

**Honours Project Final Report**

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**Submitted for the Degree of BSc Computing**

**Project Title: An Investigation into evaluating the effectiveness of Location Awareness within buildings using the pre-existing Wi-Fi infrastructure on an Android Application.**

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Abstract

With the exponential growth of technology and the availability of mobile devices over the past decade, the general use of Location Awareness (LA) has impacted many industries. There are several techniques to implement LA such as GPS in a global setting and in a local setting there is Wi-Fi Fingerprinting, Random Forest, and RFID. The main problem area with indoor LA as opposed to outdoor LA is that there are walls or roofs that may obstruct Wi-Fi signals as they must bounce or go through walls impacting the Received Signal Strength Indication (RSSI) therefore impacting the accuracy of finding the location.

This develop and test project aims to investigate if a mobile application can be made to track your location inside a building using Wi-Fi access points. The use of technologies, such as Java and a Web API, will create a framework for the app, including features that are commonly seen in map applications. Testing will consist of two separate individuals who are in different building or floors in the GCU campus and has access to an Android phone, identifying whether they can locate each other using the app or not. The use of qualitative data in the form of a questionnaire will be used to evaluate the ease in finding the other individual, this will assist in deciding if the app is a success.

The results will inform the general public whether the use of a mobile application can be used to determine an Individual’s location in an indoor setting.

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# Introduction

This section informs the reader of the different technologies associated with Location Awareness (LA) over the years, describing what LA is, what practical uses it has in society and which industries are utilising this technology for commercial gain. It will also discuss how Wi-Fi will be used to further develop indoor LA in this current technological era where Wi-Fi is becoming increasingly available. Furthermore, there will be a short description of the project involving objectives to be achieved by both the literature and technological review and a brief description of how the application will be developed.

## Project Background

With an increase in both population and technology, mobile phones have never been more ubiquitous in the daily lives of people as more than half of the total population of the world carries a phone whether it is an android or iPhone. (Tian, Shi & Yang, 2009). As a large majority use mobile phones, there has also have been an exponential increase in both development and improvement to services that have become more reliant on Location Awareness (LA) over the past decade (Leonhardt, 1998). LA refers to any device that can determine an individual location via satellite or Wi-Fi in real-time either passively or actively (Techopedia Inc, 2019). With the advance on technology the mobile phone’s use has been redefined, which was initially has been used to communicate between two people, it has now become a ubiquitous tool for many sectors such as entertainment, education, and utilities.

Through the surge of development for outdoor LA of the past decade, there have been many services from; entertainment in Pokémon Go and other augmented reality applications which use location data, location finding using Google Maps and even redirecting customers to shops when they are nearby from retailers by sending advertisements to their mobile. These services use different methods to achieve LA for Pokémon Go and Google Maps they rely on the Global Positioning System(GPS) which relies on satellites and cell phone towers to roughly pinpoint your location and append that to a real-time map, Although this is accurate if a person was just travelling on the main road, it is not nearly as reliable as signals can be interrupted by obstructions or by interference with other signals and can place your marker miles away from your current location (Li, Liu, Gao & Li, 2016). On the other-hand indoor LA while not currently having much development, can have the same amount of services or more than outdoor LA. This can be achieved by utilising the Wi-Fi infrastructure for a more accurate and convenient LA and can have entertainment services such as Pokémon Stay at Home. So, until we develop a more reliable method for consistent LA, we are stuck with using outdoor LA like Google maps.

Another problem area within LA is accuracy, as the signals generated from both a mobile phone and an access point such as satellite or Wi-Fi router can be affected by external elements such as walls, trees and other obstructions in an indoor setting that interfere with the received signal strength indicator (RSSI) (Liu, Darabi, Banerjee & Liu, 2007). Though there are solutions to this problem such as sensor technology, Location API and positioning algorithms to fine-tune LA (Guney, 2017). The company HERE, for example, has developed a relatively new service named HERE Indoor Radio Mapper which detects your current location based on RSSI, by using both Wi-Fi and Bluetooth that places your location on a preloaded floor map or a floor map of the persons choosing that can be uploaded. They most likely used techniques such as Wi-Fi Fingerprinting and Random forest and used the radio frequency identification (RFID) technology to communicate with the Wi-Fi router (Lee, Kim & Moon, 2019). This means, soon we could see a further development into LA, resulting in more advanced services and improvement to be made.

In the future, we should see the further applications of LA as technology advances, such as the development of global coverage of Wi-Fi which would enable global tracking of each person. This would result in; no missing person cases as everyone would be tracked, increase traffic control and vehicle estimation to reduce traffic congestion, decrease crime rate as criminals will be deterred and even help parents keep an eye on their children. However, this can be seen as pervasive and there should be strict guidelines in using this technology as there are numerous ways to misuse the technology. As this can include, allowing anyone to find a way to use falsified location data and give themselves an alibi to be completely anonymous making LA defunct (Duckham, 2010).

With the current technological advance being slowed, there is a demand to develop new techniques and algorithms to facilitate the growth of technology. For indoor LA, by using (RFID) and a Wi-Fi access point we are able to produce an accurate location in a building despite the walls interfering with the RSSI(Papapostolou & Chaouchi, 2012). A recent advancement into indoor LA was developed by Google developers in 2018 and was called Wi-Fi Round Trip Time (RTT), (Google, 2018). This technology is used on android Pie devices with google routers. It utilises the time it takes for the mobile signal to reach the router and back to measure the distance between devices and a multilateration algorithm to calculate your location. This technology also has the luxury of not requiring the device to connect to the AP and allows only the requesting device to determine location, making it private.

An area of concern regarding LA is privacy, as the prolonged exposure of LA and its use in the government, it has resulted in paranoia to the general populace to not use LA at all, going fully incognito and preserving their anonymity. This paranoia can be attributed to the advancement in LA and its implications, primarily being misused to track the public movements and manipulating them to be obedient citizens (Levijoki, 2001). Although this can be refuted in being unrealistic and therefore harmless, well know companies such as Facebook have sold their collection of people’s data, who frequently use their site and sell that data onto third-party companies which they for exploiting the people whose data was sold (McRae, 2018). While this has been used by many other companies, who say it will not be used by the local government for nefarious purposes. Therefore, I recommend that the general public should be aware of LA and what data they should give to both companies and government so that data is used for its purpose stated and not misused in any way or form (Shilton, 2009).

