The Effect of People Presence on WLAN RSS is Governed by Influence Distance

Iyad H Alshami
Advanced Informatics School (AIS), Universiti Teknolgi Malaysia UTM
54100 Kuala Lumpur, Malaysia
hmaeyad2@live.utm.my

Noor Azurati Ahmad
Advanced Informatics School (AIS), Universiti Teknolgi Malaysia UTM
54100 Kuala Lumpur, Malaysia
azurati@utm.my

Shamsul Sahibuddin
Advanced Informatics School (AIS), Universiti Teknolgi Malaysia UTM
54100 Kuala Lumpur, Malaysia
shamsul@utm.my

Yusnaidi Md Yusof
Advanced Informatics School (AIS), Universiti Teknolgi Malaysia UTM
54100 Kuala Lumpur, Malaysia
yusnaidi.kl@utm.my

***Abstract*— Recently, there is high demand for implementing Location Based Services (LBS) indoor. Many technologies and methods have been investigated for this issue since GPS could not prove accurate positioning indoor. Although WLAN-fingerprinting is considered as one of the most accurate IPS method, its accuracy vulnerable to WLAN RSS fluctuation. This fluctuation occurs due to the physical obstacles presence. Many research papers highlighted people's presence near to mobile device (MD) between it and Access point (AP) as RSS attenuate factor, but it is hard to find a research paper investigated this attenuation factor as in the case of walls and ceilings. People presence effect was estimated in previous work as -5dBm on closed distance from MD but it still need a lot of investigation. This paper raises the existence of people presence influence distance as a new concept related to people presence effect. In addition to this, it provides experimental work in order to prove the truth of this claim. The obtained results proved the truth of this claim and the existence of the influence distance became a fact.**

Keywords—People Presence Effect; Influence Distance; Indoor Positioning; WLAN Fingerprinting.

I. INTRODUCTION

Recently, there is a high demand for implementing Location Based Services (LBS) indoor as well as outdoor. LBS is defined as the integration of the mobile user's location and other information to provide better service to that mobile 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 LBS could not be implemented base on the Global Positioning System (GPS) due to the lack of line-of-sight (LOS) between the GPS receiver and the satellites. Hence, many researches were conducted to find other technique 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 indoor positioning systems (IPS) due to its low cost and simple configuration, achieving high accuracy still needs more attention because WLAN has two main weaknesses. These weaknesses are multipath influenced by presence of obstacles and the received signal strength (RSS) fluctuation [2, 3]. These obstacles can be wall, ceilings and/or people [3, 4]. The walls and ceilings have been investigated deeply in [5-9]. In previous work [10, 11], the experimental result showed that the presence of one person in LOS between MD and APs declined RSS by -5dBm which means that IPS accuracy declined too.

This research paper presents experimental work for new concept related to people presence effect. This concept named Influence distance, which can be defined as the distance in which people presence can obstacle the line-of-sight between access point and mobile device. The experimental work proves the new concept by showing that people presence will not affect RSS after certain distance, which is the influence distance.

The rest of this paper organized as follow: Section II provides fundamental knowledge about indoor positioning, Section III discusses the related work, Section IV explains the research method of tis research paper, Section V presents and discusses the obtained results and the last section draws the conclusion and the future work.

II. INDOOR POSITIONING

GPS was developed for military use in 1973, then it was allowed freely with degraded performance for civilian use [12]. GPS has shown the significance of LBS in people daily life [13]. LBS are defined as the integration of the mobile user's location and other information to provide better service to that mobile user [1]. LBS have been used in several areas and critical systems such as: military, emergency, healthcare, retailing, manufacturing, marketing, logistics and many other industries. For example, LBS are used in military for tracking or locating targets. LBS can be also used to notify emergency services of the locations of people in danger or in need for aid operations. Despite its great affordances, GPS service fails to accurately identify indoor locations due to the lack of LOS between GPS receiver and the satellites. This limitation has pushed many researches to explore other techniques and methods to enable LBS in such closed environments. 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, 13-15]. WLAN has been shown as the most valued technology for IPS due to its low cost, simple configuration, and widespread. Although WLAN RSS fingerprinting is the most accurate positioning method, achieving high accuracy still needs more investigation due to WLAN weaknesses: multipath influenced by obstacles presence, such as Walls; furniture; people presence, and RSS fluctuation during the day time [2, 3].

