Network Based Location Tracking Using MAC Address of Smart Devices

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Declaration

We hereby declare that this thesis report is our hard work put together, which has not been submitted anywhere for any award. All the contents written here are totally based on our unyielding labor and findings, dedicated to complete our undergraduate thesis. In this paper, we used information from other sources, which have been acknowledged and referred appropriately in the reference section.

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Acronyms and abbreviation

ADT- Android Development Tools

AOSP- Android Open Source Project

API- Application Program Interface

APK- Android Package Kit

APP- short for application

BIM- Building Information Model

CPU- Central Processing Unit

DNS- Domain Name System

EHA- Ethernet Hardware Address

GPS- Global Positioning System

IDE- Integrated Development Environment

IP- Internet Protocol

JSON- JavaScript Object Notation

LAN- Local Area Network

MAC- Media Access Control

OS- Operating System

RFID- Radio Frequency Identification

SDK- Software Development Kit

SQL- Structured Query Language

UI- User Interface

UWB- Ultra Wide Band

WAN- Wide Area Network

WLAN- Wireless LAN

Abstract

Most of the devices we use today from a day to day basis are considered smart. What do they mean by smart? What they mean is that they possess the ability to share and hold information amongst each other. Since the capacity of machines has evolved so has its needs and applications. Personnel location is one such capacity that has a huge array of applications. Our thesis, provides a segmented approach to locating targets namely staff in a working environment under a previously configured network i.e a system of routers repeater and extenders connected toeach otherfor our proposed system to work . We propose to use the 48 bit physical address known as MAC address of a regular smart phone which will help us connect to a WIFI network to track people's location. We are trying to implement an android based application which will employ Wi-Fi routers, repeaters and extenders to obtain the location of a target in a defined network. This location will be viewable through a map on the android app. After initial testing on a small network consisting of a router and a wifi signal extender which basically acts as another router we achieved total coverage every time i.e every time our discovery feature prompted a list of all connected devices without missing any device. We plan to use our university quarters as the test site and this will allow our app to access multiple MAC addresses as the campus is home to thousands of students and their devices.

Chapter 1

Introduction

1.1 Motivation

Since the establishment of well-known positioning techniques such as GPS, a lot of resources and time has been invested in the development of such technologies. Such efforts have given rise to various other techniques of location including indoor positioning which is the main subject of this paper. In recent years, wireless systems have permeated into most aspects of modern life. Medical, industrial, public safety, logistics, and transport system to name but a few. The availability and applications of wireless information access has allowed more accurate positioning in wireless networks for both indoor and outdoor environments. [1], [2].

For all these advances, to implement some of these techniques a new infrastructure has to be developed almost indefinitely. A lot of capital has to be allocated to the installation and maintenance of such systems. There lacks a system that can seamlessly sync with an existing infrastructure of a work environment so as to not raise costs elsewhere.

1.2 Thesis Goal

To develop a system that can provide stable location of personnel utilizing existing infrastructure of a work environment mainly routers and all devices that connect to those routers. The key approach that we have taken is to track the MAC(Media Access Control) address which is a 48 bit unique numeric identifier that is usually assigned to devices to distinguish them from other devices on that network. Our aim is to not provide accurate tracking to the meter yet to show the general location of an individual in the existing network. We will elaborate on this in the following chapters.

1.3 Thesis Contribution Summary

The summary of the main contributions are as follows

Several papers and extensive research has been done on tracking systems before but our approach in this paper has been to use the device MAC which is a unique identifier which

means it can used to differentiate devices. In our system, the MAC address is queried by our app using one of its features called MAC discovery. After discovery, the list of MAC address can be viewed through the app by the user. Upon receiving the list if the user wants to know thelocation of a particular individual, they can click on their discovered MAC which will be referenced in the database prior as their name. Upon clicking their name, the user is prompted onto a Google map of the work space our proposed network is mapped onto. On the map, the closest router the queried individual is connected to, is shown.

1.4 Thesis outline

In this thesis, we will discuss about-

- Chapter 02- In this chapter we discuss about background study and required components.
- Chapter 03- In this chapter we discuss how we implemented our proposed model using the necessary tools talked about in the previous chapter.
- Chapter 04- This chapter discusses the results that our setup yielded.
- Chapter 05- Finally, in this chapter we talk about the conclusion to our thesis and the future works.

Chapter2

BACKGROUND STUDY

2.1 System Description: Hardware

2.1.1 Wireless Network

Wireless network is a computer based network that does not require any kind of cables to connect into the network. Now a day's wireless network is very popular because it reduces the cost of cables and also less complicated setup procedure [1]. In 1969 at the University of Hawaii, first established the professional wireless network and it operated in June 1971 and the first commercial wireless network was WaveLan product family established in 1986. There are many kinds of wireless network like cell phone network, wireless local area networks (WLAN), wireless sensor networks, satellite communication networks and terrestrial microwave network. In our project we create a wireless network to identify the mac addresses of connected device in our network. Figure 1 shows the wireless network model.

