Peter Kiplagat

Android Vehicle Tracking System

Metropolia University of Applied Sciences

Bachelor of Engineering

Degree Programme in Information Technology

Bachelor's Thesis

7 May 2019

Author Title Number of Pages Date	Peter Kiplagat Android Vehicle Tracking System 43 pages + 12 appendices 7 May 2019
Degree	Bachelor of Engineering
Degree Programme	Information Technology
Professional Major	Software Engineering
Instructors	Jarkko Vuori, Principal Lecturer

This project was conducted for a small logistic company co-owned by the author and partners, and the purpose was to build an Android vehicle tracking system to be used as a tool for tracking of the company's vehicles. The initial implementation as outline in this report was only limited to real-time tracking as a foundation to adding more features in the future.

The mobile application was developed in Android Studio IDE using the Java programming language, while the tracking device was built from the Arduino Uno and SIM808 GSM/GPS/BT shield. Firebase Realtime database was used as a database server, and PHP was used as a script language to setup the proxy server in the Metropolia school server.

The implementation results were satisfactory with a functioning vehicle tracking system. The tracking device was capable of tracking the vehicle's speed and location and successfully sending it to a database server while the Android mobile application was capable of communicating with the server and displaying the GPS data on the device's google maps.

The developed tracking system can be used effectively to track the company's vehicles. However, it still needs more optimization and additional features to get excellent tracking information. The product is yet to receive feedback from the other partners, but notable future development would be to study how to improve the map representation on the mobile application.

Keywords	Android, Arduino, Firebase Realtime Database

Contents

Glossary

API	Application Programming Interface. A set of tools for building software
APK	Android Package. A package file format used by Android operating system for distribution and installation of mobile applications
AT	ATtension. AT Commands are instructions used to control a modem
BT	Bluetooth
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HTTP	Hypertext Transfer Protocol
IDE	Integrated Development Environment
iOS	iPhone Operating System
JDK	Java Development Kit. A software development environment used for developing Java applications and applets.
JSON	JavaScript Object Notation
NDK	Native Development Kit. A toolset used for implementing applications in native code using C and C++
SDK	Software Development Kit
UART	Universal Asynchronous Receiver- Transmitter
UI	User Interface

1 Introduction

The world has evolved and continues to evolve with technology. And this has led to tremendous growth in businesses in all aspects. Particularly the mobile phone industries. The invention of smart mobile phones has seen many companies compete to develop and consistently improve their devices to match the new technology.

More important is the focus on the software development. All mobile devices ran on different software platforms i.e. Android, iOS and Windows. This has in turn led to phenomenal development of mobile applications especially by service providers who wish to provide their services through the mobile phone.

The goal of this project was to build a vehicle tracking system for a small logistic company registered abroad and co-owned by the author and family. From a commercial perspective, GPS tracking continues to gain demand as businesses especially trucking companies continue to recognize its benefits. This has led to, for example, improved delivery time and better fleet management and hence reduced inefficiencies and operation cost.

The case company currently subscribes to tracking services from Goome GPS trackers [1]. Hence, the motivation for choosing this subject for the thesis. Although, the service fees seem negligible at the moment, a foreseeable company's growth in the future will definitely be felt. Additionally, there is a flexibility to add more features to this product in the future, but currently the product only provides GPS tracking.

This thesis has been divided into seven chapters. Chapter one introduces the purpose of the thesis while chapters two and three gives the background of the case company and the current technology being utilized along with other existing tracking technologies. Chapter four introduces the development tools that were utilized in the implementation and chapter five gives the theory on Android operating system. The step by step implementation and test results are detailed in chapter six and the report is concluded with chapter seven.

2 Current State

As mentioned in the introduction, this project was proposed as a solution to try and provide a better and optimized solution to the current technology deployed by the company associated with the author. This chapter gives a brief overview of this case company under which the project was undertaken, the current technology and the proposed solution .

The case company is a small scale logistic company registered in the year 2015 in Kenya. It is co-owned by the author and family members. And as such, the idea of the project was born by the author with the intention of using the acquired technical skills to try and provide an alternative solution to what is currently being utilized. The idea was brought to the attention of the team members with the objective of reducing the company's cost and providing more optimization.

Currently the company subscribes to tracking solutions from Goome GPS trackers, i.e. a Chinese tech company that develops and manufactures GPS tracking devices for vehicles, people and assets [1]. Like many other tracking solutions, their service includes an installation of a GPS tracking device on a vehicle and a mobile application for tracking. This comes with a one-time installation charge and yearly fee that may differ with countries.

Since the idea behind the project was to provide a cheaper and optimized alternative, a brainstorming session was raised in one of the meetings to get an insight of the team members opinions. The following were concluded:

- A cheaper solution was viable especially with the feasible growth of the company
- A flexible solution was needed because the current technology only provided GPS tracking with no modification possibilities.
- There was considerable inconvenience as it relates to maintenance from the company representatives.

For this reasons, a flexible solution was suggested with the initial aim of providing a similar GPS tracking with the possibilities of adding more features to the application in the future such as maintenance and drivers records. With a majority of the members owning an Android phone, it was concluded that the project would begin with an Android mobile application with the possibility of developing an iOS application in the future.

3 Existing Tracking Technologies

In order to successfully complete the project, a general understanding of how GPS tracking works needed to be studied. And since the company already had a working solution, i.e. from Goome GPS trackers, there was already a vague idea on how the project needed to be conducted. Basically the three obvious requirements needed were: a tracking hardware, a server and a mobile application. This chapter gives the theory on the existing tracking technologies that were studied.

Goome GPS Trackers

The studies began with Goome GPS Trackers since it was a known working technology that the company was already using. When this service was ordered back in the year 2015, the company sent there field technicians who came to install the tracking hardware's on the trucks. It was followed by an office meeting where the usage training was offered including the software downloads.

A number of vehicle tracking devices are available for sale on Goome's website. At the time of studying, the G19s model was their hot product. Figure 1 displays the G19s tracking device with its features.

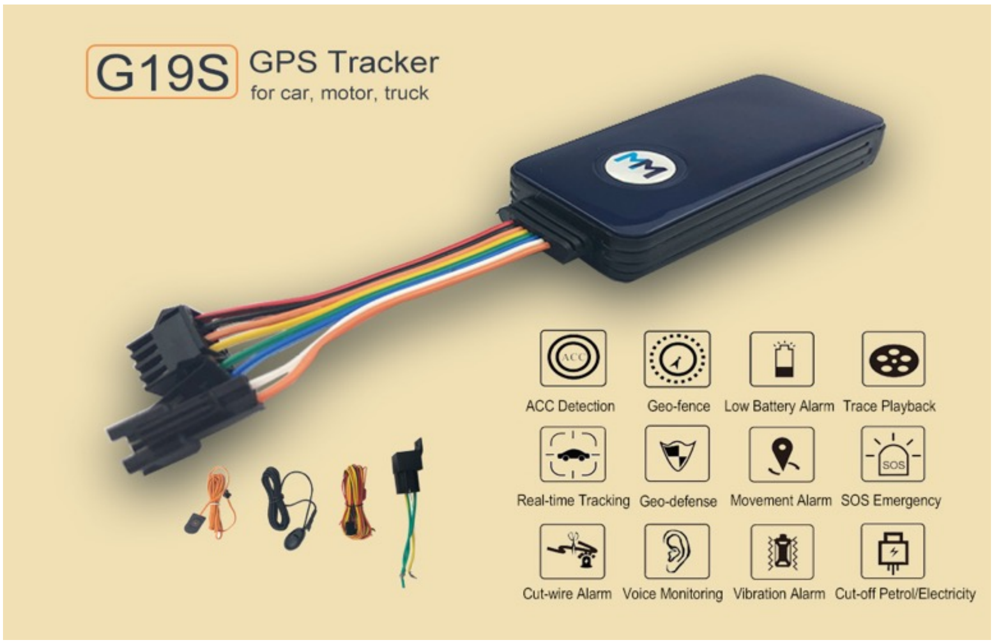


Figure 1. G19s tracker [2].

Figure 1 displays the G19S tracking device with its tracking features which include, for example, real-time tracking, geo-fence, trace playback, movement etc. A quick online chat with their customer service confirmed their prices to be very reasonable and affordable. This comes with a free mobile application for both Android and iOS.

Auto Leaders/ Sino Track

Like Goome trackers, Sino track is a Chinese company offering similar tracking solutions. At the time of studying, the ST-908 model was their latest tracking device. A general comparison of the features listed on their website found their products to be similar to Goome's with competitive prices.

In conclusion from this and other tracking providers not documented here, it was found that most of the available tracking solutions were very much similar and within the same price ranges. Most of them offer a one-time payment for their tracking devices in addition to free software applications for both the mobile and the computer. They come with user manuals and can be posted to almost any part of the continent. Most of their hardware is open source but not programmable. Their software is also customized and without the possibilities of adding more features.

4 Development Tools

4.1 Android Studio

Android application development begins with setting up the development environment. Although Android operating system is based on Linux, Android SDK and tools are available for all the major operating systems i.e. Mac OS, Windows and Linux. Android Studio is the official Integrated Development Environment (IDE) for Android application development based on IntelliJ IDEA, which offers a powerful code editor and developer tools with enhancing features such as:

- A flexible Gradle-based build system
- A fast and feature-rich emulator
- A unified environment for developing for all Android devices
- Instant Run for pushing changes to a running application without building a new APK
- Code templates and GitHub integration to assist in building common application features and importing sample code
- Extensive testing tools and frameworks
- Lint tools to catch performance, usability, version compatibility, and other problems
- C++ and NDK support
- Built-in support for Google Cloud Platform. [3]

Android Studio is freely available for download from the official Android developer home page. It comes with installation instructions, which include a setup wizard for downloading the recommended Android SDK and lists the minimum system requirements for any of the chosen operating system. Android Studio version 2.2 and higher comes bundled with the latest OpenJDK, which is the recommended JDK version for Android projects [4].

4.2 Firebase

Firebase is a backend platform for building web and mobile applications. It was launched in April, 2012 by Tamplin and Andrew Lee, initially providing API's for integrating online chats to websites and now as a *Baas* (Backend as a Service) platform for continuously improving the cloud experience with new features and functionalities [5].

Firebase Realtime Database

Firebase Realtime Database is a NoSQL cloud hosted database that provides storage of data in JSON format and real-time synchronization to all connected users. Its key capabilities include data syncing to provide live updates to connected devices unlike the use of HTTP requests, offline response through SDK persistence of data to disk, scalability across multiple databases and direct connection from either a mobile device or web browser as it does not need an application server. In addition, it provides an expression-based rules language i.e. Firebase Realtime Database Security Rules for defining the data structure and read and write permissions. [6]

Firebase Cloud Firestore

Cloud Firestore is a NoSQL cloud-hosted document database that provides direct access to mobile and web applications through native SDK's. Data is stored in documents which are organized into collections hence providing flexible, hierarchical data structures, which in turn offers fast and simplified querying of data and automatic scaling. Additional capabilities include; real-time listeners for syncing data across connected applications, offline response, serverless connection and integration with other Firebase and Google Cloud Platform (GCP). [7]

Firebase Authentication

Most applications require the identity of their users in order to securely save their data to the cloud and avail them on any of their devices. This is achieved using FirebaseUI as a complete drop-in auth solution or by using the Firebase Authentication SDK to manually integrate one or more sign-in methods into the app. Firebase supports authentication of users on applications using passwords, phone numbers and popular federated identities such as Google and Facebook. [8]

Firebase Cloud Storage

Cloud Storage enables application developers to store and serve user-generated content, such as photos or videos. Firebase SDKs for Cloud Storage provides robust uploads and downloads irrespective of network quality i.e. ensuring the client can retry the operation right where it left off, saving the users time and bandwidth. Other capabilities include integration with Firebase Authentication and automatic scaling. [9]

4.3 Arduino

Arduino is an open source electronic platform based on simple hardware and software. It came into existence at the Ivrea Interaction Design Institute as a simple tool for fast prototyping and aimed at students lacking electronic and programming backgrounds. All Arduino boards and software are entirely open-source and can be adapted by the users as they see fit. [10]

There currently exists many boards in the Arduino family with the most popular including but not limited to Arduino Uno, Arduino Nano, Arduino Mega and Arduino Due. Arduino boards use Arduino programming language as a set of instructions to read inputs and turn them into outputs. The Arduino programming language follows the C++ code structure and is made up of Functions for controlling the Arduino board and performing computations and variables for defining the Arduino data types and constants. [11]

