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Face-To-Face Proximity Estimation using Bluetooth on Smartphone

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Abstract

The communication of always–on has tremendous implications with people to interact socially. In particular sociologists are interested in the question if such pervasive access increases or decreases face-to-face interaction. As face-to-face communication happens when people are close enough to have conversation in a convenient way. Existing approaches used such as GPS and Wi-Fi triangulation are more complicated to find accurate proximity location and it insufficient to meet the requirements of flexibility and accuracy. Nowadays the Bluetooth which is commonly available on most modern Smartphone provides a compelling alternative for proximity estimation. In this paper, through experimental studies we demonstrate the efficiency of Bluetooth for this exact purpose. We propose a proximity estimation model to determine the distance based on the RSSI values of Bluetooth and light sensor data in different environments. We present several real world scenarios and explore Bluetooth proximity estimation on Android with respect to accuracy and power consumption.
Keywords- Bluetooth, RSSI, proximity estimation model, smartphones, face-to-face proximity

I. Introduction

The presence of portable devices ranging from the traditional laptop to fully fledged smartphones has introduced low-cost always-on network connectivity to significant swaths of society. Network applications designed for communication and connectivity provide the facility for people to reach anywhere at any time in the mobile network fabric. Digital communication [1] such as texting and social networking, connect individuals and communities with ever expanding information flows. When we have dinner with our friends sitting at the same table, the conversion among us is called face-to-face communication; or when we talk with someone side by side, the distance between us is also called face-to-face communication. In other words, face-to-face Communication happens when people are close enough to have conversations in a convenient way.

A key metric for sociologists is whether these networks facilitate face-to-face interactions or whether these networks impede face-to-face interactions. With the increasing availability of data in logs generated by Smartphones, there are tremendous opportunities for collecting data automatically. The critical technical challenge is how to measure face-to-face interactions, i.e., are two or more individuals within a certain distance that could afford such interactions? Interactions are not limited to any particular area and can take place at a wide variety of locations, ranging from sitting and chatting in a coffee shop to walking and chatting across a college campus. For most face-to-face interactions, the approximate distance between individuals in casual conversation is within 0.5 to 2.5 meters. One of the solutions would seem to be location-based calculation which relies on location technologies described in section II such as Wi-Fi triangulation, cell phone triangulation, GPS, or a combination of all three. Although Wi-Fi triangulation can present a reasonable degree of accuracy, its accuracy in all but the densest Wi-Fi deployments is insufficient, ranging on the order of 3 to 30 meters. Similarly, cell phone triangulation suffers from an even worse accuracy. Notably, GPS suffers from both an accuracy shortcoming (5-50 m) as well as a lack of viability indoors. However, it is important to note that face-to-face interaction does not demand an absolute position as offered by the previously mentioned schemes but rather requires a determination of proximity. Proximity refers to nearness between two or more users within a network.

Proximity detection is one of the advanced location based service(LBS) functions to automatically detect when a pair of mobile targets approach each other closer than predefined proximity distance. With that important shift of the problem definition, Bluetooth emerges as a straightforward and alternative, offering both accuracy (1-1.2 m) and ubiquity (most modern Smartphones come with Bluetooth). Bluetooth is the main device of wireless communication. The main idea of Bluetooth is to develop a way for users to connect a wide range of mobile devices quickly and easily, without cables. Although some prior work has attempted to use the detection of Bluetooth to indicate nearness, it is not enough for the face-to-face proximity estimation.

II. METHODOLOGY

The goal of our work is to estimate the proximity between two users with Bluetooth RSSI values logged on smartphones. We demonstrate the viability of using Bluetooth for the purposes of face-to-face proximity estimation and propose a proximity estimation model with appropriate smoothing and consideration of a wide variety of typical environments. We study the relationship between the value of Bluetooth RSSI and distance based on empirical measurements. We explore the energy efficiency and accuracy of Bluetooth compared with Wi-Fi and GPS via real-life measurements. We deploy an application ―Phone Monitor‖ which collects data such as Bluetooth RSSI values on Android-based phones. Based on the data collection platform, we are able to use the proximity estimation model across several real-world cases to provide high accurate determination of face-to-face interaction distance. The below Figure.1 gives the overview of the system.

The application starts automatically when the phone power is turned on and runs passively in the background using Android OS .The application will scan the other nearby devices. If found, Location Based Service Function(LBS) collects the data of the device and initially the parameters are being gathered for every 30 seconds and stored on local Data base which is present on the phone itself and send to the sever for backup and future analysis.

