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QoS of Wi-Fi performance based on signal strength and channel for indoor campus network

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ABSTRACT

The implementation of Wi-Fi on campuses brings huge benefits for campus users in communications and education development. Some campuses face existing poor quality of service (QoS) on the Wi-Fi performance which is also unjustified and issues on unsatisfied connections. This research aims to analyses the Wi-Fi performance of the campus network for three indoor access points. Signal strength, usage percentage, channel utilization, and the number of clients count per access points are measured. Results show that 56% is the highest signal percentage and the lowest signal percentage is at 1%. Access point of Ustudent is the highest at 53% and lowest at 38%. The highest signal strength of -45dBm is found and the other two are below by -2 dBm. The lowest signal strength is at -95 dBm. SSID CCNA_1 is identified has the best signal strength compared to other SSIDs because it runs on 5 GHz frequency. The most channels used are channels 1, 4, and 6. Respectively 151, 67, and 57 users are connected to Ustudent, UHotspot, and CCNA_1. This study is significant for the QoS in a campus network in providing good network services. Thus, the QoS on Wi-Fi performance is improvised, monitored and analyzed for continues supports users in the campus network successfully.

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1. INTRODUCTION

The use of Wi-Fi is normal in this generation where it has grown quickly throughout the world as a popular means for Internet access and manage of quality of data, voice and audio [1, 2]. Many people connect to wireless networks via their gadgets such as mobile phones or laptops. In 2018, the number of devices connected to Wi-Fi has raised to 20 billion. It is also reported by the Cisco visual networking index (VNI) that the internet traffic generated by Wi-Fi devices was 55% in 2013 and will be 61% in future trend [3]. Nowadays, wireless networks in campuses are beneficial as it plays an important role for any organization. The implementation of wireless networks in campuses enables academic users such as students, researchers, lecturers, and staff's access to the Internet an many recent researches still developing for best quality of services (QoS) support for campus network [4, 5]. People often prefer to connect their smartphones to Wi-Fi networks for Internet access because of their higher bandwidth lower delay and lower energy consumption [6]. QoS in a campus network is crucial to support students and staffs for mobility network connections in presented optimum teaching and learning environment. QoS performance is crucial and need regular checking for best Internet connections in any type of network thus time to time improvement for performance radio frequency in wireless communication is often designed in research [7, 8]. Thus, the need for very good wireless network becomes a priority. Today's Wi-Fi networks deliver a large fraction of traffic [9]. A computer network IT manager usually faces many challenges in maintaining excellent performance, perfect infrastructure, and security. The more devices communicate on the network simultaneously, the slower its performance thus causing the Wi-Fi performance and quality of Wi-Fi networks far from satisfactory. To ensure that users can access the Internet without any delays and wireless networks perform well, regular monitoring is required [10]. Monitoring Wi-Fi during the previous generation was not necessary because there was very little usage of the wireless network. Wi-Fi monitoring is performed using monitoring tools to check on the status, network traffic, speed, and signal strength of each network. Measuring and monitoring the performance of a wireless network is particularly challenging as there is no single tool that covers all aspects of performances. However, the situation has changed and there is now more efficient and easier use of Wi-Fi monitoring tools available across all platforms. Using the available Wi-Fi monitoring software tools on the Internet, anyone could check the status of any wireless network and determine how to optimize their network for better performance. Maintaining campus network is important especially latest trend of applications used more wireless and mobile technologies to enhance teaching and learning strategies [11].

The term of Wi-Fi is used to describe a class of certified wireless networking products that meet the IEEE's set of 802.11 wireless standards [12]. 802.11Wi-Fi networks have become increasingly important in people's daily lives as the number of Wi-Fi devices may rise up to 20 billion in future trend [13]. The 802.11 standards display improvements that enhance wireless throughput and range as well as the use of new frequencies as they become available. The 802.11 wireless standards can differ in terms of speed, transmission ranges, and frequency used, but in terms of actual implementation, they are similar. Each of the different standards has different features and they were launched at different times. The newer the 802.11 standards, the faster it is and the greater its capacity. The Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN standard in 1997 called 802.11. This standard provided a data speed of 1 or 2 Mbit/s and operates in 2.4 GHz. Due to the slow data rate of the first version, IEEE expanded by creating the 802.11b which supports bandwidth up to 11 Mbps [14]. It also uses the same 2.4 GHz frequency. The advantage of this standard is it is low cost which means the signal range is good and not easily obstructed. However, it has the slowest maximum speed and home appliances such as microwaves, ovens and other appliances may interfere on the unregulated frequency band such as the new band to support IoT appliances.

