ISSN 2089-8673 (Print) | ISSN 2548-4265 (Online)
Volume 13, Issue 2, July 2024

QOS ANALYSIS OF IMPLEMENTATION ELASTIC WLAN MECHANISM FOR ADAPTIVE BANDWIDTH MANAGEMENT SYSTEMS IN SMART BUILDINGS

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Abstract

The rapid growth of the Internet of Things technology has led to various innovative creations, However, effective management of data traffic generated by numerous sensors is essential to maintain network performance. This study develops and evaluates an adaptive Bandwidth Management System using Elastic WLAN to deal with the development of IoT system traffic so that network performance is maintained. Using Raspberry Pi as an Elastic WLAN device and a Hierarchical Token Bucket (HTB) running via Python script, this system manages Bandwidth allocation based on the number of visitors in the Smart Building. Evaluation was carried out in two rooms, comparing conditions before and after Elastic WLAN implementation. The results show that the implementation of Elastic WLAN improves network performance. This is indicated by improvements in the stability of upload and download rates, as well as very significant improvements in the Jitter and Latency parameters which are used as QoS parameters.

Keywords : Bandwidth Management, Elastic WLAN, Internet of Things, Smart Building

Received: 24-07-2024 | **Revised:** 30-07-2024 | **Accepted:** 31-07-2024
DOI: https://doi.org/10.23887/janapati.v13i2.83215

INTRODUCTION

The use of technology is proliferating, supported by the implementation of various types of integrated and collaborative technology [1]. Internet of Things (IoT) is an example of technology implementation that can change the habits of the general public [2]. Combining Artificial Intelligence (AI), Machine Learning, and Edge Computing technology creates an increasingly strong IoT network and enables more efficient data processing [3]. It has been predicted that by 2025, more than 29 billion devices will be connected to the Internet, generating more than 73.1 zettabytes of data [4].

However, this massive growth in connected devices has not been supported by the increased availability of adequate bandwidth capacity [5]. So issues arise, such as network congestion and scalability [6], which leads to decreased network performance or quality [7].

Efforts can be made to overcome this issue by implementing network management to manage traffic according to what is needed [8]. Therefore, an Elastic WLAN mechanism can change bandwidth dynamically and adaptively depending on environmental conditions or existing loads [9].

Research regarding the implementation of Elastic WLAN has managed several access points to regulate the number of hosts connected. However, this research has a weakness on the infrastructure side, which requires the availability of many access points following the number of hosts connected. Apart from that, the method in this research has not directly managed bandwidth [10].

In previous research, the Elastic WLAN mechanism has been successfully implemented in two IoT devices [11] and then developed to manage bandwidth in a smart building which manages 2 (two) room access points connected to a Raspberry Pi device, which functions as an Elastic WLAN device. This research used the number of people in the room as a bandwidth-dividing parameter. Thus, we obtain a bandwidth allocation for each access point following the ratio of the number of people in the room [12]. The research conducted has not paid attention to the impact of Elastic WLAN implementation on the condition of the managed network.

Bandwidth management systems that support dynamic bandwidth management systems can use the Hierarchical Token Bucket (HTB) method [13]. The HTB method allows for a hierarchical bandwidth distribution and is flexible

ISSN 2089-8673 (Print) | ISSN 2548-4265 (Online)
Volume 13, Issue 2, July 2024

in allocating bandwidth. This method is most suitable for use in dynamic and adaptive bandwidth allocation compared to other methods because of its real-time bandwidth adjustment capabilities based on network load [14].

In a telecommunications network, Quality of Service (QoS) parameters are critical to assess the appropriateness of quality according to specified standards, especially in WLAN networks [15] [16]. QoS for a network is very useful in monitoring network performance optimization and efficient bandwidth use. This QoS parameter will affect the implementation of other supporting services, such as video streaming [17], surveillance systems, and monitoring systems [18]. So, it is essential to evaluate the quality of service on each network being developed [19].

As established, the escalating data traffic originating from individual sensors connected to the WLAN network significantly influences the managed bandwidth capacity, thereby directly impacting service quality. Notably, prior research has not thoroughly examined the effects of deploying the Elastic WLAN mechanism on network performance. To ensure optimal network functionality, a comprehensive analysis of the Elastic WLAN implementation's impact on performance is warranted, with specific attention to various Quality of Service (QoS) parameters.

Therefore, it is crucial to conduct research that analyzes QoS parameters on the Elastic WLAN mechanism system developed to manage networks in smart building systems. Through this research, it is hoped that we can evaluate the impact that occurs when an IoT network is implemented with a dynamic bandwidth management mechanism using Elastic WLAN.