III. RELATED WORK

Many researches such as [4, 15-24] listed the people presence in LOS between AP and MD as signal attenuation factor, but it is hardly to find research investigated this attenuation factor or consider this factor in order to have accurate IPS.

Bahl, P. and V.N. Padmanabhan [24], in 2000, noticed that RSS in any measuring point varied as the orientation of the person calibrating it with respect to AP changed. To address this, the researches proposed to use four orientations RM (0o, 90o, 180o, and 270o). As a consequence of this action, the positioning accuracy enhanced by more 70%. Unfortunately, the proposed solution –using four orientations RM- increases the calibration effort and time four times and it is not applicable for the dynamic environments.

Hamida, E. and Chelius, G. [25], in 2010, investigated the impact of the human activity on WLAN performance in order to answer question "Is RSS a robust indicator for the WLAN link quality?" the authors observed that there are a relation between periodic fluctuations of RSS and the presence of people activity under WLAN coverage. That means during the day time people activity affected WLAN performance significantly in LOS and none LOS (NLOS) paths. This observation depended on the change of the standard deviation values of the calibrated RSS which were 10 and 1 for 8:00 am to 6:00 pm and for 6:00 pm to 8:00 am respectively. Unfortunately, the researchers did not mention any thing about the number of people in the environment during the day time and they did not mention who this can affect the IPS positioning accuracy.

Karadimas, P. et al. in [26], in 2013, showed that RSS fluctuate over the time due to human activity under short-range wireless network (60GH) based on Gaussian distribution analysis. The experimental results exposed that RSS fluctuated when it human body obstructed the LOS path. Furthermore, it showed that 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, from different point of view it considered only the LOS obstruction case and it did not expose the effect of people presence in NLOS case. In addition, this research did not provide any measurement of RSS, in dBm, as effect of people presence.

Turner, J.S.C., et al. [27], in 2013, studied the human movement under 2.4GHz Wireless Sensor Network (WSN) coverage. They showed that there is significant impact of the number of people and their movement speed on the WSN RSS. Moreover, they found that the RSS can be declined -6dBm and -3dBm for one person moved in slow speed and fast speed respectively and these values were doubled when the number of movement people increased. However, the researchers considered the LOS obstruction and the the moving people effect while in the indoor environments there are many cases of people presence must be considered especially in NLOS.

Fet, N. et al. [28], in 2013, stated that the manual RM creation required orientation-dependent RSS calibrating to address the signal attenuation caused by the human body as in [24], but this kind of calibration requires effort four times larger than the normal calibration effort. In addition, the researchers showed that WLAN signal distribution with distance takes ellipse shape due to people presence. Then they proposed RSS distribution model to generate multiple orientations RM depending on manual calibrating of RSS in the 0o direction which facing the targeted AP. As a result, the proposed model reduced the calibrating effort by 75% and high correlation (>0.9) between the generated RM and calibrated RM was occurred. The evaluation of the generated RM effect on IPS performance showed a small reduction in the obtained accuracy less than 7%. However, based on different point of view this work has multi defects: 1) The authors mentioned that the difference between RSS in facing AP and RSS in facing the opposite direction is -38dBm, this value is too large in comparison with the measurement from [25, 27]. 2) Using multi orientations RM means the whole IPS has high complexity. 3) The manual calibration of 0o direction RM is not suitable for the dynamic environments.

Finally, all the previous related works tried to address the effect of people presence on RSS creating multi-direction RM but none of them try to find calibration free solution for this problem. This research paper presents experimental work to prove the concept of the influence distance control the people presence effect on the calibrated RSS. Hence, based on this distance and RSS measurements the problem of people presence effect on the IPS accuracy can be addressed.

IV. RESEARCH METHOD

In order to proof the concept of the influence distance, real RSS will be calibrated in different scenarios. But before identifying these scenarios, let us clarify the concept of influence distance first then present the scenarios.