Figure 1: Wireless network Model [23]

2.1.2 Mac address

Media access control is a unique hardware identifier number that is assigned on each device in a network. It's also known as Ethernet hardware address(EHA), hardware address, adapter address or physical address.[2]Mac addresses are 48 bits in length, divided in 24 bits vendor code and 24 bits serial address and the format of Mac address is MM:MM:MM:SS:SS:SS. First 24 bits are represented the ID number of the manufacture that is assigned by an internet standard body and the last 24 bits are assigned by manufacturer. Mac address is very important to identify each device in a network and to make local Ethernet network functional. Figure 2 shows the structure of MAC address.
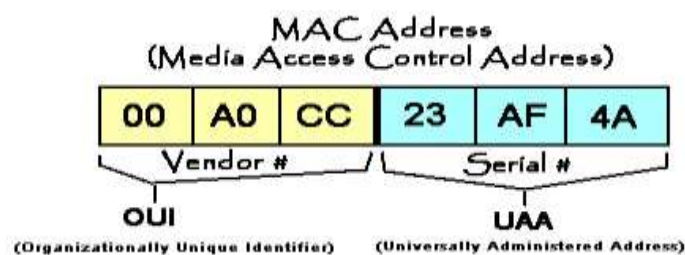
Figure 2: MAC address structure [24]

2.1.3 Router

Router is an electronic device that connects multiple computer networks through wired or wireless connection [3]. In OSI model it operates in network layer, basically a router is a layer 3 network gateway device which connects more than one network. It's also used to receive, analyse and convert data from another network. A router is different than other networking devices like hub or switch cause a hub or switch just only transfer data between computers but a router not only send data but also analyse data. A router consists of CPU memory, and I/O interface. In our project, to create a network we used a tp-link router. Figure 3 shows the creation of a wireless network through router.

Figure 3: Create network through router [21]

2.2 System description: Software

2.2.1 Android Operating System

Android is an OS (Operating System) developed by Google for such device like Smartphone's, tablets [4]. Android mobile operating system has begun its version history with the release of the Android beta version in November 2007. Android 1.0 (First version), the first commercial version was released in September 2008, but Cupcake was its first confectionary name operated in April 29, 2009.

Android is a Linux based system, this operating system can be divided in five sections and four main layers such as Applications, Application framework, Libraries and Android runtime, Linux Kernel[6]. Figure 4 shows the architecture of android operating system.
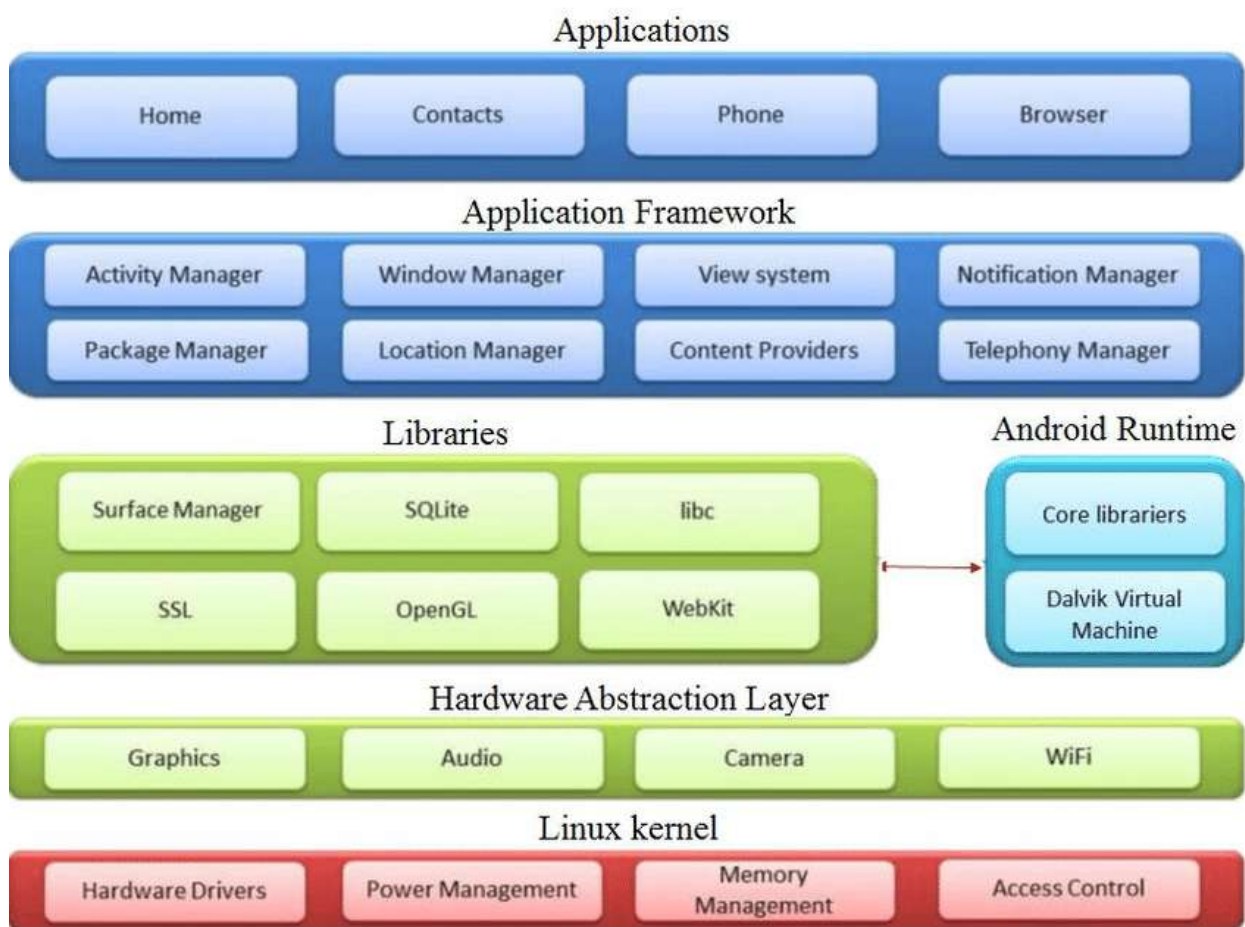