Recent analysis of substrate integrated frequency selective surface antenna for IoT applications has been done to support IoT services development [15]. IEEE has created a second extension called 802.11a which this standard supports bandwidth up to 54 Mbps provided for operation in 5 GHz frequency [16]. 802.11a has a fast-maximum speed as the regulated frequencies that prevent signal interference from other devices, but the cost is higher because it has a shorter-range signal that is more easily obstructed. In the early 2000s, a new standard emerged called the 802.11g. With a greater range, this standard supports a bandwidth of 54 Mbps and uses the 2.4 GHz [17]. It still has great maximum speed as it does not easily obstruct however, it costs more than 802.11b does. Another standard is 802.11n to improve on the previous standard in the amount of bandwidth supported. The data rate is 72 Mbps if a single channel is used on a single stream [18]. It allows operating on two frequencies of 2.4 GHz and 5 GHz. The data rate could be increased if MIMO (multiple input multiple output), channel bonding and frame aggregation are used [19, 20]. Finally, is the 802.11ac Wi-Fi standard where it exclusively works in the 5 GHz frequency with up to 800 Mbps. Another significant improvement with 802.11ac is multi-user (MU-MIMO). Moreover, the number of spatial streams is increased from four in 802.11n to eight in 802.11ac [21]. 802.11ac is aimed at improving total network throughput as well as individual link performance of the entire network [22]. Wireless network focuses only on two spectrums which are the 2.4GHz and 5GHz band.

Figure 1 shows the 2.4GHz spectrum with 20MHz channel width. On this spectrum, 13 channels can use in Europe. As for channel 14, it is allowed in another country such as Japan [23]. Each channel is separated by 5MHz. In the 2.4 GHz band, channel 1, 6, and 11 are the only non-overlapping channels without interference for each other. When interferences happen, it could lead to poor connections and slow speeds. Figure 2 shows 2.4 GHz spectrum with 40MHz channel width by joining two neighbor channels together. However, independent channel is not available for this channel width, so it is not an optimal choice for multi-access points deployment. Figure 3 shows the 5GHz spectrum of 20MHz channel width with center frequency ranging from 5170MHz to 5835MHz. As compared to 2.4GHz channel band, 5GHz channel band is more suitable for high-density wireless environment because it has more non-overlapping channels. However, 2.4GHz channel band travels on a larger distance than 5GHz which could reach bigger coverage. By selecting the proper Wi-Fi channel, it can tremendously improve the Wi-Fi coverage performance as well as improving the quality of service of the wireless network.

This paper focuses on monitoring and measuring Wi-Fi performance for indoor in campus university network to identify QoS of WI-Fi network in a Campus university network [24, 25]. Problem has been identified where network management is kept on funding upgrading network bandwidth support but less recent reports on usage of network QoS. The significance of this research focus on analyzing wireless networks based on its signal percentage, signal strength, channel utilization and the number of clients per access points. The purpose is to present the quality of service of a wireless network for the campus area. One monitoring tool was used where the quality of service on Wi-Fi performance is improvised. Thus, recent Wi-Fi performance continues to improve with each new generation of technology to cater user's capacity in campus university.

