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Bachelor Thesis

Location based service restrictions for Android devices

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Chapter 1. Introduction

This chapter describes the different aspects of this project such as the motivations for developing this software APP, what are the project goals and why the Android technology have been used in order to develop the project. Finally, the document structure will be explained in order to provide a clear idea about how this document should be read.

1.1. Introduction

In the last few years, mobile devices have experienced great improvements. Not many years ago, people used to work on their desktop computer since laptops were so heavy to carry, they were less powerful and with a short battery life.

Nowadays, those constrains have disappeared and mobile devices are becoming so popular and useful making our workspace very dynamic since we can carry all what we need with us.

But, this does not end here, the mobile phones, that have been use for basic things such as calls and texts, have now become a small computer in our pocket able to process a great amount of data, running complex software and store information. This new generation of phones are called smartphones.

Those new mobile technologies open a great new field create new applications with different features. These applications, more commonly called APPs, give our smartphones additional features and options allowing us to used them in very different ways.

Also, there are new network technologies that allow all those devices to be more connected that ever before as the 3G and the “on development” 4G networks that provide high speed broadband and connection to Internet. In addition to all these facts the continuous increasing cloud computing, gives us the possibility of access your data from anywhere.

All those new improvements in the mobiles devices and network are responsible of the new mobile devices as tablets that have become very popular.

Those new technologies do not have just advantages. In fact, there are so many different ways to access and transmit information, that from a security point of view, increase the security risk not only for the average user, but also for organizations that allow its usage inside it premises.

In this project will provided the design and develop of the software that provides us security against some of those threats by restricting some of the actions that can be performed with the mobile devices. This software provides us control over those mobile devices in an organization environment, in this way the user can decide which features are not allowed to be used reducing the risk of an attack.

1.2. Motivations

Nowadays, Smartphones are becoming more popular and useful in our work environment. Smartphones are used for so many different features such as an agenda, calendars for appointment reminders, and even as a camera, as so many different APP that can be installed in them. These APPs are becoming more powerful since the devices are getting improved in a very fast way. We can notice that when every year some company sells a new device that is much more powerful than the others in the market.

Those new options in the palm of our hand make our tasks easier but also allow others to use them in inappropriate way. As we explained above, smartphones have so many different features and since every one can carry them in their pocket, it is a hard work to control the way those devices are used.

This is the main motivation to develop a software able to control some devices to prevent situations in which our information can be at risk. The software will not allow the device to use some features that can be a potential risk, depending on the device location or Wi-Fi connection.

The main target of this software is the business environment. For instance, since companies have so many visitor and workers to their offices, it could be a security improvement if they cannot use some features of their phones in order to obtain information or use the device in a not allowed way.

This software is based on the APP permissions system used by Android and the Geolocation feature of the devices that will be explained later on this document. The APP will be developed for Android devices since it is running in a wide range of devices compared to other mobile operating systems. In this way, it gives more freedom to the company since is not force to choose among just few devices. Similar applications can be found for other systems such as iOS but with slightly differences that will be discussed in the section Similar APPs.

1.3. Project Goals

Nowadays, most of the people have mobile devices able to perform from the simplest task to complex algorithms. This fact could be a risk in some situations. For instance, the usage of the mobile devices in workstations may reduce the productivity of the employees if they are not using it form specific working purposes. Also, visitors could use theirs mobile devices to obtain some information that they are not allowed to have access for their own benefit.

The aim of this project is to control the mobile devices in a specific environment and restrict its functionalities to provide safe areas with the fewer risks as possible.

In order to archive this goal, this project designs and implements software able to control the mobile devices based on its location. This project includes the software that runs on the devices and the server that provides the management tools to setup all the devices.

The software installed in the devices will be transparent for the device users. These users will be able to work properly with their devices. The device will execute all the functionalities but the ones that are restricted by the application using the device location. When a user tries to use some functionality that is forbidden within that location, the device will not run it and so, it will not allow the user to use that specific functionality.

On the other side, a management tool will be provided. This tool allows the user to setup the devices over Internet. The administrator is the one that creates the rules that restricts the applications. Once the rules are created, the management tool allows the administrator to attach the rules to one or more devices. Then, the management tool will send those rules to each device. Every device is responsible of its own rules and the device software makes sure that the rules are satisfied.

1.4. Document Structure

In this section, a brief introduction about the project environment, some motivations and the project objectives are given. So, in this last part of the first chapter, the structure of the document will be explained.

The document will consist of chapters, and in those chapters will be different sections explaining parts related to the specific chapter.

- Chapter 2: State of Art.
    - Mobile Devices: A brief explanation of the mobile devices situation nowadays will be given in this section.
    - Similar APPs: Some application with similar functionalities that are actually in the market will be studied in this section.
    - Mobile location: A further review about all the mobile location approaches used nowadays and a brief explanation of the API used in the APP development.
    - SQLite Database: This section will provide an explanation of the SQLite library in Android by explaining some of the used methods.
    - Package Manager: All the information about how this library is used in Android and its functionalities can be found in this section.
    - Permissions in Android: A very important security aspect is based in permissions. This section will describe how Android handles those permissions.
    - Google App Engine: Some technologies as GAE have been used in the server side of the application. This section will provide further information about those technologies.

- Chapter 3: Project Analysis.
    - System requirements: All the needed functionalities to satisfy all the project objectives will be shown in this section.
    - Validation Test: Some validation test will be defined in this section in order to ensure that the requirements have been accomplish when the system has been implemented.
    - Traceability Matrix: More graphically explanation of who the requirements are tested with the validation tests.
    - Development Methodology: In this section, all the steps to follow in the development progress will be explained in details.

- Chapter 4: Project Design.
    - System Design: This section will provide an explanation about how the whole system has been designed and how it works to accomplish all the requirements.
    - App Presentation Tier: All the functionalities of the Presentation Tier and its structure will be explained in this section.
    - App Logic Tier: All the functionalities of the Logic Tier and its structure will be explained in this section.
    - App Data Tier: All the functionalities of the Data Tier and its structure will be explained in this section.
    - Server Design: All the functionalities of the Server side and its structure will be explained in this section.

- Chapter 5: Project Implementation.
    - Presentation Tier: This section will provide information about how the presentation tier module is implemented in the system.
    - Logic Tier: This section will provide information about how the logic tier module is implemented in the system.
    - Persistence Tier: This section will provide information about how the persistence tier module is implemented in the system.
    - Server Subsystem: This section will provide information about how the server module is implemented in the system.
    - Testing: All the executed texts and the results will be analysed in this section.

- Chapter 6: Project Management.
    - Project Planning: The planning followed to develop the project is provided in this section.
    - Cost Projection: A specification of all the costs involved in the project.
- Chapter 7: Conclusion and Future work.
    - Conclusions: A review over the entire project will be done in this section including a study of the objectives.
    - Future Work: What can be improved and what can be added will be discuss in this last section.
- Chapter 8: Appendix.
    - User Manual: Some guidelines of how the system has to be installed and used.
    - Acronyms: this section provides the explanation of the different acronyms used in this document.
    - Bibliography: This section provides a list with the resources used on this document.

Chapter 2. State of Art

This chapter will explain in more detail all the technologies used to develop the application providing a better knowledge of how these technologies works. Also, some APIs used in the code will be reviewed in order to clarify the usage of some specific libraries.

2.1. Mobile Devices

Often, when someone mentions the “mobile devices”, he/she is mainly refers to the mobile phones (smart phones), since these devices are the most popular in this group. Many different devices such as laptops, tablets, phones or even new generation of music players, also belong to the mobile device group.

There is no doubt that mobile phones have experienced a massive evolution since that first hand-held mobile phone in 1973 done by Martin Cooper with the Motorola Team [24]. This first phone cost approximately $10,000 USD, which compared to the actual prices is a huge amount of money.

These phones have evolved but not just the hardware of the phone itself, also the technologies around mobile phones have evolved. The first commercially automated cellular network was launched in the early 1980s.

Then, the second generation, called 2G, used a digital transmission instead of analogy and it was based in GSM standard. 2G networks provided the users the transmission of media content; in 1998 the first downloadable media content was a ring tone for phones.

The third generation called 3G was launched for the first time in Japan in 2001 and by the end of 2007 3G networks had 295 Million subscribers. This new technology provides users new possibilities such as the streaming.

Nowadays, the four-generation (4G) is coming out. This generation is already being tested in some parts of Europe such as London. It improves the 3G networks, being much faster. [25]

From the point of view of the hardware, mobile devices have also evolve very fast being able to manage all those technologies mentioned before and being able to process a huge amount of information.

The concept smartphone does not appear until 1997 but it is in 2007 when Apple introduced the original iPhone, when this market made exploded, and all the big companies such as Samsung or Nokia started being interested on what actually is known as smartphones.

Nowadays the market of the mobile devices is huge, in 2011 29 Billion apps were downloaded and in 2012 mobile subscribers worldwide reach 6.5 Billion worldwide. By the end of 2016 is predicted to raise until 8 Billions of subscribers [22].

2.2. Similar APPs

This section explains some applications, which are in the market, that have some features in common with the application that is being described in this document.

In the case of Android, it has been easier to find similar code and more developers guide about how to do some specific features. Also, some similar application can be found in iOS. Some of the most similar application will be reviewed briefly in this section.

2.2.1. Stuff on the go

Since our application is mainly based in mobile location, multiple applications based on this technology can be found nowadays in the market. "Stuff on the go" is one of those application location-based and it is developed for Android.

This application is a simple location-based task reminder. It allows setting up a specific location in the map and attaching to that location different features such as simple alarms, repeated alarms, Geo-Location alerts or SMS alerts [2].

For instance, a easy task of this application should be to set a location and when the device arrive to that point, it will deliver a SMS to notify that it is there. This application is similar to the application described in this document because it is based on location to perform operations.

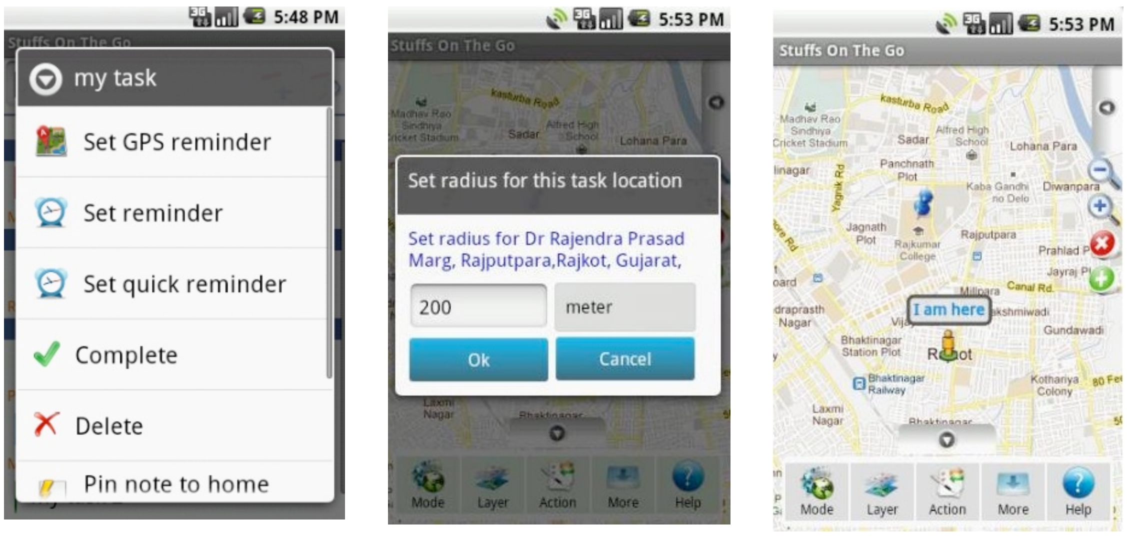


Figure 2.2.1. – Stuff on the go

2.2.2. Tasker

This is probably the most useful application that can be found for location-based task purposes. As the others, it is a location-based reminder but with a slight difference. This application use external applications such as the music player. For instance, you can set it up to launch the music player when you run out of your office. This is quite interesting since our service will be working with others application based on the device location [3].

This application is quite similar to Stuff on the go and it is also developed for Android devices. The location process in which the application is based is quite similar to the application described in this document.

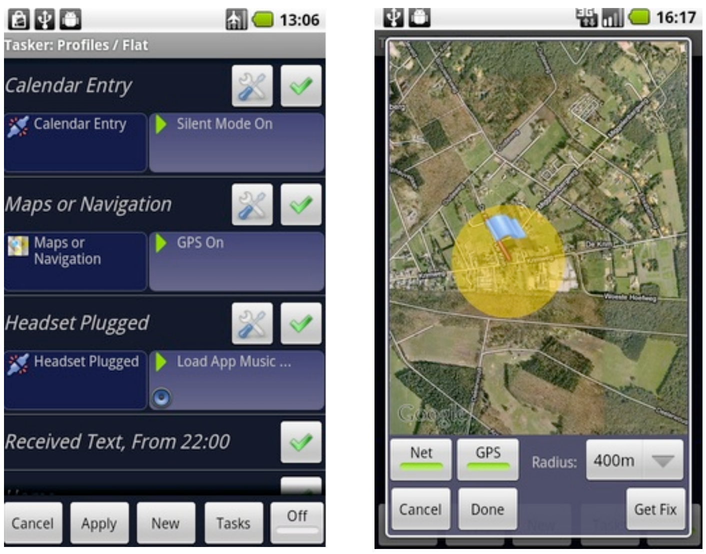


Figure 2.2.2. – Tasker

2.2.3. Todo (Appigo)

On the other side, iOS offers in millions of devices distribute applications and so many nice application are being developed for this platform everyday.

An example of those applications developed for iOS and similar to the application described in this document is “TODO”. This application allows us to set up alerts attached to a location. You can configure TODO to send an alert when arriving a specific location. A example of use is to set up to pick up your Childrens when you go out of the work [1].

Since Appingo is a great company dedicated to develop application for iOS, this application is one of the best developed and professional of those reviewed in this section.

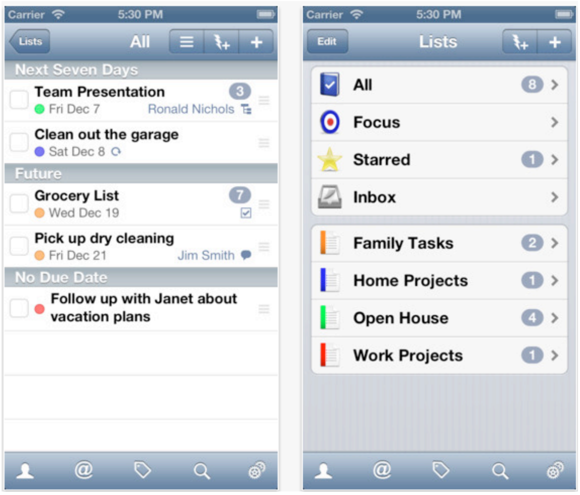
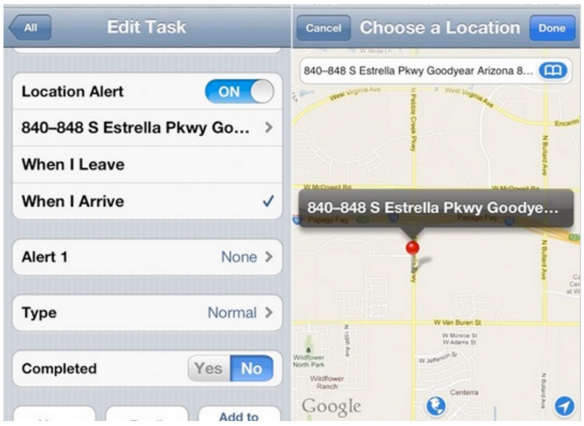


Figure 2.2.3. – Todo (iTunes)

2.2.4. Remiders

This is the native application of iOS with location-based alerts. This application is able to use Date/time or location-based notifications, search for specific reminders, reorder to-dos, view your reminders by list or date view and automatically update all your devices and calendars synchronizing them with other external programs [5].

This is another good example of location-based reminder application. It is similar to the app described in this document from the conceptual point of view of the location process.


Location Alert ON
840–848 S Estrella Pkwy Go...
When I Leave
When I Arrive ✓
Alert 1 None
Type Normal
Completed Yes [✓ No]

840–848 S Estrella Pkwy Goodyear Arizona 8...
840–848 S Estrella Pkwy Goodye...

Figure 2.2.3. – Reminders

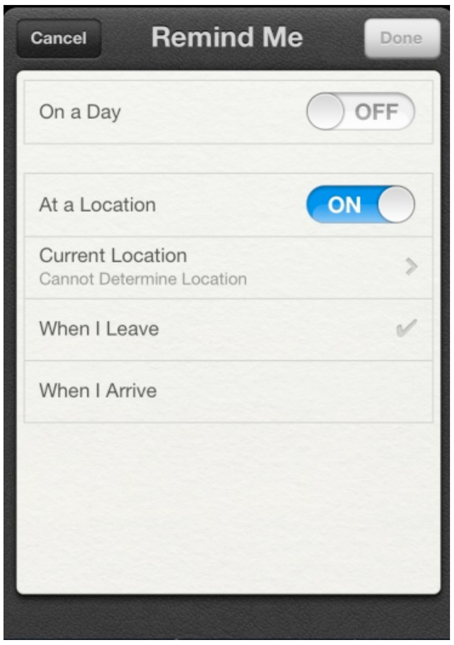


Figure 2.2.4. – Remind Me

2.2.5. Apple Configurator

All these reviewed applications have something in common and it is the location-based process. This is a very important aspect of our application but is not the only one. Our application also uses permissions to restrict the launch of specific application and none of those applications do similar features. From the point of view of restriction and security there is one application that has similar goals as our application has.

This application allows managing easily iOS devices such as iPhones, iPads and iPods touch. Apple configurator can prepare new iOS devices for distribution or supervise devices that need to maintain a standard configuration not allowing the user to modify this configuration. This feature is quite similar to what the application described in this document does from the point of view of restrictions [21].

This application also can restrict the applications that are installed into the device. This rules can be apply to a specific device or to a full series of different devices, it also keeps them up-to-date in case the restrictions change. This mechanism of controlling devices is close to the idea developed in this document.

Another important point is that the previous application are more focused in the user market, the application is downloaded and installed for the user of the phone and that user is the one who benefits from the application. In this case, as in our application, the direct beneficiary of the application is the one who wants to control the devices. For instance, the company may install the application in the devices of its employees in order to help or control them on the working environment.

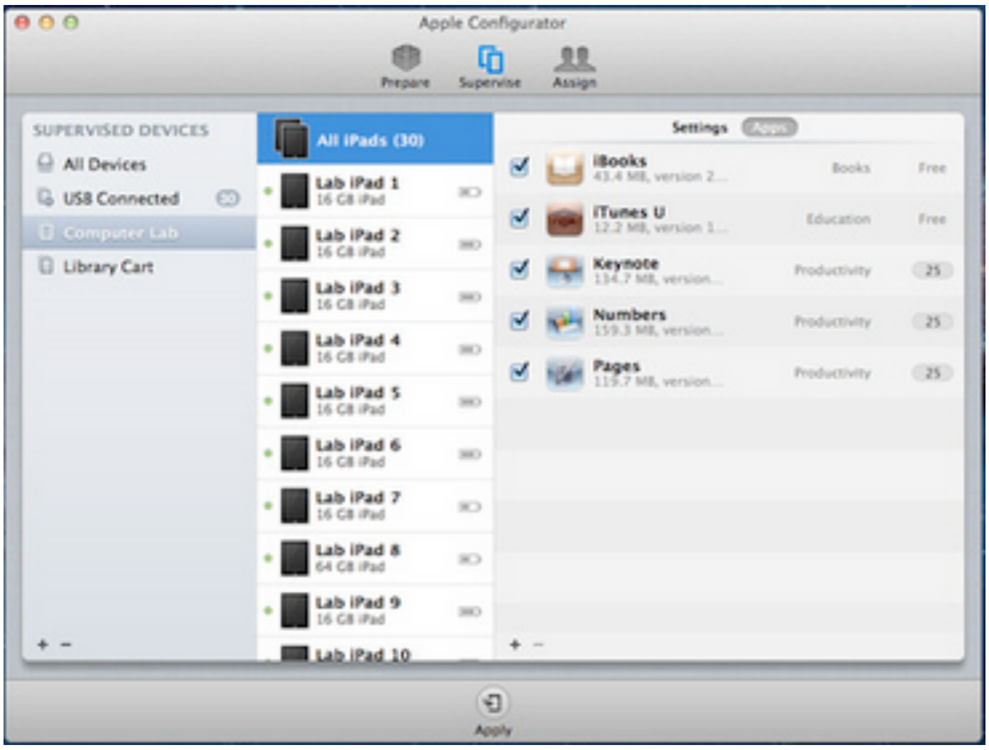


Figure 2.2.5. – Apple Configurator (iTunes)

2.3. Mobile Location

There are different location methods and different applications for them. Despite the fact that it is not the same to locate a device in a great city than locate a boat in the middle of the sea, both cases have some location method in common. Some of the location approaches are based in cell identification, angle of arrival, signal strength and time of propagation. Also, those approaches can be combined to create new hybrid location methods that can be more effective or less resource consuming [6] [8].

In this section, some of the most important methods of location will be explained in order to provide a clear idea about how our system is working.

2.3.1. Cell Identification-based

This location method uses cell identification or access point, if we are talking about WLANs to get a location point. The location point is given by the identity of the cell that is connected with the phone device. Each cell has a specific ID so knowing the cell ID, which is connected to the phone, the position of the phone can be approximated depending of the cell type. This method is known as Cell Global Identity (CGI).

This approach is easy to implement since it does not require change in the structure of the network or device. The accuracy of this method could vary depending of the cell type, in metropolitan areas it could be meters but in the rural area it will have a very poor accuracy.

Cell identification-based methods are one of the most used by the GSM-phones companies, since it is enough to provide the user with basic services on metropolitan areas. On the third generation networks other more accurate approached can be used [11] [12].

2.3.2. Angle of Arrival-based

This method is also called Direction of Arrival (DOA), it uses antenna arrays to calculate the incident angle. If a terminal is connected to an antenna and is in line of sight (LOS), the antenna array can calculate the direction by measuring the phase difference using the array or the signal strength. In order to know the position, this method will need another estimation of the incident angle. Comparing the result of both antenna and using trigonometry, the position of the device can be calculated.

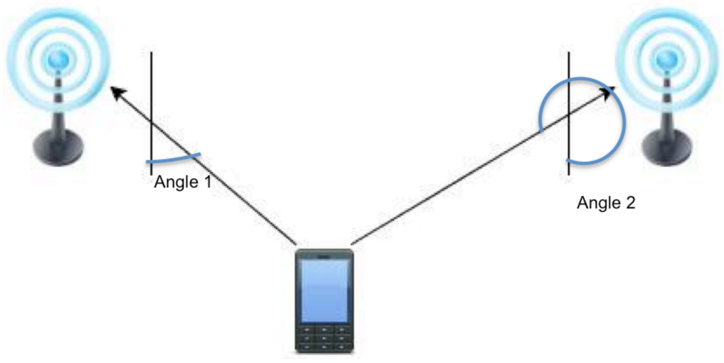


Figure 2.3.2. – Angle Of Arrival

This method can be a good approach in rural areas, since it is difficult to find a group of three antennas close enough to be effective, this approach can compute the position with only two antennas.

