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Protocol Analysis: 2.4 GHz Interference Frequency in the IEEE802.3ab Protocol

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ABSTRACT

Interference at the 2.4 GHz frequency is currently a significant problem in wireless networks. Especially on networks with environmental conditions where there are many active devices at the same time. This study analyzes the impact of interference on Delay and Jitter on IEEE 802.3ab protocol networks. The IEEE 802.3ab protocol is commonly known as the Gigabit Ethernet Protocol which already supports data transmission speeds of up to 1 Gbps. This study conducts various scenarios and simulates when interference occurs using five active access points (APs). The device's access points (APs) are all using the same 2.4 GHz frequency and channel. The data collection method uses the Wireshark application to measure the Delay and Jitter values at different interference levels. The results of simulations and tests with various scenarios show that there is a relationship between increased interference and Delay values. The Delay value is 14.129 ms when using a single AP without Interference. The Delay value increases to 1076,3730 ms in the event of interference with five APs. The jitter value increased from 0,2109 ms without interference. However, if there is interference with the active AP as much as 5 Jitter values to 17,9396 ms. Research shows that the jitter value is according to the TIPHON standard in the "Good" range. Meanwhile, the Delay value decreased significantly until it reached the "Poor" category when five APs were active. This research focuses on the need and importance of effective interference management to maintain network quality in interference-dense environments. This shows that optimizing for channel selection and frequency management is essential to reduce latency and improve transmission stability.

INTRODUCTION

A network protocol is a rule and procedure that governs how devices in a computer network communicate with each other. Good protocols must be able to ensure efficient, accurate, and secure data transmission (Cai et al., 2021; Nagaraju et al., 2022). To optimize network performance, especially in environments with multiple devices, the use of the right protocols is essential (Leyrer et al., 2021; Narsani et al., 2021). In this regard, the IEEE802.3ab protocol, also known as Gigabit Ethernet, is essential to provide fast and reliable data communication (Engmann et al., 2021a; Hoang et al., 2021; Uemura et al., 2021).

One of the main problems with wireless networks is frequency interference, particularly in the 2.4 GHz frequency band which is very popular today (Muhammad et al., 2021b). Interference is caused by the large number of devices that use the 2.4 GHz frequency, such as Wi-Fi and Bluetooth (Karaca, 2022; Lee et al., 2023; Meghana et al., 2022; Swinney et al., 2021). Frequency interference can significantly interfere with network performance. Therefore, to ensure optimal network service quality, frequency interference management is essential penting (Y. Liang, 2021; Song et al., 2022; Younes et al., 2022).

With high bandwidth and low latency, the IEEE802.3ab protocol is widely used in local area networks (LANs). This protocol supports data transmission speeds of up to 1 Gbps over twisted pair cables ("IEEE Standard for Local and metropolitan area networks-- Station and Media Access Control Connectivity Discovery Amendment 2: Support for Multiframe Protocol Data Units," 2022a; Uemura et al., 2021). Although the IEEE802.3ab protocol is commonly used in cable networks. The effect of frequency interference from wireless devices operating in the vicinity still needs to be considered. Effective flow control mechanisms allow for more stable data transmission and reduce packet loss (Khin et al., 2022; Li et al., 2023; S.-Y. Wang et al., 2021; Zhao et al., 2022).

In addition to the IEEE802.3ab protocol, frequency interference at 2.4 GHz can significantly affect network performance. Delay and jitter can be used to gauge how much interference affects (Daengsi et al., 2021; Veselá et al., 2021). Two important parameters that are greatly influenced are variations in the arrival time of data packets, and delay, which is the delay time for data transmission (Sawabe et al., 2022). To ensure that networks using the IEEE802.3ab protocol operate properly, it is critical to reduce interference (Askar et al., 2021; Khandetskyi et al., 2022; Tardioli et al., 2023).