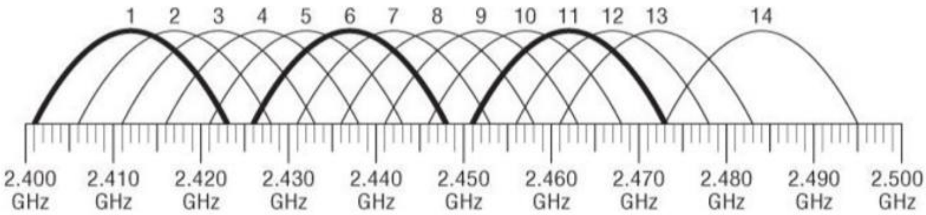

Figure 1. 2.4 GHz spectrum with 20 MHz channel width

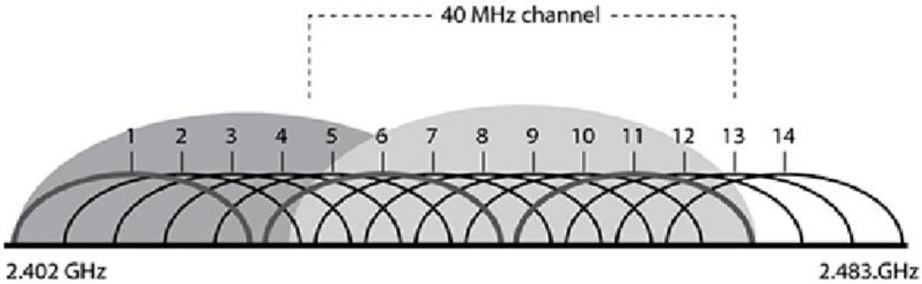

Figure 2. 2.4 GHz spectrum with 40 MHz channel width

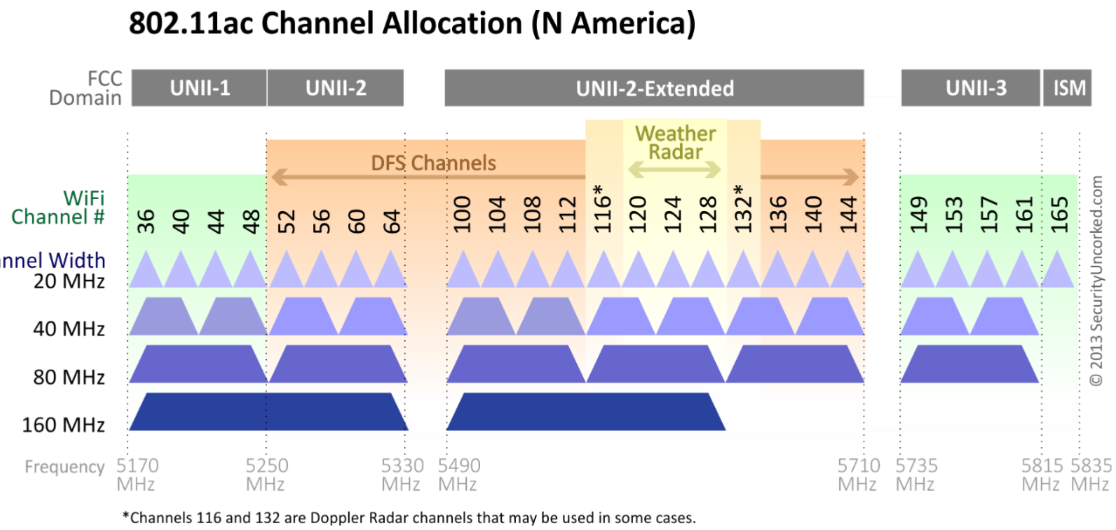

Figure 3. 5 GHz spectrum

2. RESEARCH METHOD

2.1. Flowchart

Figure 4 shows the flowchart of the process of collecting data using a wireless network monitoring tool in an indoor campus university network. This research is using a monitoring software tool known as WirelessMon. After initializing the software, the monitoring tool is connected to the access point and it displayed all the detailed information, which is the SSID, MAC address, signal strength, signal percentage, speed and more. After it is connected, the data is collected through logging. After one hour, the logging stopped, and the data are analyzed based on its channels used, the signal strength and the signal percentage of the SSID. The flow of the access points will be compared. After analyzing the selected data, the data is then exported and analyzed to Microsoft Excel, so the results are produced using graphs. The reports data will be based on signal strength, used of percentage of access points, channel utilization and number of clients based on access points. This monitoring process is done for three SSID which are CCNA_1, UHotspot, and Ustudent.

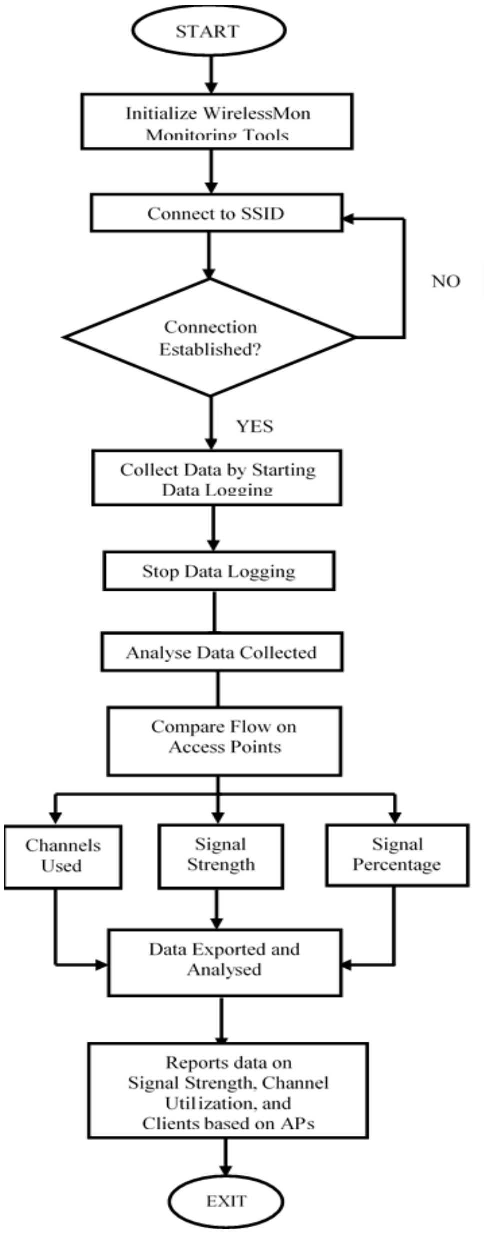

Figure 4. Process of collecting data from monitoring tools

2.2. Architecture diagram

Figure 5 shows the architecture diagram of the wireless network for indoor campus university. There are 4 levels and at each level, 8 access points were placed equally with different channels. The monitoring software will be connected to the closest access point. The coverage of the Internet connection depends on the maximum capacity connected to the access points. If an access point has reached its maximum capacity, thus traffic congestion may happen to cause some of the students unable to access Wi-Fi.

