2012 Third International Conference on Intelligent Systems Modelling and Simulation

Accuracy Enhancement of Fingerprint Indoor Positioning System

[1]Sazzad Hossain, [1]Sharifah H. S. Ariffin, [1]Norsheila Fisal, [2]Choong Khong Neng, [1]N. S. Abu Hassan and [1]L. A. Latiff
[1]Telematic Research Group (TRG), Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia.
[2]MIMOS Berhad, Technology Park Malaysia, Kuala Lumpur, Malaysia.
Email: sazzad.utm@gmail.com

***Abstract*— There are several researches have been conducted and different methods have been applied to extend the features of indoor location tracking using wireless devices. Fingerprint algorithm is one of the popular methods that have been used to track mobile nodes in indoor structure. This paper focuses on the enrichment of positioning accuracy of the Fingerprint algorithm. RSSI mechanism has been used on the Fingerprint Algorithm to encompass better performance for the accurate positioning. The paper has been proposed two different types of Fingerprint methods and their performance variants on different circumstances of indoor environment. The proposed Fingerprint Database mapping has been divided according to the RSSI data redundancy. The proposed Fingerprint methods has been successfully implemented and experimented on UTM-MIMOS CoE lab. The experimented results of two Fingerprint methods has been analyzed and compared as well.**

Keywords-Fingerprint, Indoor Positioning, RSSI, Ad-hoc networks.

I. INTRODUCTION

Due to diverse indoor environmental characteristics and high price of technology, extensive availability of indoor location tracking system remains in doubt. There are actually various ways for determining and tracking position indoors, but to do so accurately remain very costly. There are various methods for identifying and tracking user position such as Cricket [1], Active Badge [2], LANDMARC [3] and Mote Track [4]. Hence, accurate estimation of location in both environments remains a longstanding difficult task. Different indoor location tracking has their own ways to determine the position or the location of moving objects [5] [7] [8].Using location tracking mechanism, it is possible to calculate the current location of a user or an indoor object. For some applications it is sufficient to estimate the user's location in a room.

Recent years, one of the popular indoor positioning methods is Fingerprinting Tracking System [15] [16]. The reason being, its major advantage of radio infrastructures uses in IEEE 802.11[14] network. Moreover, it saves deployment costs and effort. Fingerprint method uses a map of previously stored of received signal strength different locations and denoted as Fingerprints. The most common type of measurements used for Fingerprint is the strength of radio signals. Generally, Fingerprint is used in connection with radio infrastructures, like IEEE 802.11 or GSM, mobile phones, laptops or PDAs already carried by persons can be used as position sensors.

Based on Fingerprint Database, Fingerprinting method is divided into two phases [11]. They are offline database phase and online database phase. There are four algorithms for Fingerprint positioning error estimation [10]. They have been divided into two sections; Pre-deterministic and Post-deterministic. Pr-deterministic algorithms are;

1. Fingerprint Clustering
2. Leave Out Fingerprint

The two other algorithms refer as Post-deterministic Fingerprint algorithm.

3. Best Candidate Set
4. Signal Strength Variance

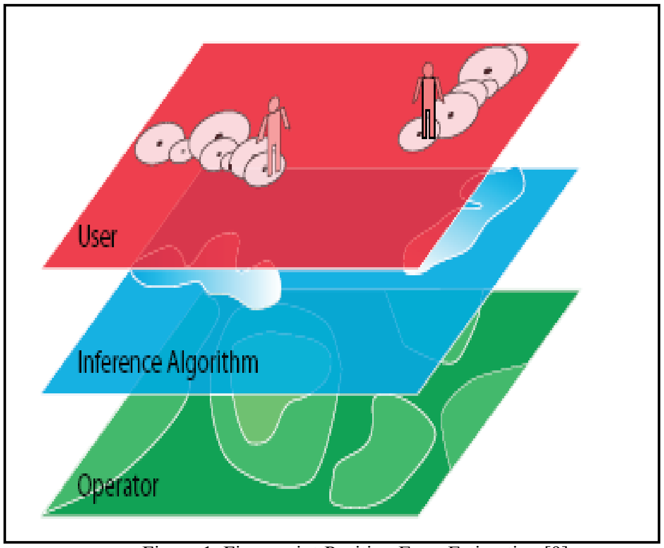

Figure 1. Fingerprint Position Error Estimation [9]

