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Indoor Positioning System using Bluetooth Low Energy

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***Abstract*—The indoor location-based services has become attractive with the fast improvement of indoor position estimation and with the spread of smart phones. Bluetooth Low Energy is one of the most recent advancements for IoT and particularly appropriate for ultra-low power sensors running on Complementary Metal-Oxide Semiconductor coin cell batteries. Bluetooth Low Energy is effective option for indoor positioning frameworks which offers sensible exactness and minimal effort arrangement. An estimation strategy utilizing Bluetooth low energy labels turns out to be most enhancing and promising among different procedures for assessing area on the grounds that a most of advanced mobile phones uses Bluetooth. The BLE tags transmit advertisement packets intermittently, which incorporate one of universally unique identifier, a major and a minor value only identified with every tag. At the point when a cellphone gets the advertisement packet, the Smartphone Indoor Positioning Application initiates the scanning by turning on Bluetooth and detects a BLE tags. In this paper, received signal strength of BLE tags and transmitting power is measured first so as to take position of BLE tag for indoor situating. BLE CY8CKIT-042 is utilized as a BLE tag to arrange the BLE segment. The figured parameter such as RSSI and transmitting power is used to accesses the distance determination between smartphone and BLE tags.**

Keywords—Indoor positioning System, Bluetooth Low Energy, I-beacons, BLE Tags, Received Signal Strength Indicator.

I. INTRODUCTION

The Indoor positioning system (IPS) and Beacon are terms often used interchangeably. Apple's innovation standardnamed as Beacon permits Mobile Apps to listen for signals from beacon tags. In essence, beacon technology permits Mobile Apps to comprehend their position on a small scale neighborhood scale, and transfer hyper-relevant content to users based on location. The underline updating communication technology is Bluetooth Low Energy (BLE). Compared with Wi-Fi, Bluetooth is designed for low power operation. It runs on Complementary Metal-Oxide Semiconductor (CMOS) coin cell battery is easy to install. On the other hand, there is drawback that an extensive number of beacons should be installed as attenuation of the signal is relatively large, and it does not transmit widely compared to the Wi-Fi network [1]. However, since such BLE tags services in cooperation with mobile are being continually spread, in the near future. It is totally based on BLE. BLE tag functions as an indoor positioning system that let activity to advertise their presence to nearby smart phones. With IPS set up, activities can send messages to users when they walk near to BLE tag. IP is standalone system that constantly sends out a Universally Unique Identifier (UUID) using Bluetooth 4.0 Low Energy. User can turn any smartphone device that has a Bluetooth 4.0 LE radio onboard into an IP System. BLE is compatible with iPhones, Android phones, Small PCBs, USBs, MAC laptops, Apple TVs [2].

There are two reasons for the excitement around Indoor positioning system. Most importantly, the technology allows a device to make determinations of location. Even under perfect conditions, GPS advancements battle to do better than a few meters, and GPS is often limited indoors. IPS can enable a distance determination within centimeters. This system will provide huge benefits for future area applications in indoor area and help to guide to navigate in museum or large hospitals and malls.

The rest of this article is arranged as follows. In the next section, review about background and different approaches to indoor positioning and focus on the RSSI based BLE technology. Section III describes framework and methodology. The experimental results are presented in Section IV and this paper is concluded with discussion in Section V.

II. BACKGROUND

In this section, a review related to indoor positioning technologies using Radio Frequency is presented. The Active Badge is first approach used for location system.This badge emitted infrared signals in every 10 seconds that is notified to the user. In this way, the badge transmits a unique identifier to respective receivers. It needs a line-of sight between the badge and the receivers to transmit the infrared signals. This infrared signal has very short range which is main drawback [3].

Another well-known location system is mTag based on RFID method. RFID receivers in different places in the location under investigation are defined by mTag. The high cost is main drawback of using RFID fordeployment [4].

WLAN technology is next location system that is widely used, where the signal strength of Wi-Fi is checked. In commercial or public buildings and environments such as airports, schools, shopping malls, subways, or libraries Wi-Fi signals widely used which is adoption of IEEE 802.11[4] [5]. A big drawback of Wi-Fi based positioning is the dependency on such infrastructure. It becomes incompatible in places

where there is no existing deployment of such communication network.

