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Research Article

Analysis of Bandwidth Management Algorithms

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ABSTRACT

The internet is one of the most important technological advancements in our era, and it is difficult to imagine what our lives would be like without the internet. The National ICT Household Survey of 2019 conducted by the DICT, only 29% out of 2,617 Barangays have installed Fiber Optic Cable (FOC). Furthermore, 60% have 4G connectivity and only 12% have free wifi. To maximize the utilization of the internet and local area bandwidth of the Local Government Unit (LGUs), this study aims to analyze the different bandwidth management algorithms to mitigate bufferbloat, which is one of the primary causes of slow internet. The method will follow the Network Development Life Cycle (NDLC) and a simulated network environment & the network analysis tool, WaveForm, will be used to evaluate the metrics based on QoS standards TIPHON which are: throughput, latency & jitter. A grading system will also be utilized based on WaveForm's Bufferbloat Test. After analyzing the results, the data gathered shows evidence of having a significant difference in network quality between before and after the bandwidth management algorithms were implemented. The best overall algorithm, layer_cake, was graded A six (6) times, and A+ four (4) times. The algorithm is categorized as either excellent or good under all parameters and is the only one out of six (6) configurations that has upload quality that is almost equal with the download quality. In conclusion, this showed that proper use of bandwidth management algorithms significantly increases internet performance. The research was able to achieve its objective of evaluating the throughput, latency, and jitter after the implementation. It has successfully shown that there is a significant difference between before and after it was implemented: the results after implementation have consistency and overall better results.

Keywords: Bandwidth management algorithms, bufferbloat, tiphon, waveform, qos.

INTRODUCTION

The internet has become essential in our daily lives, and it is hard to imagine what life would be like without it. It has revolutionized how we communicate, learn, work, and access information. Proper utilization of the internet has made activities much easier and faster. One of the most notable uses of the internet is communication. From chatting and video conferencing to emailing and social networking, a plethora of live communication options are available to anyone with an internet connection. In addition, having social media in today's age, while not necessarily a standard, is very common. According to the Statista website, the number of individuals using the internet worldwide was 5.16 billion, accounting for 64.4% of the global population in January 2023. Among these users, 4.76 billion people, equivalent to 59.4% of the world's population, were social media users [10]. Many people choose to have at least one social media account in order to stay in touch with friends and interact with others. Moreover, numerous businesses and organizations use social media platforms to connect with their customers and promote their products.

According to the National ICT Household Survey of 2019 conducted by the DICT, only 29% out of 2,617 Barangays have installed Fiber Optic Cable (FOC). Furthermore, 60% have 4G connectivity and only 12% have free wifi. Due to how important it is to have access to the internet, not having access or having limited access to the internet will be

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very detrimental, especially during the pandemic recently, the internet has become even more important (SDG 9.c). Interacting with others, learning, and even working had to be done online at one point. The outbreak of COVID-19 in early 2020 resulted in many governments imposing restricts on people's mobility and ordering workers to work from home where possible. As the pandemic has progressed, these restrictions have eased but many hope to maintain a higher frequency of working from home than they had before the pandemic. However, doing such requires a good internet connection, which negatively impacts and limits the options for those without good connections [9].

Slow internet can be caused by various factors, such as network congestion, which occurs when network nodes and links are overloaded with traffic. When multiple devices are connected to the same network and trying to access the internet simultaneously, it can cause congestion and slow down the speed of the connection. It also causes packet loss, queueing delay, or the blocking of new connections. Network congestion is one of the most common causes of slow internet [5], especially in densely populated areas where many users are trying to access the network simultaneously. This is because the performance of a network is affected by the number of clients, in which increase of the bandwidth capacity does not always guarantee the quality improvement of network services [6]. The result of such congestion is a phenomenon called bufferbloat, where large router buffers are frequently filled up, resulting in high queueing delay and delay variation. More and more delay-sensitive applications on the internet have made this phenomenon a pressing issue [12].

This study's objective is to implement and evaluate the performance of different bandwidth management algorithms in increasing the utilization of the available limited bandwidth in the LGUs. These algorithms are sets of instructions that decide which processes to prioritize and manages the network, ensuring that packets are transmitted through network devices with minimal traffic; such algorithms have been proven to increase network performance, maximizing the network throughput by 62.50% accordingly [4].