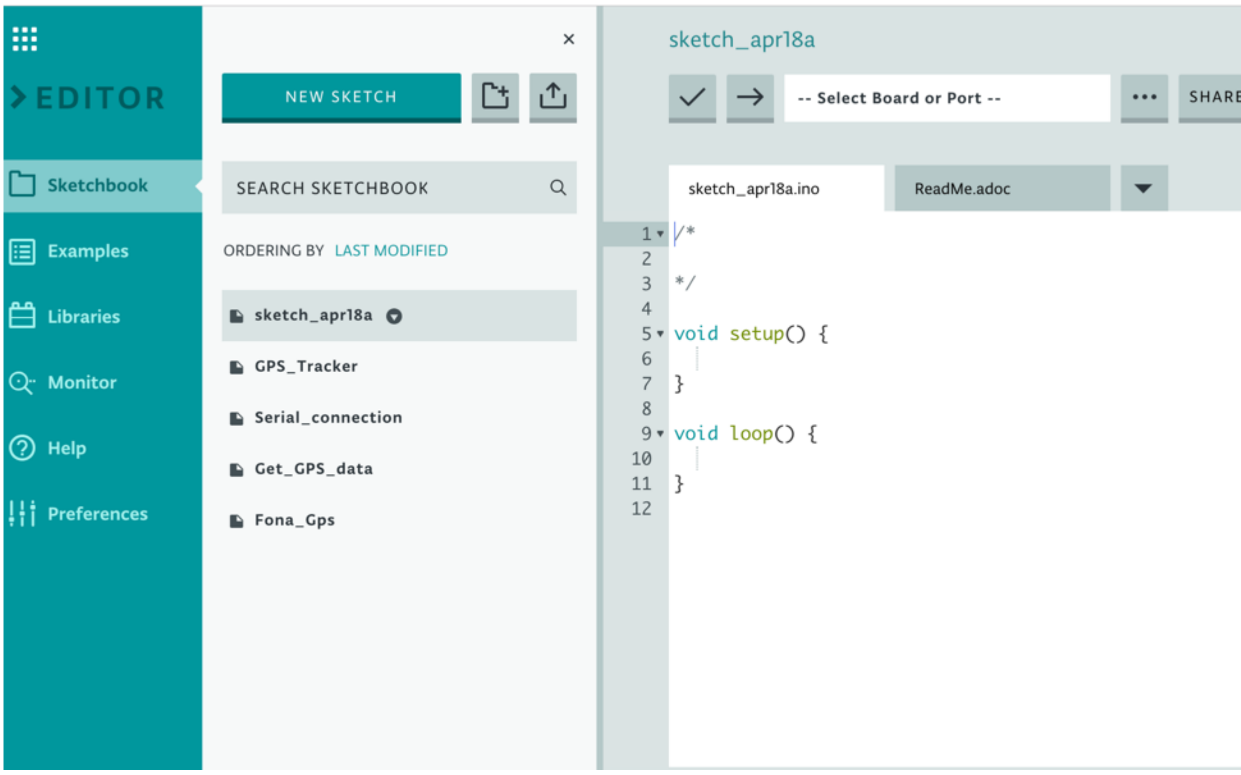
Arduino software is available for all the major operating systems i.e. Mac, Windows and Linux. Their boards are relatively cheaper compared to other available microcontrollers. For this reasons among others and their simplicity, it was chosen for this project.

Arduino IDE

The Arduino IDE is a development platform that allows users to write different kinds of embedded programs and upload them on to the many available Arduino boards. Arduino IDE is available in two options:

- Online IDE: With the Arduino Web Editor, the sketches can be saved in the cloud making them available from any device. It requires a reliable internet connection to function and the updates are automatic.
- Offline IDE: The offline IDE requires installation on to the development system. The sketches are saved on to the local machines, and they do not require an internet connection other than when uploading the codes to the boards. Updates are initiated by the user. [12]

Figure 2 shows a screen shot of the Online IDE.



```
/*

*/

void setup() {

}

void loop() {

}
```

Figure 2. Screen shot of Arduino Web Editor.

Figure 2 displays a screenshot of the Arduino Web Editor. As observed, the IDE contains a section of different folders which includes, for instance, libraries and examples meant to guide and help in the writing of the Arduino program. Also noticeable, are the two default functions needed for a working Arduino program:

- Setup() function: It is called once when the program is started i.e. powerup or reset of the board for initialization purposes.
- Loop() function: It is called after the Setup() function for looping purposes.

Uploading of the code to the board is quiet streamlined. One just needs to connect an USB cable to the USB port of the Arduino from the computer, select the board/port, compile the code and just save it to the board.

Arduino Shields

Arduino Shields are boards that can be stacked on top of the Arduino board to further extend its features [13]. Different kinds of shields are available on the market, both official and unofficial and a quick search on the net yields multiple results. They provide many features such as wireless communication in the form of GPRS or Bluetooth, additional sensors such as GPS and much more.

SIM808 module

SIM808 module is one of the latest Arduino shields used in this project that supports GSM/GPRS Quad-Band network and uses GPS technology to achieve satellite navigation. The key features include 850/900/1800/1900 MHz Quad-band, support for Bluetooth 4.0, high GPS receive sensitivity and support for A-GPS for indoor localization. [14]

Figure 3 displays a snapshot of the SIM808 module with the integrated GSM, GPS and BT chips.

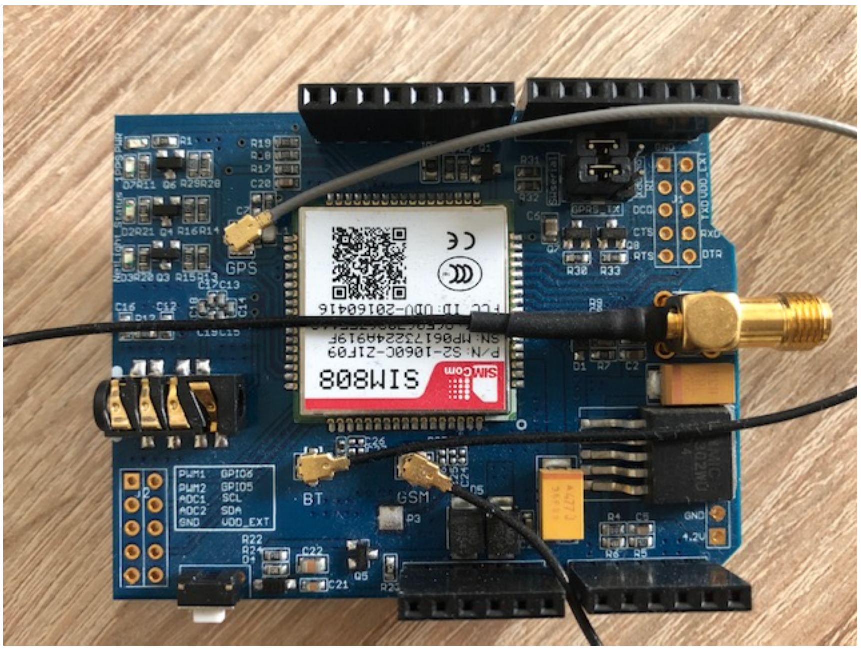


Figure 3. Snapshot of SIM808 module

As illustrated in Figure 3, the SIM808 module is integrated with the GSM, GPS and BT chips and their functionalities can be achieved by connecting them to their respective antennas.

SIM808 is controlled by AT (ATtension) commands through UART protocol to communicate with an Arduino as seen in Figure 4.

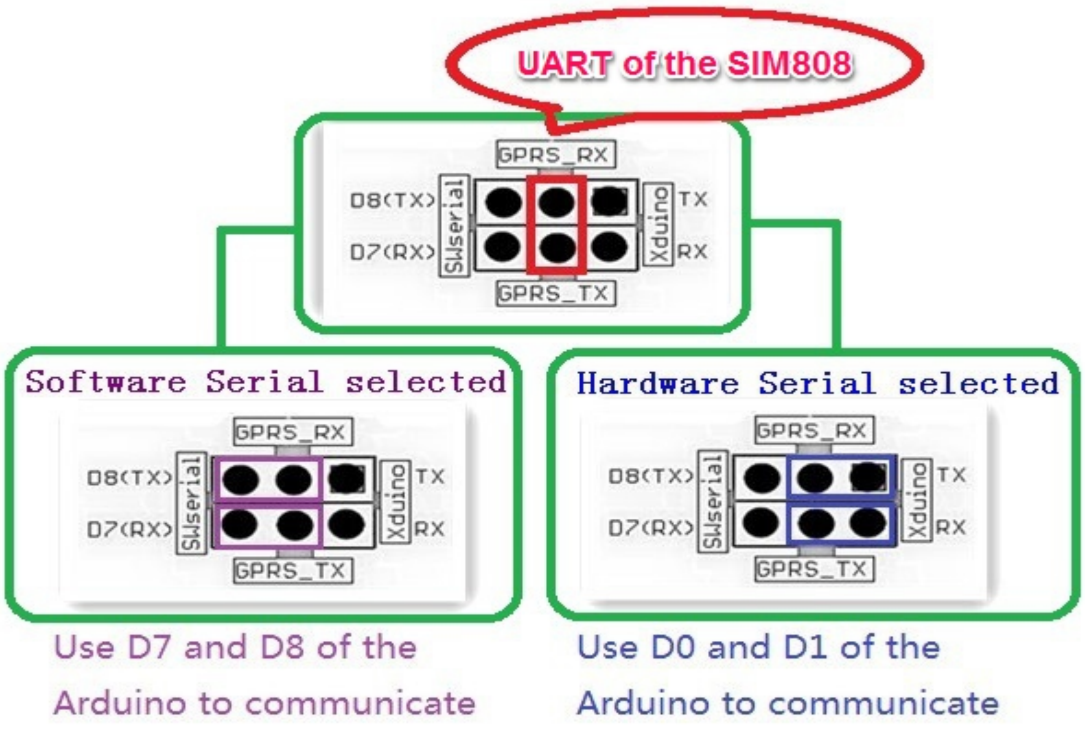


Figure 4. SIM808 shield communication port [14].

In Figure 4, hardware and software serial communication is enabled either through pins D0 and D1 or pins D7 and D8 of the Arduino, respectively. SIM808 shield was chosen for this particular project as it provided the needed capabilities of GSM and GPS communication. They are also relatively cheap and available and have a wealth of libraries.

Arduino Uno

Arduino Uno is one of the Arduino's microcontroller boards that is based on ATmega328, and consisting of 14 digital input/output pins, 6 analog inputs, USB connection, power jack and a reset button among other features. It is the reference model of the Arduino platform having been the first in a series of USB Arduino boards. [15]

It is the most robust and the most documented board of the Arduino family [15]. For this reason and the cost, it was chosen for this particular project. It is powered through an USB connection or an external battery and like the other boards, uses serial communication with the computer or other devices.

5 Android Application Development

A vast amount of free online information is available for Android application development from various web sites and forums including but not limited to Google's detailed developer guide. This section details the background of Android operating systems history and core topics.

5.1 Android Overview and Software Stack

Android is a Linux based mobile operating system originally developed by a startup with the same name. In 2005 Android Inc was acquired by Google along with its development team. Most of its code was released under the open source Apache License as it was Google's intention to make it open and free. This together with the ability to customize through addition of one's own proprietary extensions made it attractive to hardware manufacturers. [16, p. 2]

T-Mobile G1 was the first Android mobile handset with the first version of Android operating system released in the United States in October 2008. It has since undergone major transformation with the current version as of October 2018 being the Android 9 Pie. The initial version Android 1.0 included the common features like pull-down notifications, content sharing across applications and multitasking between applications but lacking advanced features such as voice search and turn-by-turn navigation which are now featured in the Android 9 Pie. The earlier versions included Cupcake (Android 1.5), Donut (Android 1.6), Éclair (Android 2.0), Froyo (Android 2.2), Gingerbread (Android 2.3), Honeycomb (Android 3.0), Ice Cream Sandwich (Android 4.0), Jelly Bean (Android 4.1), KitKat (Android 4.4), Lollipop (Android 5.0), Marshmallow (Android 6.0), Nougat (Android 7.0), Oreo (Android 8.0). [17, p. 11 ; 18].

