Modeling of Indoor Positioning System using Spanning Tree Algorithm

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Abstract: **Indoor positioning systems have become very popular in recent years as asset and indoor tracking. In order to provide location information for indoor applications and context-aware computing, a lot of research is being done since last decade for development of real-time Indoor location system. This paper provides an overview of developing an Application based on tracking User Info and Location. The application will communicate with the Wifi - Infrared Adapter using Wifi which in turns communicate with sensors by Infrared and use the information to locate the smart phones in indoors. The sensors will sense these signals and triangulate the smart phone using trilateration algorithm. Then the required destination will be given onto the smart phone and the path to the destination will be calculated by the PIR Sensor by using Spanning Tree Algorithm.**

IndexTerms - **Triangulationl, Wifi, itemset, BTLE, IndPs.**

I. INTRODUCTION

Global 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. Navigation equation is used to compute the location of the server. GPS are generally not suitable to establish indoor locations, since microwaves will be attenuated and scattered by roofs, walls and other objects. For example by using GPS, one cannot identify where ICU unit in a reputed Hospital is. However, in order to make positioning signals ubiquitous, integration between GPS and indoor positioning can be made.

Indoor Positioning System (IPS) is a solution based on magnetic, other sensor data or a network of devices used to wirelessly locate objects or people inside a building. Trilateration algorithm is used here to compute the distance.

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 Fig. 1 of three dimensional geometry, when it is known that a point lies on the surface of three spheres, then the centers of these 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).

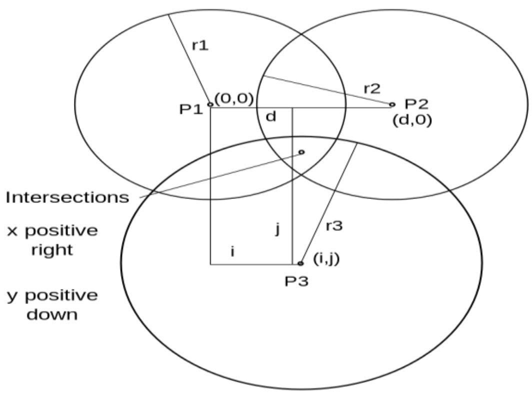

Fig. 1. Triangulation of spheres

The intersections of the surfaces of three spheres is found by formulating the equations for the three sphere surfaces and then solving the three equations for the three unknowns, x, y, and z. To simplify the calculations, the equations are formulated so that the centers of the spheres are on the z = 0 plane. Also, the formulation is such that one center is at the origin, and one other is on the x-axis. It is possible to formulate the equations in this manner since any three non-collinear points lie on a unique plane. After finding the solution, it can be transformed back to the original three dimensional Cartesian coordinate system.

We start with the equations for the three spheres:

$r_1^2 = x^2 + y^2 + z^2$

$r_2^2 = (x-d)^2 + y^2 + z^2$

$r_3^2 = (x-i)^2 + (y-j)^2 + z^2$

d is the x coordinate of point P2.

We have to subtract it from x g-to get the length of the base of the triangle between the intersection and r2 (x, y, z are coordinates, not lengths).

We need to find a point located at (x, y, z) that satisfies all three equations.

II. RELATED WORK:

What is a Global Positioning system?

Global 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. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver.

Working Methodology of GPS:

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

GPS Satellite System

24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. They are constantly moving, making two complete orbits in less than 24 hours. These satellites are travelling at speeds of roughly 7,000 miles an hour.

GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there's no solar power. Small rocket boosters on each satellite keep them flying in the correct path.

GPS Signal

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signals travel by line of sight, meaning they will pass through clouds, glass and plastic but will not go through most solid objects such as buildings and mountains.

A GPS signal contains three different bits of information - a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information. Ephemeris data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or **unhealthy**), current date and time. This part of the signal is essential for determining a position. The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

Limitations of GPS

For all of their applications — from portable navigation devices, to self-driving cars, to cruise missile targeting — the American Global Positioning System and its Russian cohort GLONASS have two fundamental flaws: They don't work indoors, and they only really operate in two dimensions.

Now, these limitations are fair enough; we're talking about an extremely weak signal that has travelled 20,200km (12,600mi), after all. Passing through concrete and other solid obstacles is hard enough for a strong, short-range cellular signal — we can't seriously expect a 50-watt signal traveling 12,000 miles to do the same. Detecting a GPS signal on Earth is comparable to detecting the light from a 25-watt bulb from 10,000 miles.