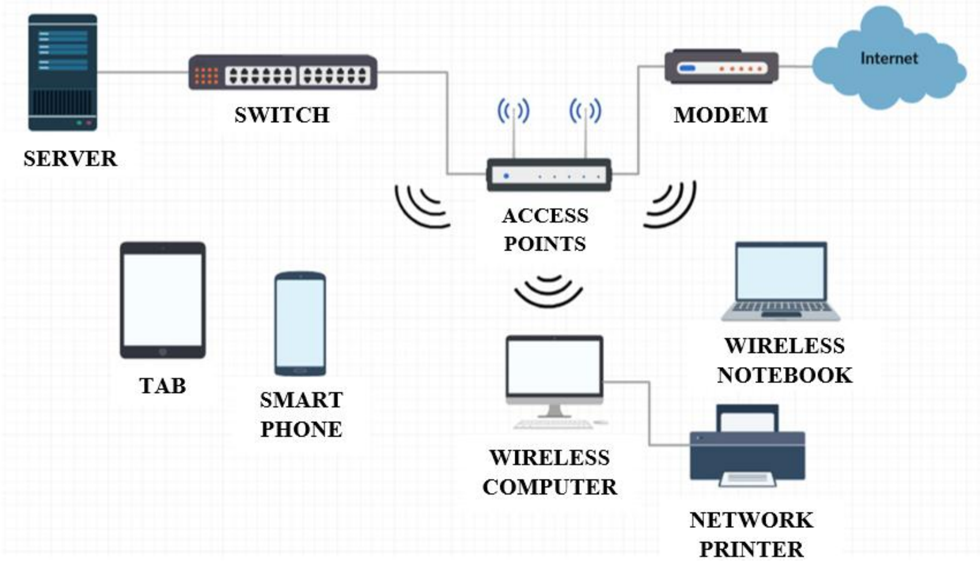

Figure 5. Architecture diagram of wireless network

2.3. Monitoring software

The software that I am using for this project is called WirelessMon. This software is used to monitor the wireless network for indoor in campus university. All the required information is collected from this software which is the network signal strength, signal percentage, channel used, frequency, bandwidth and more. From the data collected, graphs are plotted to be analyzed throughout the duration of this project. The mobile Wi-Fi Analyzer application installed in an Android phone helps to monitor the network easily instead of using the software. By connecting to the desired wireless network, the signal strength and the speed of the connected network are analyzed and evaluated. Moreover, the best channels are analyzed and a graph is displayed to show the signal strength between all the available access points. Another feature is the signal meter that shows if the connected access point is placed at the best spot. Another mobile application called Fing performs a network scan to see all the devices that are connected to one of the access points. It is the quickest way to scan the wireless network and analyze how many devices are connected during the time of collecting data. This application also identifies what type of devices that are currently connected such as mobile phones, laptops, and even routers.

2.4. Evaluation parameter

Table 1 presents the evaluation parameter for all access points. The data that has been collected were taken from 3 SSID which are CCNA_1 located at CCNA Lab, UHotspot located at PTAR Faculty of Engineering, and UStudent located at students' college. The time was chosen based on personal observation of the period of activity. The data were taken at three different times for duration of 1 hour which are at morning 9 AM until 10 AM, evening 2 PM until 3 PM, and at night from 9 PM until 10 PM. The bandwidth, 802.11 standards, channels used, running frequency and the total number of clients is summarized in this table.

Table 1. Summary data sets

SSID	CCNA_1	UStudent	UHotspot
Start date	09-10-18	05-10-18	12-10-18
Start time (morning)	9:00AM	9:00AM	9:00AM
(Evening)	2:00PM	2:00PM	2:00PM
(Night)	9:00PM	9:00PM	9:00PM
Duration of measurement	1 hour	1 hour	1 hour
Bandwidth	117 Mbit/s	159 Mbit/s	179 Mbit/s
PHY type	a/b/g/n	b/g/n	b/g/n
Channels use	4	1, 6, 11	1
Running frequency	5785 MHz	2412 MHz	2412 MHz
Total number of clients	57	151	67

3. ANALYSIS AND RESULTS

This research uses the WirelessMon software as a tool to monitor the status of the wireless network and gathered all the required information in real time. The information collected were the signal strength, signal percentage channels used, frequency and link speed. The data collected is then exported to Microsoft Excel to be analyzed. In this research, the data that is used for analysis are on the signal strength in dBm unit, signal strength in percentage and channel utilization. Furthermore, another measuring tool used for analysis is using Fing application in an Android phone to analyze the number of devices connected to the current wireless network. After scanning the network, it showed how many users connected in real time and displayed the types of devices connected to the current network.

3.1. Analysis of signal percentage per access points

Figure 6 presents a graph on the signal percentage of an access point with SSID CCNA_1 taken at CCNA Lab. The percentage is determined by using the maximum and minimum signal thresholds entered. Based on personal observation, the signal percentage almost reached 60% and it was clearly seen that the quality of Wi-Fi connection has an excellent connection, but the quality of Internet connection was average. This is because dropouts happened casually causing a loss in Internet connection.

Figure 7 presents a graph on the signal percentage of an access point with SSID UHotspot taken at PTAR Faculty of Engineering. The signal percentage for this SSID is also near 60%. It can be summarized that the quality of Wi-Fi connection and the quality of Internet connection is excellent throughout the day. However, at about 2:50 PM and 9:00 PM, the connection to the wireless network suddenly disrupted. There was no signal detected thus causing connection lost for a short while. Figure 8 presents a graph on the signal percentage of an access point with SSID UStudent. Due to the weak quality of Wi-Fi connection, the signal percentage dropped as compared to other SSID, and it was slightly above 50%. The quality of the connectivity was critically jeopardized especially during the evening. This could be the cause of many users connecting to the access point at the same time which caused congestion to the network traffic. Based on the analyzed captured presents in Table 2, it is summarized that the highest signal percentage for CCNA_1 is 56%, UHotspot is also 56% and UStudent is 53%. Whereas, the lowest signal percentage for CCNA_1 and UStudent is 1% and UHotspot is 38%. Overall, UHotspot has the excellent quality of Wi-Fi connection.

