Indoor Object Localization Based on IPS: Wi-Fi Trilateration for Smartphones

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Abstract:- **Indoor positioning system is a phenomenon which positions an object onto an indoor system in real time. Lots of research is being done since last decade for development of real-time Indoor location systemto provide location information for indoor applications. The paper provides technique of developing an Android Application which communicate with Wi-Fi enabled smart phones and they provide the application with RSSI (Received Signal Strength Indicator) and TDOA (Time Difference of Arrival). Then using these parameters, the range can be determined of which the Smartphone is present from the router. Triangulation is then done by using a mathematical principle called Trilateration. We then using a two dimensional Cartesian Coordinate system, map the position of the smartphone in indoors with their respective plan and provide the user for their desired destinations to go to. After getting the input, the phone then shows the Points of Interest (POI) in the map accordingly to provide the destination that the user requires.**

Keywords: Wi-Fi, IPS, Trilateration, Signal Propagation, RSSI, TDOA, SELFLOC, ROC.

I. INTRODUCTION

Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil, and commercial users around the world.

The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.The design of GPS is based partly on similar ground-based radio-navigation systems, such as LORAN and the Decca Navigator, developed in the early 1940s.The radio signals emitted from the GPS senders and receivers contain very good time and position of the satellite.

The GPS receiver subtracts the current time from the time the signal was sent. The difference is how long ago the signal was sent. The time difference multiplied by the speed of light is the distance to the satellite. The GPS unit uses trigonometry to calculate where it is from each satellite's position and distance. Usually there must be at least four satellites to solve the geometric equations.

To develop a system and its associated solutions for solving the problem of indoor positioning is a promising and complex task. This problem requires of creating maps based on floor plans of indoors, choosing the effective positioning technology and algorithms, deploying the appropriate positioning devices inside buildings. Modern systems like a Navizon or Wi-Fi SLAM can offer much more than just positioning with acceptable accuracy (about 3m).

Indoor positioning techniques using radio signal based approaches for localization can use different wireless technologies like Bluetooth, signals of cellular towers and ZigBee.

The methods using Wi-Fi are more preferred because Wi-Fi networks are prevalent in most public buildings and its **use don't requires an additional infr**astructure and allows determine a location of each user of mobile device and the parameters provided by Wi-Fi improves the techniques to be more precise and accurate in indoor localization.

Trilateration is the determination of absolute or relative locations by measurement of distances, using 2D or 3D geometry. By the using of this method there are three fixed points is needed to determine an indoor position.

The main idea is the calculating distances between access points (AP) and mobile device to provide an area of localization in the basis of a region. This distances can be further made accurate by such signal measurement techniques like a received signal strength indicator (RSS), time difference of arrival of several radio signals (TDoA). Theses Signal parameters provides the necessary requirements to calculate the position of a Wi-Fi enabled Smartphone.

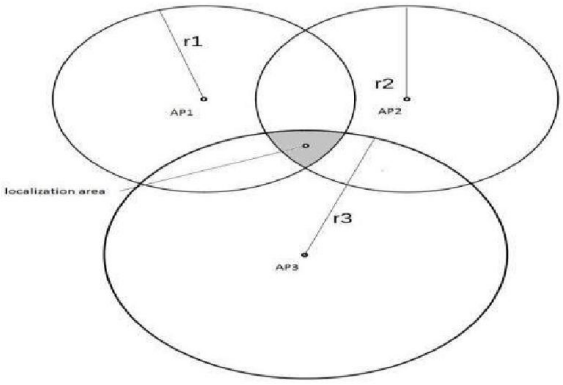


Figure 1. Principle of Trilateration

II.RELATED WORKS ON IPS

A. Indoor Localization based on signal propagation

The simplest way for estimation distances between receiver and transmitter is a using of free-space path loss model:

$$FSPL = 20\log10(d) + 20\log10(f) - 27.55 \quad (1)$$

where, d is the transmitter-receiver separation distance in meters, f is the signal frequency in megahertz, FSPL is received signal strength path loss in dBm.

During the implementation average real RSS measurements for one access point produced by Android application are compared with measurements calculated by equation 1. The measurements made for distances from 1 to 6 meters in 6 points along one line within the room in which Wi-Fi access point is allocated. The signal strength is measured 10 times for each of these 6 points. The area of the room is 25 square meters. The comparison is produced for the network with signal frequency 2412 MHz and is shown in Table I.

Presented in the table comparison results show that the free-space loss model is not effective for using even within the one room because the high difference between real and estimated values. This approach requires another path loss model that would be provide higher accuracy.

