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Indoor Positioning System Based Wi-Fi Fingerprinting for Dynamic Environment: Experimental Preliminary Result

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Abstract: Location Based Services (LBS) are an important permissive technology and it have wide range of application. The main component of LBS is location detection. It can be divided into proximity, triangulation and fingerprint. Fingerprint Wi-Fi has been preferred technology due to its accurate positioning results and minimal infrastructure cost. It is conducted in offline and online phase. In the first phase, a site survey is conducted to collect the vectors of Received Signal Strength Indicator (RSSI) at many reference points of known locations. Then users measures RSSI vector at their position in the online phase. System compares the received target vector with the stored fingerprints. People Presence Effect (PPE) has a dominant influence to RSSI in a dynamic environment. It is necessary to further research related to PPE so that it can be generated a more accurate indoor positioning system in dynamic environments such as airports, hospital and shopping area.

Key words: Wi-Fi, fingerprint, indoor positioning system, RSSI, people effect, airports

INTRODUCTION

Location Based Services (LBSs) are a significant permissive technology and it have wide range of application in our life (Raper *et al*., 2007). The main component of LBS is positioning system and it can be divided as indoor, outdoor or mixed type. For outdoor positioning, Global Navigation Satellite Systems (GNSS) such as GPS and Glonass have been used in a wide range of applications. However, we can't use GPS for indoor positioning because GPS signals are not strong enough to penetrate buildings, then people develop other system for indoor positioning. Indoor Positioning System (IPS) based service has great economic potential also it is estimated to reach US$10 billion in 2020 (2). IPS can be defined as any system that provides a precise position inside of a closed structure such as a shopping mall, hospitals, airport, a subway and university campuses (Zhang *et al*., 2010). Many technologies are developed to support these services.

Location detection techniques can be divided into three general categories: proximity, triangulation and fingerprint (Farid *et al*., 2013). Proximity detection or connectivity based is one of the simplest positioning methods to implement. The position of mobile client is determined by Cell of Origin (CoO) method with known position and limited range. Triangulation uses the geometric properties of triangles to determine the target location. It has two derivations: lateration and angulation. Lateration techniques based on the measurement of the received Radio Signal Strength (RSS), signal phase and propagation-time system (e.g., TOA, RTOF and TDOA) (Makki *et al*., 2015). Fingerprinting uses the pattern recognition techniques which combine Radio Frequency (RF) with location information, e.g., coordinates or label from the environment to obtain the real position of a mobile device. Fingerprinting is the most accurate method but its accuracy declines when an environmental change occurs (Alshami *et al*., 2006).

Radio Frequency (RF) technologies are commonly used in location position systems because of some advantages for example, radio waves can penetrate through obstacles like building walls and human bodies easily. Due to this, the positioning system in RF based has a larger coverage area and needs less hardware comparing too the other systems. In addition, RF based technologies are further divided into narrow band based technologies (RFID, Bluetooth (Faragher and Harle, 2015), WLAN/Wi-Fi, Zigbee (Hu *et al*., 2011) and FM) and Wide Band based technologies (UWB). WLAN has been highlighted as the preferred technology due to its accurate positioning results and minimal infrastructure cost (Yang and Shao, 2015).

WLAN is a wireless local network standard from IEEE (802.11) and most of mobile phone support this communication standard. WLAN signal is greatly

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influenced by environmental conditions, especially in indoor area because of multipath effect. It needs adaptive IPS that can adapt to environmental changes including the amount and human activities that are very dynamic.

Literature review: Wi-Fi fingerprinting is usually conducted in 2 phases: offline and online phase. In the offline phase, a site survey is conducted to collect the vectors of Received Signal Strength Indicator (RSSI) of all the detected Wi-Fi signals from different Access Points (APs) at many Reference Points (RPs) of known locations. In the online phase, a user samples or measures an RSSI vector at his/her position. Then system compares the received target vector with the stored fingerprints. The target position is estimated based on the most similar “neighbors”, the set of RPs whose fingerprints closely match the target’s RSSI (He and Chan, 2016).

There are 3 main issues at offline stage. First is diverse of RSSI measurements from heterogeneous devices. The second issue, collecting fingerprints database is high cost and time consuming. The last one, the Wi-Fi signal is always change affected by dynamic environmental conditions. Shu proposed Gradient Fingerprinting (GIFT) indoor localization and tracking system to overcome the last problem. The differential RSSI between nearby positions is more stable than the absolute RSSI values (Shu *et al*., 2016).

