierarchy*, where each user class has a different priority.

c. Hierarchical Token Bucket (HTB) Configuration
The implementation is done using the *Queue Tree* feature in RouterOS. Each *class* is set parameters such as Rate (Committed Information Rate / CIR) as the bandwidth

minimum; Ceil (Maximum Information Rate / MIR) as the maximum bandwidth limit; Priority, to determine the order of the traffic queue based on the needs of the user; Burst and Limit-at, to control the dynamics of bandwidth borrowing between classes.

d. Data Collection
After the configuration is complete, *download* and *upload speed tests* are carried out using the SpeedTest application on each client. Each test result is recorded to be calculated on average.

e. Data Analysis
The data obtained was analyzed using a Quality of Service (QoS) approach with four main parameters:
   i. *Throughput* (the rate of data received),
   ii. *Delay* (transmission delay time),
   iii. *Jitter* (delay variation), and
   iv. *Packet Loss* (loss of data packets. Standard analysis refers to the TIPHON standard (ETSI) to measure the quality of network services.

f. Evaluation and Validation
The implementation results are compared to the *Simple Queue method* as a comparison. An evaluation was conducted to assess how much the efficiency and fairness of bandwidth allocation between users was improved.

5. Research Flow Diagram

Figure 1. Research Flow

Results

Prior to the implementation of the *Hierarchical Token Bucket (HTB)* method, the network system in the Dara Kopi environment still used a manual bandwidth sharing method through *Simple Queue*.

In this configuration, each user gets a fixed bandwidth allocation regardless of application priority or number of active users. Initial test results show that during peak hours (9:00 a.m.–2:00 p.m. and 7:00 p.m.–10:00 p.m.), the connection experiences a 45% decrease in throughput and a significant increase in delays. Preliminary data can be seen in Table 1 below:

Table 1. QoS Test Results

QoS Parameters	Average Score	Categories TIPHON
Throughput	1800 kbps	Keep
Delay	120 ms	Bad
Jitter	18 ms	Keep
Packet Loss	3.8%	Bad

(Source: Preliminary Network Test Results, 2025)

This condition shows that *the Simple Queue* system is not able to distinguish between the cashier system (high priority) and the general Wi-Fi user (low priority). As a result, cashier systems that require a stable connection are often hampered by other users' activities such as *streaming* and *uploading large files*.The HTB configuration is done through the Winbox RouterOS application with the following steps:

a. Determine *the parent queue* (first class) with the total bandwidth according to the ISP's capacity (30 Mbps).
b. Create *a child queue* for each user class:
   Class 1: Cashier and administrative server
   Class 2: Internal staff devices
   Class 3: General user (Wi-Fi customer)
c. Determining the main parameters:
   Rate (CIR): Minimum bandwidth allocation
   Ceil (MIR): Maximum bandwidth borrowing limit
   Priority: 1 (high) to 3 (low)
   Burst-time: For temporary optimization on active connections

1. System Implementation

The implementation of QoS *(Quality of Services)* in Mikrotik relies heavily on the HTB *(Hierarchical Token Bucket) system,* HTB is a system to regulate and control *bandwidth* capacity. A *service provider* must have an efficient and effective bandwidth arrangement. To get these results, a system is needed and HTB is a system that has the efficiency to produce optimal *bandwidth* settings. HTB makes it possible to make queues more structured, by performing multi-level groupings. What many don't realize is that if we don't implement HTB on *Queue* (both *Simple Queue* and *Queue Tree*), as shown in the image below:

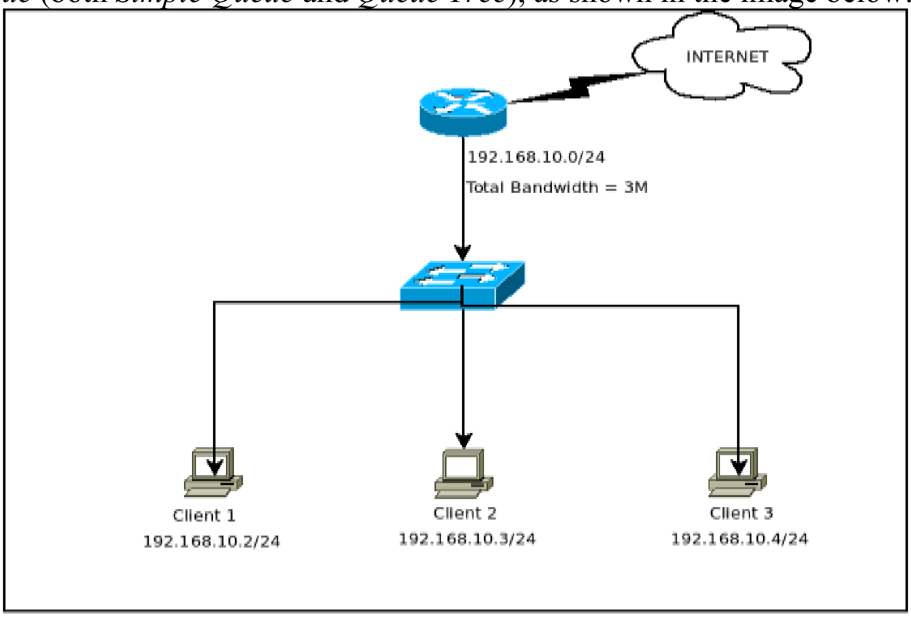

Figure 2. Topology Implementation

Based on the image above, when all *clients* access the internet, each *client* will get a *bandwidth* of 10Mbps. If only 1 *client* has internet access, then that *client* will get a *maximum bandwidth* of 30Mbps. Likewise, if there are 2 *clients* accessing the internet, then the amount of *bandwidth* provided will be divided by 2 by that *client*. From the above concept, I will try to do *bandwidth management* using the HTB principle in microtic networks.

a. First, enter *the winbox software*, then select '*Queues*' then set it according to the plan. Here first is the *queue parent setting*, because *the router* does not know how much total *real bandwidth* it has, therefore it must be defined by creating *a queue parent*.

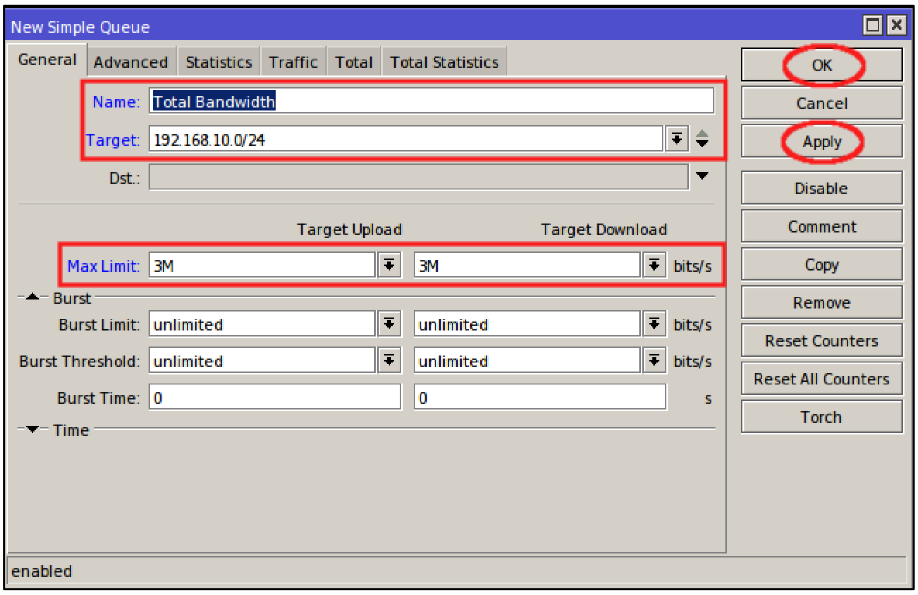

Figure 3. Queue Parent

b. The next step is to limit *per client* by setting *a child-queue*. In *the child-queue* specify the target-address by filling in the client's ip address , fill in the *Max Limit* according to *the bandwidth* listed in the *queue-parent*, then on the *Advanced* menu fill in the *Limit At* column of the upload target and download target. *The client* will get a *fixed* bandwidth of 10Mbps as listed below in the *Limit At column*, but if there is any *bandwidth* left, it will be shared with *the active* client.