However, some problems can be found in this method because some shadows in the antennas range and the reflexive signals, which have a different angle of arrival. Also, the proper installation of the antenna is a costly process and a slight change in the state of the antenna could end important precision problems [11] [12].

2.3.3. Received Signal Strength-based

This procedure is called Received Signal Strength (RSS), and it uses the power of the signal between the device and the Base Transceiver Station (BTS). When a device goes away form the BTS, the signal power decrease the distance to the second power in the air. Each BTS has a Received Signal Strength Indication (RSSI), which is the power of the signal from a specific device and so, the distance from the BTS, can be measured.

The method needs three BTS to calculate the position of the device, since with one or two BTW only the distance away from them can be calculated. This process is made be circular triangulations.

Circular triangulations use the intersection among al lest three circumferences. Each circumference has as centre the respective BTS and as radius the RSSI. The precision of this triangulation method resides on the precision how the RSSI is taken. The far away is the device from the BTS, the bigger is the error in the RSSI to calculate the signal power.

In order to increase the precision of this method, some advance propagation models or a study of the field distributed is used. Sometimes, some new hardware is needed to improve its precision such as radiofrequency monitors and fingerprints tables [11] [12].

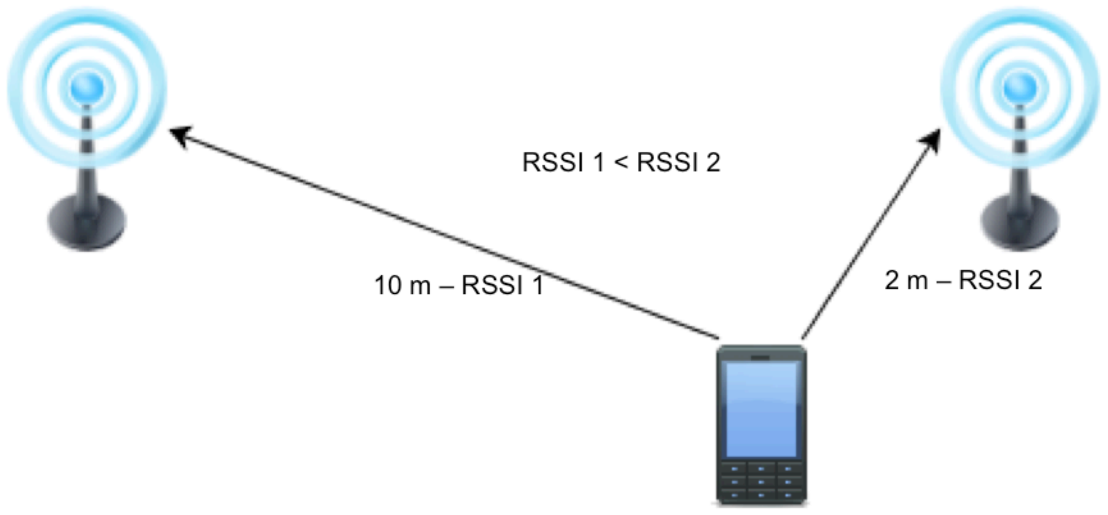


Figure 2.3.3. – Received Signal Strength

2.3.4. Time-based

In this section, the methods that are going to be explained use the time in order to calculate the position of the device. This approach is used mainly in mobile phone networks or satellite since they both work in big distances and they have big places to cover.

These methods are also used in local wireless networks, and the two more important are the following:

- Time of Arrival: As its name says, this method uses the time of arrival (TOA) of the signal from a mobile device to the station. In order to have an acceptable precision this time should be measured from three different stations and each measure must be collected in order to obtain the position by circular triangulation as we explained in the previous method, RSS.

  In order to archive a good quality precision, all the station must be in a total synchronization. Only in this case, the measures will be good enough to work with the smallest possible error. Also, there are some techniques, which relax that synchronization dependence such as for instance the round-trip-time-of-flight. That technique consists on measuring the time it takes the signal to come to the station and also to come back to the terminal. The only problem with this technique is that the time of processing the signal must be known [11] [12].

- Time Difference of Arrival: This method is quite similar to TOA, it is known as Time Difference of Arrival (TDOA). It measures the difference between the times of arrival from the terminal to a pair of stations (or from the station to the terminal). Those differences draw a curve between two stations. This curve is a hyperbola. This method draws the three hyperbolas among three stations and the cross of those three hyperbolas is the position of the device (Circular triangulation) [11] [12].

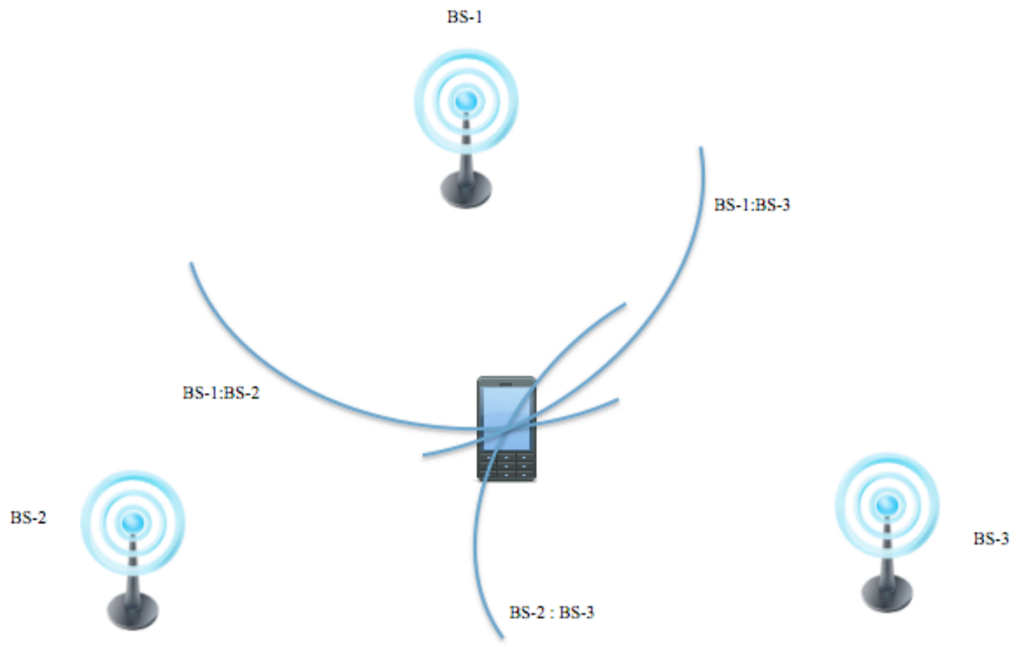


Figure 2.3.4. – Time Difference of Arrival

2.4. Outdoor Location

Some location methods that have been reviewed in the previous section are applicable for indoor location and outdoor location. In this section, the different technologies for location in outdoor environments will be reviewed.

The most important technologies and the most commonly used are Global Positioning System and the Mobile-Network Location.

2.4.1. Global Positioning System

The Global Positioning System (GPS) is able to calculate the position of a device in the terrestrial surface using at least three satellites. Nowadays, there is just one group of satellites that can be used for this positioning system (called Navigation Satellite Timing and Ranging (NAVSTAR)). This constellation is composed by twenty-four active satellites and four already prepared satellites for emergency purposes.

There is another constellation of satellites called GLONASS (Global Orbiting Navigation Satellite System). This Russian system is not as implemented as the GPS and just few devices can use it for location purposes.

Additionally, the European Space Agency (ESA) is developing another constellation called Galileo, which actually is in testing stage. It is compatible with GPS that will be free for basic location services with an error fewer that 5 meters.

The GPS system can be split in three different areas: Space area, Control area and user area. The first area is the one which contains the system satellites, the control area is composed of the terrestrial infrastructures that control the satellites, and the last one, are the different devices and software that processes the signals.

This system is able to locate a device using triangulations. It calculate the distance of a device from three of more satellites with a well know position in the orbit. These satellites are perfectly synchronized with an atomic clock, which ensures the smaller possible error in the measures. The device also has to be able to process the different signals from the satellites with the description of the satellite and notice it to the network. The location process is done measuring the time of arrival from the satellite to the device. This process is similar to the TDOA explained in the previous sections.

The GPS system has also inconvenient aspects, the precision in outdoor environment is accurate but when the environment is close as in a big city with buildings this accurate become less reliable. The device and the satellites must be in line of sight and in other cases a delay in the reception of the signal will be observed. In order to solve this problem, the Differential GPS (DGPS) is used in the metropolitan areas. This system uses the satellite signals and some information from the stations. This system is used in the Assisted GPS (AGPS) and it will be reviewed further in this section [11] [12].

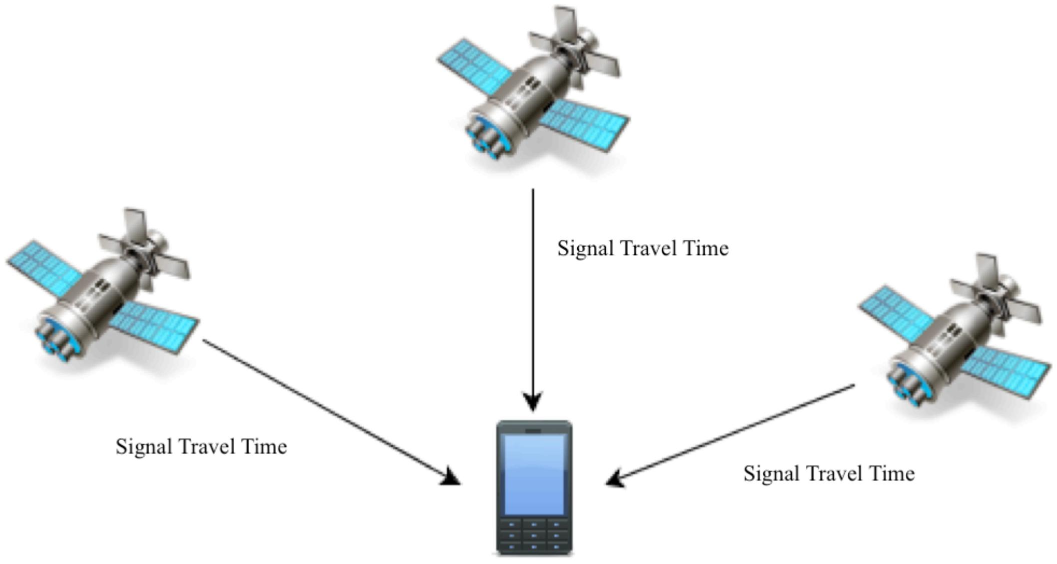


Figure 2.4.1 – GPS

2.4.2. Mobile Network-based location

All the location method described in previous sections of this document such as CGI, AOA, TOA, TDOA and more can be use for mobile network location purposes. Some of them are fully compatibles and others just need some slightly modifications in the network or some additional functionality in the terminal device.

The information for location purposes is in the cell with the GSM technology, since it is needed to establish communication with other device (the system needs to know in which cell is the terminal). This information could not be accessed from outside the network but nowadays it has been redesign in other to be able to access that information. In the Universal Mobile Telecommunications System (UMTS) location information can be accessed from inside and outside of the network.

Mobile companies use some combination of the location technologies in order to provide different ways of location. The most popular used technologies are the followings:

- Cellular Identification-based techniques:
  - Cell Global Identity, CGI.
  - Enhanced Cell-ID, TA.

- Network-based techniques:
  - Angle of Arrival, AOA.
  - Time of Arrival, TOA.
  - Time Difference of Arrival, TDOA.
  - Multipath Fingerprint, MF.

- Mobile device-based techniques:
  - Time Difference of Arrival with modified device, TOA.
  - Enhanced Observed Time Difference, E-OTD.
  - Advanced Forward Link Trilateration, A-FLT.
  - Global Positioning System, GPS.
  - Advanced Global Positioning System, A-GPS

- Hybrid techniques:
  - TDOA and RSS.
  - TDOA and AOA.
  - A-FLT and A-GPS.
  - E-OTD and A-GPS.

In Europe, the most used location services provided by the phone network companies are based in cell identification methods as Cell-ID or Enhanced Cell-ID. The method E-OTD is not so popular in this kind of services and A-GPS could be the most used in the following years but the devices that are able to use it are expensive. The European GSM uses TOA and AOA and in EEUU A-GPS, A-FLT and O-TDOA is used for CDMA and A-GPS is used for GSM as it is regulated in the document FCC E-911.

How those technologies are used and implemented nowadays in our networks will be explained. For this purpose, those technologies will be split into cell identification-based, network-based and mobile device-based methods [11] [12].

Cell Identification-based

This method is actually one of the most used for the mobile phone-network companies. In order to improve the services an improved method has been developed and it is called Enhanced Cell-ID. This method is able to locate any kind of devices over all the mobile networks as GSM, GPRS, UMTS and CDMA.

Enhanced Cell ID provides more accuracy over Cell ID using Radio Frequency parameters such as Timing Advance (TA) in order to know the position within the cell-sector. In GSM, the timing advance corresponds to an approximation in time that the signal needs to go from the device to the BTS of the cell which the phone is connected at that time [7] [9].

Network-based

In this section, two different technologies can be found: TDOA and Multipath Fingerprint (MF).

- TDOA: TOA is a very costly approach to implement because it needs Location Measuring Units called LMUs, in the other hand, TDOA works in the same way as it has been explained in time-based section, but taking into account that in urban areas it can have multipath and sometime four BTS are needed because of its reflexions. It rural areas TDOA can be combines with AOA to improve the accuracy [12] [9].

- Multipath Fingerprint (MF): This method is used mainly in urban areas since it is focused on preventing those reflexions than can be caused by the building in a big city. In order to identify these reflexions the stations have to send test units to the different received signals from the terminal and when a multipath is detected save it into the database. Then next time it receives a signal the station could check in the database. The accuracy of this method resides in the number of multipath stored in the database [11].

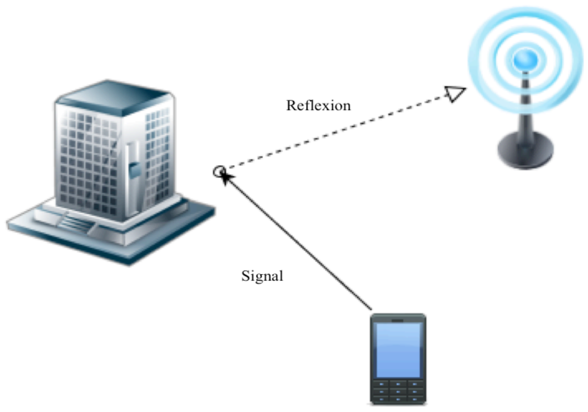


Figure 2.4.2.1. – Multipath signals

Mobile device-based

Finally in this section, some enhanced method of the previous ones will be reviewed, E-OTD, A-FLT, E-FLT and A-GPS.

First of all, the Enhanced Observed Time Difference (E-OTD), works over GSM and GPRS and it is a new technology for the network and also for the terminal devices. It works similar to the TDOA,

There are two different procedures in this method, the first one uses hyperbolic triangulation, the terminal observers the time difference of arrival from two different base stations, those observation are known as Observed Time Difference (OTD). The measured OTD of a base station defines a hyperbolic locus. The same process is repeated with a second base station and the intersection of the two hyperbolic locus gives an estimate of the location of the mobile. The more measures are done with different base stations the more accurate is this approach.

The second procedure, which uses circular triangulation needs location measurement units (LMUs). The number of LMUs involved in the location process determines the precession of it. The common approach is to use one LMU each one or two stations. These receivers and the terminals with E-OTD software are the ones that measure the signals from two or more different stations.

The network can assist the position calculation if the terminal measures the signal OTD and the network send to the terminal the rest of the information as the BTS. Or in other way, the terminal can assist the network by sending the OTD to the network, which is the one that calculate the position.

Another mobile device-based method is Advanced Forward Link Trilateration (A-FLT). This technique is used in CDMA networks and it is similar to the TDOA. A-FLT consists of measuring the delay of a signal sent to two different BTS and compares this delay with the measure of another pair of BTS. This technique locates a device using three BTSs. Enhanced Forward Link Trilateration (E-FLT) works in a similar way than A-FLT but it needs some modification in the network and in the BTS.

Finally, the A-GPS is a technology that has been developed in order to get a faster and more accuracy position than the conventional GPS and also requires less processing power and therefore, save battery life on the mobile devices.

The A-GPS is composed by a terminal device with GPS receiver, a A-GPS server with a reference GPS receiver or a differential GPS service (DGPS) and a mobile network structure. The reference GPS receivers obtain information of the navigation and differential correction data for the GPS satellites, which are in the coverage area.

Once the server obtains all these information, it provides some to the terminal devices, mainly a table with the position of all the satellites which can contact with that device. All those data messages are small packages of 50 bytes size and contain all the necessary information to complete the received GPS data.

The location server can also access to a database that contains information of the geographical area in order to provide the altitude of the devices position.

A-GPS can be used in synchronous and asynchronous networks so it can be used in GSM, GPRS, UMTS and CDMA [11] [12].

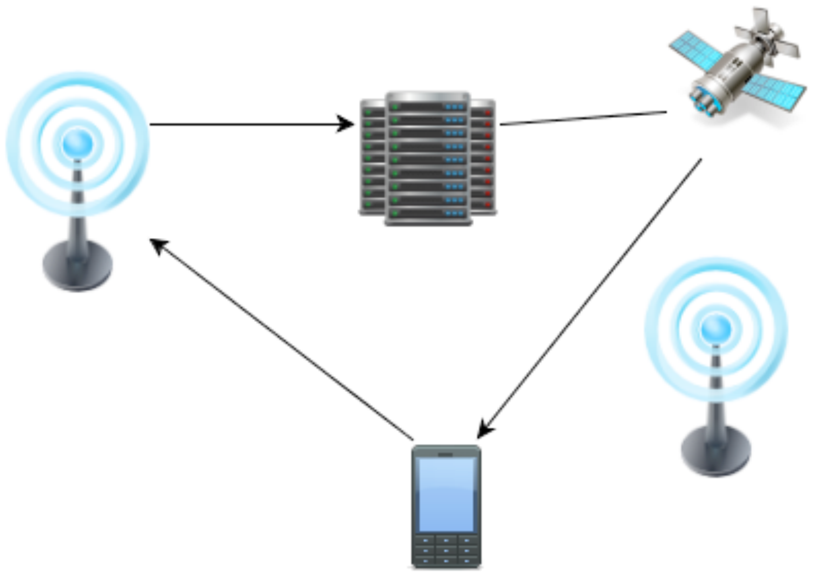


Figure 2.4.2.2. – A-GPS

Following the image above all the necessary steps to locate a device using A-GPS will be explained briefly.

1. The device sends a location request.

2. The location server processes the received Cell-ID obtained from the BS in which the device is located. Then, the location server processes that information to obtain the near satellites to that location and sends the list of satellite to the device.

3. The GPS information is combined with the BS information and they are sent to the location server.

4. Finally, the coordinates are transmitted back to the device .

2.5. Indoor Location

All the technologies that have been reviewed in the previous section provide the final user location services with good accuracy. In some cases, when the user is inside a building or in more close environments, the accuracy of those technologies will be affected and it will not provide a good service to the user. In this section, some technologies suitable for indoor location will be studied.

IEEE 802.11

Nowadays, the Wireless Local Area Networks (WLAN) has become so popular and they can be found in almost every place as hotels, shops, airports, and in some many places in order to allow the users to have broadband access. This technology provides us another way of location for indoor environments.

There are different kinds of WLAN and IEEE 802.11 is the set of standards that all of them must follow. The original version of the standard was released in 1997 and it has been improved in order to provide a faster and a easier way of connection. Actually, the most advanced is called IEEE 802.11n providing a data rate from 54Mbit/s to 600Mbit/s. Also the versions IEEE802.11ac and 802.11ad are under development.

The location using WLAN for indoor environments can be done using different approaches. The simplest one is based on the access point (AP) near the device. This cannot be used for 3D location because of its poor accuracy, this fact makes hard to know in which floor in side a building a device is located.

The devices with Neural Cellular Positioning System (NCPS) measure the signal power from the AP and if that power is lower that a limit, it changes to another AP. In this process, the device sends to the positioning system the power of the signal and the AP identification [12].

RFID

The Radio Frequency Identification (RFID) is used to identify an object or person that is in a certain distance by reading its ID included in a tag. Tags, readers and control systems compose the RFID systems. The objects or persons are the ones that carry the tags with the ID information located in those small chips. The readers are equipped with an antenna that activated the tags and is able to read its information and sometimes also write in the tags.

Those RFID tags can be distinguish into two types, passives and active tags. The passive tags do not have own power source to be activated and so, the power source of the reader is need to read the tags. Those tags are small chips which contains basic information (Object ID) that it is send to the reader when the reader send a power signal to the chip. Passive tags are cheap and small since they do not have power source but the reading range is small, until couple of meters. The bar codes are being substituted by this kind of cheap RFID tags.

On the other hand, the active tags have their own power source inside the tags that allow these tags to send information to the readers. The reading range is bigger that the one of the passive tags (dozens of meters) and also its memory and cost is bigger. Those tags are used mainly to identify mobile objects.

For location purposes the most used tags are the active tags because of its reading range, but that range also depends on the environment. Also some other aspects must be taken into account as the reading rate (tags per second), the battery life or the size of the tag.

An UHF tag with a correct reader can provide very good results as reading range of 100 meters, a reading frequency of 100 tags per second, a memory of 32kb and a 5 year battery life.

The strong point of these technology is that is becoming cheap in a fast way. They are small and easy to use for so many purposes. In case of the location, a device could read those RFID tags and send its information to a location centre that will know a approximation location of that device. RFID are used also in Android devices since they have tags able to change the behaviour of the phone just reading them [12].

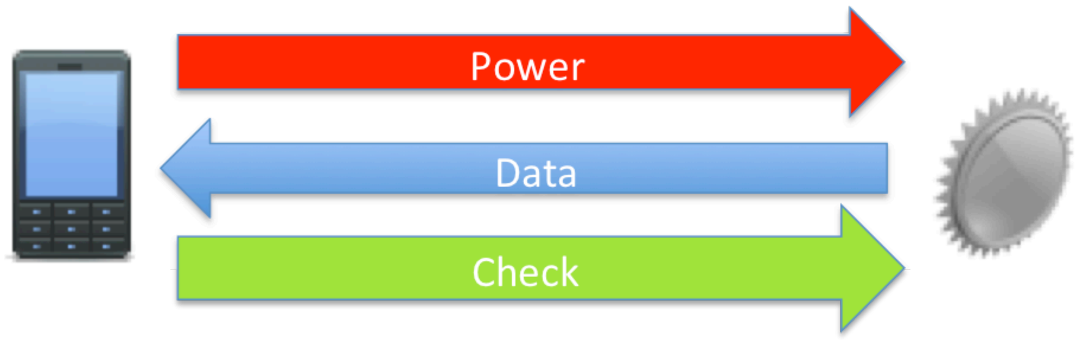


Figure 2.5 – RFID transmision

2.6. Geolocation API in Android

The location of a mobile device in Android can be done in several ways such as GPS, cell tower triangulation or via Wi-Fi networks. In order to manage and obtain the Android device location, the *android.location* package has been used.

Inside this package different classes can be found as the Location, the LocationListener class or LocationManager class which are the most important to perform the location of a device.

2.6.1. Location Class

This class provides a structure where all the information of a location point will be stored. An object will keep all the useful information of a location point and also it will provide some useful methods such as the distance between two different points.