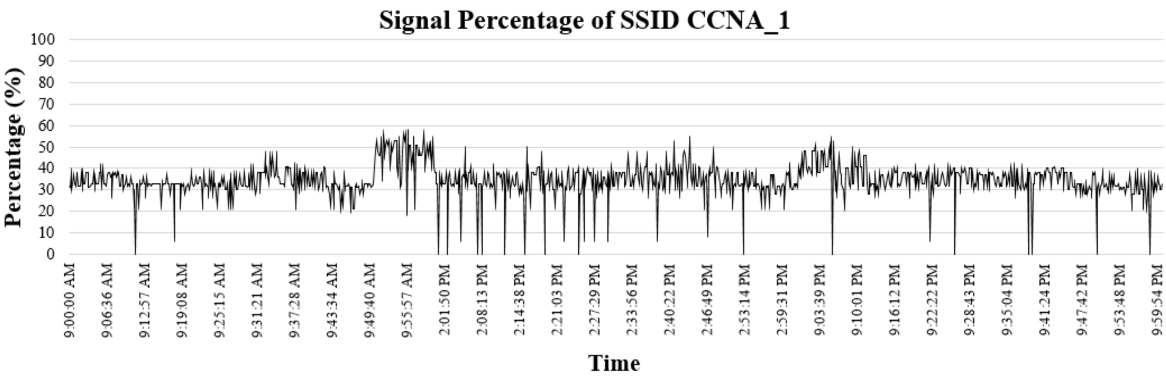

Figure 6. Signal percentage for CCNA_1

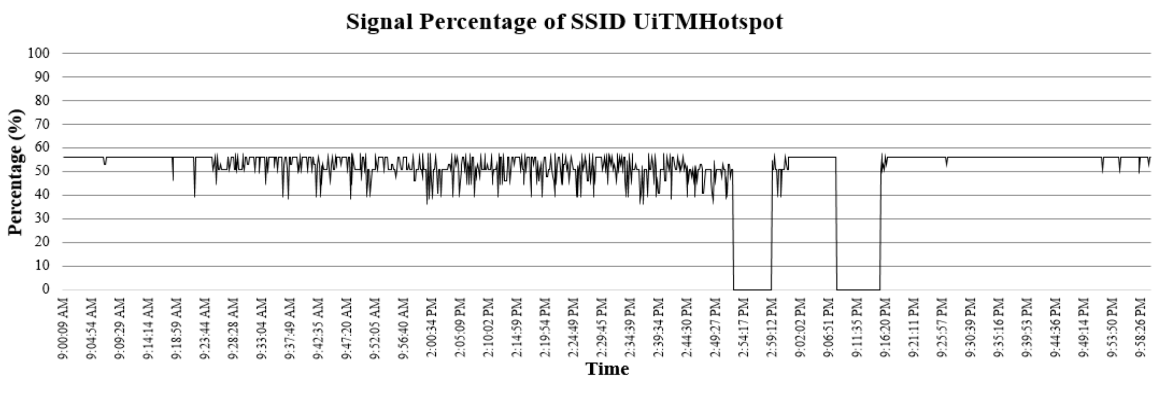

Figure 7. Signal percentage for UHotspot

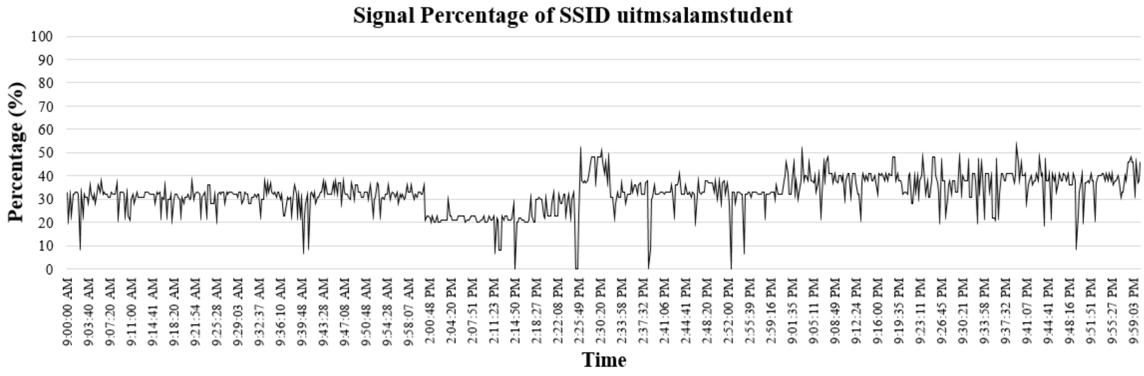

Figure 8. Signal percentage for UStudent

Table 2. Comparison of signal percentage per access points

SSID	Highest (%)	Lowest (%)
CCNA_1	56	1
UHotspot	56	38
UStudent	53	1

3.2. Analysis of signal strength per access points

Figure 9 presents a graph on the signal strength of access point with SSID CCNA_1. The signal strength measured in dBm unit does not scale in a linear fashion as the signal strength changes are not gradual. Moreover, dBm values are normally negative so the higher the values of dBm, the better the signal. Based on the figure below, the signal strength is between -40 dBm and -95 dBm. This SSID has an excellent quality of Wi-Fi connection because even when there are dropouts happened, the connection is not lost. Since it is in a lab, there are not many users connect to the SSID so there is not much competition to access the wireless network.