Fingerprint position usually depends on three variable of the environment. They are User, Interface Algorithm and Operator as the Figure 1 demonstrated. The user is notified that the estimated position might contain some Position error. This helps him to make better use of the location base service and also avoids him becoming frustrated because of many unexpected wrong positioning results. The inference algorithms utilize position estimates to derive additional information from the user. Fingerprint Position error estimates allow the inference algorithms to assess the level of trust that these position estimates contain. Hence, the algorithms can give a higher priority to estimates with a low estimated error and also assists to deliver a higher accuracy and service of quality. The operators of IEEE 802.11-based

978-0-7695-4668-1/12 $26.00 © 2012 IEEE
DOI 10.1109/ISMS.2012.114

technology positioning systems can utilize position error estimates to optimize their system to the precision required by the application.

In this research, Fingerprint has been conducted on UTM-MIMOS CoE laboratory. The proposed Fingerprint methods have been design according to the indoor structure. There are three Access Points are being placed on ten meters each and Access Point AP0 has been used as a reference point as Figure 2 has illustrated. Fingerprint Database has been created according to the coordinates.

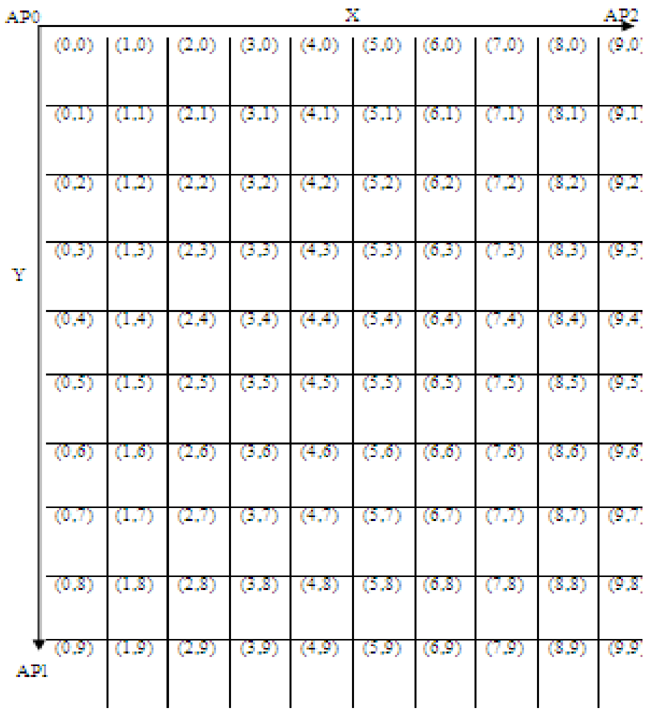

Figure 2. Fingerprint Coordinate Structure

The coordinates have been taken one meter distance each from X-axis and Y-axis. There are total hundred coordinates. Access Point AP0 to AP1 is considered as Y –axis and AP0 to AP2 is considered as X-axis on this experiment. The received signal strength has taken from all the three access point and stored into database. Indoor place has been divided into hundred coordinates. Each coordinates has one meter distance. In this research, UTM-MIMOS CoE has been used as the indoor environment to comply the experiments. During the collection of received signal strength from all the Access Points, the mobile node has been place on a fix coordinate and several readings has been taken to get the most accurate RSSI for each coordinates. After that, all the collected RSSI has been analyze and determined the best RSSI for each coordinates to create a reliable Database for Fingerprint experiment. The database has been generated according to the RSSI and their rightful coordinates based on achieved data.

II. RELEVENT WORKS

There are several research has been conducted on indoor location based tracking system. Although they show potential for indoor tracking, each has its own limitations.

