Congestion Analysis In Wi-Fi Network Of Engineering Tower (2) Due To Overloading Of Traffic

Nur Fariha Binti Zulkifli
Faculty of Electrical Engineering
Universiti Teknologi MARA
Shah Alam, Selangor
nur_fariha90@yahoo.com

***Abstract*—This paper discussed on the congestion analysis in Wi-Fi network of Engineering Tower 2 due to overloading of traffic. The objectives proposed by the paper are to study and understand the concept of Wi-Fi network, congestion and overloading in Wi-Fi network. The paper also discussed about the factors that led to congestion in Wi-Fi networks and solutions to overcome them. Wi-Fi mapping tool 'Ekahau HeatMapper' and network scanner software named 'inSSIDer' were used to collect the data. Data collecting process were doneat Level 11, Engineering Tower 2 for three selected APs at selected points during noon, evening and night for five days. It was then analyzed and results were plotted using MATLAB and Microsoft Excel for better illustration and understanding. The research and analyzing process only covers and concentrate on congestion of Wi-Fi network in Engineering Tower 2 within the use of the 2.4GHz frequency that were deployed for wireless networks in Malaysia because most devices can operate on that band.**

Keywords-component; Wi-Fi, Ekahau HeatMapper, inSSIDer, congestion, access point (AP).

I. INTRODUCTION

The wireless communication revolution is bringing fundamental changes to data networking, telecommunication, and is making integrated networks a reality. With wireless network, users are certainly freed from the cord or wired, personal communications networks, wireless LAN's, mobile radio networks and cellular systems, enable the communications anywhere and everywhere at any time[1]. A wireless network is any type of computer network that uses wireless data connections for connecting network nodes. It is a method by which homes, telecommunications networks and enterprise installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. Generally, wireless telecommunications networks are implemented and administered using radio communication that takes place at the physical layer of the OSI model. There are various type of wireless network such as Wireless Personal Area Network (WPAN), wireless local area network (WLAN), Wireless Wide Area Network (WWAN), wireless mesh network, cellular or mobile network and global area network.

This paper focused on wireless local area network (WLAN) that links two or more devices over a short distance using some wireless distribution method providing connection through an access point to the wider internet. This technology gives users the ability to move around within a local coverage area and still be connected to the network. Wireless LANs have become popular due to ease of installation, and in commercial complexes offering wireless access to their customers usually for free. There are various applications that implemented the WLANs nowadays ranging from the small networks to large that enable users to access the internet from various hotspots such as in the campus, airplanes and trains stations, restaurants, hotels and now with portable devices that connect to 3G or 4G networks. Most modern WLANs are based on IEEE 802.11 standards, marketed under the Wi-Fi brand name.

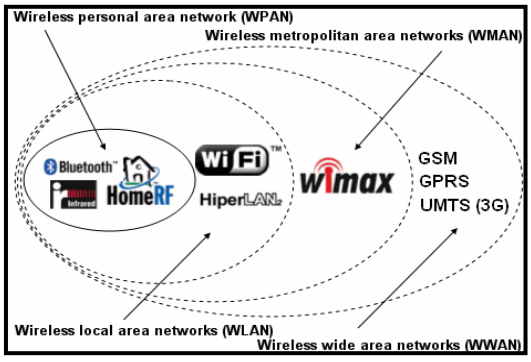


Figure 1: Various type of wireless network including WLAN and Wi-Fi

Wi-Fi also spelled Wifi or WiFi, is a popular, worldwide used technology that allows electronic devices to exchange data or connect to the internet without the use or connection of wire or physical cables, by using radio waves. Wi-Fi stands for "Wireless Fidelity" and it is define as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards. Only Wi-Fi products that complete the Wi-Fi Alliance interoperability certification testing successfully may use the "Wi-Fi CERTIFIED" trademark. All devices can connect to a Wi-Fi via an access point or also called hotspot. For each hotspot, typically have a range of about 20 meters approximately 65 feet indoors and a wider range outdoors. Hotspot coverage can covers smaller area as a single room with walls that block radio waves to prevent other waves that will disrupt the wireless network, or larger and wider area by using multiple overlapping access point within the same region or nearer.