Figure 5 displays the earliest and most recent Android handsets as of 2019.

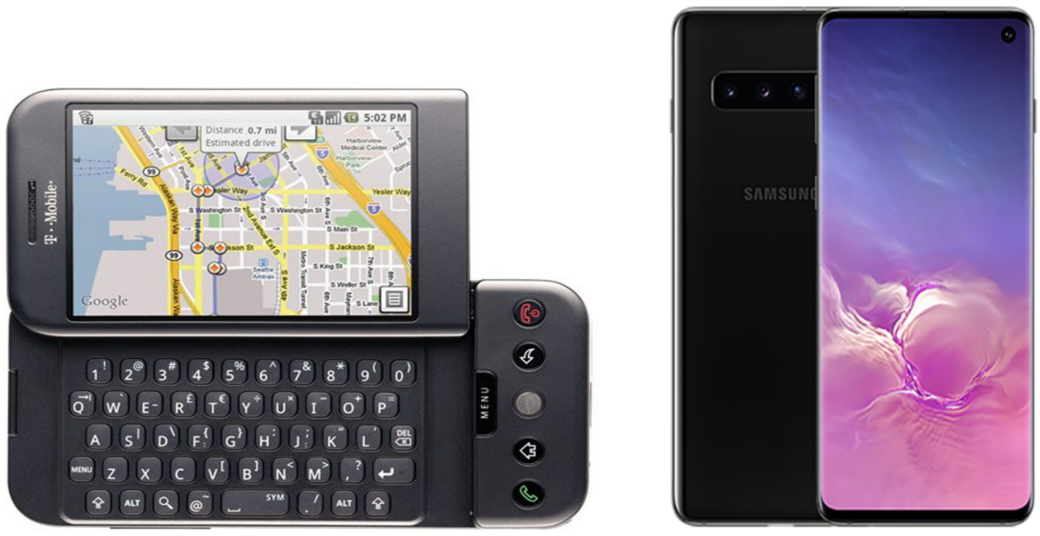


Figure 5. T-Mobile G1 with the first Android version 1.0 (left) and Samsung S10 with the latest version Android 9 Pie (right) [19; 20].

Figure 5 shows the contrast between the first and the latest android handsets with their respective versions. The device on the left is the T-Mobile G1 earlier released in 2008 adopting the very first Android operating system – Android 1.0 while the device on the right is the latest Samsung S10 recently released and running on the Android 9 Pie. The Pie emphasizes the power of Artificial Intelligence (AI) with noticeable changes being the removal of the three-button navigation setup from its predecessors. There are currently many Android devices in Market including but not limited to Smartphones, Tablets, E-readers, Internet TV'S, Automobiles and Smartwatches.

The Android operating system is simplified as a Linux kernel and a collection of C/C++ libraries exposed through an application framework that provides services for, and management of, the run time and applications. Its elements of composition are discussed below: [17, p. 15]

- **Linux kernel**: Linux 2.6 kernel handles the core services such as hardware drivers, process and memory management, security, network, and power management in addition to providing an abstraction layer between the hardware and the remainder of the stack.

- **Libraries**: This layer runs on top of the kernel and includes C/C++ core libraries such as libc and SSL. In addition is a media library for audio and video media playback, a surface manager for display management, graphic libraries for 2D and 3D graphics, SQLite for native database support and SSL and WebKit for integrated web browser and Internet security.
- **Android run time**: The Android run time, along with the core libraries and the Dalvik VM forms the basis for the application framework by powering the applications. The core libraries provide most of the functionality available in the core Java libraries in addition to Android specific libraries. While Dalvik is a register-based Virtual Machine optimized to ensure that a device can run multiple instances efficiently by relying on the Linux kernel for threading and low-level memory management.
- **Application framework**: The application framework provides the classes for creating Android applications in addition to generic abstraction for hardware access and managing the user interface and application resources. [17, p. 15]

Figure 6 displays all of these components stack together to form the complete framework.

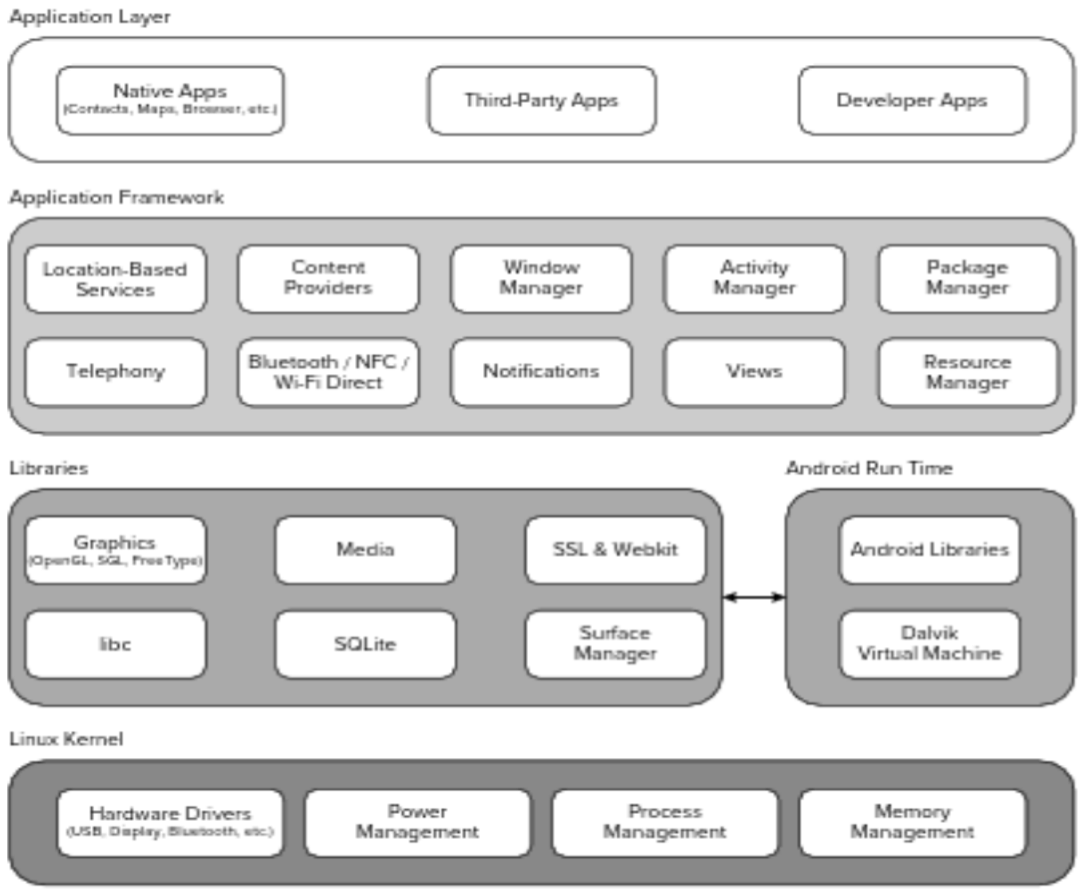


Figure 6. Android Software Stack [17, p. 16].

Figure 6 illustrates the different components discussed above as they are stacked on one another to form the complete Android Software architecture.

5.2 Android Application Framework and Components

The Application Framework layer provides Java classes to be used by the developer in designing and building applications. Component reuse being a key feature in Android's architecture enables a developer to publish and share activities, services, and data between applications. The Android framework is consists of the following key application services: [17, p. 17 ; 21]

- **Activity Manager** controls the lifecycle of applications and manages the activity stack.
- **Content Providers** allows sharing of data between applications.

- **Resource Manager** provides access to non-code resources such as strings, graphics and user interface layouts.
- **Notification Manager** enables applications to send alerts and notifications to the user
- **View System** contains a set of views to be used for creating user interfaces for applications.
- **Intents** provides a mechanism for transferring data between applications and their components. [17, p. 17 ; 21]

Application components are loosely linked by the application manifest file **AndroidManifest.xml** which gives a description of each component and how they interact. All Android applications have the manifest file which declares essential information to the Android platform it needs to know to successfully run the application. Among others, the declaration include the minimum API level, hardware/software features and permissions required by the application. [22 ; 23, p. 12]

Activities

An activity represents a single screen with a user interface through which a user can interact with the application. A single application can be composed of many activities in which one should be marked as the activity that is presented when the application is launched. For instance, an email application might have one activity showing a list of new emails, another activity for composing an email, and another activity for reading emails. An activity is implemented as a subclass of **Activity** class as shown in Appendix 1. [22 ; 23, p. 12]

The life cycle of an activity

The Activity instances in the application transition through different states of their lifecycle as the user flips through the application. The **Activity** class provides a number of call backs that allows the activity to be aware of their state transitions i.e. that the system is creating, stopping, or resuming an activity, or destroying the process in which the activity resides. The behaviour of an activity when the user leaves and re-enters the activity can be declared within the lifecycle call back methods. For instance, when building a streaming video player, the video can be paused and the network connection terminated when the user switches to another application, which will then be reconnected when the user returns allowing the video to resume from the same spot. [24]

Figure 7 provides a graphical view of an activity lifecycle.

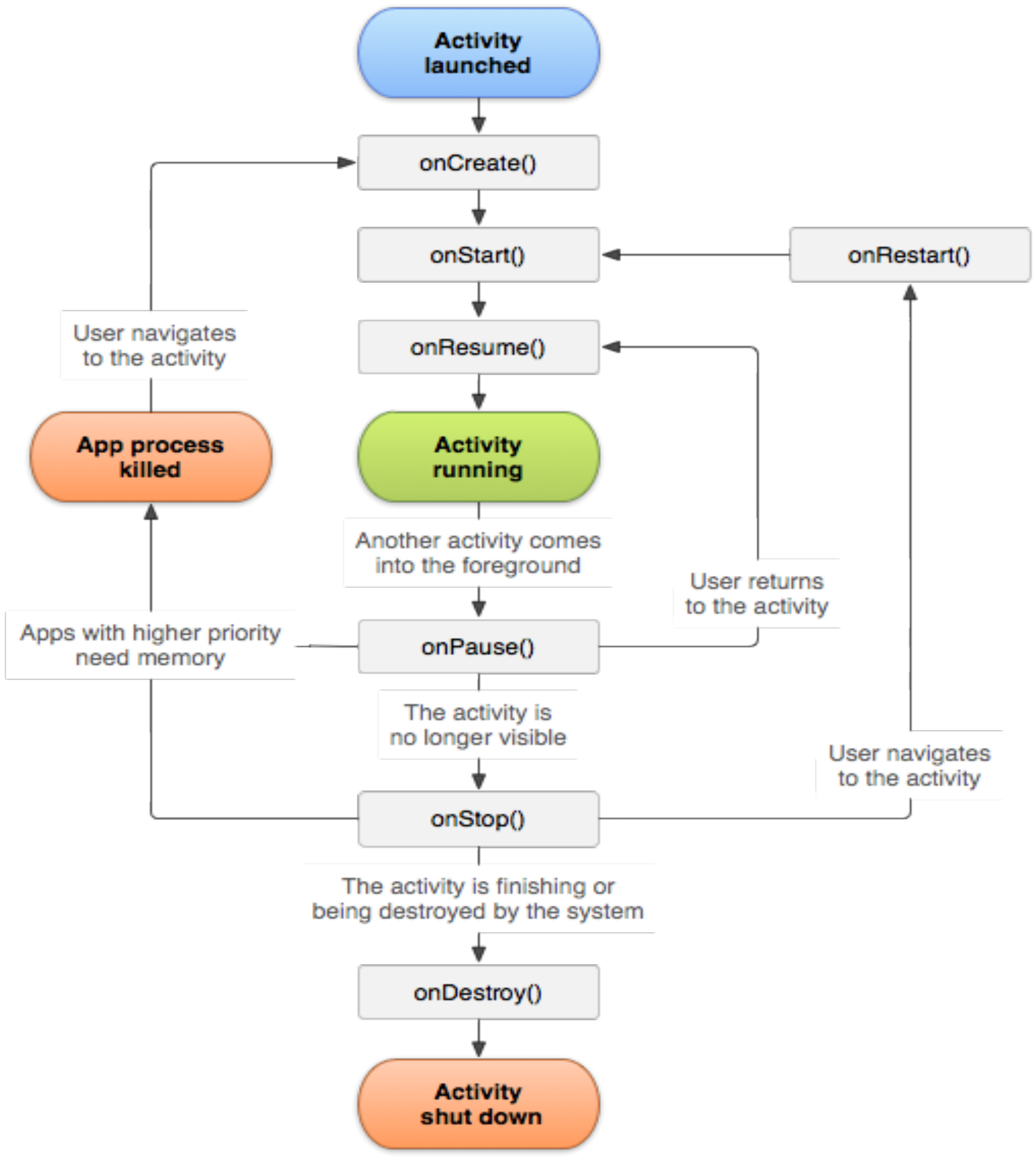

Activity launched
onCreate()
onStart()
onRestart()
User navigates to the activity
onResume()
App process killed
Activity running
Another activity comes into the foreground
User returns to the activity
Apps with higher priority need memory
onPause()
The activity is no longer visible
User navigates to the activity
onStop()
The activity is finishing or being destroyed by the system
onDestroy()
Activity shut down

Figure 7. Activity lifecycle [24].

