Using Mobiles for On Campus Location Tracking

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ABSTRACT
The wide spread of mobiles as handheld devices would naturally lead to various innovative applications that makes use of their ever increasing presence in our daily life. One such application is location-tracking in indoor environments. In this paper we discuss the implementation of a simple and cost effective system that assists users in tracking colleagues and friends within a campus environment. The system uses the information built in a typical mobile such as its IMEI and IMSI and the various WiFi access points on campuses to pin point a user's position. A mobile application program communicates with a web server and a GSM modem to provide users with real time data related to a person's movements and location.

Keywords
Mobile, Access Point, MAC Address, Tracking, WiFi

1. INTRODUCTION
Various GPS-based tracking systems have been successfully deployed and utilized in various applications such as fleet and vehicle location identification, and in route guidance. Recently, systems that integrate GPS and GSM technologies with Google earth to provide real-time data have also been proposed [1]. However, for indoors and closed environments GPS systems fall short and it becomes difficult to acquire the necessary satellites for accurate position computation [2]. Some of the alternate techniques that are proposed for indoor location tracking include the integration of Bluetooth technology with 3G networks [3]. The proposed solution suggests that Bluetooth terminals can exchange information with each other and then a Bluetooth access point provides the interface to a mobile network. In their solution they presumed that Bluetooth fixed infrastructures are expected to be installed in offices, homes and public areas which is not the case nowadays. In [4], the authors discuss the implementation of a mobile indoor GIS application that delivers maps and linked database information to indoor wireless devices such as mobile phones and PDAs. Users would then interact with the web pages on their phones while viewing floor plans around their current location, searching for an office or a classroom. A system that combines ultrasound with Zigbee technology to perform indoor localization and hence providing a location is discussed in [5]. Research activities related to indoor position are reported in [2]. The authors argue that since WiFi (Wireless Fidelity) is widely deployed in buildings such as hotels, hospitals, universities, airports and train stations, it makes sense to make use of this technology in support of cost-effective location identification or positioning solutions. The authors used an experimental testbed and simulation to study the accuracy of various techniques that might be used in indoor systems.

In line with the arguments presented in [2], in this paper, we report on the design and implementation of an indoor location tracking system that uses the existing on campus WiFi infrastructure and signal strength to determine a user's location. The solution presented is cost effective, does not require any additional hardware resources, and is transparent to the GSM operator in the country. The proposed solution uses WiFi-enabled mobile phones and access points in addition to a web server equipped with a GSM (Global System for Mobile Communications) modem. It reports to subscribers the most recent location of a user as well as a history of his or her previous locations within a specified time window.

2. PRELIMINARIES
The definitions below (although trivial for some readers) are needed as a basis for the subsequent sections where the architectural and operational features of the complete system are described.

Access Point: it is a device that allows wireless communication devices to connect to the wireless network through them by using the Wi-Fi technology and any other related standards. The access point sends and receives signals from any wireless communication device and it uses the IEEE 802.11 standards. The Access Point serves

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as the interconnection between the WLAN and the fixed wire network

Symbian OS: is an operating system specially designed for mobile devices. It is associated with user interface frameworks, multi-tasking multithreaded core, reference implementations of common tools, libraries, data services enablers, and application engines [6].

IMEI: stands for the International Mobile Equipment Identity number. It is unique to every GSM (Global System for Mobile communication) and UMTS (Universal Mobile Telecommunications System) mobile phone and for some satellite phones as well. It is basically, a unique 17 or 15 digit code that is used to identify the mobile station to the GSM or UMTS network. GSM network uses the IMEI number to identify the valid devices connected to the networks.

IMSI: stands for the International Mobile Subscriber Identity number. It is a unique 15-digit code used to identify the mobile phone users on GSM or UMTS networks. The IMSI is stored in the SIM (Subscriber Identity Module) card. When connected to the network, the phone sends the IMSI to the network. The IMSI number consists of parts namely, Mobile Country Code (MCC), Mobile Network Code (MNC) and Mobile Subscriber Identity Number (MSIN).

MAC Address: stands for Media Access Control address. It is a unique identifier assigned by the manufacturer to network interface cards (NICs) or network adapters, and it is known as the physical address.

3. SYSTEM ARCHITECTURE

The architecture depicted in Figure 1 decomposes the system into various components that seamlessly interact providing a practical solution to the positioning problem in indoor campuses. The system follows a typical client/server architecture with the client (mobile) running an application specifically built for this project. The mobile application can be installed on any Symbian OS based mobile phone.

3.1 System Components

The system consists of 4 major components which are described in the following sections.