Since the new General Data Protection Regulations Act (GDPR) that recently came out in 2018, companies have become more compliant and serious when it comes to privacy including declaring what kind of data they use and how they use it. However, for those who still use LA, entertainment companies like Pokémon Go still sell data to third parties but do it legally by declaring it in their terms and agreements and by following the other regulations of GDPR. This has sparked some controversy to many people, as those who use LA are not aware of these practices as most cannot be bothered reading the terms and conditions and some do not even care (Braghin & Del Vecchio, 2017). This could escalate further as some companies might find loopholes in the regulation resulting in the companies exploiting the general population.

Privacy in LA is still going to carry on being a public issue, as long as people still care about their freedom and privacy and so will need to be addressed, and the development of new services and tighter regulation will allow the trust between a user and the company to develop. LA applications may develop into being more complex and become advanced enough to allow greater benefits to humanity as well as gain more popularity and use for the general public. However, this project aims to develop an application that will be non-pervasive and have a reliable and accurate LA. The results of this project will indicate the success of the mobile application by enlightening the general populace about LA and if they found the app assisted with their daily lives.

## Project Overview

This section features the project outline alongside the project aims and objectives and will conclude with a hypothesis that will attempt to answer the question. Additionally, it will include the objectives of the project that will need to be achieved through the literature and technological review and identify the primary research objectives.

### Project Outline

This project aims to develop and test a mobile application for android phones to receive Wi-Fi signals, using an Web API to convert access point information to geographical data which will be then used to map onto the floor plans of the buildings within the campus and send the location on a map to another student through SMS. The application must be evaluated by two or more test subjects. One of the two participants will be advised to use the application to locate and find the other participant and vice versa in an indoor setting to prove that Wi-Fi is a viable method for indoor LA, they will then be handed a questionnaire to gauge the ease of using the app. Furthermore, they will be questioned whether if the app was effective in locating individuals rather than just a normal text message containing vague directions. This will ascertain whether the application has improved location-based services or not and contribute to the success of the project. Hence, the research question for this project is:

**Can an Android Application be made to locate your current location on campus using Wi-Fi signals with API’s converting them into coordinates and plot your location on a map to send to another student via SMS?**

### Project Aims and Objectives

**Literature and Technological Review Objectives;**

**Investigate the Technology behind Location Awareness**

This will include detailed research to identify common issues surrounding LA and current business needs which will be evaluated by available articles and websites about LA, the common problems that may arise in development as well as specific business needs from an industry standpoint. This will determine the scope and specifications when developing the app.

**Investigate Current Technology for Indoor Location Awareness**

An in-depth collection of available methods for LA will be gathered and studied. This will include comparative research into which method for indoor LA is best for Wi-Fi and compatible with mobile devices and this project. This will be done by using scholarly journals and open source GitHub projects to compare the accuracy and the effectiveness of each method.

**Inspect existing Location Awareness applications**

This will consist of researching currently available applications in the Android app store. As the Google Play Store is relatively popular and has a varied assortment of app’s which are mostly free, it will be the primary source of app’s that will be researched. Such apps include Google Maps and the recently launched HERE Indoor Radio Mapper. This will assist in the creation of the UI and the general functionality of the app.

**Consider security aspects within a mobile application**

Due to the GDPR act, both security measures and data declaration will be needed for the app. This is to protect the user’s personal data, in the form of location data and user profiles which will be encrypted. The research will include the standard of development in android applications and how they implement security features.

**Research mobile application development**

Android Studio tutorials will be used as primary research materials for developing the app and for specific problems the website Stack Overflow well be used. Research into web API’s will also be included. The final application will be made through Android Studio rather than Framework 7 as the former has an in-built emulator and is exclusively for android which limits the complexity when developing. The programming language will be in Java as that is the preferred language given the time constraints as it has a very study foundation for support.

**Development Objectives;**

**Create a Design Specification Document and Define** **Functionality**

The document will be detailing the scope and the initial UI of the overall application, including main functionality such as uploading of a floor plan, in-app SMS and the location finder.

**Produce a Test Plan for the Application**

The test plan will include UML diagrams, which are based on the requirement specification document. Each test will identify the functionality of the application, making a prototype for each increment of the life cycle.

**Stage 1 Prototype: Develop the Skeleton of the App**

The application will be made in its most basic and simplest form. This includes location tracking shown by values and a basic user interface of the app to form a foundation for the application to be further developed.

**Stage 2 Prototype: Implement the security features and HCI elements**

This will include the use of user login so that each user can only log in from one phone. It will also include security features for back end development such as encrypted passwords and prepared statements. This section will also include error handling of the system.

**Stage 3 Prototype: Implement location tracking on a floor plan**

Include the display of the user’s location on a floor plan. Allow the User the option to upload a floor plan onto the app. This will enable the app to locate the user and plot their location onto the loaded floor map.

**Obtain testing participants and technology**

When the app has been completed, a small group of participants is needed to evaluate the functionality of the application. The participant will have limited knowledge of the app. They will be told of the requirements for the test beforehand and a brief tutorial will be given.

**Conduct testing and obtain testing results**

Testing will be done in pairs; one will be testing the app sending SMS messages to their location while the other will use the SMS messages to find the one who is testing the app. They will then be handed a questionnaire for qualitative data describing the ease of using the app and relevance to society. Quantitatively data will be collected in the form of the successful location of participates.

**Analyse results and draw a conclusion.**

Analysis and an evaluation will be done to the results from the questionnaires, to identify whether the app is functional and is relevant to the general public. The evaluation will draw a conclusion and will answer the question.

### Hypothesis

The proposed hypothesis for this project is: By using the Indoor Location App, individuals should be able to locate each other more efficiently and with ease in comparison to individuals who use vague directions to locate others by using the App for its accurate location information and its delivery of near-instantaneous speed.