Figure 10 presents a graph on the signal strength of access point with SSID UHotspot. The signal strength for this SSID is between 0 dBm and -60 dBm. Even there were many devices connected to this access point, the signal strength is still favorable. The signal maintained a stable connection throughout the day. However, users had experienced limited connection from time to time. Figure 11 presents a graph on the signal strength of access point with SSID UStudent. The signal strength for this SSID is between 0 dBm and -95 dBm. It can be seen that this SSID has an average Wi-Fi connection. Besides many users connecting to this access points, interferences such as walls, trees, and buildings could be the obstacles in getting a good Internet connection. These interferences cause slow performance or disconnection to the wireless network.

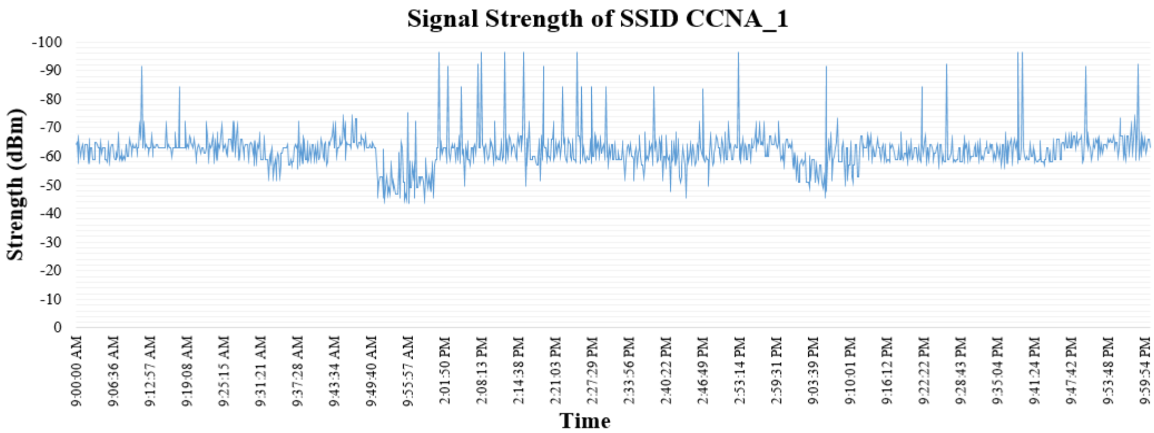

Figure 9. Signal strength for CCNA_1

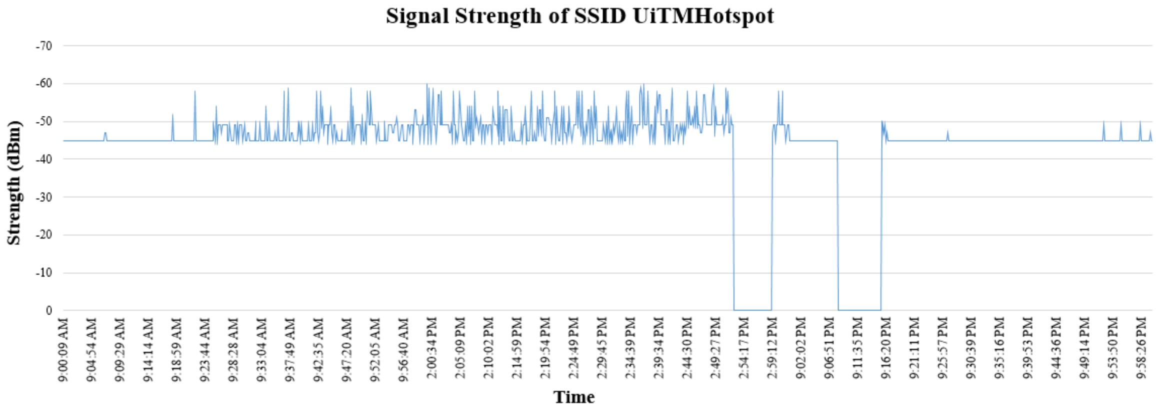

Figure 10. Signal strength for UHotspot

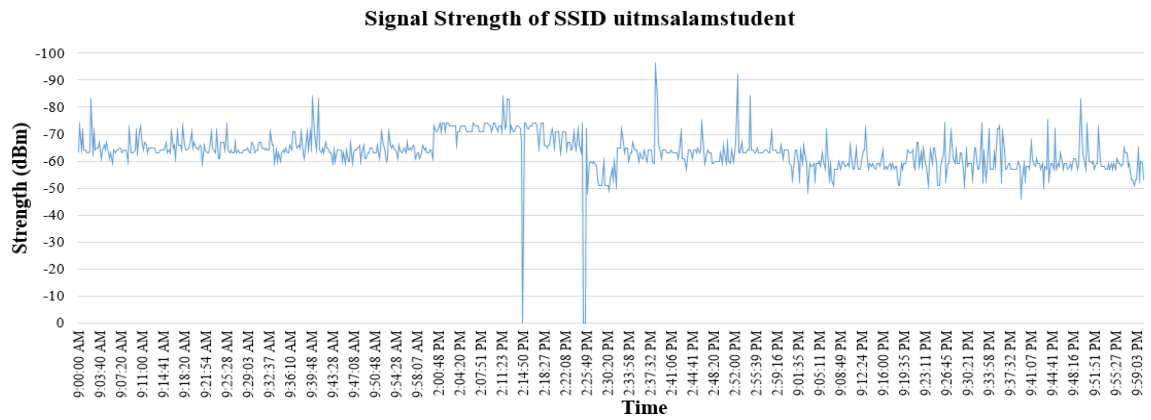

Figure 11. Signal strength for UStudent

Based on the analyzed captured present on Table 3, it is summarized that the excellent signal strength for CCNA_1 is at -47 dBm whereas the lowest signal strength is at -95 dBm. As for UHotspot, the excellent signal strength is at -45 dBm whereas the lowest signal strength is at -59 dBm. Moreover, -95 dBm is the lowest signal strength for UStudent and -45 dBm is the strongest signal strength. Overall, it is concluded that UHotspot has the best signal strength among the SSID.

Table 3. Comparison f signal strength per access points

SSID	Strongest (dBm)	Weakest (dBm)
CCNA_1	-47	-95
UHotspot	-45	-59
UStudent	-45	-95

3.3. Analysis of channel utilization per access points

