Indoor Localization and Tracking using Wi-Fi Access Points

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Abstract *Location finding by using wireless technology is one of the emerging and important technologies of wireless sensor networks. GPS can be utilized for outdoor areas only it cannot be used for tracking the user inside the building. The main motivation of this paper is to implement the system which can locate and track the user inside the building. Indoor locations include buildings like an airport, huge malls, supermarkets, universities and large infrastructures. The significant problem that this system solves is of tracking the user inside the building. The accurate indoor location can be found out by using the Received Signal Strength Indication (RSSI). The additional hardware is not required for RSSI, and moreover, it is easy to understand. The RSS (Received Signal Strength) values are calculated with the help of WiFi Access points and the mobile device. The system should provide the exact location of the user and also track the user. This paper presents a system that helps in finding out the exact location and tracking of the mobile device in the indoor environment. It can also be used to navigate the user to a required destination using the navigation function.*

Keywords — *Received Signal Strength, Global Positioning System, Indoor Localization, WiFi.*

I. Introduction

GPS is the most efficient technique used for tracking, but it can be utilized only for outdoor locations. When people need the indoor localization or tracking, GPS is not at all useful. GPS can be used only for outdoor areas and not for indoors. Indoor locations include buildings like supermarkets, big malls, parking, universities, and various other infrastructures with the wide area. In these regions, the accuracy of the GPS location is substantially reduced. When GPS is used for indoor localization, the map shown by GPS is not much correct. But for the indoor localization, it requires the higher accuracy, so GPS is not compatible for indoor tracking, also when the GPS is used in the mobile device the amount of battery consumption is quite more as compared to other applications.

Indoor tracking can be very useful in large buildings such as airports, shopping malls, and enterprises during emergencies. Indoor localization provides vital services for mobile and general applications such as advertisement of a product or promotion of new shops in the shopping mall. It can also be very helpful for navigation during an emergency rescue. Now days, mobile phones have become the most important information interface between users and environments, motivating extensive research on localization based on smartphones.

In recent few years, localization of indoor things such as pedestrian or rooms or exit doors in a building has become an exact requirement for which a variety of technologies have been introduced to obtain the good accuracy. The challenge is in developing the map based on floor plans of interiors, selecting the useful indoor positioning technology and various efficient algorithms and developing the proper indoor positioning devices for the buildings. The existing systems that deal with indoor localization services mostly use different wireless technologies like Wi-Fi, RFID Tags, Bluetooth, signals of cellular towers and ZigBee. Existing indoor localization systems can be divided into three types based on the structure of service areas. The three types of systems which can do indoor localization are 2D (two dimensional) service areas, 3D (three dimensional) service areas, and large building.

The remaining paper is arranged as follows: Section II gives an overview of related work already done on indoor localization systems, section III includes the proposed system, Section IV includes mathematical model section V includes results and discussion, and Section VI consists of conclusion and future scope.

II. Related Work

Various systems have been developed for indoor localization. Some of critical systems that are developed are discussed below.

A WaP

The paper [1] "WaP: Indoor Localization and Tracking Using WiFi-Assisted Particle Filter," is discussed below. The authors of this paper are F. Hong, Y. Zhang, Z. Zhang, M. Wei, Y. Feng, and Z. Guo., it was published in 39 Annual IEEE Conference on Local Computer Networks, 2014. Dead Reckoning is the tracking system which determines the current position of a thing by using the knowledge and information from the previously known location. It can also be useful to predict the future locations, by analyzing the current position.

Indoor tracking can be done by using DR technology along with the help of some other techniques. Working with DR can be classified into two methods [1].

1] The First method uses the accelerometer and magnetometer which help in analyzing reference direction towards the gravity. The accumulation of orientation error is avoided which is one of the advantages of this method. The limitation of this system is that the additional errors will be produced due to incomplete separation of gravity signals from linear acceleration imposed on phones.

2] The second method is to use the sensors with the gyroscope, which are less noisy and error free. They are also not affected by the external interface. But they cannot measure the angular position, instead of that, they can only measure angular velocity because of which only relative movement of the phone can be known with the help of gyroscope readings [1].The heading direction can be efficiently found out by merging these two techniques. The raw values as received from accelerometer, magnetometer, and gyroscope are given as inputs to the filter and output is an estimate of azimuth, pitch, and the roll of the phone in the global home.

