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Indoor Positioning System with Light Fidelity Assistance

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Abstract

With the advancement in technology, there has been a rise in the need of smart homes, smart working premises and advanced recreational spaces. Indoor navigation is one of such technologies which has made living spaces smarter and convenient. Various technologies such as Wi-Fi, Bluetooth, and RFID can be used to provide indoor navigation services. The use of Wi-Fi based indoor navigation allows to locate and track smartphone users within an area, therefore, location-aware intelligent solutions can be applied to increase the ease of access. These location-aware indoor services require real-time indoor localization with high accuracy, which is a necessity to guarantee high quality of service in smart spaces .In this paper we propose a new Wi-Fi based indoor localization technique that can significantly improve indoor positioning accuracy with the help of Li-Fi(Light fidelity) assisted coefficient calibration. The proposed technique combines the existing wi-fi structure along with a new updated Li-Fi framework to provide indoor accurate localization .

Index Terms—Li-Fi, Indoor navigation positioning, Smart buildings, Wi-Fi , RSSI

I. INTRODUCTION

Navigation and positioning are currently highly developed for outdoor purposes using Global Positioning System that employs satellites. But indoor positioning has proven to be difficult as signals from satellites cannot be detected accurately inside closed building. A solution is needed to obtain accurate position information in an easy to set-up way with minimal infrastructure to create indoor maps, especially in shopping centers, hospitals, offices & industrial complexes.

Location based services can be used in various fields such as military, intelligent transportation, environmental monitoring, agricultural production, emergency communications, Medical and health and other fields. Wi-Fi, Bluetooth, ZigBee, RFID, ultrasonic, infrared, ultra-wideband are the widely used tech for indoor positioning.

The constant signal damping with distance is used to calculate location in an area in the Wi-Fi based System.
A Bluetooth-based method uses a Bluetooth low-energy
(BLE) beacon to calculate the location. The RFID method requires an RFID tag and an RFID reader as a method for identifying a user. Bluetooth and RFID based methods have restrictions because they require an additional installation which increases the cost significantly. In particular, the use of RFID is limited because the tag cannot be recognized by a smart device and the range of RFID is also limited. Indoor location recognition using Wi-Fi uses a Wi-Fi AP installed in an existing building, and

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thus there is no need to create an additional environment, and most smart devices have an advantage in supporting Wi-Fi.

Wi-Fi is installed in most indoor areas, it is, therefore, highly utilized, and research on indoor location recognition technology based on Wi-Fi is actively underway. Indoor location recognition methods that can be used for Wi-Fi include triangulation and fingerprinting using RSSI.

II. INDOOR NAVIGATION

GPS satellite signals are not being accurately traceable in case of navigation apps and hence indoor navigation is a popular application of positioning using Wi-Fi. An indoor navigation solution makes sense wherever complex structures are to be found. Especially in airports, railway stations, shopping centers, hospitals, museums, offices and industrial complexes, an indoor navigation app can significantly improve the experience for visitors and employees by getting voice directions to preferred destination & back

Fig : Indoor positioning using Wi-Fi [1]

III. Wi-Fi POSITIONING

Wi-Fi positioning uses several techniques such as triangulation and fingerprinting to locate a connected object or device. Wi-Fi location uses already existing infrastructure and Wi-Fi access points to calculate the location of a device. The device need not connect to the access point but must be able to listen to it. Even though the range of Wi-Fi is small, the signal can be extended upto 150m. The accuracy generally depends on the number of APs nearby and the environment in which they are deployed. The higher the abundance of APs in a given area and the more the precision in their position is obtained, the more accurate the location will be. Wi-Fi can provide about 20m accuracy using existing crowd sourced Wi-Fi infrastructure with no calibration. However, through calibration, surveying and fine tuning, Wi-Fi can achieve 5-8-meter accuracy in indoor environments.

- *Cons of Wi-Fi that can be refined using Li-Fi*

- Inaccuracy in range (5-15m)
- no constant latency times
- use of randomized MAC address when smartphone is not connected to Wi-Fi network

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- incompatible with iOS devices which are popular in the western regions.

IV. FINGERPRINTING

Traditional fingerprinting is RSSI-based, but it is dependent on the recording of the signal strength from various access points in range and storing this information in a database along with the known coordinates of the device in an offline phase. In online tracking phase the RSSI vector at a given unknown location will be compared with the already stored vector in the fingerprint. The closest location will be approximated and returned. Such systems may provide a median accuracy of 0.6m and tail accuracy of 1.3m. Any changes of the environment such as adding or removing furniture or buildings pose a problem to this technique as changing the environment may change the "fingerprint" that corresponds to each location, requiring an update to the fingerprint database.[3]

V. RSSI

RSSI localization involves combining the signal strength received from a device to various access points with a propagation model to calculate the distance between the device and the access point. Trilateration can also be used to determine the relative position of the device using the known location of the access point. Though one of the cheapest and easiest methods to implement, its disadvantage is that it does not provide very good accuracy , because the RSSI measurements tend to fluctuate according to changes in the environment or multipath fading.[2]

Triangulation uses the reference of 3 or more known points on a plane to calculate the relative position of the moving device.