This research was carried out in an existing environment, namely two rooms with an access point connected to an Elastic WLAN device in the form of a Raspberry Pi 4B. In the research method, this device monitors the Upload Rate, Download Rate, Jitter and Latency parameters when the number of people in the two rooms changes randomly. The research results show QoS monitoring before and after implementing the Elastic WLAN mechanism.

METHOD

This research develops an adaptive and dynamic bandwidth capacity management model based on the number of room visitors in the smart building system. This bandwidth management system was developed using the Elastic WLAN Mechanism. This system connects all IoT and visitor devices to the Access Point in each room. To optimize bandwidth management, the Elastic WLAN mechanism will dynamically and proportionally regulate bandwidth allocation in

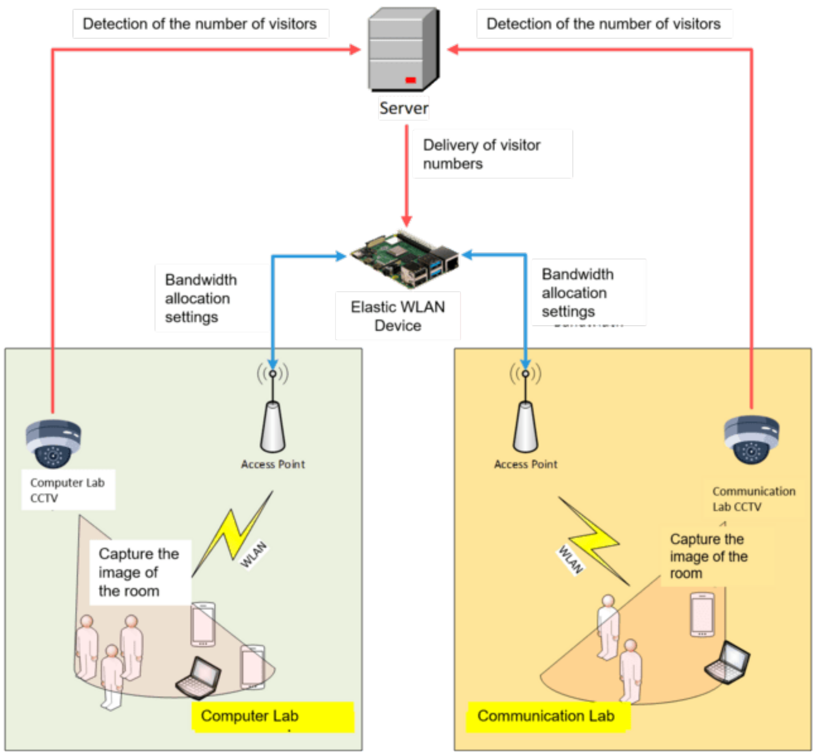

Figure 1. Bandwidth Management Mechanism

ISSN 2089-8673 (Print) | ISSN 2548-4265 (Online)
Volume 13, Issue 2, July 2024

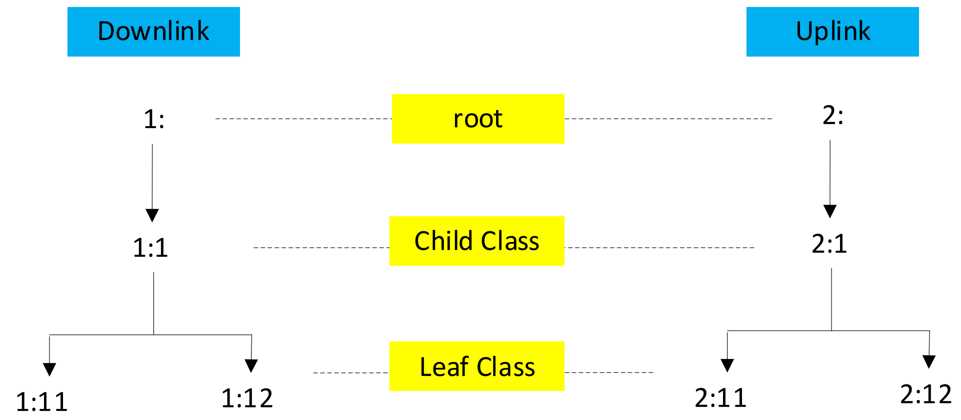

Figure 2. HTB Configuration on Elastic WLAN Mechanism

each room based on the number of visitors in the room. The arrangement is carried out on the principle of providing a higher bandwidth allocation to rooms with more visitors.

Figure 1 shows dynamic bandwidth allocation. Where, the CCTV in each room captures images and then sends them to the server by streaming. So that all images in the room can be monitored via the server. The server then performs image processing to detect the number of people in each room image. The output from image processing is the number of people designated as a parameter in setting room bandwidth allocation. When the bandwidth allocation value has been obtained based on the number of people in the room, the Elastic WLAN device will limit the bandwidth to each access point. So, the bandwidth and internet speed are different in each room.