To test this hypothesis, two individuals each carrying an android device will test the application and proceed to answer a questionnaire about their experience of the app.

This will be evaluated by using the successful completion of the test as well as looking at the completed questionnaires to see if using the application is a viable method for location awareness.

# 2.0 Literature and Technological Review

The literature and technological review are an essential element of the project; it is needed to gather the fundamental information that is a prerequisite for the completion of the project. It is carried out by looking at past research articles that were written by others similar field. This allows the head researcher to structure and carry out the project. It will also be useful for those who are researching the same topic in the future.

The literature and technological review will follow the same objectives stated in the project outline;

* Investigate the Technology Behind Location Awareness
* Investigate Legacy and Current Technology for Location Awareness
* Inspect Existing Location Awareness Applications
* Consider Security Aspects within a Mobile Application
* Research Mobile Application Development

## 2.1 Investigate the Technology Behind Location Awareness

As the project background gave a brief description of the popularity of Location Awareness as well as the many advantages it has brought to the various industries in society, it would be well advised to investigate them thoroughly to understand how the industry uses the technology and to apply it to further the aid in the development of the project.

Location Awareness refers to how devices capture and determine your current location through passive or active methods (Alam *et al.*, 2009). There is a multitude of applications that relate to LA, for example, one of its most famous uses is GPS through the transportation industry. An example shown in figure 1 uses Google Maps to plan your route to your destination.

A picture containing text

Description automatically generated  
Figure 1 : Google Map with GPS device screenshot

This was made possible by using active GPS tracking technology, Google Maps uses a GPS signal from a device that transmits and receives GPS signals to the satellites in order to calculate the coordinates of your current position. The device also has to have access to the internet for the device to connect to the online database to compare the coordinate from the satellites to finally display the map with your location appended (Brown & Sturza, 1993). With the assistance of web technologies such as Ajax and JavaScript, the web application allows data visualisation to occur, such as an interactive map that can be used to plan your journey on the map (Svennerberg, 2010). Active based location awareness is when the device is constantly sending out signals and updating the coordinate regularly over the internet while passive location awareness locates by checking the sensors and comparing data within the application’s database on the device or by comparing its sensor data to the last known location (Layson Jr, 2000).

However, while GPS is perfect for Outdoor LA, it is not suitable for Indoors LA due to various condition that affects its accuracy. Its inaccuracy may include obstruction of the signals caused by the walls in buildings, interference from other devices and to the different scales between streets and hallways. This is why we have to resort to Wi-Fi based Indoor LA for this project as it is able to give a more accurate location due to nearer access points (Zeimpekis, Giaglis & Lekakos, 2002).

## 2.2 Investigate Current Technology for Indoor Location Awareness

As mentioned in the background text, there are many technologies associated with LA. One of the recent technologies is Bluetooth Beacons which rely on the Received Signal Strength Indicator (RSSI) (Ma *et al.*, 2017). They use beacon type devices that send RSSI signals to a mobile device and calculates the distance by using a distance algorithm. Figure 2 shows an example of the Free-space path loss formula for the distance algorithm (Katircioğlu *et al.*, 2011).

A close up of a logo

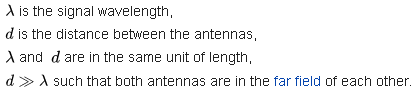
Description automatically generated

Figure 2 : Free-space path loss formula

This formula can be amended to suit the needs for this project, as it needs just the RSSI and the frequency signal that comes from a mobile device to Wi-Fi to calculate the distance between them. As well as coordinate data from placing the beacons. They can then be used for an algorithm such as trilateration to locate your position (De Blas & López-de-Ipiña, 2017). Figure 3 shows an example of the Cartesian Trilateration algorithm which gives 3-dimensional coordinates.

A screenshot of a cell phone

Description automatically generated

Figure 3 : Cartesian Trilateration algorithm

Although Wi-Fi-based systems can use this method as well, it can at times be inaccurate due to other Wi-Fi signal’s interfering and other factors (Zhao *et al.*, 2014). This is why many proposed using Wi-Fi Fingerprinting technique which uses an assortment of known reference points that contains RSSI signals and its coordinates to determine your current location (Mok & Retscher, 2007) however this can be both costly in time and resources as it requires storage of the recorded reference points. It is more efficient to use Wi-Fi Trilateration although it is inaccurate, as it is more cost friendly and simpler to implement.

A new method for Wi-Fi-based systems that have been recently released, called Wi-Fi Round Trip Time (RTT) and is supposed to be more accurate and power-efficient compared to other methods. This technology uses the time it takes to send and receive signals from a mobile phone to an access point (AP) and calculates the distance without the need to connect to an AP (Ibrahim *et al.*, 2018). Although this new technology can be considered for this project it is not entirely suitable for this project as it relies on up-to-date technology such as the mobile devices requiring Android 9 Pie and 802.11mc FTM standard and the AP must also include 802.11mc FTM standard as well (Android Developers, 2018) while this project will be focused on existing infrastructure.

Therefore, the most optimal method for this project will be to use the Cartesian Trilateration algorithm to calculate the user location with conjunction of the Free-space path loss formula to calculate distance needed for the algorithm.

## 2.3 Inspect Existing Location Awareness Applications

As mentioned in the background information, many applications relate to LA in Google Play Store which hosts many types of mobile applications. Another source of applications that relates to LA and has sample code can be found in GitHub a well-known repository of projects. Most of the project/apps that were on these hosting platforms have used technology that was already covered in this report. The GitHub projects have two main types of User Interface (UI), one of them is a map-based approach which shows a floor map with a marker that has your current position and updates regularly (Steppschuh, 2019). While the other features a reference-based approach showing what reference point is closest based on your current position (schollz, 2018). Although they are not exactly full solutions, they can be used as building blocks of the project.

For this project, the Map-based approach would be best for the visualisation of the user Location while the reference point approach does has some advantages in that its more precise in data gathering, it is not that appealing to normal users.

