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An Open Wi-Fi based Indoor Positioning System for Smartphones

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Abstract:
Wi-Fi positioning is base of various mobile applications. Acquiring better positioning accuracy is particularly difficult in both indoor or outdoor or hybrid environment. Thus, a positioning system should be deployed which can localize any mobile terminal in an environment at low cost. In this paper, we propose a Wi-Fi based Indoor Positioning System. The first part of the paper, provides an insight into typical architecture of a Wi-Fi based Indoor Positioning System. The second part of the paper, considers received signal strength parameter of wireless positioning based on theoretical propagation model. We conclude the paper by experimentally validating the proposed system in a real-time scenario.

Keywords: Indoor Positioning, Received Signal Strength, Wireless Sensor Networks**.**

I. INTRODUCTION

Hardware mounted GPS receivers and online mapping services have replaced traditional maps from society. Comparing these advances in mobile navigation, hard mounted maps and signboards continue to be the primary reference for indoor navigation in health care, colleges, shopping malls, and other large places. Today Satellite-based GPS positioning systems provide users with the position of their smart phones when they are outdoors to navigate. Indoors, however, GPS loses its efficiency because this technology relies on very weak signals from satellites that are easily blocked by roofs, walls, etc. The result is a significant drop in accuracy for GPS systems. To attain an accuracy of 1-5 meters indoors need a completely different solution: Indoor Positioning System (IPS). The importance recently reached by the indoor localization is also demonstrated by the interest shown by Google in this direction over the last two years. The new Indoor Google Maps service lets to explore indoor environments such as shops, malls, museums, hotels, railroad stations, airports, etc. using a mapping contained within the application. In other words, the localization function, already existing in Google Maps, lets to navigate even in indoor environments that have a partnership with the Google company, providing their floor plans. This pave the way to many benefits for visitors to these indoor environments. For example, if a person goes to a hospital for a medical examination, the opportunity to walk virtually through the corridors will allow him/her to find immediately the right room. The indoor localization system proposed by Google has already been explored in the literature [1]. In last decade, mobile computing and wireless communication infrastructure have evolved drastically. Today Internet, the development of broadband networks, rental application, payment for the use and the quest for mobility. This gave birth to the new concept of infrastructure and IT solutions called Cloud Computing. Indeed, the cloud consists of outsourcing IT infrastructure to specialized providers. Users Today Wi-Fi is available nearly everywhere. In a hospital for instance, a device may recognize many Wi-Fi access points at the same time. For smartphones, the Wi-Fi measurements are available and can be readily used for the positioning system. Thus, in this paper, a Wi-Fi based Indoor Positioning System is discussed. We have organized our paper as follows. The next section, section **2**, we explain the basic architecture of the Wi-Fi based Indoor Positioning System. In section **3** we introduce the proposed Wi-Fi based Indoor Positioning System. Next, in section **4** we experimentally validate the proposed system. Finally, in section **5** we deliver our conclusion.

II. TYPICAL MOBILE CENTERED SYSTEM ARCHITECTURE

The configuration where infrastructure executes all the processing elements requires several elements [2]:

- **Access Points(Wi-Fi):**

Referred to as transceiver. Mostly used for short-area wireless networking. It is commonly used for indoor environment such as homes, offices to create a network that can be accessed by computers, smartphones, etc. It is used to access the information for positioning the users indoors using smartphones.

- **Mobile Terminals:**

Mobile PCs, cell phones and PDAs, as well as smartphones are considered as mobile terminals equipped with Wi-Fi support.

- **Database:**

Typical architecture of a Wi-Fi based positioning system includes database for collaborating all the Wi-Fi data for positioning user in an indoor environment. It's also used to store the basic layout of buildings i.e. maps or blueprints. Also, required for navigation for storing the graphs. At least three APs are required in the deployment building and at least one more is required to be placed in a different vertical plane; that's the minimal configuration to compute mobile altitude. In the further section 3 we would be discussing the proposed system for Indoor Positioning in detail.