A Low-cost Fingerprint Positioning System in Cellular Networks [12] proposes mobile positioning method providing high estimation accuracy to the user within minimum delay and at minimum cost. Conventional location techniques based on trilateration and triangulation rely on line-of-sight path between the base station antenna and the mobile unit. the location performance of the conventional techniques and motivates the need for development of more accurate technique suited for these areas. Positioning system developed in this research is divided into three sub-systems. The first sub-system solves the problems related to fingerprint localization and involves neural network as key element of the positioning algorithm. The post-processing tasks which include tracking and map-matching are performed in the second and third sub-systems respectively. Pre-processing of the fingerprints has a great impact on the accuracy of the fingerprint-based approaches. The conducted experiments, a TDNN (Time-Delay Neural Networks) has been applied to remedy to stochastic effect of the RSS and then calibration of the predicted RSS was performed. NN (Neural Networks) positioning, KFtracking and Map-matching were developed in order to create a reliable positioning system working within cellular networks and providing a reasonable positioning accuracy with low demanding effort and minimum cost.

Wi-Fi Fingerprint-Based Topological Map Building for Indoor User Tracking [13] introduces an indoor user tracking system that constructs a topological map with Wi-Fi signal calibrations, assigns semantically meaningful labels into the map, and estimates the semantic location of the user based on the current Wi-Fi observation. The system does not require a geometric map or radio map building process. The implementation of the system with the off-the-shelf Smartphone and experimentally validated the scheme. This system consists of three phases; place learning, place naming, and place estimation. Place learning is to build a human-readable map. In this phase, the system uses Wi-Fi signals as an environmental observation, and uses motion sensors to detect the kinetic movement of the user. Based on the sensing data, the system automatically builds a topological map of Wi-Fi calibration vectors, and organizes spaces accordingly. Place naming assigns a label on the place in the topological map. Although users can manually name the places, we devised simple methods to extract semantic information from observations. Place estimation is designed to predict the current location of the mobile user based on current observations. Estimation is achieved by comparing the Wi-Fi signal with the calibrated vectors. Our system is specifically designed for the commercially available Smartphone.

III. PROPOSED FINGERPRINT DESIGN AND METHODOLOGY

The proposed FPM (Fingerprint Method) has been drawn based on the closet match of RSSI value of database. The developed Fingerprint positioning system is less hardware base and more on software base. Figure 3 demonstrate the data flow of the Fingerprint Algorithm. Previously, the database has been created by taking several readings from the each coordinates as it is shown on the Figure 2. Fingerprint experiments have been conducted at the same indoor environment as it had the same environment when data were collected to create the database. The Fingerprint database mapping has been designed to improve the accuracy in indoor environment positioning. The developed Fingerprint more focus on the difference between Database RSSI and the achieved RSSI from mobile node. The Fingerprint program has been drawn to find the closet match of RSSI value from the FPM (Fingerprint Method) Database which has been developed earlier on this research. There are few variables which are mainly concern on this developed Fingerprint method. They have been detailed on following.