The bandwidth management system based on the number of visitors in the laboratory room is carried out by detecting the number of people in the room using the YOLOv3 (You Only Look Once) algorithm, which is run on the server. Previous research has successfully carried out this process [20]. The number of visitors to each room is set differently to obtain different bandwidth allocations. Furthermore, the Elastic WLAN mechanism in this research was adapted using the Hierarchical Token Bucket (HTB) method.

Here is a detail of the process involved in developing an adaptive and dynamic bandwidth management system for smart buildings, as illustrated in Figure 1. In this research endeavor, we undertook a systematic approach to design an efficient bandwidth management system tailored for smart buildings. The development process comprised several key stages: Occupancy Estimation Mechanism, Bandwidth Allocation Algorithm, and Capacity Allocation Strategy.

At the Occupancy Estimation Mechanism stage, here a robust method is designed to accurately determine the number of occupants in each room. As can be seen at Fifure 1, the research design uses two rooms: the Telecommunication Laboratory Room and the

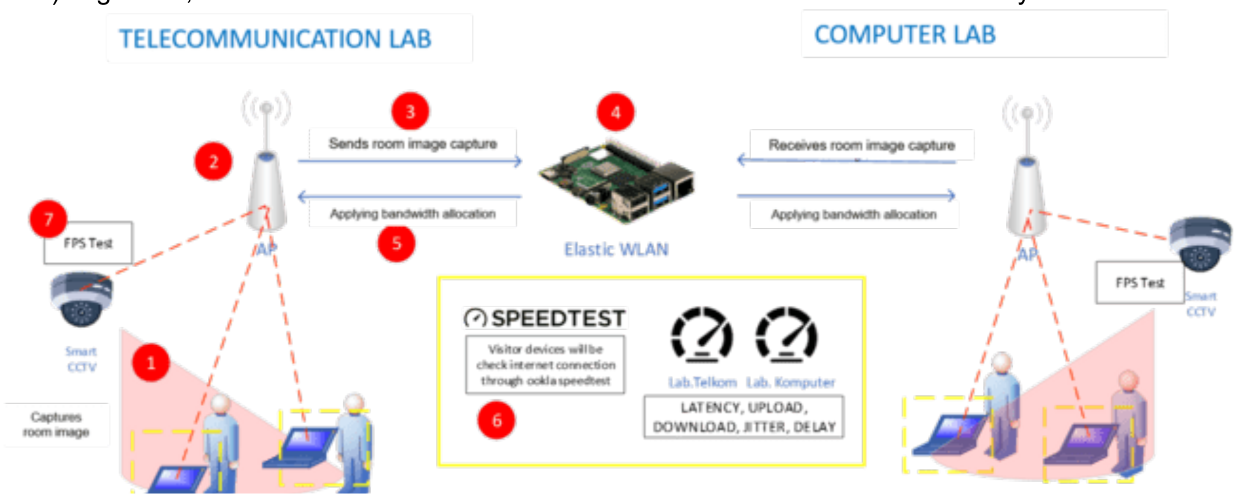

Figure 3. Elastic WLAN Mechanism Testing Scheme for Smart Building Networks

ISSN 2089-8673 (Print) | ISSN 2548-4265 (Online)
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Computer Laboratory Room in the Electrical Engineering Study Program, Udayana University. As previously stated, the image of the room conditions is captured by CCTV placed in each room. Furthermore, the image data is processed by YOLOv3 to identify and count the number of people in each room.

Then, at the Bandwidth Allocation Algorithm stage, we formulated an algorithm that dynamically allocates bandwidth to individual rooms based on the number of people attend in each room. This mechanism is carried out by the Raspberry Pi device which functions as an Elastic WLAN device. The calculation of the bandwidth capacity allocated to each room uses the following equation:

$$AB_n = \frac{a_n}{T} x\ B \qquad (1)$$

Where, AB_n is the bandwidth allocated to room-n, a_n is the number of people in room-n, T is the total number of people in all rooms, B is the maximum bandwidth in the smart building.

Figure 2 shows the configuration divided into two parts, namely the Downlink configuration and the Uplink configuration. This configuration plays a role in regulating the amount of data traffic that can be passed on the Elastic WLAN device interface. The Downlink Limitation process will be carried out on each interface connected to the Elastic WLAN device, while the Uplink Limitation process will be carried out on the virtual interface.