B. Magicol

The authors Y. chaoShu, C. Bo, GuobinShen, C. Zhao, L. Li, and F. Zhao in the paper [2] "Magicol: Indoor Localization Using Pervasive Magnetic Field and Opportunistic WiFi Sensing" described the techniques for indoor tracking. It was published in IEEE Journal on selected areas in communications, vol. 33, no. 7, July 2015. Magicol is the system which uses the magnetic field for indoor tracking and localization. It is beneficial for Smartphone users. Fig 1 shows the architecture of Magicol. This system uses the device called as magnetometer which is present in almost all Smartphone. It does not require the additional setup of hardware. Magicol is very efficient as it uses the magnetic sensing that consumes a tiny amount of energy and also it can be utilized for all indoor environments. Recognizing that the indoor geomagnetic field anomalies are ubiquitous, location specific and temporally stable, Magicol forces the locally disturbed magnetic signals as location-specific signatures [2].

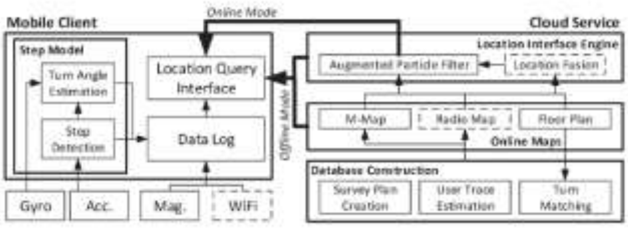

Fig 1: Magicol Architecture [2].

During the implementation of to it comes across three main challenges which are discussed below:

1] Magnetic signal as not much distinguishable. In Magicol system collects the user motion to form a set of multiple observations and it is called as the vector. This vector is then compared with predetermined Magnetic Signal Map (M-Map). M-Map is the offline map that is already created and stored in the database. The user may walk randomly in any direction or can stop or start to walk at any point. To handle such complexity the vectorization is out on per-step basis.

2] Secondly Magicol is not dependent on WiFi or access points. It can work in infrastructure which is not supported by WiFi or any other access points.

3] The another important challenge in Radio Frequency indoor localization system is that the database of indoor may need to construct in advance. This is the major challenge and has been studied recently here they proposed a complaint walk (CW) based solution for a site survey. In this system, the person who is doing survey needs to walk along the pre-determined path. The mobile device analyzes and collects sensor readings and magnetic signals which surveyor is walking. Then the real walking traces are compared with survey path through dynamic programming and form the tracking path [2].

C. The Horus

The authors M. Youssef and A. Agrawala in their paper, [3] "The Horus WLAN location determination system" which was published in Proceedings of 3rd ACM MobiSys described the Horus system for indoor localization. It was released in Horus is a Radio Frequency based indoor location determination system. Current working of Horus is done in the context of 802.11 wireless LAN's. Horus uses the Received Signal Strength (RSS) technology. The components of HORUS are shown in Fig 2. In this technology the signal strength, this measured to find the location. WLAN location determination system consists of two types: client based and infrastructure based. Horus works primarily into two phases, offline phase, and online phases [3].

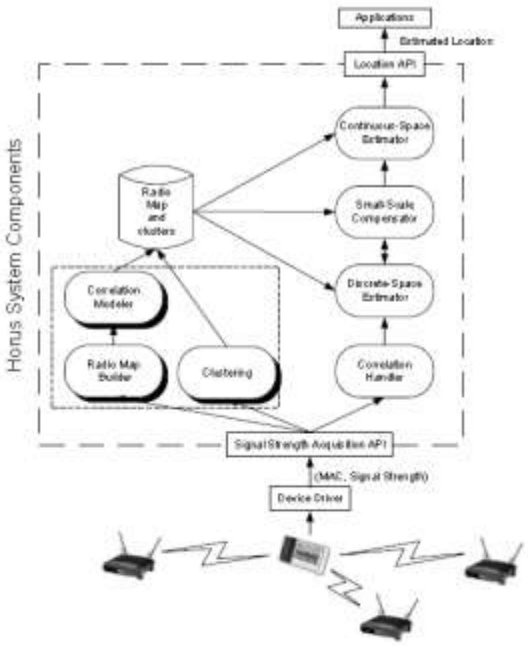

Fig 2: Components of HORUS [3].