Figure 4: Android Operating System hardware [22]

Application is the top layer in android architecture. In this layer we can install our application or we can write our own application code [27].

Android SDK is the most commonly used software development kit for android, it provides API libraries and tools to develop android application in java programming language. By using SDK, develop a new android application is called Application framework.

Libraries can be divided in two parts, one is implemented as part of Android open source project (AOSP) such as Bionic libc library, Dalvik virtual machine library, Media library anf android OpenGL [6]. Another one is integrated into ASOP from external open source project like Open SSL, SQLite database engine, webkit etc.

Runtime actually makes a device an android device rather than mobile version of Linux kernel.

Last layer of android architecture is Linux Kernel, it gives a level of speculation between the device hardware, it also takes care of device hardware like display, camera, keypad etc [28].

2.2.2 Android Application Development implementation

- **Prototyping:** Photoshop CS6 has been used for prototyping, it actually shows how an app look like after implementation

- **User Interface:** Basic building block for android user interface is layouts; some important layouts are Frame layout, linear layout, Relative layout, Grid layout.

- **Testing UI in different version:** Test the application in different version like maximum compatibility in Ice cream sandwich to updated version android Nougat.

- **Volley Instantiation:** Volley library has been used to transfer data from server.

- **Parsing JSON Data from Server**

- **Implementation of the controller**

- **Handling the image**

In our project, we have to find location of a specific person under a network. To implement this we build an android application which name is "MACTRAK". MACTRAK is an android application which will give real time location update. This application is successfully run in android operating system device like Smart phones and tablets.

2.2.3 API (Application Program Interface)

API is an application programming interface. It is like an engine under the hood and is behind the scene that we take for granted [7]. API works as a communication source which takes request from the system and decides what to do and then return the response. An API is a set of rules or protocols that decides how the components of an application should interact. For example, if you want to book an airline ticket, you use usually use various websites to book your ticket. But how come different websites give you a seat in the same plane? Here comes the API. It makes the direct communication to the airline software and book the ticket. In our project we have used a Wi-Fi API which will provide us the mac addresses and IP addresses of the connected devices to a router network. Figure 5 shows how API works.
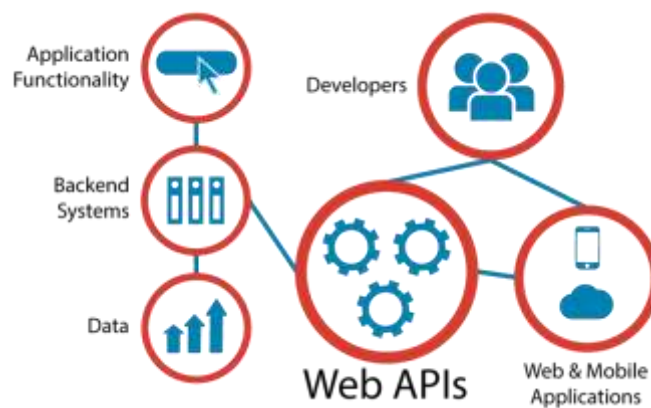

Figure 5: Application Program Interface [25]

2.2.4 Android Studio

Android Studio is an integrated development environment (IDE) for developing for the Android platform. It was declared on May 16, 2013 at the Google I/O conference by Google's Product Manager, Katherine Chou [5]. Android Studio is the most popular platform for

android developer; it allows developer to write code using java and control the android device. It's replaced eclipse android development tools (ADT) because it's easy to implement and design. Table 1 shows the comparison between Android Studio and Eclipse ADT.

