Analysis of Indoor Location and Positioning via Wi-Fi Signals at FKEKK, UTeM

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***Abstract*— Global Positioning System (GPS) is widely used as public location and positioning system in navigation of user. However, this application signal is limited, not operational, not available and inefficient for indoor environment. Therefore, the purpose of this project is to analyze indoor location and positioning utilizing the Wi-Fi signals. Wireless position estimation is based on distance measurement in determining the coordinates of user. Scene analysis which called fingerprinting technique is implemented in this project with measurement of received signal strength (RSS) from all the access point. The project has two phases to go through which are the surveying phase and online phase. The unknown location of the target user RSS during online phase will be compare to the database that has been collected during surveying phase. The Euclidean distance algorithm is implemented in calculating the location estimation which the MATLAB software used as the simulation tools. Several analyses have been done to determine the accuracy and effectiveness of the positioning error due to numbers of access point and environment traffic condition.**

Keyword-Location Estimation, Positioning, Received Signal Strength (RSS), Fingerprint

I. INTRODUCTION

Positioning system is a technology that used in locating and positioning geo-location coordinates of user. Positioning system technologies can be divided into two categories which are outdoor and indoor positioning. The most popular and establish outdoor positioning system is Global Positioning System (GPS). This system uses satellites to navigate the location of the target or user. The current indoor positioning systems technology is Wi-Fi, RFID (Radio Frequency Identification), laser, infrared, and ultrasound.

GPS is the most effective positioning system for outdoor environment and plays a dominant role in localization. It can provide precise locations of mobile devices with worldwide coverage. However, GPS has it weakness and is not available, not operate or suitable for indoor environments [1][2][3]. This inefficiency is due to the signals disability to penetrate most building materials [4]. It performance fades in indoor use and in urban environments due to multipath fading [5].

Indoor location systems has become very important and popular in recent years [6][7]. It gradually play an important role in all aspects of people's daily lives including e.g. living assistant, navigation, emergency detection, surveillance or tracking target-of-interest and many other location-based services [4]. Nowadays, WLAN technology can be found in almost every building. It is because an advancement of technology in developing devices like smartphones which can directly connected to the internet. Internet has become a daily needs especially for getting knowledge.

There are many principles that are used in estimation the exact location of user for indoor applications as mention in [9]. Currently there are no standard or establish for indoor positioning but can be categorized by three general categories. The first common technique is the proximity, which the detector is placed at specific location. When the user is within the region of the detector, the position of the user will be identified. The precision of this technique usually are within the distance range of the coverage of the cell detector. Another most popular technique is the triangulation technique where it used the mathematical of triangle to calculate the exact location of user. These methods calculate the distance from the entire transmitter to the user, and get intersection for exact location. The approach include manipulate the received signal strength (RSS), time of arrival (TOA), and the time different of arrival (TDOA)[9][5]. The last categories are scene analysis or fingerprint technique [9][5]. This technique is based on characteristic of a signal at each specific location. *Fingerprint* locates a target by comparing RSS from AP with database over a coverage area. An offline phase is the first from two stages have to go through for this position algorithm. During this phase, a site survey is performed on the coverage area. The locations with unique RSS from nearby APs are collected. All the fingerprints then will be stored as database. During the online phase, a location positioning technique uses the currently observed signal strengths and previously collected information to figure out an estimated location.

The backbone of this study is to analyse the factor that effect the location estimation accuracy based on Euclidean distance algorithm using scene analysis. The site survey is perform based on the receive signal strength (RSS) of the Wi-Fi signals. For starting point the site that is chosen for this project is the pedestrian area near the lecture rooms, located on Block B FKEKK. This is where many people especially the students commute to class and labs.

II. METHODS

One of the benefits of scene analysis or fingerprint technique positioning algorithm needs no hardware modification in determining target position [8]. It also does not require knowledge of APs, not require an estimation of distance between AP and client and static object in the environment do not affect the system [2]. However, the problem is the RSS value could be affected by diffraction, reflection and scattering in the propagation environments [6].

This project can be categorized to 3 phases which are the offline phase, online phase, and lastly the analysis phase. The offline phase is where the measurement or surveying the RSS of each APs for each point location. Before that could be done, the area location needs to divide by constant location point where all the data measurement will be stored in database. The diagram in Fig. 1 shows the idea of each phase.