The main attributes of this object are the latitude and the longitude which are the two needed coordinates to determine the position of a point in the map. These attributes can be accessed by the method *getLatitude()* and *getLongitude()*. Also the attribute provider can be useful to know where the location information comes from and it can be accessed by the method *getProvider()*.

Additionally, the distance that exists between two points in the map is important to be known. This object provide us the method *distanceTo()* which give us the distance between the location that calls the method and the location introduced by parameter in the method [13].

2.6.2. LocationManager Class

This class provide a full control over all the location features GPS, cellular location and Wi-Fi by providing status of the device and methods to obtain the location.

The method isProviderEnabled() is used to know if a provider is enable in a specific moment and can be used to obtain the location. Once the provider has been check if is enable the LocationManager request for the location using an specific provider by calling the method requestLocationUpdates() which mainly receive a provider and a LocationListener that will be reviewed in the next section and received the location of the device. The LocationManager also has to close the update when it not necessary to receive any more by calling the method removeUpdates().

Another important function of this object is the last know location process. Since the LocationManager is in charge of controlling the location, it is the one that knows the last location on each moment and in case of the request for new location fails the method *getLastKnownLocation()* can be accessed [13] [6].

2.6.3. LocationListener Class

The location listener is used to receive the notification from the LocationManager. When a new update arrives, here is where the location is received and saved in a LocationResult. The main function of this class is to obtain the location when the locationManager asks for updates. The method that receives the locations is called *onLocationChanged()* and received as a parameter a Location object which is where the received location will be stored. [13] [15]

2.6.4. Wi-Fi location

In order to provide a better location on indoors, a Wi-Fi based location has been used. For this purpose the package *android.net.wifi* provides us two useful classes, *WifiInfo* and *WifiManager*.

The WifiManager control the Wi-Fi status and provides all the necessary information such as the enable status using the method isWifiEnabled(). Also, it provides information about Wi-Fi connections that can be stored in a WifiInfo.

This object can realize Wi-Fi scans to show the available connections around the device using the method startScan(). To realize the scan and the method getScanResults() to obtain a list of connection that are in the range of the device.

Each of those connections can be stored in an object WifiInfo in order to access some useful information such as BSSID that identifies a Wi-Fi connection [14].

2.7. SQLite Database API

SQLite is a light database embedded into Android OS. This database is very useful since it is a light databases and consumes low memory while running which is important in mobile devices with restricted memory.

This database does not require any setup or administration, it is managed automatically by the operating system and it only requires defining the SQL statements for creating and updating the tables. Every operation in the database results in an access to a file, so it is recommended to perform every operation to the database asynchronously.

In order to use this database some packages should be imported as the *android.database.sqlite,* which contains the specific classes for creating and using the d SQLite database. The SQLiteOpenHelper class is in charge of creating and updating the database and the SQLiteDatabase in the one that provide the methods to perform every action to manipulate the database [16].

2.7.1. SQLiteOpenHelper Class

This is the base class for creating an SQLite database. Here is where all the tables and update rules are defined. In the constructor the method super is called with a name and the version of the database that want to be created.

Also in this class is important to create more methods as onCreate(), which creates the tables by executing a SQL statement. In those statements all tables will be defined with the specific fields, types, primary keys and name of each table.

The method *onUpgrade()* defines the rules that must be executed when the version of the database is increased. The tables can be dropped in order to create new ones with different schema or just add some more rules or changes.

These methods receive as parameter objects of the class, which will be, explain in the following subsection *SQLiteDatabase*. Also, the object *SQLiteDatabase* can be access the calling the methods *getReadableDatabase()* or *getWriteableDatabase()* provided by *SQLiteDatabase* depending if a read or a write is needed [17].

2.7.2. SQLiteDatabase Class

This class is basic for working with the SQL database. It provides all the needed methods to open, query, update and close the database. The methods provided by this class are called *insert(), update() and delete()*. Also, the methods *close()* and *open()* that allows us to start/stop reading or writing from the database are provided by this class and finally the method *execSQL()* that allows to execute all the SQL statements.

One very useful object that is used while working with SQLite databases is ContentValues. This object allows defining key/values. The key is the identifier field of a table and the value is the content of that specific field. This object is commonly used to insert and update tables in the database.

The queries can be created using the method *rawQuery()* which receives a string with SQL statements to execute. In order to keep the result of that query the object Cursor is used. A cursor works as a list of result and points to one of them in this way all the results can be buffered and it is not need to store into memory. The method *getCount()* return the number of results and it can be iterated with the method *moveToNext()*.

The most simple use of the cursor is to move to the first position with the method *moveToFirst()* and then check if it is the last result with *isAfterLast()*, if it is not the method *moveToNext()* is called after getting the information of that result.

If the result has several columns, they can be accessed using *getString(column index)* where column index in the number of the column that is be accessed. After all, the cursor must be close using *close()* [17].

2.8. Package Management API

The APPs in the Android devices are installed as packages where all the information about the APPs can be found. In this section, the different APIs used in order to obtain that information and manage those packages is explained.

For this purpose, different packages can be distinguished. In one side, the classes that control the running processes in the device and, in the other side, the classes that manage the installed APPs in the device.

The class *android.app.ActivityManager* provides us access memory information such as the running processes, also the ActiviyManager allows to manage the memory. An interesting method that provides the running processes in the device is *getRunningAppProcesses()* which returns a list of processes. That list is composed of objects called RunningAppProcessInfo which contain useful information such as the processName and the PID (Process identifier).

The classes that manage the installed packages in the device are android.content.pm.PackageManager and android.content.pm.PackageInfo. The PackageManager is quite similar to the ActivityManager but it provides information about all the packages installed and not just the running processes. This class allow us to obtain information from the packages such as permissions using the method *getInstalledPackages()* the attribute of the method indicates what information about the packages is required, for instance, in case of permission it should be PackageManager.GET_PERMISSIONS. This method returns a list of PackageInfo objects which are also similar to the RunningAppProcessInfo object and it contains the name of the APP but in this case the permissions of the APP can be found in this object.

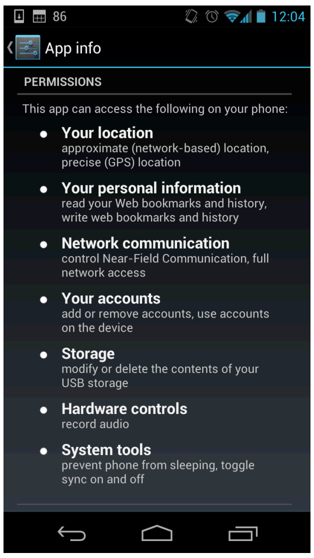
Using those classes it should be easy to obtain, for instance, all the permissions of the running processes in the Android device. In following sections the importance of the permissions in the Android OS will be explained [18].

2.9. Android Permissions

This section describes how the permissions are used in Android applications for security features. The main point of the security based in permission is that no application has, by default, permission to perform any operation that would impact other applications, the operating system or the user by default. Some examples of this operation are reading user data (Contact list or mails), accessing to other applications data or accessing the network features.

In Android OS, application are sandboxed from each other, and this makes that the application have to share resources among them. The permissions are different in each application, This mechanism restricts the application of doing any operation unless the specific permissions has been granted.

These permissions required are shown during the installation. The user must read the list of permissions that the application requires. The user must read the list of permissions and if the permissions are accepted. In case the user accept or deny the permission list, the whole list will be apply or refuse but the user cannot choose just some permissions from the list and it will be apply to the application permanently. This means that if the list is accepted the permissions of the application cannot be deny unless the application is uninstalled from the device. Android has no mechanism for adding permission in runtime since it would complicate the user experience while running the application. [20]


86 12:04

App info

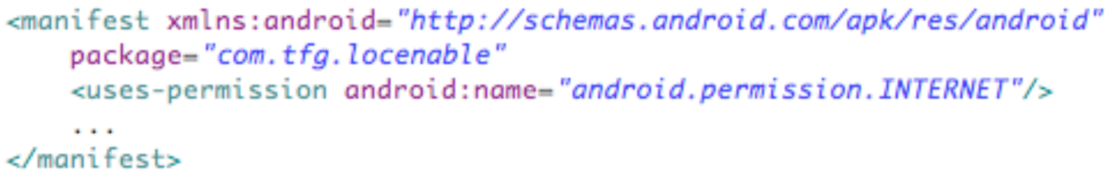
PERMISSIONS

This app can access the following on your phone:

- **Your location**
  approximate (network-based) location, precise (GPS) location
- **Your personal information**
  read your Web bookmarks and history, write web bookmarks and history
- **Network communication**
  control Near-Field Communication, full network access
- **Your accounts**
  add or remove accounts, use accounts on the device
- **Storage**
  modify or delete the contents of your USB storage
- **Hardware controls**
  record audio
- **System tools**
  prevent phone from sleeping, toggle sync on and off

Figure 2.9.1. – Android Permissions List

In order to add permissions to the application, the permissions must be included in the application AndroidManifest.xml using the tag <uses-permission>. For instance, an application that requires Internet access must include the following line in the manifest:



```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.tfg.locenable"
    <uses-permission android:name="android.permission.INTERNET"/>
    ...
</manifest>
```

Figure 2.9.2. – Manifest example

During the application install time, the package installer grants the permissions requested by the applications just if the user checks and agree the permissions list. No more checks are done during the running time. If any permissions have been granted the application could use that feature as it desires or in the other case, if the permissions have been denied, the application have no way to performance the requested operation. In both cases, the user won't be noticed. [20]

The permissions are constantly changing. This means that the developer must be aware and launch updated versions of the application with the new permissions to ensure that the application is running well.

2.10. Google APP Engine

Google APP Engine is a cloud system where the web applications can be stored and run. This cloud system is different from others cloud systems, it is neither IaaS (Infrastructure-as-a-Service) nor SaaS (Software-as-a-Service). It is something in-between called PaaS (Platform-as-a-Service).

The motivation of this choice is the robust, scalable and the easy application deployment. GAE provides an API to develop the web applications using Java technologies. This platform is scalable. As the number of request to the web application increases, the App Engine automatically allocates more resources for the web application in order to handle those requests. [30]

Other good point of using Google App Engine is that web application can be built in using standard Java Technologies, the App Engine used Java Servlets for the web application. The easy web application deployment is another advantage to this technology since Google manages the application and the user does not have to worry about managing resources.

Finally, Google App Engine provides scalable databases using the Datastores. These Datastores use a High Replication Datastore (HRD) which uses the Paxos algorithm to replicate data across multiple data centres.

The data is written in the Datastore as entities and each entity has a key that indentifies the object, then more attributes can be added to the entity. These Datastore can also execute SQL queries. Also, the Datastore can be managed and motorized from the Google App Engine web application using a friendly user interface providing the user a friendly view of the database structure. The user can also realized SQL queries.

Google App Engine also provides a XMPP service to communicate with other applications over this protocol. This service provides a fast messaging protocol which can be used to interchange information among different applications. Those messages are encrypted using SSL/TLS, which provides a secure communication between the clients and the server.

Finally, the easy deployment, the scalability of the system and the compatibility with different systems and languages make the Google App Engine a good reasonable technology to implement in our system.

Chapter 3. Project Analysis

The purpose of this chapter is to describe the project by specifying its requirements. There are different kinds of requirements. First of all, the functional requirements define some functions that the program must accomplish. Then, the non-functional requirements (also known as quality requirement), which impose constrains on the design and implementation (such as performance requirements).

After defining those requirements, some tests are needed in order to ensure a correct performance and that every requirements has been implemented in a proper way into the system.

Finally, a development methodology and lifecycle, which will be followed, is going to be described by providing and explaining all the project stages in order to schedule and develop a good quality product.

3.1. System Requirements

This section will provide information about the Software Requirements of this project, including their description, functionalities and more important characteristics. These requirements will be divided between Functional and Non-Functional Requirements.

During the project analysis phase one of the most critical steps are the system requirements specification. In order to archive the best results in this phase, the IEEE recommended practices have been followed [26]. This document provides us the basic issues that the system requirements shall address such as functionality, external interfaces, performance, attributes and design constrains.

Also, according this standard in order to archive a good system requirement specification those system requirements should have the following characteristics:

- Correct: a software requirement is correct if, and only if, every requirement meets a functionality of the program.
- Unambiguous: a software requirement is unambiguous if, and only if, has only one interpretation.
- Complete: a software requirement is complete if, and only if, includes all significant requirements.
- Consistent: a software requirement is consistent if, and only if, agrees with the rest of the requirements and it does not make conflicts.
- Ranked for importance and/or stability: a software requirement is ranked if, and only if, each requirement in it has an mark of the importance/stability.
- Verifiable: a software requirement is verifiable if, and only if, there is any process to check that the requirement has been implemented.

- Modifiable: a software requirement is modifiable if, and only if, can be changed easily.

- Traceable: a software requirement is traceable if, and only if, the origin of each requirement if clear and unique.

Identifier	YR-XX		**Type**	Type of the SR.	
Name	Short and descriptive name of the SR.				
Actors	What is affected by the SR.				
Description	A detailed description of the SR.				
Verifiable	Yes/No	**Criticality**	1 to 5	**Purpose**	The objective
Essential	Yes/No	**Desirability Level**	1 to 5	**State**	The current state

Table 1 – System Requirements Template

The fields in the template above must be filled for each of the requirements with the following information.

- **Identifier**: a unique and descriptive identifier in the entire project, which format is YR-XX, where Y is F when the requirement is functional or NF when the requirement is non-functional and the XX are the identification number of the requirement.

- **Type:** the possible values are: “Functional”, “Architecture”, “Scalability”, “Performance”, “Technology”, “Availability”, “Supportability”, “Security”, “Usability” and “Interface”.

- **Name:** short and descriptive names of the SR that can let the user make an idea about the purpose of the requirement.

- **Actors:** what is affected by the SR or “-“ if the field is not applicable for the requirement.

- **Description:** a detailed description of the requirement.

- **Verifiable:** whether or not the SR can be proved as having been implemented in the resulting system. Its value must be “Yes” or “No”.

- **Criticality:** the level of criticality: its value must be “1”, “2”, “3”, “4” or “5”, where “1” means **LOW** criticality and “5”, **HIGH** criticality.

- **Purpose:** the main objective of the SR.
- **Essential:** whether or not the SR is essential for the resulting system to work properly.
- **Desirability level:** its value must be "1", "2", "3", "4" or "5", where "1" means **LOW** desirability and "5", **HIGH** desirability. All essential requirements have a "5" value.
- **State:** the current state of the SR: its value must be "Stable", "Unstable" or "Suspending", where "Stable" means that the SR is not likely to change, "Unstable" means that the SR may be dependent on feedback from the testing or the user, and "Suspending" means that the SR may be pending resources which are becoming available.

3.1.1. Functional Requirements

Identifier	FR-01		**Type**	Functional	
Name	Restrictions Mechanism				
Actors	System				
Description	The system must be able to restrict the execution of APPs based in the location mechanism such as the Wi-Fi and the location (GPS and Network).				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 2 – FR-01

Identifier	FR-02		**Type**	Functional	
Name	Rules Syntax				
Actors	System				
Description	The Rules must be composed by the following field: - Location: Value to locate the device and its max distance. - Restrictions: The permissions that must be restricted. - Exceptions: The APPs that can still run in the device.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 3 – FR-02

Identifier	FR-03		**Type**	Functional	
Name	Rules restriction				
Actors	System				
Description	The restriction mechanisms shall be based on a rule system, being each rule defined by an administrator. The rules will be composed by locations, restrictions and exceptions. The administrator is able to associate restrictions to locations and the exceptions will be APPs which will not be affected by those restrictions on that location.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 4 – FR-03

Identifier	FR-04		**Type**	Usability	
Name	Basic Exceptions				
Actors	System				
Description	The system must be able to add some basic exceptions that cannot be restricted in other to protect the basic functionality of the device. Input Systems, System UI, Phone and Messaging Services, Settings, Launcher. The project application will be included in the exceptions in order to prevent it to be restricted.				
Verifiable	Yes	**Criticality**	4	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 5 – FR-04

Identifier	FR-05		**Type**	Functional	
Name	Scan and obtain Wi-Fi identifier				
Actors	System				
Description	The system must be able to scan the Wi-Fi stations near the device and obtain the BSSID of each of them.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 6 – FR-05

Identifier	FR-06		**Type**	Functional	
Name	Obtain GPS Location				
Actors	System				
Description	The system must be able to obtain the location of the device using the GPS technology.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 7 – FR-06

Identifier	FR-07		**Type**	Functional	
Name	Obtain Network Location				
Actors	System				
Description	The system must be able to obtain the location of the device using the mobile Network.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 8 – FR-07

Identifier	FR-08		**Type**	Functional	
Name	Obtain Last Known Location				
Actors	System				
Description	The system must be able to obtain the last known location of the device in case the other mechanism fail.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 9 – FR-08

Identifier	FR-09		**Type**	Functional	
Name	Location Distance				
Actors	System				
Description	The system must be able to measure the distance between two different location in order to ensure that the device is/is not in a restricted location.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 10 – FR-09

Identifier	FR-10		**Type**	Functional	
Name	Obtain running process				
Actors	System				
Description	The system must be able to list all the running processes in the device.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 11 – FR-10

Identifier	FR-11		**Type**	Functional	
Name	Obtain installed APPs				
Actors	System				
Description	The system must be able to list all the installed APPs in the device.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 12 – FR-11

Identifier	FR-12		**Type**	Functional	
Name	Get APP permissions				
Actors	System				
Description	The system must be able to access the required permissions of every APP in the device.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 13 – FR-12

Identifier	FR-13		**Type**	Functional	
Name	Read Rules File				
Actors	System				
Description	The system must be able to access the device assets. The file with the rules will be located in the assets. This file will be read to add/modify rules in the system				
Verifiable	Yes	**Criticality**	4	**Purpose**	Capability
Essential	Yes	**Desirability Level**	4	**State**	Stable

Table 14 – FR-13

Identifier	FR-14		**Type**	Maintainability	
Name	Automatic Updated				
Actors	System				
Description	The system must be able to download update files with rules in order to keep the rules up to date.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Capability
Essential	Yes	**Desirability Level**	4	**State**	Unstable

Table 15 – FR-14

Identifier	FR-15		**Type**	Security	
Name	APP Heartbeat				
Actors	System				
Description	The system must be able to sent a check message to a server in other to ensure that the APP is running in the device.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Capability
Essential	Yes	**Desirability Level**	4	**State**	Unstable

Table 16 – FR-15

3.1.2. Non Functional Requirements

Identifier	NFR-01		**Type**	Performance	
Name	Locate and check location every 30 seconds				
Actors	System				
Description	The system must request the device location every 30 seconds and check if it is in a restricted area.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 17 – NFR-01

Identifier	NFR-02		**Type**	Functional	
Name	Store Rules				
Actors	System				
Description	The system must be able to have access and store all the rules in the database. This requirement includes all the necessary actions to manage the database such as add rules, find rules or apply filters.				
Verifiable	Yes	**Criticality**	5	**Purpose**	Capability
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 18 – NFR-02

Identifier	NFR-03		**Type**	Scalability	
Name	Scalable Database				
Actors	System				
Description	The system database must be able to manage a great quantity of data in order to keep all the restrictions. Each device must be able to store 10,000 rules in the database.				
Verifiable	Yes	**Criticality**	4	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	4	**State**	Stable

Table 19 – NFR-03

Identifier	NFR-04		**Type**	Supportability	
Name	Not Device Dependency				
Actors	System				
Description	The system must run in as much different devices as possible.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	4	**State**	Stable

Table 20 – NFR-04

Identifier	NFR-05		**Type**	Usability	
Name	Transparent to the user				
Actors	System				
Description	The system must be transparent to the user. The user of the phone does not have to known that the APP is running (Except when some APP is restricted).				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	4	**State**	Stable

Table 21 – NFR-05

Identifier	NFR-06		**Type**	Availability	
Name	System availability				
Actors	System				
Description	The system must be available all the time in order to ensure a correct performance				
Verifiable	Yes	**Criticality**	5	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 22 – NFR-06

Identifier	NFR-07		**Type**	Performance	
Name	Location Deadlines				
Actors	System				
Description	The system must have a deadline that changes the location mechanism if one o them are slow. First try to locate by GPS and if it is slow locate with Network and if both fail get the last known position.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 23 – NFR-07

Identifier	NFR-08		**Type**	Performance	
Name	Check APPs each 1.5 seconds				
Actors	System				
Description	The system must check if the APPs are restricted each 1.5 seconds.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	3	**State**	Stable

Table 24 – NFR-08

Identifier	NFR-09		**Type**	Usability	
Name	APP cannot be stopped				
Actors	System				
Description	The system will inform the server when the APP has been stopped.				
Verifiable	Yes	**Criticality**	2	**Purpose**	Constraint
Essential	No	**Desirability Level**	2	**State**	Stable

Table 25 – NFR-09

Identifier	NFR-10		**Type**	Security	
Name	Secure connection				
Actors	System				
Description	The system must connect with the server through a secure channel (HTTPS) in order to ensure security while downloading the rules.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 26 – NFR-10

Identifier	NFR-11		**Type**	Usability	
Name	Start APP when device start				
Actors	System				
Description	The system must start running when the device starts.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	Yes	**Desirability Level**	5	**State**	Stable

Table 27 – NFR-11

3.2. Validation tests

The validation tests allow verifying the correct performance of the different parts of the system. These test provide some input into the system, then, the system responses with an output. If the output is not the expected, it means that there is something wrong in the tested module.

One of the most important aspects in this validation phase is that all the system requirements should be covered. In this case, the validation of all the required system functions is ensured. This will ensure a high quality software that meets all the specified requirements.

All the tests will be defined on this document, providing the different step that must be taken to execute the test correctly. In some cases, the test can be successful for two different modules but when they work together may exists some problems. This is the reason that some test just affect a specific module in the project but some other tests can affect different modules of the project, ensuring the correct performance when different modules work together.

All the tests that are specified follow the following table template:

Identifier	VT-XX
Target	Specific test target.
Pre-Conditions	Input values to the test.
Description	Brief description of the step that must be followed.
Post-Conditions	Expected results.
Source	System requirements tested.

Table 28 – Validation Test Template

The fields in the template above must be filled for each verification test with the following information:

- **Identifier:** a unique and descriptive identifier in the entire project, which format is VT-XX, where XX in the identification number of the test.
- **Target:** what is going to be tested.
- **Pre-Conditions:** the required values that are going to be needed in test.
- **Description:** a brief description of the different steps to perform during test.
- **Post-Conditions:** the expected output results of the test.

- **Source:** system requirement source for the test.