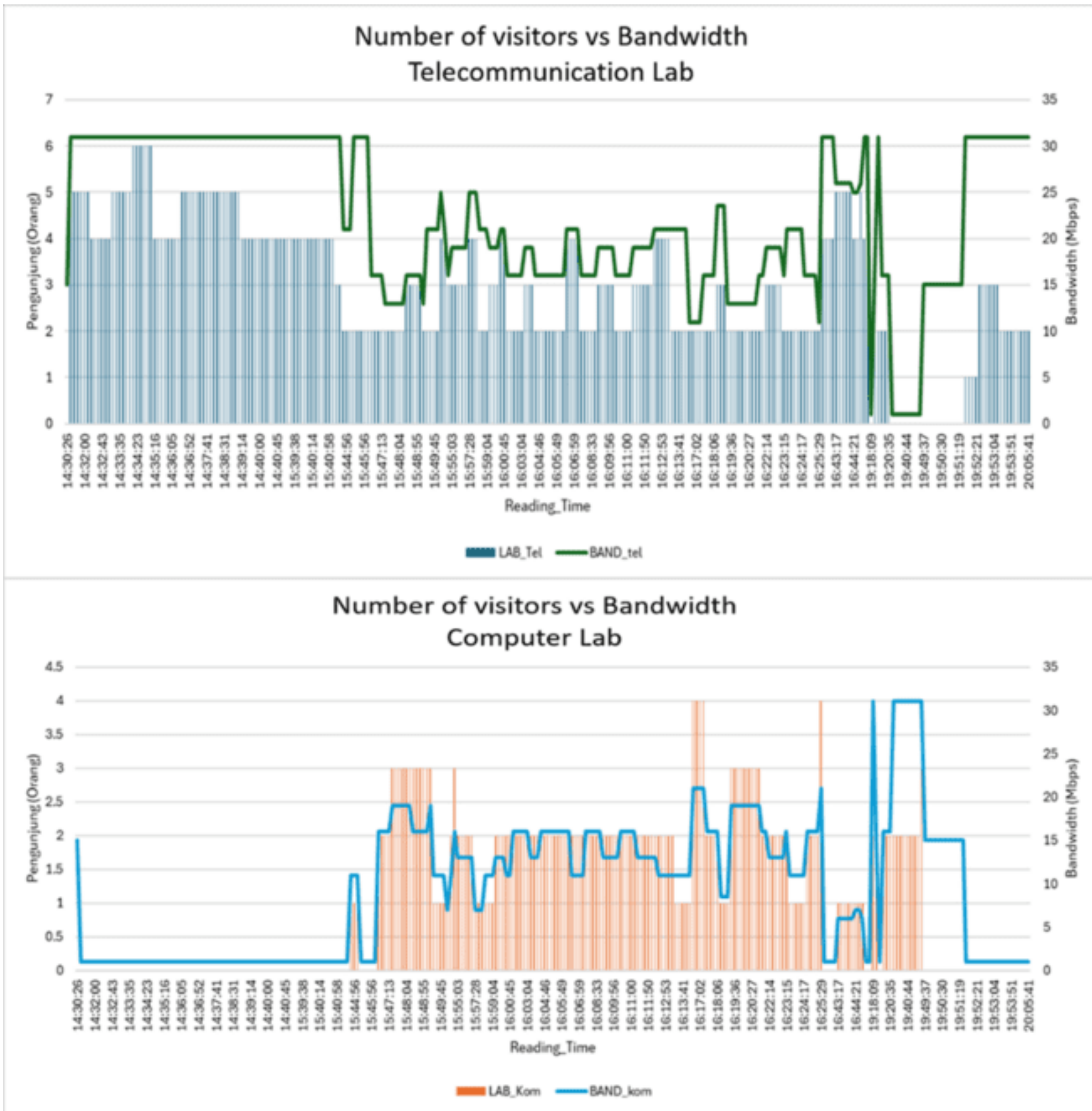

Figure 2. Comparison of Number of Visitors Telecommunication and Computer Lab Bandwidth

ISSN 2089-8673 (Print) | ISSN 2548-4265 (Online)
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HTB manages the root class configuration on the Elastic WLAN device's ethernet interface. Next, the child class will set the total bandwidth available in the smart building. In leaf classes, different bandwidth settings are made depending on the number of rooms available so that the number of leaf classes follows the number of rooms. In the leaf class section, room bandwidth capacity allocation is configured based on the number of visitors in the room.