Figure 7 illustrates a set of core call back methods used by an activity to transition between the different stages of its lifecycle. Although they all do not have to be always implemented, they provide developers a platform to achieve the desired user expectations through various processes as discussed below:

- **onCreate()** is a call back method that should always be implemented. It is called when an activity is first created i.e. from a user choosing to start an application. Basic application start up logic that should only happen once for its entire life are performed here. For instance, creating views, initializing variables and binding data to lists. After its execution, the system calls the *onStart()* and *onResume()* methods in quick succession to enter the *Started* state as an activity does not reside in *Created* state. Any lifecycle-aware component tied to the activity's lifecycle in the *Created* state also receives the *ON_CREATE* event.
- **onStart()** is invoked after the *onCreate* and just before an activity is visible to the user [23,14]. Through this call, the application prepares the activity to be visible and interactive to the user for instance by initializing the code that maintain the UI. Any lifecycle-aware component tied to the activity's lifecycle in the *Started* state also receives the *ON_START* event. Once completed, the activity enters the *Resumed* state has it neither resides in the *Started* state, and the system invokes the *onResume()* method.
- **onResume()** is invoked once the activity enters the *Resumed* state and becomes visible to the user. The application remains in this state until otherwise something happens e.g. receiving a phone call. An interruptive event moves the activity to the *Paused* state and the system invokes the *onPause()* method. Any lifecycle-aware component tied to the activity's lifecycle in this state receives the *ON_RESUME* event.
- **onPause()** is invoked when an activity's view becomes partially blocked and is no longer the focus of input [23,14] . The activity remains in this state until it either resumes by invoking the *onResume()* method or becomes completely invisible by invoking the *onStop()* callback. Any lifecycle-aware component tied to the activity's lifecycle in this state receives the *ON_PAUSE* event.
- **onStop()** is called once the activity moves to the Stopped state and becomes invisible to the user. From this state, the activity either reappears and the system invokes *onRestart* or is finished and the system invokes *onDestroy()* . Any

lifecycle-aware component tied to the activity's lifecycle in this state receives the *ON_STOP* event.

- **onRestart()** is called after the *onStop()* when the current activity is being re-displayed i.e. the user navigating back. It is followed by *onStart()* and *onResume()* successively [25].
- **onDestroy()** is the final call before the activity is destroyed. The system invokes this callback either because the activity is finishing (the user completely ending the activity) or the system is temporarily destroying the activity due to a configuration change (e.g. device rotation). Any lifecycle-aware component tied to the activity's lifecycle in this state also receives the *ON_DESTROY* event. [24]

Services

Services are application components lacking the user interface and running in the background. They can perform the same actions as activities but without the user interface and are useful for long-running operations. For example, a service might play music in the background while the user flips through different applications. A service is implemented as a subclass of **Service** class as shown in Appendix 1. [22 ; 26, p. 31-32]

Broadcast Receivers

Broadcast Receivers are application components without the user interface that simply respond to broadcast messages from either other applications or from the system, for example, a system initiated broadcast due to low battery or an incoming call. A broadcast receiver is implemented as a subclass of **Broadcast Receiver** class and each message is broadcaster as an Intent object as shown on Appendix 1. [22 ; 23, p. 18]

Content Providers

Content Providers are application components that provide interfaces for sharing data between applications. For example, the Contact application uses Contacts Provider to retrieve data about user's contacts. The Contacts application itself does not have any contacts data, and the Contacts Provider does not have any user interface. It is implemented as a subclass of **Content Provider** as shown in Appendix 1. [22 ; 26, p. 32-33]

Intents

Intents are messaging objects used to communicate between application components. The fundamental use cases are starting an activity, starting a service and delivering a broadcast. They can either be **Explicit intents**, i.e. they specify the application that will perform the action, or **Implicit intents**, i.e. they declare a general action to perform without specifying any component. [27]

6 Design, Implementation and Testing

This chapter describes the step by step development cycle of the software and hardware, from the design stages up until completion of the entire project.

6.1 Phase One: Design

The initial stage of the implementation began with the design of the visual layout of the desired end product. This was used as the basis of determining the hardware and software requirements and the visual logic needed for the implementation. The design chart in Figure 8 illustrates the process flow of the project.

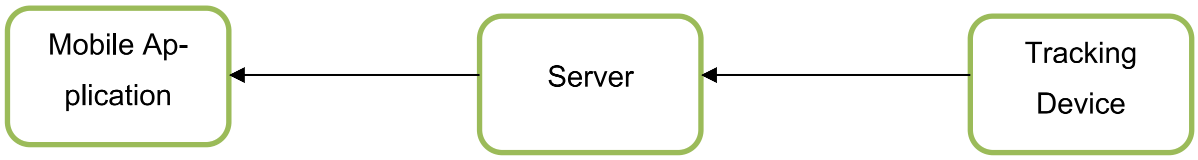


Figure 8. Project design as a process flow chart.

Figure 8 illustrates the logic and process flow of the desired end product. The tracking device would be responsible for tracking the location and speed of the vehicle and sending it to a server. The server would then store the data and avail them on request to the mobile application. Finally the mobile application would provide an interface for viewing the tracking information of the vehicle.

Before beginning to implement the design, certain requirements were set. The mobile application needed to be user friendly and easy to use and the cost needed to be kept as low as possible. For this reasons, two variables were chosen to be tracked: vehicle speed and location (latitude and longitude).

6.2 Phase Two: Implementation First Cycle

The first cycle of the implementation began with the design and building of the tracking device. The hardware and software tools needed to achieve this, as discussed on chapter 4 were chosen on the basis of the minimum variables set in Phase One of the implementation i.e. vehicle speed and location.

6.2.1 Hardware Installation

The hardware tools needed are listed below:

- Arduino Uno,
- SIM808 shield with GSM and GPS antennas and 3 V lithium battery
- 9 V battery
- USB cable
- SIM card

Figure 9 displays the complete hardware installation of Arduino Uno stacked with SIM808 shield.

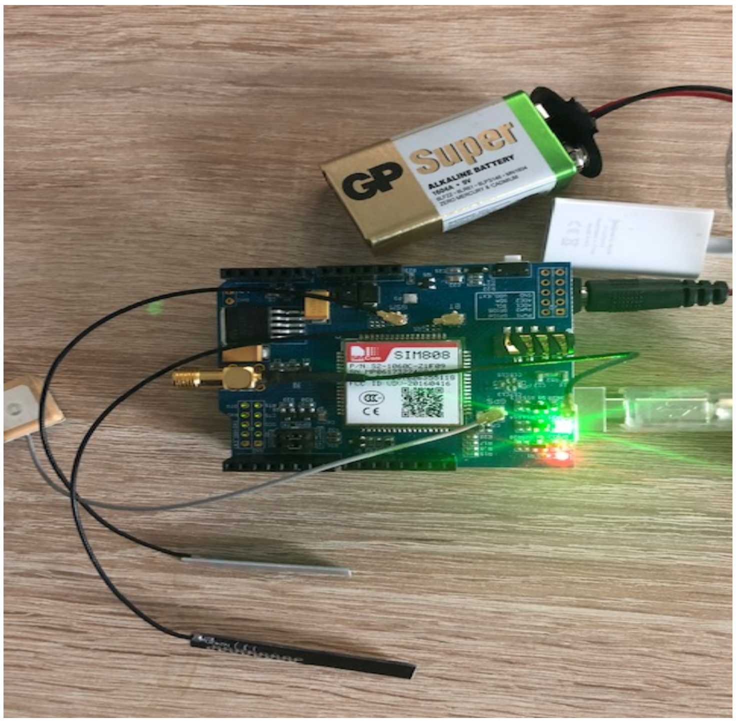


Figure 9. Arduino Uno with SIM808 shield.

The installation as shown in Figure 9 was pretty straightforward with the help of the user guide. The SIM card was unlocked and inserted on to the SIM card holder, the GSM and

GPS antennas were connected, the 3V lithium battery was inserted on the battery holder, then finally stacked on top of the Arduino Uno. The 9V battery was left for the final installation as the USB cable used for programming provided power supply needed for the initial set up and testing.

6.2.2 Software Installation and Programming

Once the hardware installation had been completed, the project moved to the final implementation of the first cycle, i.e. programming of the Arduino to track the speed and location. The development system used was a workstation with Mac operating system. In addition, Arduino IDE was needed for programming. The two available options were to download the Arduino IDE or use the Arduino Web Editor. The latter was chosen as it provided an easy setup with just an installation of the Arduino Plugin being required.

Next, the program was written. There exists a wide amount of libraries from the Arduino community. Tiny GPS, Tiny GPS++, DF Robot, SIM808 and Adafruit Fona are most of the libraries that were studied and experimented with. The project finally settled on Adafruit Fona library as a personal preference as it turned out to be more stable and simplified.

The most important parts of the code is highlighted in Listing 1 below, whereas the entire code can be viewed in Appendix 2.

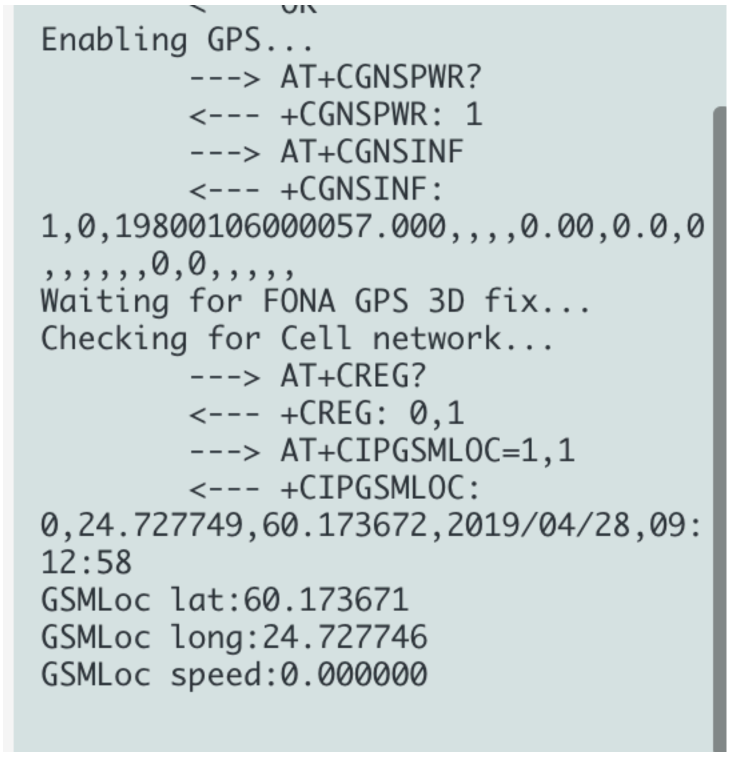
```
// Instances
SoftwareSerial fonaSS = SoftwareSerial(7, 8);

// Global variables for holding gps data
float latitude, longitude, speed_kph;

// Turn GPRS off & on again
  if (!fona.enableGPRS(false))
    Serial.println(F("Failed to turn off"));

  delay(1000);
  if (!fona.enableGPRS(true))
    Serial.println(F("Failed to turn on"));

  delay(1000);

boolean gps_success = fona.getGPS(&latitude, &longitude,
&speed_kph);
```

Listing 1. Section of the code for initializing and enabling GPRS.