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This study will analyze interference at the 2.4 GHz frequency with a focus on jitter and delay measurements on the IEEE802.3ab protocol. This research will find effective patterns and solutions to manage frequency interference by measuring jitter and delay in interference conditions. This research is expected to help in the development of network protocols that are more resistant to interference, especially in the environment of 2.4GHz frequency-dense devices.

LITERATURE REVIEW

Protocol: The IEEE 802.3ab standard, also known as Gigabit Ethernet enables data transmission at speeds of up to 1 Gbps over twisted-pair Cat 5e and Cat 6 copper cables, without the need for more expensive fiber optic infrastructure ("IEEE Standard for Local and metropolitan area networks-- Station and Media Access Control Connectivity Discovery Amendment 2: Support for Multiframe Protocol Data Units," 2022a; Uemura et al., 2021). This protocol is essential for improving local area network (LAN) performance. IEEE 802.3ab used in networking shows significant efficiency improvements and latency reductions compared to previous standards, such as Fast Ethernet (IEEE 802.3u). This advantage makes the IEEE 802.3ab protocol the best option for networking, where high bandwidth is critical for many types of applications (Engmann et al., 2021b; Nduka et al., 2023).

In addition to improving performance, IEEE 802.3ab also emphasizes compatibility with other Ethernet standards that allow the transition from previous technologies ("IEEE Standard for Local and metropolitan area networks-- Station and Media Access Control Connectivity Discovery Amendment 2: Support for Multiframe Protocol Data Units," 2022b; W. Liang et al., 2021). Compatibility with Ethernet standards that allows for easy and inexpensive network upgrades. In addition, the IEEE 802.3ab protocol supports a variety of Quality of Service (QoS) mechanisms, making it essential for applications that require real-time processes such as VoIP and video streaming. This makes IEEE 802.3ab a highly flexible and efficient solution to meet the evolving needs of modern networks (López-Aguilera et al., 2019).

Frequency 2.4: GHz Frequency 2.4 GHz is one of the most widely used spectrums for wireless communication, especially in Wi-Fi technology and IoT devices. Because this frequency is wider and stronger in range than higher frequencies such as 5GHz (Kulkarni et al., 2020; Muhammad et al., 2021a; Nikoukar et al., 2020; H. Wang et al., 2021). However, due to the large number of devices using the 2.4 GHz frequency, there is network congestion that can cause degradation and interference(Mohamed et al., 2020; Mucchi et al., 2020).

Some Internet of Things (IoT) applications still use the 2.4G Hz frequency, especially in the smart home and healthcare industries (Al-kahtani et al., 2022). The 2.4G Hz frequency can provide a good balance between range and data speed. This is especially important for communication between connected devices (Lavric et al., 2022; X. Liu et al., 2023; Loredana-Maria et al., 2023). However, the main problem has to do with interference management and connections in congested networks. Therefore, it requires a creative approach to design network management that is resistant to traffic congestion.

Interference Frequency: One of the main problems in managing wireless networks is frequency interference, especially for Wi-Fi and cellular networks. Interference occurs when signals from various sources collide with each other (Karaca, 2022; P. Wang et al., 2022). Sources of interference can come from a variety of electronic devices, such as microwaves, cell phones, and Bluetooth devices that operate on the same frequency. This causes poor signal quality and reduces the speed and quality of data transmission (Ji et al., 2023).

There are various channel selection strategies that can be used to overcome frequency interference on wireless networks. This technique allows network devices to automatically select less dense or interference-free channels to improve signal quality and network performance (Mantilla-González et al., 2023; Marche et al., 2023). An effective method to reduce interference in wireless communication is to monitor the frequency spectrum in real-time and adaptive channel selection. This method involves using tools to track spectrum usage and find interference signals. Allows the network to switch to a more quiet or interference-free channel according to the spectrum conditions that occur. This is to reduce interference from other devices by improving the quality and efficiency of the wireless network. In addition, to maintain the speed and stability of the connection (L. Liu et al., 2022).