The evaluation of the developed Elastic WLAN Mechanism aimed to assess its suitability for adaptive and dynamic bandwidth allocation within the proposed design. Additionally, the impact of implementing this mechanism on the performance of the Smart Building network was investigated. The testing protocol involved varying the number of room visitors across four distinct conditions. These controlled scenarios allowed us to analyze the system's responsiveness and effectiveness under different occupancy levels. The testing used four (4) conditions for the number of room visitors, namely:

1. Number of visitor at the Telecommunication Lab > Computer Lab
2. Number of visitor at the Telecommunication Lab < Computer Lab
3. Number of visitor at the Telecommunication Lab = Computer Lab
4. Number of visitor at the Telecommunication Lab & Computer Lab = 0

The Elastic WLAN mechanism can automatically manage bandwidth capacity based on the number of visitors who randomly enter and exit visitors, so monitoring the bandwidth allocation of the number of two smart building rooms is carried out. Testing of this system was conducted in the Telecommunications Laboratory room and Computer Laboratory room, both located in the Electrical Engineering Study Program Laboratory Building at Udayana University. The test was carried out over six (6) hours. Next, bandwidth allocation is supervised according to the number of visitors to each room.

This research examines the effect of implementing the Elastic WLAN mechanism on the QoS of the smart building system network by testing several QoS parameters, including Upload Rate, Download Rate, Jitter and Latency.

The configuration of the test scheme mechanism can be seen in Figure 3. It is shown that the bandwidth allocation process does not directly change the bandwidth of each room. The first process is CCTV detecting people in the room. Furthermore, the image obtained from CCTV is sent to the server via an access point connected to the Elastic WLAN device. Furthermore, the number of people is detected from the image by running the Yolov3 program. After that, the bandwidth of each room is applied based on the calculation results with the number of people. Furthermore, to ensure that the bandwidth limitation process can be carried out successfully, an internet speed test is carried out using the Speed Test application.

RESULT AND DISCUSSION

Figure 4 shows two comparison graphs of bandwidth versus the number of visitors in each Lab room. Telecommunications and Lab space. Computer. In this condition, Elastic WLAN regulates bandwidth capacity allocation based on the number of people in the room, which continues to change throughout the test. So, it