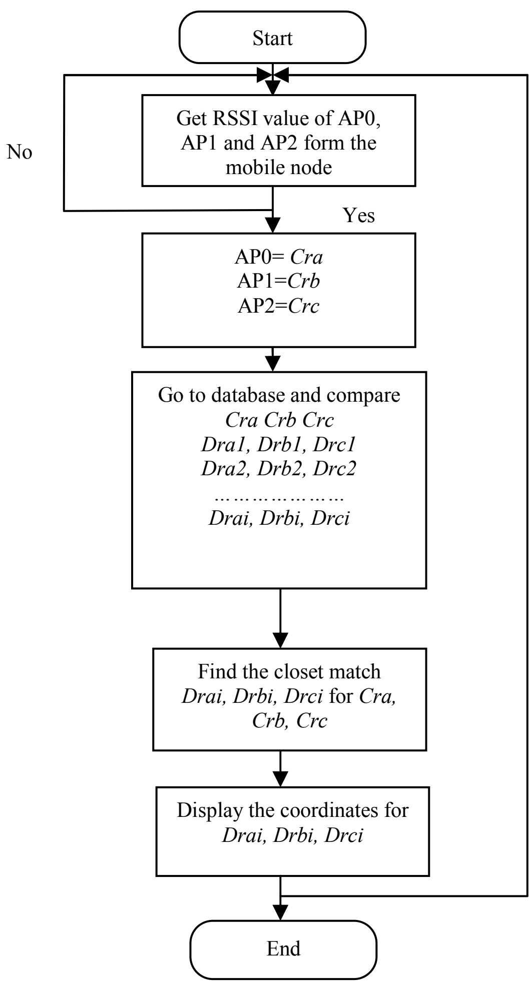

Figure 3. FPM Flow of Program

Cra = RSSI value of Access Point AP0 from the mobile node
Crb = RSSI value of Access Point AP1 from the mobile node
Crc = RSSI value of Access Point AP2 from the mobile node

Once the program starts, Location server collects all RSSI value from each Access Points and stores into *Cra, Crb* and *Crb*. The program will not move further until it collects all the RSSI value from three Access Points AP0, AP1 and AP2. The database has been designed as the three fixed RSSI value of Access Points for each coordinate of the indoor environment. Next, the program will read the FPM database.

Dra = RSSI value of Access Point AP0 from the Database
Drb = RSSI value of Access Point AP1 from the Database
Drc = RSSI value of Access Point AP2 from the Database

The program refers to the database and reads Dra, Drb, Drc and their referred coordinates. The program will loop i times until it finishes to read the *Dra, Drb* and *Drc*, and their assigned coordinates. Here *i* is the number of the iteration which depends on the number of coordinates in database. On these experiment i = 100, because there are hundred coordinates on the mapping structure of the indoor environment where the experiment has been conducted. After comparison, program will find the closest Dra, Drb and Drc and display their coordinates which has assigned on database.

The Pseudo Code of Find the Closet match has been displayed on Figure 4. The program reads the database *Dra, Drb, Drc, coordinates*; here coordinates refers the value of X axis and Y axis position for each Dra, Drb, and Drc. After that the program subtracts *Cra, Crb, Crc* from each *Dra, Drb, Drc* and save the subtraction into diff. i represents the number of iteration. Then the program will go for another iteration j. the number of iteration j is hundred times. After that, the program will compare diff with *min; min* refers the minimum difference which has been stored on previous iterations. If the diff is less then min the program will store diff into min and it will save coordinates of diff on possible coordinate and displays it to user. Otherwise the program will carry on with the coordinates of min which was given by diff on previous iterations. The number of iteration j is hundred. Figure 5.4 shows the Pseudo Code of the Closet Match Technique.

```
FOR i = 0 to 99
    READ Dra, Drb, Drc, coordinates
        diff = (Cra – Dra) + (Drb- Crb) + (Drc - Crc)
END FOR

FOR j = 0 to 99
    IF diff < min
        min = diff
        possible coordinates = coordinates
    END IF
END FOR
DISPLAY possible coordinates
```

Figure 4. Pseudo Code of Find the Closet match

IV. TESTBED IMPLEMENTATION

Figure 5 shows the Testbed of Figure Print Method (FPM) Location tracking system. There are three Access Points, AP0, AP1 and AP2 has been placed on a distance of ten meter each. Distance from AP0 to AP2 has been considered as Y axis and Distance from AP0 to AP1 has been considered as X axis. Fingerprint Database mapping has been designed in linking areas of these three Access Points. FPM Location server is connected with a wireless Switch which will create a network and the mobile node will be connected with that network. Here, mobile node is considered as the device which will be tracked by the FPM Location Server.

