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Indoor Positioning System: A Next Generation of Awareness System

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Abstract:
Currently for determining routes and tracks for various purposes is mostly done by using global positioning system (GPS) but there is no system which helps us to keep track of human density in public/ private places, offices, institutes, etc which proves to be useful for emergency situations, for public management, and even security related applications. In the era of digitization there is an increase in use of internet connections and personal digital assistants (PDAs). These systems can help us to make efficient Indoor Positioning System (IPS). Thus, increasing demand for location based services inside buildings has made indoor positioning a significant research topic. This study deals with indoor positioning using the combination of Wireless Ethernet IEEE 802.11 standard (Wi-Fi) and Wireless Surveillance Cameras in various buildings to design Video Based Indoor Positioning System (VIPS).It also helps in making great use of Bluetooth Low Energy Beacons to implement IPS.

Key Terms: Global Positioning System (GPS), Indoor Positioning System (IPS), Video Based Indoor Positioning System (VIPS), Received Signal Strength (RSS), Bluetooth Low Energy (BLE).

I. INTRODUCTION

Positioning Systems are navigation systems that provide location information of a mobile device, anywhere within the coverage network using some signaling system to gauge the location by measuring various signal parameters and exploiting signal properties. As people travel to new places every day, remembering every route is tedious task. But with the advent of technology, and easy access to smartphones, positioning system has been a revolutionary step towards helping people with exploring unknown realms of the world.

Global Positioning System (GPS) using satellite infrastructure has been very successful so far with millions of userscurrently using this technology.

DISADANTAGES OF GPS-

- If you are using GPS on a battery-operated device, there may be a battery failure and you may need a external power supply which is not always possible.
- Sometimes the GPS signals are not accurate due to some obstacles to the signals such as buildings, trees and sometimes by extreme atmospheric conditions such as geomagnetic storms.
- Does not direct to any particular building floor or any sort of room. Just guides till the given building and not through it.

Now people are focusing on Indoor Positioning System to improve navigations for indoors.Although Wi-Fi has not been designed for positioning, its radio signals can be used for location estimation by exploiting the Received Signal Strength (RSS) values measured in any off-the-shelf mobile device equipped with Wi-Fi facilities – and no additional special-purpose hardware is required.Most of the proposed Wi-Fi indoor positioning systems use either proximity detection via radio signal propagation models or location fingerprinting techniques.

Another method is to place BLE beacons throughout the place and make use of them to guide people through floor or place. The BLE beacons operate on battery and usually have long term battery life.

II. INDOOR POSITIONING SYSTEM

Wireless indoor positioning system is a system to locate objects or people inside a building using radio waves, magnetic fields, acoustic signals, or other sensory information collected by mobile devices. With increasing popularity over recent years, indoor location positioning systems provide a new layer of automation called automatic object location detection. These systems have varied applications like community settlement planning, military applications, surveillance, monitoring, mining, travelling and development of location-based services.

Global Positioning System (GPS), being the most popular technology in location determination, is not suitable for indoor location estimation as users' devices might not have GPS interface, and even if they do, the devices are unable to catch radio waves from satellites if the user is indoor of some building. Moreover, GPS requires a strong computing platform which is not available in sensor networks. Sensor nodes, being lowcomputing power units, can efficiently perform only basic arithmetic operations. The execution of complex arithmetic operation may quickly deplete the battery of the sensor node which is practically an undesirable feature.

BLE Beacons are small devices which can be easily mounted on walls. Their mission is to help Smartphones determine the location. BLE beacons use a battery power supply and consume very little energy. Good beacons can run for years on a single battery charge.

ADVANTAGES OF INDOOR POSITIONING SYSTEM-

- The answer lies within big buildings where some may spend enormous amount of time finding what they are looking for.
- Shopping centres, airports and museums are just some organizations where indoor positioning would bring great benefit to people.
- Can you just imagine that everybody would have an indoor map marked with their current position on a mobile phone? This would definitelyrevolutionise navigation indoor.
- Then, there are of course also benefits for organizations. With indoor positioning systems, organizations can deliver location-triggered content, location-based advertising and much more.