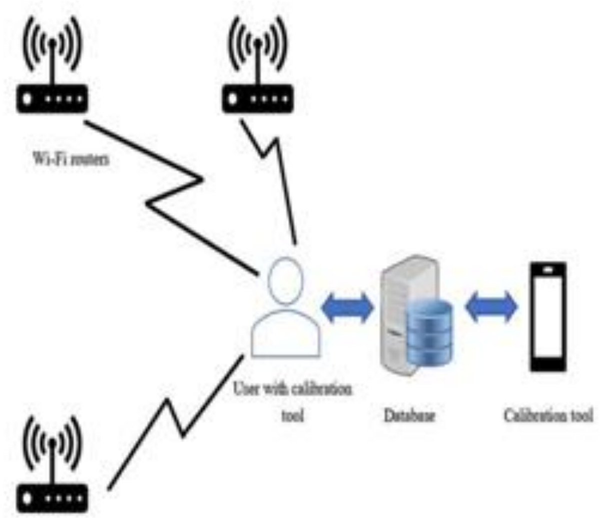

Figure.1. Typical architecture of a Wi-Fi based positioning system

III. PROPOSED SYSTEM

The Indoor Positioning System consists of five modules as shown in the Fig. 2. Shown within each module are the important components of the Indoor Positioning System. The *Database* module takes information about the environment and provides it in a format that can be used by the other modules. The building blueprint is used to create the maps. Displaying the information including the map of the building, current location and the directions to get to the destination is in the *User Interface* module. It basically handles the interaction between the user and the system. The hardware layer consists of sensors in the smartphones which include:

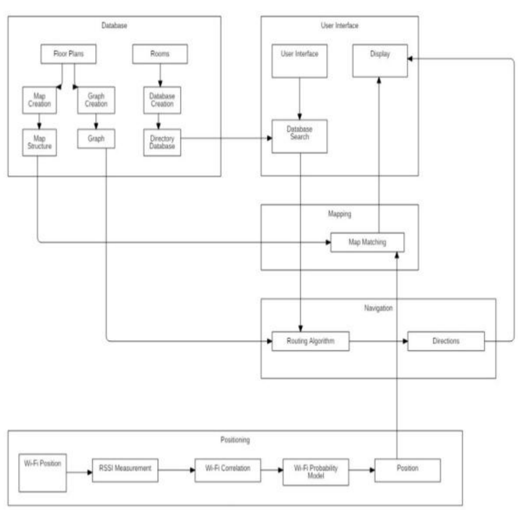

Figure. 2. Proposed Indoor Positioning System Modules

The Wi-Fi chipset, accelerometer and the compass. Raw data from these sensors is converted into needed information and processed by the *Positioning* module. In the Positioning module, Wi-Fi (RSSI) technology is used to determine the position of the smartphone. The Wi-Fi positioning module correlates measure-d Wi-Fi signal strengths to a pre-generated database of emulated signal strengths values for WAPs that are known to be in the area. The database generated models the signal strength and the location of the Wireless Access Points inside the building. Information from this system is used to provide an approximation of the devices position. This information is then equated to the map of the building to facilitate calculation of a route to the user's destination. The other two models are *Mapping* and *Navigation* used for map matching and getting directions respectively. The Navigation module holds the routing algorithm used to provide directions to the user.

3.1 Wireless Data Acquisition

The first step to determine the geographical position of the module device is to gather the relevant Wi-Fi information. The smartphone scans the Wi-Fi environment for all accessible wireless network signals. For the RSSI approach the SSID, the received signal strength and the frequency of the signal are the tuples needed [3].

3.2 Wireless Data Acquisition

a) Indoor Propagation Models

Received Signal Strength is affected by walls, peoples and various other objects. To accurately determine the location Indoor Propagation Models are required.

Free Space Model: In this model, received signal power is inversely proportional to the square of the distance. Received power P_r and distance r vary per the relation:

$$P_r \propto \frac{1}{r^2} \quad \ldots (1)$$

In signal propagation, we need to consider the path loss (P_r) dividend by transmitted power (P_t) as follows:

$$PL_{dB} \equiv 10 \log_{10} \left(\frac{P_r}{P_t}\right) \quad \ldots (2)$$

d = distance from the transmitter

d_1 = power at a reference distance from the transmitter is used as follows:

$$PL_{dB}(d) = PL_{dB}(d_1) + 20 \log_{10} \left(\frac{d}{d_1}\right) \ldots (3)$$

Using this model, free space propagation loss can be determined when only the distance from the transmitter and the propagation loss at a reference distance from the transmitter are known. To calculate the distance, we prefer to use the formula as mentioned below:

distance = 10 ^ ((27.55 - (20 * log10(frequency)) + signalLevel)/20) … (4)

b) Tracking by Trilateration

Trilateration means to determine relative locations of points by measurement of distances, using the geometry of circles, spheres or triangles. The same concept is implemented in Wi-Fi Indoor Positioning System.[4] The distance between the Access Point and the client/user is estimated by using the strength of the signal received by the AP from the client/user (RSSI -Received Signal Strength Indicator).