1] Offline phase: - In the offline phase, initially the construction of radio map is done. Clustering of radio map locations and preprocessing of the Received Signal Strength model is performed.

2] Online phase: - In online phase, the actual tracking is carried out. Here the user location is found out by using the Received Signal Strength from each access point and radio map, which is constructed in offline phase [3].

Horus is the system that lies in the category in which multiple possible outcomes occurs. It is designed to satisfy the two primary goals: first is high accuracy and second are low computational requirements. Horus system analyzes the various causes of the wireless channel and helps in solving them to achieve high efficiency.

D. MADT

The paper [4] named Energy-Efficient Indoor Localization of Smart Hand-Held Devices Using Bluetooth is described below. The authors of this article are YU GU and FUJI REN, and it was published in Department of Information Science and Intelligent Systems, University of Tokushima, Tokushima, Japan, 2015. MADT i.e. Motion Assisted Device tracking, is a unique and efficient algorithm which is used for quick localization of target devices. It does not require any additional labor survey of the site and also it does not need any access point. MADT uses the fundamental rules of RSSI and the environmental factor such as direction and distance instead of signal entries from access points. This helps to guide the user to move gradually towards the direction of the target [4].

MADT can be combined with either Bluetooth or WiFi to form a complete system for indoor tracking. But the challenge is to find out, which of these two technologies are efficient for use along with MADT. After comparing both Bluetooth and WiFi regarding various attributes, the obtained result shows that Bluetooth will be more efficient than WiFi for MADT [4] [5].

The basic idea of MADT is to set the target device as the signal emitting source which sends the signals and gradually draws the user in its direction. The movement of user shows the particular pattern which supports the rules derived in the empirical study. It uses two main rules: Rule 1 – It decides whether target in close range or not.

Rule 2 – To find the direction of search i.e. target. The pseudo code for MADT is divided into four parts [4].

1] Selecting the start point: - Choose the starting point of the search area manually.

2] Calculate the RSSI reading: - Place the receiver facing towards all four directions and calculate the distances.

3] Choose the search Direction: - Identify the correct quadrant by considering the gained RSSI values from step 2.

4] Identify whether the target is closer or user or not.

E. RFID

The authors P. Bahl and V. N. Padmanabhan in the paper [5] "RADAR: An In-building RF-based User Location and Tracking System" which was published in Proceedings of 9th IEEE INFOCOM. RFID is a means of loading and gaining back the data through an electromagnetic transmission to an RF compatible integrated circuit. It is now being seen as a means of enhancing data handling processes. A RFID system has various important components which include RFID readers, RFID tags, and the communication between them. The RFID reader can read the data emitted from RFID tags. RFID readers and tags use a defined RF and protocol to transmit and receive data. RFID tags are of two types, as either passive or active. Passive RFID tags can work without need of the battery [5]. The traditional barcode technology is replaced by RFID. Moreover, RFID tags are much lighter in weight and smaller in volume, and are less expensive than active tags. The RF signal transmitted to RFID is reflected from a reader and add information by modulating the reflected signal [5]. The only drawback of RFID is that its range is very limited. The typical reading range is 1–2 m, and the cost of the readers is relatively high. Active RFID tags include the small transceivers. These transceivers can actively transmit their ID or any other additional data in reply to a request. Frequency ranges used are almost similar to the passive RFID case except for the low-frequency and high-frequency ranges.

F. Fingerprinting

The authors N. Kothari, B. Kannan, Evan. Glasgow and, and M. Dias in the paper [6] "Robust Indoor Localization on a Commercial Smart Phone," which was published in the International Workshop on Cooperative Robots and Sensor Networks, 2014 have described the technique of fingerprinting. Fingerprinting also was known as mapping or scene analysis is the approach that is used for tracking which is based on geometrical measurements. This system shows the basic idea of fingerprinting is to build a database with features of the scenario at reference locations and then apply regression techniques to match the measurement and infer current position. It consists of access point's database to store results and fingerprints. Fingerprinting can be classified mainly into types as follows [6].