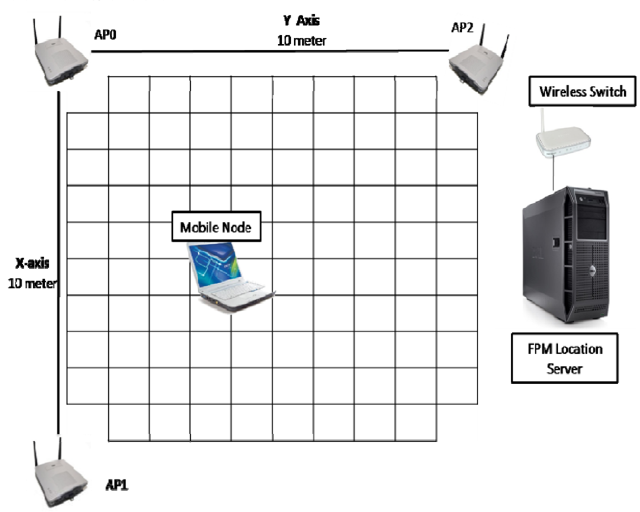

Figure 5. Fingerprint Location Tracking Testbed

FPM Location Server is consisted of Fingerprint Database and the Fingerprint Location Tracking Program. The Fingerprint Database has been plotted according to the design of the Fingerprint Location Tracking Method. Once the mobile node connects with the network of the FPM location Server network, they can start to communicate each other. Mobile node has the client program, which collects the RSSI from the Access Points and sends to the Location Sever Program via IP Address.

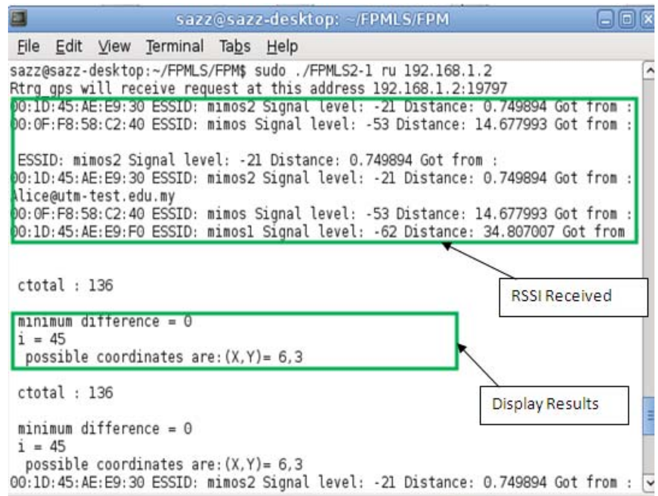

Figure 6. FPM Location Tracking Program

Figure 6 shows the FPM Location Tracking Program of FPM Location Sever. First the FPM Location tracking Program receives the RSSI value of the Three Access Points and compares them with FPM database. After that program finds the closet match for current the RSSI value which has given from the mobile node and displays it on program window.

V. EXPERIMENTED RESULTS AND ANALYSIS

Fingerprint experiments have been divided into two methods to enhance the positioning accuracy of the Fingerprint method. These approaches could assist to monitor the positioning error on different coordinates of the indoor environment. First method of Fingerprint experiment is Fingerprint Database with Data redundancy. In this phase, the experiments have been done without removing the equivalent data of RSSI of different coordinates. Second method of the experiments is Fingerprint Database without Data redundancy. In this phase, all the experiments have conducted by removing the redundant data of RSSI from different coordinates. These two phases have been discussed following.

A. FPM Experiments With RSSI Data Redundancy

These experiments have been performed without removing the equivalent value of the RSSI data from the Database. These experiments have been divided into sections. They are Small Area Experiment and Large Area Experiment. In Small Area Experiment, the Access Points has been placed five meter distance each means that AP1 and AP2 has been placed five meter distance from the AP0. In Large Area experiment, AP1 and AP2 has been placed ten meter distance from AP0.

1) Small Area Experiment

Figure 7 demonstrates the comparison between the real location and the experimented results. Diamond shape dotted line on the graph shows the original positions which have been increased from one meter of X axis and one meter of Y axis on every transition. Square shape dotted line show the experimented results which are calculated by the FPM Location Server. There are variations of experimented results on two places on graph.