Wi-Fi based area frameworks have mostly been utilized two indoor situating approaches, i.e. propagation based and fingerprint-based methodologies [5]. Propagation based methodologies utilize triangulation or trilateration identified with transmitters at known directions. They appraise the separation between the cell phone and obvious transmitters utilizing indoor propagation model of sorts, and after that gauge the directions of the cell phone with these separations [6]. They are exceptionally error prone inclined in indoor environment, on account of the dynamic nature of signals, signal attenuation. Then again, area fingerprint coordinating methodologies evaluate the position sensibly, vast arrangements of information are accumulated by the framework, and an arrangement of exploration and investigations are performed to produce a guide to location. Both of these instruments proactively exploit the entrance of current keen cell phones and their quickly expanding hardware capabilities [7].

Author in [8] present, Indoor Positioning System based on RSSI using BLE technology. The system is energy efficient compared to other techniques such as Wi-Fi, GSM or GPS. The BLE tag is expected as a promising approach to determine the location of smartphone. The deployment is quick as these BLE tags are easy to configure and can run several months using a small battery. Depending on required functionality, a BLE device may operate in different modes. There are three modes related to the neighbor discovery i.e. advertising, scanning and initiating [8]. It operates in the spectrum band 2402-2480 MHz, divided by 40x2MHz channels. The central peripheral relationship is one of the primary reasons that BLE consumes low energy. A peripheral device (BLE tag) can simply broadcast its information, while central devices (Smartphone) in the area can collect that data. BLE generally uses Client/server modeloperates in central and peripheral role. A Client connects and accesses one or several server [9].

BLE operates either in master or slave role. A master can deal with numerous simultaneous connections with a number of slave devices, but a slave can only be connected to a single master. Master scans designated advertisement channels in order to detect slaves [10]. Data transmitted in the form of connection events in which the master and the slave wake up to exchange frames in order to maintain synchronization. The rest of time both devices are in sleep mode. The BLE device only transmits when is asked for it [11].

III. PROPOSED SYSTEM ARCHITECTURE

In this proposed framework IPS technique is explained. As shown in Figure 1. system architecture is divided into three major components: BLE Tags, mobile applications (APP), and system communication interface. In the first phase, BLE tags are configured and calibrated. In the second phase, the indoor positioning APP is installed in user's mobile devices, and then carefully observed RSSI values in order to optimize BLE tags information. When deploying a BLE, there are many parameters to consider including: BLE tags, Transmitting power, RSSI, BLE mobility. Many of this parameter are inter dependent e.g. BLE tags unable to maintain the coverage distance if the transmitting power is reduced [12]. In this System, figure 2 below shows CY8CKIT-042. Here BLE kit is used as BLE tags and programming, configuration is done in software tool called PSoC Creator with version 3.3.

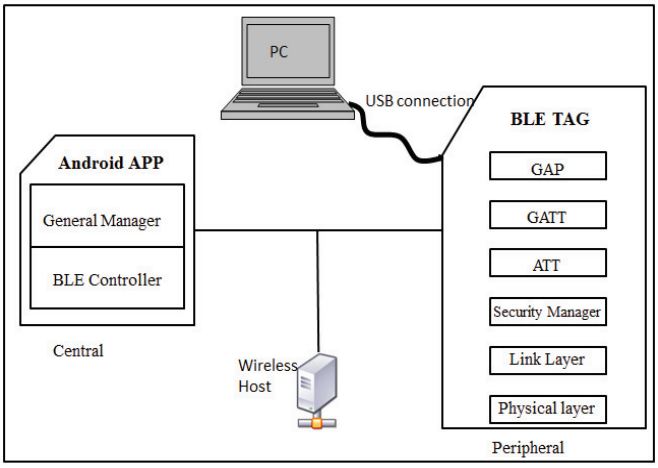

Fig. 1.Indoor Positioning System

BLE tag is configured through its Generic access profile (GAP) and Generic attributes (GATT) setting. The Master and Slave relation acts between BLE tags and Smartphone respectively. The BLE tags continuously transmit packets of data in regular intervals. These BLE tags are deploying in indoor area as per our requirement. When user goes through BLE tag range area the Indoor Positioning System application (IPSAPP) automatically starts to extract the BLE signal. The mobile with IPSAPP scans RSSI and transmitting power value to the nearest tag and uploads information whichever BLE is configured. The android application is created in android studio platform with programming language Java. In this platform, the native Application program interface (API) such as CyBLE API and Bluetooth API is used to create the libraries for experiment [13]. BLE tag implementing into an IPSAPP starts with Bluetooth services manager includes device activities and services. The only way to interact with a BLE tag is to configure the UUID, Major and Minor values. UUID is unique identity to distinguish the tags from one another, while Major and Minor values are usually optional, used to specify BLE service in groups. Each location has the unique RSSI values and transmitting power value which is used to evaluate the distance of particular position. The positioning algorithm [14] based on mapping RSSI values and transmitting power values evaluates the distance in meter between BLE tags and Smartphone. The positioning algorithm is as follows:

