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PEOPLE'S PPRESENCE EFFECT ON WLAN-BASED IPS' ACCURACY

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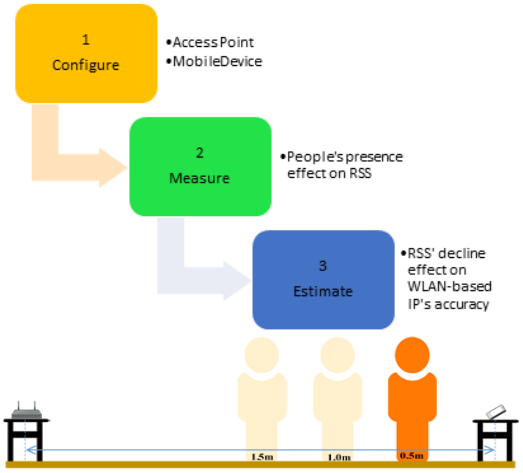
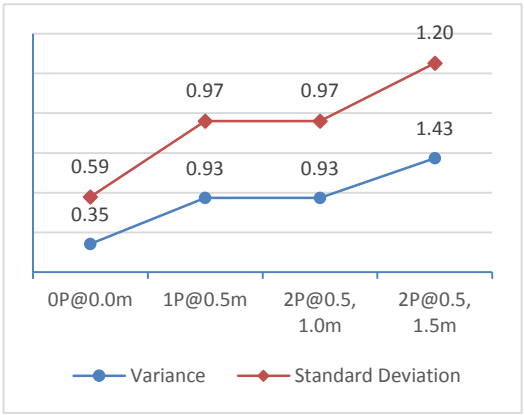
Graphical abstract





Abstract

In order to enable Location Based Service (LBS) closed environment, many technologies have been investigated to replace the Global Positioning System (GPS) in the localization process in indoor environments. WLAN is considered as the most suitable and powerful technology for Indoor Positioning System (IPS) due to its widespread coverage and low cost. Although WLAN Received Signal Strength Indicator (RSS) fingerprinting can be considered as the most accurate IPS method, this accuracy can be weakened due to WLAN RSS fluctuation. WLAN RSS fluctuates due to the multipath being influenced by obstacles presence. People presence under WLAN coverage can be considered as one of the main obstacles which can affect the WLAN-IPS accuracy. This research presents experimental results demonstrating that people's presence between access point (AP) and mobile device (MD) reduces the received signal strength by -2dBm to -5dBm. This reduction in RSS can lead to distance error greater than or equal to 2m. Hence, any accurate IPS must consider the presence of people in the indoor environment.

Keywords: People's presence, Signal attenuation, Indoor Positioning, WLAN Fingerprinting, Radio Map

Abstrak

Di dalam menyediakan Servis Berdasarkan Lokasi persekitaran tertutup, terdapat banyak teknologi yang telah dikaji untuk menggantikan Sistem Posisi Global dalam melokasikan proses persekitaran dalaman. WLAN telah dianggap sebagai teknologi yang paling sesuai dan berkeupayaan tinggi bagi Sistem Posisi Dalaman (IPS) disebabkan liputannya yang luas dan murah. Walaupun Penunjuk Penerima Kekuatan Isyarat (RSS) WLAN pencetakkan jari boleh digunakan sebagai kaedah yang paling tepat, ketepatan ini boleh dikurangkan disebabkan fluksuasi RSS WLAN. Fluksuasi ini disebabkan oleh banyak laluannya dipengaruhi oleh kehadiran halangan. Kehadiran orang ramai di dalam liputan WLAN boleh dikira sebagai salah satu daripada halangan utama yang memberi kesan kepada ketepatan WLAN-IPS. Kajian ini menunjukkan keputusan eksperimen bahawa kehadiran orang ramai di antara Pencapai Tunjuk (AP) dan Peralatan Komunikasi mengurangkan RSS dari -2dBm ke -5dBm. Pengurangan dalam RSS boleh menyebabkan jarak ralat melebihi atau bersamaan dengan 2m. Oleh itu, IPS yang tepat harus mengambilkira kehadiran orang ramai dalam persekitaran dalaman.