However, the scope of study and research only covers and concentrate on congestion of Wi-Fi network in Engineering Tower 2, not including the usage of mobile network or other technologies below and other than wireless or Wi-Fi. This is to consider the fact that congestion issues become more reliable and critical within the usage of mobile data networks and of course wireless network especially among engineering students.

II. LITERATURE REVIEW

One of the often problem contributed to slowing down a network is the phenomenon of Wi-Fi congestion. It is very difficult to prevent interference between Wi-Fi and Bluetooth, or other wireless services to occur even though the network experience of being alongside one another. Kang Shin, a professor at the University of Michigan, who has studied the phenomenon said: "They cannot really speak the same language and understand each other at all. These devices do not have a direct means of communicating, since they use different protocols". In fact, the different technologies cannot notifies each other and therefore end up crammed for space which in turn create an immerse level of congestion, which can be enough to slow down your entire network[2]. The congestion issues that become troublesome nowadays to the network providers and especially the network users itself, it is most likely to affect the Quality of Service they experienced. Quality of Service (QoS) is the mechanism in mobile communications provides by the providers to the users to control the performance, reliability and usability of a telecommunications service. The traffic within data network is expected to grow drastically in the next few years due to the explosive growth of network accessing on electronic devices such as notebooks, smartphones, tablets, and etc.

X. Gelabert, J. Perez-Romero, Sallent, R. Agusti stated that most of the data traffic today is in the form of audio accesses from smartphones, and the demand for these applications is projected to keep developing exponentially. Most providers have modified their network pricing plan in responses to congestion [3]. The data traffic also occurs in the wireless network with exactly the same causes that led to the wireless network to congest. Experts in the communication industry across the board worldwide have agreed that this trend will continue as the technology and communication will keep evolving and developing slowly and sometimes drastically.According to Erik Fledderus, professor of Wireless Communication at TU Eindhoven, there are now so many hotspots that they interfere with each other [4]. Nikos I. Passas and Lazaros F. Merakos stated that bandwidth demanding sources can readily overload the system leading to congestion [5]. Sneha K. Kasera, Ramachandran Ramjee and Sandra Thuel has discussed that congestion occurs when the offered traffic exceeds radio access networkcapacity[6].

III. METHODOLOGY

This chapter discussed on the method of completing the study including the process flowof the study, data collecting process or techniques, the algorithm and material used such as software, equipment and data analyzing tools.

A) Flow Chart

The flowchart of the project started with the study and research on the topics related to Wi-Fi congestion. The process continued with the research work progress such as the literature review, the software used and few testing done to familiarize with the software. The process continued with the next stage which is the data collection process with the used of insider and Ekahau HeatMapper. The next section will elaborate more on the software used. Few data were collected and analyzed before the results were tabulated and plotted. If the data obtained were found to be appropriated, the results were then plotted and tabulated by using MATLAB and Microsoft Excel for better understanding and further works such as data analyzing process. Appropriate data is needed in order to tabulate correct results from the data analyzed. The data must include the signal strength, overlapping channel, co-channel interference and the link score of the analyzed network.

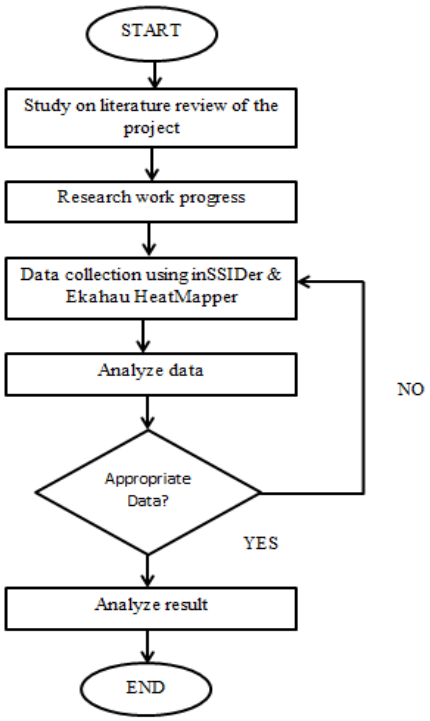


Figure 3: Flowchart of the project

B) Ekahau HeatMapper

It runs on Microsoft Windows and support 802.11 a/b/g/n/ac wireless networks. Ekahau HeatMapper is used to discover and locate Wi-Fi coverage on map, locate all access points, and detect security settings and finds open networks. It is free of charge and easy to install. Figures below show some illustrations of the uses of this software.