Figure 12 presents a bar graph on channel utilization of access point with SSID CCNA_1. It is seen that only channel 4 is used throughout the day. This means that there is no interference thus it has no problems n connecting to the access point. The highest number of access points connected to channel 4 is 389 counts throughout the day. Figure 13 presents a bar graph on channel utilization of access point with SSID CCNA_1. The channels that are mostly used are channel 1 throughout the day. However, there are times drop out happened which disconnect the devices from the wireless network. The highest number of access points connected to channel 1 is 384 counts which are in the morning.

Figure 14 presents a bar graph on channel utilization of access point with SSID CCNA_1. When a channel has too many clients used, it became limited thus there is no more space for clients to use the channel. Due to this, the clients will be connected to another channel which is available. Channel 1, 6, and 11 are the only channels that do not overlap thus it will not cause interferences among the connected devices. To minimize interference, same-channels access points will be placed as far away from each other. The highest number of access points connected to channel 6 is 252 counts which are in morning and night.

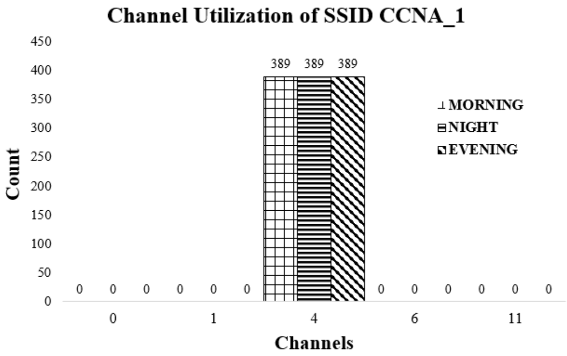

Figure 12. Channel utilization for CCNA_1

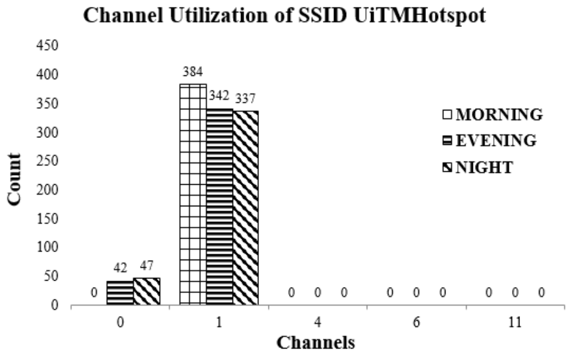

Figure 13. Channel utilization for UHotspot

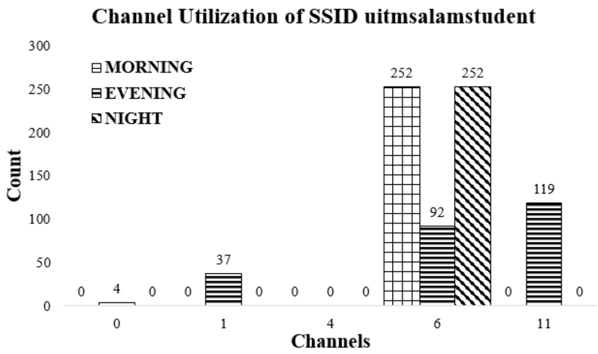

Figure 14. Channel utilization for UStudent

3.4. Analysis of number of clients count per access points

Figure 15 presents a bar graph showing the total number of clients connected to the access points respectively. For CCNA_1, the total number of clients count is 57 whereas, for UHotspot, the total number of clients count is 67. However, for UStudent, the total number of clients count is 151. UStudent has the most total number of clients count because the coverage is larger thus students could connect to this access point anywhere that is available. In contrast with the other access points, it is because the access point for CCNA_1 is only available in CCNA lab and UHotspot is only available at the front of PTAR Faculty of Engineering.