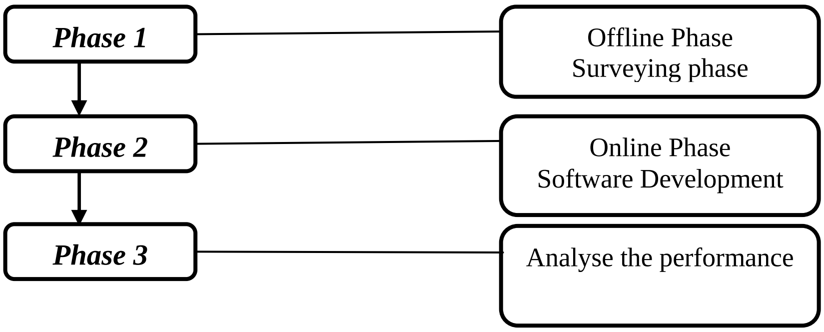
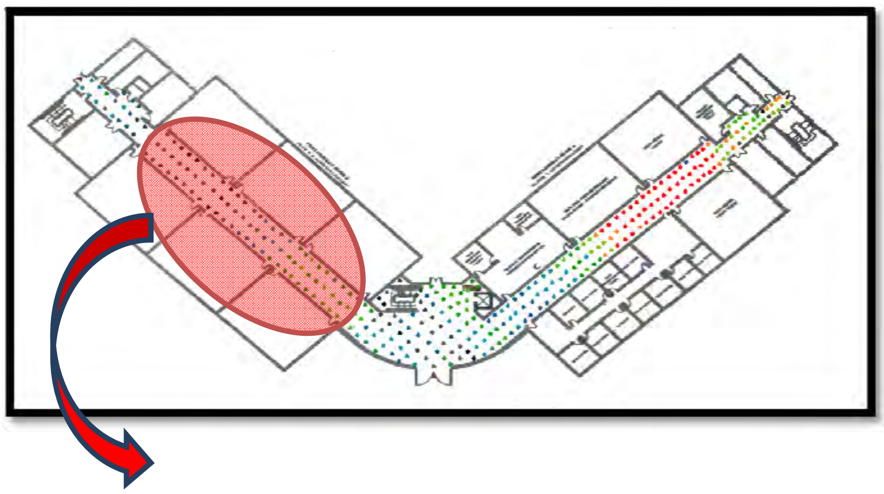


Fig.1. Phase development

I. Offline Phase

During this phase, a laptop with VisiWave Site Survey sorftware is used for surveying process or measurement the RSS on each location point. This software provides free trial version within 31 days of expiry date. It can be used without any limitation during that period if compared to other software available. The surveying process was done on Ground Floor Block B, FKEKK, UTeM as shown in Fig. 2. The area of study include the pedestrian in front of lecture rooms, where it is divided into 3 times 19 constant points based on the floor tiles structured. There are five Access Point (APs) located on the wall in each lecture rooms which are BK1, BK2, BK3, BK4, and BK5. At each point of measurement, a laptop computer receives different kind of RSS that oriented in four different positions: facing right and left of the *x*-axis and up and down on the *y*-axis. All the data is recorded in database and only the average measurement is counted for algorithm processing.



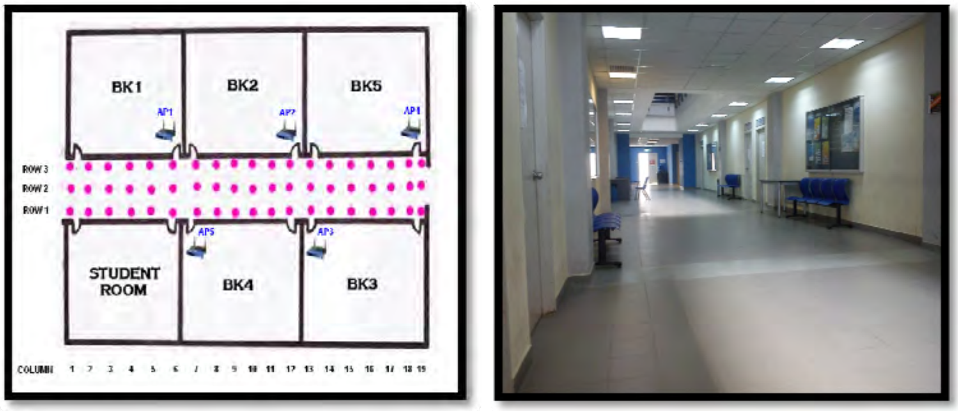


Fig. 2. Coverage area – Lecture classroom

The data collected was extracted in WordPad as shown in Fig. 3.