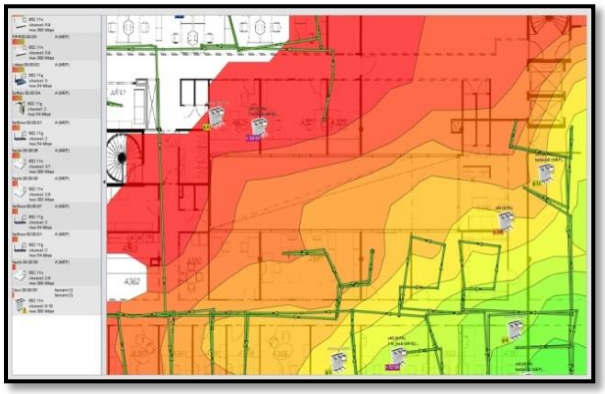


Figure 4: Illustration of the features of Ekahau HeatMapper

From the figure shown above, the software able to display the Wi-Fi coverage based on a floor map or based on grid (in the software itself). Besides that, it also locates all access points with their signal strength within the coverage displayed.

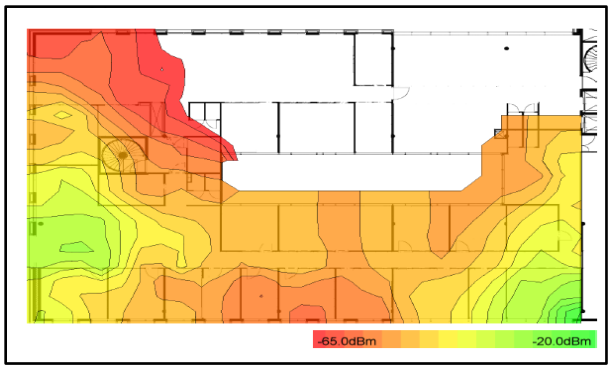


Figure 5: Signal strength reading on Ekahau

The green color show better signal strength compared to the red one. This is probably because the AP is located nearby or at the region within the green colored coverage.

C) inSSIDer

inSSIDer is a Wi-Fi network scanner software for Microsoft Windows and Apple OS X developed by MetaGeek. The features of this tool are such it gathers information from wireless card and software. It also helps to choose the best wireless channel available by viewing the graphs signal strength over time and shows which Wi-Fi network channels overlap between each other's.

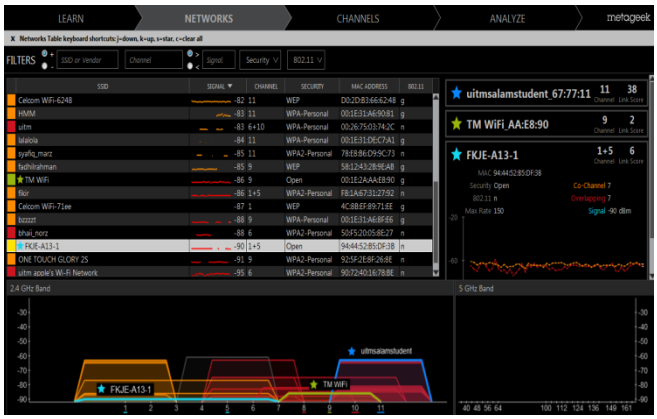


Figure 6: Illustration of inSSIDer.

Figure 6 shows the features of inSSIDer software that is capable of displaying the Wi-Fi network's information such as various access points, SSID, the signal strength, channel, security type and MAC address. The right side of the figure show the starred network to be analyzed. The display shows the graph of the signal and overlaping channel involved among the selected network.

D) Steps and Procedures

The data collecting process was done by using inSSDer and Ekahau HeatMapper. By using inSSIDer, the data were collected at three selected point at Level 11, Engineering Tower 2. At each point, three APs were tested and analyzed. The data and readings were captured and saved to tabulate results by plotting graph, tables and bar charts. The same procedures were repeated for each points for three different times per day which is during noon, evening and night, repeatedly for 5 days.