## 2.4 Consider Security Aspects within a Mobile Application

The background discussed a brief concern of how application; store, protect and use personal data of the population due to the new General Data Protection Act (GDPR). This includes additional clauses such as storing and protecting the digital footprint of Personal Identifiable Information (PII) data (McAllister, 2017). As the application requires the use of Short Message Service (SMS) the app will need to have followed GDPR guidelines to make it GDPR compliant. The guideline includes the use of Encryption and Data storage, Right to Be Forgotten and Log/Justify the Data Collection within the application or state it in terms and conditions (Petrequin, 2019). Since the application will need to use web APIs to calculate coordinate data, the developer needs to be aware that the web APIs that he uses need to be secure and will need to follow the GDPR guidelines to ensure that there are no data leakages (Enck, Octeau, McDaniel & Chaudhuri, 2011).

## 2.5 Research into Mobile Application Development

As discussed in the Secondary Objective, the development environment will be Android Studio as they have an ample amount of documentation, libraries and testing can be done either through its inbuilt emulator or from loading the application into an android phone using a data USB cable (Zapata, 2013). The programming language will be Java as it is the more preferred programming language for developers and has overwhelming support from seasoned professionals for complicated projects and problems. Although Kotlin has more features geared solely for mobile development and its simplicity, it still a relatively new language that needs more time to propagate for professionals to interact with this programming language to become more reliable (Banerjee, Bose, Kundu & Mukherjee, 2018).

Therefore, Android Studio is more suitable and stable for this project as it already has an established user base with numerous seasoned experts in java while Kotlin is still a relatively new language with limited documentation.

# 3.0 Execution

The following will include a discussion on the original problem as well as the analysis of the problem and the solution that was applied.

## 3.1 Problem and System Analysis

This project aims to develop and test a mobile application for an android phone to receive Wi-Fi access point signals. By using an web API to convert the access point information to the geographical position of the user, which will be then used to map onto the floor plans of the buildings within the Glasgow Caledonian University (GCU) campus and send the location on a map to another student through SMS. As the researcher’s understanding has been expanded through the literature and technological review from many other researcher’s articles, projects, and studies. Those conclusion and perspectives from their research will be influenced when development on the project begins as well as influence on the user testing criteria. This includes the discoveries of location algorithms, designs from other map-based projects and development tools from the literature and technological review. This will determine if the application has helped improved location-based services and the success of the application.

The application will be evaluated by two or more test participants. One of the two participants will be asked to use the application to locate and find the other participant and vice versa, they will then be given a questionnaire to evaluate the ease of using the app. They will also be asked whether if the app was effective in locating individuals rather than just using normal text message containing approximate location details.

## 3.2 Execution Methods

During the execution of the primary research phase, there were several tasks that were undertaking by the researcher that assisted on the theories, design, development, and testing of the project. The main stages that took place though the execution phase where Requirements, Design, Development and Evaluation.

### 3.2.1 Requirements of the Indoor Location Android App

The first step in the implementation of this project was to identify and recognize the requirements of the Indoor Location Application being developed. From the conclusion that was made from section 2.3 of the literature and technological review which concluded that the Indoor Location was split into two types and that the map-based approach was going to be used as it was more effective in showing the user location to the user. To make sure that the research from the literature and technological review were put to good use, an further investigation was conducted to find all the requirements that was needed, by looking into other indoor Location application to see which functions were prevalent. The rest of the requirement were then verified by examining the present issues in indoor Location systems from this paper (Basiri *et al.*, 2017) .

#### 3.2.1.1 Investigation of other Indoor Location Apps

Prior to the primary research phases carried out, to determine the main functional and non-functional requirements of the Indoor Location App, a further investigation was done to confirm the right requirements. The investigation had aided in revealing the key functional aspects of the Indoor Location App which would further aid in the direction of what kind of application, in terms of indoor Location, was being developed. An outlining method was used to show the different technologies considered and which were more suitable than others. This was completed by re-evaluating the hypothesis, the research question of the researcher and examining common features of indoor Location application to break down the steps needed to complete the primary research phase as well as an attempt to answer the question and hypothesis. Each of the categories can be used to identify which approach is best in terms of existing infrastructure and costs. This allows other researcher to find out alternative solutions to Indoor based location and the researcher a clear line of though towards the project.

From the main areas that this project is founded on. The preferred approach of the application was found that allowed the groundwork for the overall UI design and visual experience to be handed over to the design phase of the execution. There is further detailed for the requirement analysis in section 3.3.

#### 3.2.1.2 Current Issues of Indoor Location

(Basiri *et al.*, 2017) embark on an investigation into the challenges that occur when constructing and developing an indoor Location system on smartphone devices. The paper then goes on to describe the current issues, challenges, and possible solutions for the implementation of Indoor Location systems for mobile devices. This paper was analysed to find the main requirements needed to successfully develop the Indoor Location App. This work is advantageous to this project as it evaluates issues based on costs, availability, and existing infrastructure. All core components that the application being developed will take under consideration.

### 3.2.2 Design of the Indoor Location Android App

Due to the initial requirements of the Indoor Location App, the design that was most favourable was the map-based approach as it would be utilised for the existing infrastructure of GCU Wi-Fi Access Points. This allows the development of the application to initiate using the map-based approach as its core. Since agile development was carried out in the implementation, some design and functional aspects might change as they become redundant or unnecessary for the application. The utilization of wireframes in the project allows the visualisation of the researcher ideas to accrue, based on the requirements already identified. A few were created to show the scan results of the Access Points, calculations screens and the final location of the user on a floor map.

### 3.2.3 Implementation of the Indoor Location Android App

With the aid of Literature and Technological Review, section 2.5 “Research into Mobile Application Development” and the design phase completed, the start of the iterative development of the application can be carried out. Choices were made for the following areas; Integrated Development Environment (IDE), Programming Language, web API and other tools such as Google Maps API. These choices were made based on the literature and technological review, however they were also influence by the design and requirements of the execution.