The situation is a little more complex when it comes to detecting a change in altitude; GPS and GLONASS can measure altitude, but generally the data is inaccurate and too low-resolution (on the order of 10-25 meters) for everyday use. Even with these limitations, though, space-based satellite navigation systems have changed almost every aspect of society.

III. INDOOR POSITIONING SYSTEM

What is an Indoor Positioning system?

An indoor positioning system (IPS) considers only indoor environments such as inside a building. The location of users or their devices in PNs can be determined by an IPS by measuring the location of their mobile devices in an indoor environment. Dempsey [2] defines an IPS as a system that continuously and in real-time can determine the position of something or someone in a physical space such as in a hospital, a gymnasium, a school, etc. [3]. From this definition, an IPS should work all the time unless the user turns off the system, offer updated position information of the target, estimate positions within a maximum time delay, and cover the expected area the users require to use an IPS. An IPS can provide different kinds of location information for location-based applications required by the users.

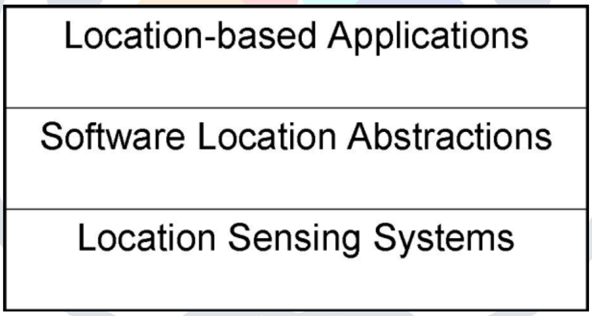

Fig 2. Location-aware Computing System Architecture

Working principle of indoor positioning system:

Indoor navigation is an important enabling technology for applications such as finding a conference room in an office building, safety egress during an emergency or targeted retail advertisement in a shopping mall. While GPS or cell signals are commonly used for navigation in an outdoor environment, robust and accurate indoor positioning remains as an unsolved problem.

Because of the lack of reliable GPS signals inside a building, researchers have explored the use of Wi-Fi beacons, magnetometer, vision or ultrasound, to name a few, for coarse level indoor positioning. But few of them have achieved the needed meter-level accuracy for the above mentioned applications. Besides, Wi-Fi and other infrastructure assisted approaches rely on installation of beacons. Other approaches rely on inertial sensors (or IMU, short for inertial measurement unit) to track a user by continuously estimating displacement from a known location. The so-called pedestrian navigation system (PNS) is an instance of such a dead reckoning approach, without the need for infrastructure assistance. While most of these existing PNS approaches rely on a dedicated sensor device on the user body for tracking, few has exploited the now widely available Smartphone with Wi-Fi beacons for indoor positioning, with acceptable accuracy.

Indoor positioning and navigation system can be used in smart phones and tablets which relies on the synergistic fusion of different indoor localization techniques: it uses Bluetooth Low Energy (BTLE) 4.0 technology for the installed sensors acting as broadcasters merged with others effective technologies such as a novel RSSI fingerprinting approach used in conjunction with other patent pending intelligent algorithms.

A fast convergence and position estimation algorithm is proposed to localize more precisely the user, in real-time, inside an indoor building. All the logic works inside the smart phone/tablet, so the presence of a remote (online) infrastructure during the localization is not needed. The number of sensors to be deployed in each room depends on the room size. These sensors are very cheap and it is possible to manage a 50 m2 room with only 3 sensors with a cost of about 20$ per sensor. The accuracy of the described approach goes from an error of 2 meters in worst cases (the 13% of time) to 0 meters of error (the 28% of time). In average the system has about 0.4 ~ 0.9 meters of error for most of the time.

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.

Overcoming the current limitations from the research to our proposed model:

The research tells that by using the Wi-Fi systems, we can't be able to correctly track the position of the Smart phone in Indoors. But, we propose a system consisting of some inertial algorithms based on trilateration in which Wi-Fi band can be used to Track the position of the Smartphone and moreover provide the functionality to direct the user to his particular destination in Indoors.