Table 1: Difference between Android Studio vs Eclipse

Feature	Android Studio	Eclipse ADT
Build System	Gradle	Apache Ant
Maven-based build dependencies	Yes	No
Build variants and multiple –APK generation	Yes	No
Advanced Android code completion and refactoring	Yes	No
Graphical layout editor	Yes	Yes
APK signing and keystore management	Yes	Yes
NDK support	Yes	Yes

Android Studio is available for download on Windows, Mac OS and Linux. We used android studio to development our application "MacTrak".

2.2.5 Programming language

We have predominantly used java to code most of modules of the app. We have also used XML so that it was easier to move the source code from one device to another in order to individually modify the code.

2.3 Related Research

A lot of research has been aimed at the development and implementation of indoor positioning systems. DOLPHIN (Distributed Object Locating System for Physical-space Internetworking) is an indoor based positioning system that uses Ultrasound to locate objects in the system, done by Fukuju et al. [10]. It can also perform with the help of Radio Frequency. In order to locate objects, some of the objects are manually identified first and using their positions and a recursive algorithm, DOLPHIN manages to position all the objects in the system.

IndoorAtlas, another indoor positioning system, produces a map of a building and spots the desired subjects in the system using geomagnetic technology [11]. This method of technology uses Earth's magnetic field and the magnetic sensors in our Smart phones to recognize the subjects. Unlike other tracking systems, IndoorAtlas can track the location or movement of individuals in real time.

Bayesian indoor positioning systems, on the other hand, uses wireless networks to pin point its subjects [12]. Due to the use of wireless networks, Bayesian systems are able to locate multiple subjects at once. The system implements a Bayesian hierarchical model to assume the indoor location of the subjects by using already saved or stored data which erases the hassle of collecting data and feeding it to the system.

A Low-Cost Ultra-Wideband Indoor Ranging System obviously uses short pulse ultra-wide band (UWB) signals[13]. The entire system includes a transmitter and a receiver where the transmitter emits UWB signals. The frequency of the pulse produced helps calculate the distance between the devices and the client.

Android Based on Campus Location Tracking with Bluetooth – This system is mainly to be used in environments like a campus. It implements the access of the Bluetooth module of a smart phone to track or locate individuals created by Tisgaonkar et al.[14]. Servers store the unique Bluetooth Id and the identity of the corresponding personnel along with the location of the device. The information can then be accessed via mobile application which retrieves the information required from the server.

There were also many researches on finding location using GPS. We all know that GPS does not perform that much efficiently inside the building. In M Kjærgaard et al. article he tried to show how much GPS is efficient in different material made houses like wooden house, brick house, shopping mall [19]. J. Chung et al. used geo-magnetism to track indoor, basically he used magnetic sensors which gives data through Bluetooth and a stepper motor which will move to track within range [20].

BIM-Based Indoor-Emergency-Navigation-System for Complex Buildings – BIM (Building information model) is the process of generating digital representations of places in accordance to their physical and functional characteristics [Wikipedia]. These are usually used to view building plans on mobile devices or for routing purposes. With the help of BIM and wireless LAN (WLAN), ultra-wide-band (UWB), and radio frequency identification

(RFID), this system finds out the shortest way through a public building done by Rueppel et al.[15]. However, this can also be used to pin point devices within the range of the network.

The next system is tracking in indoor symbolic space using RFID sensors. Clearly, this involves use of RFID sensors which picks up the radio frequencies emitted by devices but first they have introduced a framework which holds the graph created for the space that can be tracked and it was developed by Kang et al.[16]. This is followed by the use of the RFID sensors and a construction algorithm to locate the subjects or clients. The full form of RFID is radio frequency identification. It usually use radio signals to detect location. Electromagnetic fields were used to perform the task of a RFID. RFID works as a tag and reader system, a tag is like a small chip which is attached to the object that we want to track and the reader is the one that reads the signal of that tag. S. Chukamon et al. published an article on blind navigation system using RFID for indoor environment [17]. They have used a RFID tag with a blind people and RFID reader will locate its location inside the building. Tesoriero et al. paper on finding location using active and passive RFID technology helped to detect location inside the building. RFID tags can be active or passive. Active RFID uses its own power supply usually a battery whereas passive RFID tags do not need power supply because the induce current is enough to transmit the response [18]. The function of RFID is easy to use but one of the major drawbacks is the cost of RFID tags. To track a single person this device might be very much helpful but to track vast number of people RFID will not be cost efficient.