1] Offline training phase:

The scenario is surveyed at known locations, and the features of the environment at each site are then recorded into a database. These features are referred to as fingerprints and could be RSS, magnetometer measurements, or any other type of data that is position-dependent. For instance, when RSS is considered for fingerprinting, the database is composed of the coordinates of the training location, and the RSS of the nearby AP's measured at this place.

2] Online phase:

Online phase is also known as operating phase, as in this stage actual tracking is carried out. This phase needs offline phase as the prerequisite. This step includes the process where the mobile node navigates from one point to other while sensing the same type of fingerprints that were recorded in the database. The results that are obtained are then used to perform matching with the content of the database and provide a correct position of the mobile device which is handled by the user.

III. PROPOSED SYSTEM

Indoor localization requires the higher accuracy. GPS cannot be used for tracking inside the building, so to find out the accurate location for indoor environment system use the RSSI-based trilateral localization algorithm. This algorithm is the low cost, and the algorithm does not require any additional hardware support. The algorithm is also easy to understand. The battery consumption by this technique is quite low as compared to the battery consumption of the GPS. Due to these reasons, this algorithm has become the important factor for localization algorithm in the wireless sensor networks.

Due to increase in development of the wireless sensor networks and the smart devices, the use and amount of WiFi access points are also increasing. The mobile devices in users hand is used to detect three or more public WIFI access points position and using the RSS values from these WIFI routers it calculates the current location of the mobile device. The proposed system can find out the exact location of the mobile device under the indoor environment and can traverse to the destination using the navigation function and also can enable the less consumption of the smart mobile battery for the tracking purpose.

The proposed system architecture has shown in Fig 3. The system has one web application and one application running on the smartphone mobile. The smartphone mobile user first downloads the map of the indoor environment for which he wants to enable the navigation. The position of the person is found out by using Received Signal Strength (RSS) values. The RSS is measured in decibel microvolts per meter (dB-microvolts/m). The system takes the assistance from the mobile sensors also for the low battery consumption and the more accurate location of the smart mobile in the indoor area.

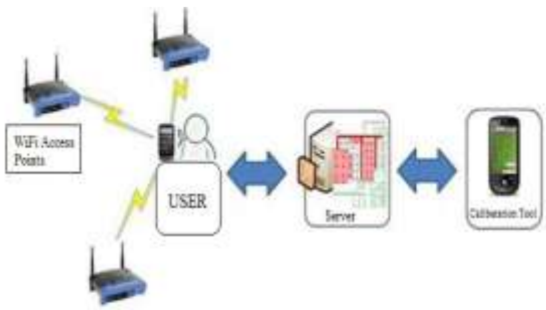

Fig 3: Proposed System Architecture.

In the environment developer can't guess the user behavior, the user might be at one position, or he can take turns, or the speed variation, all these behavior can be pointed out using the accelerometer and the orientation sensors. These sensors send the location samples to the server, and those are plotted on the map, and the trajectory is achieved. The mobile sensors and the WiFi routers can be utilized for the indoor localization because of their high accuracy and less consumption of the battery.

The mobile device has the number of the sensors embedded within it, but for this system, it uses the accelerometer and the Gyroscope. It calculates the distance value to plot the mobile device location and to check the movements of the user. To test the speed and the path changes, system takes the sensor values. The Magnetometer helps in analyzing reference direction towards the gravity. WiFi access points are used for identifying the user client location by using the RSSI algorithm. In the indoor location with each WIFI routers, there are some characteristics. The system will be using the strength that is the level and the frequency for the calculation of the distance of the mobile from the

WIFI routers, but as the system is dealing with the accurate location finding and also less consumption of the battery, it takes the assistance from the mobile sensors.