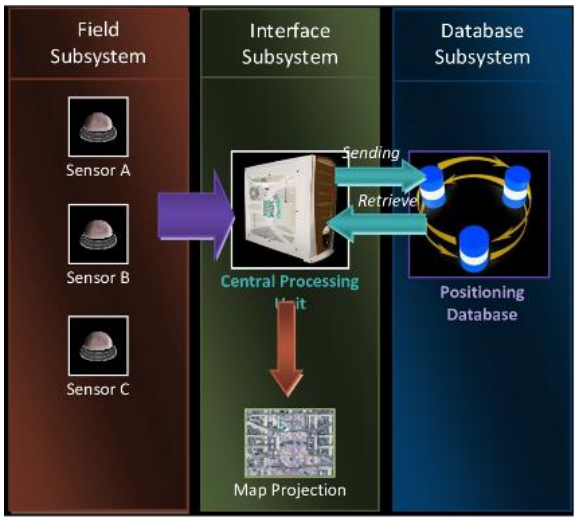

Fig. 1. Basic Architecture of Indoor Positioning system

III. WAYS TO BUILD AN IPS

In order to have a well developed IPS we can use various methods. Let us see these methods-

A. Bluetooth Low Energy

Bluetooth Low Energy (BLE) signals from battery driven beacons are at the core of the indoor location technology. It's one of the latest technologies that has emerged and become an industry standard available on most devices today. It uses so called BLE beacons (or iBeacons) that are inexpensive, small, have a long battery life and do not require an external energy source. The device detects the signal from the beacon and can calculate roughly the distance to the beacon and hence estimate the location.

➢ HOW IT WORKS

1) Positioning the user

BLE beacons are the cornerstones of indoor positioning. With this technology, the device can detect when in range of a beacon and even calculate its position if in range of more than two beacons.

Positioning based on BLE developed in the last couple of years. First prototypes were only able to detect which Beacon is closest to the user, but today we are able to use distance data from many beacons and position the user in 2D space on indoor map. Accuracy does vary depending on circumstances but can be as good as within +-1.5 meters.

This technology will develop further which will be achieved by utilizing as well the use of magnetic field detection, gyroscope, accelerator meter and Near Field Communication (NFC) chips.

2) From the perspective of customer or visitor – Application

Customers and visitors use this technology for navigation and for location-based content reception.For that they use their PDA/s with an app they install. The app provides indoor maps and location specific content automatically.

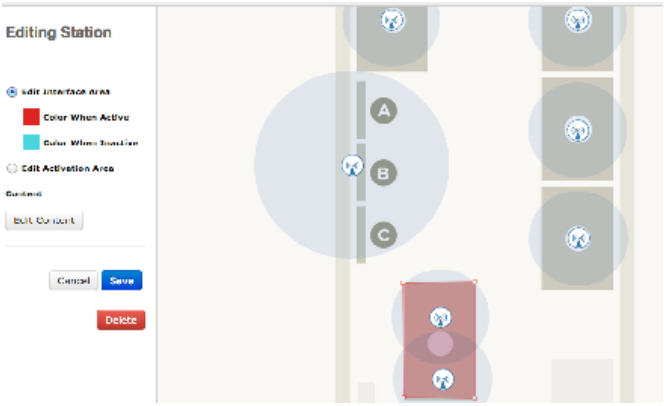

Fig.2. Working of BLE

B. An Indoor Visible Light Positioning System Based on Optical Camera Communications

We implement an indoor visible light positioning system based on optical camera communications, in which the transmitted coordinate data is spatially separated and demodulated by a camera. The receiver's position is calculated based on the coordinates of light-emitting diodes in the real word and in the image.