A. Influence Distance

According to WLAN experts, such as CISCO, it is recommended to mount the access points as high as possible since obstructions tend to located closer to floor level [29, 30]. Based on this, LOS between AP and MD can be represented by hypotenuse (C) line in Fig. 1. Where aph is AP height from the horizontal line with MD, d is base distance between AP and MD in horizontal line, C is hypotenuse C " LOS length between AP & MD", α is Alpha Angle, ph is person height 1.5-1.7m, mdh is mobile device height and d' is person height influence distance. Based on the triangle geometry, the influence distance d' can be formulated as

$$d' = \frac{ph - mdh}{tan(\alpha)} \quad (1)$$

$$\tan(\alpha) = \frac{h - mdh}{d} \quad (2)$$

Then the influence distance d' will be

$$d' = \frac{d(ph - mdh)}{(h - mdh)} \quad (3)$$

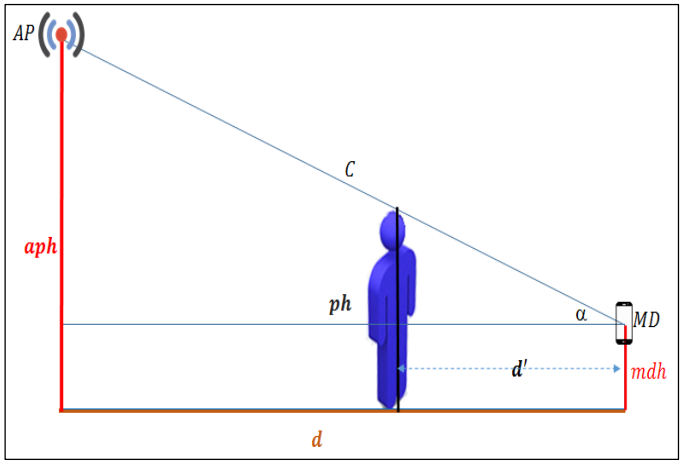

Fig. 1. Triangle Geometry Defining Influence Distance

B. *RSS calibration Scenarios*

In this work, measuring the effect of only one person on RSS is targeted to proof the concept of the influence distance. In addition to this, the same MD –SAMSUNG GALAXY T231- will be used to calibrate RSS on the same AP –CISCO WAP4410n- three different scenarios reflect all the possible scenarios of people presence indoor. The first scenario represents LOS and the other two represent Distance Virtual LOS (VLOS) where wall will be exist in the first VLOS scenario and ceiling will be exist in the second VLOS scenario. RSS will be calibrated for 250 times in five different cases, as it described in Table 1, and each case will represented by the median value of RSS to overcome any RSS outlier occurrence for any unexpected error. In addition to this, RSS will be calibrated first as in np case and it will be considered as the control case to show the real effect of people presence in each of the other cases with margin greater than $\pm 1 dBm$.

TABLE I. EXPERIMENTAL WORK SCENARIOS DESCRIPTION

Scenarios Codes	Case Code	Description
P_LOS P_VLOS1 P_VLOS2	np	Measuring RSS without people presence in LOS
	1p_0m	Measuring RSS with 1person presence on 0m of distance from MD in LOS
	1p_1m	Measuring RSS with 1person presence on 1m of distance from MD in LOS
	1p_2m	Measuring RSS with 1person presence on 2m of distance from MD in LOS
	1p_3m	Measuring RSS with 1person presence on 3m of distance from MD in LOS
	1p_4m	Measuring RSS with 1person presence on 4m of distance from MD in LOS

V. Results and Discussion

In this section, people presence in LOS scenario are presented first then the other two VLOS scenarios.

A. *People Presence Effect in LOS (P_LOS)*

RSS in P_LOS scenario, as shown in Fig. 2, was calibrated with the following facts: AP height is 3.5m; MD height is 0.8m; the horizental distance between AP and MD is 8.8m. Hence, the computer influence distance is 2.93m. The linear chart in Fig. 3 shows RSS median value, in dBm, for each case in P_LOS scenario and the vertical dot line determines the influence distance on the chart. The chart shows that RSS has been strengthen as the person stands on further distance from MD since it ranges between -62dBm to -56dBm for 1p_0m and 1p_4m cases respectivly. In addition to this, it shows that as the person stands on distance less than the influence distance –which is 2.9m, RSS still less than its strength in np case –which is -57dBm. This means that, the person's body obstacles LOS between AP and MD. On the other hand, when the person stands on distance further than the influence distance, such as in cases 1p_3m and 1p_4m, his/her body can not obstacle LOS so that RSS reaches -58dBm and -56dBm respectivly and this means RSS strengthen to reach RSS as in np case. Hence, the presented calibrated RSS in this scenario proves that the truth of the influence distance in LOS.