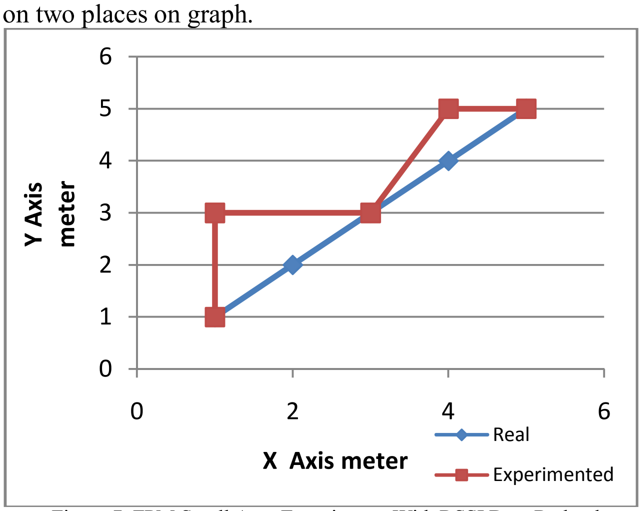

Figure 7. FPM Small Area Experiments With RSSI Data Redundancy

2) Large Area Experiment

Figure 8 shows the graphical observation between the real location and the experimented results on Large Area Experiments with RSSI data redundancy. This is the graphical representation of Table 5.2. Straight line diamond shape dotted on the graph shows the original positions of X axis and Y axis on every transition. The distance between each transition is one meter. Fluctuated Square shape dotted blocks show the experimented results, calculated by the Location Server which has been found few dissimilarity compare to the original position of the mobile node on every changeover of place.

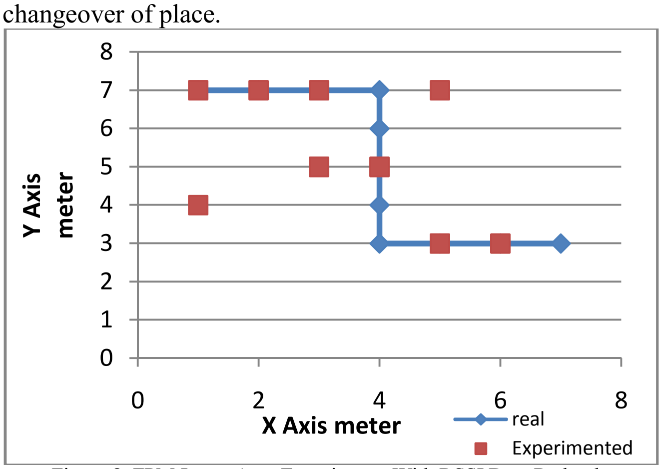

Figure 8. FPM Large Area Experiments With RSSI Data Redundancy

B. FPM Experiments Without RSSI Data Redundancy

On the second Fingerprint Method of the experiments, the redundant value of RSSI has been removed from the FPM Database. The elimination process of redundant RSSI value from FPM Database has been done manually base on the each changeover of mobile node. These experiments have been also divided into two sections. They are; Small Area Experiments and Large Area Experiments. They have been discussed following;

1) Small Area Experiment

Figure 9 demonstrates the graphical representation of the experimented results calculated by the FPM location server and real location of the mobile node. Square Dotted line shows the real location of the mobile node and Diamond shaped dots represents the experimented results of mobile each transition. Each transition of the mobile node is distance of one meter. Distance between the each transition of the mobile node is one meter.

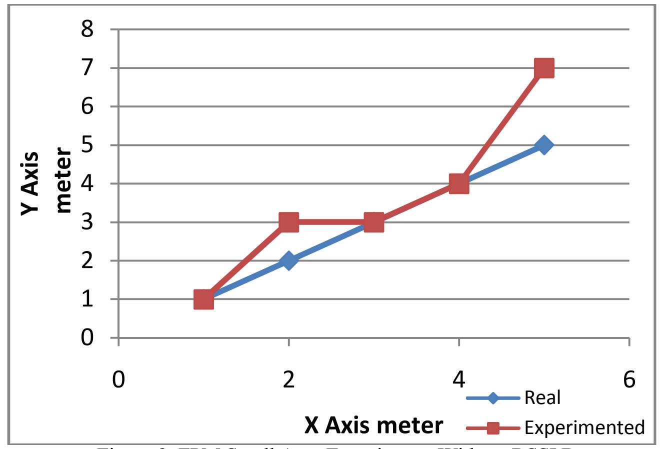

Figure 9. FPM Small Area Experiments Without RSSI Data Redundancy

2) Large Area Experiment

Square Dotted line point to the experimented data which is calculated by FPM location Server Program and Diamond shape dotted line shows the real location of the mobile node, it is has been demonstrated on Figure 10. There is one meter inconsistency of FPM Location Tracking Accuracy in two changeover of mobile node's place during these experiments.