The IPSs using light-emitting diodes (LEDs) are getting major attention from both academic and industry due to the advantages of high positioning accuracy, license-free operation, no electromagnetic interference and low-cost front-ends, etc. The indoor positioning methods based on visible light communications (VLC) are mainly classified as: triangulation, proximity and image positioning.

- The proximity method is very simple but depends on resolution of grid.
- In the triangulation method, thetarget's position is determined by distances measurement using the received signal strength (RSS), time of arrival (TOA), and time difference of arrival (TDOA) techniques. The transmitter (Tx) and receiver (Rx) must be perfectly synchronized for TOA & TDOA to work perfectly.
- In RSS, the Rx needs to receive signals without any interference from Tx to work accurately.
- The image positioning method determines the position of the Rx based on the coordinates of LEDs in the real word and in the image.
- Most studies work assuming that the coordinates of LEDs in the real word are already known before hand to determining the position of Rx. However, they are unknown in practical applications.
- So, it is important to establish the communications link between the LEDs and the Rx in order to acquire the coordinates of LEDs.

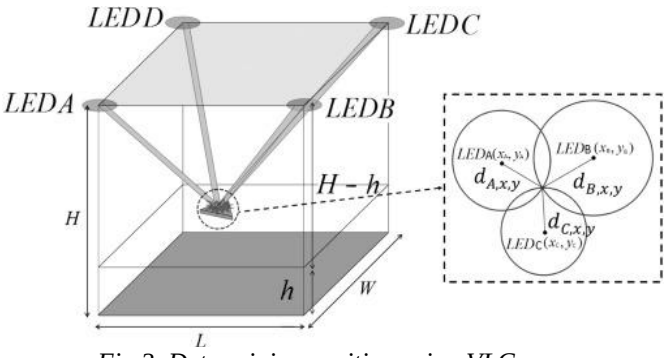

Fig.3. Determining position using VLC

C. RSS Scheme for Indoor Navigation

It is most common for positioningsytems to estimate the unknown receiver's position by exploiting the geometric relations between Tx and Rx and they can be characterised by the measurements used for estimating position, including Received Signal Strength (RSS), Angle of Arrival (AoA) and timing information such as Time of Arrival (ToA), Time Difference of Arrival (TDoA).

RSS is defined as the power measured by a received signal strength indicator circuit, or equivalently reported as the squared magnitude of the signal. If the path loss model is known, it can be used for positioning purposes by relating it with distance.

1) ADVANTAGES

- Relatively cheap.
- Can be achieved using low complexity algorithms [8].
- Doesn't need time synchronization.

2)DISADVANTAGES

- Reference power value at known distance should be accurately measured
- Gives best result only in close distance.

D. Wifi Based Indoor Positioning

With the advancement of wireless and embedded technology, local wireless networks are common, and in times when these technologies have flourished due to smartphones, tablets and other PDAs it can be used for powerful computations and communication capabilities using built-in sensors for various functions. Smartphones serve as best tools to interface users with their surroundings, as users keep their devices with them round-the-clock.

Using Wi-Fi communication for indoor navigation has long been researched and tested, with advanced algorithms. By using dense network of access points, taking RSSI measurements over Wi-Fi signals, determining distance of user's device from individual access points, and finally applying trilateration (Fig. 4.) for accurate position determination renders a close estimation of mobile device's position in indoor setting[8].

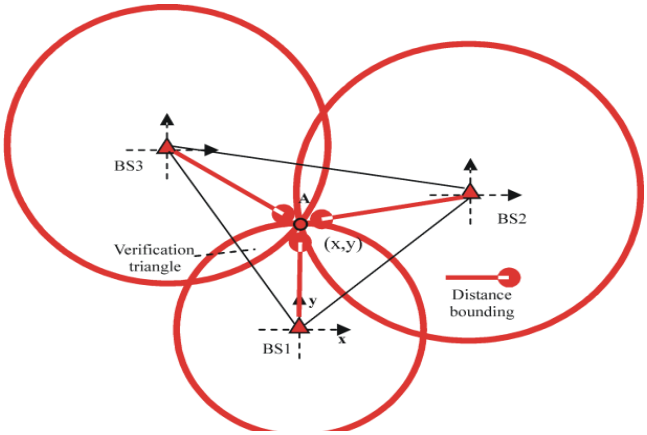

Fig.4. Trilateration method used in Wifi Positioning.