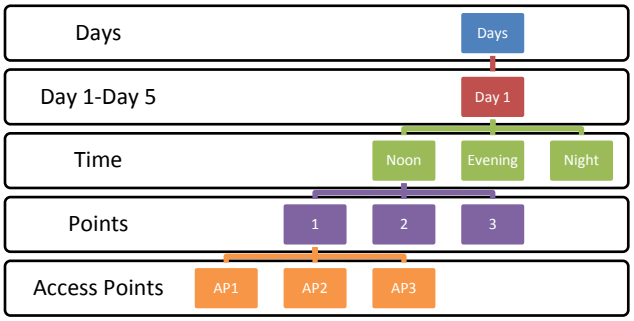


Figure 7: Hierarchy of the data collecting details

IV) RESULT AND DISCUSSION

The raw data on congestion that occurs in the Wi-Fi network of Engineering Tower 2 were collected from the Wi-Fi mapping tool or network scanner software and analyzed using MATLAB software for better illustration on how the issues occur and affected the network. Besides that, it is expected to find out the best solutions from the researches on how to overcome the congestion issues that become an unstoppable crisis in the wireless and mobile communications. Below is the parameter details related to the data collection process:

Table 1: Parameter details for data collection

Parameter	**Details**
Location	Level 11
Point of Testing	3
No. of AP analyzed	3
Duration	5 Days
Time	Noon, evening and night

Table 1 shows the parameter details for data collection process. The location tested was at Level 11 where engineering students often have their study group, discussions or doing assignment and studies that required the use of Wi-Fi. There are three points of testing which is at the entrance (nearby the elevator), middle point is the study place nearby the information board and the third point is at Chemical Engineering study places. Figure 8 below shows the example of data collected and its details.

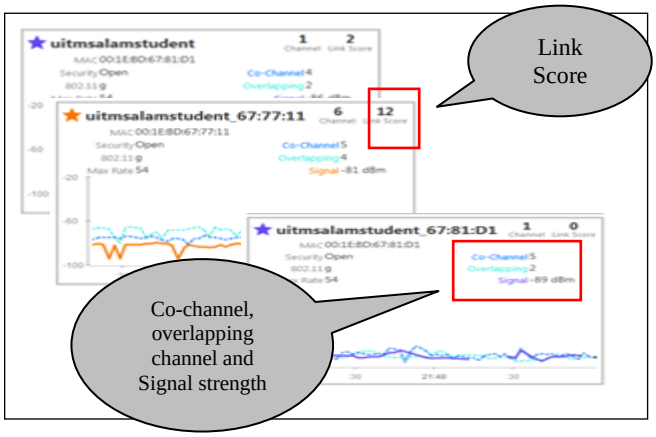


Figure 8: Example of data collected

A) Factors

There are few factors that can cause the network to be overloaded and congested. Below are the factors determined and discussed from the data collected.

i) Time and Day

One factor that led to the congestion of Wi-Fi network is the time. This can be proved by the table and the graph plotted by using MATLAB.

Table 2: Signal Strength and time recorded for AP1(as shown in Figure 8 and highlighted below)

AP1	
Time (24 Hours)	Signal Strength (dBm)
12.19	-86
12.24	-86
12.29	-64
17.33	-81
17.38	-95
17.43	-88
21.43	-89
21.56	-77
22.13	-59