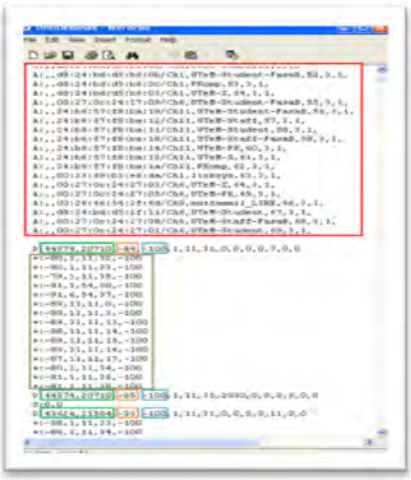


Fig. 3. Data extracted

From the data extracted, coordinates, element orientation, RSS, SSID and channel at each AP was obtained. There are multiple of SSID for each AP, even the same SSID could be found across all the APs. To differentiate different APs, the MAC Id is recorded into the database. All of these data then is calculated to get the average and was saved in excel file as database for comparison purpose. It will used to compare with the user target vector during online phase. Table I below shows the database of the surveying phase at each RL on the coverage area. There is 57 points at all with five numbers of APs. It is then reshaped in matrix form with 3 rows and 19 columns.

TABLE I
Received Signal Strength database in dBm

Reference Location (RL)	**AP1 (dBm)**	**AP2 (dBm)**	**AP3 (dBm)**	**AP4 (dBm)**	**AP5 (dBm)**
1	-75	-82	-84	-87	-71
2	-78	-80	-82	-85	-72
3	-79	-79	-79	-85	-70
4	-73	-78	-79	-81	-69
5	-73	-78	-79	-80	-65
57	-73	-83	-73	-66	-66

TABLE II
Received Signal Strength in matrix form

Reference Location	Matrix Form (y,x)
1-19	(1,1), (1,2), (1,3), (1,4), (1,5), (1,6), (1,7), (1,8) (1,9), (1,10), (1,11), (1,12), (1,13) (1,14) (1,15) (1,16) (1,17) (1,18) (1,19)
20-38	(2,1), (2,2), (2,3), (2,4), (2,5), (2,6), (2,7), (2,8) (2,9), (2,10), (2,11), (2,12), (2,13) (2,14) (2,15) (2,16) (2,17) (2,18) (2,19)
39-57	(3,1), (3,2), (3,3), (3,4), (3,5), (3,6), (3,7), (3,8) (3,9), (3,10), (3,11), (3,12), (3,13) (3,14) (3,15) (3,16) (3,17) (3,18) (3,19)

The database vector entry can be obtained by:

$$V_n = [\ x^n\ ,\ y^n\ ,\ p^n\ ,\ s_1^n\ ,\ s_2^n\ \ldots\ s_5^n]^T \qquad (1)$$

where, n is the index of reference point, x^n and y^n are element coordinates, p^n is element orientation and s_1^n , s_2^n and s_3^n are RSS at APs. Superscript T, for transpose, makes the expression equivalent to a column vector. Then, An estimate location can be determined by using Euclidean distance algorithm:

$$D_n=|S - S^n| = \sqrt{\sum_{i=1}^{3}(S_{i}n - S_i)2} \qquad (2)$$

$$S = [\ s_1\ ,\ s_2\ ,\ s_3 \ldots\ s_5\ ]^T \qquad (3)$$

where, D_n is distance target, S is online RSS vector and *i* is an index of the AP.