Design and Implementation

3.1 Proposed Model

Figure 6 shows a detail block diagram of our proposed model.
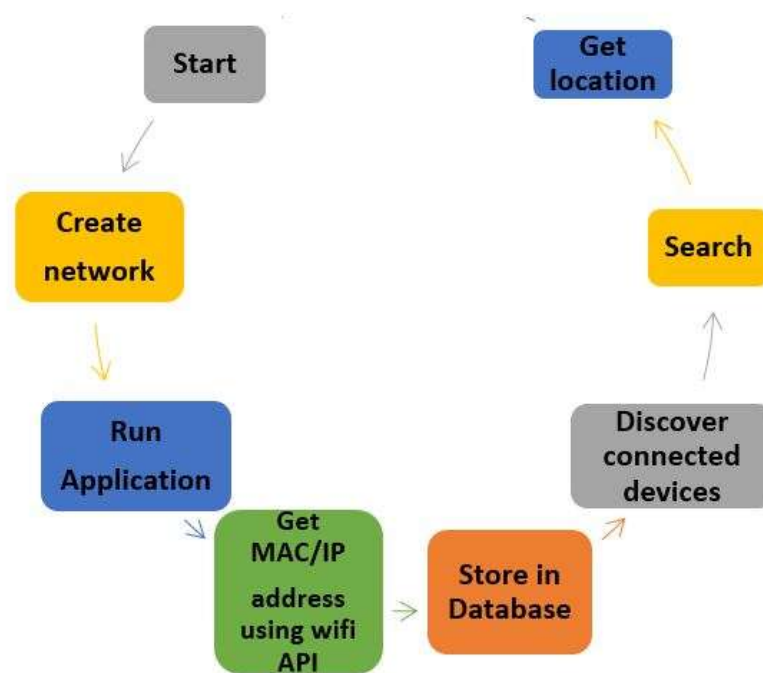

Figure 6: Visual representation of proposed model

3.2 Model Description

3.2.1 Proposed Network Setup

In order for our proposed model to work multiple routers, extenders or access points need to be connected under one network. That means all the routers and access points need to be connected through Ethernet cables. This allows for repeater and extenders to be put in place that can connect to the routers and access points through WPS (Wireless Protected Setup). Through much trial and error we have seen that extenders or repeaters work equally as well

as routers and the setup is quicker and does not require extensive knowledge of how routers and extenders work. If multiple hard wired access points or routers can be arranged in a physical space then multiple extenders and repeaters can also be used to widen the network hence giving our system more accessibility to data it needs. This proposed network setup is beneficial to our system because our system shows the proximity of the closest router that individual devices are connected to. So the more the number of routers access points and extenders it will help our system pinpoint the location of the user more precisely without the possibility of deadzones preventing network access   .Theoretically for a builiding with 10 stories 30 routersin total or a mixture of one router per floor accompanied by2 extenders or2 access pointsper router to amplify signal is adequate. Figure 7 shows our proposed network.
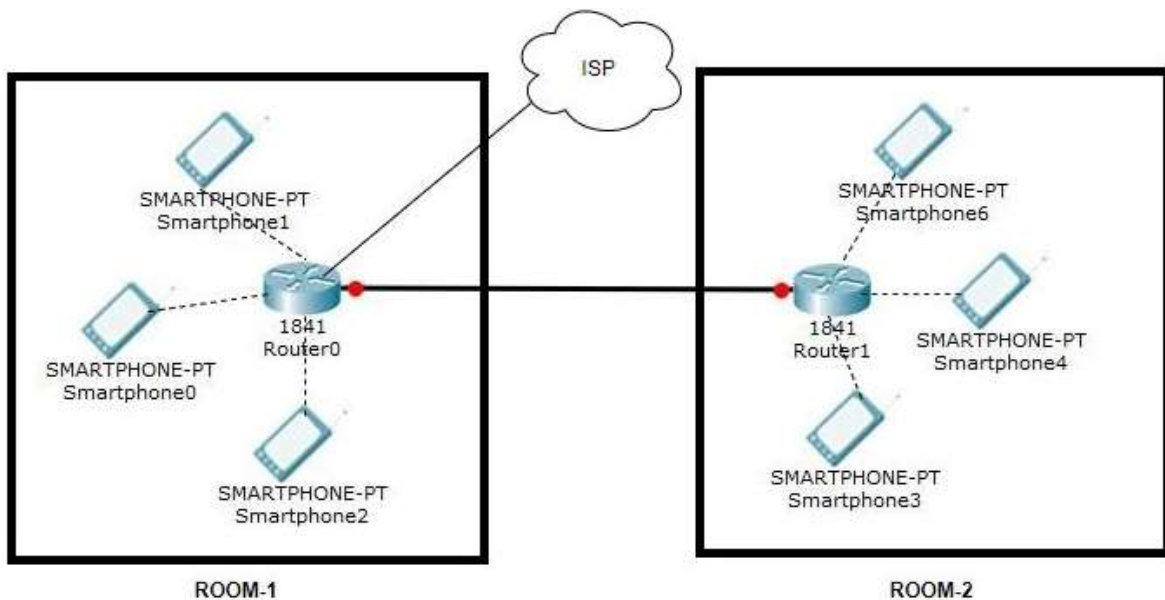