Kata kunci: Kehadiran orang ramai, pengecilan isyarat, Posisi dalaman, WLAN pencetakkan jari, Peta radio

1.0 INTRODUCTION

In recent days, there is a high demand for Location Based Services (LBS) to be applied in indoor environments as well as in outdoor environments. LBS can be defined as services that integrate the mobile user's location with other information in order to provide valuable information to the user [1]. LBS can be involved in several important systems in our daily life such as: Emergency services, healthcare, manufacturing, retailing, logistics and many other industries. Indoor positioning systems (IPS) gained in importance after the Global Positioning System (GPS) fails in determining a location accurately inside buildings due to the lack of line-of-sight (LOS) between the GPS receiver and the satellites. Hence, a lot of researches have been conducted to find other techniques to enable the LBS to provide its services in the indoor environment. Although Wireless Local Area Network (WLAN) technology is a valuable technology to be used for IPS due to its low cost and simple configuration, achieving high accuracy still needs more investigation because the WLAN has two main weaknesses. These weaknesses are multipath influenced by presence of obstacles and signal strength fluctuation during the day time [2, 3]. These obstacles can be wall, ceilings and/or people [3, 4]. The walls and ceilings have been investigated deeply in [5-9].

This research presents experimental results to show that people's presence under the coverage of WLAN will cause a decline in the received signal strength (RSS), hence the positioning accuracy will be reduced also. The experimental results show that the presence of one person in the WALN coverage will decline the RSS by -2dBm to -5dBm, and this will lead to less accuracy and more distance error.

1.1 Positioning Background

In 1973 the GPS has been developed for military use, then it has been allowed freely for civilian use but with a degraded performance [10]. The widespread usage of the GPS shows LBS as a significant part of the people's daily life [11]. LBS can be defined as services that integrate the mobile user's location with other information in order to provide valuable information to the user [1]. These services vary according to the characteristics of the targeted domain such as: Military to track/determine target location, Civil defence to determine the appeal location, marketing to helping possible customers, Healthcare to find the current location of a doctor for emergency cases; and Management to follow up the employees or object locations. Since LOS between the GPS satellite and the GPS receiver could not be achieved in the indoor environment, a need for alternative technology has been raised. Many technologies have been proposed for IPS such as: Radio Frequency Identification (RFID), Infrared Radiation (IR), Ultra Wide Band (UWB), Wireless LAN (WLAN), Ultrasound, and Bluetooth [3, 4, 11-13]. WLAN has been introduced as the most valuable technology for IPS (due to its low cost, simple configuration, and widespread technology). Although WLAN RSS fingerprinting is the most accurate positioning method achieving high accuracy, it still needs more investigation because the WLAN has two main weaknesses: multipath influenced by obstacles presence (Walls, furniture, people presence), and signal strength fluctuation during the day time [2, 3].

2.0 RELATED WORK

A lot of researches such as [4, 13-22] list the presence of people in the indoor contributes significantly to signal attenuation, but unfortunately it is hard to find researches investigating the actual attenuation factors.

Microsoft' researchers introduced the first WLAN-based IPS "RADAR" [22]. The researchers noticed that RSS in any location varied based on the orientation of the person calibrating, with respect to the access point. In order to overcome this problem, they built four oriented RM (0o, 90o, 180o, and 270o), as a result of this action accuracy enhanced by more 70%. Unfortunately the proposed solution, four orientations RM, increasing the calibration effort four times and it is not applicable for dynamic environments.