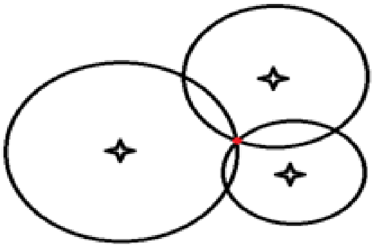

Figure.3. Trilateration

The three circles are nothing but the three Access Points whose co-ordinates are known. The point of intersection of three circles is the position of receiver. To know distance from access point and receiver can be done by solving set of equations mentioned below:

$$(x_1-x)^2 + (y_1-y)^2+(z_1-z)^2 = d1^2 \ldots (5)$$
$$(x_2-x)^2 + (y_2-y)^2+(z_2-z)^2 = d2^2 \ldots (6)$$
$$(x_3-x)^2 + (y_3-y)^2+(z_3-z)^2 = d3^2 \ldots (7)$$

These equations can be reduced to linear set of simultaneous equations which can be further solved to get the required location.

c) Software Overview

The OPPO F1 Selfie was used as the device platform for the proposed system. Reason for selecting this device includes the open source development platform of the Google Android operating system, the high computational power of the device and large number of built in sensors. The positioning technologies and principles considered to determine the location of the user in the building has already been discussed in the 3.1 and section 3.2. The database block takes information about the local environment and provides it in a format that can be used by other subsystems. The map floor plan is used to create the building walls structure that is necessary for creation of the propagation model. The map floor plan is also used to create a graph system to use in routing algorithm. The navigation subsystem is able to give directions to the user from their current location to their destination along an ideal path. The device navigates using a building blueprint of simplified nodes and links. The nodes will be placed at entrances, exits, in front of points of interests and inside each room. The final navigational necessity is that it also does not require more computational power to function. The mapping subsystem will map the approximate position onto the actual floor plan of the building. It does this in a manner that correctly determining the user's position [5].

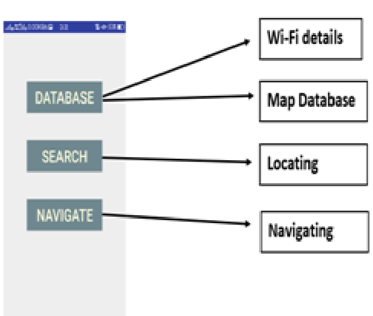

Figure. 4. Software overview

IV. EXPERIMENTAL VALIDATION

The proposed system has been tested experimentally in a real-time environment that is college campus equipped with 4 Wi-Fi access points. The system set up required only to access the floor map and to identify access points. For the performance assessment, we selected fourth floor of the college building with the access points as shown in the Fig. 5.

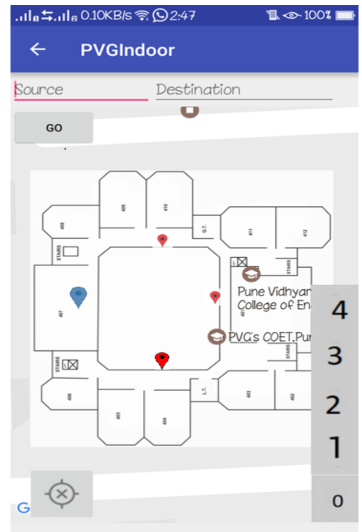

Figure.5. Blueprint of the considered floor. Red spots refer to the access points and blue spot represents the floor located using trilateration algorithm.

Table. 1. Performance Assessment

ID	SSID	Distance (by app)	Actual Distance	Percent Accuracy
AP1	Wifilab	5.984	4.472	66.19%
AP2	PVG-Wi-Fi-2	17.887	16.613	92.33%
AP3	PVG-Wi-Fi-3	28.122	24.331	87.51%

V. CONCLUSION

The proposed system is designed to evaluate the positioning technique in a 3-dimension space. There was an error of about 3 meters in a very heterogeneous environment at start of the evaluation with a density of 4 APs. It had been observed that the building inner environment, constantly keeps on evolving. For instance, the number of people depends on time; there are various elements which reduce the efficiency of the system like walls, doors, etc. All these factors influence the signal behavior which will be removed by using various aspects of free space models in future systems.

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