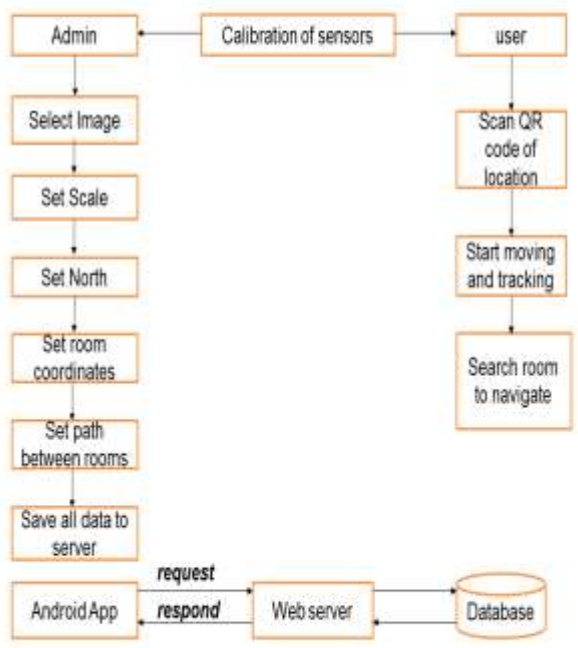

Fig 4: Block Diagram of Proposed System.

The flow of system architecture diagram of the indoor tracking system is explained in Fig 4. The system mainly consists of two actors, one is the admin, and other is the user. Initially, the admin selects the image of room in which the user is going to track owns location. In second step admin needs to set the scale and north direction. He has to adjust the room coordinates according to X and Y co-ordinates. Admin then sets the path between different places present in map. The user tracks his location and movements with the help this route. After building this M-Map admin has to save all this data on the server. The user, on the other hand, has to scan the QR code of location where he is standing. Once he selects the site, he has to download the M-Map of that site from the server. Once the map is downloaded, user can track and locate his location on the map with the help of his mobile device.

IV. Mathematical Model

S= {S, s, X, Y, T, f_{main}, DD, NDD, f_{friend}, memory shared, CPU_{count}}

- **S (system)**:- Is our proposed system which includes following tuple.
- **s (initial state at time T)** :-GUI of wireless indoor tracking. The GUI provides space to enter a query/input for the user.
- **X (input to system)**: **-** Input Query. The user has to first enter the query. The query may be ambiguous or not. The query also represents what user wants to search.
- **Y (output of the system)**: **-** List of URLs with Snippets. The user has to enter a query into wireless indoor tracking then wireless indoor tracking generates a result which contains relevant and irrelevant URL's and their snippets.
- **T (No. of steps to be performed)**:- **6**. These are the total number of steps required to process a query and generates results.
- **f_{main}(main algorithm)** : **-** It contains Process P. Process P contains Input, Output and subordinates functions. It shows how the query will be processed into different modules and how the results are generated.
- **DD (deterministic data)**: **-** It contains Database data. Here we have considered Rooms information, floors information, route information i.e. Database which contains a number of rooms information. Such as routes uploaded by admin will be shown to users when requested as a result.
- **NDD (non-deterministic data)**: **-** No. of input queries. In our system, user can enter numbers of queries so that we cannot judge how many queries the user enters into the single session. Hence, Number of Input queries are our NDD.
- **f_{friend}**: **-** WC and IE. In our system, WC and IE are the friend functions of the main functions. Since we will be using both the functions, both are included in the f_{friend} function. WC is Web Crawler which is a bot, and IE is Information Extraction which is used for extracting information on the browser.
- **Memory shared**: **-** The database will store information like the list of receivers, registration details, and numbers of receivers. Since it is the only memory shared in our system, we have included it in the memory shared.
- **CPU_{count}**: **-** 2. In our system, we require 1 CPU for server and minimum 1 CPU for the client. Hence, CPU_{count} is 2.

Subordinate functions:

Identify the processes as P.

S= {I, O, P....}

P= {SM, SR}

Where,

- SM is floor site.
- SR is site route.
- P processes.

SM= {U, MAX, SC}
Where,

- U= x, y co-ordinates for rooms
- MAX = {1, 2, 3, … , n}
- SC site created with number of rooms.

SR= {SC, Triangulation Algorithm, Info}
Where,

- SC is input which contains rooms and path information

Triangulation algorithm is used to calculate user's current x, y co-ordinates from the current physical location over site map on the phone.

V. RESULT AND DISCUSSION

The experiment was done to check the accuracy for indoor location. The table 1 showed the results of actual distance and calculated distance between the mobile device and AP, and also the difference between them. The table 2 consists of the gained signal strength at the particular distance. The Received Signal Strength (RSS) is calculated in dBm (decibel-milliwatts). The results were obtained from the single access point.