Manual radio map is time-consuming process, especially in large urban areas by collecting RSSI value at each point in the building (Bahl and Padmanabhan, 2000). The simplest way to solve this problem is by reducing the sample points and reducing the number of data collection at each point but it will decrease the level of accuracy. Then automatic radio map generation is constructed to reduce time required (Alshami *et al*., 2014; Du *et al*., 2015). Du proposed RSSI Geography Weighted Regression (RGWR) to solve the fingerprint database construction problem. GWR is a regression method that has many coefficients. These coefficients are affected by the known anchors surrounding, the distance from anchors and the located regions change (Du *et al*., 2015). This method needs modified WLAN AP and anchors so it is less practical because it requires additional device. Lin proposed an unsupervised Simultaneous Localization and Mapping (SLAM) system for automatic floor map and radio map construction. A surveyor walk-through the area to collect RSS traces and then the floor map is discovered by observing the correlation pattern of the RSS measurements. The points of interest (rooms alongside corridors) included in map and a radio map is constructed on top of the floor map. Lin solution only work for room-scale indoor positioning and it need high computation. Iyad used Multi-Wall signal path loss model to generate the radio map automatically. Basically it use path loss models in wireless signal. It has proved that the attenuation is related to the distance and obstacles. It needed the knowledge of the environment layout and AP location information (Alshami *et al*., 2006).

Hybrid mechanism that combine manual data collecting and user collaboration was proposed by Kim *et al*. (2015). First step is constructs a partial radio map using a lightweight site survey. Then, the radio map is updated and completed by user collaboration using smartphone-based Pedestrian Dead Reckoning (PDR). The accuracy of this system is strongly influenced by the accuracy of the PDR. Yuan tried to improve the performance by implement Trusted Portable Navigator (T-PN) to develop radio map automatically (Zhuang *et al*., 2016). T-PN is an advanced inertial sensor navigation solution based on motion constraints, mode detection and attitude tuning. Reducing fingerprint collection also done by Gu *et al*. (2016). The small number of collected data are merged into the merging matrix. Then, Singular Value Decomposition (SVD) method is used to find the hidden structure and redundancy characteristics, later absent fingerprints is recovered based on compressive sensing. It can reduce time for collecting the fingerprint but it still needs high computation.

The RSSI received at a certain point from an AP varies with different time periods and physical surroundings. In such a dynamic environment, the radio maps obtained in one time period may not be applicable in other time periods. The location estimation might be less accurate if the RSSI in the online phase deviate significantly from the database that collected in the offline phase. So, it needs to be made adaptive system that will automatically update the radio map because of environmental changing. Since, the reference points are subject to the same effect in the environment as the tracked mobile device so the update observed RSSI values received by the reference points can be used to dynamically update the radio map. Yin presents a method to adapt the temporal radio maps use update RSSI at sparsely located reference and regression analysis techniques (Yin *et al*., 2005). If the RSSI value at the reference point changed from the default values, radio map will be updated automatically. However, this solution is not practical because they require additional tools as reference points. Installation of new APs and breakage of APs will change the radio map also user feedback that consist of captured fingerprint, time stamps, events and confidence value can be used to update the radio map automatically (Lim *et al*., 2013).

The obstacles that can cause fluctuations in signal strength can be wall, ceilings and/or people (Farid *et al*., 2013). The walls and ceilings have been discussed by Andrade and Hoefel (2010), Sadiki and Paimblanc (2009). People effect has been investigated by Karadimas *et al*. (2013) for 60 GHz (Hamida and Chelius, 2010) for 868 MHz and Alshami *et al*. (2014) and Turner *et al*. (2013) for 2.4 GHz. The result shows that people's presence in Line of Sight (LOS) between AP and Mobile Device (MD) decreased the RSS by -2 to -5 dBm. This RSS's decline can lead to big distance error >2 m. People Presence Effect (PPE) has a dominant influence in a dynamic environment. However, there is a lack of research on IPS and PPE area. This study provide some experimental works, enhance from Iyad's work (Alshami *et al*., 2014) to make a more accurate IPS in dynamic environments (large space with many people activities) such as airports, shopping area, etc.