The coordinates of AP1, AP2, and AP3
are defined as (x1, y1), (x2, y2), and (x3, y3) in Fig., the distance from each AP can be calculated using the Pythagoras theorem.

$$D^2 n=(x-xn)^2+(y-yn)^2$$

The received signal strength indicator is substituted in a propagation model to calculate the distance d. This specific propagation model is expressed as (Liu, 2012)

$$P_x=P_0-10n\log(d/d_0)$$

where P_x: received power at node X,

P_0: received power at reference node, d: distance between node X and Wi-Fi transmitter, d_0: distance between reference node and Wi-Fi transmitter, n: a parameter that models the behavior of the environment (Arias, 2004) (Liu, 2012)

The RSSI algorithms are contingent on the fact that a radio signal attenuates as the distance between the emitter increases. If the emitted power is known, measuring the incoming power at the receiver, the distance between the two of them can be estimated as the received power (P_x) in the indoor environments is strongly influenced by multi-path interference and obstacles, the general power balance can be summarized using Equation:

$$P_x=P_0-10n\log(d/d_0)$$

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P_0 is the received power at a distance d_0 from the emitter, d is the distance between the emitter and the receiver and n is a parameter, which models the behavior of the environment (both for obstacle attenuation and multi-path interference). As a matter of fact, this n parameter varies with the environment and with distance (the further the receiver is, the more obstacles the signal will find in its way). If d_0 is small enough, one can expect low variability of the P_0 parameter, but the standard deviation of n will always be high.

The objective of this algorithm is estimating the exact location of the unknown node using only the RSSI measurements and the positions of the beacons. Despite the distance measurements not being reliable, due to errors produced by reflection, attenuation or interference with other signals, this algorithm provides location estimation.
Alternatively, the distance d and parameter n can be expressed as:

$$d=d_0^{\,(P0-PX)/10n}$$

$$n=(P_0-P_x)\ /\ (10\log(d/d_0))$$

VI. LIFI

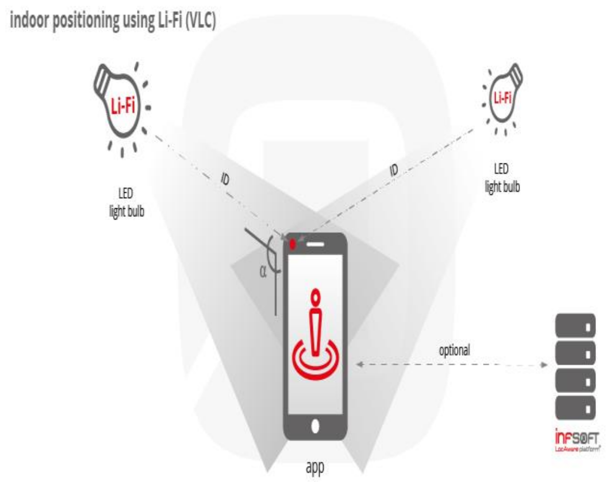

FIG: indoor positioning using Li-Fi

Li-Fi stands for light fidelity. Li-Fi, a derivative of optical wireless communications (OWC) technology utilizes light from light-emitting diodes (LEDs) as a medium to deliver network, mobile, high-speed communication which is similar to Wi-Fi. The principle of Li-Fi is based on sending data by amplitude modulation of the light source in a well-defined and standardized way. Visible light communications (VLC) works by switching the current to the LEDs on at a very high speed which is unnoticeable to the naked eye, thus no flickering is observed. The data is transmitted in the form of binary codes using this activity. It is capable of transmitting data at high speeds over the visible light,

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ultraviolet and infrared spectrums. Li-Fi offers various advantages, most prominently a wider bandwidth channel, the ability to safely function in areas otherwise vulnerable to electromagnetic interference and offers higher transmission speeds.

To overcome the drawbacks posed in Wi-Fi positioning systems a new idea where Li-Fi assistance is used is being proposed in this paper. A prototype is developed based on a transmitter and receiver which are Light Fidelity based along with Arduino Uno as the microcontroller unit to control these. The received sequence maybe decoded with the help of a finite state machine such as Pushdown automata or Turing machine. This system is tested under different levels of ambient lighting as well as average speed of mobility of possible users is considered. The location update was found to be instant and precise. Thus by using the required lighting fixtures inside a building we can instantaneously obtain the location of a user.[4]

VII. WORKING

Upon entering the premise the user may connect to the indoor navigation service if he/she wishes to. Analogous to gps the Li-Fi software also needs to be activated in order to enable the devices light signal sensing. The Wi-Fi signals are received by Wi-Fi antenna of this smartphone or tablet. After the activation of the photo detector the device can identify the identifier of the LED-lamp. The current location can be detected with the region of a particular lamp. Thus, according to the building floor map, the distance between Wi-Fi access point and this identified Li-Fi lamp is obtained . After substituting this distance back to the theoretical equation leads to a derived coefficient value (i.e., parameter n in equation 3). Moving speed of a person inside buildings is not very fast, the derived coefficients can be used in real-time Wi-Fi based localization until the photo detector is triggered again in a different region on a device. The indoor position is computed by the smartphone or tablet based on the RSSI values and calibrated coefficient value according to the trilateration principle.
As there is no need for frequent updation of look-up tables this method is more efficient than the traditional fingerprinting method used in calculating indoor position.

VIII. CONCLUSION

The proposed indoor hybrid Li-Fi and Wi-Fi positioning system can achieve more precise location estimation than existing Wi-Fi based positioning systems and other similar standalone positioning systems. Li-Fi based systems also help to overcome the problem of limited bandwidth in the Wi-Fi systems. The proposed approach is not labor intensive and is user friendly as well. Line of sight is required at all times for transmission. This problem can be overcome with future research and advancement. This solution provides a clean wireless alternative for data transmission at high speeds

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