#### 3.2.3.1 Development Platform and Environment

In line with the research that was carried out in the literature and technological review the appropriate platform for this project would be for android mobile phones. This is also due to the functionality, mobility, availability, and the cost of the equipment needed to carry out the evaluation. The environment as stated in the literature and technological review will be Android Studio as it provides ample documentation and support. The simplicity and familiarity to the researcher was another deciding factor. As the development of the application was between 2 to 3 months schedule, a steady and established IDE and programming language was required. The researcher has used Intellij Idea and Eclipse, both of which predominantly uses Java however, since they would require many plugins to install and configure for Android implementation, Android Studio was chosen as it has similar environment to Intellij Idea. As the researcher continues in expanding his experience both academically and personally with different IDE including Android Studio, this makes the IDE more probable to be used.

#### 3.2.3.2 Web API

With the research in the literature technological review, section 2.2 “Investigate Current Technology for Indoor Location Awareness” the section concluded that trilateration would be the best for this project in terms of costs and existing infrastructure. Since trilateration requires geo coordinate points of access points, there is a need to find these geo coordinate points. An investigation into finding the geo coordinate points were made, it was discovered that for the application, a Web API was needed to be included in the implementation of the application.

After a further investigation, it was concluded that there were two suitable API’s that fit this projects criteria, a free public database with global coverage of known Wi-Fi access points hosted and developed by (Mylnikov, 2015). The other was Googles, Geolocation API which also has global coverage of known Wi-Fi access points although it has $200 free quota, it has a requirement to sign up with a payment system. Although the free public Web API does not return an altitude or elevation value, it is still better suited for the application than the Google Geolocation API.

#### 3.2.3.3 Google Maps

Since the design was decided to be the Map-based approach in the execution, it was decided to use Google Maps with the floor maps of GCU to be appended to the map for the application. Originally, it was first designed to use just use the floor maps however since the location data received from the Web API uses geo-referencing of latitude and longitude, it was decided that Google Maps would be used as it is able to take in the geo-reference points and display the location via markers. Additionally, Google Maps can be easily implemented into the application in android studio. Although most of the additional API’s made by Google requires membership and paid quotas, the Google Maps API by itself is free to use with no limit, apart from commercial gain.

### 3.2.4 Evaluation of Mobile App

The final phase of the execution of the primary research entails alpha testing which consisted in users using an android phone to locate each other using the application developed and then given a questionnaire and informal interview discussing the application.

#### 3.2.4.1 User Testing

The testing consisted of two participants that will be separated and placed into two locations each having an android phone and at least one in the GCU campus. The one in the campus will use the application to find his current location and send his location to the other participant via SMS. The other participant will then proceed to locate the participant using the sent location. Once the participant has been found by the other, the test is complete.

#### 3.2.4.2 Questionnaires

After they have completed the test, they will be given a questionnaire which is provided in Appendix A. The questionnaire included 4 questions and an extra space for additional comments. These questions were related to the usability of the application and whether they succeeded in the test or not. The question was made to be simplistic so that they did not strain the cognitive functions of the user. This way, the questionnaire responses would not be skewed by the inability of the user, making the responses more viable.

#### 3.2.4.3 Interview

After the test and the questionnaire has been concluded, a short informal interview will be undertaken between the users and the researcher. The interview question will be centred on the functionality of the application and what could be done better next time. The interview purpose is to give additional details that may aid the researcher, where written word might fail to fully convey their responses.

#### 3.2.4.4 User **Feedback** and Evaluation

By looking at the test results of the participants finding each other, it should suggest if it was feasible to use Wi-Fi for indoor location and by using the questionnaire, it should show if the app was more efficient compared to other methods. Both results will aid in answering the proposed question and finalising the final report as well as the poster presentation.

## 3.3 Development Lifecycle

By using a correct software development lifecycle for the project, this ensures its probability of success. An Agile approach will be used in increments which facilitates several rounds of iterative development, separately producing a working prototype (Bor-Yuan Tsai, Stobart, Parrington & Thompson, 1997). This method is more efficient in time, productivity and allows many changes while developing compared to the classic waterfall method as the methodology is an entirely linear approach making it quite rigid in changing requirements and is more costly.

![A picture containing drawing, device

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAeAB4AAD/4RDuRXhpZgAATU0AKgAAAAgABAE7AAIAAAAMAAAISodpAAQAAAABAAAIVpydAAEAAAAYAAAQzuocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFl1IEhvbmcgTGVlAAAFkAMAAgAAABQAABCkkAQAAgAAABQAABC4kpEAAgAAAAMxNgAAkpIAAgAAAAMxNgAA6hwABwAACAwAAAiYAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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Figure 4 : Agile Methodologies (hackernoon.com, 2020)

Figure 4 shows a base example of the agile development lifecycle that was implemented into this project. This example shows the six stages of the Agile lifecycle (Requirements, Design, Development, Testing, Deployment, and Review). For this project lifecycles, each iteration will carry out the first 4 stages while the last two will be used at the end of this project. After the first iteration has been completed, the requirements of subsequent iteration will be carried out if there is changes that are needed once the testing stage has been concluded from the previous iteration. This follows the doctrine of the Agile development of allowing the change for requirements after each iteration.

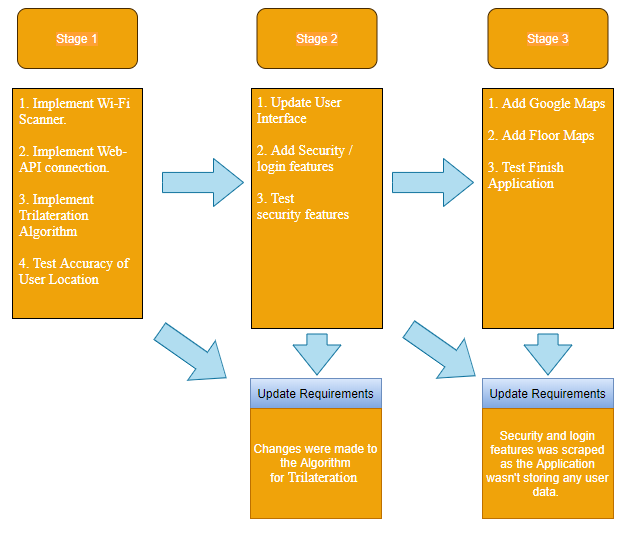


Figure 5 : Planned Lifecyle

As seen in Figure 5, the following stages after stage 1 is built upon the original prototype, some of the requirements are changed or removed as they become redundant to the design of the application. This is to add more complex functionality while also making a sound application by removing unnecessary parts and updating the base application.