METHOD

This research method consists of Topology Design, Data Acquisition, Data Processing and Data Analysis shown in figure 1.

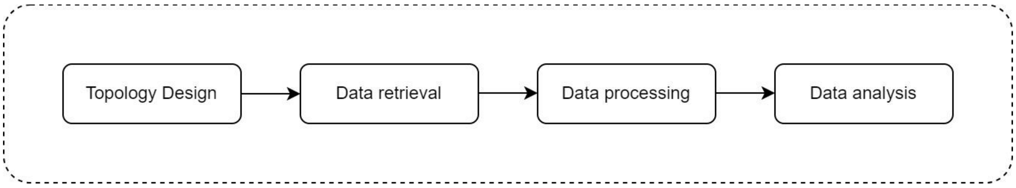

Fig. 1 Block Diagram Research Methods

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The stages of the research are carried out from topology design to data analysis. At this stage, the results of the analysis that have been calculated are Delay and Jitter. The research method used is a literature study and analysis of the characteristics of data traffic quality when interference occurs, which results from the scenario that has been designed. Data was collected from simulations using wireshark.

Topology: The test scenario uses 5 Access Points with the same specifications and types and 1 laptop computer equipped with wifi 2.4 GHz. The topology of the test scenario is shown in figure 2.

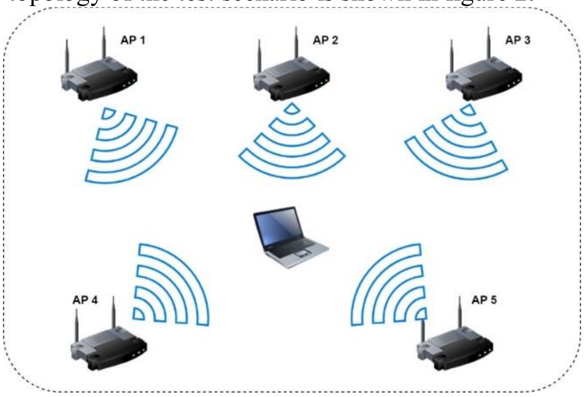

Fig. 2 Test Scenario Topology

The Access Point uses the IEEE802.3ab protocol with a frequency of 2.4GHz. Each access point uses the same channel for the test scenario. Channels consist of 1 (2410 MHz) to channel 11 (2465 MHz).

Data Retrieval: The data collection process is carried out in several stages. Data collection is shown in figure 3.

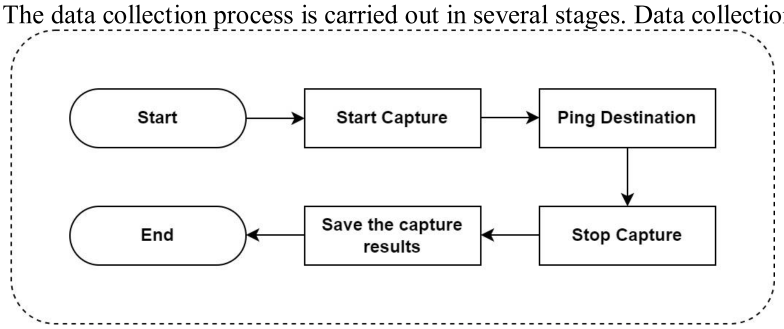

Fig 3. Data Retrieval Diagram Block

Data collection by sampling method with capture using wireshark. Ping destination IP 74.125.130.91 ping duration is 5 minutes. Stop capture when the Ping duration is 5 minutes. Then save the capture results. Ping destinations with the same IP in each simulation scenario. In addition, the capture time is also of the same duration. This is done to obtain the same and proportional sampling in each scenario.

Data Processing: There are several stages of data processing, data processing is shown in figure 4.