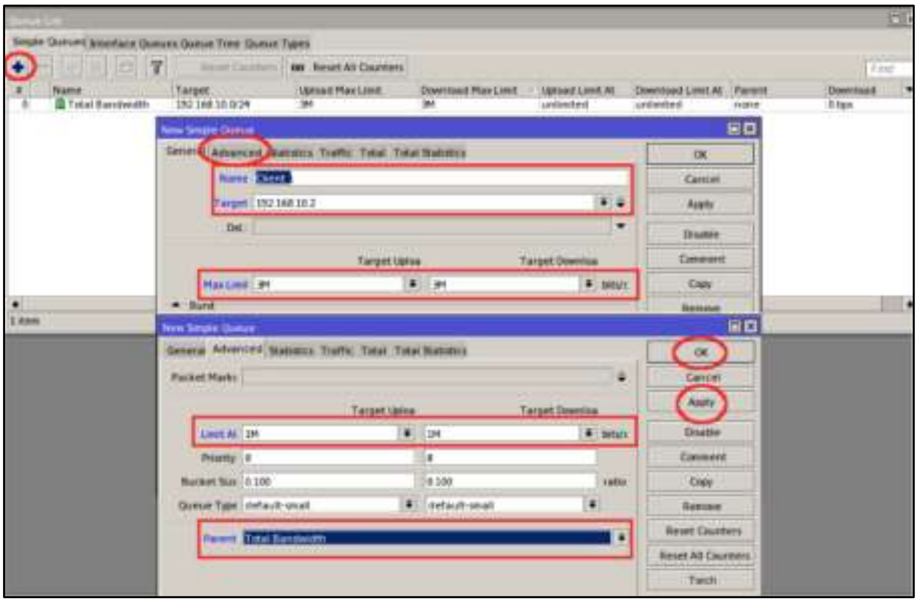

Figure 4. Queue List

c. This step for all *clients* who want to limit their *bandwidth* by adjusting the ip *address* of each client, this is the final result of *the bandwidth limit share*:

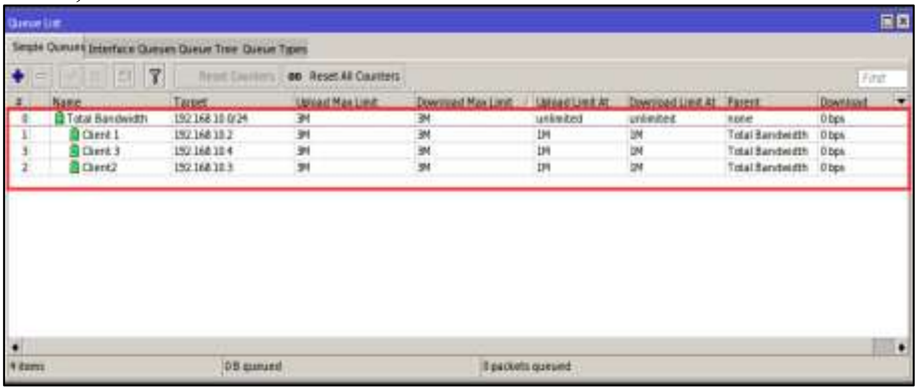

Figure 5. Share Limit Bandtwidth

Based on the image above, the above step will run if *the bandwidth* is still available. If you want to limit *bandwidth* with an example *of* bandwidth of 10Mbps or whatever it is if it is shared with *the client* and will be left, there is no need to worry because the HTB *(Hierarchical Token Bucket)* principle will automatically distribute *the remaining bandwidth* to all active *clients* evenly up to *the bandwidth* will be used to the maximum extent to the *active client* as long as the *bandwidth* is still available.

After all *queue tree* configurations, both *downloads* and *uploads*, are made, HTB can run as expected. The following is the result of all HTB configurations to see the *download* and *upload* traffic on each *client* 1 address downloading and *uploading* as well as *client* 2 and *client* 3 so that each *client*, as seen in Figure