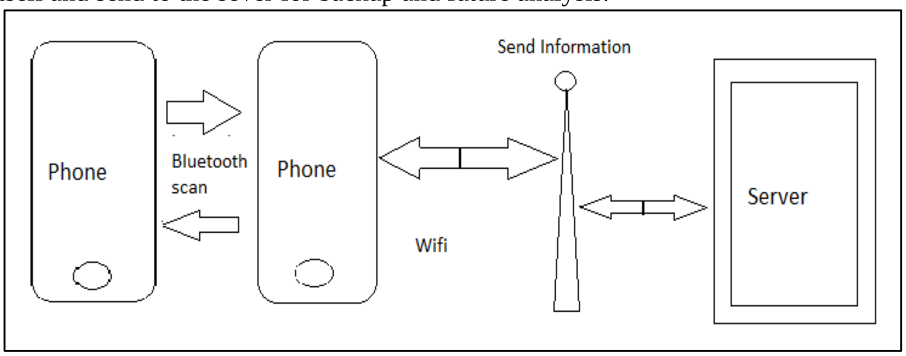

Fig. 1: Overview of System

Similarly the same process is done in all the smartphones in which the application is installed. Based on these data that are available in the server the RSSI value is calculated. By using the range based algorithm the obtained RSSI value is mapped with the distance.

A. Proximity Estimation Model

In this model we explore the relationship between Bluetooth RSSI and distance in real world scenarios. The first method is using RSSI value threshold to determine whether two phones are in proximity or not. The second method introduces the light sensor data to determine whether the phone is indoors or outdoors, inside the backpack or in hand. By differentiating environments and smoothing data, a face-to-face proximity estimation model is outlined to improve the estimation accuracy.Our proposed model consists of following modules:

1) Data Collection System
2) Proximity Estimation
3) Periodically updating server

1) Data Collection System

In this module, our system collects Bluetooth data including the detailed values of RSSI, MAC address, and Bluetooth identifier (BTID). The data is recorded once the phone detects other Bluetooth devices around. In addition to Bluetooth, data points from a variety of other subsystems (light sensor, battery level and etc.) are gathered in order to compare and improve the proximity estimation. Separate threads are employed to compensate for the variety of speeds at which the respective subsystems offer relevant data.

We also record the location data reported by both GPS and network providers (either Wi-Fi or cell network). In order to determine whether the phone is sheltered (e.g., inside a backpack or in hand) and the surroundings (e.g., inside or outside buildings) during the daytime, we keep track of the light sensor data. The battery usage percentage is recorded for the energy consumption comparison. The Android platform is selected for its customization capabilities through normal API or rooted customized interfaces with respect to hardware-level interactions. We keep the data records in a local SQLite database on the phone and upload them to MySQL database on the servers periodically with security for backup and analysis. With current Android APIs, each kind of data is invoked through the corresponding function calls. The default sensing granularity in terms of updating time interval for Bluetooth is 30 seconds. Intuitively, larger time intervals can help save energy; hence we also enable the changing of such sensing interval in order to explore its impact on the energy consumption.