Web Server

The web server functions were implemented using PHP scripts [7]. The server is the hardcore of the system. The main tasks of PHP server are: register users, update the database, retrieve user location, sends out user location information via SMS and post it online.

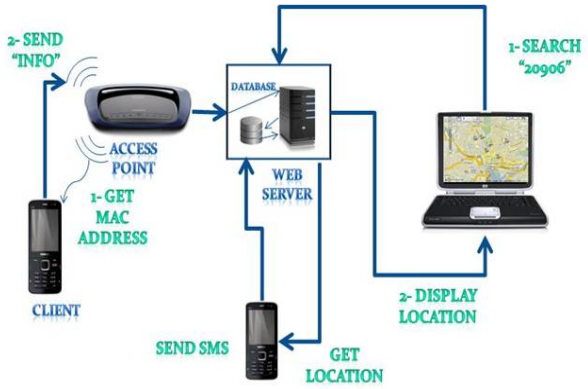

Figure 1: System Architecture

Application

On the mobile side, the application was developed and implemented using Java 2 micro edition (J2ME) [8]. The J2ME application runs on any Symbian OS based phone. Note that the application can only operate on a WiFi-enabled mobile phone.

Database

The server uses a MySQL database. MySQL is an open source relational database management system which uses Structured Query Language (SQL). MySQL was chosen because of its reliability, speed and flexibility. The server receives requests from the application program. The request can be either to register a new user, update user information, or locate an existing user. The server tokenizes the user requests, and issues the appropriate SQL statement to perform the required action.

GSM Modem

A Siemens tc35i GSM modem is used to send/receive the SMS messages. The GSM modem is connected to the web server. The GSM modem was programmed to send/receive the SMS messages using a C# application [9]. We chose C# language as it contains many useful libraries like:

- **System.Timers:** used for scheduling the tasks and running the application in the background 24/7.
- **System.IO.Ports:** for creating serial ports and listening to the ports from any incoming or received information coming through the serial ports (GSM modem is connected to port com1)
- **MySql.Data.MySqlClient:** used to open a connection the MySQL database (server database), and retrieve the needed information by executing SQL queries.

3.2 System Operation

The operational steps of the proposed system on the server and client side can be categorized into 5 modes as follows:

- **Server Configuration Mode:** Initially, a database with the MAC addresses of the various WiFi access points (APs) on campus is developed. Each AP is associated with a physical location description on the campus, e.g. *Library 2nd Floor West Side*, as well as a graphical image of the AP location. The physical description of the location (in a text format) will be sent via SMS to the mobile that issued the request to locate an individual, whereas the graphical display of the location will be projected to the web system users.

- **Client Configuration Mode:** The client installs the application on his/her mobile phone and configures (if different from the default values) the web server's IP address, the GSM Number and the Refreshment Rate of which the application will be sending data. An example is shown in Figure 2.

Figure 2: Screenshot of Mobile Configuration.

- **Registration Mode:** The application prompts the user to enter name, gender, nickname, id, age, etc, and then retrieves IMEI number, IMSI number, and MAC address of the mobile phone. Following that, it generates an SMS that is sent to the GSM number specified in the Configuration Mode. On the server side, the SMS is received by the GSM modem and broken into segments that identifies the user with his personal and mobile details and this information is stored it in the server database. The mobile phone number is retrieved from the SMS header, that is set by the telecommunication company, to validate the user's identity. At this point, the user is registered and his information can be used to locate him/her. An additional feature of the system is that it allows users to create a public or private profile. The default public profile allows the user's location to be identified to any system user that issues a request to locate. The private profile on the other hand, allows only a set of pre-selected users to view the location. These selected users are specified during registration time using their usernames or mobile phone numbers.

- **Running Mode:** The application program running on the mobile of all system users, periodically (at the refreshment rate specified in the registration mode) sends the IMEI, IMSI, timestamp, and MAC address of each mobile phone to the specified server via the WiFi access point it is connected to. The application also retrieves and sends the MAC addresses of all APs within the mobile phone coverage range, with their corresponding signal strengths. The IMEI, IMSI, and mobile phone MAC address are used by the server to identify the user. Although, the mobile phone MAC address is enough to identify the user, the additional details, i.e. IMEI and IMSI, are used to further confirm the user's identity. The server validates the 3 parameters by comparing it against the information stored in the database during the registration phase. In case any of the parameters didn't match, the packet is dropped. The MAC addresses of the APs are used to accurately locate the user as will be explained in the next section.

- **Locating Mode:** The user can locate a person either via an SMS request or online using the web. The looked-up person's identity can be specified using his/her username, name, or mobile phone number. Upon receiving the request, the server first checks if the looked-up person's profile is valid. It then checks if the looked-up person has a public or private profile. In case, the profile was private, the server verifies if the requester is allowed to access the looked up person.