Identifier	VT-01
Target	Scan and obtain Wi-Fi identifier process.
Pre-Conditions	A test Wi-Fi stations will be required to execute this test.
Description	- Add a rule with location based in the testing Wi-Fi BSSID. - Check if the restrictions and exceptions execute outside the Wi-Fi range. - Check if the restrictions and exceptions execute inside the Wi-Fi range.
Post-Conditions	All APPs execute outside the range but inside the range just the exceptions and non-restricted APPs are be able to execute.
Source	FR-01, FR-02, FR-03, FR-05, NFR-01, NFR-02, NFR-04, NFR-05, NFR-06, NFR-08

Table 29 – VT-01

Identifier	VT-02
Target	Obtain GPS Location
Pre-Conditions	The device GPS should be active
Description	- Add a rule with location based in the testing location GPS point and the maximum distance. - Check if the restrictions and exceptions execute outside the GPS range. - Check if the restrictions and exceptions execute inside the GPS range.
Post-Conditions	All APPs execute outside the range given by the maximum distance from the GPS point but inside the range just the exceptions and non-restricted APPs are be able to execute.
Source	FR-01, FR-02, FR-03, FR-06, FR-09, NFR-01, NFR-02, NFR-04, NFR-05, NFR-06, NFR-08

Table 30 – VT-02

Identifier	VT-03
Target	Obtain Network Location
Pre-Conditions	The device must have signal and the GPS disabled.
Steps	- Add a rule with location based in the testing location point and the maximum distance. - Check if the restrictions and exceptions execute outside the location range. - Check if the restrictions and exceptions execute inside the location range.
Post-Conditions	All APPs execute outside the range given by the maximum distance from the location point but inside the range just the exceptions and non-restricted APPs are be able to execute.
Source	FR-01, FR-02, FR-03, FR-07, FR-09, NFR-01, NFR-02, NFR-04, NFR-05, NFR-06, NFR-08

Table 31 – VT-03

Identifier	VT-04
Target	Obtain Last Known Location
Pre-Conditions	The device must not have signal and the GPS disabled.
Steps	- Add a rule with location based in the testing location point and the maximum distance. - Check if the restrictions and exceptions execute outside the location range. - Check if the restrictions and exceptions execute inside the location range.
Post-Conditions	If the last location was in a restricted area the associated rules are applied, if it was not, the APP can be executed.
Source	FR-01, FR-02, FR-03, FR-67, FR-07, FR-08, FR-09, NFR-01, NFR-02, NFR-04, NFR-05, NFR-06, NFR-07, NFR-08

Table 32 – VT-04

Identifier	VT-05
Target	Basic exceptions
Pre-Conditions	The device must be in a restricted area.
Description	- Add a rule with a specific location and restricting permissions of a basic APP such as the Phone should be added. - The device must be located inside the range of the rule location. - Execute the basic APP (Phone APP in this case) while being in the restricted location.
Post-Conditions	The system will not restrict the basic services and the device will work properly using those basic services.
Source	FR-01, FR-02, FR-03, FR-04, FR-10, NFR-01, NFR-02, NFR-04, NFR-05, NFR-06, NFR-08

Table 33 – VT-05

Identifier	VT-06
Target	Add Rules from File and Execute.
Pre-Conditions	The rules must be written in the XML file with the specific syntax.
Description	- Create an XML file with the correct structure indicating to add a new rule. - Send the file to the device assets folder. - The device must be located inside the range of the rule location. - Check if the device can execute the restrictions and the exceptions in the specified location. - Move the device to other location. - Check if the rules still apply trying to execute restricted APPs.
Post-Conditions	The system must be able to execute the specified exceptions and will not execute the restricted APPs in the location.
Source	FR-01, FR-02, FR-03, FR-04, FR-05, FR-06, FR-07, FR-08, FR-09, FR-10, FR-11, FR-12, FR-13, NFR-01, NFR-02, NFR-03, NFR-04, NFR-05, NFR-06, NFR-07, NFR-08, NFR-10

Table 34 – VT-06

Identifier	VT-07
Target	Service Start and Automatic Updates
Pre-Conditions	The system must be turned off.
Description	- New rules must be added to the rules file. - Start the device. - Check in the running services if the APP is running - Check if the APP contact with the server to download the new file. - Check if the database the new rules have been added correctly.
Post-Conditions	The new rules will be added to the database.
Source	FR-13, FR-14, NFR-02, NFR-04, NFR-05, NFR-06, NFR-10, NFR-11

Table 35 – VT-07

Identifier	VT-08
Target	App cannot be stopped
Pre-Conditions	The system must be running in a device.
Description	- Check if the APP is running in the device. - Force it to stop the APP. - Check if the APP has stopped and the server receive the alert.
Post-Conditions	The system will alert that the user have stopped the APP.
Source	FR-15, NFR-09

Table 36 – VT-08

Identifier	VT-09
Target	Check if the connection is secure.
Pre-Conditions	The device is doing an Update
Description	- Use a tool to capture packages in the network. - Capture the updating packages of the APP. - Check if the information has been encrypted.
Post-Conditions	The communication will be encrypted.
Source	FR-14, NFR-10

Table 37 – VT-09

3.3. Traceability Matrix

This section provides the traceability matrix. In this matrix each row represents a requirement and each column represents a test. When a test covers a requirement is marked with the symbol X.

Every requirement must be validated with at least one test, which means that every row must have al least one X. This matrix provides a graphical way to have a clear idea of which requirements are going to be tested by each test.

TEST	VT-01	VT-02	VT-03	VT-04	VT-05	VT-06	VT-07	VT-08	VT-09
SR									
FR-01	X	X	X	X	X	X			
FR-02	X	X	X	X	X	X			
FR-03	X	X	X	X	X	X			
FR-04					X	X			
FR-05	X					X			
FR-06		X		X		X			
FR-07			X	X		X			
FR-08				X		X			
FR-09		X	X	X		X			
FR-10					X	X			
FR-11						X			
FR-12						X			
FR-13						X	X		
FR-14							X		X
FR-15								X	
NFR-01	X	X	X	X	X	X			
NFR-02	X	X	X	X	X	X	X		
NFR-03						X			
NFR-04	X	X	X	X	X	X	X		
NFR-05	X	X	X	X	X	X	X		
NFR-06	X	X	X	X	X	X	X		
NFR-07				X		X			
NFR-08	X	X	X	X	X	X			
NFR-09								X	
NFR-10						X	X		X
NFR-11							X		

Table 38 – Traceability Matrix

3.4. Development Methodology

The software development methodology followed in this project corresponds to the Waterfall model [27], which was described in 1970 by Winston W. Royce but in that article Royce did not refer to this model as “Waterfall”.

This model provides a simple planning process since one phase cannot be started until the previous one is finished. This procedure allows us to calculate the time to finish a specific part of the project and establish concrete deadlines.

In the waterfall model, all the phases must be absolutely correct. Special dedication should be taken in the requirements and design. A mistake in previous phases has a big impact in the time, effort and cost of the project since some redesign will be probably needed in order to fix the errors.

In this project, the software requirements are well described and fix since they are unchanging and stable requirements. This methodology is a good approach to develop this kind of stable projects. Also, the waterfall model puts so much emphasis on the requirements in order to ensure that they are correct and fixes errors at a very low cost with out having to redesign or implement code.

The development methodology will not be a straight waterfall model since it will have feedback to previous phases. The main phases of the waterfall model are the following:

- Requirements: This first step is also the most important, because it is here where everything that the software must accomplish in the following phases is specified. A deep analysis will be done in this phase in order to provide the best-defined and clearest requirements and avoid errors that could be costly in further phases.

- Analysis and Design: This phase is where the software and hardware is defined to satisfy the requirements mentioned in the previous phase. In the design phase, some test will be defined to ensure that the requirements are met in further phases of this project. Important design decisions are taken in this phase and they will guide and restrict some approaches of the implementation phase.

- Implementation: The implementation phase consist basically in implementing the design described in the previous phase. The development team consisting of programmers does this part of the methodology. The output of this phase should be a first beta of the product that will have some bugs to be tested.

- Verification: Also called testing. The tests defined in the Analysis and Design phases will be executed in order to ensure that the requirements have been met in the implementation. This phase is important to ensure a good quality product to the customer.

- Maintenance and Deployment: All the software requires maintenance in order to ensure a proper performance by updating the software and fixing some errors that could not be detected in the verification process. In this project, the maintenance is not provided but the system is deployed and it will be running in a device to provide a testing beta to the user.

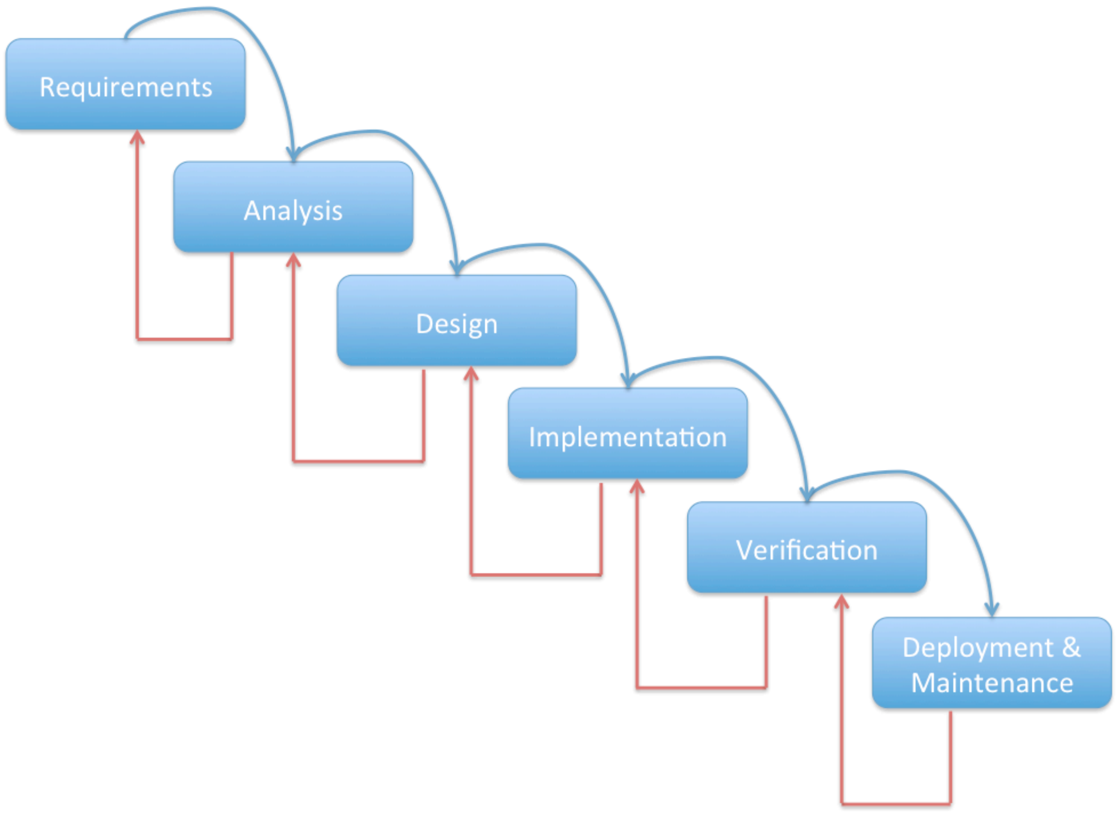


Figure 3.3. – Waterfall development model

In this case, the waterfall model has some feedback on each stage in order to prevent errors and in case of having some errors, this feedback make it easier and less costly to fix them. These feedbacks are represented in the Figure 3.3 as red lines that go to the previous phase.

Every phase has its documentation that can be found over this document. This documentation contains important decisions and results of each of the phases involved in this project development.

Chapter 4. Project Design

The purpose of this chapter is to provide a high-level description of how the system has been designed in order to accomplish the given requirements in the chapter 3. First, a general description of the system will be given, starting at the side of the administrator that manages the system and finishing at the end-device application.

Then, the device application will be reviewed showing in a high-level description the different tiers that compose the application.

This application follows a multitier architecture composed by presentation tier, logic tier and data tier. The presentation tiers controls all the information that is shown to the user through the user interface. Then, the logic tier, also known as middle tier, is where resides the most complex part of the application, it provides services and manages all the information. Finally, the data tier is where all the information is stored.

4.1. System Design

The aim of this project is to restrict the execution of some applications in different locations. In order to archive this goal some design decisions have been taken. In this section those design decisions will be explained.

This system works as a dynamic firewall based on its location. The system restricts different permissions depending on the device location. This is made using some rules provided by the administrator.

In order to restrict the applications the system uses some defined rules with a specific syntax. The rules indicate what permissions are restricted, the location where those permissions are restricted and if there are any exceptions.

In Android, all the applications require a set of permissions that the user must agree for allowing the application to be executed in the device. Those permissions indicate what can be access by the application. The system will use the application permissions to known which device functionalities are being used by the different applications.

The permissions restricted will be mentioned as restrictions; they are the name of the functionality that is restricted, for instance, Internet. The restrictions indicate that all the application that uses a restricted permission is not allowed to be executed in the device.

Those restrictions will be attached to a location. The system uses location information to know where the device is located. Depending on the location some restrictions will be applied. The system allows the administrator to set up restrictions in different locations.

The rules include exceptions. Those exceptions are attached to a location. These exceptions allow the administrator to keep some application running even if the application has some permission restricted in that location. The following figure shows a graphic example of how a rule is defined in the system.

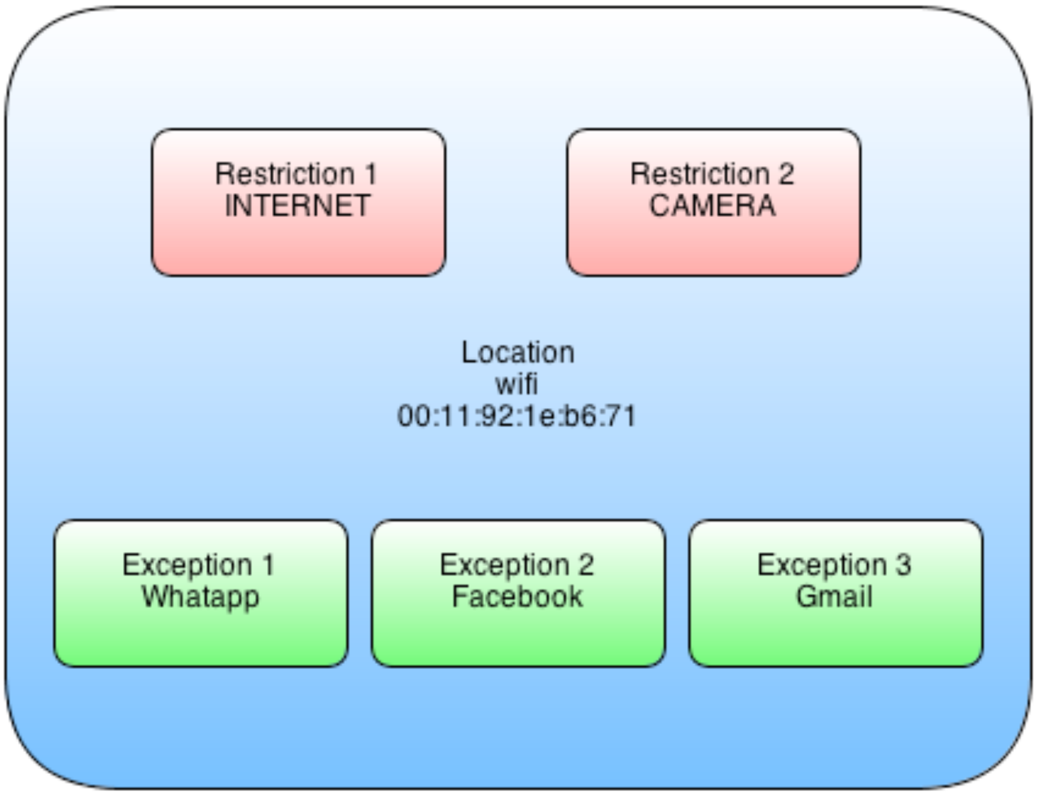


Figure 4.1.1. – Rule Design

This example shows a location using Wi-Fi Mac address that is restricted. The restrictions on the specific location are Internet and camera permissions so, all the application installed in the device that uses those permissions cannot be executed but there are three exceptions provided within the rule and they are the applications Whatsapp, Facebook and Gmail. Just those three applications that have the restricted permissions can be executed inside that location.

The system obtains the running processes in the device and analyse its permissions, using the rules and the location services. Then, the device location is compared to the rules locations and if there is a match, the system obtains the restrictions and exceptions in order to stop those processes that are not allowed to run within that location.

Once the rules have been designed and the application restriction process has been explained, the next step is to explain how the administrator sends the rules to the different devices.

Three main parts compose the system. The first one is the administrator; this is the person that sends files to the server. The files follow a XML schema that contains information for the device application.

The second part is a server which stores the information that the administrator wants to send to the devices. This server will be accessed from the device application in order to download the files. Every device has a different file with its identifier number (IMEI) associated. In this way, the devices access to its file to download its specific information. The server is implemented over Google App Engine using a Datastore database which stores those XML files with rules for each device.

The last part is the application that runs in the devices. This application is the main part of the project; it controls the devices by restricting the applications that can be executed based on its location. These restrictions follow some rules given by the administrator.

The following figure shows the system architecture graphically.

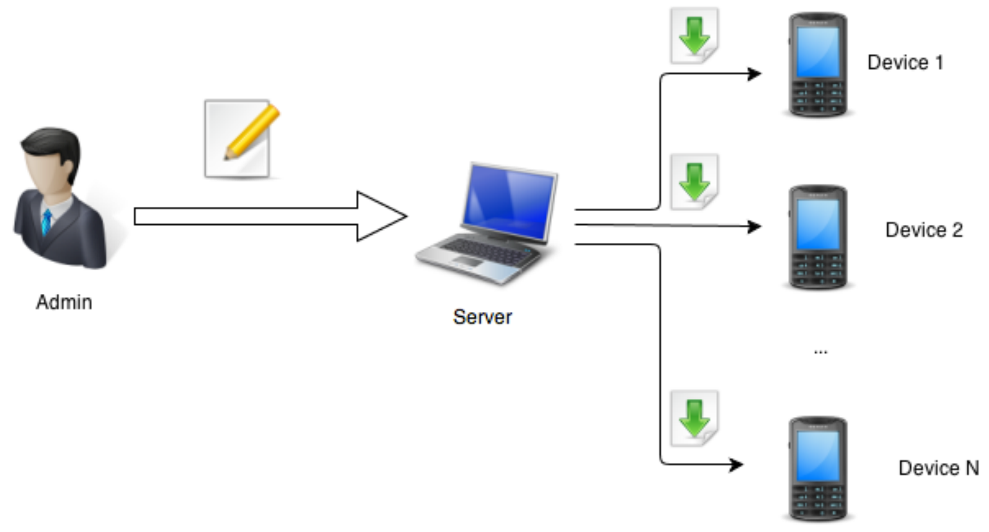


Figure 4.1.2. – System Architecture

From the point of view of the device user, the application running in the device is complete transparent. The user just has to start the application the first time and when it starts everything is done automatically. Then, the application access to the files in case it needs an update and it stores the information in the database for accessing in the following executions.

The administrator will manage the device using the XML files, it is required to follow a simple XML schema that will be explained in the section XML Files and also in the User Manual can be found a guide for defining rules in those files.

The restrictions are based on permissions, those rules will restrict some application permissions and every application that requires those permissions is restricted. Also, the rules have exceptions included where the administrator can add specific application that can be executed even if they have restricted permissions.

4.2. Application Design

Once the interactions among the three parts of the system have been explained, the Android application that runs in the devices will be explained into more detail. This application is the one that performs all the heavy work, updating the rules tables, controlling the running APPs, getting the APPs permissions, locating the device, checking the restricted locations, killing the restricted running APPS, etc.

The structure of the application will follow a multitier architecture which is composed by three tiers: presentation tier, logic tier and data tier. Every tier will run in the device, just the logic tier will access an external file to update the device.

The following figure shows the software architecture which is composed by interconnected modules grouped by its functionality.

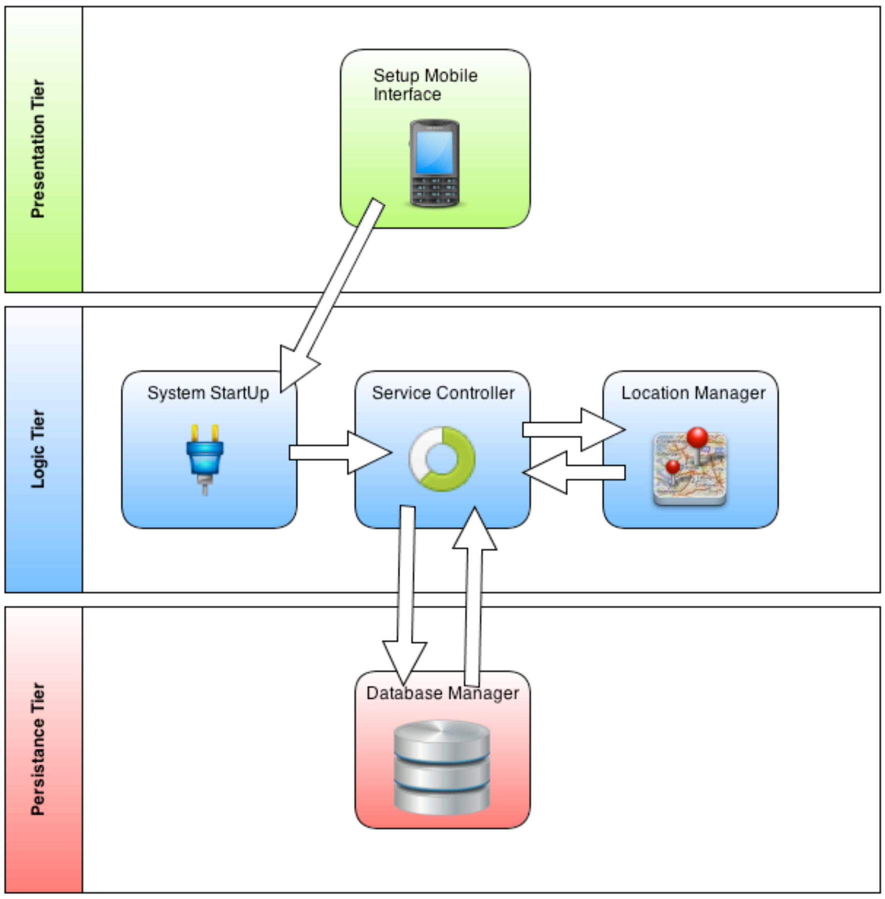


Figure 4.2. – Application Design

The white arrows show interactions among the modules. In this case, the mobile interface module will be the one in charge of initiating the system the first time that the application is launched. Also, it provides useful information to the user through the user interface.

The starting system module starts the service module that controls the device. This service module uses the location manager to obtain location information and the database to retrieve and store data.

The location manager module manages all the location systems such as the Wi-Fi, the GPS and the Network. Also it keeps providing location information to the service module.

Finally, the Database Manager Module provides and stores the data that the server module needs such as the rules that the administrator sends to the devices.

4.2.1. Presentation Tier

The Presentation tier is the first tier in the application architecture. This tier manages all the system interface tasks such as showing information to the user and, in this case, starting the application service the first time that the app is launched. This tier will receive information that the Logic tier wants to show to the user through the user interface.

4.2.1.1. Set-Up Mobile Interface Subsystem

This tier is composed by one subsystem called Setup Mobile Interface which provides a simple user interface. This interface is used to show the user some setup information such as the steps that the user must follow to start the service. Also, this subsystem activates the System Start-up module the first time that the application is launched in the device. This step is required because since Android 3.0 all the application are installed in a Stopped state and the user needs to activate the application.

When the application is launched this module sends a signal to the System Start-up module indicating that the application has started, in the case of an improved version of Android that allows the installation of apps without interface, this would be eliminated and changed by an interface that generates log files. Then, the application is in an active state and it will receive the following signals from the operating system every time the device boot is complete. The following figure shows the presentation tier architecture.