Figure 7: Proposed Network Setup

3.2.2 MAC address discovery

We have used Androids very own Wi-Fi API to discover MAC addresses of devices connected to the network. The WifiInfo and WifiManager classes deal with the kind of data required for our system to run. Using the WifiInfo class we prompted information such as the link speed, SSID, BSSID and most importantly and crucially the MAC address of a device after the app pings the network to which the device is connected to. WifiManager was one of the integral android classes used during our thesis. This class provided us the primary API to manage and manipulate the various aspects of Wi-fi connectivity required for the location

based services our app offers. Wi-fi and its specific operations played a huge role in allowing us to accomplish much of our desired targets relating to this thesis. We used methods under the WifiInfo class to obtain the necessary device information required by our app to find the location of a device or the router it's connected to within our proposed network. A few examples of methods we used are .getLinkSpeed(), .getSSID(), .getBSSID() and getMacAddress().

3.2.3 Storing device information in database

For storing all the information fetched from a device we have used android.database.sqlite which uses database management classes to store information is its own private database. We had a few options for using different databases in our app namely the fully open sourced MySQL relational database, Cloud storage or SQLite. We chose the SQLite for a specific purpose. As we know in today's technological world security issues plague a lot of connected systems and as our app deals with private information such as device MAC and other relevant information of the user it was imperative that we used a private database. Cloud storage was also a viable candidate for its usability accessibility and relative low costs but security issues of a cloud based database could not be overlooked owing to the private nature of the data being stored. We also alluded using the fully sourced MySQL to reduce complexity of code as it would have required us to generate PHP scripts and write additional application code with necessary parametersto send to the PHP page and this in turn would fetch data from the MySQL database. Both the alternate storage techniques could replace the existing storage system in the future if at some point the data load gets too much for the phone memory to handle.

3.2.4 Searching, locating and displaying location in map

One of the features afforded by the private database system is that all individual users and their information (MAC, IP) and also routers can be stored for future reference. We have further implemented a search option which lets you search for a particular individual if their device MAC has been stored by the app prior to search. This allows us to locate an individual using a map which has been integrated with the app using Google maps android API. Basically how this works is that all routers are fed to the app database prior to launch so that when particular device and the router its connected to is discovered it pops up on the map with the router name (example, bulding1, floor 7 which is the router name) and we can locate the individuals general location. The physical location can be viewed through the app.

Chapter 4

Experimental Setup and Results Analysis

4.1 App Interface

Our app uses a relatively straight forward user interface to keep things as simple and straightforward so that users from all walks of life have an uncomplicated user experience. It has a home page that holds a discover button and an option button. Figure 8(a), 8(b) shows the user interface of the application in two different android versions.
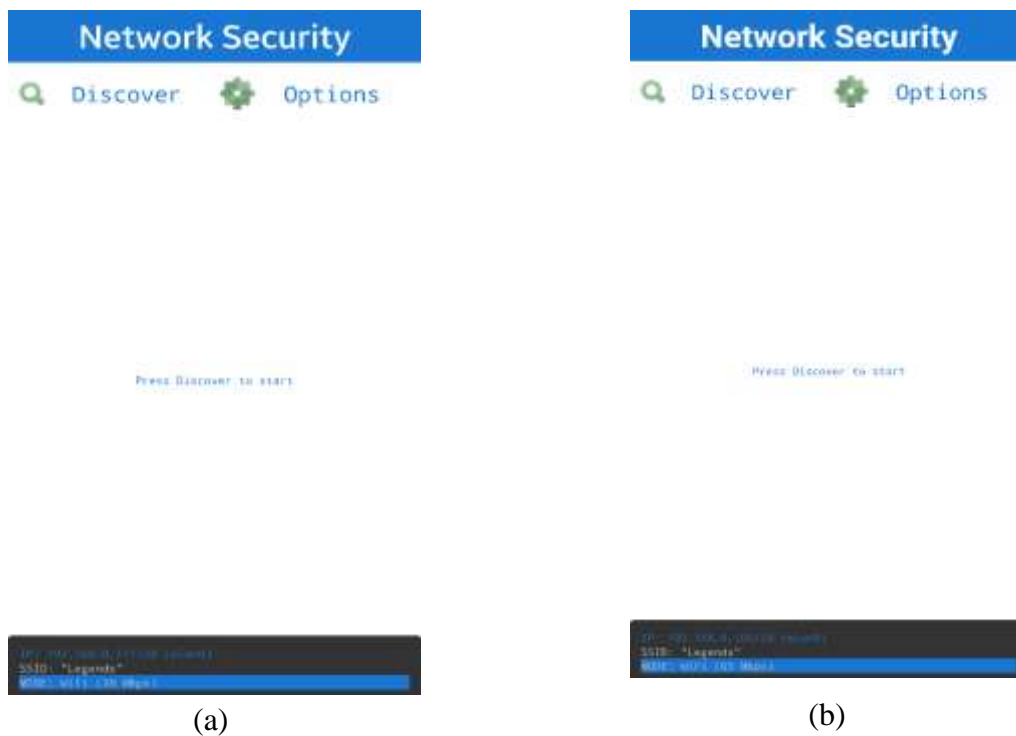