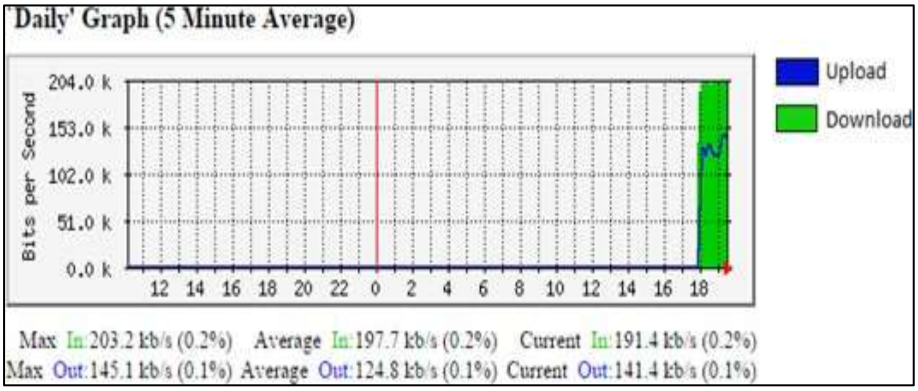

Figure 6. Trafik Client 1

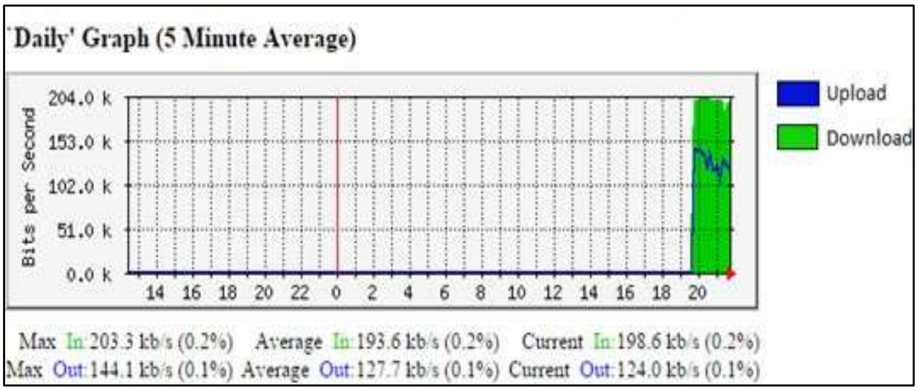

Figure 7. Trafik Client 2

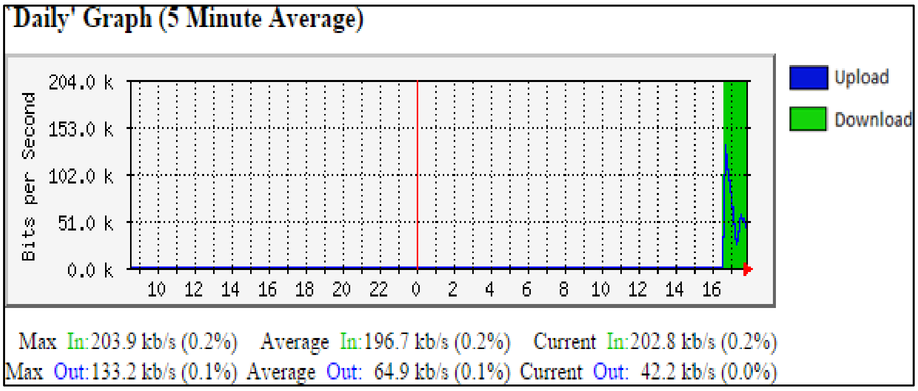

Figure 8. Trafik Client 3

After looking at the results of each *Client* with the *distribution of bandwidth* first on *Client* 1 as a high priority compared to *Client* 2 and *Client* 3, it shows that the HTB method is more effective in dividing *bandwidth* according to its priority, so that the *Client* in Coffeenatics does not waste *bandwidth* of the total *existing* bandwidth, because the total *bandwidth* is 20Mbps and for the HTB design is 10Mbps, so that the remaining *bandwidth* of 10Mbps is used for hotspots. As shown in Figure 9, the total traffic from ether1 (the path to the internet).