TABLE 1: RESULT ANALYSIS TABLE.

Sr No	AP Number	Actual Distance	Calculated Distance	Difference
1	1	7	5	2
2	2	10	12	-2
3	3	15	13	2
4	4	4	4.5	-0.5
5	5	6	8	-2
6	6	7	6	1
7	7	20	17	3
8	8	16	15	1
9	9	18	19	-1

The results of the first table were obtained from nine access points from different floors. The values of actual distance and calculated distance between mobile user and access points are measured and compared. The comparison does not show the major difference between the actual and calculated distances. The actual distance is measured physically, by using measuring equipment's, while the calculated distance is measured by the system. The application is developed which shows this calculated distance. Results are shown in the following table, and its graphical representation is also shown in Fig 5.

The graph shows the comparison of actual and calculated distance. The difference between actual and calculated distance is very low. The X axis in the graph represents the access point number, and the Y axis represents the distance in meters. The blue line in the graph represents the actual distance, and red line represents the calculated distance.

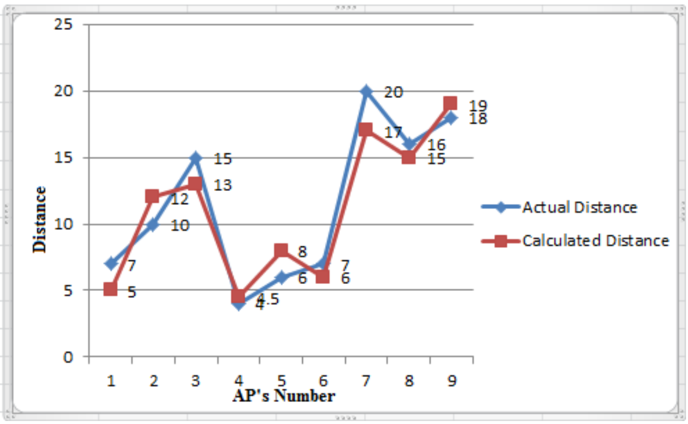

Fig 5: Calculated distance versus Actual distance.

The graph shows the comparison of actual and calculated distance. The difference between actual and calculated distance is very low. The X axis in the graph represents the access point number, and the Y axis represents the distance in meters. The blue line in the graph represents the actual distance and red line represents the calculated distance.

TABLE 2: RSS AT PARTICULAR DISTANCE

Sr. No	Distance (m)	RSS (dBm)
1	1.5	-53
2	5	-60
3	9	-70
4	14	-79
5	25	-86

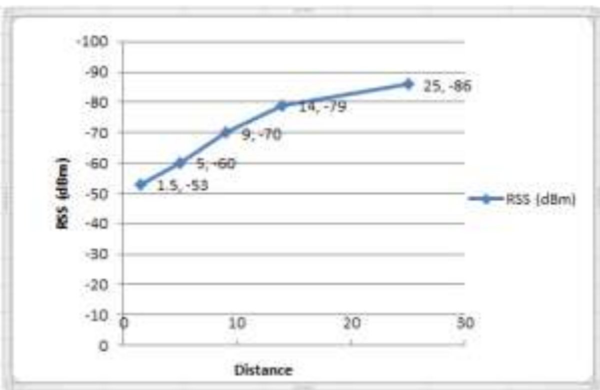

Fig 6: RSS verses Distance

Table 2 shows the distance and amount of RSS at that distance. The distance is calculated in meters whereas the RSS is calculated in dBm (decibel-milliwatts). The graph of distance verses RSS is shown in fig 6. The x-axis shows the distance in meters and y-axis shows the RSS in dBm.

VI. Conclusions and Future Work

The system mainly introduces a new tracking system that relies on Wi-Fi and mobile device. The main aim is not only to make the best utilization of the existing infrastructure available in an organization but make the deployment of the system most commercially viable by using technologies that are already available to the consumers.

In the future, the system can be integrated with the outdoor tracking and positioning to form the complete system which will help the user to enable the tracking for both indoor and outdoor locations. An indoor system for user and device tracking for security reasons can also be the future scope of the system.

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