| (a) | (b) |

Figure 8 : (a)Android version UI 6.0.1, (b) Android version UI 6.0

4.1.1 Discover button

Upon pressing the discover button our app pings the network to which the devices are connected and outputs a list of all those devices. If the queried persons MAC is present in the list then upon pressing that individuals name it will output their general location i.e. the location where the router they are connected to is situated. In our initial testing where we built a simple network consisting of a router and a signal extender, we used up to 15 devices

at once which were all discovered by the system and was also successfully showed the location of the router on the map. Figure 9 shows the devices connected to the network in discover mode.

Figure 9:Android version UI 6.0.1 after discovery

4.1.2 App settings

The app settings allow you to change a few basic parameters relating to the app. In the general settings, the app can be configured to connect to a particular network interface from a list of prior interfaces. There's a resolve hostname option by enabling which IP addresses can be resolved using Android system DNS. Vibration can be enabled which lets users know when discovery has completed successfully and if the user wishes to check the updated data base they can download it to their phones. The default MAC discovery method is the ping.

Custom IP range can also be set allowing for another search technique if an IP address is known prior. Figure 10 shows the application in settings mode.

Figure 10: App setting

4.1.3 Location Map

After all the MAC addresses are discovered, to locate an individual if their name is clicked on from the screen the user is prompted onto a Google map showing the building that individual is in and the router that their device has connected to. Routers in our system will be named using their actual location hence the map legend will immediately show the device location. Figure 11(a) shows the location prompt action box and after clicking "Track" figure 11(b) shows the physical location of a device connected to a specific created network.
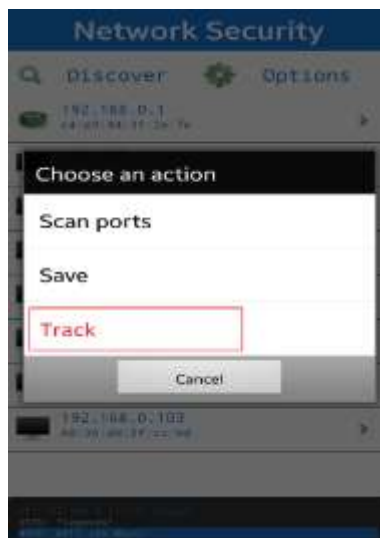

Figure 11(a): Location Query

Figure 11(b): Map View

4.1.4 Comparison to similar techniques

As we have mentioned before, our technique uses MAC Address to query location. Other similar techniques have been used for location with varying degrees of efficiency and accuracy. RFID tag, Bluetooth module, UWB based techniques etc. are examples of other location tracking systems. These happen to be more expensive and require much more complicated installation processes than a wireless network based technique. Other than ours, several other systems applied wireless network for location tracking, some using MAC addresses and some using IMEI, IMSI. MacTrak, however, executes the tracking operation and simplifies it to an android application. This makes it exceptionally user friendly allowing the general population to utilize this technology in their daily lives.

4.1.5 App performance

The charts below show a real time sample diagnostic of how our app runs. The amount of memory usage, CPU cycles and network speeds hat can be expected when the app is running perfectly. This is provided to serve as a base to show how the data should look when there is no issue. Figure 12 shows the CPU usage of our application.
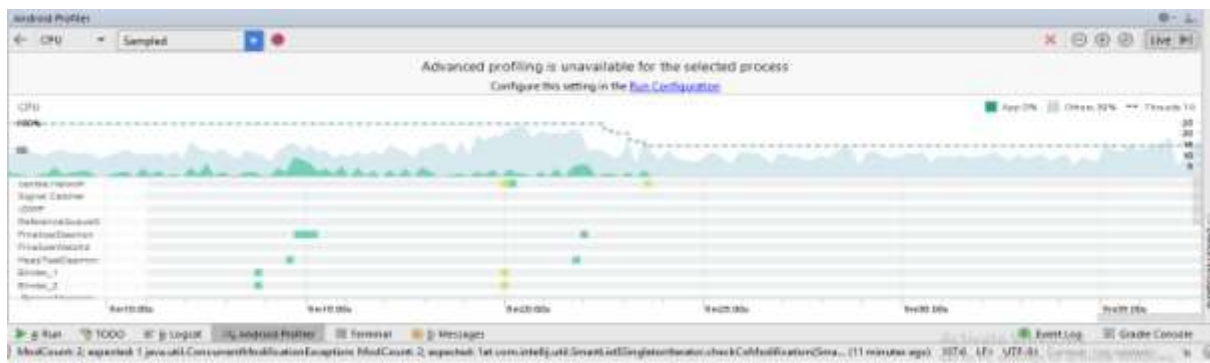
18