Ben Hamida and Chelius [23] provided an experimental approach which investigated the impact of the human activity on the performance of the indoor WLAN in order to the answer question "Is RSS a robust indicator for the WLAN link quality?". They observed the relation between presence of periodic fluctuations in RSS and the presence of people activity within WLAN coverage. It showed that during the day time the people activity has a significant impact on the WLAN performance in line-of- sight (LOS) and none line-of- sight (NLOS) paths. This observation depends on the value of the standard deviation values of the collected RSS which are 10 and 1 for the period 8:00 am to 6:00 pm and for 6:00 pm to 8:00 am respectively. Unfortunately, the researchers did not mention about the number of people in the environment during the day time.

Karadimas *et al*. [24] statistically proved that the signal strength can vary over the time based on the human activity in the short-range wireless network, 60GHz. The experimental results showed that there is a Gaussian distribution of the effect of the human body when it obstructed the LOS path. In addition to that, it showed that the effect can be increased by the number of people. Although this research has a valuable indication about the effect of the people presence or activity, but from another point of view it only considered only the case in which the human body obstructed the LOS and it did not provide any indication about RSS reduction, in dBm, as effect of single human body.

Turner *et al*. [25] studied the human movement in 2.4GHz Wireless Sensor Network (WSN). They proved experimentally that there is significant impact of the number of people and their movement speed on the WSN signal strength. More specifically, they found that the RSS can decline 6 dBm and 3 dBm for one person movement in slow speed and fast speed respectively, and these values are doubled when the number of people movement increases. Here, the main focus is on the LOS obstruction and the effect of moving people. The work appears limited as in the dynamic indoor environment such as banks, people presence in different states needs to be considered also.

Fet *et al*. [26] mentioned that the manual building of RM required orientation-dependent RSS calibration to overcome the signal attenuation by the human body. This orientation-dependent calibrating needs four times effort. The researchers showed that WLAN signal distribution with distance takes ellipse shape due to people presence. Then based on the ellipse properties and some empirical measurement they proposed RSS distribution model to generate multiple orientations RM depending on the 0o direction – access point facing – calibration. The proposed model reduced the calibrating effort by 75% and the analytical correlation between the generated RM and calibrated one is greater than 0.9. In order to measure the effects of the generated RM on IPS performance, KNN algorithm has been used and the result showed a small decline in the accuracy less than 7% depending on the multi orientations RM. This work has multi defects; firstly, the authors mentioned that the difference of RSS values between the facing AP and the AP facing the opposite direction is -38dBm, this value is too large in comparison with the measurement from [23, 25] and this research results will be shown in the next sections; secondly, using multi orientations RM means extra computational cost for the whole IPS. Thirdly, the 0o direction RM calibration performed manually which is not suitable for the dynamic environments. Finally, all the previous related works either tried to involve people presence to enhance the IPS accuracy by creating multi-direction RM (as sign for the huge effect of people presence) or tried to measure the effects of the presence of people using WSN not the usual WLAN. In this research, we present experimental preliminary results to show that people presence under the coverage of WALN affects the RSS, hence the IPS accuracy will decline.

3.0 EXPERIMENTAL RESULT AND DISCUSSION

In order to find out the effect of people's presence, in the LOS between AP and MD, on WLAN-based IPS' accuracy, four different experiments have been conducted. These experiments have been conducted in the 3rd Level of Menara Razak in the Universiti Teknologi Malaysia (UTM) Kuala Lumpur, as shown in Figure 1, mainly in the Graduate Assistant Room (RO3) and the Western Corridor (WCO). Each of these experiments has different scenarios, and each scenario reflects a real state of people's presence under the coverage area of WLAN. Only two devices are used in these experiments; the first one is the transmitter (AP) which is a dual band CISCO WAP4410N Wireless-N Access Point. This access point has been configured to generate four beacons in each second;