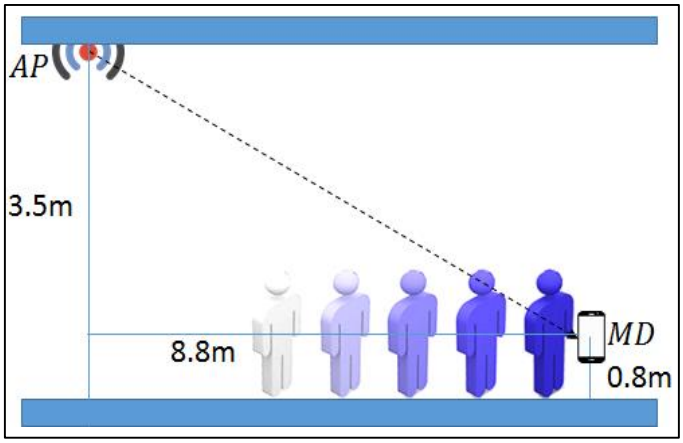

Fig. 2. P_LOS Scenrio's Description and Distances

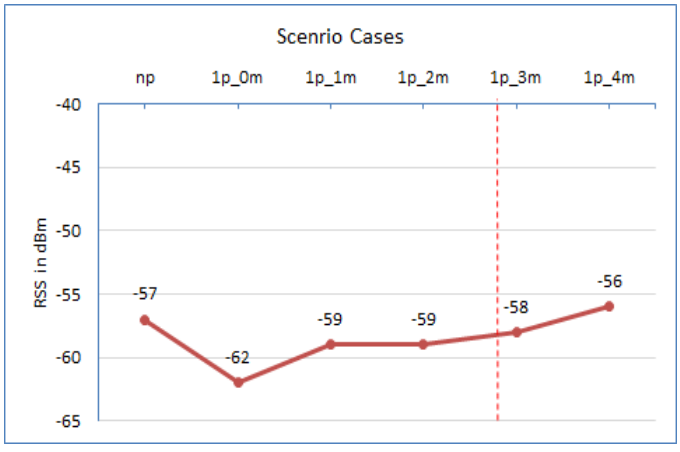

Fig. 3. RSS Median for P_LOS' Cases

B. *People Presence Effect in Virtual LOS (P_VLOS1)*

RSS in P_VLOS1 scenario was calibrated with the following facts AP height is 3.5m, MD height is 0.8m, the horizontal distance between AP and MD is 9.6m with a wall obstacles this LOS as shown in Fig. 4. Hence, the computer influence distance is 3.2m. The linear chart, in Fig. 5, represents P_VLOS1 scenario shows that RSS has been strengthen as the person stands on further distance from MD since it ranges between -68dBm to -64dBm for 1p_0m and 1p_4m cases respectivly. In addition to this, it shows that as the person stands on distance less than the influence distance –which is 3.2m, RSS still less than its strength in np case –which is -63dBm. This means that, the person's presence affects RSS because his/her body obstacles VLOS between AP and MD. On the other hand, when the preson stands on distance further than the influence distance, such as in cases 1p_4m, his/her presence effect vanished because when he/she stands on further distance RSS has an opportunity to be strengthen due to multi-paths to reach -64dBm. Hence, the presented chart supports the existance of the influence distance as in P_LOS scenario.