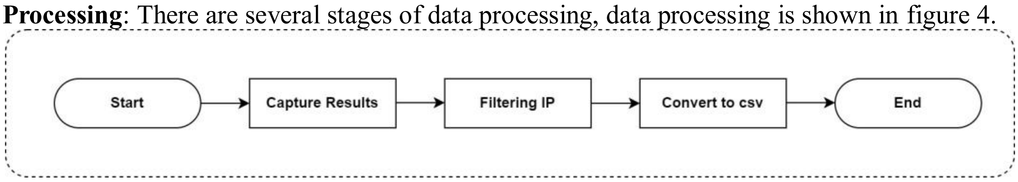

Fig. 4 Data Processing Flowchart

Data processing is the result of capture in the wireshark application. It is then filtered by destination IP 74.125.130.91 so that the processed IP destination is clean of unwanted IPs. Because data retrieval uses the wireshark application. So, the type of data generated is in the form of a file format that can only be opened using the wireshark application. To be processed, the filtered data is converted into csv. This is to facilitate data processing using the Excel application.

Delay (Latency): Delay is the time it takes for a package to get from origin to destination. Delay can be affected by Distance, transmission medium and Processing time. Based on the Tiphon version, the delay is categorized into 4 which are outlined in table 1.

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Table 1. Delay

Category Latency	Large Delay	Index
Very Good	< 150 ms	4
Good	150 s/d 300 ms	3
Medium	300 s/d 450 ms	2
Poor	> 450 ms	1

(Source: TIPHON) (Tiphon, 1999)

Delay calculation equation:

$$\text{Average Delay} = \frac{\text{Total delay}}{\text{Total packets received}} \qquad (1)$$

Jitter: Jitter is a variation of the arrival time of the package, the time of data processing, the length of the queue, and the time of re-collection of the package at the end of the trip. With respect to latency, interference is known as delay variation and indicates many variations in interference in data transmission on the network. In accordance with the Tiphon version, there are four categories of network performance degradation based on the peak jitter values outlined in table 2.

Table 2. Jitter

Category Degradation	Peak Jitter	Index
Very Good	0 ms	4
Good	0 s/d 75 ms	3
Medium	75 s/d 125 ms	2
Poor	125 s/d 225 ms	1

(Source: TIPHON) (Tiphon, 1999)

Jitter calculation equation:

$$\text{Jitter} = \frac{\text{Total delay variation}}{\text{Total packages received}} \qquad (2)$$

$$\text{Total delay variation} = \text{Delay} - \text{Average Delay} \qquad (3)$$

RESULT

Based on the interference scenario simulation, it uses a frequency of 2.4 GHz on Wireless Channel 11 (2465) and a Channel Width of 20 MHz. The results of the scenario with the occurrence of inference are shown in figure 5.

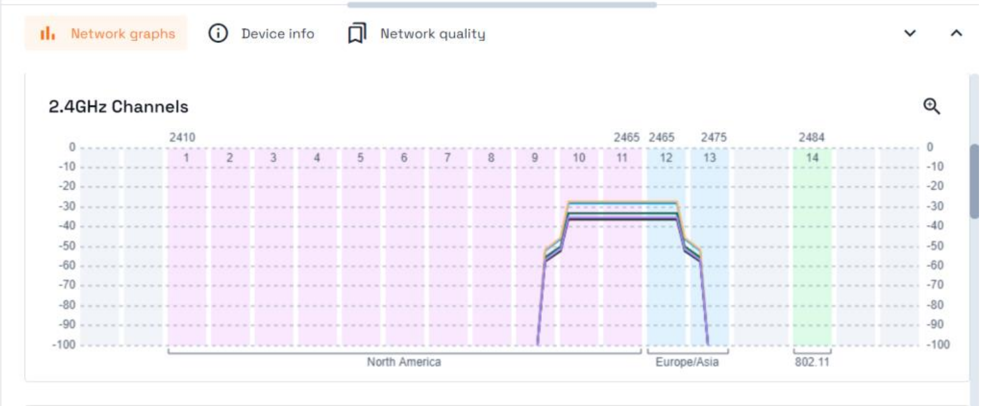

Fig. 5 Chanel 2.4 GHz Frequency Device

The graph shows that channel 11 with a frequency of 2465 MHz has 5 devices with almost the same signal strength. This shows that on channel 11 frequency 2465 MHz interference occurs. The details of the signal strength Access point information on each Access point are shown in figure 6.