MATERIALS AND METHODS

Methodology and preliminary result: This study will discuss the methodology and preliminary results of experiments related to the effect of the presence of people on the value of the RSSI of Wi-Fi signal. This research consists of five experiments. First and second experiments want to know the effect of people presence to RSSI when the position of transmitter and receiver are in same height from floor (horizontal). Then, the third experiment conduct to explore the effect of people presence to RSSI when the position of transmitter is higher than receiver (diagonal). How the user position or orientation can affect the RSSI is explore in the fourth experiment. Finally, the last experiment conducts to get information about effect of many people around the receiver.

RESULTS AND DISCUSSION

People presence effect on horizontal signal path: This experiment is based on experiments carried out by Iyad. People are standing in a position that blocking the LOS path between transmitter and receiver. The sender is an access point (Linksys WAP300N) and receiver is a mobile device (Xiaomi note 3). Distance between transmitter and receiver is 6 m and the height of access point and mobile device are 70 cm from the floor. Description of the experiment can be seen in Fig. 1. This experiment was conducted in the 3rd floor of the Razak Tower, Universiti Teknologi Malaysia (UTM) on the west corridor with size 2×20 m.

The first experiment is one person stands between access points and mobile devices by setting the distance between people with MD (from 5-0.2 m). We measured

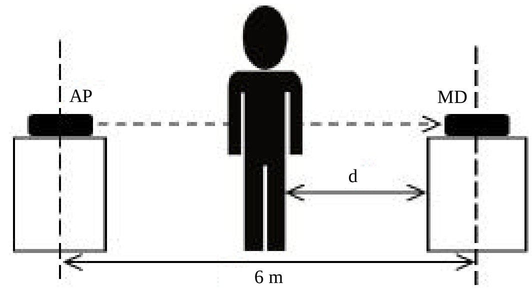

Fig. 1: People blocking the horizontal LOS path

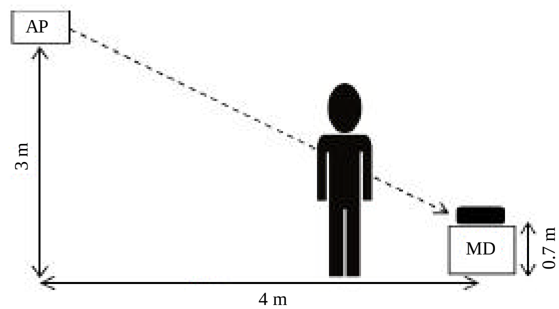

Fig. 2: People blocking the diagonal LOS path

Table 1: RSSI when 1 people blocking the horizontal LOS path

Distance people to MD (m), d	RSSI (dBm)
5	-43
4	-43
3	-44
2	-44
1	-43
0.2	-48

Table 2: RSSI when n-people blocking the horizontal LOS path

No. of people between AP and MD (n)	Range of RSSI (dBm)
1	-48 to -43
2	-47 to -45
3	-50 to -45
4	-56 to -43

40 data RSSI at each position. The experimental results can be seen in Table 1. As a comparison, when no one is blocking LOS, the median value of RSSI received by mobile devices is -42 dBm. It appears that the people as a barrier between the AP with MD on LOS path can reduce the value of RSSI, especially when the people as barriers are very close to the MD (Fig. 2).

The second experiment is many persons (1-4 persons) stand between AP and MD with some variation of position. Detail of experiment result show on Table 2, when there are more people so the value of attenuation are also getting bigger and then the RSSI decreasing. Same as the previous experiment we also measured 40 data of RSSI at each position.

People presence effect on diagonal signal path: The third experiment is one person stands between AP and MD by

Table 3: RSSI when 1 people blocking the diagonal LOS path

Distance to MD (m)	RSSI (dBm)
4	-49
3	-50
2	-50
1	-50
0.2	-54

Table 4: Effect of user orientation to RSSI

	RSSI (dBm)	
People orientation (°)	AP1	AP2
0	-63	-59
45	-58	-62
90	-61	-58
135	-58	-63
180	-57	-63
225	-58	-59
270	-54	-58
315	-54	-61