Nearest Wi-Fi Enabled sensor

This is the simplest method, though by itself, it is the least precise. This capability, supported by most wireless network vendors in their management systems, determines the 802.11 access point (AP) to which a client device is associated. It assumes that this sensor is the closest sensor to the device. It then computes how far the signal radiates.

The diameter of the 360-degree radiation "cell" surrounding the sensor (in three dimensions, mind you) is as precise as this method alone gets, even presuming that the client does indeed associate with the nearest sensor. If an 802.11b/g AP has approximately a 100-by-100-foot coverage area, for example, the nearest-sensor method tracks the client to within a 10,000-square-foot area. Note, though, that a client might associate with a sensor a bit farther away if the nearest one is overloaded or its signal strength is otherwise not as strong.

Trilateration

The nearest-sensor measurement can be combined with others to pinpoint location more precisely. Trilateration measures the distance between sensors or other reference points, rather than the angles between them.

In geometry, 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.

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TDOA and RSSI

On the cellular side, GPS systems combine triangulation with a measurement called time difference of arrival (TDOA) over a network of satellites. TDOA measures the relative time delay of signals arriving at different sensors and can be used with trilateration in 802.11 networks, too. 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[9]. In addition to TDOA measurements, received signal strength indication (RSSI) can be used to measure the RF power loss between transmitter and receiver to calculate distance. To date, GPS isn't used much in 802.11 WLANs because GPS chipsets are expensive, compared to using information radiating from a Wi-Fi client, and satellite reception within buildings can be iffy.

RF fingerprinting

A more sophisticated category of location tracking used in 802.11-based WLANs is c alled as RF fingerprinting. This technique uses intelligent algorithms to improve location-tracking precision by accounting for the environmental effects - such as object, human, mirrors, windows, attenuation and multi-path - on the wireless signal. A "fingerprint" of the wireless environment is calculated by a physical walk-around using a handheld spectrum analysis device. These measurements are later compared to deviations in the real-time environment to locate the client device.

IV. Proposing model

We create an Android based Application named IndPS (based on IPS) to a smart phone which communicates with the D-link ADSL Wi-Fi routers which will be placed in indoors in a cluster formation which altogether knows the distance between every router in them.

When the Application is switched on, It sends a distress Wi-Fi broadcast signal to the three nearest Wi-Fi Sensors placed in such a way that smart phone will be in range with 4 Wi-Fi sensors at all times so that when any one of the sensors got damaged, still the tracking can be done with ease. After, receiving an acknowledgement from the three nearest Wi-Fi Sensors, 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.

System architecture

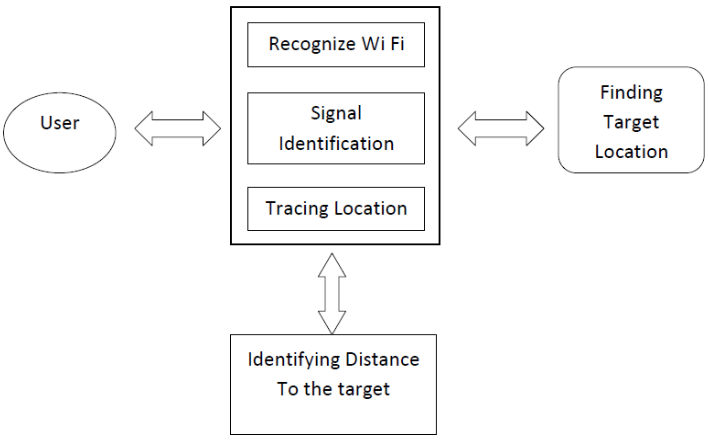

Fig. 3. System architecture

Fig. 3 shows the complete architecture of the proposed system. User identifies the hot spot in the indoor positioning system and calculates distance to provide target location of the user by recognizing the WiFi signal. Point of interest is calculated by using trilateration method.

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 calculates the path based on the Points of Interest (POI) kept already stored in the phone's database to the nearest one so that the user can reach the destination correctly and accurately[10]. The calculation of the destination path can be found out by using Spanning Tree Protocol as it provides a result with the shortest path and the easy way to reach the destination.

The whole application will be integrated on to Google Maps who has IndPS. The Integration will be done by providing the Whole data of an Indoor of a Location to a specific Latitude-Longitude to that particular location in the GPS in the Google Maps so that when a user wants to see where his indoor destination is present from anywhere in the world, He can see it by using IndPS with the integration of IndPS.