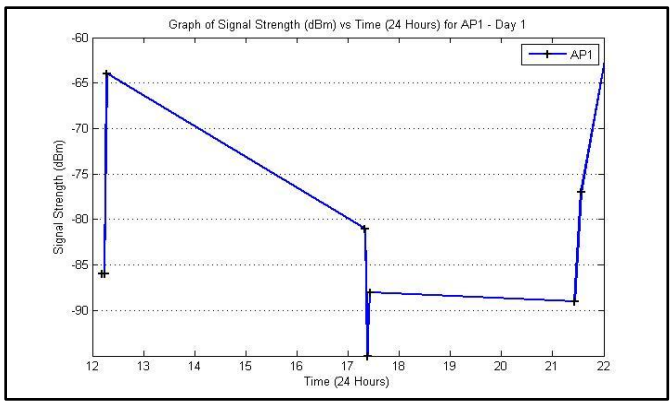


Figure 5: Graph of Signal Strength (dBm) vs Time (24 Hours) for AP1

Table 2 and Figure 5 show the signal strength and time recorded for AP1 and the graph plotted from the data. It can be concluded that the signal strength is lower during the peak hour and higher during midnight. This is because during noon and evening the network is said to be overloaded with data traffic, because Wi-Fi users or students were using the Wi-Fi to do their works. It can be seen that during night time, up to 10 o'clock in the night, amount of Wi-Fi users are lesser as they have stopped accessing the internet.

Table 3: Signal Strength and time recorded for 3 Aps

Time (24 Hours)	Signal Strength (dBm)		
	AP1	AP2	AP3
12.19	-86	-89	-68
12.24	-86	-95	-70
12.29	-64	-87	-81
17.33	-81	-85	-84
17.38	-95	-77	-72
17.43	-88	-92	-77
21.43	-89	-95	-72
21.56	-77	-82	-74
22.13	-59	-86	-83

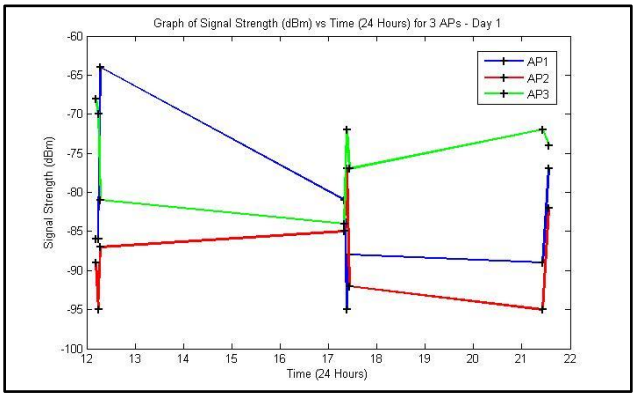


Figure6: Graph of Signal Strength (dBm) vs Time (24 Hours) for 3 APs

From the Table 3 and Figure 6, it can be seen that the signal strength of the three APs were congested at approximately same time which is during noon and evening. It can be concluded that these signal were congested during the peak hours where students are using the Wi-Fi for their works. The networks can be congested when radio spectrum allocated to wireless communications is limited, while the population of the WI-FI users is increasing.

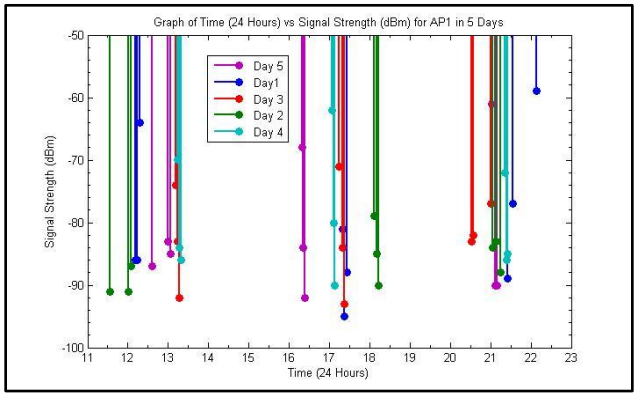


Figure 7: Graph of Signal Strength (dBm) vs Time (24 Hours) for AP1 in 5 days

Figure 7 above shows the graph of spike of signal strength by following the point of testing. It can be clearly seen as the graph below.