Furthermore, most routers are not portable thus limiting its utilization outdoors [8]. The aim of this study is to solve the aforementioned problems by running the best possible bandwidth management algorithm on Raspberry Pi running OpenWrt, a credit-card sized computer. These algorithms will be programmed to control the traffic of the packets, divided bits of data sent over computer networks, hence improving the speed and quality of the internet without increasing the bandwidth.

METHODS AND METHODOLOGY

A simulated environment was setup similar to the common LGUs network configuration parameters. Figure 1 below shows the topology of the network including intermediary & end devices. It also shows how these devices are connected to each other. The inclusion of an IoT device running OpenWrt is used to facilitate the execution of bandwidth management algorithms.

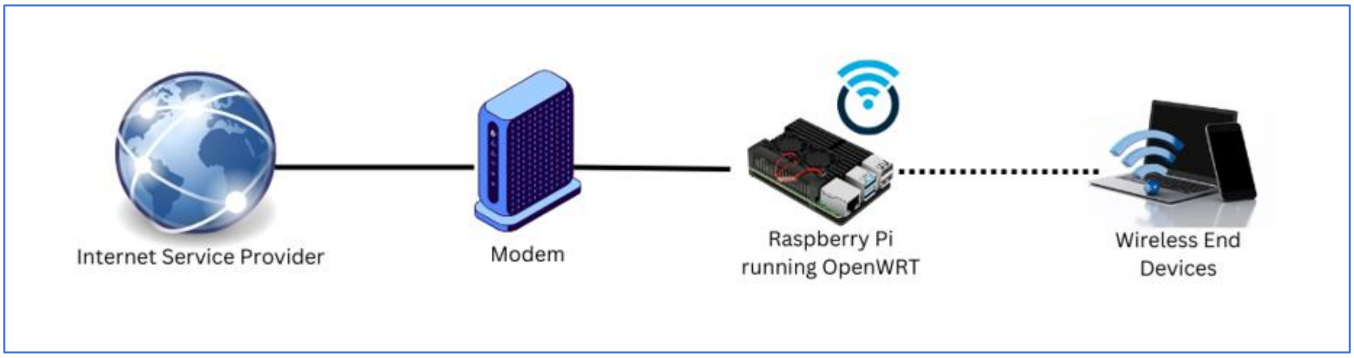

Figure 1 Network Topology

Table 1 shows the five (5) different Bandwidth Mangement Algorithms which will be evaluated using repeated tests. The evaluation will be carried out using the BufferBloat Test on WaveForm. A total of Ten (10) test runs will be executed using this tool.

Table 1. CAKE with Five (5) Bandwidth Management Algorithms

Algorithm	Description
layer_cake.qos	**This uses the cake qdisc as a replacement for both htb as shaper and fq_codel as leaf qdisc. This exercises cake's diffserv profile(s) as different "layers" of priority. This script requires that cake is selected as qdisc and forces its usage.**
piece_of_cake.qos	**This just uses the cake qdisc as a replacement for both htb as shaper and fq_codel as leaf qdisc. In other words, it is literally a "piece of cake". This script requires that cake is selected as qdisc and forces its usage.**
simple.qos	**BW-limited three-tier prioritization scheme with your qdisc on each queue.**
simplest.qos	**Simplest possible configuration: HTB rate limiter with your qdisc attached.**
simplest_tbf.qos	**Simplest possible configuration (TBF): TBF rate limiter with your qdisc attached. TBF may give better performance than HTB on some architectures.**

The tables below (Tables 2-4) show the standard metrics used by the QoS standardization of “Telecommunication and Internet Protocol Harmonization over Networks” (TIPHON). Data from the simulated network bandwidth quality measurements will be compared with QoS standards that use the TIPHON standardization.

Table 2. TIPHON Standard Metric for Throughput

Adjectival Rating	Throughput (%)
Excellent	**< 100**
Good	**80 – 99**
Average	**60 – 79**
Poor	**40 – 59**
Very Poor	**> 40**

Throughput is the total number of packets that control the movement of data sent to reach its destination in a given interval divided by the duration of the interval. Throughput capacity is an organization sending information with the equation of how much information In the process of sending data, there is a formula used to calculate the amount of data sent in a period. (Aprianto Budiman et al., 2020)

Table 3. TIPHON Standard Metric for Delay (Latency)

Adjectival Rating	Delay (Latency) (ms)
Excellent	**< 100**
Good	**80 – 99**
Average	**60 – 79**
Poor	**40 – 59**
Very Poor	**> 40**