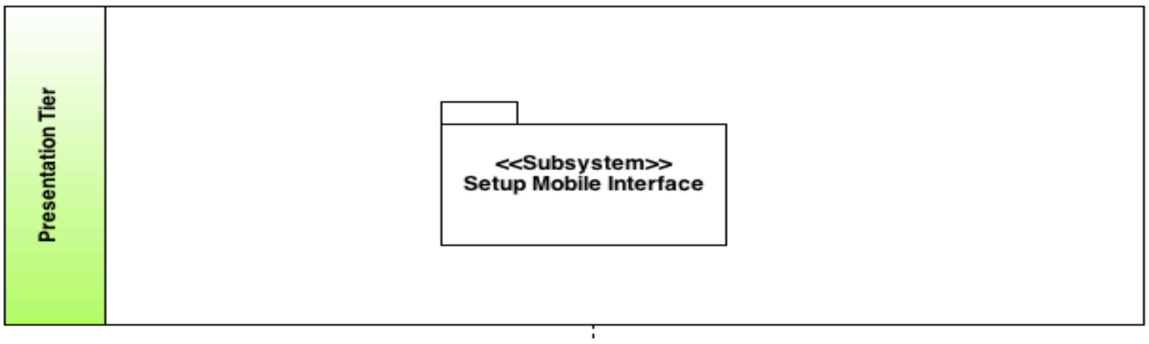


Figure 4.2.1. – Presentation Tier

4.2.2. Logic Tier

The second tier is known as the Logic tier. This tier is more complex since it performs most of the application functionalities. The Logic tier process all the information retrieved from the database in order to provide functionalities to the system and also it sends information to the Presentation tier which shows that information to the user.

In the following sections, the System Start-up, the Service Controller and the Location Manager subsystems that compose this intermediary tier will be reviewed.

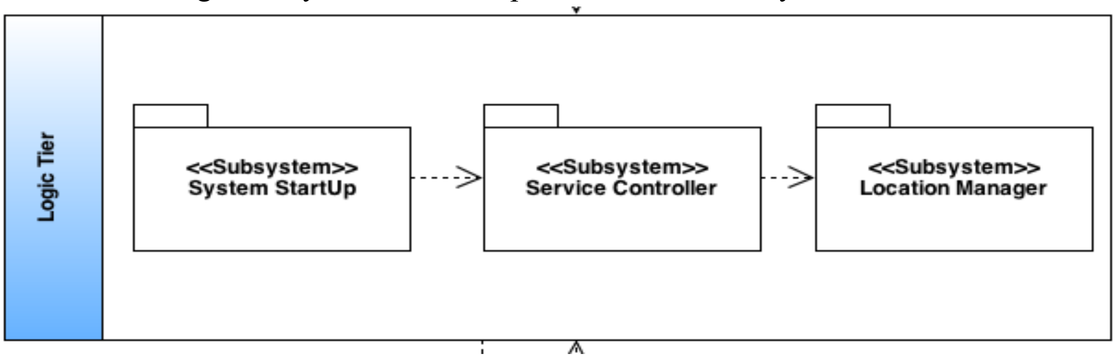


Figure 4.2.2. – Logic Tier

4.2.2.1. System Start-Up Subsystem

According to the system requirements the application must start running every time that the device is booted, so this subsystem listens the operating system signal that is sent when the boot is completed and it starts the Service Controller module.

Starting with Android 3.1 when an application is installed in the device it is in a stopped state and it will not receive boot complete signals from the operating system. That means that the application must be launched the first time to change its state to active and in that way, the application will be able to receive the boot complete signal form the operating system.

So, the System Start-up subsystem listens to the signal send by the Set-up Mobile Interface the first time that is launched to start the Service Controller. Once this first time is done this subsystem will be able to listen the operating system signal boot complete to start the service with out the user interaction.

4.2.2.2. Service Controller Subsystem

The Service Controller Subsystem contains the service that is running continuously in the device. This service is the one that manages the running processes in the device and using the information provided by the Location Manager subsystem allows/stops the execution of the restricted applications.

In order to explain in detail this subsystem, a normal execution of this module will be followed.

Once System Start-up starts the Service Controller module, the first task of this server is to start the database. The service checks if the database is created, in case the database is not created, it will create all the database structure where the rules information will be stored.

Then, the Service Controller module will run the application updater that connects to the Google App engine server in order to obtain the XML files. In the XML file can be found two different kinds of actions: add rules or delete rules.

An XML parser retrieves the information from the file to create new rules objects. The rules objects has an attribute called action that indicates if that rules is going to be added or deleted from the database. Based on the action attribute of each object, the Service Controller module will store or delete the rule form the database.

After the database creation and updating process, some the basic exceptions are added to a list in order to preserve the basic functionalities of the device.

The next two tasks executed in the Service Controller module are executed simultaneously. One task checks if the device location is in a restricted area using the Location Manager Module and the second one checks the running applications and obtains its permissions to check if the application is allowed. The first task is going to be called Location check and the second task APP killer in this section.

The Location check task obtains the location using the Location Manager Module. In order to know the device location this service uses the Wi-Fi location and the GPS/Network location.

First it scans the near Wi-Fi stations and obtains its BSSID (Identifier number). Then, all the near BSSID are compared to the location in the database with the type "wifi" and if it finds a match the location will be saved and a flag will be activated to indicate that the device is in a restricted area.

Since the location via Wi-Fi station is more precise in indoor environment this process is done before the GPS/Network location. In case the Wi-Fi is restricted, the task does not have to use the GPS/Network location and will apply the rules of the Wi-Fi location.

In case that the Wi-Fi station is not restricted, the service will calculate the distance of the current location to the GPS locations in the database and if any of those location has a different lower than the maximum distance provided in the database means that the device is in a restricted area. The service will set a flag to restricted and it will save the location.

Using this approach the Wi-Fi location has preference over the GPS/Network location but there is still a problem when two different areas restricted by the same type of location match. The following figure provides us a graphic schema of that situation.

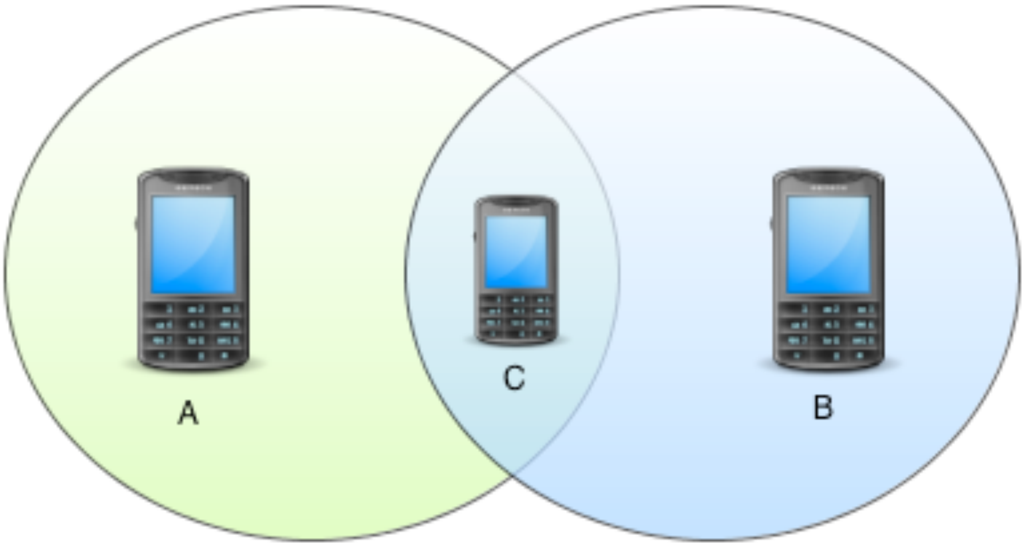


Figure 4.2.2.1 – Restricted zone matching

In the case of the device A, the rules that belong to the location coloured in green are applied and the same in the case of the device B. But when two different zones share an area the application apply the restrictions and the exceptions of both areas as in the case of the device C. The administrator must be aware of this situation and be cautious at the time of defining rules, since the device C could have ambiguous rules and allows the user to perform not allowed operations in A but allowed in B and vice versa.

Finally, the APP killer task obtains the running processes and the installed application on the device. Then, depending on the flag set and the saved locations in the previous Location check task, this service will obtain the restrictions and the exceptions applied to that location.

Once the task has all the information, the next step is to check if the running processes are in the basic exception or in the rule exceptions. In case it is in the exception the process will continue running, in the other case, the service will obtain its permissions comparing the process with the installed applications and if it has restricted permissions by the rules applied to that location, the process will be force stopped.

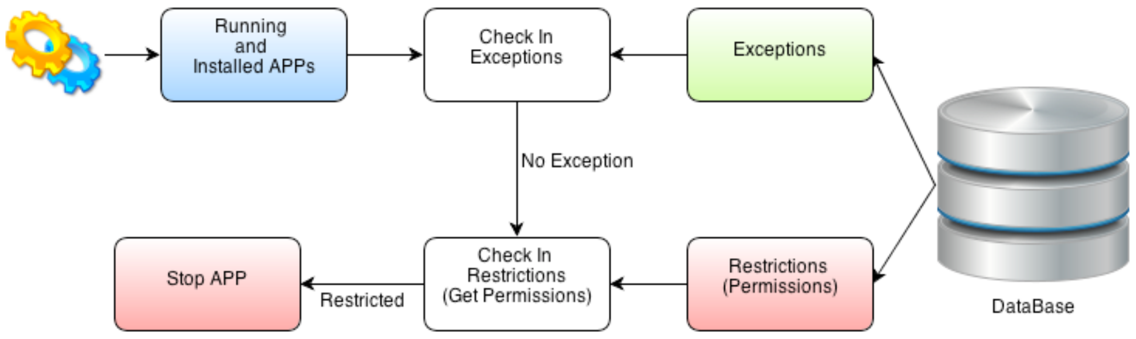

Running and Installed APPs
Check In Exceptions
Exceptions
No Exception
DataBase
Stop APP
Restricted
Check In Restrictions (Get Permissions)
Restrictions (Permissions)

Figure 4.2.2.2 – Service Flow Chart (Restrict Apps)

4.2.2.3. Location Manager Subsystem

The Location Manager subsystem allows the application to obtain its location using different location systems. This module manages the different location system such as the Wi-Fi, the GPS or the Network in order to provide the application the most accurate and fastest location. In this section, how this subsystem manages the different location systems will be reviewed.

First of all, the Wi-Fi location, this location has preference over the GPS or Network location since it is more accurate on indoor environments. This subsystem scans the different Wi-Fi stations near the device and obtains its BSSID (station identifier) providing to the Service Controller subsystem a list of Wi-Fi stations in the ranges of the device. Then, the Service Controller subsystem is the responsible to check if any of those Wi-Fi stations is restricted. In order to obtain the Wi-Fi stations this subsystem actives the device Wi-Fi in case it is not active a then it provides scan results.

The second location method involves the GPS and the Network location systems. The subsystem checks if the GPS and the Network provider are enabled in order to know which location systems can be used in the device. There are three different possible cases.

If the GPS and the Network is not active the device cannot be located using this systems. The situation may occur when the device has no signal. This module will not active the GPS in case it is not enable. This decision was motivated by the battery life time, since the application is working in a mobile device if the GPS is active all the time the battery life of the device will be too short.

If the Network is activated the subsystem requests the location updates to the Network system and the location is sent to the Service Controller module.

If the GPS is activated the subsystem starts a timer and requests the location updates to the GPS device system. If the location using the GPS system is too slow, the timer will request the location updates to the Network system which is faster to obtain. Once the location is obtained, it is sent to the Service Controller module.

Also, there is a timer for GPS and Network location, in case those location systems are too slow this time will provide the last known location of the device.

4.2.3. Data Tier

The data tier contains the resources for persistent storage such as the structure creation and the management systems, as well as the structures required to accessing the data from the logic tier.

This data tier is build over a relational database management system that will be reviewed into more detail in the implementation chapter. The chosen database is SQLite which is an Open Source Database embedded into Android. This database supports SQL syntax, transactions and prepared statements. The choice of this database over other alternatives was motivated by the low memory requirements of this database at runtime (200Kbyte) [16].

The data tier will be accessible by the Service Controller in the logic tier in order to obtain the information and access to stored data. This last tier is composed by the Database Manager subsystem.

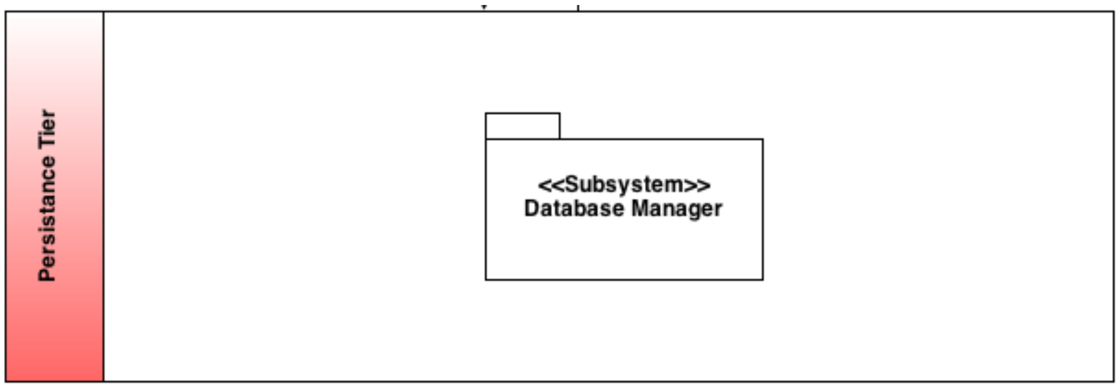


Figure 4.2.3. – Service Diagram

4.2.3.1. Database Manager Subsystem

This subsystem contains all the data which is required by the logic tier. This data contains the rules that the Service Controller stores in the database. These data is accessed by the Service Controller subsystem in order to obtain the location, the restrictions and the exception included in the rules.

4.3. Server Design

The server side is composed by a web application deployed in the Google App Engine. This web application contains one Java servlet that listens to the application requests and responds to each request. The protocol to obtain the XML schema from the server described below.

1. The mobile application connects to the server and sends a message to the web application with its device identifier (IMEI).
2. The server access to the database using the device IMEI to obtain its XML schema.
3. The server sends the schema to the device application.
4. Finally, the device application stores the rules of the schema in the device database.

The communication between the server and the devices uses SSL/TLS protocol in order to provide security to this information exchange.

The administrator has to load the XML schemas in the server database with the specific IMEI of the device. The App Engine associates each XML schema to each device IMEI.

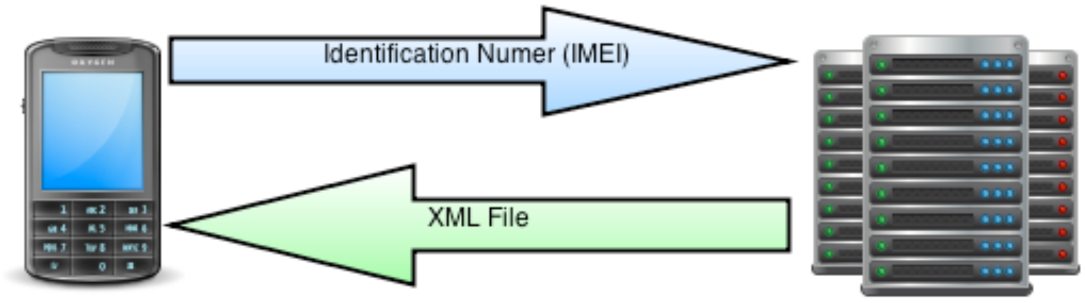


Figure 4.3 – Server Protocol

4.3.1. Server Subsystem

The server subsystem stores the XML file associated with each device IMEI. This subsystem provides to the device application the rules that the administrator stores in the database.

The server subsystem receives information from the administrator through a simple form in the web application. This subsystem reads the data introduced in the form and stores it in the database. Then, When the device requires an update, this subsystem will sent to the device the updated file with the rules.

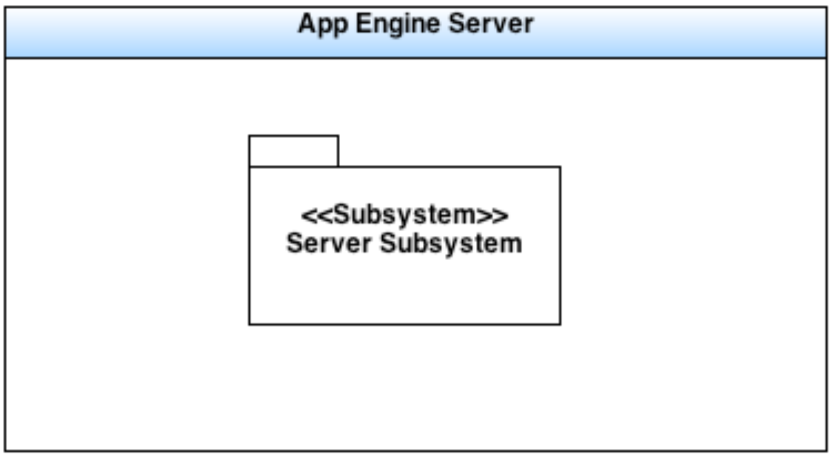


Figure 4.3.1 – Server Subsystem

Chapter 5. Project Implementation

The aim of this chapter is to explain the implementation of the different system modules. Those modules are implemented to satisfy the system requirements following the design reviewed in the previous chapter.

The system is divided intro three tiers: the presentation tier, the logic tier and the persistence tier. Each of the three tiers is composed by subsystems which are composed by classes that interact with each others. In this section, those classes and interactions are going to be explained.

5.1. Presentation Tier

This section details the different classes in the presentation tier. This tier is composed by one subsystem called Setup Mobile Interface which shows the user some useful information about the application set up and also, it starts the system the first time it is launched.

5.1.1. Set up Mobile Interface

The MainActivity class forms this subsystem. This class creates the main user interface that shows to the user some useful information about the system such as the steps to follow to make it work properly. The following figure shows the class subsystem implementations.

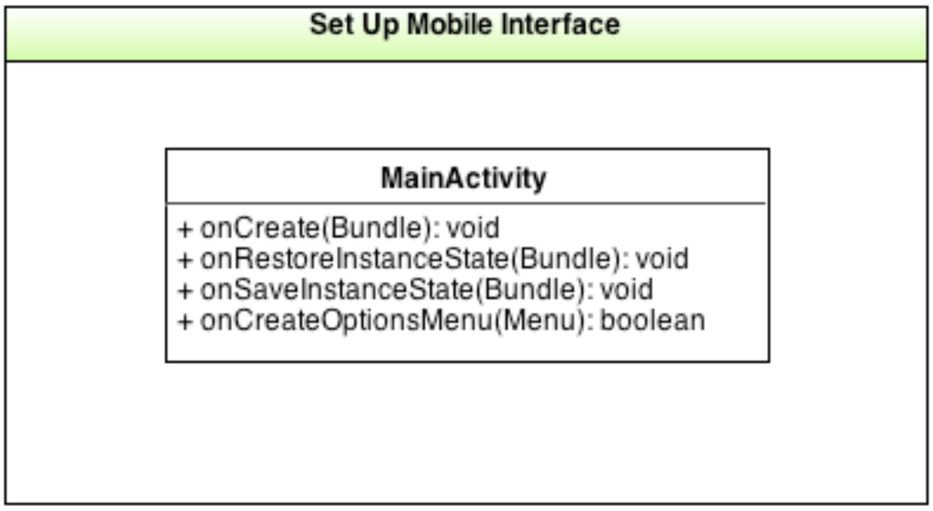

Set Up Mobile Interface
MainActivity
+ onCreate(Bundle): void
+ onRestoreInstanceState(Bundle): void
+ onSaveInstanceState(Bundle): void
+ onCreateOptionsMenu(Menu): boolean

Figure 5.1.1. – Setup Mobile Interface

This subsystem has a simple implementation since it is just a basic user interface and the information is not retrieved from any database. It is just static information printed in the application interface.

This class is going to be executed the first time that the user launches the application in order to send a signal to the StartAtBootServiceReceiver class. That signal will start the service when the application is in stopped state. Once this step is done, the application will be in active state so it will be able to receive the boot signal, as it will be reviewed in the StartAtBootServiceReceiver class.

The signal name sent when the application is launched the first time is called "com.tfg.locenable.first". The first execution time signal is sent as an Intent to the receiver as the following code shows.

```
Intent intent =
new Intent(mContext,StartAtBootServiceReceiver.class);
intent.setAction("com.tfg.locenable.first");
mContext.sendBroadcast(intent);
```

5.2. Logic Tier

This section details the different classes in the logic tier. This tier is composed by three subsystem: the System start up which starts the service when the device boot is completed, the Service Controller, which is the main subsystem of the application, it controls the running app in the device and finally, the location manager subsystem that provides the service controller the information about the device location.

In the following sections each subsystem is going to be reviewed in a low-level of abstraction, analysing the classes that compose each subsystem and its interactions.

5.2.1. System Start up

The System Start up subsystem listens to the system signal when the boot is completed and also, it listens to the MainActivity class, which has been reviewed in the previous sections, to get the signal when the application is first time launched.

The subsystem is composed by one class called StartAtBootServiceReceiver. This class is a BroadcastReceiver that implements the method onReceive which is executed each time a signal is broadcasted.

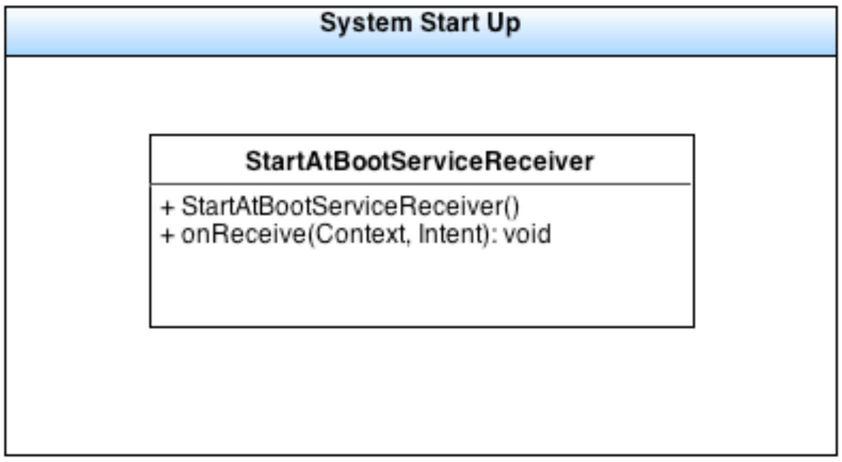

System Start Up
StartAtBootServiceReceiver
+ StartAtBootServiceReceiver()
+ onReceive(Context, Intent): void

Figure 5.2.1. – System Start Up

When the device boot is completed the “boot complete” signal is broadcasted. Also when the application is launched the first time, the MainActivity sends a specific signal called “com.tfg.locenable.first”.

Those signal execute the onReceive method in this class which starts the service sending the intent. The following code show how the service is started using an intent.

```
Intent pushIntent =
new Intent(context, LocEnableService.class);
context.startService(pushIntent);
```

When those signal are received the intent starts the service executing the onCreate method in LocEnableService class, that class will be reviewed in the following sections.

5.2.2. Service Controller

The subsystem Service Controller is the main part of the application. This subsystem creates/starts the device database, starts the rules updater, checks if the device location is in a restricted location and stops those application which are executing in the device but its execution is not allowed in the current location.