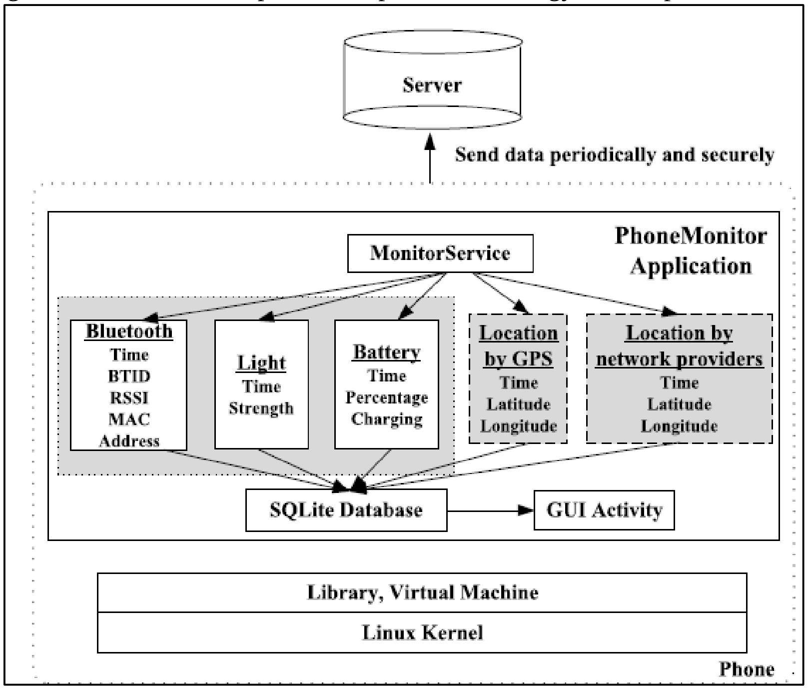

Fig. 2: Data Collection System

2) Proximity Estimation

Proximity refers to nearness between two or more users within a network. Proximity detection is one of the advanced location based service (LBS) functions to automatically detect when a pair of mobile targets approaches each other closer than predefined proximity distance. As we said in the Proximity estimation model, Proximity estimation is based on RSSI value of Bluetooth. RSSI value mainly depends on signal strength and in turn this signal strength depends on the distance. Therefore, RSSI value is inversely proportional to distance. So using this RSSI value we are evaluating proximity. The relationship between RSSI and distance becomes more complicated. Our challenge was to assess how much impact these environmental factors have on Bluetooth RSSI values. Therefore, we carried out several experiments to understand how the Bluetooth indicators fade with distance under these environmental influences. Indoor experiments were conducted in a noisy hallway(around seven other Bluetooth devices detected) in the cam-pus engineering building.

3) Periodically Data Storage on Server

Once the User logs in through the Smartphone data collected by the data collection module is stored on the server. For the backup and analysis the admin is allowed to monitor the data and can view all the details of user and device such as username, device name, userID, Bluetooth adapter name to which we have connected, MAC address of the user using application, latitude, longitude using GPS, battery level and power of the device. The data is periodically updated on the server. The application checks if there are any other device found, its details will be updated in the database. Using all these details location on the map can be viewed.

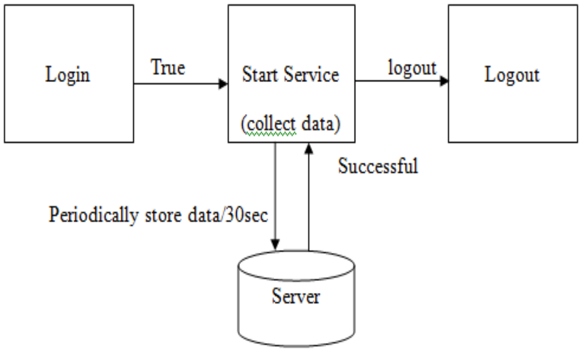

Fig. 3: Periodically updating of server

III. RESULTS

Proximity estimation is based on RSSI value of Bluetooth. RSSI value mainly depends on signal strength and in turn signal strength depends on the distance. Therefore, RSSI value is inversely proportional to distance. So using this RSSI value we are evaluating proximity. The figure 4 shows the relation between RSSI and distance.