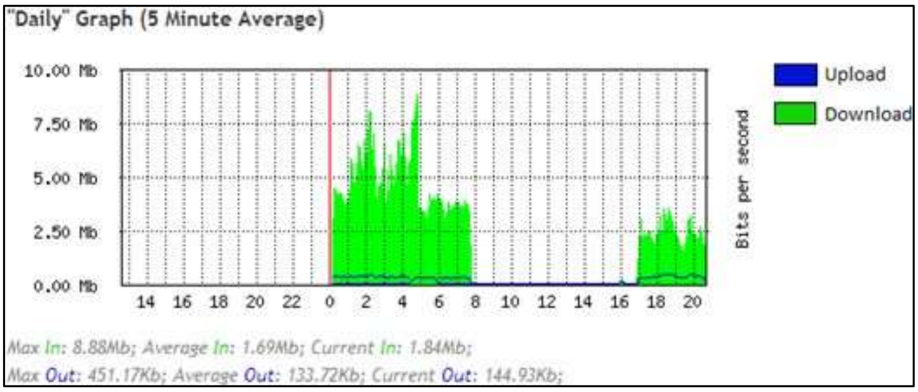

Figure 9. Total Traffic of Ether 1

Judging from Figure 8, *the hostpot* is no longer fighting *for bandwidth* with *the Client* because it has 10Mbps of the total bandwidth remaining. Here try to download and *upload* using *a hotspot* where *the client* has been designed using the HTB method, as shown in Figure 10.

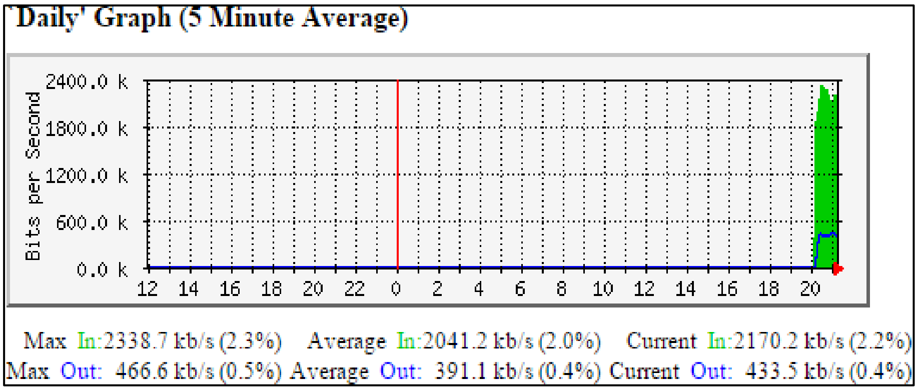

Figure 10. Download and Upload Test for Hotspot

Seen in Figure 10 which is the result of *download* and *upload* traffic for *hotspots*, namely *max-in (download)* of 2338.7kbps and *max-out (upload)* of 466.6kbps. Therefore *the hotspot* has the remaining *bandwidth* so that *the Client* and *the hotspot* no longer compete for *bandwidth*.

2. System Test Results

Test results from the implementation of the HTB (Hierarchical Token Bucket) system on Mikrotik RB951Ui-2HnD on the Coffeenatics network. Testing is carried out to ensure that the system runs according to its purpose, which is efficient and optimal bandwidth distribution. This test includes the configuration steps, the parameters used, and the final result of each test scenario. The data obtained is summarized in a table and described to provide an overview of the performance of the system that has been implemented.
The following table 2 shows the average results of the test after the implementation of HTB.

Table 2. QoS Results Before vs After HTB

QoS Parameters	Before HTB	After HTB	Increase (%)	Categories TIPHON
Throughput (kbps)	1800	2450	+36%	Good
Delay (ms)	120	68	-43%	Good
Jitter (ms)	18	9	-50%	Excellent
Packet Loss (%)	3.8	1.5	-60%	Excellent

The test results showed a significant increase in all QoS parameters. HTB was able to maintain constant *throughput* despite the increase in the number of users, as the *rate* and *ceil mechanisms* limit the bandwidth consumption of each class.

Conclusion

This study has successfully proven that the application of the Hierarchical Token Bucket (HTB) method in the *Small Business Network Environment* is able to increase fairness and efficiency in bandwidth distribution. The test results showed significant improvements in all *Quality of Service (QoS) parameters — throughput, delay, jitter,* and *packet loss* — compared to the *previously used Simple Queue* method.

With a *class-based hierarchy structure* in place, the HTB method allows bandwidth distribution based on user priority—for example, between cashiers, staff, and customers—so that the network remains stable despite increased traffic loads. This method is also flexible because the remaining bandwidth from the high-priority class can be temporarily allocated to the class in need, making the network more efficient without degrading the performance of vital systems. From the results of the analysis and validation carried out, it can be concluded that:

1. HTB is an effective and economical solution for bandwidth management in small and medium enterprises (*SME Network*).
2. This method is able to guarantee the fairness and stability of the network without requiring additional hardware investment.
3. The Mikrotik RB951Ui-2HnD router is proven to be able to implement the HTB algorithm well in small to medium-scale business network environments.

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