TABLE I. THE COMPARISON REAL AND ESTIMATED RSS

Distance, m	Real RSS, dBm	Estimated RSS, dBm
1	33.3	46.0
2	45.7	53.0
3	50.9	56.5
4	51.7	59.0
5	51.8	60.9
6	53.4	62.5

6	*53.4*	*62.5*

B. Indoor Localization based on SELFLOC

There is an introduction of an idea of combining different wireless IPSs because they are not available everywhere, and the coverage of collection will provide a more pervasive services. However, they only use averaging without weights and have no discussions about the rationale. Experiments show that improvements of midpoint of results from K Nearest Neighbor (KNN) and triangulation of Bluetooth signal range from 2%-52%.

It consists of a Selective Fusion Location Estimation (SELFLOC) algorithm and Region of Confidence (RoC) algorithm. Both of them are data fusion methods of IPSs. SELFLOC is essentially a linear weighted averaging calculation. However, they consider little about the nature **of the mechanism of IPSs, and therefore don't discuss** how and what weights should be assigned to each IPS, let alone the context awareness, which we will describe in this paper. On the other hand, RoC can only be used for location determination during triangulations, which is just a little portion among all IPSs. Similar to SELFLOC, they **didn't dive into how to eliminate the erroneous IPSs in** triangulations using context awareness. Another problem of triangulations is that universal obstacles in commercial buildings almost preclude accurate line-of-sight distance measurements, which is crucial in triangulations. This is **also the primary reason that we don't use triangulations in** our WiFiLoc.

II EXISTING MODEL

A. Global Positioning System

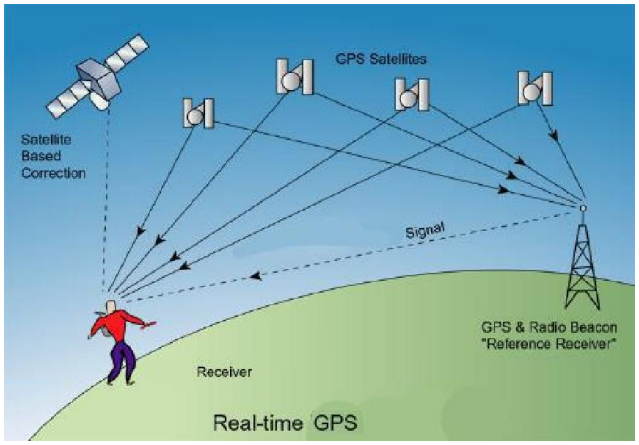
Global Positioning System (GPS) is a worldwide radio-navigation system formed from the constellation of 24 satellites and their ground stations. The Global Positioning System is mainly funded and controlled by the U.S Department of Defense (DOD). The system was initially designed for the operation of U. S. military. But today, there are also many civil users of GPS across the whole world. The civil users are allowed to use the Standard Positioning Service without any kind of charge or restrictions.

B. Working of GPS:

A GPS tracking system uses the Global Navigation Satellite System (GNSS) network. This network incorporates a range of satellites that use microwave signals that are transmitted to GPS devices to give information on location, vehicle speed, time and direction. So, a GPS tracking system can potentially give both real-time and historic navigation data on any kind of journey.

GPS provides special satellite signals, which are processed by a receiver. These GPS receivers not only track the exact location but can also compute velocity and time. The positions can even be computed in three-dimensional views with the help of four GPS satellite signals. The Space Segment of the Global Positioning System consists of 27 Earth-orbiting GPS satellites. There are 24 operational and 3 extra (in case one fails) satellites that move round the Earth each 12 hours and send radio signals from space that are received by the GPS receiver.

The control of the Positioning System consists of different tracking stations that are located across the globe. These monitoring stations help in tracking signals from the GPS satellites that are continuously orbiting the earth. Space vehicles transmit microwave carrier signals. The users of Global Positioning Systems have GPS receivers that convert these satellite signals so that one can estimate the actual position, velocity and time.



C. GPS Tracking System

A GPS tracking system can work in various ways. From a commercial perspective, GPS devices are generally used to record the position of vehicles as they make their journeys. Some systems will store the data within the GPS tracking system itself (known as passive tracking) and some send the information to a centralized database or system via a modem within the GPS system unit on a regular basis (known as active tracking) or 2-Way GPS.

A passive GPS tracking system will monitor location and will store its data on journeys based on certain types of events. So, for example, this kind of GPS system may log data such as where the device has traveled in the past 12 hours. The data stored on this kind of GPS tracking system is usually stored in internal memory or on a memory card, which can then be downloaded to a computer at a later date for analysis. In some cases the data can be sent automatically for wireless download at predetermined points/times or can be requested at specific points during the journey.

An active GPS tracking system is also known as a real-time system as this method automatically sends the information on the GPS system to a central tracking portal or system in real-time as it happens. This kind of system is usually a better option for commercial purposes such as fleet tracking or monitoring of people, such as children or elderly, as it allows a caregiver to know exactly where loved ones are, whether they are on time and whether they are where they are supposed to be during a journey. This is also a useful way of monitoring the behavior of employees as they carry out their work and of streamlining internal processes and procedures for delivery fleets.