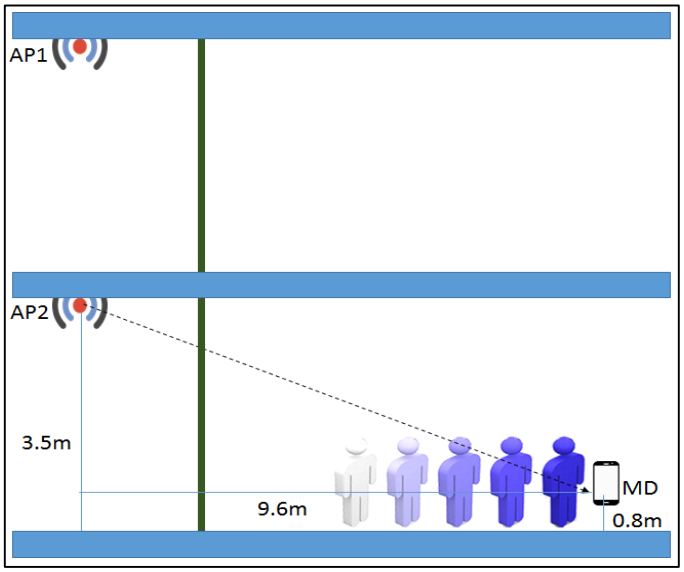

Fig. 4. P_VLOS1 Scenrio's Description and Distances

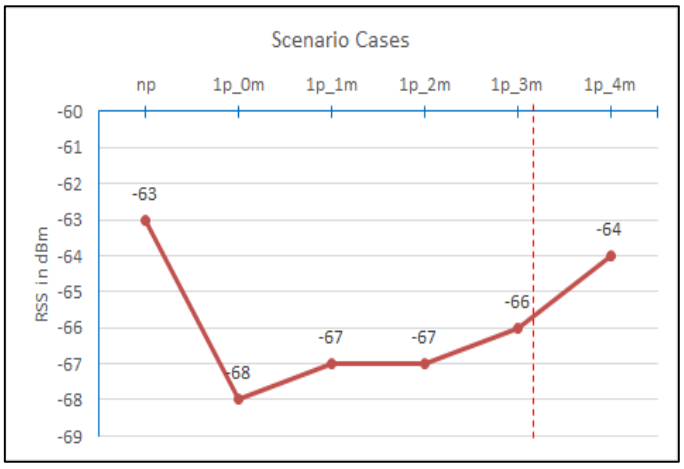

Fig. 5. RSS Median for P_VLOS1's Cases

C. *People Presence Effect in Virtual LOS (P_VLOS2)*

RSS in P_VLOS2 scenario was calibrated with the following facts AP height is 7.5m, MD height is 0.8m, the horizental distance between AP and MD is 9.6m with a wall and ceilling obstacl this LOS as shown in Fig. 6. Hence, the computer influence distance is 1.29m. The linear chart, in Fig. 7, represents P_VLOS2 scenario shows that RSS has been strengthen as the person stands on further distnace from MD since it ranges between -90dBm to -86dBm for 1p_0m and 1p_4m cases respectivly. As in the previous two scenarios, the chart shows as the person stands on distance less than the influence distance –which is 1.2.9m, RSS still less than its strength in np case –which is -85dBm. This means that, the person's presence affects RSS because his/her body obstacles VLOS between AP and MD. On the other hand, when the preson stands on distance further than the influence distance, such as in cases 1p_2m; 1p_3m and 1p_4m, the effect of his/her presence vanished gradually. This gradual disappear of people presence because of the further distance allow bigger opportunity to RSS to be strengthen due to multi-paths to reach -86dBm.