II. Online Phase

The data obtained is used to determine the vectors of each point on the surveyed map. L Nearest Neighbor is uses for database comparison. MATLAB GUI then is used as user interface that allows interaction between user and electronic devices. It’s going to shows and plots an actual location and estimate location of user during simulation process. An analysis based on numbers of AP and traffic condition is measure to determine the accuracy. Fig. 4 illustrated the flow chart of distance program.

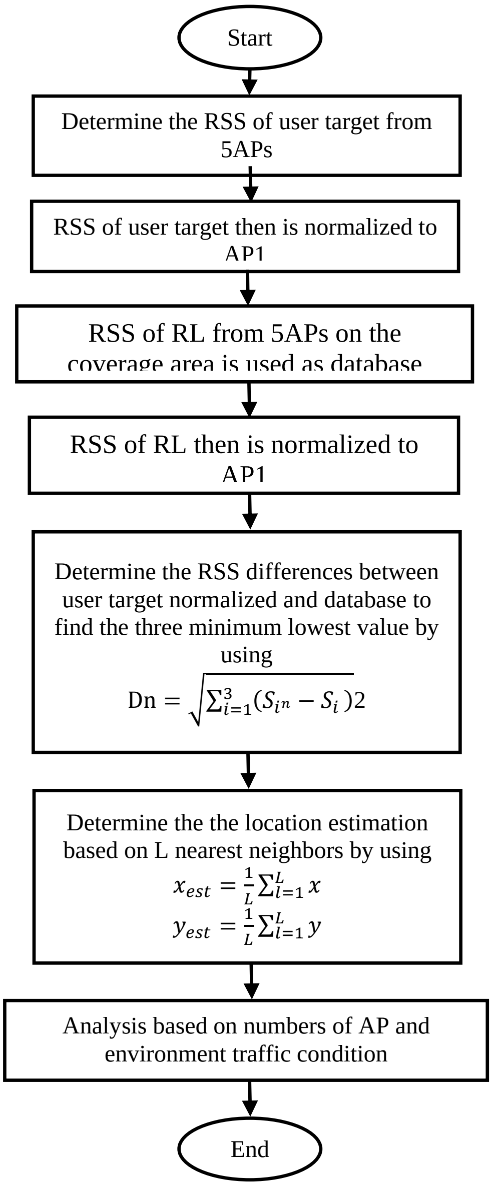


Fig. 4 Flow chart of Location Estimation

III. RESULTS AND DISCUSSION

I. Location Estimation

The first location of the target user is recorded at x = 21.6m and y=2.4m. The RSS of target user from all APs can be used to determine the location estimation:

User_target = (AP1 AP2 AP3 AP4 AP5) dBm

= (-65 -60 -60 -64 -73) dBm

It then normalized to AP1:

User_target_normalized = (0 5 5 1 -8) dBm

Table IV show the RSS normalized values in RL on the coverage area, while Table V show the Euclidean distance (D) between user normalized and database value which can be obtain by using:

$$D^2 = (AP1\ target\ normalized - AP1\ normalized)^2 + (AP2\ target\ normalized - AP2\ normalized)^2 + (AP3\ target\ normalized - AP3\ normalized)^2 + \cdots (APn\ target\ normalized - APn\ normalized)^2$$

Table IV
Received Signal Strength Normalized at Access Point 1

Reference Location	**x , y**	**AP1**	**AP2**	**AP3**	**AP4**	**AP5**
1	1 , 1	0	-7	-9	-12	4
2	2 , 1	0	-2	-4	-7	6
3	3 , 1	0	0	0	-6	9
4	4 , 1	0	-5	-6	-8	4
5	5 , 1	0	-5	-6	-7	8
57	19 , 3	0	10	17	17	2

Table V
Received Signal Strength Differences between User Normalized and database values

RL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Distance	25	20	20	21	23	26	38	25	19	15	20	6	21	23	11
RL	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Distance	10	8	18	14	29	19	22	22	26	28	43	24	18	21	16
RL	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Distance	9	21	29	27	15	17	13	21	30	28	26	26	25	28	30
RL	46	47	48	49	50	51	52	53	54	55	56	57			
Distance	26	20	22	13	13	15	22	21	15	18	22	23			