D. Degradation of GPS Signal

Signal multi path — this occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.

Orbital errors — also known as ephemeris errors, these are inaccuracies of the satellite's reported location.

Number of satellites visible — the more satellites a GPS receiver can "see," the better the accuracy.Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.

Intentional degradation of the satellite signal — Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. DoD. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

III. PROPOSED MODEL INDOOR POSITIONING SYSTEM

A. Trilateration

Trilateration is the process of determining absolute or relative locations of points by measurement of distances, using the geometry of circles, spheres or triangles. In addition to its interest as a geometric problem, trilateration does have practical applications in surveying and navigation, including global positioning systems (GPS). In contrast to triangulation, it does not involve the measurement of angles.

In two-dimensional geometry, it is known that if a point lies on two circles, then the circle centers and the two radii provide sufficient information to narrow the possible locations down to two. Additional information may narrow the possibilities down to one unique location.

In three-dimensional geometry, when it is known that a point lies on the surfaces of three spheres, then the centers of the three spheres along with their radii provide sufficient information to narrow the possible locations down to no more than two (unless the centers lie on a straight line).

B. Wi-Fi trilateration based on RSSI measurement

In presented paper signal strength levels was measured by distance of three access points allocated in the three rooms within the floor. This data are collected to distance estimation for trilateration method described above. These measurements are made in 15 points at the 1 meter interval for each access point using developed Android application. This application found three different access points by MAC addresses and measured the RSS levels 10 times for each of 15 distances for every access point. The RSS level changes at time therefore it is necessary to use its average value. The AP RSS levels are displayed in the Table II.

TABLE II. THE RSS MEASURE RESULTS FOR THREE ACCESS POINTS

Distance, m	AP1 RSS, dBm	AP2 RSS, dBm	AP3 RSS, dBm
1	33.3	38.8	55.3
2	45.7	43.1	50.3
3	50.9	48.9	65.7
4	51.7	55.2	61.2
5	51.8	75.1	62,5
6	53.4	75.5	66.4
7	57.8	76.4	70.5
8	62.4	80.8	72.3
9	65.7	80.8	74.7
10	62.9	76.0	78.0
11	72.9	88.6	76.0
12	72.7	88.2	86.0
13	63.9	91.0	79.3
14	74.0	91.9	85.8
15	76.7	92.1	82.5

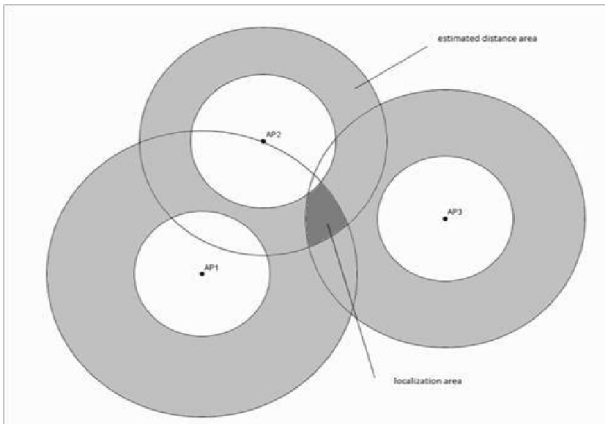


Figure 3. Principle of Trilateration

Proceeded measurement points may be selected for distance estimation as reference points. The reference points are the points with RSS level difference more than observational error calculated for each of 15 measurement points. Thus it is possible to determine the distance by the RSS as a segment between two values (Fig. 2). The observational error is calculated by formula:

$$\Delta = \sqrt{(\sigma \cdot t)^2 + A^2}$$

where, is the observational error in dBm, is the standard deviation divided by square root of number of measurements, is the quintile function of Student's t-distribution, is the observational error of the mobile device.

For localization the Android-based application is used that calculates an intersection of circle areas corresponding to estimated RSS level. This application uses java.awt library for building geometrical primitives and founding these intersections.

C. Parameters

IPS systems combine trilateration with a measurement called time difference of arrival (TDOA) over a network of Wi-Fi Smartphones.TDOA measures the relative time delay of signals arriving at different intervals of time between the Smartphones and can be used with trilateration in 802.11 networks. Because time is proportional to the distance traveled, the distance to each sensor within range can be estimated and,

consequently, the location of the client can accurately be identified. In addition to TDOA measurements, received signal strength indication (RSSI) can be used to measure the RF Signal Strength between transmitter and receiver to calculate distance and identify the position of the smartphone.

D. Android Application

An Android based Application is created in a smart phone which communicates with the Wi-Fi Hotspots which will be placed in indoors in a formation such that it is fixed at all times in a constant place. Then, the Wi-Fi should be enabled in the Smartphone and connect with the Wi-Fi hotspot with a unique ID.

