Realtime Indoor Positioning System Using Wireless Access Points

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Abstract—**Realtime indoor navigation is an essential necessity in urban life due to massive growth in numbers of larger buildings. As satellite based Global Positioning System does not work accurately indoor, the necessity for an alternative positioning system is existing. Wi-Fi access points become very popular lately and like any other radio frequency signal, WiFi signals from more than two access points can be used to triangulate a user's location. This paper proposes an architecture to use Received Signal Strength Indicator from beacon frames originated from generic consumer end access points for indoor navigation.**

Keywords—Wi-Fi, indoor navigation, positioning system.

I. Introduction

With the increasing number of large high-rise buildings and their involvement with our daily life, it has become very important to be able to navigate in these buildings. But satellite-based radio navigation systems like Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), BeiDou Navigation Satellite System (BDS) and Galileo shows significant degradation in term of accuracy and availability in indoor environment. On the other hand, from 1999, after the formation of Wi-Fi Alliance with six companies and adopting IEEE 802.11 specification as standard, Wi-Fi enabled devices started to be available in the consumer market [1]. And with the increasing number of Wi-Fi enabled devices, the number of Wi-Fi routers and access points began to rise. A 2007 research shows 1,854 APs/km^2 in Manhattan and 729 APs/km^2 in Boston area of USA [2]. Though similar statistics were not available for the year this paper was written, it can be extrapolated that the number would be larger. High density and availability of Wi-Fi access points make it a logical candidate for usage in indoor positioning system for urban buildings to achieve greater accuracy than a satellite-based positioning system.

Consumer end wireless access points are not uniform in the perspective of hardware and firmware and thus it is not possible to formulate a unified rule that will work for every AP available in market. It makes the implementation extremely complex. This paper proposes an architecture that enables the usages of consumer end APs, despite of hardware or firmware differences, for indoor positioning based on RSSI of beacon frames of wireless APs [3]. With availability of smartphone and other Wi-Fi integrated devices, the proposed positioning system can prove to be very efficient and user-friendly.

II. Related Studies

Generally, satellite-based radio positioning systems does not work indoor with expected accuracy because the signal from the satellites get attenuated and scattered by roofs, walls and other surrounding objects. A 2016 study established negative impact on indoor GPS accuracy of number of overlaying stories, the roof material, material of numbers of walls and closeness to surrounding buildings [4]. IEEE 802.11 standard published on 2016 defined Beacon RSSI on section 11.45 that contains all the necessary information about a network.

A 2015 and a 2016 paper by You Li et al. proposed a hybrid navigation system collaborating Wi-Fi, magnetic matching (MM) and pedestrian dead-reckoning (PDR) together [5], [6]. Similar approach were followed by Chai et al. on 2012 [7]. They used Adaptive Kalman Filtering method for dead reckoning. But the complexity of these proposed systems makes the public deployment impractical. Battery consumption of multiple sensor working actively in a portable device such as, smartphones and laptops, is also a matter of concern in this case.

In this paper, we followed radio triangulation method which is historically used in positioning systems like, GPS. The principle of radio triangulation is elementary and eliminates computational and practical complexities.

III. Methodology

A. Beacon RSSI

Beacon frame is one of the management frames defined in IEEE 802.11 standard. Beacon frames contain all the necessary information about a particular network and are transmitted periodically to announce the presence of an AP. Upon receiving the beacon frame (dot11BeaconRssi), a station can measure the received signal strength of the frame with 95% confidence interval and reported in dBm unit [3]. This indicator is known as Received Signal Strength Indicator (RSSI).

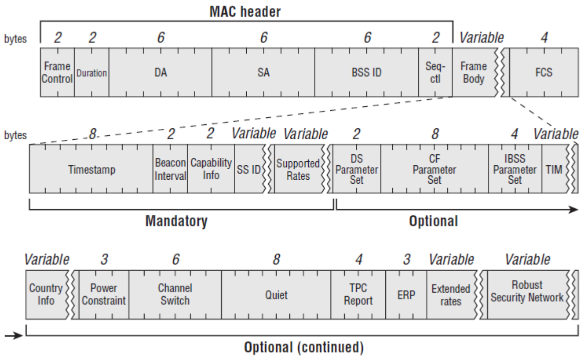

Figure 1: Beacon frame structure

B. *Relationship between RSSI and distance*

To determine the relationship between RSSI and distance of a station from an AP, a common consumer grade Wi-Fi router "Netgear JWNR2010v5" was used as AP and an ASUS ZenBook UX410U equipped with Intel Dual Band Wireless-AC 8260 network controller was used as station.