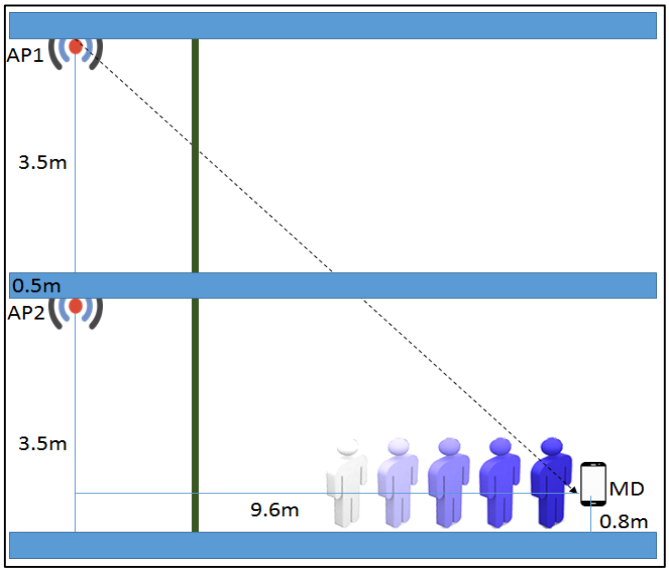

Fig. 6. P_VLOS2 Scenrio's Description and Distances

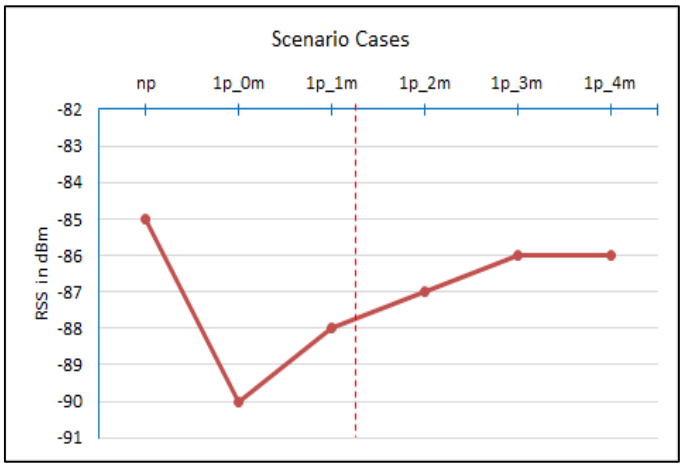

Fig. 7. RSS Median for P_VLOS2's Cases

Although RSS is -87dBm with the second case 1p_2m is less than np case by -2dBm, it is still accepted since standing up on 2m is to closed to MD and this can obstcal the multi-paths. Hence, the presented chart supports the existance of the influence distance as in the previous two scenarios.

CONCLUSION AND FUTURE WORK

Although WLAN-fingerprinting can be consider as the most accurate IPS method, WLAN RSS fluctuates due obstacles presence decline it positioning accuracy. People's presence near to MD between AP and MD can be considered as one of these obstacles which attenuate RSS, but it is hard to find a research paper estimates this attenuation as in the case of walls and ceilings. People presence effect was estimated in previous work, but it still need a lot of investigation. This paper raised the existence of people presence influence distance as new concept related to people presence effect. The experimental work, with 15 cases, was presented in order to prove the truth of this proposed concept. The obtained result proved the truth of this claim and the existence of the influence distance became a fact. The future work of this research has two directions. The first one is to estimate the effect of more than one person presence within the influence distance and second direction is to involve people presence effect in IPS to get more accurate positioning result.

ACKNOWLEDGMENT

This work has been supported by the Fundamental Research Grant scheme (FRGS), VOTE No.(5F787). Hence, the authors would like to thank the Ministry of Education (MoE) Malaysia and Universiti Teknologi Malaysia (UTM) for their support.

REFERENCES

[1] Schiller, J. and A. Voisard, *Location-based services*. 2004: Elsevier.

[2] Mantoro, T., M.A. CutifaSafitri, and E. Ayu, *Optimization of Cellular Automata for User Location Determination Using IEEE 802.11.* 2012 International Conference on Indoor Positioning and Indoor Navigation, 13-15th November 2012, 2012.

[3] Farid, Z., R. Nordin, and M. Ismail, *Recent Advances in Wireless Indoor Localization Techniques and System.* Journal of Computer Networks and Communications, 2013. 2013: p. 12.

[4] Liu, H., et al., *Survey of wireless indoor positioning techniques and systems.* Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 2007. 37(6): p. 1067-1080.

[5] Andrade, C.B. and R.P.F. Hoefel. *IEEE 802.11 WLANs: A comparison on indoor coverage models*. in *Electrical and Computer Engineering (CCECE), 2010 23rd Canadian Conference on*. 2010. IEEE.

[6] Borrelli, A., et al. *Channel models for IEEE 802.11 b indoor system design*. in *Communications, 2004 IEEE International Conference on*. 2004. IEEE.

[7] Seidel, S.Y. and T.S. Rappaport, *914 MHz path loss prediction models for indoor wireless communications in multifloored buildings.* Antennas and Propagation, IEEE Transactions on, 1992. 40(2): p. 207-217.

[8] Lott, M. and I. Forkel. *A multi-wall-and-floor model for indoor radio propagation*. in *Vehicular Technology Conference, 2001. VTC 2001 Spring. IEEE VTS 53rd*. 2001.