When the Application is switched on, It sends a distress Wi-Fi broadcast signal to the nearest Wi-Fi Hotspots placed in such a way that smart phone will be in range with 4 Wi-Fi Hotspots at all times so that when any one of the Hotspots got damaged, still the tracking can be done with ease. After, receiving an acknowledgement from the three nearest Wi-Fi Hotspots, the calculations of RSSI and TDOA will be done and so from that calculated data, we can get the result from the phone that it is at what distance from the sensors. Then using the calculated data, we use the method of Trilateration to accurately find the position of the smart phone with an error distance of up to ~0.5m.

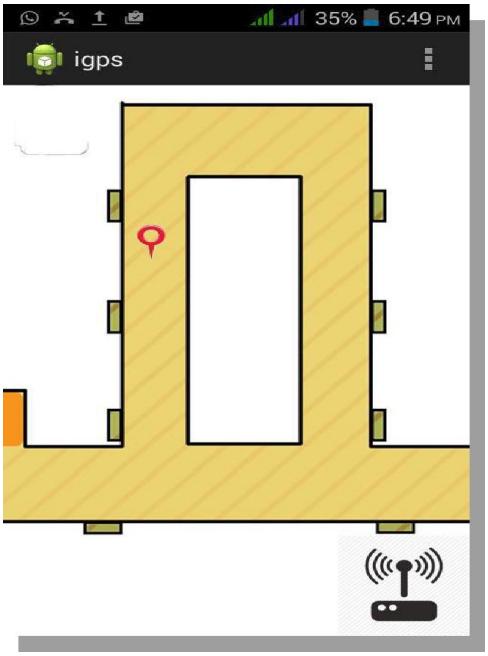


Figure 4. Android Application

Then, the next step is to receive the input from the user for their desired destination to go to. After getting the input, the phone compares to the list of Points of Interest (POI) kept already **stored in the phone's** database and then points the user to show the desired destination and can be reached directly.

IV. CONCLUSION

In the initial round of experimentations, the results are crude and still have many untested cases. The probability of finding the correct match for the fingerprinting method can be significantly improved by incorporating certain database correlation algorithms such as K nearest neighbors, probabilistic algorithms like Hidden Markov Model or fingerprinting. There are difficulties in the current system to compute an accurate elevation using the trilateration method.

Main obstacle to designing an algorithm for smart phones is the limitations of the phones themselves. One major limitation for phones is battery life. This is in fact the single largest obstacle to designing more complex algorithms, as we cannot insist that the user constantly be scanning Wi-Fi networks in order to localize, as that would be an enormous strain on battery consumption. One aspect of phones that we could not account for at all was dealing with the wide variety of phones and corresponding hardware, putting limits on how much we could trust the data given to us. Finally, the computing and memory requirements have to be taken into consideration. While it is true that smart phones are highly capable machines, the users themselves don't want an application that takes gigabytes of data just to improve accuracy in localization. Indoor localization on smartphones is critical to enable novelfeatures for location based applications. However, existing approaches have yet to prove that they can satisfy what isdesiredin many business scenarios. Due to the prevalence of Wi-Fi infrastructure, it is imperative to study the accuracy that Wi-Fi localization can practically achieve on smartphones.

V. FUTURE WORKS

When it comes to Security and Privacy of a Confidential Building such as Government Organizations and Military Bases, There comes a problem such that anyone can see the indoors of the Buildings easily from a remote location. This issue will be overcome by us in the future by implementing protocols for authentication of a

specific person or an specific organization or subsidiary organization who is in need of the information of the indoors of the Main Organizations.

The Future Applications where IPS prevails are

- Hospitals
- Guided tours of museums
- Shopping mall maps
- School/College campus

VI. REFERENCES

[1] Maxim Shchekotov,"*Indoor Localization Method Based on Wi-**Fi Trilateration Techniques",*** St. Petersbrug, Russia, 2014.

[2]Anupam Mahajan, MadhurChanana,"*Wi-Fi Localization using RSSI in Indoor Environment via a **smartphone",*** Dronacharya College of Engineering,India, 2012.

[3]AnjaBekkelien, Dr. Michel Deriaz, Dr. St_ephaneMarchand-**Maillet, "***Bluetooth Indoor Positioning***" 2012.**

[4]HakanKoyuncu, Shuang Hua Yang, "*A Survey of Indoor Positioning and Object Locating Systems***",** 2010.

[5] http://www.doc.ic.ac.uk/teaching/distinguished-projects/2013/a.chandgadkar.pdf

[6]http://www.eetimes.com/document.asp?doc_id=127836 3

[7] http://gps.about.com/od/glossary/g/trilateration.htm

[8] http://www.pocketgpsworld.com/howgpsworks.php