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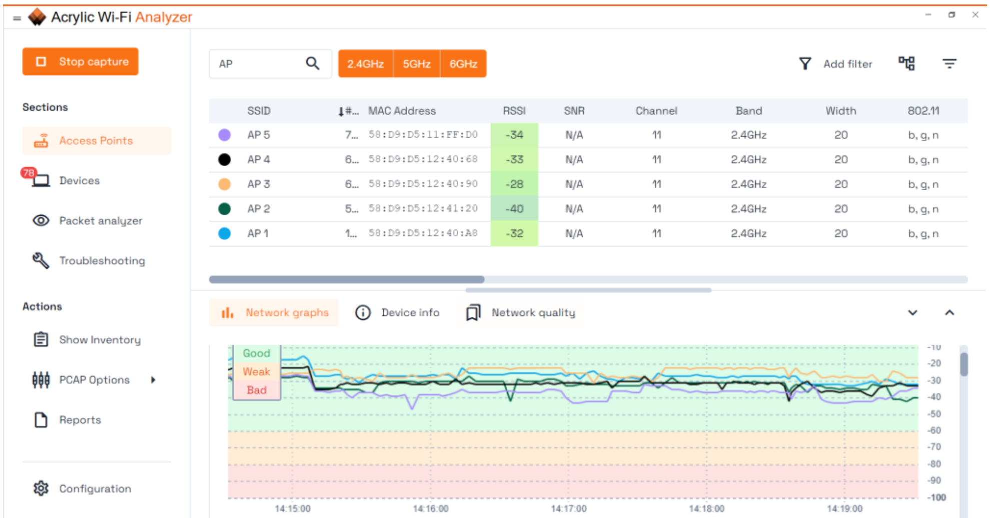

Fig. 6 Signal strength of each Access point

The Received Signal Strength Indicator (RSSI) at AP 1 is -32, AP 2 is -40, AP 3 is -28, AP 4 is -33 and AP 5 is -34. The signal strength is strongest on AP 3 with RSSI -28 and the signal strength is weakest on AP 2 with RSSI -40. Meanwhile, in the 5 AP network graph used, the simulation shows good graph strength. This is shown in the graph is in green. The results of the delay measurement are shown in table 3.

Table 3. Delay Measurement

Measurement	AP Active				
	AP 1	AP 2	AP 3	AP 4	AP 5
Delay (ms)	14,1290	191,0660	354,5700	811,1160	1076,3730

AP delay measurements show that each different scenario produces a different delay. At the time there is 1 AP active delay of 14.1290. When there are 2 active APs, the delay increases to 191.0660. When the AP is active, there are 3 delays of 354.5700. When the AP is as many as 4 active the delay increases to 811.1160. When all 5 APs are active simultaneously, the delay increases to 1076.3730. The graph of the amount of delay and its change in each scenario is shown in figure 7.

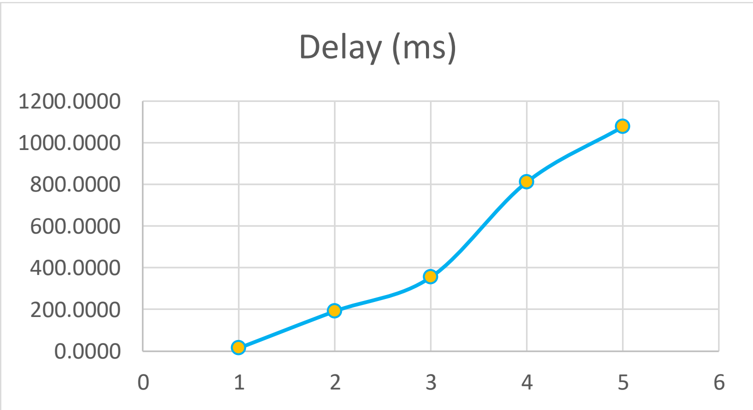

Fig. 7 The graph delay

The measurement of Jitter in each different scenario shows that the jitter value has changed. The results of the Delay test parameters are shown in table 4.