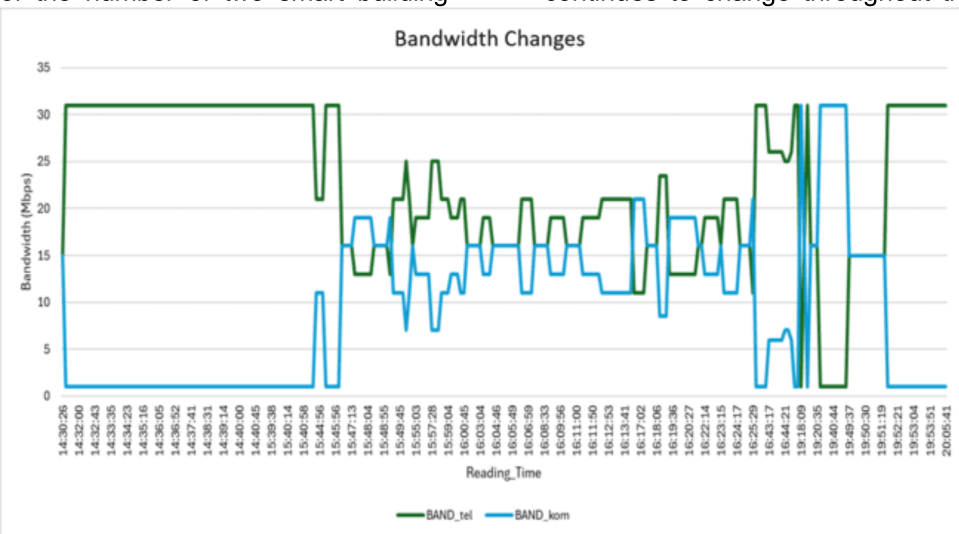

Figure 3. Bandwidth Changes on Telecommunication Labs and Computer Labs

ISSN 2089-8673 (Print) | ISSN 2548-4265 (Online)
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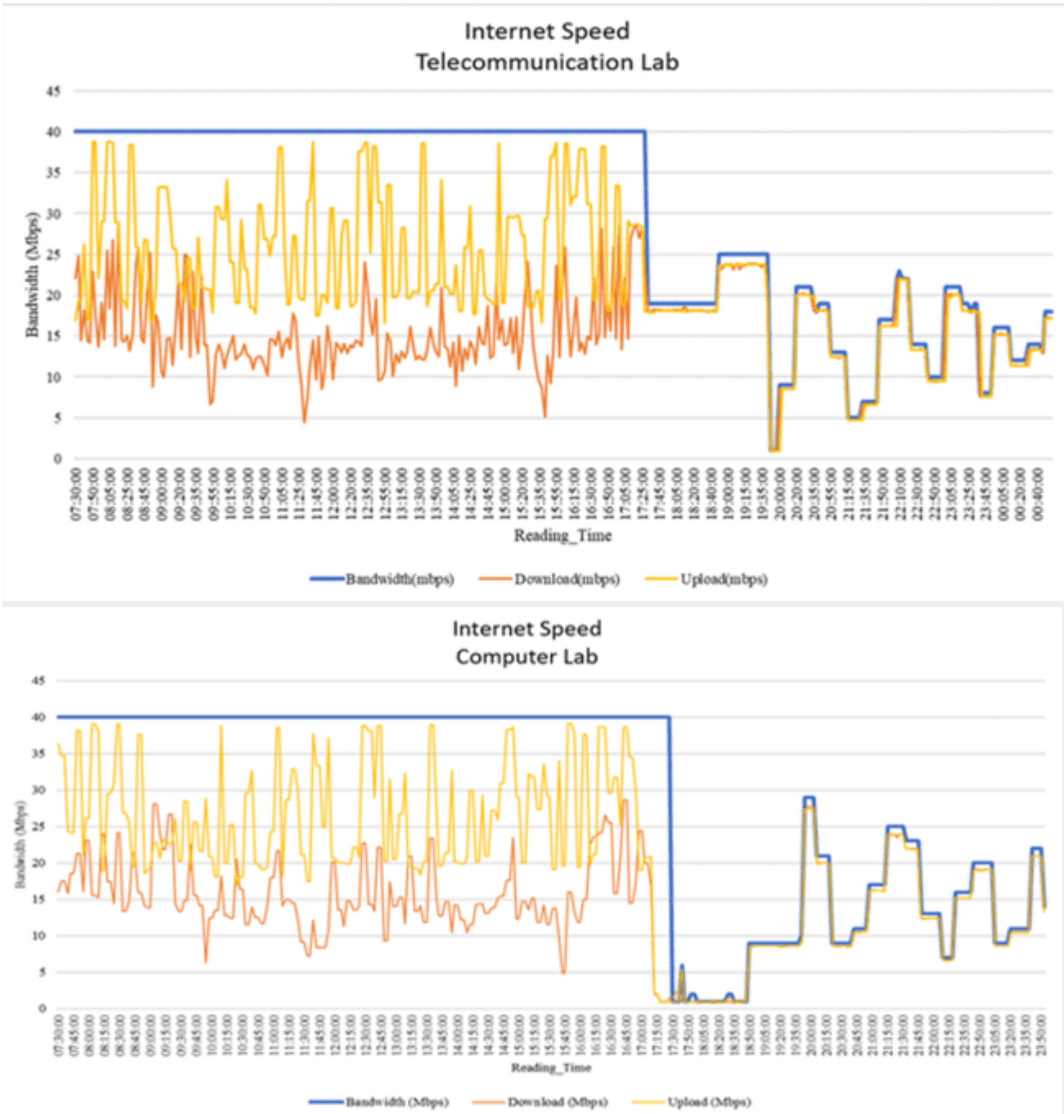

Figure 4. Effect of Elastic WLAN on Upload rate and Download rate on both rooms

was found that the green line in the Telecommunications Lab and the blue line in the Computer Lab show that bandwidth capacity varies based on the number of people present. Based on this, it is shown in the two graphs that the bandwidth has cha nged depending on the number of visitors in the room.

As can be seen in Figure 4, the bandwidth allocation dynamically changes following the number of visitors that varies at any time. Likewise in the Telecommunication Lab room, an increase in the number of visitors is followed by an increase in bandwidth. As the first test scenario is with one having more visitors, in figure 4 it is shown at the time duration from 14.30 to 15.44. It can be seen in the figure that the bandwidth in the Telecommunication Lab is 30 Mbps and the Bandwidth of the Computer Lab is 1 Mbps. This condition occurs because in that period, the Telecommunication Lab had 5 visitors and the Computer Lab had no visitors. So the bandwidth allocated to the Telecommunication Lab is much larger than the Computer Lab.

The second test scenario was conducted by changing the number of visitors in both laboratory rooms. The results of this test are shown in the time duration from 15.45 to 19.18. The image shows that there is a change in the bandwidth capacity allocated to each room according to the number of visitors in the room. The third scenario with the number of visitors to both rooms is empty, shown at the duration from 19.49 to 19.51. In this condition, it can be seen in the image that the bandwidth allocation in each room is the same, namely each is allocated 15 Mbps.