The figure below (Figure 6) shows the finished plan and start times of the iterations. Although some of the task was behind schedule due the tasks complexity, they were still within tolerance made by the researcher. The Gantt chart is based on the academic year for a fourth-year student which is 1-24 weeks however project work includes additional time during the holidays and weekends. This substituted time negated the time taken for being the behind schedule.

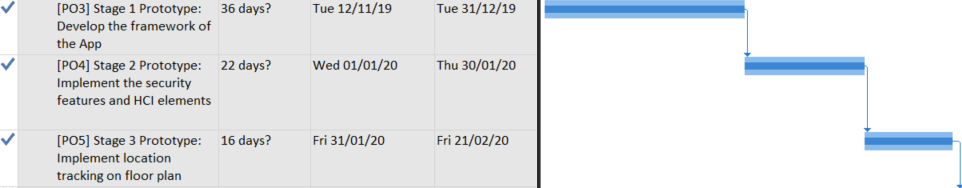


Figure 6 : Lifecycle Gantt Chart

## 3.4 Requirements

As mentioned in section 3.2.1.1 involving the Requirement Analysis methods, a further investigation into the Indoor Location Applications was conducted to identify the functional and non – functional requirements of the application. As said before, the research question was examined to identify the essential topics areas of the system. The research question being;

**Can an Android Application be made to locate your current location on campus using Wi-Fi signals with API’s converting them into coordinates and plot your location on a map to send to another student via SMS?**

The four main criteria that can be extracted from this question are Android Application, API’s, Current Location, and Map. These areas could then be examined to reveal what functionalities is required. Beginning with the Current Location area, it was apparent to the researcher that this area can be subcategorised from Indoor Location Strategies such as Trilateration, Wi-Fi Fingerprinting and Wi-Fi Round Trip Time. After this, the technology and costs that are needed for these approaches are realized. The following figure (Figure 7) is a simple outline of the research carried out to identify what is required to find the current location of a user in an indoor setting.

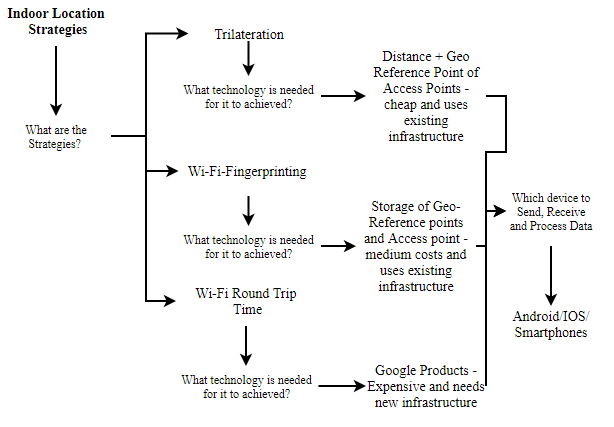


Figure 7 : Requirement Outline Flow - Indoor Location

Figure 7 shows a few of the methods to achieve indoor location and their associated costs and equipment needed. Nevertheless, it does not list all the available methods and/or equipment. Only the ones that are necessary for this project are shown. An identical method was carried out whether to use a map – based approach or not to compare whether the map – based approach was the best for the system. The complete outline can be found in appendix C.

### 3.4.1 Functional Requirements

The conclusion from the investigation of other Indoor Location Apps can be used for the design and implementation sections by recording them into pseudocode like requirements for the application.

1. Scan for Wi-Fi Access Points
2. Calculate Distance based on Access Points information
3. Send Access Point to get Geo Refence points
4. Retrieve Geo-Location Reference point of the Access Point
5. Calculate current location using the Trilateration Algorithm
6. Display Location on floor map appended on Google map

Requirement 5 is the functional requirement that is the basis of this project and application. If not for the Trilateration Algorithms, there would be no way to calculate indoor location using the existing infrastructure for the primary research concerning the research question and conclusions found in the literature and technological review. With this requirement in the system, a comparison and evaluation can be made to answer the research question.

As the question mentioned the GCU campus, requirement 6 will display the appended floor plans on the Google Map. This was done as the Trilateration algorithm uses geo-reference points. This also allow for the expansion of the other floor maps of the building to be used, not just the George Moore building that was used for this project.

### 3.4.2 Non-Functional Requirements

During the research into other indoor location applications, the following non-functional requirements were gathered.

1. Easy portability
2. Use of existing infrastructure
3. Low cost of equipment

Since the application will be built for an Android phone, this satisfies the first requirement. By choosing the Trilateration algorithm, the existing infrastructure of the Wi-Fi access point were used. The cost of equipment will be kept to its minimum throughout this project.

## 3.5 Conclusion

The problem and system analysis consisted of determining the technology and equipment that were required to carry out the main execution of this project. While the development lifecycle was decided on based on resources and time allocated to the developer to undertake the development of this project. The identified requirement from the research and literature review allowed for a clear set of goals when progressing to the design phase.

# 4.0 Design

Since the main requirements have been identified in the execution phase, a simple class diagram was made to identify some of the classes, methods and some of the variables that will be used for the development of the application.