Figure 3: Netgear JWNR2010 WiFi router and Intel Dual Band Wireless-AC 8260

The station i.e., laptop was running Debian GNU/Linux operating system. RSSI information for all APs in range can be retrieved in that particular OS using following command-

```
# iw dev wlp2s0 scan
```

It lists all the APs in range and outputs their meta information like SSID, Signal Strength (RSSI), and other information such as, Timing Synchronization Function (TSF), beacon interval, HT and VHT capabilities etc. To filter our only SSID and RSSI, the output of the mentioned command is piped through an *egrep* command.

```
# iw dev wlp2s0 scan | egrep
'SSID | signal'
```

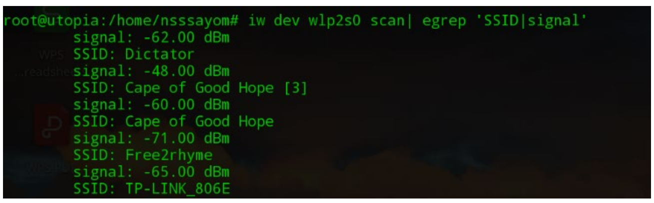

Figure 5: Output of ***iw dev wlp2s0 scan | egrep 'SSID|Signal'*** *command*

RSSI data was collected after every one-meter distance for the specific AP mentioned earlier with a specific SSID. The data yielded the following graph:

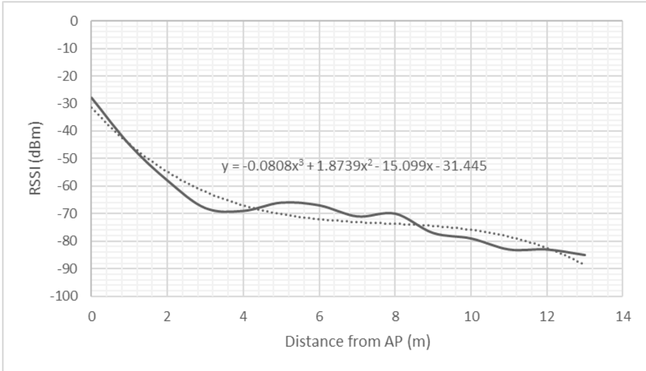

Figure 2: RSSI vs Distance form AP graph

A three-degree polynomial relation can be established between RSSI and distance between an AP and a station. Equation that can be derived from the data is:

$$s = 0.0808d^3 + 1.879d^2 + 15.099d - 31.445 \quad (1)$$

Here, d is distance between an AP and station and s is the RSSI value of the station for that particular AP.

C. *Triangulation*

If the value of RSSI, s_0 is known for a particular AP-station pair from beacon RSSI, value of distance d_0 can be derived solving (1). If we consider the station and AP (denoted by AP0) in a cartesian plane, the station's position is at any point in the circumference of the circle can be drawn considering the AP as a center and with a radius equal to d_0. Now, if the station is in range of another AP (denoted as AP1) with known position, another circle can be imagined with the AP at center and a radius equal to the distance of the AP to the station, d_1.

These two circles intersect at two points p0 and p1. This narrows down the probable position of the station to two points. But this is not sufficient for an indoor positioning system.

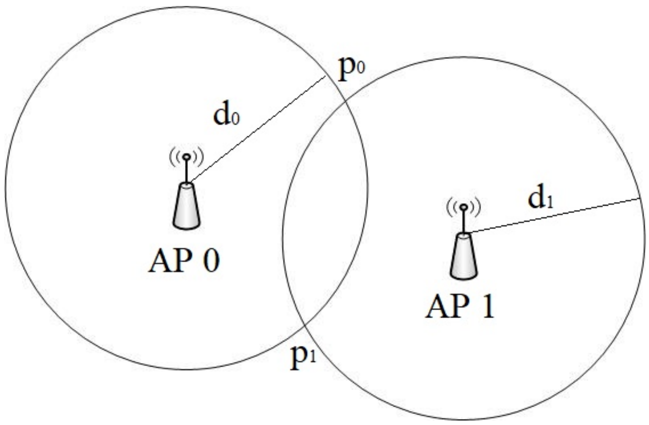

Figure 4: Triangulation step with two APs

A third AP in range (denoted as AP2) is necessary at to be the center of another circle that can be drawn with radius equal to its distance to the station, d_2. This third circle will intersect previous two circles either at point p_0 or p_1. And the intersecting point will be the position of the station of interest.