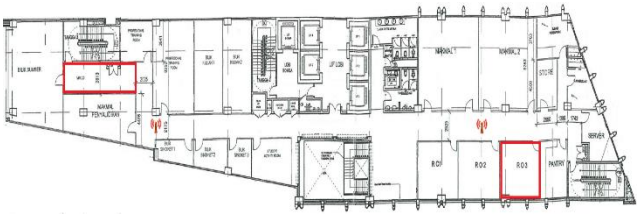


Figure 1 Menara Razak Level 3 Layout

The second device is the mobile device (MD), which is ASUS Zenfone4. This mobile phone has Android 4.4.2 "KitKat" OS and it is equipped with WiFiscanner, home-developed application [27], in order to collect the wireless beacons and to extract the RSS from the collected beacons. Around 1200 beacons have been collected over five minutes in each scenario in order to have all the possible RSS variation due to people's presence. Then, after collecting the desired RSS data, two data pre-processing steps have been performed to get valid and consistent dataset. Firstly, in each scenario the first 10 seconds readings have been deleted to get more stable readings. Secondly, all the possible duplicated beacons have been deleted to get consistent/unbiased readings. Finally, since this paper aims to show/measure the effect of people's presence on WLAN-based IPS' accuracy, all the statistical analysis has been be directed to show the relation between people's presence and RSS. Centroid values, such as Mean; Median; and Mod, and distribution values, Variance; Standard Deviation; and Range, has been extracted in each scenario as in all the previous experiments.

3.1 The First Experiment

The first experiment has been conducted in 5m x 5m Graduate Assistant Room in order to measure the effect of the presence of one person on RSS. AP and MD are fixed on 0.75m height portable cabinets and 3m distance. Then, beacons have been collected in five different scenarios, described in Table 1 and graphical notation for the experimental design is shown in Figure 2.

Table 1 The 1st and 2nd Experiments' Scenarios Descriptions

No	Scenario Label	Scenario Description
1	0P@0.0m	no people in the room
2	1P@0.0m	1 person on 0.0m from MD
3	1P@0.5m	1 person on 0.5m from MD
4	1P@1.0m	1 person on 1.0m from MD
5	1P@1.5m	1 person on 1.5m from MD

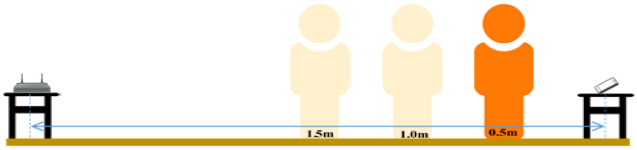


Figure 2 Graphical notation for the experimental design

Figure 3 shows the RSS's centroid values for all scenarios as previously described Table 1, and it easily deduces the negative effect of people presence on the received signal strength.

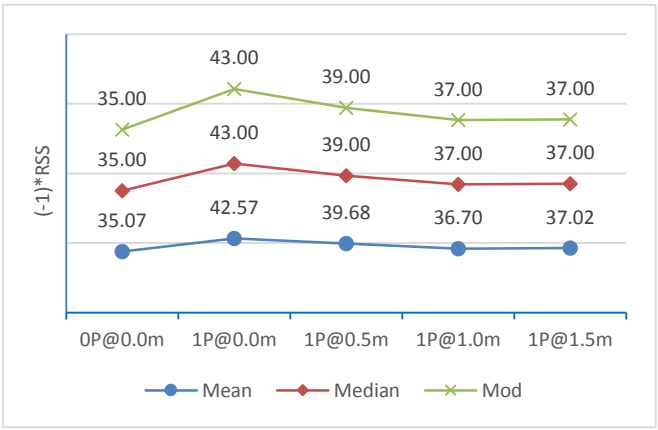


Figure 3 Centroid Values due to 1 Person Presence

This effect reaches its peak when the person is very close to the MD, and that effect declined gradually when the person is further away from the MD. On the other hand, to compare the RSS's distribution value on the previous scenarios the distribution's measures, Variance and Standard Deviation, as shown in Table 2. The distribution values show that the received RSS's distribution is the highest when the person is very close to the MD, and vice versa. This phenomenon, which is shown in Figure 3 and Table 2, occurs when the person is very close to the MD he/she will impede the LOS and most of the NLOS multipath except those reflected from the opposite side behind the MD. On the other hand, the MD has an opportunity to receive from the NLOS multipath as the distance between the person and the MD is increased.