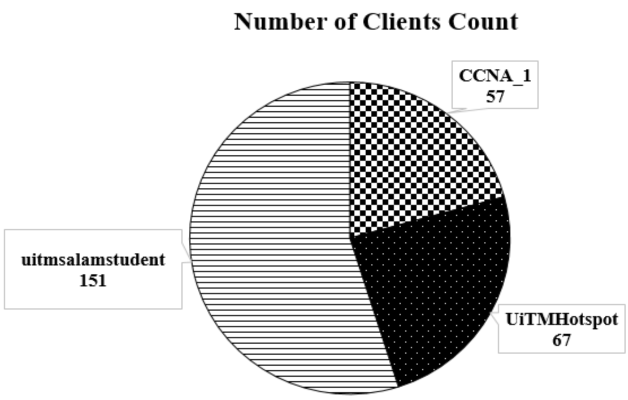

Figure 15. Number of clients count

3.5. Comparison of the access points

The access points with SSID UHotspot and UStudent are using the same frequency bands which are 2412 MHz (2.4 GHz) whereas CCNA_1 is using the 5785 MHz (5 GHz) frequency band. There are many differences between these two bands in terms of interference, range, and bandwidth. Firstly, the 2.4 GHz is prone to interferences compared to 5 GHz. This is because many wireless devices run on 2.4GHz such as Bluetooth, microwaves, and other electrical appliances. In addition, there are only 3 non-overlapping channels on 2.4 GHz which are channels 1, 6, and 11 as compared to 5 GHz which has 23 channels. Therefore, SSID CCNA_1 has the best signal strength compared to other SSIDs because it runs on 5GHz frequency signal which has more non-overlapping channels. Furthermore, in terms of its range by means on how far the data travels, 5 GHz radio waves drop more energy transporting through walls, air or other obstacles than 2.4 GHz waves. There are many external influences affected the wireless network range such as walls, tiles, concretes and many more. Thus, SSID UStudent and UHotspot have better range than CCNA_1.

Moreover, to compare the bandwidth or speed of data transmission between 2.4 GHz and 5 GHz, the higher the frequencies, the faster the data transmission. 5GHz allows much faster network as data transmission is faster compared to 2.4 GHz. Which is why according to this term, SSID CCNA_1 has the better speed of data transmission compared to the two access points. Thus, it can be concluded that even when UHotspot and UStudent have the best range compared to CCNA_1, CCNA_1 has the excellent network speed as it offers more bandwidth and faster data transmission. Channel interference could also be minimized as there are 23 non-overlapping channels for 5GHz frequency band which offers more space. Figure 16 shows the comparison of the three access points which are UHotspot, CCNA_1 and UStudent in terms of its signal strength.

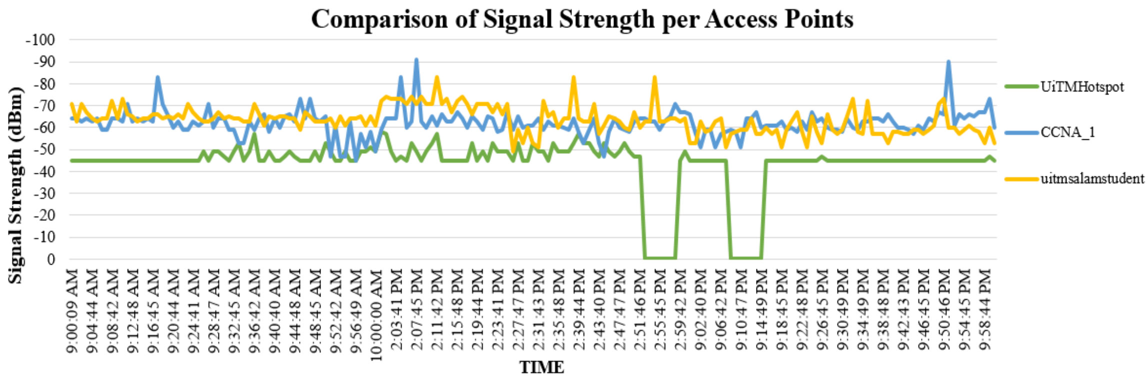

Figure 16. Comparison of signal strength per access points

4. CONCLUSION

This research has succeeded and met its objectives that measured the Wi-Fi performance based on the signal strength and used of percentage per access points for indoor campus networks. The analysis of users' connections to access point channel utilization for three different times is successfully achieved. The analysis showed that the channels used on the access points are important in the performance of the wireless networks. The comparison of the three access points for signal strength, percentage usage, and channel utilization is analyzed and discussed the QoS for Wi-Fi performance of the indoor campus university network. Wi-Fi performance is often to be ensured for QoS, thus proper planning is needed in network management. The QoS may be improved by using the right channels for good Wi-Fi connection and overcome any existence of interference. As a conclusion, the performance of a wireless network depends on the position of the access points and connected devices. Traffic congestion usually happens when an access point has lots of active users and reached its limits. Analyzed on best location near to the access point to get better and faster coverage is needed. Besides, placement of the access points with the same channels also plays an important role as this is to avoid overlapping interference which can cause interference on neighboring networks. The best choice is by using channels 1, 6, and 11 to achieve less interference. However, the statistical analysis of data is unpredictable as every day, network traffic changes over time depending on how many clients are connected to the wireless networks. Other ways may be used to improve the performance of a wireless network in Campus University. In future steps, the author wishes to improve and extend throughput prediction by using Wi-Fi Heatmap to show the coverage for each access point and to discover deeper on the performance of wireless networks on different parameters such as link speed, bandwidth and security measurements.

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