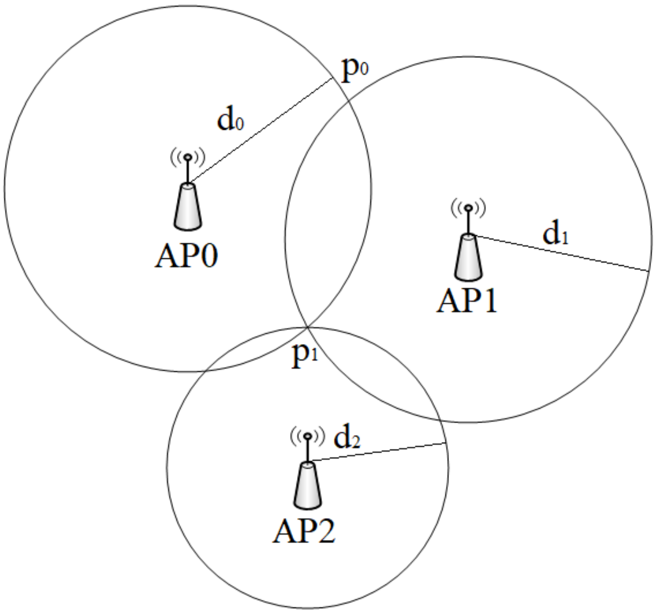

Figure 7: Triangulation with three APs. p_1 is the position of the station

IV. System Architecture

A. Database

1) Central database Server: The system will have a central database server to store access point SSID and geo-location. System specific unique SSIDs will be chosen and assigned to an access point and will be crowd sourced to the database with a public web API.

2) Local Application databse: This will be an database embedded to the navigation application that will be discussed later in this paper. The local database will be a subset of the central database containing data of specific buildings. Local database will be syncronised with the central database using a web API.

B. Web service

The system will have a web service to transact data between database and navigation application. A RESTful public web API [8] will receive request with valid arguments and serve the user with valid response.

C. Navigation Application

A cross platform application will be developed with embedded database. The application will be equipped to synchronize the local database with central database upon any update. The navigation application will look for system specific SSIDs and carry out the triangulation as explained before in the paper.

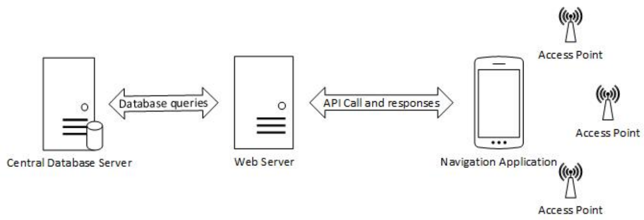

Figure 6: System Architecture

V. Conslusion

Indoor navigation being a very important necessity of everyday life, and given the fact that, satellite-based positioning systems are not accurate enough in indoor environment, an alternative positioning system that uses existing infrastructures can prove to be very practicable. Wi-Fi is a widely used technology that has contributed to the mass internet usage. Most of the consumer end devices are equipped with Wi-Fi enabled hardware now. And this situation makes the solution proposed in this paper more adequate and relevant. One of the main limitations of this study is that, we could not take account of the external factors like temperature and humidity while collecting data. That can affect the calculations. And also, more advanced mathematical and statistical approaches could be used to evaluate the data for better mathematical models. We also could not present any prototype of the system.

VI. Future Work

We are currently working on the implementation of the system that we have proposed in this paper. The preliminary results are satisfactory. In future this study could be continued further by trying to minimize the limitations. The software architecture can be updated with modern technologies. New standards of IEEE 802.11 such as, IEEE 802.11ax [9], IEEE 802.11ay [10], IEEE 802.11az [11] can bring new possibilities to be explored for a more efficient indoor positioning system using Wi-Fi technologies.

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