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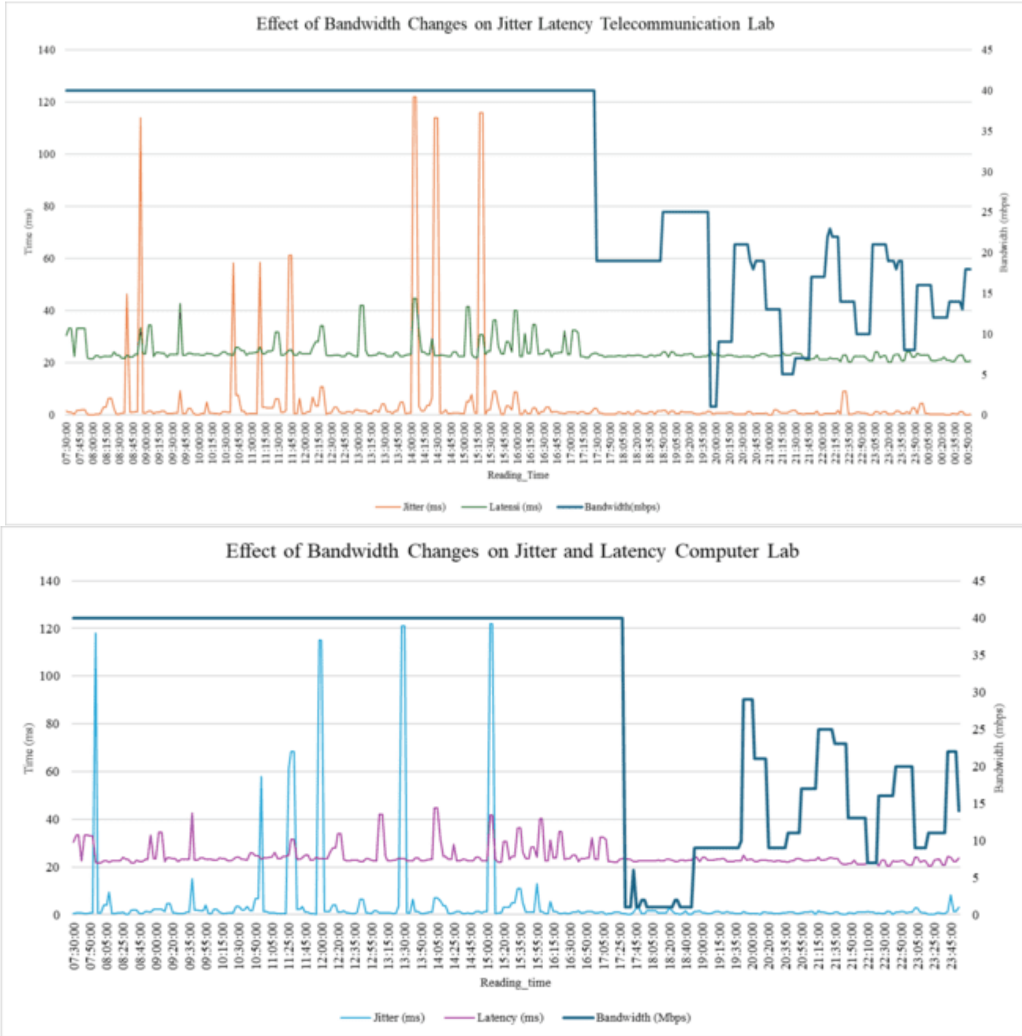

Figure 5. The Effect of Elastic WLAN on Jitter and Latency in Both Rooms

Dynamic bandwidth changes between the Telecommunication Lab and the Computer Lab are shown in Figure 5. The figure shows that the green line is the Telecommunication Lab Bandwidth and the blue line is the Computer Lab Bandwidth. During the testing process, it is shown that the bandwidth of both rooms changes dynamically according to the test scenario being carried out.

This testing mechanism shows that the Elastic WLAN mechanism has been successfully implemented to dynamically and adaptively manage bandwidth allocation based on the number of visitors to each room in a smart building.

The effect of implementing the Elastic WLAN mechanism can be seen in Figure 6. In the Computer Laboratory, before the implementation of the Elastic WLAN Mechanism in the time range of 07.30 to 17.00, there was a random fluctuation in the upload and download rates that looked like a grass-shaped graph with an average gap of 24 Mbps between the upload and download rates. After the Elastic WLAN Mechanism was executed from 17.30 to 00.00, bandwidth was allocated based on the number of people in the Computer Lab. These results indicate that the implementation of Elastic WLAN can reduce fluctuations and produce a more stable internet speed graph by the bandwidth allocation.

When the number of visitors in the Telecommunications Lab is lower than in the Computer Lab, it is shown that the bandwidth regulated in the Telecommunications Lab is smaller than in the Computer Lab. Likewise, when the Telecommunication Lab has more visitors than the Computer Lab, the bandwidth allocated will be greater. There are conditions when there are no visitors and the same number of visitors. Hence, Elastic WLAN regulates the bandwidth equally, which is obtained by dividing the maximum bandwidth of the smart building by the number of rooms available. These results show that the impact of implementing the Elastic WLAN mechanism has succeeded in managing upload and download traffic dynamically and adaptively in both managed rooms according to the number of visitors in each room.