As it can been observed from Listing 1, Software serial communication was enabled with pins 7 and 8 as RX and TX respectively. Global variables for holding the GPS data were declared as floating values, and finally the GPRS was enabled. The last line of code was used inside the **getGPS()** function to retrieve the GPS data i.e. latitude, longitude and speed.

6.2.3 Phase Two Testing

The first cycle was concluded with testing of the code on the serial monitor of the Arduino IDE. This was achieved by connecting the Arduino to the computer with an USB cable and switched ON with the ON/OFF button. The baud rate on the monitor was selected to match the baud rate in the code i.e. the recommended 19200 bps. The code was then compiled and after fixing of the errors was uploaded to the board. Figure 10 displays a section of the results on the serial monitor.



```
Enabling GPS...
        ---> AT+CGNSPWR?
        <--- +CGNSPWR: 1
        ---> AT+CGNSINF
        <--- +CGNSINF:
1,0,19800106000057.000,,,,0.00,0.0,0
,,,,,,0,0,,,,,
Waiting for FONA GPS 3D fix...
Checking for Cell network...
        ---> AT+CREG?
        <--- +CREG: 0,1
        ---> AT+CIPGSMLOC=1,1
        <--- +CIPGSMLOC:
0,24.727749,60.173672,2019/04/28,09:
12:58
GSMLoc lat:60.173671
GSMLoc long:24.727746
GSMLoc speed:0.000000
```

Figure 10. Screenshot of Arduino IDE Serial monitor.

Phase two was completed successfully with the output of the desired results i.e. latitude, longitude and speed as can be observed in Figure 10.

Table 1 describes the AT commands implemented in the Arduino code as displayed in Figure 10.

Table 1. SIM808 AT commands.

Syntax	**Description**
AT+CGNSPWR?	Queries the status of GNSS power supply
AT+CGNSINF	Reads GNSS navigation information
AT+CREG?	Queries the cell network
AT+CIPGSMLOC=1,1	Retrieves GSM location and time

The Arduino software implemented AT commands as described in Table 1 to enable the GPS and used the **Serial.println()** function to output the results to the serial monitor mainly for debugging purposes.

6.3 Phase Three: Implementation Second Cycle

The implementation of the second Cycle was to setup the Server, which in this case was the Firebase database so that it could receive GPS data from the Arduino tracking device.

6.3.1 Firebase Realtime Database

The two available options discussed in chapter 4.2 were Firebase Realtime database and Cloud Firestore. The project opted to use the Realtime database as the latter was still in beta stage.

The sign up and configuration follows the user guide and is not detailed in this report. Figure 11 displays an overview of the Firebase Realtime Database.

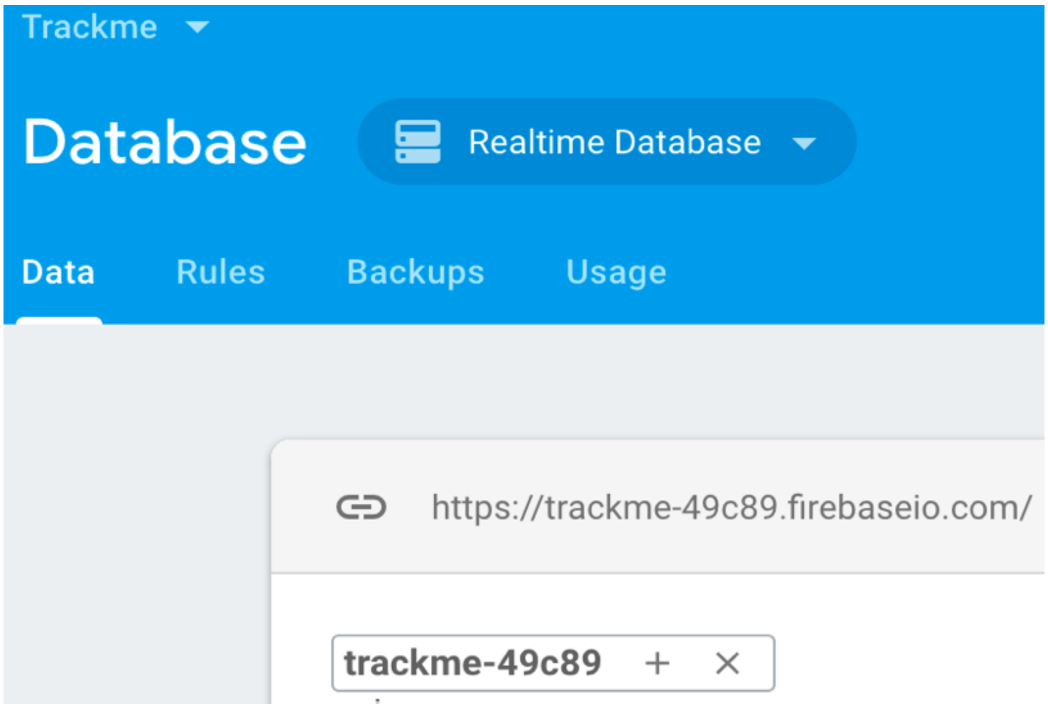


Figure 11. Screenshot of Firebase Realtime Database.

The read and write permissions are set in the Rules section and data is accessed in the Data section as seen in Figure 11. Noticeable, is also the URL link for accessing the database. Firebase Authentication, also briefly discussed in chapter 4.2 was used to authenticate the database using the email and password.

6.3.2 Proxy Server

The next task was to establish the HTTPS connection between the database and the Arduino tracking device in order to transmit the GPS data. However, it was realised that Arduino only supported HTTP communication while the Firebase accepted only HTTPS requests. This necessitated building of a proxy server to provide the linkage.

The design chart in Figure 12 illustrates the updated process flow of the project with the proxy server included.

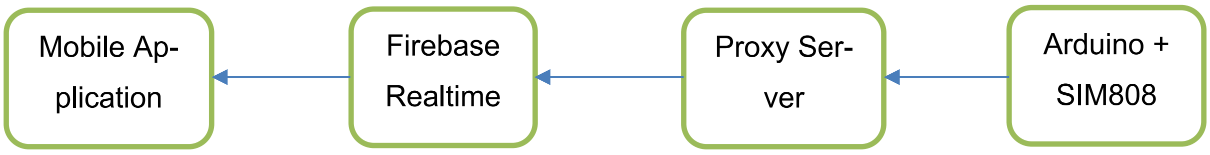


Figure 12. Project design as a process flow chart with the proxy server included.

As illustrated in Figure 12, the Arduino sends the GPS data using HTTP to the proxy server. The proxy server in turn forwards the data using HTTPS to the Firebase Realtime Database. And finally it is accessed via the Android application on the mobile phone.

Firebase has third party libraries in different programming languages for creating an interface to interact with the Firebase REST API (Representational State Transfer Application program interface that uses HTTP requests to modify data). Listing 2 shows a part of the PHP file implemented using the Firebase PHP library to create an interface for linking the Firebase to the Arduino. The entire PHP library file can be viewed from Appendix 3.

```
//Connect to firebase / secret contains the credentials
        $acc = ServiceAccount::fromJsonFile( '../../secret/trackme.json');

// Write data to firebase using Push method
    public function insert(array $data) {
        if (empty($data) || !isset($data)) { return FALSE; }

        $ref     =     $this->database->getReference()->getChild($this->dbname)-
>push($data);

        return $ref->getKey();
    }
```

Listing 2. Section code of the PHP file for connecting to Firebase database

As observed from Listing 2, HTTPS request was achieved by appending .json at the end of the Firebase Realtime Database URL. Data was then written using the PUSH method. Notice that **‘secret’** folder contained the firebase credentials.

The setup of the proxy server was concluded by hosting the created PHP file in the personal home drive of Metropolia’s school server. This was uploaded into the **public_html** folder as seen in Figure 13.

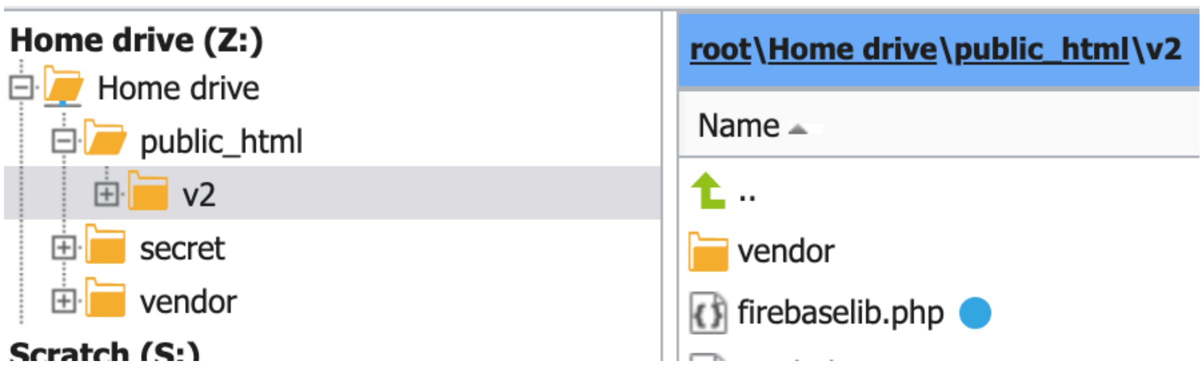


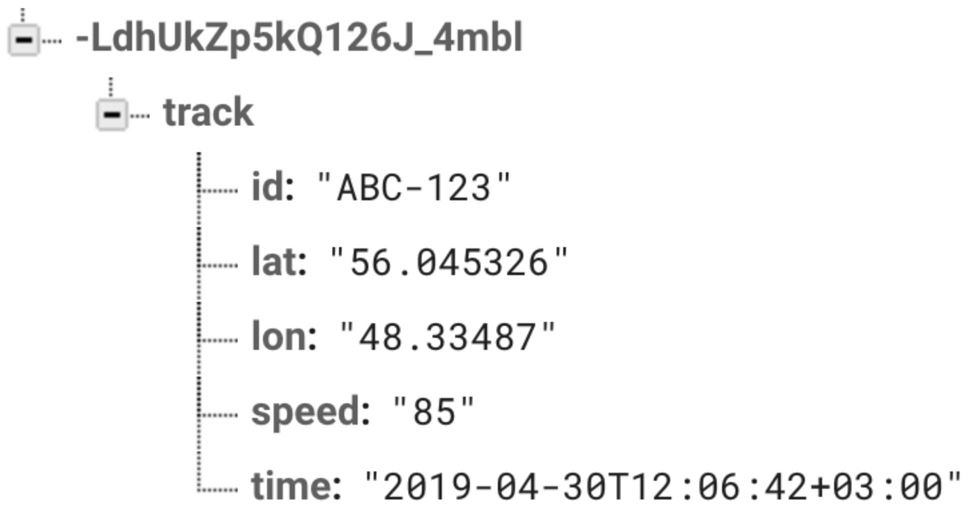
Figure 13. Screenshot of school personal home drive.

Figure 13 shows the Firebase PHP file named '**firebaselib.php'** in addition to the vendor directory hosted in the personal home drive. The vendor directory not discussed in the report contained the Composer and the PHP autoload used in creating the Firebase library file.

6.3.3 Phase Three Testing

The second cycle of the implementation was concluded by testing the communication between the proxy server and the Firebase Realtime database. This was achieved by manually entering random values for the GPS data within the URL link: http://users.metropolia.fi/~peterkip/v2/firebaselib.php?deviceid=ABC-123&lat=56.045326&lon=48.33487&speed=85 and checking the database if it was registering the same values.

Figure 14 shows the expected updates on the Firebase Realtime database.



```
-LdhUkZp5kQ126J_4mbl
    track
        id: "ABC-123"
        lat: "56.045326"
        lon: "48.33487"
        speed: "85"
        time: "2019-04-30T12:06:42+03:00"
```

Figure 14. Firebase Realtime Database update.

The random values entered in the URL link above i.e. latitude (lat = 56.045326), longitude (lon= 48.33487) and speed (speed= 85) were updated on real time on the database as seen in Figure 13. This concluded phase three with success.

6.4 Phase Four: Implementation Third Cycle

Having setup and configured the connection between the Firebase Realtime database and the proxy server, the third cycle implemented a connection between the proxy server and the Arduino tracking device. This was achieved with additional programming of the Arduino using the Fona library code as seen in Appendix 2. Notice, that the Fona library code has example implementations for SMS response and incoming call response in addition to GPS tracking. Further capabilities can be achieved through modifications by the programmer.