E. Wifi Round Trip Time (RTT)

In Android P Developer Preview 1 (DP 1), Google has added support for IEEE 802.11mc, which allows apps to measure the distance to nearby WiFi access points anddetermine your exact indoor location.The IEEE 802.11mc is more commonly known as WiFi Round-Trip-Time (RTT). Using RTT, apps can measure how long it takes for signals to travel between you and the AP. With a single WiFi access point, all you get from that is a distance measurement. With three or more nearby APs, an app can triangulate your location with an accuracy of 1-2 meters.

WiFi Round-Trip-Time in Android P DP1 does not require your phone to connect to any WiFi access points, and only the phone is used to determine distance, not the APs. This feature is also tied into Android's existing location system to preserve your privacy. Apps using RTT need the location permission, and you must have location services enabled at the system level.

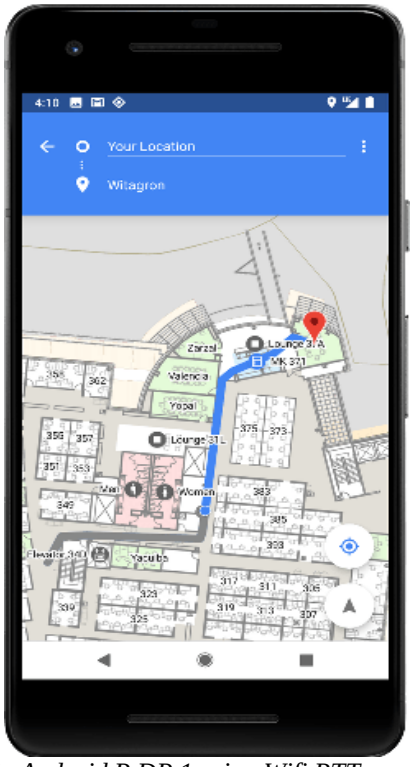

Fig.5. IPS in Android P DP 1 using Wifi RTT

IV. IMPLEMENTATION

These are the steps used to create a context aware indoor application for PDA/s-

1. Uploading the floor plan Floor plan of the site has to be uploaded on the application. The floor plan must be according to scale. In case of less distinctive reference points, a grid can be drawn on floor plan. The grid cell size can be 1.5 meters by 1.5 meters or lessdepending on the floor being drawn. The tool uses MapBox and Here maps for floor plan alignment. The map can be aligned manually or exact coordinates can also be specified. The second option can be used if the context aware application is going to overlay the floor plan on Google Maps.

2. Fingerprinting –

In this step magnetic, Wi-Fi and BLE fingerprints are to be collected. IndoorAtlas[11] provides a map creator application that can be used to collect the fingerprints.

3. Map generation and testing –

It's done after location fingerprinting is completed properly. It is done by the click of a button on either IndoorAtlas's web tool or the android/iOS application. After map generation, testing should be done to check the accuracy. If the accuracy is satisfactory then one can go ahead and create the application. In case of less accurate positioning redraw the floor plan and again upload it in the application.

4. Building the application IndoorAtlas provides an API for localization and for fetching the floor plan. One can place a floor plan overlay on Google maps to render the location of the user.

The location that is rendered by the API is in WGS84 format. This can be converted to image coordinates. An important caution to be taken is to get the user permission for accessing internet, storage, Wi-Fi, Bluetooth and coarse location.