The three lowest values then are extracted to obtain its matrix form for location estimation. The lowest values are 6, 8 and 9 at RL 12, 17, and 31 with matrix of (1, 12), (1, 17) and (2, 12). These matrix forms of x and y can be used to determine the location estimation of user by using L nearest neighbours algorithm:

$$x_{est} = \frac{1}{3}\sum_{l=1}^{3} (12 + 17 + 12) \quad (4)$$

$$= 13.6667$$

$$y_{est} = \frac{1}{3}\sum_{l=1}^{3}(1 + 1 + 2) \quad (5)$$

$$= 1.3333$$

$$x = x_{est}*1.6m \quad (6)$$

$$y = y_{est}*1.5m \quad (7)$$

The result of estimation in x and y axis then need to times with the scale used in actual measurement. The location estimation based on fingerprint technique gives (21.87m, 2m) which just slightly different from actual target location (21.6m, 2.4m). The distance error is 0.74m which is just acceptable.

A location estimation program has been developed to test the accuracy of the algorithm chosen. The program was developed on MATLAB environment and Figure 5 below shows the MATLAB GUI. The user needs to enter the actual location of the target user and measurement of RSS of that specific location. A single click on location estimation button, it will pop new window and display the output result of actual and estimate location as shown in Figure 7.

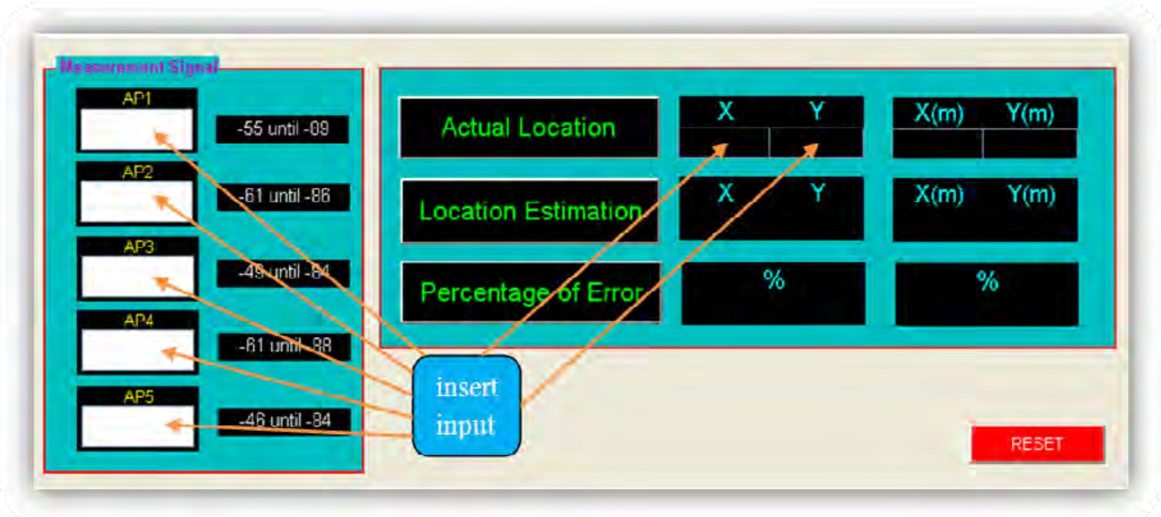


Fig. 5. MATLAB GUI

Fig. 6 and Table VI, shows 3 sample different actual target user location with blue, yellow and green colour taken for more analysis.

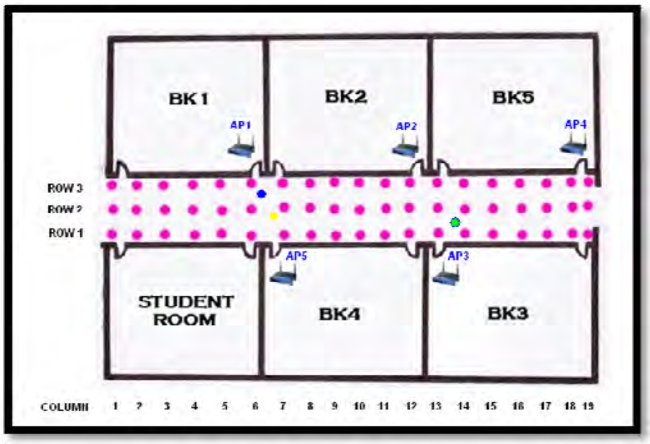


Fig.6. Actual location based three different sample points.