Listing 3 highlights part of the code used inside the **sendToFirebase()** function in Appendix 2.

```
//build the URL to the proxy
  String url = "http://users.metropolia.fi/~peterkip/v2/firebaselib.php?/";
  url += "&deviceid=";
  url += String(deviceid);
  url += "&lat=";
  url += String(latitude);
  url += "&lon=";
  url += String(longitude);
  url += "&speed=";
  url += String(speed_kph);
```

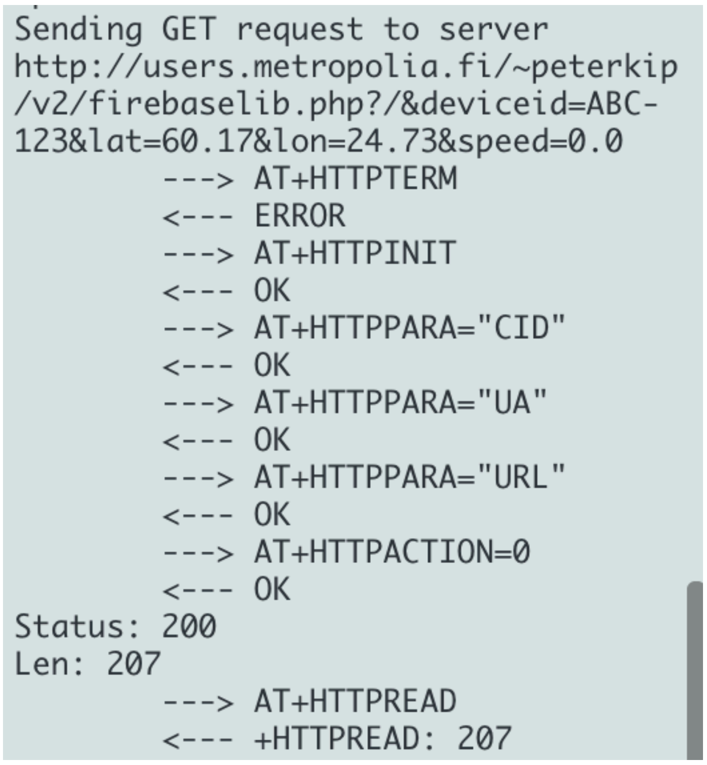
Listing 3. URL link to proxy server.

Listing 3 illustrates how the URL link was built. Device id which can also be the vehicle registration was appended to the base URL together with the GPS data. This was then used by the Fona library to implement AT commands earlier introduced in phase two, to establish HTTP connection between the tracking device and the proxy server and send the GET request.

Phase Four Testing

The third cycle was concluded by testing the Arduino code and checking the database for data updates. This was achieved using an USB cable and the setup procedure discussed in phase two testing.

Figure 15 displays a section of the results printed on the Arduino serial monitor.



```
Sending GET request to server
http://users.metropolia.fi/~peterkip
/v2/firebaselib.php?/&deviceid=ABC-
123&lat=60.17&lon=24.73&speed=0.0
        ---> AT+HTTPTERM
        <--- ERROR
        ---> AT+HTTPINIT
        <--- OK
        ---> AT+HTTPPARA="CID"
        <--- OK
        ---> AT+HTTPPARA="UA"
        <--- OK
        ---> AT+HTTPPARA="URL"
        <--- OK
        ---> AT+HTTPACTION=0
        <--- OK
Status: 200
Len: 207
        ---> AT+HTTPREAD
        <--- +HTTPREAD: 207
```

Figure 15. Arduino output.

Phase four was completed successfully with the output of the expected results as displayed in Figure 15. The status code of 200 confirmed a successful GET request which was also double checked against the data in the database. The serial monitor also displays the AT commands implemented in the Fona library.

6.5 Phase Five: Implementation Fourth Cycle

So far, the system had been tested to function up to the server. Next, was the fourth cycle implementation which was also the final implementation of the project. The focus here was to design and build the Android application and connect it to the Firebase.

Taking into consideration, the tracking information stored in the database and what was expected to be displayed to the user, the application settled on two Activities: Login Activity for authentication and Map Activity for displaying the GPS data (location and speed).

6.5.1 Setting up Development Environment

Android Studio earlier introduced in chapter 4.1 was used as the development environment for the Android application. The Mac OS also earlier mentioned in phase two of the implementation was used as the development system. It is worth noting that the Android Studio was already pre-installed in the development system from a previous Android course and as such it was only updated to the newest version i.e. version 3.4.

The Android studio also had an emulator already pre-configured i.e. Nexus 5. However, the author already owned an Android phone i.e. Huawei P smart and as such it was preferred for this project. Connecting this phone to the Android studio was pretty straightforward with just an installation of the USB drivers in the development system and enabling of USB debugging from the phone's settings.

6.5.2 Login Activity

Login Activity was implemented as the user interface of the application i.e. the main activity of the application. This was responsible for the following:

- Taking the user credentials for authentication
- Calling the Map activity on successful authentication.

This was achieved by implementing Firebase Authentication as discussed in chapter 4.2 using "email" and "password".

Android Studio comes with Firebase assistant window under the ‘Tools’ section. This provided an easy setup wizard. Although not detailed in this report, the email and password authentication was selected from the Authentication feature, together with Realtime database then connected to Firebase.

Figure 16 displays the Login page of the application on Huawei P smart mobile phone.

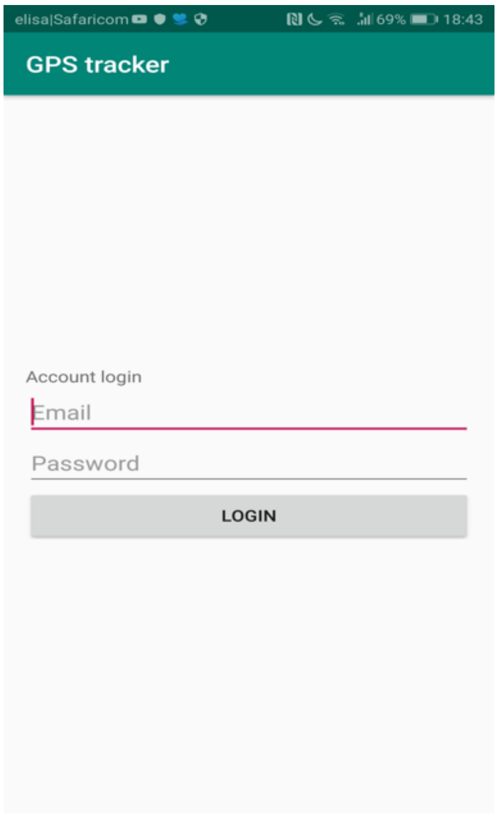


Figure 16. Login page

Figure 16 displays the login page of the application requiring email and password. This was implemented using Edit Text fields and a button with onClick listener. The entire Java code is detailed in Appendix 4 excluding the XML file.

6.5.3 Maps Activity

Maps Acivity was the second activity of the application responsible for displaying the Map with the GPS location and speed. The activity used markers to display the location on Google map and Text View to display the speed.

The activity implemented OnMapReadyCallback library among other libraries and functions as detailed in Appendix 5. Listing 4 highlights part of the java code as implemented on Android Studio.

```java
@Override
//calls the Google maps when ready
public void onMapReady(GoogleMap googleMap) {
    mMap = googleMap;
    mMap.setMaxZoomPreference(20);

    onLocationChange();
}

//Listens to Firebase for updates and displays the data upon updates
private void onLocationChange() {
    DatabaseReference reference = FirebaseDatabase.getInstance().getRefer-
ence("gps");
    reference.addChildEventListener(new ChildEventListener() {
        @Override
        public void onChildAdded(DataSnapshot dataSnapshot, String previ-
ousChildName) {
            //Clear previous markers
            mMap.clear();
            //Set marker to currentLocation
            setmMarkers(dataSnapshot);
        }

        @Override
        public void onChildChanged(DataSnapshot dataSnapshot, String previ-
ousChildName) {
            //Set marker on the updated location
            setmMarkers(dataSnapshot);

        }
```

Listing 4. Functions for calling google map.

Listing 4 illustrates the main functions implemented on Android Studio to successfully call the google map with the GPS data. The OnMapReady() function displays the google map when it is ready and available and calls the onLocationChange function. The onLocationChange() function is tasked with listening to Firebase for updates, upon which it calls the setMarker() function to insert the markers on the Map and display the speed on the Text View field.

6.5.4 Phase Five Testing

Like all the other implementation cycles, Phase Five was concluded with testing of the Android application. This was done using a Huawei mobile phone that was already configured to the Android Studio. Running the application on Android Studio while the phone is connected to the computer with an USB cable installs the application on the phone.

Figure 17 illustrates the testing of the application.

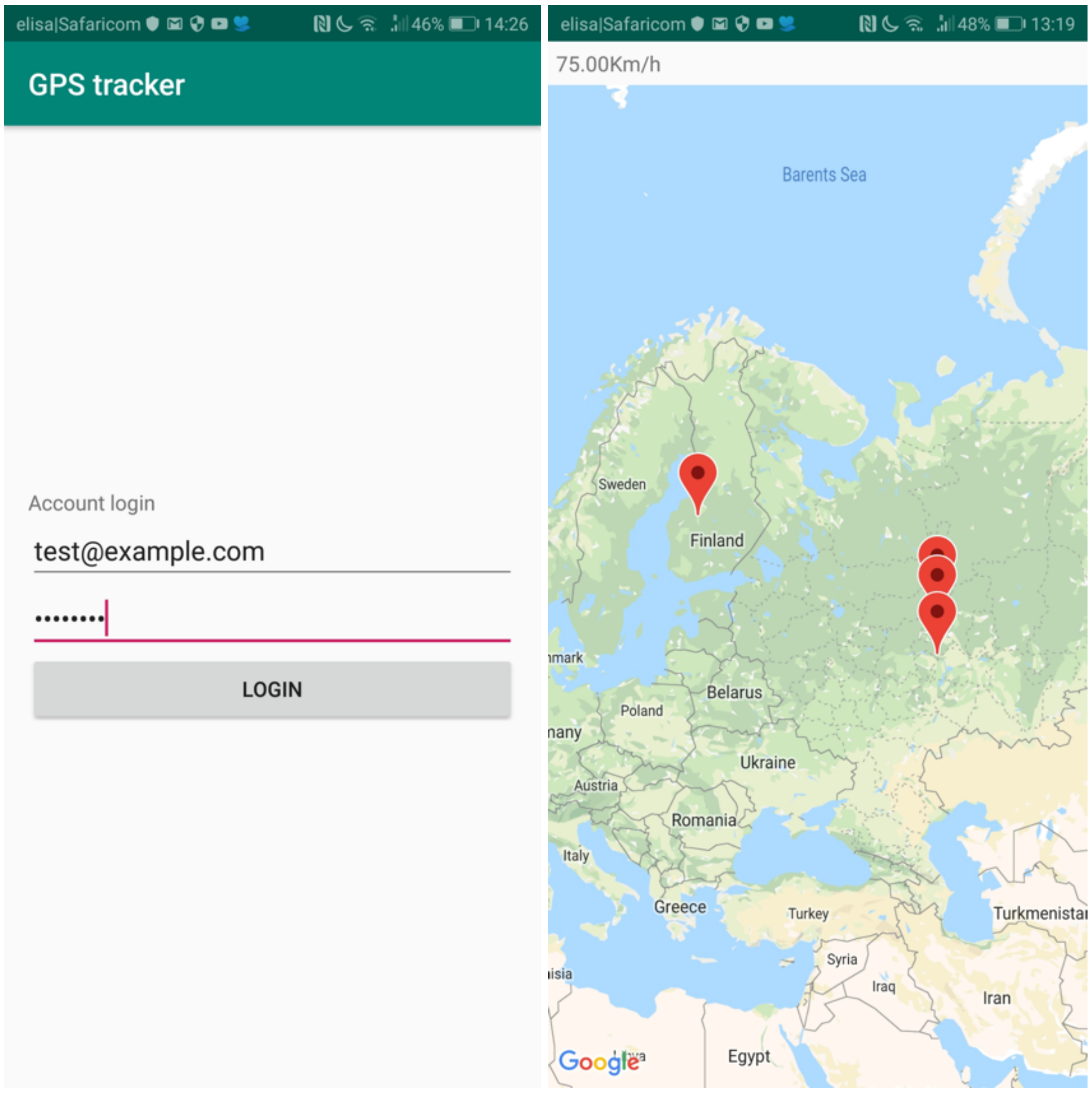


Figure 17. GPS tracking application

Figure 17 illustrates how the application was tested and the results. This was verified from the data stored in the Firebase Realtime database. To achieve this, the database was first populated with random GPS data and a random user was registered using a random email and password. Entering the correct credentials and clicking the login button would then display the map with the latest GPS data as stored in the database while wrong credentials would toast a failed login message.