As the region changes, appropriate floor plan has to be downloaded from the IndoorAtlas's server. A region listener that listens to the region change events has been implemented. Two methods on EnterRegion and on ExitRegion have been implemented. IAResourceManager is a helper class that is used to retrieve the floor plan. It has to be instantiated using the create() method. After the floor plan has been downloaded it can be rendered on the Image View. A subsampling ImageView that supports pinch to zoom, panning, rotation and animation support which can display large images.

An app for Smartphone or tablet is required to provide visitors navigation and location triggered content. Organisations usually choose between generic and branded apps. Branded apps are better for promotion of the organisation as they are only for their customers using their content only and brand.

V. APPLICATIONS

With inception of IPS, many people are fascinated by it. Today there are many industries that are investing heavily in development of applications of IPS. Let's have a look at few –

1) A Video-Based Indoor Positioning System (VIPS)

The VIPS [9] system integrates installed surveillance cameras with the IoT to provide highlyaccurate positioning information to indoor people, which efficiently enable smicro location-aware IoT applications and services in smart environments. VIPS can estimate the precise position of an individual and detect the facing direction for each individuals.

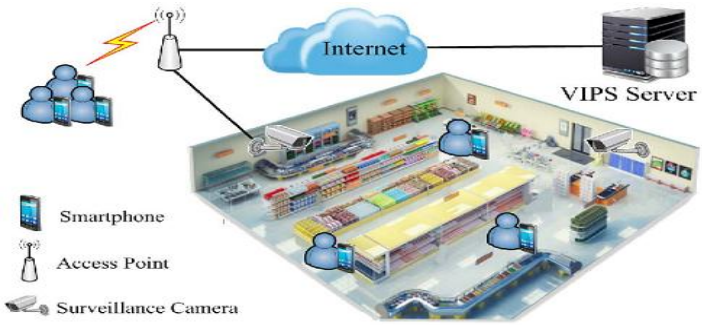

Fig.6. Architecture of VIPS System

Indoor positioning units (IPUs) are installed in different areas, which capture, detect, and broadcast the positioning information of individuals in the monitoring space. The IPU consists of a wireless network interface for communications, a surveillance camera for image capturing, a database for mapping pixels to locations, and a microprocessor for face recognition and pixel mapping.

On the individual side, a mobile handheld unit (MHU) is used by an individual to receive positioning information from the IPU. The MHU consists of a wireless network for communications and a microprocessor for identifier matching. With multiple surveillance cameras installed at different places to monitor the same area, the facing direction of the individual can be detected even if her/his current position is not changed. Fig.7. depicts this.

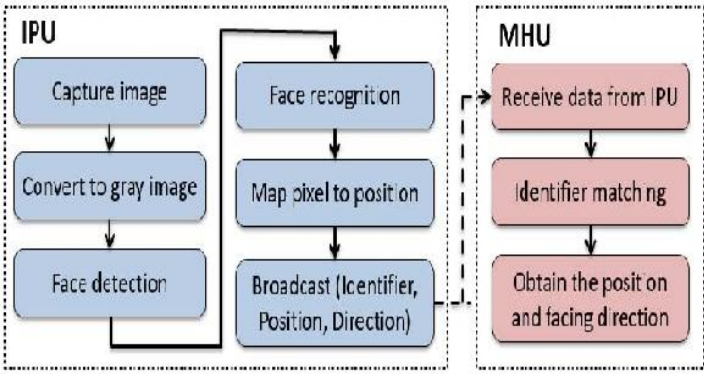

Fig.7 Operation in VIPS

2) Attendance monitoring in classroom using smartphone & Wi-Fi fingerprinting

Academic performance is directly affected by student attendance during the lecture hours. There are existing manual and automated attendance tracking systems that work to ensure that students attend the lectures without fail. However, the practical implementation of most automated systems have drawbacks such as high monetary cost, the need to install specialized hardware, and proneness to fake or proxy attendance. To address this, a novel attendance marking system with which students may mark attendance using their smartphones. While applying facial recognition via the smartphone's front camera to determine the student's identity, the system also makes use of the campus Wi-Fi network to determine the student's location. The proposed system does not require high monetary cost or specialized hardware and yet incorporates adequate foolproof measures to counter fake or proxy attendance.