Table VI
Received Signal Strength at three different sample location

Sample location	**Actual location**	**AP1**	**AP2**	**AP3**	**AP4**	**AP5**
Blue	(6.3,2.5)	-61dBm	-68dBm	-68dBm	-78dBm	-57dBm
Yellow	(6.8,1.8)	-68dBm	-70dBm	-77dBm	-72dBm	-49dBm
Green	(13.5,1.6)	-65dBm	-60dBm	-60dBm	-64dBm	-73dBm

Comparison between actual location and location estimation based on the MATLAB simulation is shown in map in Fig. 7. The result shows that estimate location only a bit drift from the actual location (*). Details comparison in figures is shown in Table VII.

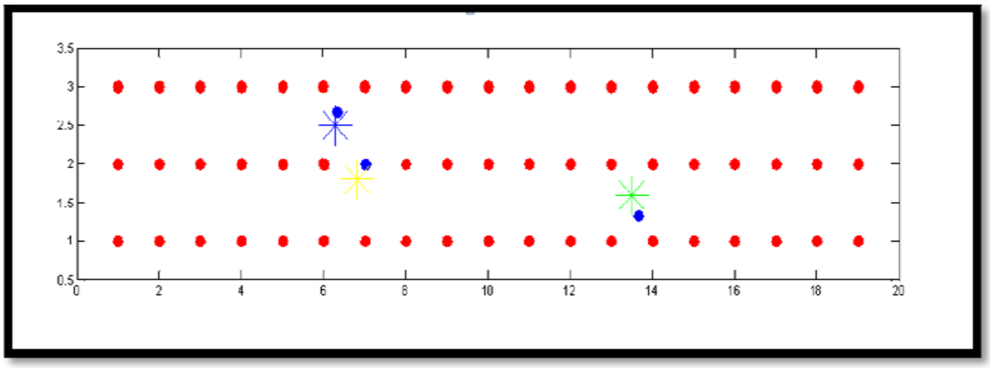


Fig.7. Location estimation of sample location taken

TABLE VII
Location estimation in real time

Sample location	Actual location in meter X	Actual location in meter Y	Location estimate in meter X	Location estimate in meter Y	Differences (m)	Location Error (m)
Blue	21.60	2.40	21.87	2.00	(0.43,0.60)	0.74
Yellow	10.08	3.75	10.13	4.00	(0.08,0.38)	0.39
Green	10.88	2.70	11.20	3.00	(0.51,0.45)	0.68

II. Comparison between Numbers of Access Point Counted

From the previous result, the algorithm is based on just three APs. Then, we increased the number of APs to 4 and 5 counted in simulation to investigate the accuracy of the location estimation. The results in Fig. 8 shows clearly when we increase the numbers of APs, it also give better location estimation accuracy for all three different location. All the distance error location give less than 1 meter for 5 RSS of each APs counted, while two of these results show less than 0.5m which are quite good.