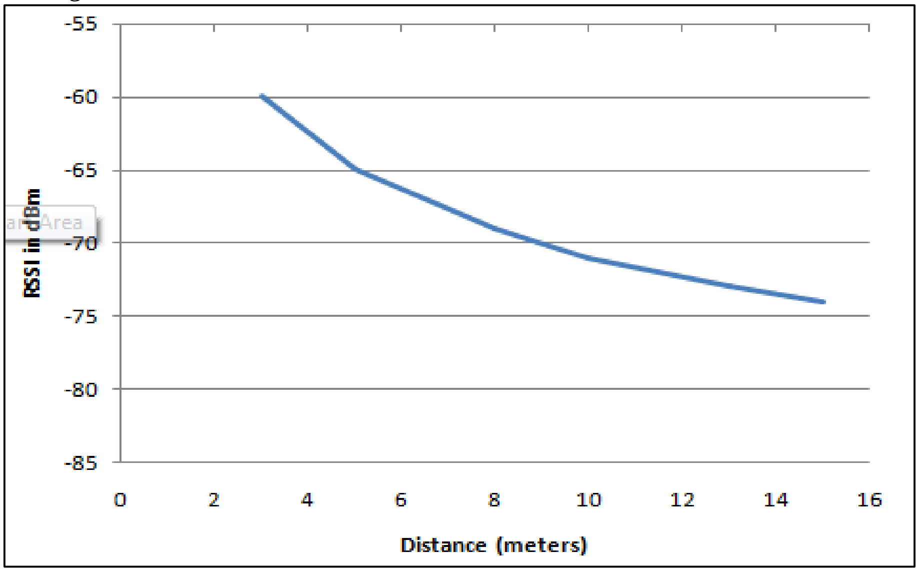

Fig. 4: RSSI versus Distance

The data varies significantly even within the same distance, there is a noticeable gap exists between different distances. Indoor experiments were conducted in a noisy hallway (around seven other Bluetooth devices detected) in the campus engineering building. Outdoor experiments were conducted in the open area outside the building. In the measurement there were no obstacles between the two phones and the antennas of the phones were aligned towards each other. In such a way, we tried to build up a relatively simple and ―ideal‖ environment where the possible impact factors are reflection and noise only. We repeated the measurements over the period of an hour with the distance being increased by 1 meter between each round. In figure 5 we present indoor, outdoor, and theoretical results for Bluetooth across a variety of distances (0-5 meters).

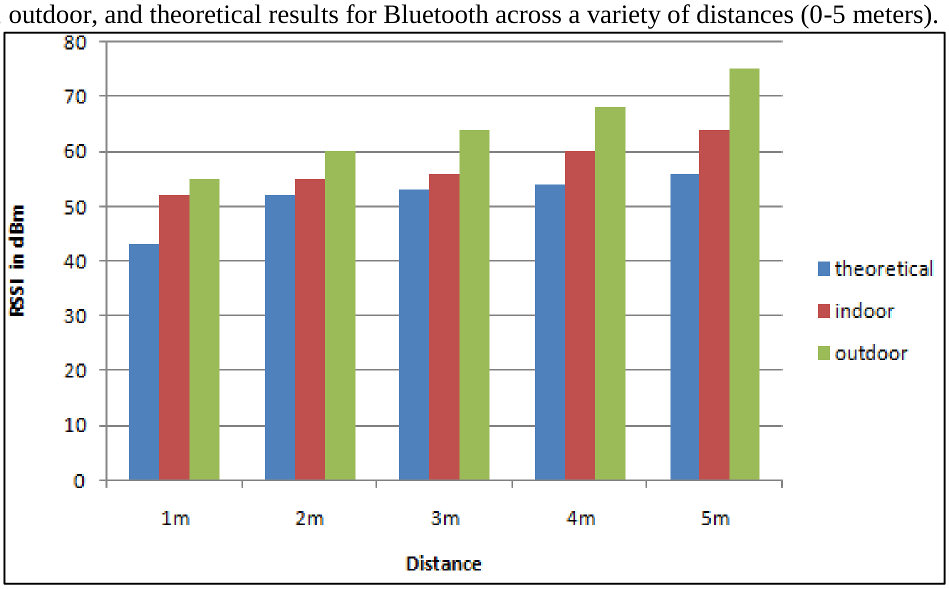

Fig. 5: Bluetooth RSSI versus distance—theoretical, indoor, and outdoor.

Wi-Fi triangulation/trilateration is a widely used method to do location indoors while GPS is perhaps the most popular way to do location outdoors. Here we use Wi-Fi and GPS to do the face-to-face proximity estimation in order to compare the accuracy of them with the Bluetooth method we proposed. Table 9.1 summarizes the differences of popular techniques, their prominent features and the performance.

Table 1: Different Proximity Estimation Techniques Comparison

	Bluetooth	Wi-Fi	GPS
HW Cost	Medium	High	High
Security	High	High	Not applicable
Power Usage	Medium	High	High

Bluetooth is proved to be an effective and efficient way in both aspects of accuracy and power usage. We collected both network-provider location and GPS location data on the phone for the comparison. With the API provided by class Location Manager in Android SDK, we can get both kinds of location data by choosing different location providers with the frequency of three minutes. The GPS provider determines location using satellites while the network provider determines location based on availability of cell tower and Wi-Fi access points. In the network provider method, the triangulation is used to get the location of the phone with the knowledge of cell towers' or APs' locations. When each phone's location is known, the relative distance as well as the accuracy is easy to calculate.

IV. CONCLUSIONS

Our presented work validates the usage of Bluetooth as a tool for face-to-face proximity detection. This paper proposes the real time proximity estimation model by combining Bluetooth RSSI value, light sensor data as well as data smoothing together. The proximity estimation model on the realistic data is analyzed. Compared with the existing method of collecting data all devices around, the proximity estimation model is used to estimate high accuracy between two devices in a direct communication which is improved dramatically. The results demonstrate that Bluetooth offers an effective mechanism that is accurate and power efficient for measuring face-to face proximity to increase Bluetooth signal length. If needed then appear before the acknowledgment and references.

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