Table 4. Parameter Delay

Testing	Measurement Result (ms)	Tiphon Standards
AP 1	14.1290	Very Good
AP 2	191.0660	Good
AP 3	354.5700	Medium
AP 4	811.1160	Poor
AP 5	1076.3730	Poor

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Based on the delay parameters generated in each scenario. At the time of AP 1 shows results based on the Tiphon Very Good standard with a delay value of 14.1290. When AP as many as 2 is activated, the Tiphon standard value decreases to Good with a delay value of 191.0660. Meanwhile, when AP as many as 3 are active at the same time, the Tiphon standard value becomes Medium with a delay value of 354.5700. When AP is active as many as 4 at the same time, the Tiphon standard value decreases to Poor with a delay value of 811.1160. When AP is active as many as 5 simultaneously the Tiphon standard value becomes Bad with a delay value of 1076.3730.

The jitter measurement value is shown in table 5.

Table 5. Jitter Measurement

Measurement	AP Active				
	AP 1	AP 2	AP 3	AP 4	AP 5
Jitter (ms)	0,2109	3,2384	7,5440	10,2673	17,9396

At the time of 1 AP active the jitter value is 0.2109. If 2 APs are active at the same time, the jitter value is 3.2384. When the AP is active, there are 3 jitter values of 7.5440. When AP is active as many as 4 jitter values, the jitter value increases to 10.2673. When all 5 APs are active at the same time, the jitter value increases to 17.9396. The graph of the magnitude of jitter and its changes in each scenario is shown in figure 8.

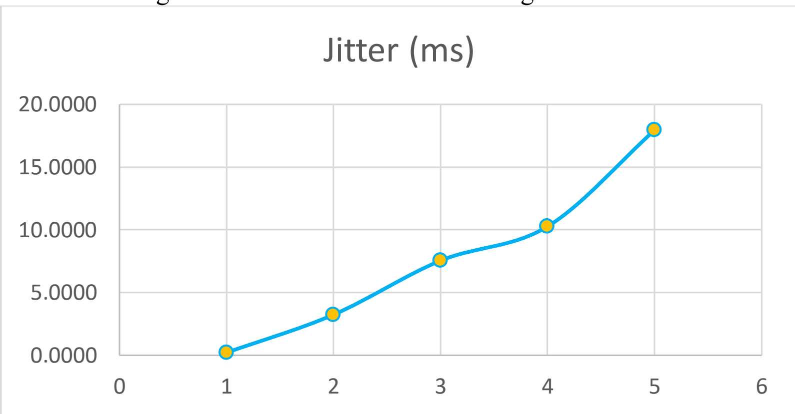

Fig. 8 The graph Jitter

The results of the Jitter test parameters are shown in table 6.

Table 6. Parameter Jitter

Testing	Measurement Result (ms)	Tiphon Standards
AP 1	0.2109	Very Good
AP 2	3.2384	Good
AP 3	7.5440	Good
AP 4	10.2673	Good
AP 5	17.9396	Good

Based on the Jitter parameters generated in each scenario. When AP 1 is active, a jitter value of 0.2109 shows results based on the Very Good Tiphon standard. When there are 2 active APs at the same time, the jitter value is 3.2384, the result is based on the Tiphon Bagus standard. Meanwhile, when 3 APs are active at the same time, the Jitter value is 7.5440 based on the Tiphon Bagus standard. At the time of active AP, there were 4 Jitter values of 10.2673 based on the Tiphon Bagus standard. If all APs as many as 5 are activated at the same time, the jitter value is 17.9396, the standard value of Tiphon Good.