In order to implement all these functionalities the subsystem has been divided in several classes which implements the different functionalities. The subsystem class and its interaction are shown in the following figure.

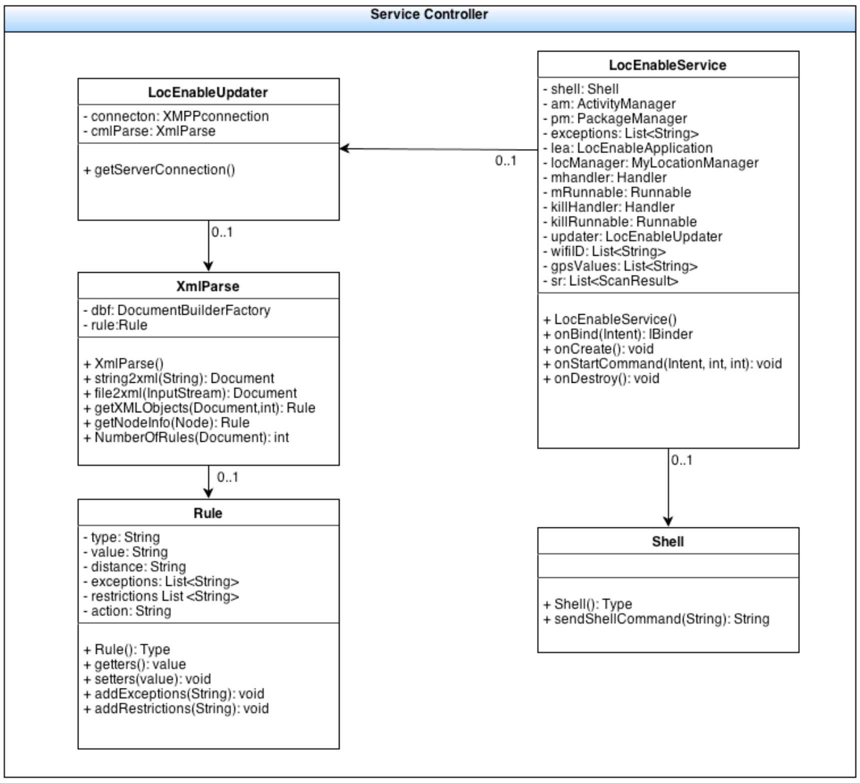

Service Controller
LocEnableUpdater
- connecton: XMPPconnection
- cmlParse: XmlParse
+ getServerConnection()
0..1
0..1
XmlParse
- dbf: DocumentBuilderFactory
- rule:Rule
+ XmlParse()
+ string2xml(String): Document
+ file2xml(InputStream): Document
+ getXMLObjects(Document,int): Rule
+ getNodeInfo(Node): Rule
+ NumberOfRules(Document): int
0..1
Rule
- type: String
- value: String
- distance: String
- exceptions: List<String>
- restrictions List <String>
- action: String
+ Rule(): Type
+ getters(): value
+ setters(value): void
+ addExceptions(String): void
+ addRestrictions(String): void
LocEnableService
- shell: Shell
- am: ActivityManager
- pm: PackageManager
- exceptions: List<String>
- lea: LocEnableApplication
- locManager: MyLocationManager
- mhandler: Handler
- mRunnable: Runnable
- killHandler: Handler
- killRunnable: Runnable
- updater: LocEnableUpdater
- wifiID: List<String>
- gpsValues: List<String>
- sr: List<ScanResult>
+ LocEnableService()
+ onBind(Intent): IBinder
+ onCreate(): void
+ onStartCommand(Intent, int, int): void
+ onDestroy(): void
0..1
Shell
+ Shell(): Type
+ sendShellCommand(String): String

Figure 5.2.2. – Service Controller

In this section the different classes that compose the Service Controller subsystem will be explained to provide a clear description of how this module is implemented.

This subsystem is divided into the LocEnableService class, which is the main class. This class starts the LocEnableUpdater which connects with the server in order to obtain the updated rules file, and also, it updates the database with the new received rules. For this purpose, this class uses the XmlParse class to obtain the information from the received XML schema. The XmlParse returns the rules that are defined in the XML schema.

Finally, the LocEnableService uses the LocationManager subsystem to obtain the device location and checks with the stored rules in the database if the location is restricted. In case the location is restricted, this class will execute the kill-command in the shell to stop those applications that are not allowed to execute.

5.2.2.1. LocEnableService

The LocEnableService class executes the method onCreate() when the System Start Up subsystem sends the intent to this class after receiving the boot complete signals.

In order to explain the implementation of the method onCreate(), the execution flow process is going to be followed. First of all, this method uses the Database Manager in order to start the device database, if the database is already created the Database Manager will just active the handler in order to access and manage the device database. The Database Manager will be reviewed into more details in the section 5.3.

Once the database is started, the next step is to start the LocEnableUpdater, the updater is going to send a message with the device IMEI and the server will replay with a XML schema that defines new rules to the specific device. The updater stores the new rules into the database and the service will be ready to use them. How the LocEnableUpdater is implemented will be explained in the following sections.

Meanwhile the updater stores the new rules into the database, the Service Controller module creates a list of basic system exceptions for the proper performance of the device such as the input systems, package installer, launcher, settings, location services, media services, user interfaces. These exceptions cannot be restricted to ensure the proper functionality of the device.

Other exceptions have been added for security reasons. Some examples of these exceptions are the phone or keychain. These applications cannot be restricted because that action may have dangerous consequences in case of emergency.

Additionally, other exceptions have been added in order to not be intrusive in the user device and keep as much functionalities as possible. An example of these exceptions is the calendar or the contacts. In the following table a list of basic exception is provided.

Process Name	Type
Package installer	Performance
Input systems	Performance
System UI	Performance
Updater	Performance
System	Performance
Settings	Performance
Launcher	Performance
Super User	Performance
Location Service	Performance
LocEnable	Performance
Contacts	Functional
Calendar	Functional
Media	Functional
Partner Set-up	Functional
Help Information	Functional
Phone	Security
Keychain	Security

Table 39 – Basic Exceptions

After setting up those exceptions, the server use two different handlers that run different threads, the thread that checks if the position is restricted and the thread that stops the application executions.

The first handler runs a thread that uses the LocationManager subsystem which provides all the functionalities to obtain the location using different approaches. This thread will scan the Wi-Fi in range and it will obtain the Wi-Fi associated BSSID using the LocationManager.

Then, all the scanned Wi-Fi BSSID will be compared to the Wi-Fi BSSID stored in the database. If any of the scanned BSSID is in the database means that there is a Wi-Fi restriction. This kind of restriction sets the restriction flag to the value 3.

In case there are no Wi-Fi restrictions, the next step is to check if the GPS/Network location is restricted. The LocationManager provides to this service the location through the gotLocation() method. A similar process is followed to check the restrictions, the current device location is compared to each of the stored location in the device database and if the distance between the current location and the stored location is less than the maximum distance within the stored location means that the location is restricted. In this case the restriction flag is set to the value 2.

If in this thread the restriction flag is set to the value 1 that means that the location is unknown so the restriction are not apply, if there is not restrictions the flag value will be 0 at the end of the iteration. The following table explains the flag values meaning.

Value	Meaning
0	No location restriction
1	Intermediate State
2	GPS/Network restriction
3	Wi-Fi restrictions

Table 40 – Restriction Flag values

The second handler runs a thread that checks the restriction flags and it just runs in case the flag is greater than 0. In case this flag is greater, the thread obtains the running app processes using the ActivityManager and also it obtains the installed packages using the PackageManager provided by the Android SO.

Then, depending on the flag value and the location obtained in the other handler thread, this thread will obtain the exceptions and the restrictions of the location. If the flag is set to the value 2, the restrictions and the exceptions of the provided Wi-Fi locations will be obtained from the database. In the other case, if the value of the flag is 2, the restrictions and exceptions of the provided GPS/Network locations will be obtained from the database. The database access is done through the DatabaseManager subsystem.

Once the thread obtains all the rules for the location, it will check every running process comparing them to the basic exceptions and the exceptions obtained form the database. If the running processes are in the exceptions, the process will be allowed to run in the device. In the opposite case, if the running processes are not in the exceptions the thread will proceed to check its permissions.

Using the PackageManager, the permissions of every running process will be obtained in order to compare them with the restrictions obtained from the location rules in the device database.

If the running process has some permission included in the restrictions, it will obtain its PID (Process identifier) and the command line "su –c kill pid" will be executed to stop the execution of that process in the device.

Those two handlers are executed periodically, the first one that controls the location will be executed each 36 seconds and the second one that kills the running processes will run each 1.5 seconds. Both handlers will start running when the method onStartCommand() from the service is executed.

The following figure shows the flow diagram of this main service. The diagram corresponds with the workflow of this implemented class and some interactions with externals modules such as the database and the location modules.

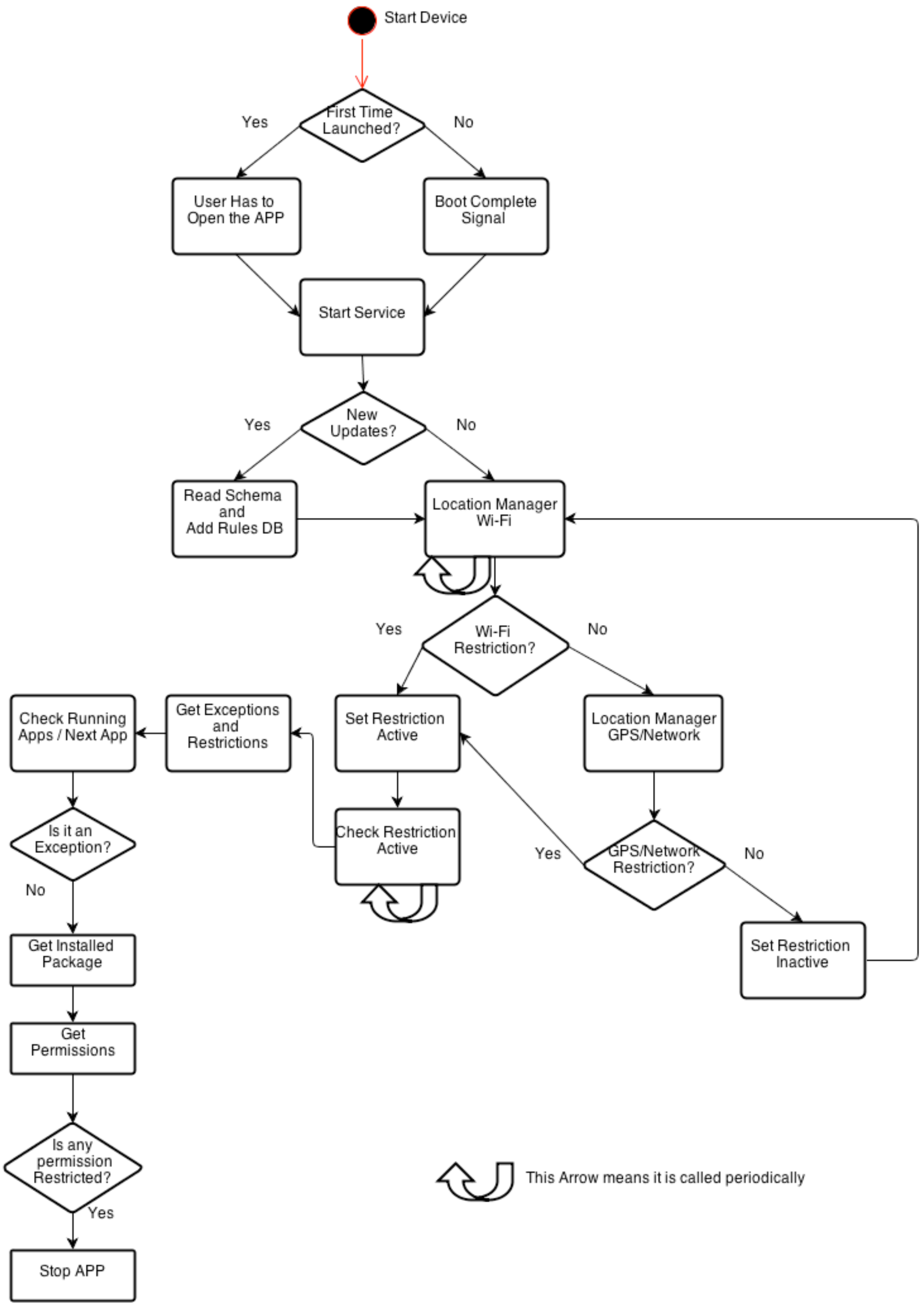


Figure 5.2.2.1 – Service Controller Flow Diagram

5.2.2.2. LocEnableUpdater

The LocEnableUpdater is called from the LocEnableService class to activate the application updates. This class will get a connection with the server that stores the XML schema associated to an IMEI.

This class will establish a secure XMPP connection by using the service “talk.google.com” through TLS/SSL. Then, the application will send the device IMEI to the server in order to obtain the specific XML schema that contains the rules for that device.

A PacketListener is created to listen the incoming messages that will be received from the server. The PacketListener checks if the incoming messages come from the server side by checking its source ID. If the incoming packet is a server message the XmlParse will obtain the rules from the received XML schema and those rules will be stored in the database through the DatabaseManager subsystem.

In case the connection to the server fails, the database is not updated but the updater keeps try to connect until the connection with the server is established and the XML schemas are received.

5.2.2.3. XmlParse

This class is an XML parse as its name says. The java libraries DOM has been used create the XML schema using the received string from the server.

A DocumentBuilder is used to parse the String into a XML format, in this way, the XML information can be obtained from each node as a tree where the information is contained in the leafs.

First of all, the parse identifies the number of rules in the document by getting the nodes labelled as <rule>.

Then, for each rule, a recursive method will get the Child of each node until the node is a leaf. When a leaf is found, the parse will get the node information and it will be stored in a Rule object that contains all the attributes of the XML schema. This method will return a Rule object with all the obtained attributes.

5.2.2.4. Rule

The Rule class represents a specific rule of the XML schema. This class is used to store the rules into the device database. The XmlParse will set all its attributes to the values that will be obtained from the XML schema. The Rule class has as attributes:

- Type: It is referred to the location type, a location can be “wifi” location or “gps” location.

- Value: The value is the GPS coordinates or the MAC address of a Wi-Fi device.

- Distance: It is the maximum distance where the device can be located from the GPS coordinates. Giving a GPS point and the distance (Radio) a circumference can be drawn. If the device is inside the circumference the rules of that value will be applied.

- Exceptions list: The list of exceptions attached to that location value.

- Restrictions list: The list of restrictions attached to that location value.

- Action: This attribute defines if the rule is going to be added or deleted from the database.

The Rule class also implements all the basic necessary methods such as getters and setters in order to create Rule objects from read rules.

5.2.2.5. Shell

The shell class is a simple class that receives a String to be executed as a command in the internal device shell. For this purpose this class access to the Runtime.getRuntime() method and then, using the method exec(String), it executes the given commands by parameters.

5.2.3. Location Manager

The LocationManager class provides to the service all the location related functionalities and its information. Several location approaches have been implemented on this class.

The first one is the Wi-Fi location, this class provides a method called scanWiFiBSSID(Context) which returns a list with all the near Wi-Fi stations and its information. This method checks if the Wi-Fi is active and in case it is not, it will enable the Wi-Fi to proceed with the scan.

In order to implement this method the class WifiManager provided by Android libraries has been used. The class WifiManager provides methods to obtain the Wi-Fi state, to enable the Wi-Fi and to scan the near Wi-Fi stations.

The GPS/Network location approach has been implemented in the getLocation(Context, result) method. This method checks either if the network and the GPS are active. In case the GPS is active, it will require updating its position using a LocationListener that will return the results directly to the server when the updates are received. A timer will be set to avoid the listener to be waiting too long. So, in case the GPS location is too slow, the timer will stop the LocationListener for the GPS and it will request updating position to the network provider. The same thing happens in case that the network provider is too slow, the method will stop the listener and it will obtain the last known location.

In order to implement those functionalities the android package location has been used. This package contains the Location objects, the LocationListeners and the LocationManager to request the updates.

5.3. Persistence Tier

This section details the different classes in the persistence tier. This tier is composed by one subsystem called Database Manage which creates the database structure the first time the application is launched, also this subsystem manages the data by proving information to the Service Controller and storing the rules read from the XML schema.

5.3.1. Database Manager

This subsystem is divided into two classes that interact with each other. The DataBaseHelper class is the one that defines the structure and the database schema rules in case of a database update. Then, the LocEnableApplication class is the class that executes SQL statements over the database to store and retrieve data.

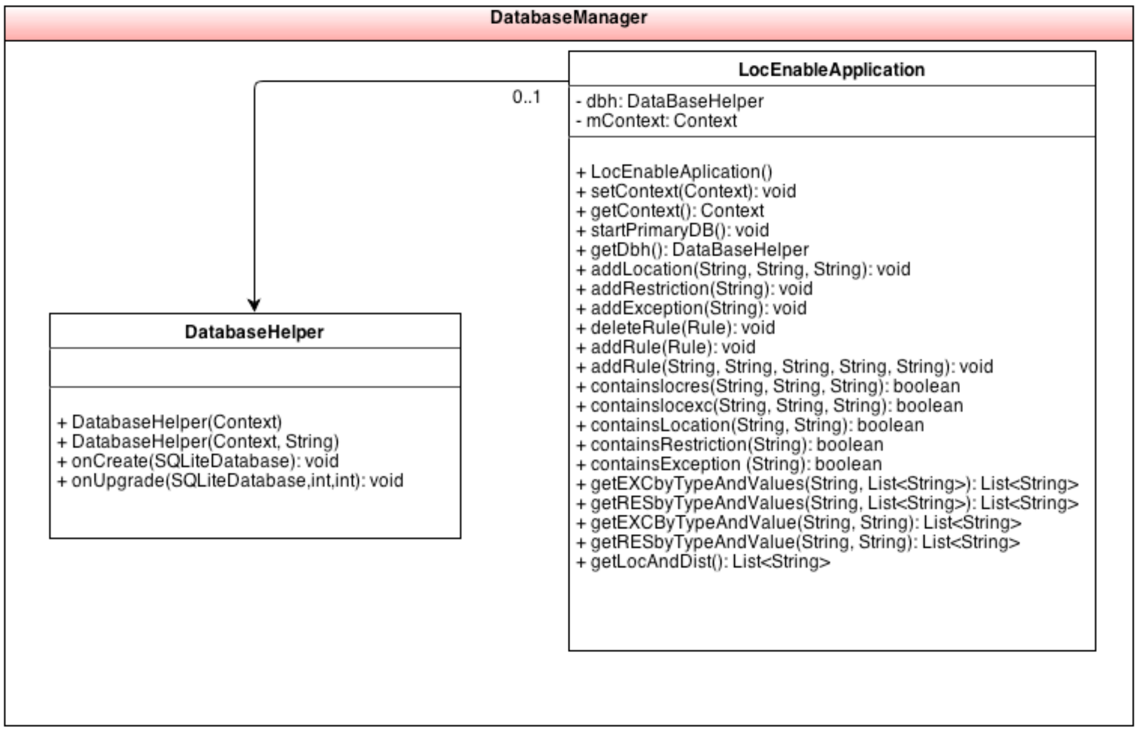

DatabaseManager
0..1
LocEnableApplication
- dbh: DataBaseHelper
- mContext: Context
+ LocEnableAplication()
+ setContext(Context): void
+ getContext(): Context
+ startPrimaryDB(): void
+ getDbh(): DataBaseHelper
+ addLocation(String, String, String): void
+ addRestriction(String): void
+ addException(String): void
+ deleteRule(Rule): void
+ addRule(Rule): void
+ addRule(String, String, String, String, String): void
+ containslocres(String, String, String): boolean
+ containslocexc(String, String, String): boolean
+ containsLocation(String, String): boolean
+ containsRestriction(String): boolean
+ containsException (String): boolean
+ getEXCbyTypeAndValues(String, List<String>): List<String>
+ getRESbyTypeAndValues(String, List<String>): List<String>
+ getEXCByTypeAndValue(String, String): List<String>
+ getRESbyTypeAndValue(String, String): List<String>
+ getLocAndDist(): List<String>
DatabaseHelper
+ DatabaseHelper(Context)
+ DatabaseHelper(Context, String)
+ onCreate(SQLiteDatabase): void
+ onUpgrade(SQLiteDatabase,int,int): void

Figure 5.3.1. – DatabaseManager Subsystem

5.3.1.1. DataBaseHelper

This database implements a relation schema by creating the tables and its relations. This database contains five different tables that store the information for the system.

The table "location" is composed by a text field named "type", a text field named "value" and a text field named "distance". The combination of the field type and value composes the primary key of this table.

locations	Type	Value	Distance

Table 41 – Locations table

The table “restrictions” is composed by a text field named “res_name” which is the name of the permissions restricted and is unique. The “res_name” field is the primary key on this table.

restrictions	Res_Name

Table 42 – Restritions table

The table “exceptions” is composed by a text field named “exc_name”, which is the name of the application that can be executed in that location with no restrictions. The “exc_name” is primary key on this table.

exceptions	Exc_Name

Table 43 – Exceptions table

The table “Locres” is composed by a text field named “res_name” which is a foreign key from the restrictions table, a text field named “type” and a text field named “value” which both are a foreign key from the location table. The combination of all the fields is the primary on this table.

Locres	Res_Name	Type	Value

Table 44 – Locres table

The table “Locexc” is composed by a text field “exc_name” which is a foreign key of the exceptions table, a text field “type” and a text field “value” which are a foreign key of the location table. The combination of all the fields is the primary on this table.

Locexc	Exc_Name	Type	Value

Table 45 – Locexc table

The table Locres is created because there is an n-to-m relation between the location and the restrictions. A location can have more than one restrictions attached and a restriction can be applied in more than one location. This also happens in the case of the exceptions since both, the restriction and the exceptions, are attached to locations.

Once the different tables that compose the database are defined. The relation among them is shown in the following relational schema.