1. Collect the RSSI and Transmitting power value for each location.

2. If RSSI=0, then it cannot determine accuracy and return to -1.0.
3. Calculate distance, D= rssi*1.0/Tx power.
4. If (ratio<1.0) then return to Math. pow(ratio,10).
5. Calculate best fit curve to measured data point, constants values such as 0.89976, 7.7095, and 0.111 are used for: double accuracy = (0.89976*Math.pow(ratio,7.7095)+0.111.

The accuracy depends on nature of signal, signal attenuation and noise, which increases with signal strength [15]. With an IPSAPP or platform will be able to identify exactly where a user is behind the wall. This gives a chance to send users highly contextual, meaningful messages and advertisements on their smart phones.

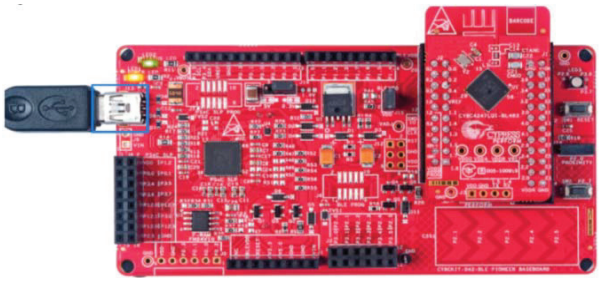

Fig 2. BLE tag CY8CKit-042 [16].

IV. EXPERIMENTAL RESULTS

RSSI can't be a dependent parameter to compute an accurate distance. Any little change in position could provoke dynamic variation in RSSI values. To enhance the precision of the distance estimation and to adapt with the instability of RSSI, an arrangement of RSSI estimation takes only one instantaneous value.

The Figure 3 shows the plot of various positions of BLE tags by moving smartphone randomly in range of 3 meters.

TABLE I. Positioning with RSSI values

Distance Of BLE Tag in (meter)	RSSI of BLE 1(dbm)	RSSI of BLE 2(dbm)
0.03	-53	-52
0.1	-61	-62
0.2	-65	-67
0.4	--67	-69
0.5	-68	-66
0.6	-75	-70
0.93	-74	-75
1.2	-77	-78
1.5	-78	-79
1.8	-83	-80
2.0	-84	-85
2.2	-87	-86
2.6	-88	-91
3.0	-90	-92

The experimental results shows that when BLE tag is moving away with respect to the users Smartphone the RSSI values are decreased and similarly when user is near to range of BLE tag the RSSI signal is strong. The RSSI measurement is inversely proportional to distance of BLE tags.

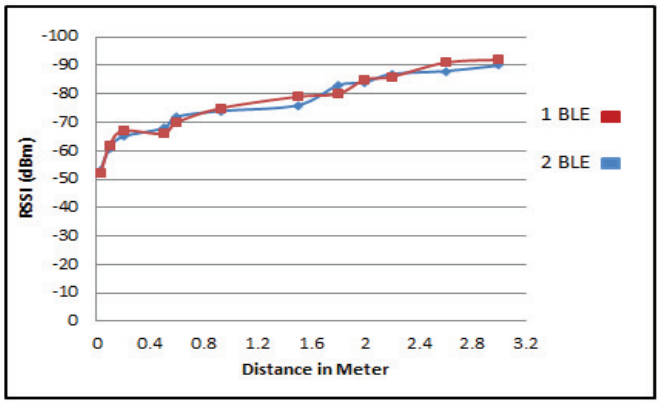

Fig. 3. RSSI values of BLE tags for various position

The table 1 depicts the respective RSSI values are changed for each unique distance in both BLE. As long as the user is in vicinity of BLE tags the RSSI values are obtained in its range. The range is decided by transmitting power of BLE tags. For experimentation, both the transmitter powers are kept same; i.e. -76dbm. As the user moves in the region of BLE tags, RSSI values are obtained by varying distance from 0.03m to 3m as shown in table 1. The corresponding RSSI values received at BLE receiver are obtained as summarized in the table 1. Each RSSI value shows its unique determination of position.