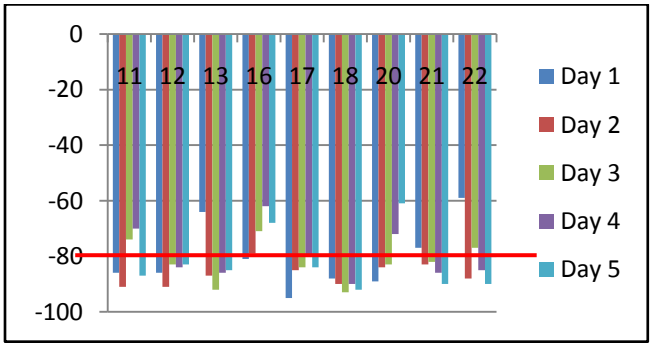


Figure 8: Graph of Signal Strength (dBm) vs Time (24 Hours) for AP1 in 5 Days

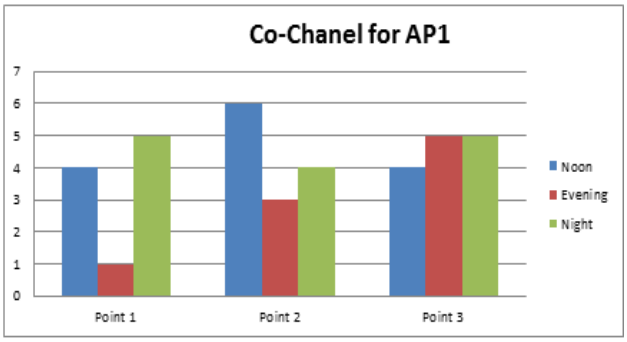
Most signal are congested during Day 2 (Thursday) and Day 5 (Sunday) that recorded signal strength more than -80dBm. The red line indicates the reference signal strength at -80dBm which is in the condition of far and poor signal strength. It is determined by the amount of days the AP will likely to undergo congestion in the network. It is said to be congested because Day 2 and Day 5 is the day where lots of students will come to Level 11 to use the Wi-Fi and completed their works. The signal is weaker because there are lots of users are accessing the internet. Day 1, 3 and 4 is not considered to experienced congestion because, during Wednesday, most Engineering

Faculties will not having classes after 1pm. Day 3 is the Friday where male students are having their prayer while Day 4 is Saturday where some students are having classes (for selected or elective subjects) and they are not staying for working purposes. Signal strength which is below -75dbm is said to be good and not congested. Signal strength is the most basic requirement for a wireless network. As a general guideline, low signal strength means unreliable connections, and low data throughput. Below are range of signal strength and their performance according to wireless network expert:

Excellent: -45 dBm to -57 dBm
Good : -58 dBm to -75 dBm
Far : -76 dBm to -85 dBm
Poor : -86 dBm to -95 dBm

ii) Co-channel Interference

Another factor that can contribute to the overloading and congested network is the co-channel interference. Co-channel or co-channel interference is crosstalk from two different radio transmitters that are using the same frequency.



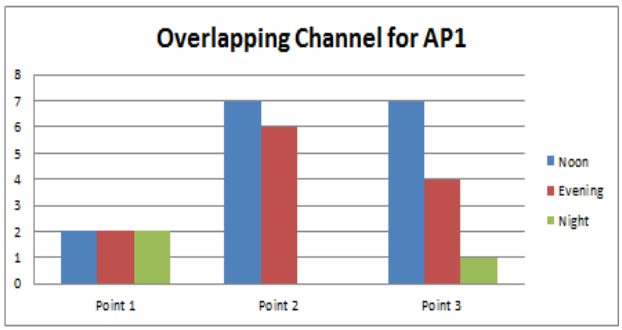
Bar chart 1: Co-channel for AP1

Bar chart above show the co-channel experienced by AP1. The amount of co-channel interference experienced by AP1 is said to be higher during daytime which is the noon time. During evening, the co-channel is lesser because during that time, it is the end time of working and classes' session. But, the amount of co-channel at Point 2 and Point 3 is the same during evening and night because there are still some users that were still accessing internet after working/classes hours. Moreover, at Point 2 and Point 3 is the student working areas (and to be considered, students are working outside classes' hours). Therefore, there might be possibility of few devices will transmit at the same time and causes co-channel.

In WiFi, a channel is the medium of getting the data across. So when users connect to an AP on channel 1, his/her end device and the AP are talking to each other on channel 1. But, if there are two devices on the same channel transmit data at the same time, within the same frequency channel, the transitions will interfere with each other and cause data corruptions.There are few factors that can cause co-channel radio interference such as bad weather condition, poor frequency planning and overly crowded radio spectrum taking into account the daytime and night time as discussed previously.

iii) Overlapping Channel and Point of Testing

Another factor that can lead to congestion in wireless network is the overlapping channel.There are 11 channels designated for wireless networks in the 2.4-GHz frequency band that are spaced 5 MHz apart from each other. The protocol requires 25 MHz of channel separation, meaning that it is possible for nearby channels to overlap and then interfere with each other. For this reason, most Wi-Fi professionals recommended the uses of only channels 1, 6, 11 because they are least congested compared to the others[7].