3.2 The Second Experiment

The second experiment has been conducted in the western corridor, 2.8m x 8m, and the scenarios of the previous experiment, described in Table 1, have been applied here except the distance between AP and MD which is set to be 4m. Figure 4 and Table 3 show the distribution and centroid RSS's values of the second experiment respectively.

Table 2 Distribution Values due to 1 person Presence

Measure/ Scenario	0P@ 0.0m	1P@ 0.0m	1P@ 0.5m	1P@ 1.0m	1P@ 1.5m
Variance	0.43	0.36	0.78	0.49	0.26
Standard Deviation	0.65	0.99	0.74	0.70	0.51

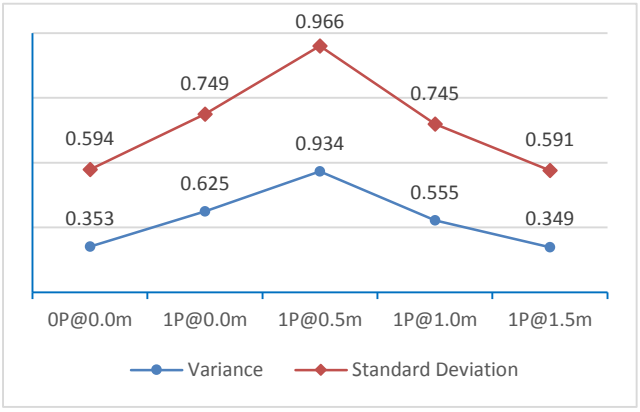


Figure 4 Distribution values due to 1 Person Presence in WCO

The result of the second experiment comes to support the first experiment's result but with a little variation in the value due to the corridor width. Here, there is the same increment in distribution value due to people's presence.

Table 3 Centroid Values due to 1 Person Presence in WCO

Measure/ Scenario	0P@ 0.0m	1P@ 0.0m	1P@ 0.5m	1P@ 1.0m	1P@ 1.5m
Mean	-40.02	-45.02	-43.08	-39.9	-42.2
Median	-40	-45.00	-43	-40	-42
Mod	-40	-45.00	-43	-40	-42

3.3 The Third Experiment

The third experiment has been conducted in the western corridor, 2.8m x 8m, and the setting of the previous experiment have been applied here except in this experiment two persons have been involved. Table 4 describes the scenarios in which the beacons will be collected. The result of the experiment reflects the effect of two persons' presence on the RSS's centroid and distribution RSS values and these results are summarized in Table 5 and Figure 5 respectively.

Table 4 Two Persons Presence Scenarios

No	Scenario Label	Scenario Description
1	0P@0.0m	No one in the Corridor
2	1P@0.5m	1 person on 0.5m from MD
3	2P@0.5m,1.0m	2 persons, on 0.5m and 1.0m from MD
4	2P@0.5m,1.5m	2 persons, on 0.5m and 1.5m from MD

Table 5 shows there is very small variation in the RSS's centroid values. This small change occurs due to the short distance on the corridor and the distance between the persons themselves and the distance between MD give an opportunity to the multipath to strengthen the signal.

Table 5 Centroid Values due to 2 Persons Presence in WCO

Measure/ Scenario	0P@ 0.0m	1P@ 0.5m	2P@ 0.5m, 1.0m	2P@ 0.5m, 1.5m
Mean	-40.02	-43.08	-40.17	-40.83
Median	-40.00	-43.00	-40.00	-41.00
Median	-40.00	-43.00	-40.00	-41.00

On the other hand, Figure 5 shows a gradual rise in the distribution values with the increase in the number of people's presence and their distances. This means there is a strong effect of people's presence under the wireless coverage even though the RSS strength shows a little bit of variation.