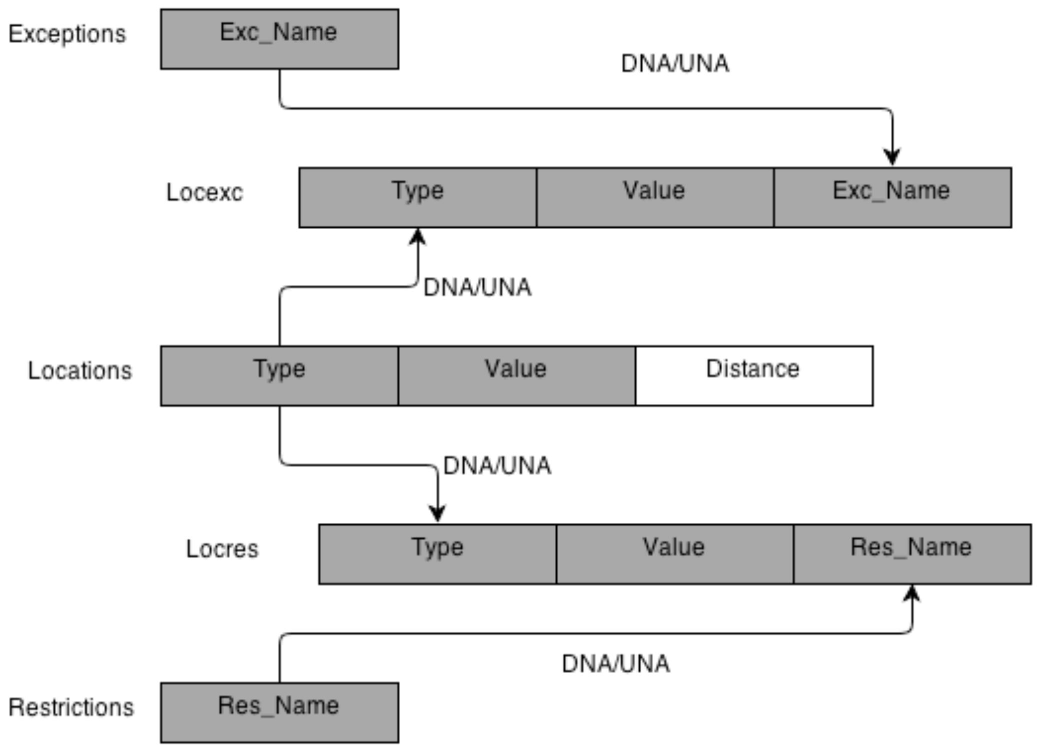


Figure 5.3.1.1. – Database Relation Schema

5.3.1.2. LocEnableApplication

The LocEnableApplication class provides methods to manage the database information such as add, retrieve or delete data. This class interacts with the Updater providing the functionalities to store or delete the rules read from the received in the XML schema into the database. Also, the server uses this class to access to the data stored in the database such as the locations, the exceptions or the restrictions and it obtains the relations among them.

5.4. Server Subsystem

The Server subsystem is composed by two servlets: LocEnableServerServlet that provides the XMPP service and responses to the Android application requests and the LocEnableServerForm that obtains the information introduced in the form through the web application and stores it into the Datastore. The following figure shows the classes and its interactions within this subsystem.

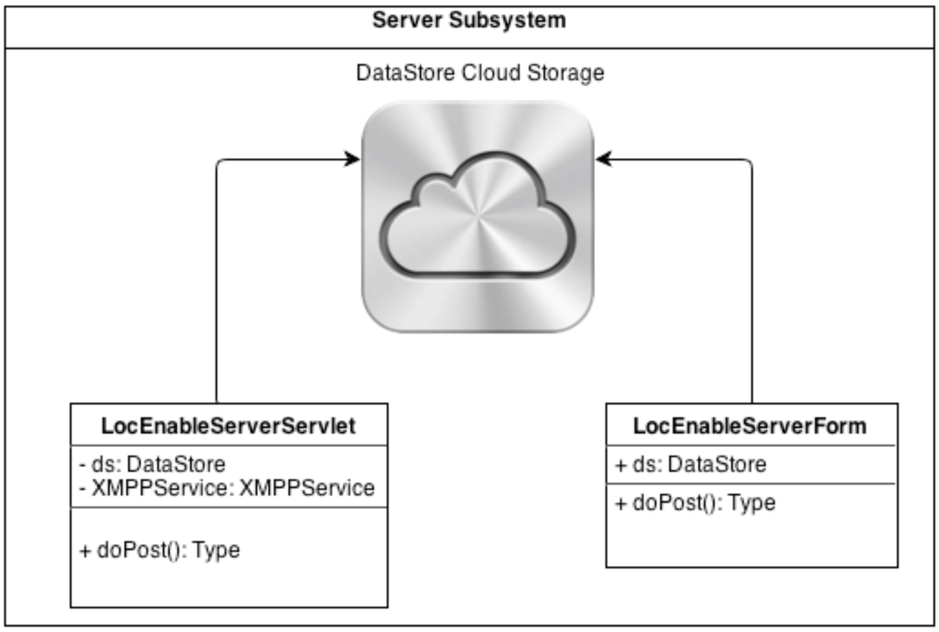


Figure 5.4. – Server Subsystem

The Datastore Cloud Storage is provided by Google when the application is deployed in the Google App Engine. This Datastore uses entities in order to store the data. The entities that are stored in the system are called device and they contain the device IMEI and a XML schema. The following table shows the table field stored in the Datastore.

Device	IMEI	XML Schema

Table 46 – Device table Datastore

Where the IMEI is the device identifier stored as a String and the XML schema is the content of the XML schema stored as a Text (No byte limits).

5.4.1. LocEnableServerServlet

This class is a servlet that provides the XMPP service and it has access to the Datastore in order to retrieve data.

In the method doPost(), the servlet receives the messages sent from the Android App. These messages contain the IMEI of the Android devices. When a message is received, this method will obtain its content (IMEI) and it will query in Datastore using the received IMEI, since it is a identification key the Datastore will return an entity with the IMEI and the XML schema associated.

Once the XML schema is obtained the servlet will send a replay to the Android device with the XML schema.

5.4.2. LocEnableServerForm

This class is a simple servlet that obtains the information that has been introduced by the administrator in the web form. The server will create an entity with the form information and that information will be stored in the Datastore. Using this web application, the administrator is able to introduce new XML schemas and devices into the Datastore.

5.5. Testing

This section provides the tests results which validate that the system cover the requirements. In order to obtain these results, each of the tests described in the section Validation Test is going to be executed.

Those tests have to meet the preconditions and the indicated steps must be followed to ensure the proper test execution. Once the test is executed in the system, the results must be compared with the expected result of each test.

In case the results of the execution are the expected results, it means that the system past the test successfully. In other case, if the results are not the excepted results, the system must be fixed and the test must be repeated until it is executed successfully. All the tests that have been done follow the following table template:

Identifier	VT-XX
Target	Specific test target.
Result	Expected results.
Correction	System Fixes

Table 47 – Validation Test Result Template

The fields in the template above must be filled with the following information:

- **Identifier:** a unique and descriptive identifier in the entire project, which format is VT-XX, where XX in the identification number of the test.

- **Target:** what was tested.

- **Result:** the test results. This field value can be “Right” or “Wrong”.

- **Correction:** In case the test result was “Wrong”, this section provides a brief description of the fixes.

Identifier	VT-01
Target	Scan and obtain Wi-Fi identifier process.
Result	Correct ✓
Correction	No corrections made.

Table 48 – Result VT-01

Identifier	VT-02
Target	Obtain GPS Location
Result	Correct ✓
Correction	No corrections made.

Table 49 – Result VT-02

Identifier	VT-03
Target	Obtain Network Location
Result	Correct ✓
Correction	No corrections made.

Table 50 – Result VT-03

Identifier	VT-04
Target	Obtain Last Known Location
Result	Correct ✓
Correction	No corrections made.

Table 51 – Result VT-04

Identifier	VT-05
Target	Basic exceptions
Result	Correct ✓
Correction	No corrections made.

Table 52 – Result VT-05

Identifier	VT-06
Target	Add Rules from File and Execute.
Result	Correct ✓
Correction	No corrections made.

Table 53 – Result VT-06

Identifier	VT-07
Target	Service Start and Automatic Updates
Result	Correct ✓
Correction	No corrections made.

Table 54 – Result VT-07

Identifier	VT-08
Target	App cannot be stopped
Result	Failed
Correction	Android OS does not allow this feature.

Table 55 – Result VT-08

Identifier	VT-09
Target	Check if the connection is secure.
Result	Correct ✓
Correction	No corrections made.

Table 56 – Result VT-09

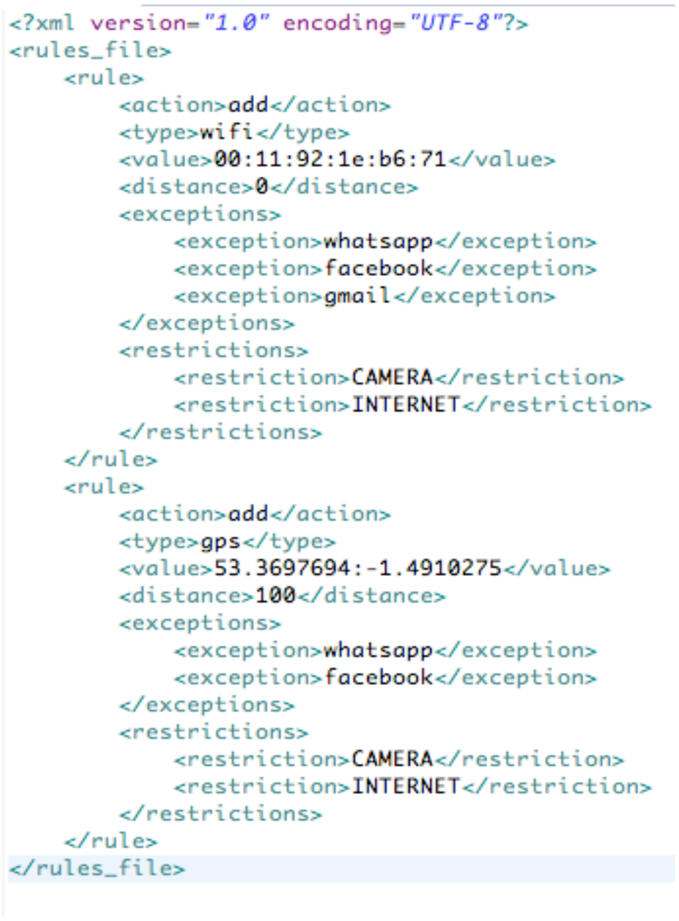
5.6. XML Files

This section describes the XML schema that is exchanged between the server and the devices. This schema is used to store the configuration of each device in the server and also, it is sent to the devices to store the rules in its own database.

The rules are composed by a location, which includes a type (gps or wifi), a value and the maximum distance to that value. Additionally, the rules contain some exceptions and restrictions which are defined by the names of the permissions in case of the restrictions and the application name in case of the exceptions.

The following figure shows that the root of the schema is <rules_file> which contains several rules labelled as <rule>, this schema contains from 1 to n rules. In side each rule, the first parameter is the action which value can be "add" or "delete". This parameter determines what the device is going to do with the specific rule. If the attribute is "add" the rule is going to be added in the device database, in the other case, the rule is going to be deleted. Then, the type represents the kind of location system in which the rule is based (GPS or Wi-Fi) and the distance represents the maximum distance from the point that is restricted.

Finally, the exceptions and restrictions are represented in the fields labelled as <exceptions> and <restrictions> which contain subfields with the name of each application and the permissions for the restriction.



```xml
<?xml version="1.0" encoding="UTF-8"?>
<rules_file>
    <rule>
        <action>add</action>
        <type>wifi</type>
        <value>00:11:92:1e:b6:71</value>
        <distance>0</distance>
        <exceptions>
            <exception>whatsapp</exception>
            <exception>facebook</exception>
            <exception>gmail</exception>
        </exceptions>
        <restrictions>
            <restriction>CAMERA</restriction>
            <restriction>INTERNET</restriction>
        </restrictions>
    </rule>
    <rule>
        <action>add</action>
        <type>gps</type>
        <value>53.3697694:-1.4910275</value>
        <distance>100</distance>
        <exceptions>
            <exception>whatsapp</exception>
            <exception>facebook</exception>
        </exceptions>
        <restrictions>
            <restriction>CAMERA</restriction>
            <restriction>INTERNET</restriction>
        </restrictions>
    </rule>
</rules_file>
```

Figure 5.6. – XML Schema

Chapter 6. Project Management

On this chapter, the project planning will be given in order to show each of the project phases and its schedule. The planning has been design based on the system development methodology.

Also, a study of the different resources cost is provided. The cost projection has taken into account the human resources based on two persons involved on this project and the physical resources or equipment resources based on what have been used to develop the system.

6.1. Project Planning

This section details the project planning. For this purpose, the project has been split into different parts following the structure of the waterfall model explained in the previous section 3.4.

This planning has taken into in account that there is one developer and the project manager which are working five days a week four hours per day that makes a total of 20 hours a week. The estimated time for this project is 2 months and 28 days starting the day Monday, 12 November 2012.

Before developing the application some previous researches has been realized in order to provide as much information as possible for each of the technologies involved in the project. That information can be found in the State of Art section of this document.

These researches have been done over a period of one-month length. So, the estimated time for this project increases to 3 month and 28 days starting the day Friday, 12 October 2012.

The first part of the project will be the Requirements. This part consists on a meeting with the tutor to describe the system requirements, which will be documented and finally verified in order to ensure a proper definition of them.

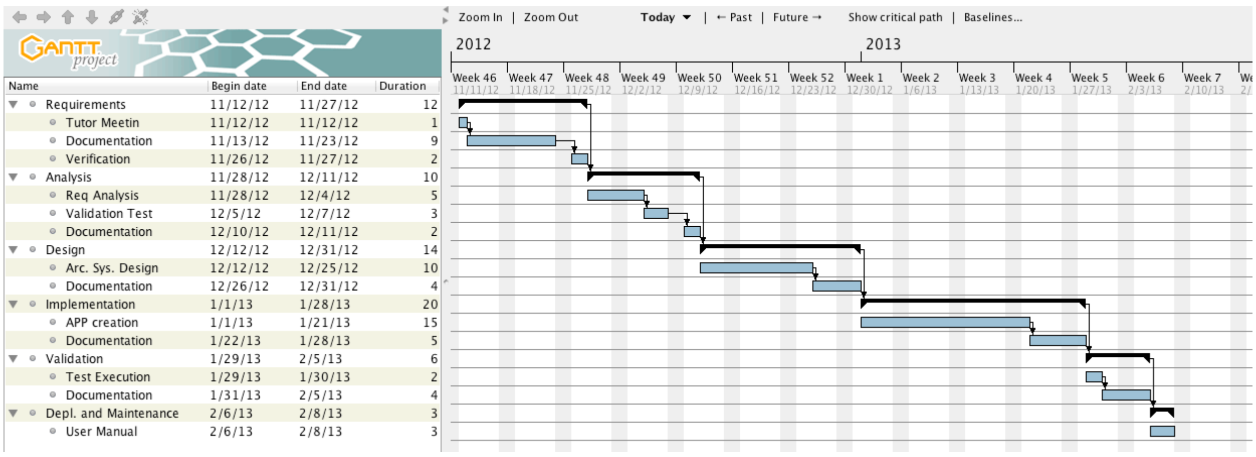
The next phase is the Analysis. In this part, the requirements will be analysed and organized in order to archive the clearest definition and avoid potential issues in future phases. Also, some test will be defined. The aim of these tests is to ensure that each requirement given in the previous phases has been implemented properly. During this phase some documentation is required.

Then, the third phase is the Design. In this phase, the architecture of the project is designed in order to satisfy all the requirements. The design decisions and its architecture must be documented in order to ensure the proper development of the system.

Following the Design phase, there is an Implementation phase. This phase is where the APP code is written following the design defined in the previous phase. Also, some important decisions are taken and they must be documented in this phase.

Once the APP is implemented, the next step is to verify that everything works properly. This is done in the Validation phase, which includes the tests execution and the documentation where the test results are provided.

Finally, the Deployment and Maintenance phase prepares the APP to be released and the user manual will provide the user a guide of how to set up and use the APP properly. The maintenance is not going to be provided in this project.



Name	Begin date	End date	Duration
Requirements	11/12/12	11/27/12	12
Tutor Meetin	11/12/12	11/12/12	1
Documentation	11/13/12	11/23/12	9
Verification	11/26/12	11/27/12	2
Analysis	11/28/12	12/11/12	10
Req Analysis	11/28/12	12/4/12	5
Validation Test	12/5/12	12/7/12	3
Documentation	12/10/12	12/11/12	2
Design	12/12/12	12/31/12	14
Arc. Sys. Design	12/12/12	12/25/12	10
Documentation	12/26/12	12/31/12	4
Implementation	1/1/13	1/28/13	20
APP creation	1/1/13	1/21/13	15
Documentation	1/22/13	1/28/13	5
Validation	1/29/13	2/5/13	6
Test Execution	1/29/13	1/30/13	2
Documentation	1/31/13	2/5/13	4
Depl. and Maintenance	2/6/13	2/8/13	3
User Manual	2/6/13	2/8/13	3

Figure 6.1. – Gantt Chart

6.2. Cost Projection

This section provides specifications of all the costs involved in the project development process. For this cost projection the human resources, the equipment and the consumables used during the development will be analysed.

The human resources costs are composed by the developer and the project manager salaries. For this project, there is one developer and a project manager working five days a week, four hours per day. The estimated time for this project is 3 months and 28 days that makes 87 working days.

Roles	Cost/Hour	Working Hours	Total Cost
Project Manager	35 €	348 h	12,180 €
Developer	25 €	260 h	6,500 €
		Total Cost	18,680 €

Table 57 – Human Resources

The equipment and consumables costs include software licences, workstations, developing and testing devices and other consumables. An average life time of 5 years for the hardware (depreciation of 20% per year) and 2 years for the software (depreciation of 50% per year) has been taken into account to calculate the equipment costs [29] [30].

Equipment	Unit Cost	Units	Depreciation per Month	Months	Total Cost
Office 2010 license	139 € full	1	5,8 €	4	23,2 €
Eclipse SDK	0 €	1	0 €	4	0 €
Android SDK	0 €	1	0 €	4	0 €
MacBook Pro	1,281 €	1	21,35 €	4	85,4 €
Galaxy Nexus	300 €	1	5 €	4	20 €
				Total Cost	128,6 €

Table 58 – Equipment Resources

The choice of Android as development platform has reduced considerable the project cost since most of the development tools and license are free. Also, the fact that just one developer and the project manager are involved in the project has a big impact in the human resource costs.

The total cost projection including all the resources involved in the development of this project can be found in the following table:

Concept	Total Cost
Human Resources	18,680 €
Physical Resources	128,6 €
Total Cost	18,808,6 €

Table 59 – Total Cost projection

Chapter 7. Conclusions and Future Work

This section provides the conclusions of the project. However, this project can be improved. The section future work will propose some improvements and new functionalities for this project. These future works will ensure that all the user requirements are satisfied in the future. Also, the new functionalities will provide a better user experience and they will improve the system with more suitable solutions to the problems that have been solved in this project.

7.1. Conclusions

This project has reached the main goal proposed in this document which is the creation of software able to control mobile devices in different environments. The software provides a management tool to control the mobile devices and the application that is installed in every device.

In order to have some conclusions about the project, some of the most important decisions of the management tool and the Android application may be analysed separately.

First of all, the management tool consists in a web application created with Google App Engine. This decision provides an easy implementation of the services in the web application. This web application allows the user to create new rules and add them to the database, and also, it provides a secure communication between the server and the applications through the XMPP service.

This solution is considered to be the most suitable for this project since it is easy to implement and it provides great services to create the web application. Also, this technology offers an interface to control the web application services such as the database viewer and the logs.

In the other side, in the Android application, some important decisions to solve certain problems have been taken. The location system provides the user a good accuracy in indoor environment using the Wi-Fi approach and the GPS/Network location is a good solution for the outdoor environment since its range is bigger than the Wi-Fi.

Also, the restriction based on permissions has provided good results in the implementation and testing process. Since all the applications in Android have to provide a list of the functionalities that the application may have access, the system will know what a specific application is able to access using that list of permissions, and based on these permissions, the system will decide to stop the application or let it run in the device.

Another important decision is the rules syntax. The rules allow the administrator to restrict the device applications but also to provide exceptions. These exceptions provide a good solution to the administrator that can restrict the device and preserve the device basic functionality.

Additionally, the tests defined in this document have been executeed satisfactory except one. This test failed because the Android security architecture does not allow that an application cannot be stopped but this problem has been mitigated with the inclusion of a server heartbeat.

Finally, this project meets all the defined requirements and it provides good solutions to the different encounter problems. This software provides a good service able to create a safety area where the mobile devices can be controlled and so, their potential risk is reduced.

7.2. Future Work

The purpose of this section is to propose future functionalities. Those functionalities can be implemented in the system in order to improve or add some characteristics that could not be implemented during this project period.

These additional functionalities improve some security aspects of the system. Also some functionalities that are already implemented can be improved by increasing the performance and the user interface can also be improved to offer the user the best experience using the system.

The same tables used for the system requirements will be used to provide the functionalities as requirements that could be implemented in future developments of the project.

Identifier	FWR-01		**Type**	Functional	
Name	Block APP before run.				
Actors	System				
Description	The system must be able to block the App before it starts running.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Capability
Essential	No	**Desirability Level**	4	**State**	Stable

Table 60 – FWR-01

Identifier	FWR-02		**Type**	Functional	
Name	NFC location				
Actors	System				
Description	The system shall read NFC tags and apply the restrictions associated with the NFCs.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Capability
Essential	No	**Desirability Level**	3	**State**	Stable

Table 61 – FWR-02

Identifier	FWR-03		**Type**	Functional	
Name	Hidden App.				
Actors	System				
Description	The system uninstaller must be hidden from the user so the user cannot uninstall the App or stops the service.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Capability
Essential	No	**Desirability Level**	3	**State**	Stable

Table 62 – FWR-03

Identifier	FWR-07		**Type**	Functional	
Name	Service start with boot (No user interaction).				
Actors	System				
Description	If some new Android version make it possible. The system must be able to run with out the interaction of the user (Even the first time).				
Verifiable	Yes	**Criticality**	2	**Purpose**	Capability
Essential	No	**Desirability Level**	2	**State**	Stable

Table 63 – FWR-07

Identifier	FWR-04		**Type**	Security	
Name	Cipher databases information.				
Actors	System				
Description	The system Datastore of the web application server and the device database must be encrypted.				
Verifiable	Yes	**Criticality**	4	**Purpose**	Constrain
Essential	No	**Desirability Level**	4	**State**	Stable

Table 64 – FWR-04

Identifier	FWR-05		**Type**	Security	
Name	TLS/SSL web application.				
Actors	System (Web application)				
Description	The web application access must be done using HTTPS.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	No	**Desirability Level**	4	**State**	Stable

Table 65 – FWR-05

Identifier	FWR-06		**Type**	Security	
Name	Web Application log in.				
Actors	System (Web application)				
Description	The web application must ask for the login information to the administrator.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Constraint
Essential	No	**Desirability Level**	4	**State**	Stable

Table 66 – FWR-06

Identifier	FWR-07		**Type**	Performance	
Name	Increase performance.				
Actors	System				
Description	The system must be able run smoothly with the less resources as possible.				
Verifiable	Yes	**Criticality**	2	**Purpose**	Constraint
Essential	No	**Desirability Level**	2	**State**	Stable

Table 67 – FWR-07

Identifier	FWR-08		**Type**	Interface	
Name	Friendly User Interface				
Actors	System (Web application)				
Description	The system must show to the user a friendly and easy to use interface.				
Verifiable	Yes	**Criticality**	3	**Purpose**	Capability
Essential	No	**Desirability Level**	4	**State**	Stable

Table 68 – FWR-08

Identifier	FWR-09		**Type**	Usability	
Name	User alert.				
Actors	System				
Description	The system must show the user when the device is under a restriction. This could be made showing a red/green light in the status bar.				
Verifiable	Yes	**Criticality**	1	**Purpose**	Constraint
Essential	No	**Desirability Level**	2	**State**	Stable

Table 69 – FWR-09

Chapter 8. Appendices

Appendix A

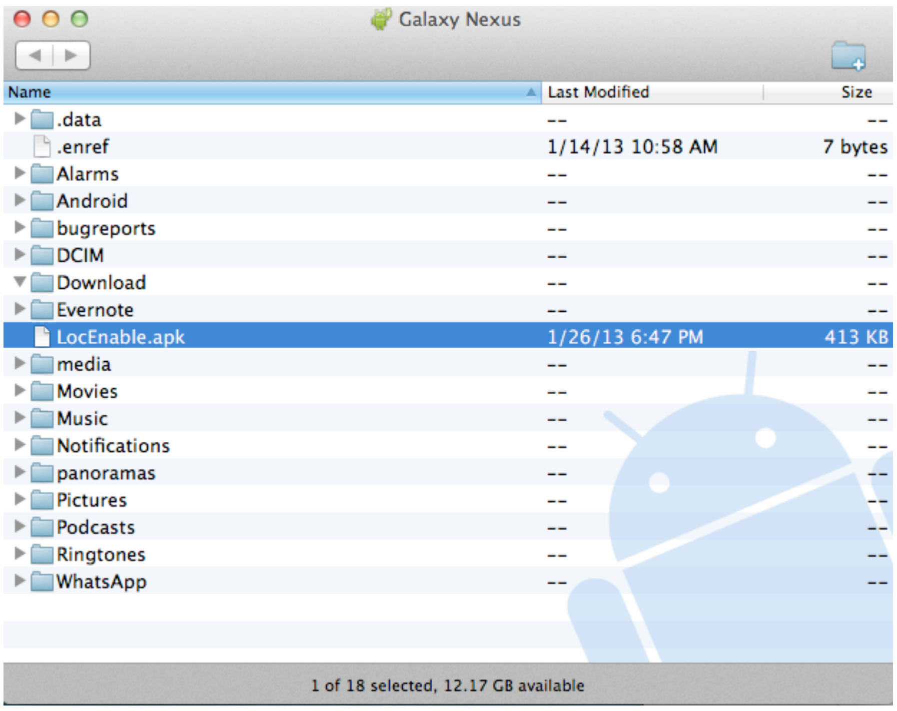
A.1. User Manual

This section will explain the use of the software provided for this project. This software can be split into two different parts that interact with each other. The first part is the mobile App, which will be installed in the device and it interacts with the server. The other part is the GAE server, which will provide a web application for introducing information and control the Datastore. That Datastore is used to send the different XML schemas to the devices.