Bar chart 2: Overlapping channel for 3Aps and for AP1

From the bar chart above, it can be seen that number of overlapping channel for AP1 is higher during noon especially at Point 2 and Point 3. This is because, as stated in previous section, the point of testing affects the data collected and causes the results to be varied. There are same amount of overlapping channel at Point 1 during the days. This is because at Point 1 is the entrance (nearby the elevator), where there are no suitable spaces for the users to access the internet compared to Point 2 and Point 3, which is the middle and the third point which indeed are used for the study and working/discussions purposes.

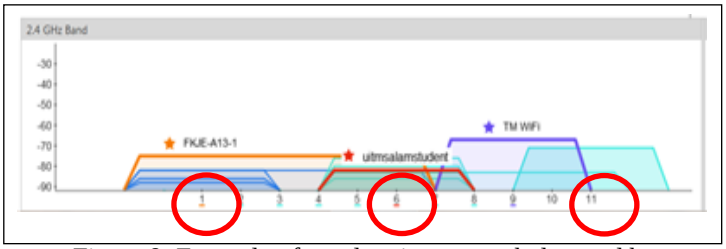
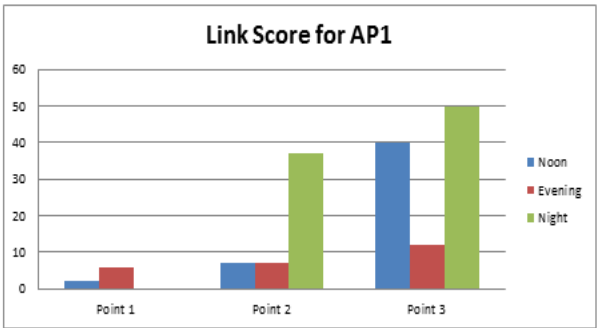


Figure 9: Example of overlapping network detected by using inSSIDer

Phenomenon of network overlapping occurs when the spread spectrum technology takes the data for transmission process, and spreads it over a range of frequencies channels. When a device is on channel 6, it is known to be the "centre frequency". It will actually spread the transmission over channels 4, 5, 6, 7 and 8. That is why the experts are referring channels 1, 6 and 11 as being the only channels that do not overlap each other. When a network or the AP is too close to each other, some of the channel space will overlap. This will affect the data in the overlapping bits to be corrupted and have to be re-transmitted, which can cause all types of issues such as transmission corruption and slow performance for connected devices. Overlapping networks have a more critical impact on performance than co-channel networks that will lead to experiencing the congestion.

iv) Link Score

Besides the three factors stated above, another features in inSSIDer that can be applied to analyze the congestion in the network is the link score. Bar chart below shows the link scores performance for AP1.



Bar chart 3: Link score for AP1

Link Score is the performance score in inSSIDer. It is a grade for each network calculated by its signal strength, channel power, and number of networks competing for airtime. The closer the score is to 100, the better performance can be expected from the network. The score varied because it is affected by the measurements or data collecting process, low signal strength, and large numbers of co-channel and overlapping networks and the signal strength. The link score for AP1 is higher during night time because there are not too many Wi-Fi users during that time compared to noon and evening.

v) Distance

The distance between the users and the AP was also one of the factors that can cause the network to be congested. It can be proved by looking at the Wi-Fi coverage captured using Ekahau HeatMapper as shown in Figure 10.