Fig. 4. Shows a screenshot of IPSAPP, which detects the device ON which BLE tag is attached and displays the distance in meter and RSSI strength.

The mobile IPSAPP takes care of all BLE related services, which includes connecting the device, writing and

reading characteristics, broadcasting updates, initiating discovery, and defining which GATT services are relevant to the device.The figure 4 shows that the device scan activity, a search for discoverable devices can be initiated. Once the scan is initiated by turning on BLEs, respective tags are detected and corresponding parameters are displayed in the IPSAPP as shown in figure 4. These parameters are device name and RSSI value in decibel in mill watt (dBm) for each position and transmitting power in mill watt. BLE1_tag and BLE2_tag show its UUID to distinguish to each other. The major and minor values are used to determine location based services configured in BLE tags. Here, service is only gives position of location so its value is configured as 1 in both BLE. Each RSSI value shows unique distance that depends on transmitting power value. The transmitting power also varies with distance covered by radio signal. Accuracy of distance estimation depends on nature of signal, signal attenuation, transmitting power value.

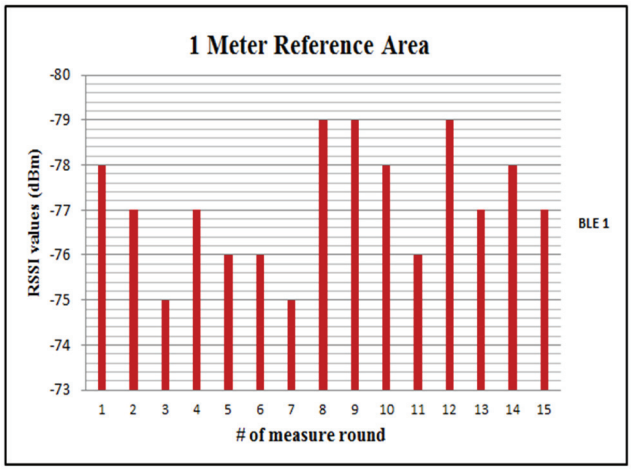

Fig. 5. RSSI from 1 m distance

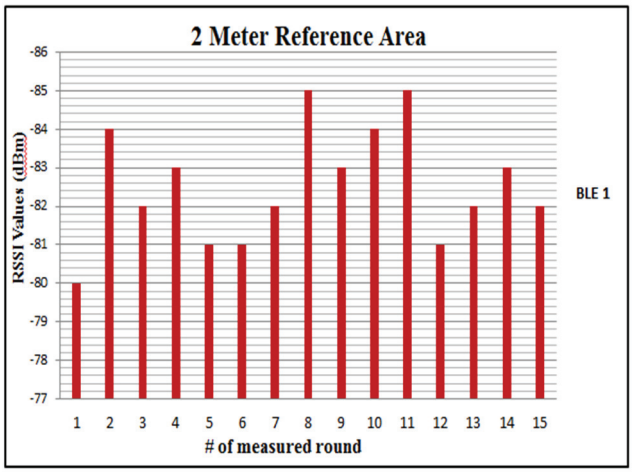

Fig. 6. RSSI from 2 m distance

Accuracy is determine by averaging the 3 RSSI values computed for a unique position in 1 and 2 meter radius area as shown in figure 5 and 6 respectively. The range of RSSI values are lies within -73 to -80 dbm in 1 meter radius of reference area which indicates that distance of position can be accurate. So, the accuracy can be realized with descriptor also. If the distance is between 0-0.5 meter range it indicates "Immediate" while in between 0.5-3 meter range it indicates "Near", and above 3 meter range shows "Far" so that user may got his position according to descriptor of position is shown in Table II.

TABLE II. Description of BLE distances

Descriptor	Range
Immediate	0-0.5 meter
Near	0.5-3 meter
Far	Above 3 meter

V.CONCLUSION

This paper explores the Bluetooth Low Energy technology and provides us with an alternative to traditional technology used for positioning, such as Wi-Fi or GPS. The technology is most useful in localized settings, where scalability and portability are important.

Proposed framework is an indoor positioning utilizing BLE tags which build up connection and measures distances based on RSSI values and similarly shows targeted BLE tags data. The smart phone IPSAPP permits us to make estimations of BLE Tags which users can get the location determination based on parameters such as RSSI and transmitting power value. The accuracy of distance estimation is approximately up to 4 meter in range which shows notification of description of distance location such as Immediate, Near and far depends on range of meter. Hence, Positioning using BLE tags will be more accurate than WIFI and trilateration localization advancements.

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