[9] Mardeni, R. and Y. Solahuddin. *Path loss model development for indoor signal loss prediction at 2.4 GHz 802.11n network*. in *Microwave and Millimeter Wave Technology (ICMMT), 2012 International Conference on*. 2012.

[10] Alshami, I.H., N.A. Ahmad, and S. Sahibuddin, *PEOPLE'S PPRESENCE EFFECT ON WLAN-BASED IPS'ACCURACY.* Jurnal Teknologi, 2015. 77(9).

[11] Alshami, I.H., N.A. Ahmad, and S. Sahibuddin. *People effects on WLAN-Based IPS' accuracy experimental preliminary results*. in *Software Engineering Conference (MySEC), 2014 8th Malaysian*. 2014.

[12] Pace, S., et al., *The global positioning system: assessing national policies*. 1995, DTIC Document.

[13] Liu, Y., et al., *Location, localization, and localizability*. Journal of Computer Science and Technology, 2010. 25(2): p. 274-297.

[14] Yanying, G., A. Lo, and I. Niemegeers, *A survey of indoor positioning systems for wireless personal networks.* Communications Surveys & Tutorials, IEEE, 2009. 11(1): p. 13-32.

[15] Deak, G., K. Curran, and J. Condell, *A survey of active and passive indoor localisation systems.* Computer Communications, 2012. 35(16): p. 1939-1954.

[16] Chen, P., et al., *Survey of WLAN Fingerprinting Positioning System.* Applied Mechanics and Materials, 2013. 380: p. 2499-2505.

[17] Gezici, S., *A survey on wireless position estimation.* Wireless Personal Communications, 2008. 44(3): p. 263-282.

[18] Fang, S.-H., T.-N. Lin, and K.-C. Lee, *A novel algorithm for multipath fingerprinting in indoor WLAN environments.* Wireless Communications, IEEE Transactions on, 2008. 7(9): p. 3579-3588.

[19] Kaemarungsi, K. and P. Krishnamurthy, *Analysis of WLAN's received signal strength indication for indoor location fingerprinting.* Pervasive and mobile computing, 2012. 8(2): p. 292-316.

[20] Chiou, Y.-S., et al., *Design of an adaptive positioning system based on WiFi radio signals.* Computer Communications, 2009. 32(7–10): p. 1245-1254.

[21] Wang, H., et al. *Dynamic radio map construction for WLAN indoor location*. in *Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2011 International Conference on*. 2011. IEEE.

[22] Parodi, B.B., et al., *Initialization and online-learning of RSS maps for indoor/campus localization.* proceedings of IEEE/ION PLANS, 2006.

[23] Youssef, M. and A. Agrawala, *The Horus WLAN location determination system*, in *Proceedings of the 3rd international conference on Mobile systems, applications, and services*. 2005, ACM: Seattle, Washington. p. 205-218.

[24] Bahl, P. and V.N. Padmanabhan. *RADAR: an in-building RF-based user location and tracking system*. in *INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*. 2000.

[25] Ben Hamida, E. and G. Chelius. *Investigating the impact of human activity on the performance of wireless networks — An experimental approach*. in *World of Wireless Mobile and Multimedia Networks (WoWMoM), 2010 IEEE International Symposium on a*. 2010.

[26] Karadimas, P., B. Allen, and P. Smith, *Human Body Shadowing Characterization for 60-GHz Indoor Short-Range Wireless Links.* Antennas and Wireless Propagation Letters, IEEE, 2013. 12: p. 1650-1653.

[27] Turner, J.S.C., et al. *The study of human movement effect on Signal Strength for indoor WSN deployment*. in *Wireless Sensor (ICWISE), 2013 IEEE Conference on*. 2013.

[28] Fet, N., M. Handte, and P.J. Marrón. *A model for WLAN signal attenuation of the human body*. in *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing*. 2013. ACM.

[29] Mitchell, B. *Where's the Best Place For Your Wireless Router?* 2015; Available from: http://compnetworking.about.com/cs/wirelessproducts/qt/locate_aprouter.htm.

[30] Sharma, V. *Best Practices for positioning Access Points (AP's) and Antennas*. 2005; Available from: https://supportforums.cisco.com/document/64431/best-practices-positioning-access-points-aps-and-antennas.