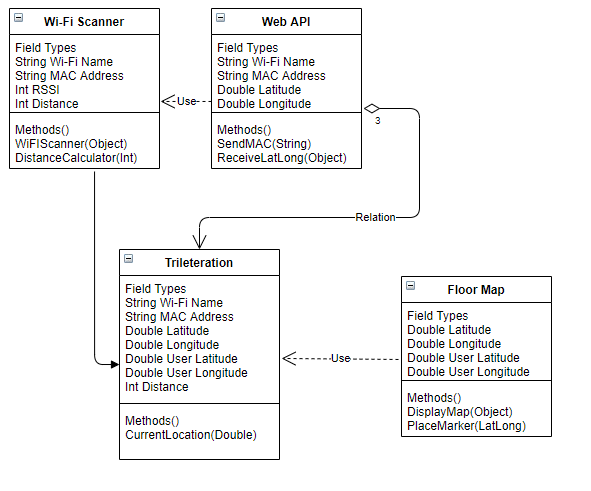


Figure 8 : Class Diagram - Indoor Location

Figure 8 shows what is likely to appear in the implementation of the application. It is used as a starting point for the researcher to develop the application. It is normally used by Object-Oriented languages, this included Java which is used in this application. The diagram shows that the scanner received the following variables Wi-Fi Name, MAC Address and Received Signal Strength Indicator (RSSI). The other variable Distance is calculated by the RSSI. They are then passed to both Trilateration and Web API class. The Web API Longitude and Latitude of a Wi-Fi Access Point by sending the MAC address or Wi-Fi name to a Web API. They are then passed to the Trilateration which requires 3 Access points locations and 3 distances to the Access point to calculate the current location of the user. They are then passed to the Floor Map class where they display the Map with Markers for the location of Access Points and the current location of the user.

## 4.1 Wireframes

Based on the execution phase, a simple wireframe was made to show the UI of the application. The wireframes was made to show what graphical components were needed for the application and how they were positioned.

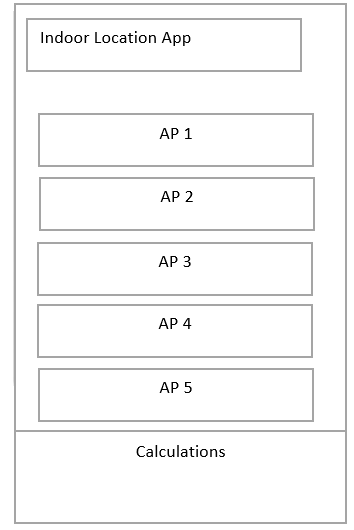
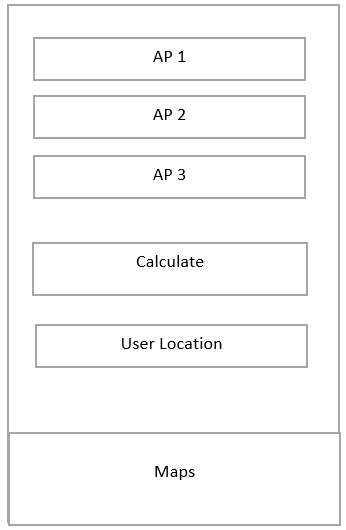
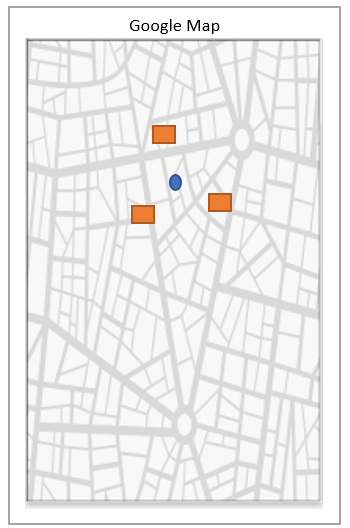


Figure 9 : Wireframes – Indoor Location Application

Figure 9 shows the design wireframes to be used for the application. The first wireframe was to show the access points in the area, there is scope that the user may be able select the three access points of their choosing, however the application will only take in the first 3 as they will be the closest and therefore the more accurate access point to find the user current location.

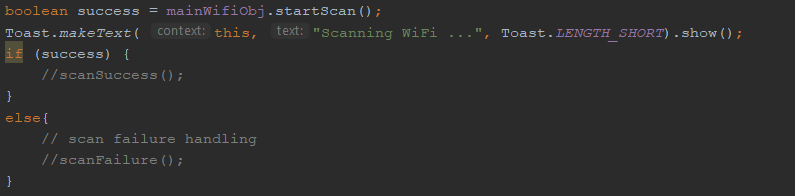
The second wireframe is used to display the first 3 access points which are used to calculate the user location, this is for research purposes as normally it would run in the background and only display the last wireframe. The last wireframe displays the user location as well as the 3 access points.

# 5.0 Implementation

As the execution section discussed the justification of using the specified programming language, development environment and deployed platform as well as the requirements of the application being developed. This section will primarily focus on the specific code and programming methods that were used to create the Indoor Location Application based on the previous design phase.

## 5.1 Wi-Fi Scanner

For the application to do any of the listed requirements, it must be able to actively scan for the closest Wi-Fi access points to receive data such as Wi-fi name, MAC address and RSSI values. The scan would run once the application opens, an additional scan can be started after pressing the button on the first page. The code below shows how the scan initiates.



After the scan is complete, the RSSI and frequency is then passed to the Distance Formula method for each access point. The resulting scan and calculation are then stored into an array list and displayed in a list view for the user. The array list is then passed on the web API call. The resulting scan is shown in the following figure (Figure 10).

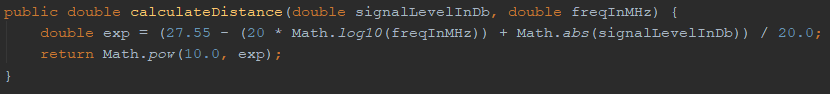
A screenshot of a cell phone

Description automatically generated

Figure 10 : Wi-Fi Scan Screenshot

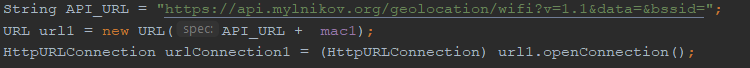
## 5.2 Distance Formula

The distance formula used for Java was written by (Kutlev, 2013) and based on the FSPL mentioned in the Literature Review. The formula takes in both RSSI and frequency to calculate the distance in meters between the Access Point and the user.



## 5.3 Web API Call

The web API call uses an async task to connect to the server and starts when a button has been clicked. The HTTPS request has an appended MAC address of the Access Point shown in the following code snippet.