6.6 Phase Six: Practical Testing

The project had now reached the final milestone and was ready to be deployed for practical use. As mentioned before, the intention so far had been to track the location and speed of the vehicle, and all the preceding test results had proven that the system was functioning as expected. However, so far all the tests had been done with the device connected to the computer and with random generated data. The final phase, therefore, was to confirm this results with a practical test of the product.

Unlike the previous tests, this time the Arduino tracking device was disconnected from the computer and powered with the 9V lithium battery. The pre-requisites were the sim card had to have some active data, and the Huawei mobile phone needed to have access to the internet. With the help of a friend, the system was placed inside a car and a small test drive was done while the application was open.

Figure 18 displays the GPS location and speed as viewed on the Map activity of the application and the phone’s location on google map.

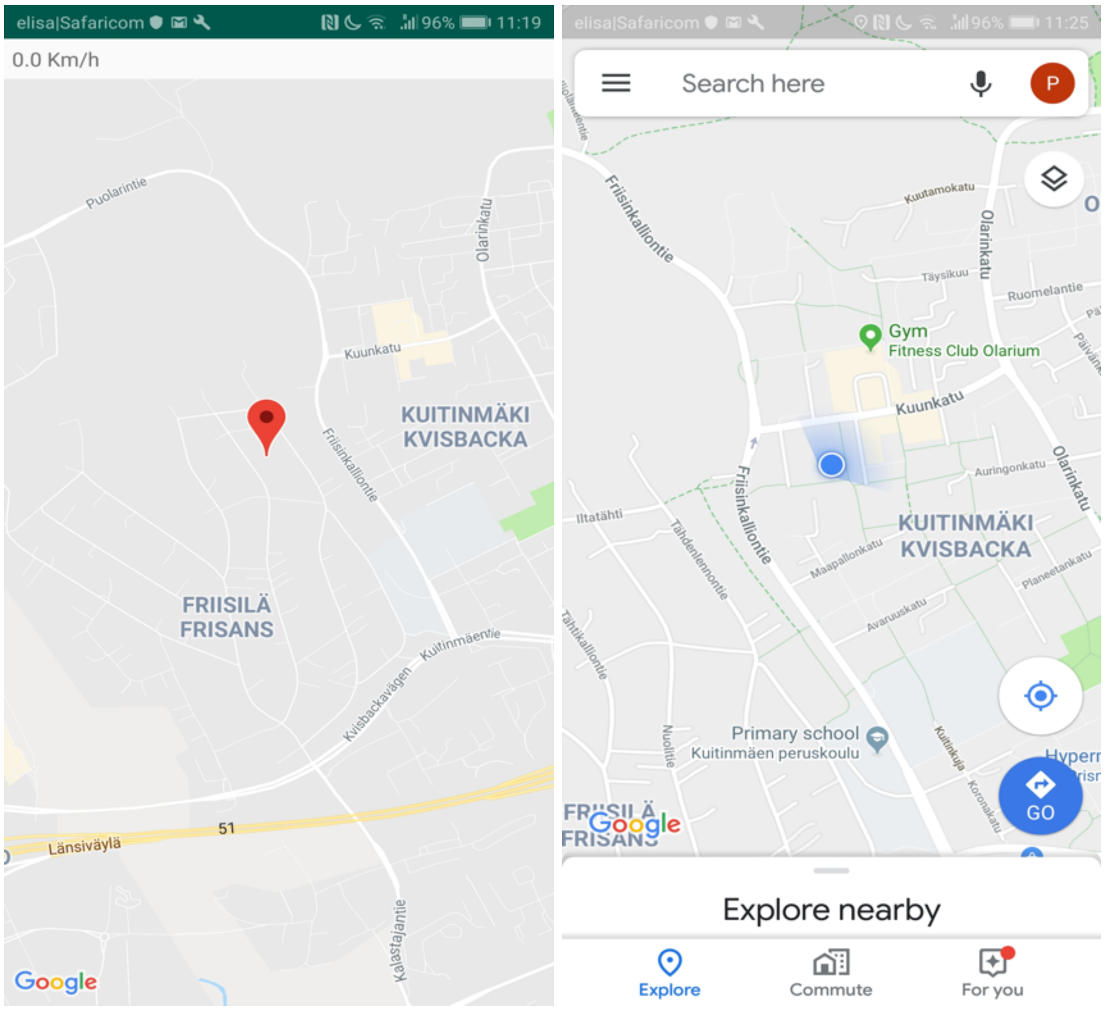


Figure 18. Map page of the application (left) vs google map location (right).

The images displayed in Figure 18 captures the same instances as viewed from the same phone on both the map activity of the application and the google map current location.

The Map activity of the application uses red markers and text to display the current GPS location and speed respectively. This data was then compared to the google map current location and driving speed of the car. Notice that the images displayed above were captured while the car was stationary i.e. speed reading of 0.0 km/hr.

The results displayed in Figure 18 confirms that the system is working as designed. However, the GPS accuracy has not been achieved. Also worth noting is that the speed reading were mostly inaccurate especially when the car was in motion. In some instances a speed of over 50km/h was recorded, and yet the car had been stopped.

It is also worth noting that the Arduino tracker had been set to a 10 second delay and SIM808 automatically selected the position sampling frequency from the four available frequency bands as mentioned in chapter 4.3 (850/900/1800/1900 MHz). These were some the factors attributed to the inaccurate GPS readings.

7 Summary and Conclusions

The overall outcome of the project was successful. The tracking device built from the Arduino and SIM808 shield is capable of tracking the vehicle's speed and location, and sending it to the database, while the Android application developed is capable of displaying this data as initially intended.

However, the accuracy of the GPS results is still not met. From the final results noted in chapter 6, there was a big variation in the GPS data especially the speed. It is assumed that this inaccuracy might be attributed to the sensitivity of the GSM module and the position sampling frequency. Additionally, the location variables (latitude and longitude) were retrieved as double variables in the Android application. For this reason, it is assumed that floating variables might provide more location precision in the future.

The objective of the project was to build an Android vehicle tracking system to be used as a monitoring tool for the company's vehicles. Judging by the results, it can be concluded that this goal has been successfully achieved upon completion of this project. The Android application is very easy to use and the tracking device can easily be installed on the vehicle.

The whole experience has been positive with many lessons learnt concerning time management and expectations. If this was to be repeated, then definitely better planning and more research on the topic would have to be undertaken before embarking on the project.

In conclusion, the project has achieved its purpose by providing a functional Arduino vehicle tracking device and an Android mobile application as a final product. This can already be utilized by the company. However, this application is not fully developed to its potential, and due to the deadline of this report, the assumptions noted above are left to be studied and implemented later. In addition, further studies are needed for better representation of the GPS data on the map.

References

1. Shangai Gumi Industrial Co. Ltd [Internet]. Goomegpstracker.com. 2019 [cited 27 March 2019]. Available from: http://www.goomegpstracker.com/COM-PANY/About-Us/About-Us.html

2. G19S GPS Tracker [Internet]. Goomegpstracker.com. 2019 [cited 28 March 2019]. Available from: http://www.goomegpstracker.com/PRODUCT/Vehicle-GPS-Tracker/car-gps-tracker/33.html

3. Meet Android Studio [Internet]. Developer.android.com. 2019 [cited 15 March 2019]. Available from: https://developer.android.com/studio/intro

4. Configure Android Studio [Internet]. Developer.android.com. 2019 [cited 15 March 2019]. Available from: https://developer.android.com/studio/intro/studio-config

5. Kumar A. Mastering Firebase For Android Development [Internet]. Chaudhari K, Raman R, Carneiro F, Sunilkumar S, Editing S. Birmingham: Packt Publishing Ltd; June 2018 [cited 20 March 2019]. Available from: https://books.google.fi/books?id=RMNiDwAAQBAJ&printsec=frontcover&dq=in-title:Mastering+Firebase+for+Android+Development+:+Build+Real-Time,+Scal-able,+and+Cloud-enabled+Android+Apps+with+Fire-base&hl=en&sa=X&ved=0ahUKEwiziJbG-ZDhAhWE16YKHduYB34Q6AEIK-TAA#v=onepage&q=intitle%3AMastering%20Firebase%20for%20An-droid%20Development%20%3A%20Build%20Real-Time%2C%20Scala-ble%2C%20and%20Cloud-enabled%20Android%20Apps%20with%20Fire-base&f=false

6. Firebase Realtime Database [Internet]. Firebase.google.com. 2019 [cited 20 March 2019]. Available from: https://firebase.google.com/docs/database/

7. Cloud Firestore [Internet]. Firebase.google.com. 2019 [cited 20 March 2019]. Available from: https://firebase.google.com/docs/firestore/

8. Firebase Authentication [Internet]. Firebase.google.com. 2019 [cited 15 March 2019]. Available from: https://firebase.google.com/docs/auth/

9. Cloud Storage [Internet]. Firebase.google.com. 2019 [cited 15 March 2019]. Available from: https://firebase.google.com/docs/storage/

10. What is Arduino? [Internet]. Arduino.cc. 2019 [cited 23 April 2019]. Available from: https://www.arduino.cc/en/Guide/Introduction

11. Language Reference [Internet]. Arduino.cc. 2019 [cited 23 April 2019]. Available from: https://www.arduino.cc/reference/en/

12. Getting Started with Arduino and Genuino Products [Internet]. Arduino.cc. 2019 [cited 23 April 2019]. Available from: https://www.arduino.cc/en/Guide/HomePage

13. Shields [Internet]. Arduino.cc. 2019 [cited 24 April 2019]. Available from: https://www.arduino.cc/en/Main/arduinoShields

14. SIM808 GPRS/GSM+GPS Shield v2.0 [Internet]. Elecrow.com. 2019 [cited 25 April 2019]. Available from: https://www.elecrow.com/wiki/index.php?title=SIM808_GPRS/GSM%2BGPS_Shield_v2.0#Resources

15. Arduino Uno Rev3 [Internet]. Arduino.cc. 2019 [cited 24 March 2019]. Available from: https://store.arduino.cc/arduino-uno-rev3

16. Lee W-M, DiMarzio J.F. Beginning Android Programming with Android Studio [Internet]. 4th ed. John Wiley & Sons, Incorporated; October 2016 [cited 7 March 2019]. Available from: https://ebookcentral.proquest.com/lib/metropolia-ebooks/reader.action?docID=4714030

17. Meier R. Professional Android 4 Application Development [Internet]. 3rd ed. John Wiley & Sons, Incorporated; April 2012 [cited 9 March 2019]. Available from: https://ebookcentral.proquest.com/lib/metropolia-ebooks/detail.action?docID=818033

18. Celebrating a Sweet Decade of Android [Internet]. Blog.google.com. 2019 [cited 9 March 2019]. Available from: https://blog.google/products/android/celebrating-sweet-decade-android/

19. Android: A 10-Year Visual History [Internet]. Theverge.com 2019 [cited 9 March 2019]. Available from: https://www.theverge.com/2011/12/7/2585779/android-10th-anniversary-google-history-pie-oreo-nougat-cupcake

20. Galaxy S10e|S10|S10+ [Internet]. Samsung.com. 2019 [cited 9 March 2019]. Available from: https://www.samsung.com/fi/smartphones/galaxy-s10/buy/

21. Android – Architecture [Internet]. Tutorialspoint.com. 2019 [cited 11 March 2019]. Available from: https://www.tutorialspoint.com/android/android_architecture.htm

22. Android – Application Components [Internet]. Tutorialspoint.com. 2019 [cited 13 March 2019]. Available from: https://www.tutorialspoint.com/android/android_application_components.htm