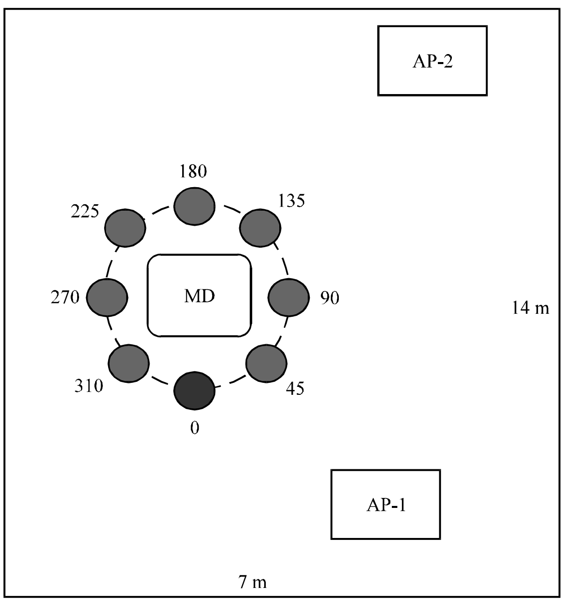

Fig. 3: User orientation and RSSI

setting the distance between people with MD (4-0.2 m). We measured 40 data of RSSI at each position. Table 3 summarizes the result of the experiments. As a comparison when no person is blocking LOS, the median of RSSI received by mobile devices is -49 dBm. When the position of people is getting close to the MD, the RSSI value received will significantly reduce.

Effect of user orientation on RSSI: Body of people who carry MD also be a barrier Wi-Fi signal because the position is very close to the MD, the effect become significant. The fourth experiment, a user who carries MD is located at 8 direction orientation as shown in Fig. 3. The RSSI measurement results are presented in Table 4, it

Table 5: Effect of people around MD to RSSI

		RSSI (dBm)		
No. of people	Distance people to MD (m)	AP1	AP2	AP3
0	0.0	-59	-86	-60
4	0.5	-64	-90	-75
4	1.0	-57	-90	-57
4	1.5	-58	-86	-55
4	2.0	-59	-86	-58
8	1.0	-72	-89	-60
8	1.5	-59	-84	-60
8	2.0	-57	-84	-60

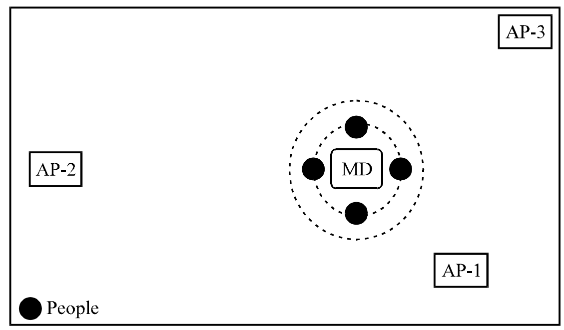

Fig. 4: Figure caption

appears that when the user's position in the direction that block the LOS path, it will affect the RSSI value from AP concerned. This experiment was conducted in the 4rd floor of the FTI Building, Universitas Islam Indonesia (UII). Exactly on the room of Telecommunication Laboratory that size is 7×14 m.

Effect of people around MD: The fifth experiment is a group of people (4 and 8) stands around MD at a certain distance. The purpose of this experiment was to determine the effect of a number of people around the MD of the RSSI value received by MD. This experiment was conducted in the 4th floor of the FTI Building, Universitas Islam Indonesia (UII) with size 20×14 m.

The measurement results are showed in Table 5. First, there are 4 people standing around MD as shown in Fig. 4. The distance between people and MD are 0.5, 1, 1.5 and 2 m. Each position has 60 measured data of RSSI value. Second, there are 8 people standing around MD.

The results clearly show that when there are a number of people around MD, RSSI value received by MD are reduced, especially if the distance people with MD fairly close (0.5 and 1 m). When 4 people around MD with radius 0.5 m, RSSI from AP1/AP2/AP3 decreased 5/4/15 dBm. Overall, the RSSI value decreased 4-15 dBm.

CONCLUSION

Wi-Fi fingerprinting technique has been preferred technology in indoor positioning system due to its accurate positioning results and minimal infrastructure cost. Fingerprinting is the most accurate method but its accuracy declines when an environmental change occurs. The obstacles that can cause fluctuations in signal strength (RSSI) are not only wall and ceilings, people also has significant impact so it need to be concerned.

About 5 experiments have been conducted, related to people presence effect on the value of RSSI. The results proved that the people near or around the MD effect on RSSI value received by MD. It should be a primary consideration to make more accurate indoor positioning system in a dynamic environment.

SUGGESTIONS

The future work is to make adaptive IPS system that can adapt to environmental changes, specifically the presence of humans. The main purpose is to improve the accuracy of the system.

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