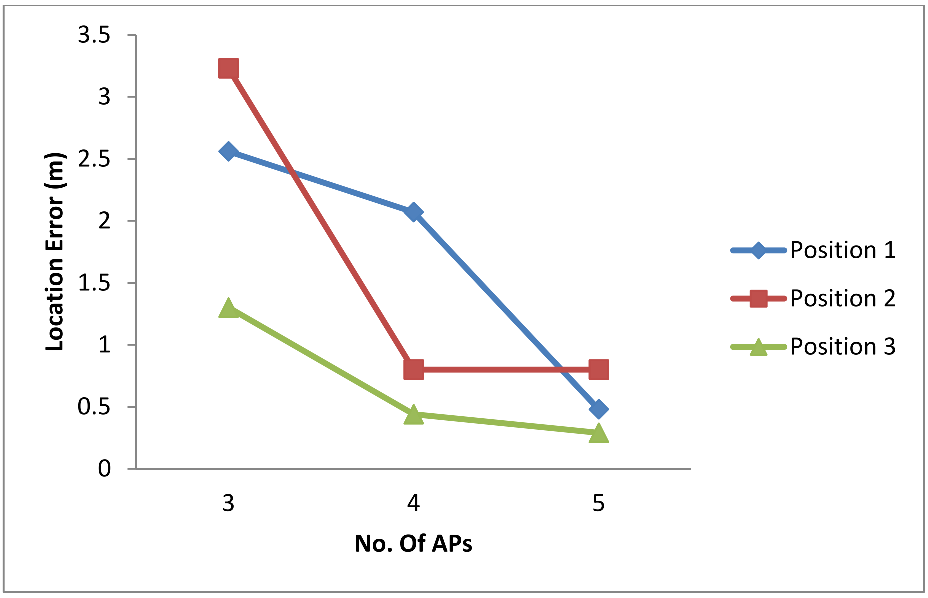


Fig 8. Location Error vs No. of APs

III. Comparison between Numbers of Access Point and Traffic Condition

Fig. 9 below show how the traffic condition affected in determining the location estimation of target user at x=13.5m and y=1.6m. There are three types of condition where the area in light, medium and heavy traffic with the pedestrian.

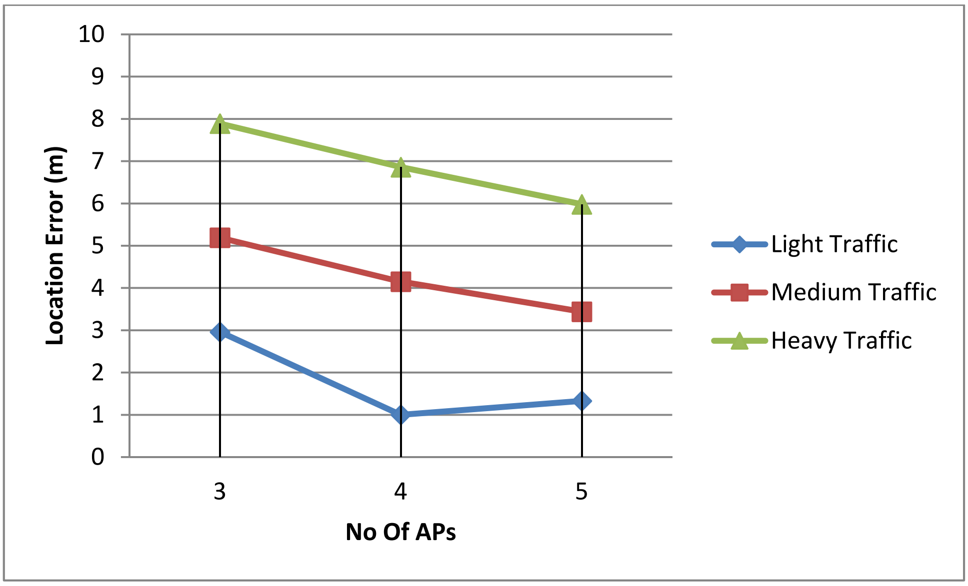


Fig 9. Location Error vs Traffic Condition

Based on the results show that the heavier of the area congested with the pedestrian, the location error will increase. For the same traffic condition show the same pattern throughout the numbers of APs counted except for light traffic condition slightly increase from 4 to 5 numbers of APs counted. This is due to wireless propagation effect to the obstacle such as diffraction, reflection and attenuation of the signals.

IV. CONCLUSION

Upon completion of this project, the development of a location and positioning simulation based on MATLAB software at FKEKK, UTeM is successfully done. The user needs to give several inputs such as actual location and RSS from numbers of APs at the current target location. This simulation software will estimate location and positioning of the target user and compared to the precise/actual location. The result shows that the margin of error between actual location and estimate location up to 0.74m. Several analysis has been done regarding Euclidean distance algorithm. The first analysis is based on the numbers of AP which up to five APs while the second analysis is based on the traffic condition at the Block B, FKEKK, UTeM. The results show that the more RSS of APs counted in algorithm will gives more accurate location estimation to the user target. The environment traffic condition will affect the estimate location. The more heavy traffic condition of the pedestrian area will give greater margin of error of the estimate location. Several of improvement can be included in this algorithm. One of the techniques is by applying data fusion technique with other wireless communication system such as cellular communication, or with GNSS [10][11].

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