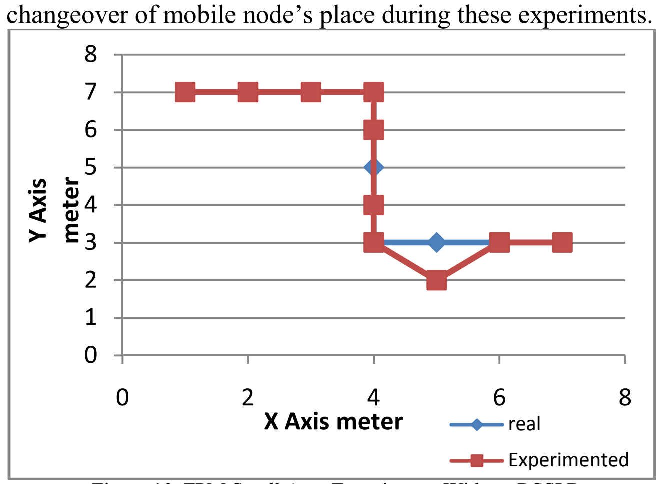

Figure 10. FPM Small Area Experiments Without RSSI Data Redundancy

C. Tracking Performance Comparison

Figure 11 shows the Accuracy Rate of Fingerprint Method with RSSI Data Redundancy and Fingerprint Method with No RSSI Data Redundancy. The Accuracy rate of these two methods has been taken based on their average results of the Small Area Experiments and the Large Area Experiments. As from the Figure can be seen, Fingerprint with No RSSI Data Redundancy has the highest accuracy rate which is around 95% and the Fingerprint Method with RSSI Data Redundancy has the accuracy of 89% which has little lower accuracy rate than the other method.

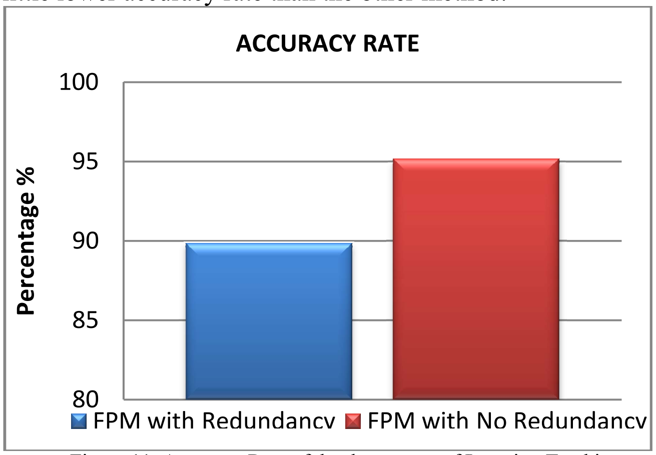

Figure 11. Accuracy Rate of the three types of Location Tracking

VI. CONCLUSION

This paper proposes new approach of Fingerprint positioning system for indoor environment. This paper also discusses about the improvement of Fingerprint indoor positioning accuracy. The implementation of Fingerprint Method (FPM) Location tracking system on a real test bed has been elaborated as well. The Architectural design of FPM Location tracking system has been discussed and the tools and techniques used to create FPM Location Tracking System have been detailed on this paper. The Fingerprint Experiment has been conducted applying two methods to observe the variation of the tracking performance. They are; FPM with RSSI data redundancy and FPM without RSSI data redundancy. During the FPM without RSSI data redundancy experiments the redundant data of RSSI has been eliminated from the database manually depending on the changeover of place of mobile node. The comparison has been made according to the achieved data from the experimented results, also have been discussed in this chapter. In future, an algorithm can be proposed to measure and terminate the redundant RSSI data from the FPM database automatically by the FPM location server.

ACKNOWLEDGMENT

I would like to thank the entire member of Telematic Research Group and MIMOS Berhad for their communications and especially to my generous Supervisor Dr. Sharifah Hafizah Syed Ariffin for her permanent source of help. Thanks to Ministry of Higher Education (MOHE), Technology and Universiti Teknologi Malaysia Research Management for their services and VOT No. 4f046 funding for this project.