23. Panigrahy N. Xamarin Mobile Application Development for Android [Internet]. 2nd ed. Birmingham: Packt Publishing Ltd; August 2015 [cited 13 March 2019]. Available from: https://books.google.fi/books?id=3bVrCgAAQBAJ&printsec=frontcover&dq=intitle:Xamarin+Mobile+Application+Development+for+Android+-+Second+Edition&hl=en&sa=X&ved=0ahUKEwiUs6DavfTgAhWd6KYKHS9sDMQQ6AEIKTAA#v=onepage&q&f=false

24. Understand The Activity Lifecycle [Internet]. Developer.android.com. 2019 [cited 13 March 2019]. Available from: https://developer.android.com/guide/components/activities/activity-lifecycle

25. OnRestart [Internet]. Developer.android.com. 2019 [cited 14 March 2019]. Available from: https://developer.android.com/reference/android/app/Activity.html#onRestart()

26. Gargenta M. Learning Android [Internet]. 1st ed. Oram A, Jepson B. Sebastopol: O'Reilly Media, Inc; 2011 [cited 14 March 2019]. Available from: https://books.google.fi/books?id=oMYQz4_BW48C&printsec=frontcover&dq=Learning+Android&hl=en&sa=X&ved=0ahUKEwjl4ZbBq_rgAhVlwcQBHbhvA98Q6AEIMDAB#v=onepage&q&f=false

27. Intents and Intent Filters [Internet]. Developer.android.com. 2019 [cited 14 March 2019]. Available from: https://developer.android.com/guide/components/intents-filters

Appendix 1. Activity, Service, Broadcast Receiver and Content provider

```
public class MainActivity extends Activity {
}

public class MyService extends Service {
}

public class MyReceiver  extends  BroadcastReceiver {
   public void onReceive(context,intent){}
}

public class MyContentProvider extends  ContentProvider {
   public void onCreate(){}
}
```

Appendix 2. Arduino Software Code

```
//Libraries
#include "Adafruit_FONA.h"
#include <SoftwareSerial.h>

// Instances
SoftwareSerial fonaSS = SoftwareSerial(7, 8);
SoftwareSerial *fonaSerial = &fonaSS;

// Fona instance
Adafruit_FONA fona = Adafruit_FONA(4);

//Global variables for holding gps data
float latitude, longitude, speed_kph;

void setup() {
  // Initialize serial
  while (!Serial);
  Serial.begin(19200);
  Serial.println(F("Initializing...."));

  fonaSerial->begin(19200);
  if (! fona.begin(*fonaSerial)) {
    Serial.println(F("Initialization failed"));
    while (1);
  }

  // Setup GPRS settings => APN
  fona.setGPRSNetworkSettings(F("internet"));

  // Wait
  delay(1000);
  // Turn GPRS off & on again
  if (!fona.enableGPRS(false))
    Serial.println(F("Failed to turn off"));

  delay(1000);

  if (!fona.enableGPRS(true))
    Serial.println(F("Failed to turn on"));

  delay(1000);

  Serial.println(F("Enabling GPS..."));
  fona.enableGPS(true);

  //getGPS();
  //sendToFirebase();

}
void loop() {
  getGPS();
  sendToFirebase();

}

//Sending data to Server
void sendToFirebase() {

  // Setting the device ID/ In this case the Vehicle Reg
  String deviceid = "ABC-123";

  // Log
  Serial.print("DeviceID: ");
  Serial.println(deviceid);
  Serial.print("latitude: ");
  Serial.println(latitude);
  Serial.print("longitude: ");
  Serial.println(longitude);
  Serial.print("speed: ");
  Serial.println(speed_kph);

  // Prepare HTTP request
  uint16_t statuscode;
  int16_t length;

  //http://users.metropolia.fi/~peterkip/v2/firebaselib.php?de-
viceid=123&lat=56.045326&lon=48.33487&speed=82
  //build the URL to the proxy
  String url = "http://users.metropolia.fi/~peterkip/v2/firebaselib.php?/";
  url += "&deviceid=";
  url += String(deviceid);
  url += "&lat=";
  url += String(latitude);
  url += "&lon=";
  url += String(longitude);
  url += "&speed=";
  url += String(speed_kph);



  char buf[80];
  url.toCharArray(buf, url.length());

  Serial.print("Sending GET request to server  ");
  Serial.println(buf);

  // Send GPS data to Firebase
  if (!fona.HTTP_GET_start(buf, &statuscode, (uint16_t *)&length)) {
    Serial.println("Failed!");
  }
  while (length > 0) {
    while (fona.available()) {
      char c = fona.read();
      Serial.write(c);
      length--;
    }
  }

  fona.HTTP_GET_end();

  // Wait
  delay(10000);

}

//Getting the GPS data
void getGPS()
{
  delay(2000);

  // if you ask for an altitude reading, getGPS will return false if there isn't a 3D fix
  boolean gps_success = fona.getGPS(&latitude, &longitude, &speed_kph);

  if (gps_success) {

    Serial.print("GPS lat:");
    Serial.println(latitude, 6);
    Serial.print("GPS long:");
    Serial.println(longitude, 6);
    Serial.print("GPS speed KPH:");
    Serial.println(speed_kph);

  } else {
    Serial.println("Waiting for FONA GPS 3D fix...");
  }

  // Fona 3G doesnt have GPRSlocation :/
  if ((fona.type() == FONA3G_A) || (fona.type() == FONA3G_E))
    return;
  // Check for network, then GPRS
  Serial.println(F("Checking for Cell network..."));
  if (fona.getNetworkStatus() == 1) {
    // network & GPRS? Great! Print out the GSM location to compare
    boolean gsmloc_success = fona.getGSMLoc(&latitude, &longitude);

    if (gsmloc_success) {
      Serial.print("GSMLoc lat:");
      Serial.println(latitude, 6);
      Serial.print("GSMLoc long:");
      Serial.println(longitude, 6);
      Serial.print("GSMLoc speed:");
      Serial.println(speed_kph, 6);
    } else {
      Serial.println("GSM location failed...");
      Serial.println(F("Disabling GPRS"));
      fona.enableGPRS(false);
      Serial.println(F("Enabling GPRS"));
      if (!fona.enableGPRS(true)) {
        Serial.println(F("Failed to turn GPRS on"));
      }
    }
  }

}
```

Appendix 3. Proxy Sever PHP File

```php
<?php

require_once './vendor/autoload.php';

use Kreait\Firebase\Factory;
use Kreait\Firebase\ServiceAccount;

class firebaselib
{
    protected $database;
    protected $dbname = 'gps';

    public  function  __construct(){

        //Connect to firebase / secret contains the credentials
        $acc = ServiceAccount::fromJsonFile( '../../se-
cret/trackme.json');//__DIR__ .

        $firebase = (new Factory)->withServiceAccount($acc)->create();

        $this->database = $firebase->getDatabase();

    }

    // Write data to firebase using Push method
    public function insert(array $data) {
        if (empty($data) || !isset($data)) { return FALSE; }

        $ref = $this->database->getReference()->getChild($this->dbname)-
>push($data);

        return $ref->getKey();
    }

}

$gps = new firebaselib();

var_dump($_GET);
$id = htmlentities($_GET["deviceid"]);
$lat = htmlentities($_GET["lat"]);
$lon = htmlentities($_GET["lon"]);
$speed = htmlentities($_GET["speed"]);
```

```
$time = date('c');

var_dump($gps->insert([
    //'track' => [
        'id'=> $id,
        'lat' => $lat,
        'lon' => $lon,
        'speed' => $speed,
        'time' => $time
   // ]
]));
```

Appendix 4. Android Login Activity

```
public class MainActivity extends AppCompatActivity {

    private static final String TAG = MainActivity.class.getSimpleName();

    private EditText firebase_email, firebase_password;
    private Button loginBtn;
    private ProgressBar progressBar;

    private FirebaseAuth mAuth;


    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);

        // Initialize Firebase Auth
        mAuth = FirebaseAuth.getInstance();

        initializeUI();

        loginBtn.setOnClickListener(new View.OnClickListener() {
            @Override
            public void onClick(View v) {
                loginUserAccount();
            }
        });
    }

    private void loginUserAccount() {
        progressBar.setVisibility(View.VISIBLE);

        String email, password;
        email = firebase_email.getText().toString();
        password = firebase_password.getText().toString();

        if(TextUtils.isEmpty(email)){
            Toast.makeText(getApplicationContext(),"Please enter email...",
                    Toast.LENGTH_LONG).show();
            return;
        }
        if(TextUtils.isEmpty(password)){
            Toast.makeText(getApplicationContext(),"Please enter password...",
                    Toast.LENGTH_LONG).show();
            return;
        }

        mAuth.signInWithEmailAndPassword(email,password)
                .addOnCompleteListener(new OnCompleteListener<AuthResult>() {
            @Override
            public void onComplete(@NonNull Task<AuthResult> task) {
                if(task.isSuccessful()){
                    // Sign in success, update UI with the signed-in user's
information
                    Log.d(TAG, "Login successful!");
                    progressBar.setVisibility(View.GONE);
                    Intent intent = new Intent(MainActivity.this, MapsActiv-
ity.class);
                    startActivity(intent);
                }else{
                    // If sign in fails, display a message to the user.
                    Log.w(TAG, "Login failed!", task.getException());
                    Toast.makeText(getApplicationContext(), "Authentication 
failed.",
                            Toast.LENGTH_SHORT).show();
                    progressBar.setVisibility(View.GONE);
                }
            }
        });
    }

    private void initializeUI() {
        firebase_email = findViewById(R.id.email);
        firebase_password= findViewById(R.id.password);
        loginBtn = findViewById(R.id.login);
        progressBar = findViewById(R.id.progressBar);
    }

}
```

Appendix 5. Android Map Activity

```
public class MapsActivity extends FragmentActivity implements
OnMapReadyCallback {

    private static final String TAG = MapsActivity.class.getSimpleName();
    private HashMap<String, Marker> mMarkers = new HashMap<>();
    private GoogleMap mMap;

    LatLng currentLocation;
    TextView speedMeter;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_maps);

        speedMeter = (TextView) findViewById(R.id.textView);

        SupportMapFragment mapFragment = (SupportMapFragment) getSupportFrag-
mentManager()
                .findFragmentById(R.id.map);
        mapFragment.getMapAsync(this);
    }

    @Override
    //calls the Google maps when ready
    public void onMapReady(GoogleMap googleMap) {
        mMap = googleMap;
        mMap.setMaxZoomPreference(20);

        onLocationChange();
    }

    //Listens to Firebase for updates and displays the data upon updates
    private void onLocationChange() {
        DatabaseReference reference = FirebaseDatabase.getInstance().getRefer-
ence("gps");
        reference.addChildEventListener(new ChildEventListener() {
            @Override
            public void onChildAdded(DataSnapshot dataSnapshot, String previ-
ousChildName) {
                //Clear previous markers
                mMap.clear();
                //Set marker to currentLocation
                setmMarkers(dataSnapshot);
            }

            @Override
            public void onChildChanged(DataSnapshot dataSnapshot, String pre-
viousChildName) {
                //Set marker on the updated location
                setmMarkers(dataSnapshot);

            }

            @Override
            public void onChildMoved(DataSnapshot dataSnapshot, String previ-
ousChildName) {
            }

            @Override
            public void onChildRemoved(DataSnapshot dataSnapshot) {
            }

            @Override
            public void onCancelled(DatabaseError error) {
                Log.d(TAG, "Database Error", error.toException());
            }
        });
    }

    private void setmMarkers(DataSnapshot dataSnapshot) {
        //Set the updated location with a marker on the map
        String key = dataSnapshot.getKey();
        HashMap<String, Object> value = (HashMap<String, Object>) dataSnap-
shot.getValue();

        double lat = Double.parseDouble(value.get("lat").toString());
        double lon = Double.parseDouble(value.get("lon").toString());
        String speed = value.get("speed").toString();
        String vehicle_id = value.get("id").toString();

        currentLocation = new LatLng(lat,lon);

        if (!mMarkers.containsKey(key)) {
            mMarkers.put(key, mMap.addMarker(new MarkerOptions().title(vehi-
cle_id).position(currentLocation)));
        } else {
            mMarkers.get(key).setPosition(currentLocation);
        }

        LatLngBounds.Builder builder = new LatLngBounds.Builder();
        for (Marker m : mMarkers.values()) {
            builder.include(m.getPosition());
        }

        mMap.moveCamera(CameraUpdateFactory.new-
LatLngBounds(builder.build(),300));
        speedMeter.setText(speed + " Km/h");
    }

}
```