Figure 12: CPU usage
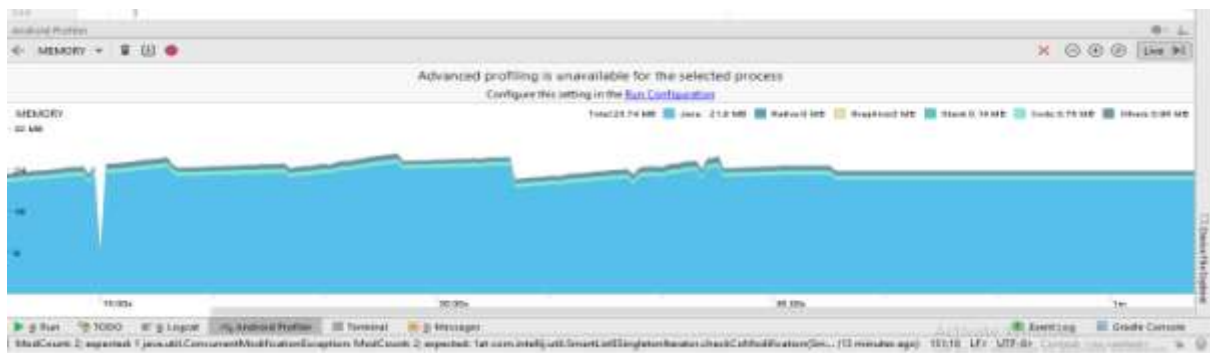
Figure 13 shows the memory usage of our application.

Figure 13: Memory usage

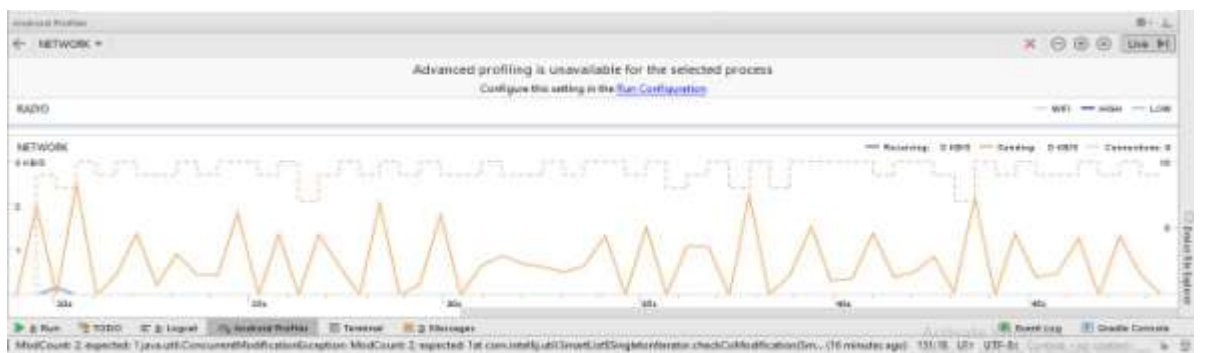Figure 14 shows the network usage of our application.

Figure 14: Network usage

Chapter 5

Conclusion and Future Plan

5.1 Conclusion

Through our app we hope to provide a stable, relatively cost effective and seamless means of locating personnel in work environments. Our MAC driven approach ensures that no external devices such as GPS, RFID etc. are required to provide comparatively accurate positioning. User MAC is discovered using android Wi-Fi API and stored in SQLite database. Users can be discovered or searched individually if they are inside the proposed network setup and their MAC has been referenced the app prior to search respectively.

5.2 Future works

Routers and networking devices are integral to our system as tracking their location gives us the location of users. Pinpointing the router location gives us the chance to infer the location of the user because most routers have fixed range. In the future, we hope to implement a more comprehensive location set up using custom maps of work environments where our app will be used. This will allow for a more vivid representation of our router network. We can also further refine our app adding a lot of features such as a messaging module and call option. At this point in time the only factor limiting the number of users our app can handle is the size of our database. We hope to implement an online server in the future whether cloud based or a fully stand-alone open sourced MySQL database as we have mentioned previously to deal with the huge load of device data that our app will have to store.

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