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Delay is the amount of time it takes for data to travel from the starting point to the end point. Delays can be affected by factors such as distance, physical media, traffic density, or longer processing times. Delay can be calculated by dividing the ping time by the number of pings sent. (Rachmat, 2021)

Table 4. TIPHON Standard Metric for Jitter

Adjectival Rating	Jitter (ms)
Excellent	< 100
Good	80 – 99
Average	60 – 79
Poor	40 – 59
Very Poor	> 40

Jitter is the delay in preparation over time. Jitter is also defined as interference in digital or analog communication caused by changes in signal due to time position reference. The existence of this jitter can result in data loss, especially in high-speed data transmission.(Eko Nugroho & Daniarti, 2021)

WaveForm's Bufferbloat test will determine the internet connection's condition in terms of Web Browsing, Audio Calls, 4k Video Streaming, Video Conferencing & Low Latency Gaming. The QoS Standard TIPHON metrics is embedded in this test. It will measure the latency of the internet connection. Then compare the results to a latency test performed while running a download speed test and an upload speed test. If the latency increases while the upload or download tests are ongoing, the router/networking equipment suffers from bufferbloat. Table 5 shows the grading system used by WaveForm.

Table 5. Grading System by WaveForm

Grade	Latency (ms)
A+	< 5
A	< 30
B	< 60
C	< 200
D	< 400
F	400 +

RESULTS AND DISCUSSION

After a series of implementation and testing of the different bandwidth management algorithms using WaveForm, the following results were generated based on the specified criteria. The succeeding tables (Table 6, 7 & 8) shows the results based on TIPHON's criteria. The summary of scores are as follows:

Table 6. Summary of Scores based on Latency

QoS	Grade	Unloaded	D. Active	U. Active
No QoS	D	17 ms	+206 ms	+6 ms
layer_cake.qos	A	25 ms	+10 ms	+5 ms

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piece_of_cake.qos	**A**	**19 ms**	**+14 ms**	**+9 ms**
simple.qos	**A**	**20 ms**	**+13 ms**	**+6 ms**
simplest.qos	**A**	**16 ms**	**+12 ms**	**+6 ms**
simplest_tbf.qos	**A**	**16 ms**	**+7 ms**	**+8 ms**

Table 7. Summary of Scores based on Jitter

QoS	Unloaded	D. Active	U. Active
No QoS	2.1 ms	91.6 ms	6.2 ms
layer_cake.qos	11.9 ms	14.6 ms	9.7 ms
piece_of_cake.qos	4.3 ms	13 ms	11 ms
simple.qos	6.0 ms	12.2 ms	7.7 ms
simplest.qos	1.3 ms	10.2 ms	6.5 ms
simplest_tbf.qos	1.4 ms	6 ms	8.2 ms

Table 8. Summary of Scores based on Throughput

QoS	Download	Upload
No QoS	102.3 Mbps	36.2 Mbps
layer_cake.qos	83.3 Mbps	83.9 Mbps
piece_of_cake.qos	83.1 Mbps	63.9 Mbps
simple.qos	84.8 Mbps	60.2 Mbps
simplest.qos	84.3 Mbps	59.7 Mbps
simplest_tbf.qos	87.2 Mbps	62.6 Mbps

After analyzing the results, the data gathered shows evidence of there being a significant difference in network quality between before and after the bandwidth management algorithms were implemented.

The best overall algorithm, layer_cake, was graded A six (6) times, and A+ four (4) times. The algorithm is categorized as either excellent or good under all parameters and is the only one out of six (6) configurations that has upload quality that is almost equal with the download quality.

In comparison to the configuration without QoS, all the configurations with QoS received grades of A and A+, and were able to effectively mitigate bufferbloat, as evidenced by the consistency of their parameters.

CONCLUSION

These conclusions were drawn based on the summary of the findings. First, Bandwidth Management Algorithms are effective in mitigating bufferbloat; and among the evaluated bandwidth management algorithms, the best algorithm overall is layer_cake. Bandwidth quality was measured based on TIPHON's metrics (latency, jitter & throughput) and the results were evaluated based on WaveForm's Bufferbloat grading system. The aforementioned algorithm was graded with A six times and A+ for times as compared to others which received lesser.

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No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflict of Interest:

The authors declare that there is **no conflict of interest.**

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