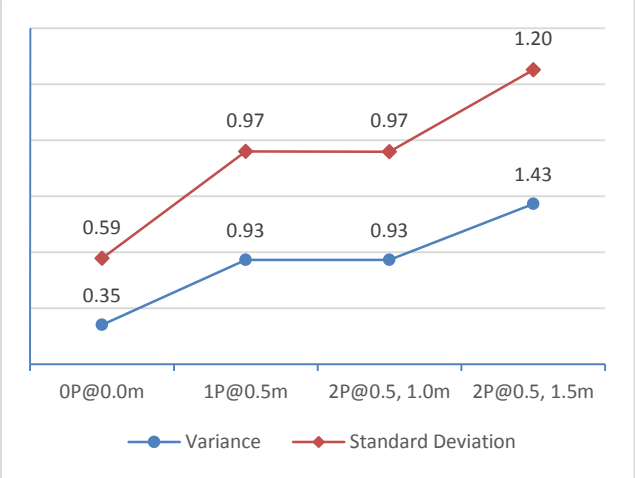


Figure 5 Distribution Values due to 2 Persons Presence in WCO

3.4 The Fourth Experiment:

Finally, in order to show people's presence effect on WLAN-based IPS's accuracy, a simple radio map for 27 different points in three neighboured rooms has been built (as shown as the bold number in Figure 6. Each cell in this radio map has been represented by the mean value of the collected RSS. The previous experiment results proved that people's presence in the LOS of WLAN has an effect on the RSS.

This effect declines RSS 2dBm to 5dBm for each person according to the separation distance between the person and the MD. Hence, in order to show the effect of the RSS decline on the IPS's accuracy, the radio map has been built for three neighbouring rooms as shown Figure 6. Table 6 shows the average RSS's values for nine points in the ASL1 room in, which is the middle room (RO2) in Figure 1. The differences between the average values in Table 6 shows that RSS's decline, due to people's presence and ranges between -2dBm and -5dBm, leads to false positioning with distance error value exceeded 2m. Hence, IPS must take into account people's presence effect in order to achieve high level of localization accuracy with minimum distance error.

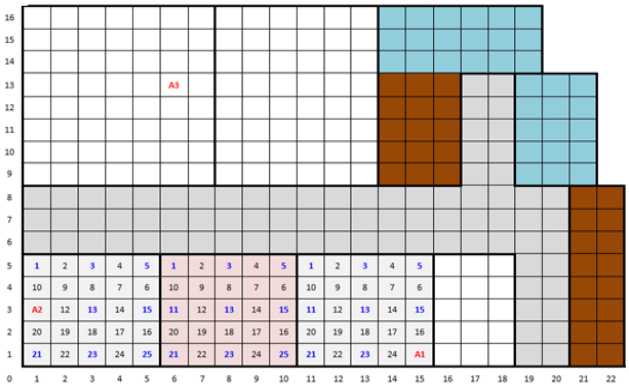


Figure 6 Radio Map Points in the Site Layout

Table 6 Radio Map for ASL1 Room Averaged Values

Point No	RSS1	RSS2	RSS3
1	-54	-52	-68
3	-56	-50	-56
5	-52	-56	-68
11	-53	-52	-62
13	-50	-53	-63
15	-48	-53	-58
21	-57	-51	-58
23	-53	-50	-57
25	-50	-53	-62

4.0 CONCLUSION

Many technologies have been proposed to be used in IPS in order to activate the LBS in indoor environments. WLAN occurs as the most suitable technology for IPS due to its widespread and low cost. WLAN RSS fingerprinting can be considered as the most accurate IPS method, but RSS fluctuates due to multipath being influenced by obstacles presence. People's presence in LOS between AP and MD can be considered as one of the main obstacles presence which can affect the WLAN-IPS's accuracy. This research presented experimental results to show that people's presence in LOS between AP and MD

decreased the RSS by -2dBm to -5dBm. This RSS's decline can lead to big distance error more than 2m. Hence, any accurate IPS must consider the presence of people in an indoor environment.

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