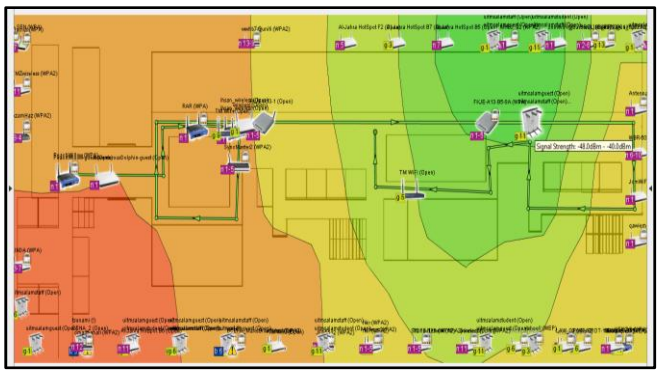


Figure 10: The Wi-Fi coverage using Ekahau HeatMapper

From the figure above, the signal is stronger and higher at the green colored area which is at the Point 3 at the Faculty of Chemical Engineering study area. This is because the AP is located whether upstairs or downstairs near Point 3. As the end device (in this case, the Ekahau HeatMapper was run using a laptop during the data collecting process) move further away from the AP, the signal strength is getting lower and lower indicated by the yellow area to orange area and getting worst during the red colored area. At the most basic level, of course, Wi-Fi continues to get faster, at least for users that are close to the AP itself.

vi) Capacity

Congestion can be realized in many ways, let say, at any time interval, when the total sum of demands on a source is more than its available capacity, the source is said to be congested for that interval.

$$\Sigma \text{ Demand} > \text{Available Resources}$$

In simplest term, it is the same concept applied when there are too many Wi-Fi users at one time accessing the internet often with heavy accessed such as web browsing, uploading and downloading, voice over internet protocol, and other data-heavy multimedia services. The overload conditions might occur if the communication needs of a number of wireless terminals populating a small area were to exceed the total capacity of all access points within their reach. Congestion occurs when offered traffic load exceeds available capacity at any point in the network.

There is no feature of analyzing the capacity of a wireless network by using either Ekahau HeatMapper or inSSIDer. It is because the study is done using trial and free version software. But, the capacity measurement and other parameters such as throughput and SNR can be analyzed by using the other product of Ekahau named Ekahau Site Survey with the purchased version.

B) Solutions

Therefore, to overcome all the factors that has contributed to the congestion problems as discussed above, few researchers has suggested solutions that can be taken into account such as to rebuild the network or create space on another band, such as the 5GHz frequency, which is also free. However, those devices such as routers and modems must be suitable for that frequency. Other than that is the deployment of single-channel virtual cell architectures using smart antennas and full wireless traffic engineering. Moreover, the network providers can improve the Wi-Fi standards to more efficient use of spectrum. While the users can play role by reserving resource in the access network by using properly designed policies to control and avoid congestion.Since network resources in wireless network are limited through spectrum allocation and budget for capital expenditure, these data growths is increasingly and cause the shortage of resources in the network.

V) CONCLUSIONS

From the study, it can be concluded that the initial objectives stated previously has been achieved. From this research, few factors have been identified that cause congestion in Wi-Fi network as shown by data collected and analyzed using MATLAB and Microsoft Excel. For each factors discussed above, it can be concluded that the signal or data were overloaded and congested according to the behavior that have been discussed such as time and days, co-channel interference, overlapping channel, link scores, distance and the capacity of the network itself. Some solutions to overcome them have been suggested according to the previous investigation on the subject. Congestion introduces loss and delay jitter in the user traffic. Uncontrolled loss and delay jitter could drastically reduce the quality of communications.The exponentially growth of the high-technology users end devices, 3G networks and the growing popularity of wireless networks has also led to cases of heavy utilization and thus introduce congestion in the network itself.

VI) ACKNOWLEDGEMENT

In the great name of Allah and with his grateful for grace, I manage to accomplish the tasks that have been assigned successfully. I prayed thousands thanks to Allah and very grateful to be given the opportunity to complete this project as well as learning new things although being faced by many obstacles and challenges.First of all, I would like to say thousands thanks to those who have greatly contributed to help me in preparing my project especially to my Supervisor, Assoc. Prof. Norhayati Binti Ahmadwho has helped, guided and taught from the very beginning to the very end. I would also extend my thanksto my parents and family on the advice and supports they had always given to me. Last but not least, to all my fellow friends, housemates and classmates who helped and contributed to the completion ofthis project. Thank you very much.

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