5. Evaluation

Wifi Router is used to identify mobile signals so that distance can be calculated by trilateration method.

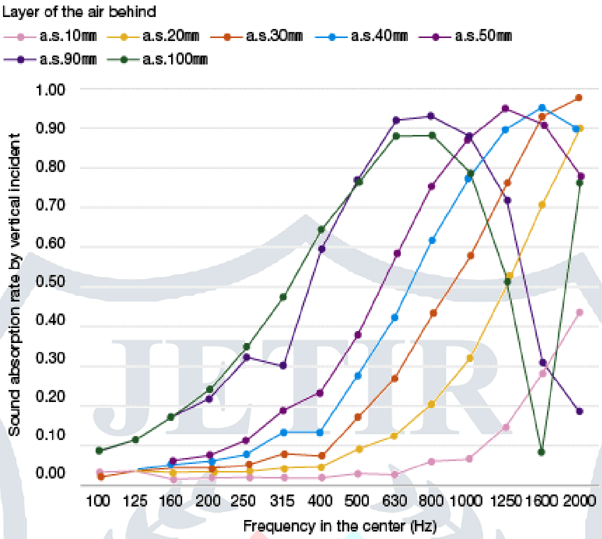

Fig. 4 Comparison of Run-time Performance on Indoor position using Wifi router

Instead of using a three medium to estimate the locations of the targets, combining some positioning technologies can improve the quality of positioning services. Similarly an alternate sensor can be fixed so that it can be used when any of the sensors is currently inactive. Fig 4 shows the performance comparison.

It is asked with the users to count how many steps they were walking and stop when they reached the target number of steps [4]. It was asked them to do this twice and averaged the results for all the ten samples. Table 1 shows the results we obtained from this investigation.

Table 1. Detection accuracy of Infrared Adapter in indoors.

Number of steps	Steps detected (Average)	Range
5	5.5	4-6
10	9.3	6-13
25	22.3	18-27
50	45.4	38-51

Ultrasonic and Infrared techniques can be integrated with RFID techniques. Better indoor planning and positioning of the sensors can also coupled with these techniques to increase the accuracy levels.

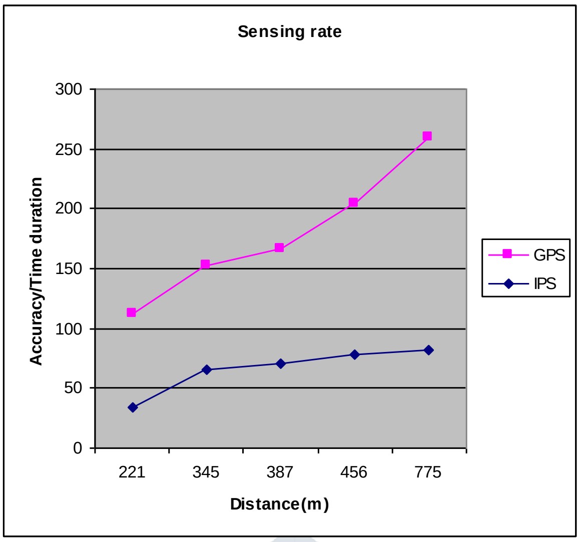

Fig 5 Comparison of Performance on Indoor position system with GPS

Table 2, below, was prepared to overview and compare various positional systems. It was aimed that the reader would have a comprehensive view of these systems and would decide which one to use for his/her purpose. If the accuracy and the cost are the most important parameters, then the systems using ultrasonic techniques are the desirable systems according to Table 2.

Table No: 2. Detection accuracy of Infrared Adapter in indoors.

	IPS	GPS
221	34	78
345	66	87
387	70	96
456	78	126
775	82	178

VI CONCLUSION

The determination of 3D positions of people and objects in indoor environment is an hot topic . People would like to know their positions in large buildings to a great accuracy . As discussed in this paper there are many attempts to define the 2D and 3D positions of objects by using ultrasonic , infrared and RF technologies. In this article, we describe the concept of IPSs and introduce the types of location data offered by IPSs.

Applications benefiting from indoor location include:

- Hospitals
- School/College campus
- Guided tours of museums
- Shopping mall maps
- Public building maps
- Warehouses
- Multi-storey indoor parking.

VII 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.

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