Wi-Fi signals are only attenuated at walls, and not eliminated. A similar problem arises in the Bluetooth Low Energy (BLE) based attendance marking systems.

To tackle indoor location tracking within the campus, we apply the fingerprinting technique using the campus Wi-Fi network, which avoids need of specialized hardware for the purpose. It requires scanning of Received Signal Strength Indicator (RSSI) values from nearby Access Points (APs) using the smartphones.

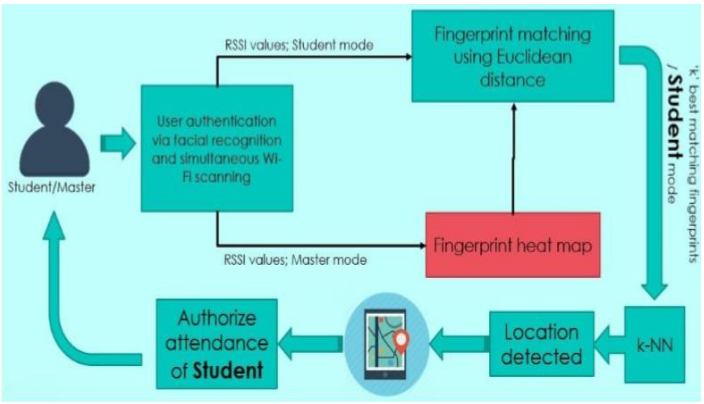

Fig.8. Working Of Student Monitoring System Using Wifi

3) Context Management System (CMS)

CMS is where you prepare floor plan, place beacons, trigger points and control the content. CMS is usually hosted online and maintained by chosen indoor positioning system provider. Different providerare available. Using this in a mall or public place proves to be very efficient as various advertisements, new offers, sales which are ongoing in nearby locations are pushed onto the user's PDA.

It's very helpful in museums, offices, institutes, airports where the distance to go from one place to another is quite far. Also in case of delays at transport stations, the user will get notifications about things he/she can do while waiting. In museums the user can get information off various exhibits that are displayed and can decide from where to start and what will be the next destination.

4) EMERGENCY SITUATIONS

There are many emergency situations where the emergency crew needs to know how many people are present in any given area so that depending on that data they deploy their crew members. But since many times this data is not available, they have to deploy crew based on data collected before the incident happens.

For example consider a situation where due to fire many passengers are trapped at airport while many others are scattered through out the airport in order to seek safety. In such cases by taking looking at the IPS data collected, the emergency crew can deploy number of their members where many people are present and situation is quite dire.

Another example is customer executives present in malls. After a thorough scan of all floors is made, the mall management can obtain which floor has maximum human density and ask their representatives to be assigned accordingly. Due to this all the requirements of a customer are met.

VI. INDOOR POSITIONING FUTURE

The future of indoor positioning is definitely bright with new applications emerging utilizing the technology. BLE beacons are inexpensive, easy to install and easy to maintain thus making this technology available to almost every organization.Many organizations are taking efforts of making use Wifi based positioning system by reducing the amount of signal getting attenuated. The wifi RTT, which is still in development phase will be first of its kind application which all users will be able to use universally. A step further is combination of Augmented Reality (AR) and IPS through Google Glasses so that context regarding messages will be displayed directly on glasses rather than on PDAs.

VII. CONCLUSION

Indoor positioning technologies are beyond the pilot phase and are helping a variety of organizations to improve their customers' experience. There is big potential for this technology within museums, shopping centers, airports, theme parks, conferences and events organizers, basically everywhere, where indoor navigation and location-based content is important.

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