To identify the user's location, the algorithm retrieves from the database the MAC addresses of the AP in the vicinity of the user with their corresponding signal strengths. In our current implementation, the search algorithm simply associates the looked-up person with the AP with the strongest signal strength. The pre-stored physical location of this AP is then looked up and sent to the requester as either an SMS text message or a visual plot displayed on a webpage.

An example of an exchanged SMS message to locate a user John using his mobile number is:

Locate 0502255765

The server's response will be:

The user John (0502255765) was last located in the 2nd floor of the library, east wing at 12:47pm.

←T→	MacAddress	Location	X_Axis	Y_Axis
	00:0B:85:73:56:8A	Library 2nd Floor - Middle	839	357
	00:0B:85:73:99:DA	Library 2nd Floor - East Side	871	409
	00:0B:85:73:8F:BA	Library 2nd Floor - Airport Road	918	394
	00:0B:85:73:9B:0A	Library 2nd Floor - Airport Road	934	362
	00:0B:85:73:A3:FA	Library 2nd Floor - Airport Road	912	327
	00:0B:85:73:A3:8A	Library 2nd Floor - Engineering Side	866	312
	00:0B:85:73:99:0A	Library 2nd Floor - Engineering Side	819	329
	00:0B:85:73:50:BA	Library 2nd Floor - Main Building Side	775	364
	00:0A:6F:87:99:A2	Architecture 1st Floor	350	247
	00:0A:6F:27:9B:A7	Student Center 1st Floor	411	243

Figure 3: Example of APs at the American Univ. of Sharjah with their associated physical locations.

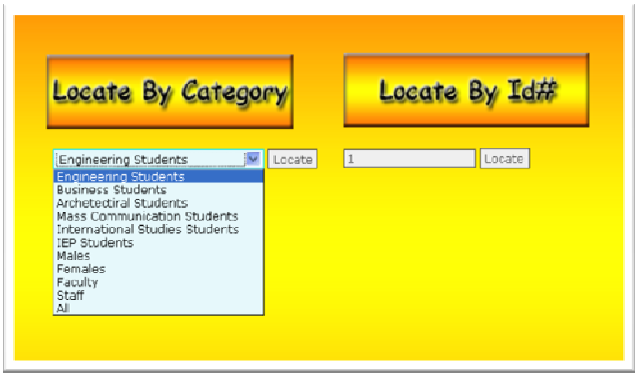

Figure 4: Example of the available search options. Users can locate specific users by providing the user ID. Users can also locate a group of users based on their categories.

4. EXPERIMENTAL RESULTS

The library of the American University of Sharjah (AUS) was used as a test bed. It consists of three floors and is equipped with 9 access points (APs) on each floor. The MAC address of each AP with its corresponding physical location was recorded in the server's database. Figure 3 displays an example of the physical description of some of the APs.

Ten students were selected to test the system. Each user registered via SMS. Half of the students set their profile to public and the other half set their profile to private. Random lookup requests were made through SMS or web and returned successful results. The history of the looked up user information is also displayed either in an SMS message or web based page (see Figure 5). The students felt that the application was easy to understand and use.

The system was also extended to identify categories of users based on various parameters such as major, gender, faculty/staff/student, etc. This can help in studying movement patterns among humans with different backgrounds. Figure 4 shows the list of implemented parameters.

Figure 5: Example of a tracing the user's location.

5. FEASIBLE APPLICATIONS

A typical application of the proposed system is to track colleagues at work, students at universities and schools, patients and doctors in a hospital. The system can be integrated to social networking websites, such as facebook, to allow people to track their friend's locations (upon the friend's approval).

It can also be used to secure the safety of children by tracking their movements in indoor locations such as schools or shopping malls. The system can be adjusted to alert the parents in case the children are no longer within an allowed area.

The proposed solution can also be used to study human movement patterns and promote gender equality. For example, it can trace and study the movements of women and men in locations such as malls to study their shopping patterns. Analysts can then use this information to improve the mall facilities.

6. CONCLUSIONS

Wi-Fi infrastructures are increasingly being deployed in major building such as hospitals, hotels, universities, train stations, parks, shopping malls and airports. If we take into account that most if not all future generation of mobile phones will be WiFi-enabled, then the positioning approach presented in this paper seems to be the logical solution to the indoor tracking problem. The solution requires minimal additional resources to the existing infrastructure and was tested with favorable results. In the near future the algorithm used in the paper will be enhanced by adding sophisticated positioning techniques such as fingerprinting and triangulation.

7. REFERENCES

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