DISCUSSION

Increase in Delay Due to Increase in Active AP: The results show that when the number of active APs increases, the delay value also increases significantly. When one AP is active without interference, the delay value is 14,129 ms, which is in the "Very Good" category based on the TIPHON standard. However, when the number of active APs increased by five, the delay value increased to 1076,373 ms, which is included in the "Bad" category. This increase indicates that frequency interference causes longer delays in the transmission of data packets as the number of devices operating on the same channel increases.

Mechanism of Delay in Solid Interference Conditions: Delays in the network occur because the data transmission process is disrupted by signal collisions from other devices using the same frequency. At the 2.4 GHz frequency, which is a non-licensed frequency and is used by a variety of devices, the potential for signal collisions is very high, especially in environments with many active devices. This condition requires the device to force the wait until the path at that frequency is empty. Waiting for an idle path results in an increase in the amount of time it takes for

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a data packet to be delivered from the source to the destination. This process becomes even more pronounced as the number of active devices increases. This can be seen from the test results on five APs that are active at the same time.

Jitter Remains Stable in Good Category: Although the delay value has increased quite significantly with the increase with the number of active APs. During testing with one AP, the jitter was recorded at 0.2109 ms, and when five APs were active, the jitter increased to 17.9396 ms. Despite the increase, this jitter value was still in the "Good" category based on the TIPHON standard. This relatively stable Jitter value shows that even though there is a delay in sending packages, the variation in the arrival time of packages between devices is maintained in good condition.

Implications of Results on Device-Dense Network Design: The results of this study have important implications for the design and management of networks operating in dense environments of devices with the same frequency. When multiple devices operate at the same 2.4G Hz frequency, network performance can degrade drastically, especially in delay. Therefore, it is important to implement effective interference management strategies, such as selecting the right and quiet channels, setting packet delivery time intervals, or switching to other less dense frequencies, such as 5GHz. Good frequency management can help reduce latency and ensure connection stability is maintained, especially in environments with high data traffic.

Interference Reduction Strategies in Wireless Networks: To reduce the impact of frequency interference, one approach that can be used is real-time spectrum monitoring and adaptive channel selection. In this strategy, the network device can automatically select a channel that is more free of interference based on the current frequency conditions. This can be done by developing software or algorithms that monitor frequency usage and direct the device to a less congested channel.

Research Contributions: This research makes an important contribution to the understanding of the impact of frequency interference on the IEEE 802.3ab protocol, especially in terms of delay and jitter. With the increasing use of wireless devices, interference management is becoming increasingly important to maintain network quality. This research also opens up opportunities for further research related to the use of other frequencies or the development of protocols that are more resistant to interference. In addition, the application of more advanced frequency technologies such as dynamic frequency selection (DFS) can be a future solution in reducing the impact of interference in wireless networks.

CONCLUSION

From the results of the analysis and test scenarios, it is shown that each scenario affects the Delay and jitter values. The delay value continues to increase in the event of an active AP addition or interference addition. In addition, it will also affect the standard value of Tiphon. The test result of the Tiphon value is Very Good with a Delay value of 14.1290 if there is no Interference. If the interference is dense with 5 APs active with a delay value of 1076.3730 so that the value is in the Tiphon standard is Bad.

The Jitter score will continue to increase as more APs are active simultaneously with the same channel. The Jitter value is 0.2109 without interference so that the score on the Tiphon standard is Very Good. If AP is 2 active, the jitter value is 3.2384, AP 3 is active jitter is 7.5440, AP 4 is active jitter is 10.2673, AP 5 is active jitter is 17.9396. From the change in the value of the active AP Jitter as many as 2 to 5 active at the same time and there was a value interference in the Tiphon Bagus standard. In the test scenario carried out for Active AP as many as 2 to 4 simultaneously, the value of the Tiphon standard did not change, namely Good.

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