REFERENCES

[1] A. Smith, H. Balakrishnan, M. G oraczko, and N. Priyantha," Tracking Moving Devices with the Cricket Location System", MobiSYS 04: Proceedings of the 2nd international conference on Mobile systems, applications, and services, 2004, pp. 190-202.

[2] R. Want, A. Hopper, "Active badges and personal interactive computing objects", IEEE Transactions on Consumer Electronics. Vol. 38, Issue 1, 10 – 20.

[3] X. Yinggang, W. Zhiliang, Z. Shanshan, "On RFID positioning base on LANDMARC and improved algorithm", Control Conference (CCC), 2010 29th Chinese. 29-31 July 2010. Beijing, China, 4831 – 4836.

[4] Y. Zhang, Z. Li, "IPv6 conformance testing: theory and practice", Test Conference, 2004. Proceedings. ITC 2004. International. 26-28 Oct. 2004. Beijing, China, 719 – 727.

[5] Z. Li, C. Chu, and W. Yao, "SIP-RLTS: An RFID Location Tracking System Based on SIP", 2008 IEEE International Conference on RFID The Venetian, Las Vegas, Nevada, USA, April 16-17, 2008, pp.172-182.

[6] Wikipedia Foundation, "Global Positioning System", http://en.wikipedia.org/wiki/GPS, 10 July 2011.

[7] I. Ramani and R. Bharadwaja, P. Venkat Rangan, "Location Tracking For Media Appliances In Wireless Home Networks", IEEE International Conference on Multimedia & Expo, ICME 2003, vol. 2, July 2003, p.p. II .

[8] S. Ponnekanti, , B.T. Patel, R. Prasad, "Integrated Location Management in Mobile Multimedia Networks and its role in the Development of Human Tracking Systems", Vehicular Technology Conference Proceedings, 2000. VTC 2000, vol. 2, May 2000, p.p. 1555.

[9] D. Dearman, A. Varshavsky, E. de Lara, K.N. Truong, "An exploration of location error estimation" In Procedings of the Nineth Interational Conference on Ubiquitous Computing, 2007.

[10] H. Lemelson, M. B. Kjærgaard, R. Hansen, and T. King, "Error Estimation for Indoor 802.11 Location Fingerprinting", LoCA '09 Proceedings of the 4th International Symposium on Location and Context Awareness. 2009. Berlin, Germany, 138 – 155.

[11] Ting Wei and Scott Bell, "Indoor localization method comparison: Fingerprinting andTrilateration algorithm", Spatial Knowledge and Information SKI-Canada 2011, 3rd March 2011, Qubec, Canada.

[12] C. Takenga, K. Kyamakya, "A Low-cost Fingerprint Positioning System in Cellular Networks", Second International Conference on Communications and Networking in China, CHINACOM '07,2007, China, pp. 915 – 920.

[13] Hyojeong Shin, Hojung Cha," Wi-Fi Fingerprint-Based Topological Map Building for Indoor User Tracking", IEEE 16th International Conference on Embedded and Real-Time Computing Systems and Applications, RTCSA, 2010, pp. 105 – 113.

[14] Wikipedia Foundation, "IEEE 802.11", http://en.wikipedia.org/wiki/IEEE_802.11, 10 July 2011.

[15] S., Hossain, S.H.S. Ariffin, , N. F. Hassan, N.S.A. Hassan, L.A. Latiff, L.A., C. K. Neng," Performance analysis indoor location tracking framework with SIP on IPv6", 4th International Conference on Modeling, Simulation and Applied Optimization (ICMSAO), 2011, Kualalumpur, Malaysia, pp. 1 – 7.

[16] S. Hossain, S. H. S. Ariffin, N. Fisal, K. N. Choong, S. A. H. Norhidayu, L. A. Latif, "Seamless Multimedia Communication Applications using Location Tracking Platform on IPv6 Network", Cyber Journal: Journal of Selected Area in Telecommunications, April 2011.