In more detail from Figure 6, it can be seen that, before the implementation of Elastic WLAN, the upload and download rates in the Telecommunication Lab fluctuated with an average of 35 Mbps and 25 Mbps respectively. This is shown in the duration from 07.30 to 17.00. The same thing also happened in the Computer Lab.

Based on the Upload and Download rate char acteristics observed in the Telecommunications Lab and Computer Lab rooms, the Elastic WLAN mechanism minimizes the same problems. Before there was a bandwidth management mechanism, the upload and download rates obtained had a gap of up to 10Mbps. Apart from that, the upload rate and download rate fluctuate and are random over time, with an upload rate ranging from 0.93 Mbps to 39.1 Mbps and a download rate ranging from 0.93 Mbps to 28.7 Mbps. When the Elastic WLAN mechanism is implemented with dynamic bandwidth allocation based on the number of people in the room, the gap between upload and download rates can be reduced and maintained stable according to the allocated bandwidth.

The effect of dynamic bandwidth management using the Elastic WLAN Mechanism in the Telecommunication Lab and Computer Lab on the Jitter and Latency parameters is shown in Figure 7. The figure shows that from 07.30 to 17.30, monitoring of the jitter and latency conditions of the network in both rooms was carried out with the condition that the Elastic WLAN Mechanism had not been implemented and bandwidth management began using the Elastic WLAN Mechanism at 17.30 to 00.00 in both rooms.

In conditions where bandwidth management has not been carried out with the Elastic WLAN mechanism, the highest jitter spike can be seen at 14:05, which is 122 ms throughout the observation. In addition to jitter, there is also a latency spike indicated by the blue line on the graph. Latency and Jitter data can also be seen in Table 1, which shows the highest recorded latency spike of 44.8 ms. After the implementation of the Elastic WLAN Mechanism in the Telecommunications Lab, there was a significant decrease in jitter of 93%, with the highest value only reaching 9.06 ms. Latency also decreased by 44%, with the highest recorded spike of 25 ms. From this test, it can be seen that the implementation of the Elastic WLAN Mechanism can minimize, jitter and latency spikes can be minimized continuously during testing, indicating a significant increase in network performance.

Table 1 shows the effect of implementing the Elastic WLAN Mechanism in two laboratory rooms. The table shows the minimum and maximum values of jitter and latency obtained referring to conditions before and after the Elastic WLAN Mechanism was implemented. Before the implementation of Elastic WLAN, the average jitter obtained in both rooms was 0.13 ms to 122 ms to only 0.1 ms to 8.68 ms, and the previous latency of 22 ms to 44.8 ms became only 20 ms up to 25 ms.

In the internet speed test carried out, there was no network management system that managed data packets in the two rooms previously. So, there is no guarantee of network quality and reliability. Instability or fluctuations occur in upload rate, download rate, jitter, and latency due to a lack of control and management of the network.

CONCLUSION

The Elastic WLAN mechanism can manage bandwidth capacity allocated dynamically and automatically in two rooms using the Hierarchical Token Bucket (HTB) method running on the Raspberry Pi device in the Smart Building. The implementation of the Elastic WLAN mechanism affects the upload rate and download

Table 1. The QoS of the Influence of the Elastic WLAN Mechanism on the Network of both rooms

Room	**Before Using Elastic WLAN**				**After Using Elastic WLAN**			
	Jitter (ms)		***Latency (ms)***		***Jitter (ms)***		***Latency (ms)***	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Telecommunication Lab	0.09	122	21.6	44.8	0.1	9.06	20.4	25
Computer Lab	0.16	122	21.6	44.8	0.1	8.29	20.4	25
Mean Score	***0.13***	***122***	***22***	***44.8***	***0.1***	***8.68***	***20***	***25***

rate from previously fluctuating and random with an upload range of between 0.93 Mbps to 39.1 Mbps and a download range of 0.93 Mbps to 28.7 Mbps to become more regular according to the bandwidth capacity allocated. Implementing the Elastic WLAN mechanism can reduce jitter spikes from 0.13 ms to 122 ms to only 0.085 ms to 8.675 ms and latency from 22 ms to 45 ms to only 20 ms to 25 ms in Smart Buildings. Based on the results of the tests carried out, implementing the Elastic WLAN mechanism improves the performance and quality of Smart Building services.

ACKNOWLEDGMENT

Acknowledgments to the Institute for Research and Community Service (LPPM) Udayana University for the research support under the grants Number: B/1.631/UN14.4.A/PT.01.03/2023.

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