A.1.1. Device Application

First of all, this Manual provides some steps to follow in order to install the application into the devices. The first step is to get the application with the extension ".apk" this file will contain all the necessary information to install the app into the devices.

The second step is to introduce the file into the root directory of the internal memory of the device. The use of some file explorer to go through the device file system is recommended.



Galaxy Nexus

Name	Last Modified	Size
.data	--	--
.enref	1/14/13 10:58 AM	7 bytes
Alarms	--	--
Android	--	--
bugreports	--	--
DCIM	--	--
Download	--	--
Evernote	--	--
LocEnable.apk	1/26/13 6:47 PM	413 KB
media	--	--
Movies	--	--
Music	--	--
Notifications	--	--
panoramas	--	--
Pictures	--	--
Podcasts	--	--
Ringtones	--	--
WhatsApp	--	--

1 of 18 selected, 12.17 GB available

Figure 8.1. – Device File Manager

Finally, the application file .apk, which is inside the memory, must be executed in order to get it installed. The user must follow the instructions that will be shown in the device to finish the installation process.

Once the application is installed in the device, the next step is to launch the application. The user of the device must launch this application the very first time that it is executed in the device. The reason of this approach is that since Android 3.0, the application cannot be executed when the boot is complete if the user has not previously launched the application. In order to execute the application the user must go to the application screen on its phone as is shown in the following figure.

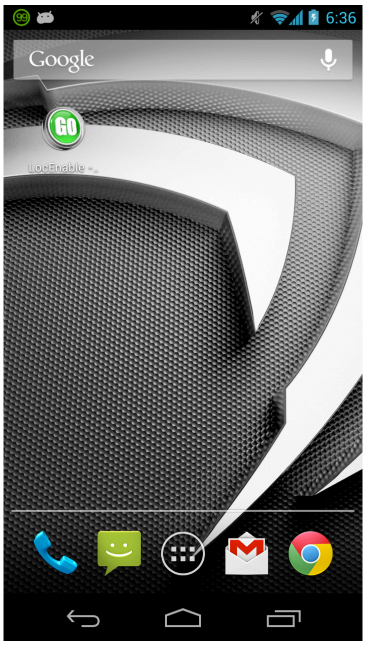
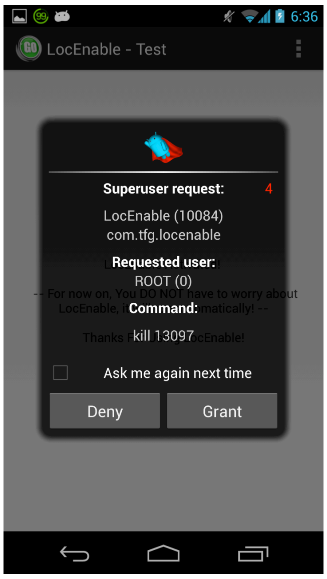


Figure 8.2. – Application Screen

Then, the user must tap the application icon and wait until the application sets up all the system. Once the service starts the application will ask the user for root privileges to be able to close those application that are not allowed to run in the different locations.

Do not select the option “ask me again next time” for a better user experience, if this option is selected every time that the service has to close an App, it will ask the user for granting root privileges.


6:36
LocEnable - Test

Superuser request: 4

LocEnable (10084)
com.tfg.locenable

Requested user:
ROOT (0)

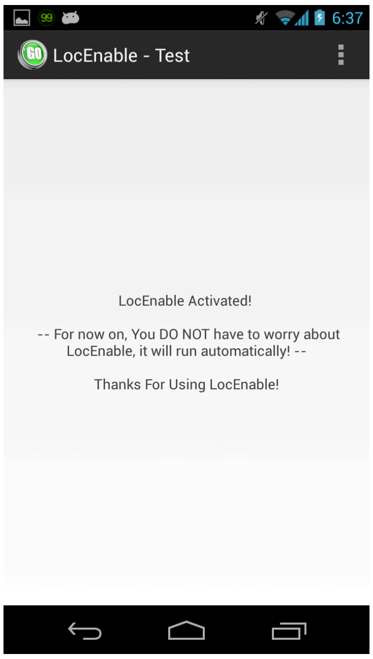
Command:
kill 13097

Ask me again next time

Deny Grant

Figure 8.3. – Root priviledges request

When the application gets the root privileges, the service will start running in the device. This will be transparent for the user and for now on, the service will start when the device boot is completed. This information is shown to the user in the application main interface.



LocEnable Activated!

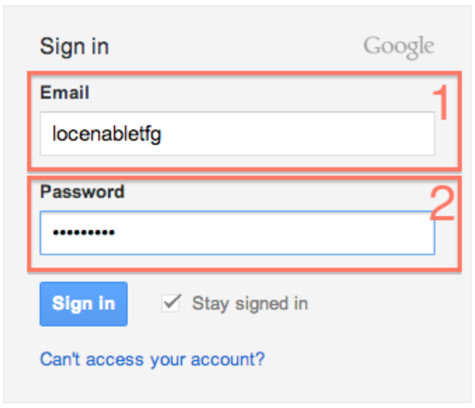
-- For now on, You DO NOT have to worry about LocEnable, it will run automatically! --

Thanks For Using LocEnable!

Figure 8.4. – Main Interface

A.1.2. Web Application

The Google App Engine server provides the access to the Datastore, where all the devices and its XML schema are stored, also with the GAE the user can access to the server logs and the web application. The first step to use the Google App Engine is to sign in into the system. The following image shows the log in interface.



Email: locenabletfg

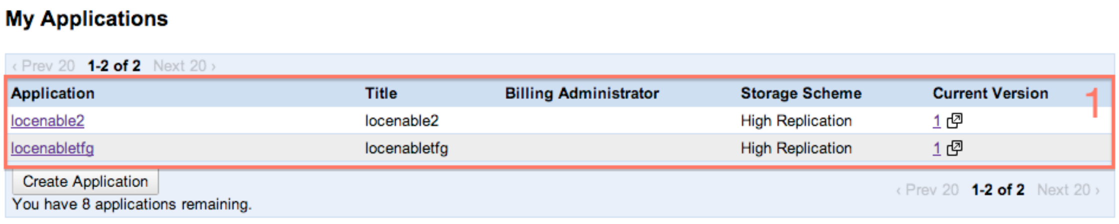
Password: •••••••••

✓ Stay signed in

Figure 8.5. – Log in GAE Interface

In this interface, an Email input box (1) used to log in into the system and the password input box (2) can be found to proceed with the sign in. This is a well-known interface since this service is provided by Google. A Google account is required to use this service.

After the sign in process, a list of web application can be found. This list shows all the applications that are available associated with that Google account. The following image shows an example of that interface with the application list (1) and all its information


My Applications

‹ Prev 20 **1-2 of 2** Next 20 ›

Application	Title	Billing Administrator	Storage Scheme	Current Version
locenable2	locenable2		High Replication	1
locenabletfg	locenabletfg		High Replication	1

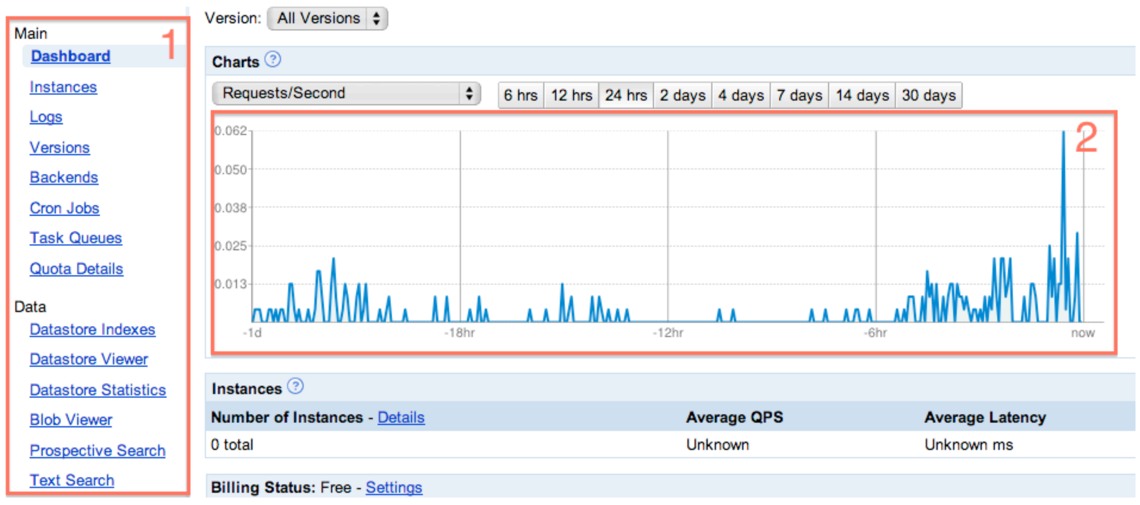
Create Application

You have 8 applications remaining.

‹ Prev 20 **1-2 of 2** Next 20 ›

Figure 8.6. – Application List

In this list, the administrator has to select the application that wants to manage. Once it is selected, a main interface is shown as it can be seen in the following figure.



Instances

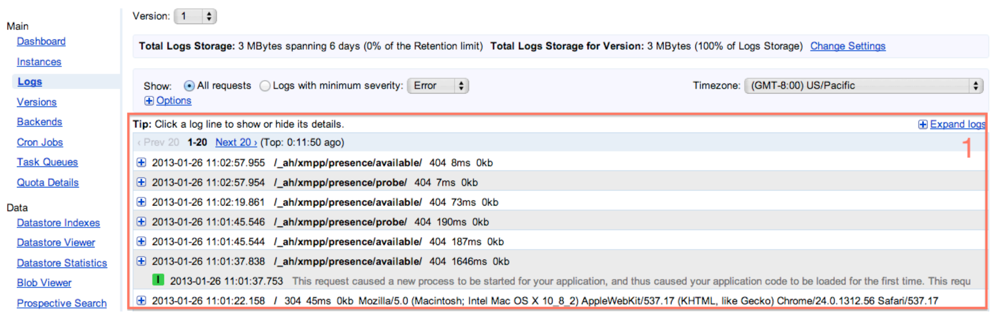
Number of Instances - Details	Average QPS	Average Latency
0 total	Unknown	Unknown ms

Billing Status: Free - Settings

Figure 8.7. – Main interface

This main interface can be split in two different parts, the list of features (1) at the right side of the image. This list provides the user an easy way to go though the web application features and its information. Then, the second part is where the information is shown (2) that may change depending on what is selected in the list. In this case, a graph with all the in/out coming requests is shown in order to provide a clear idea of how much traffic the server is supporting.

One of the most used features is the application log. The logs show every request that the server receives and they log information from the server (1). On these logs the administrator can find device requests for the XML schema and also the XML schema sent to the devices. This feature provides the system an easy way to control the server traffic. In the case of an attack, the logs can be obtained in order to know more information about those connections.



Version: 1

Total Logs Storage: 3 MBytes spanning 6 days (0% of the Retention limit) **Total Logs Storage for Version:** 3 MBytes (100% of Logs Storage) Change Settings

Show: [✓ All requests] Logs with minimum severity: Error Timezone: (GMT-8:00) US/Pacific

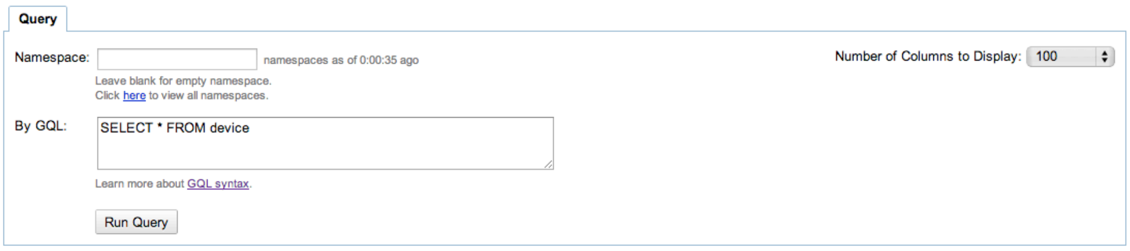
Tip: Click a log line to show or hide its details.

‹ Prev 20 **1-20** Next 20 › (Top: 0:11:50 ago)

```
2013-01-26 11:02:57.955  /_ah/xmpp/presence/available/  404  8ms  0kb
2013-01-26 11:02:57.954  /_ah/xmpp/presence/probe/  404  7ms  0kb
2013-01-26 11:02:19.861  /_ah/xmpp/presence/available/  404  73ms  0kb
2013-01-26 11:01:45.546  /_ah/xmpp/presence/probe/  404  190ms  0kb
2013-01-26 11:01:45.544  /_ah/xmpp/presence/available/  404  187ms  0kb
2013-01-26 11:01:37.838  /_ah/xmpp/presence/available/  404  1646ms  0kb
    I 2013-01-26 11:01:37.753  This request caused a new process to be started for your application, and thus caused your application code to be loaded for the first time. This requ
2013-01-26 11:01:22.158  /  304  45ms  0kb  Mozilla/5.0 (Macintosh; Intel Mac OS X 10_8_2) AppleWebKit/537.17 (KHTML, like Gecko) Chrome/24.0.1312.56 Safari/537.17
```

Figure 8.8. – Logs interface

Finally, this service provides an easy way to maintain and motorize the Datastore that is associated to the application. This interface allows the user to execute GQL statements as is shown in the Figure 8.9 and it also provides a friendly interface to manage the database.



Namespace: namespaces as of 0:00:35 ago

Leave blank for empty namespace.
Click here to view all namespaces.

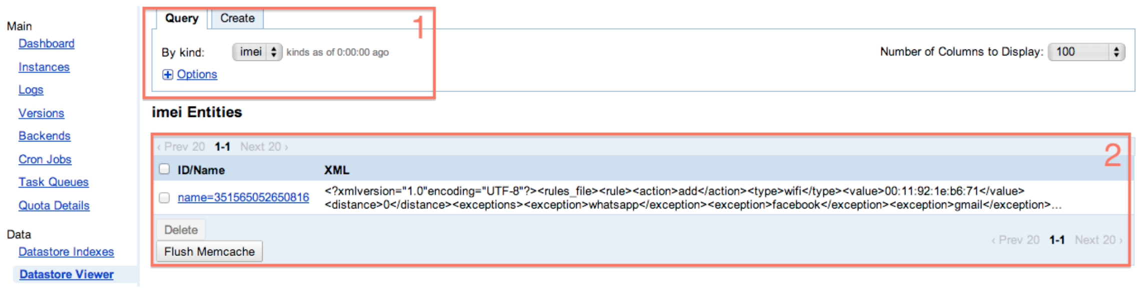
Number of Columns to Display: 100

By GQL: SELECT * FROM device

Learn more about GQL syntax.

Figure 8.9. – GQL Datastore interface

The interface provides us the option of creating our own queries or just execute basic queries using the interface (1) as the following figure shows.



By kind: imei kinds as of 0:00:00 ago

Number of Columns to Display: 100

imei Entities

‹ Prev 20 **1-1** Next 20 ›

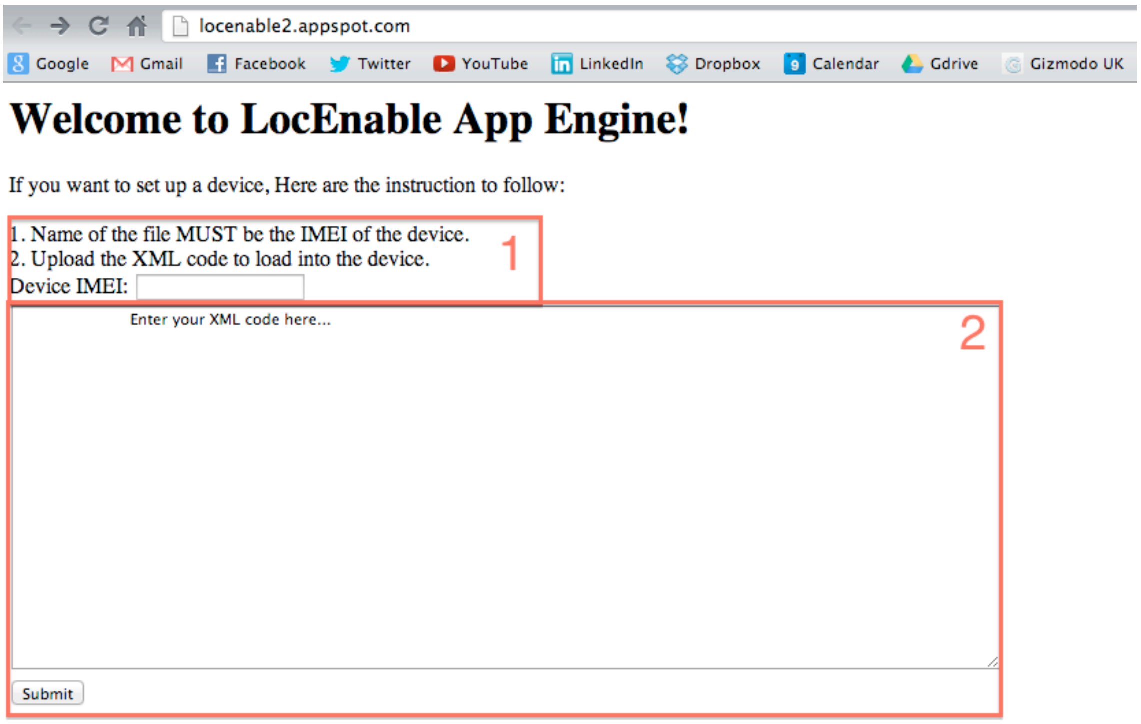
ID/Name	XML
name=351565052650816	<?xmlversion="1.0"encoding="UTF-8"?><rules_file><rule><action>add</action><type>wifi</type><value>00:11:92:1e:b6:71</value><distance>0</distance><exceptions><exception>whatsapp</exception><exception>facebook</exception><exception>gmail</exception>...

‹ Prev 20 **1-1** Next 20 ›

Figure 8.10. –Datastore interface

The results are shown with an entity id and the information of every field. The user can select a result and realize some operations such as modify or delete by just click in the specific entity id. Also some new entries can be added to the Datastore using the Web application interface associated to this GAE service.

The following figure shows a form that must be fulfilled in order to add a new device within its XML schema where the rules are contained. The IMEI field (1) corresponds with device IMEI that the user wants to add within the rules in the XML. Then, the big input box (2) is where the user must introduce the restrictions and exceptions to apply in a certain location in the XML form. That information is going to be stored and associated to the corresponding IMEI.


locenable2.appspot.com

Welcome to LocEnable App Engine!

If you want to set up a device, Here are the instruction to follow:

1. Name of the file MUST be the IMEI of the device.
2. Upload the XML code to load into the device.
Device IMEI:

Figure 8.11. – Web Application interface

Appendix B

B.1. Acronyms

- **3G**: Third Generation of mobile telecommunications technology.
- **4G**: Fourth Generation of mobile telecommunications technology.
- **A-FLT:** Advanced Forward Link Trilateration.
- **AGPS**: Assisted GPS.
- **AOA**: Angle of Arrival.
- **API**: Application Programming Interface.
- **APP**: Also called mobile App, it is application software for mobile devices.
- **BSSID**: Basic Service Set Identifier is a unique address that identifies the access point that creates the wireless connection.
- **BTS**: Base transceiver Station is the equipment that facilitates the wireless communication between user and network.
- **CDMA**: Code Division Multiple Access is a channel access method used in radio communication technologies.
- **CGI**: Cell Global identity is an identifier for the mobile phone cells.
- **DGPS**: Differential GPS is an enhancement of the Global Positioning System.
- **DOA**: Direction of arrival is provided the received signal direction.
- **DOM:** Document Object Model is JAVA library that allow the creation of XML documents.
- **E-OTD**: Enhanced Observed Time Difference.
- **ESA**: European Space Agency.
- **GAE**: Google App engine is used to develop and host web applications.
- **GLONASS**: Global Orbiting Navigation Satellite System.
- **GPRS**: General Packet Radio Service.
- **GPS**: Global System Positioning.

- **GSM**: Global System for Mobile communications.
- **HRD**: High Replication Datastore is used to replicate information in different server of the Google App Engine.
- **IMEI**: International Mobile Station Equipment Identity.
- **iOS**: Operating System used in Apple devices.
- **LMU**: Location Measurement Unit.
- **LOS**: Line Of Sight.
- **MAC Address**: Media Access Control address is the unique identifier of a device.
- **MF**: Multipath fingerprint.
- **NAVSTAR**: Navigation Satellite Timing And Ranging.
- **NCPS**: Neural Cellular Positioning System.
- **PID**: Process Identifier.
- **RFID**: Radio Frequency Identification.
- **RSS**: Received Signal Strength.
- **RSSI**: Received Signal Strength Indication.
- **SDK**: Software Development Kit
- **SQL**: Programming language designed for managing data in the relational database management systems.
- **SSL/TLS**: Secure Sockets Layer/Transport Layer Security.
- **TA**: Timing Advance.
- **TDOA**: Time Difference Of Arrival.
- **TOA**: Time Of Arrival.
- **UML:** Unified Modelling Language.
- **UMTS**: Universal Mobile Telecommunications System.
- **Wi-Fi**: Technology that allow the wireless exchange of data.

- **XML**: Extensible Mark-up Language.
- **XMPP**: Extensible Messaging and Presence Protocol.

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