This is used to identify the access point in the database on the web server. The request is sent 3 times for each access point and returns a Json object where it then gets parsed into type Double for geo referencing values. The geo referencing values are then passed to the Trilateration algorithm. The resulting Web API Call is shown in the following figure (Figure 11).

A screenshot of a cell phone

Description automatically generated

Figure 11 : Web API Call Screenshot

## 5.4 Trilateration Algorithm

For the Trilateration algorithm, the 3 access points location and distances from the user, are gathered from the previous methods that were used. The Java equivalent of the algorithm was written by (Methe92, 2014) and was adapted and used for this application. The following figure (Figure 12) shows the resulting calculations.

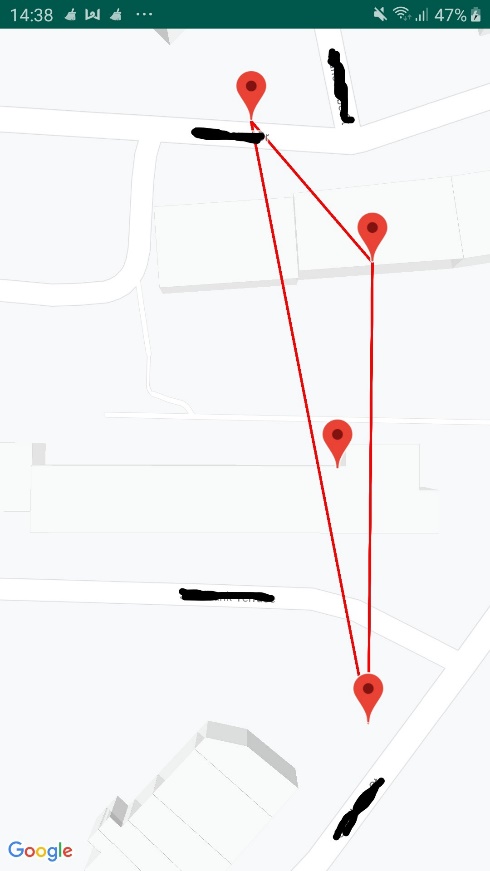
A screenshot of a cell phone

Description automatically generated

Figure 12 : Trilateration Screenshot

## 5.5 Google Maps Display

After the Trilateration calculation, all the values to display the user location and the 3 access point will have been found. A free API key associated with the researcher Google account was used to enable the google map function for the application. 3 Makers were placed based in the 3 access points and a separate marker was placed for the user’s location. These 3 markers were then joined by a polyline to form a triangle to distinguish the makers and to see if the user location was within the markers. Since the application will be used for indoor location a floor map was appended to the google map. The following figure (Figure 13) shows the markers being placed on the google map as well as the floor map appended.

 A picture containing text, map

Description automatically generated

Figure 13 : Google Maps Screenshots

## 5.6 Additional implementation

After the completion of each iterative prototype in the development lifecycle mentioned in the execution. Some steps have been taken to mitigate and to catch errors so that the application would not crash, and work as intended. Black box testing was carried out to test the functionality of the application, so that it could be evaluated without the possibility to crash unexpectantly.

# 6.0 Evaluation

This segment of the report will include the evaluation of the application designed and development of this project. The methods used for the implementation of the project will be used to assess and confirm the hypothesis. This will include the execution and conclusions of the testing and evaluation phases. The results will be examined closely to see if they satisfy the overall outcome of the project.

To evaluate Indoor Location functions within the application, qualitative evaluation methods were used. As the testing of the application is based on how accurate the tracking methods are compared to textural directions, the user’s opinion is essential to the evaluation of the hypothesis. Hence, the participation of the user for the main evaluation would allow for a more thorough and conclusive set of results. The evaluation will be a live testing session with multiples of two participants, where they will be separated on the ground floor of the George Moore building. They will then proceed to locate each other based with the usage of the application and sending screenshots via SMS or other messaging system. They will then be given a questionnaire and a brief interview to discuss their opinion on the application. With the results given from these evaluation methods a critical analysis can be made which will address the main requirements made in the hypothesis.

## 6.1 Testing Condolences and alternative

Due to the recent global pandemic of the Corona Virus, all planned testing methods were cancelled, with testing originally planned to taken place on the 17th March 2020. Due to this an alternative test was made for the researcher to carry out at home. This test involved the researcher to test the application at home several times, performing a quantitative evaluation method. The results show that the final user location is accurate when the user is close to the access point, however there are times where the marker is far away from it should be when there is an exponential increase in distance to the access point. This shows that for this application to work they would have to be fairly close to the access point After further investigation into both the distance formula and the Trilateration algorithm, it was found that the further away the distance was, the more the distance would be raised exponentially resulting in skewed data. The following figure (Figure 14) shows the discrepancies of the location.

A screenshot of a cell phone

Description automatically generated A close up of a map

Description automatically generated

Figure 14 : Discrepancies Screenshots

The application was also shown to the researcher’s family to give a general feedback of the UI of the application. From their feedback, they found that the calculations were a bit much, and that they should ideally, be run in the background, having the map display with markers only. They also mentioned that the position of the marker could be more accurate however they were still able to identify that the marker does show my current position. Another comment they made was it was better to show a map with your location rather than written directions as it can show certain landmarks so that it might assist a person to find a specific location.

## 6.2 Conclusion

Since the live testing session could not be done, an in-depth test into the application was done in its place to show that it can indeed locate the current location of the user and opinions were gathered to confirm that it would be better to use the application rather than using written directions.

To conclude, the quantitative results completed by the researcher in-depth test of the application allowed for the research question to be answered while the pseudo qualitative evaluation methods provided by the researcher’s family validated the hypothesis made. The evaluation of the indoor location application for android devices shows that although it is inaccurate at times, it is possible to use Wi-Fi access points to determine the current location using an android device.

# 7.0 Discussion and Conclusions

This section contains the overall conclusion of the project undertaken. A brief summary of the summary of the project will be shown first before the examination of results and outcomes of the execution of the project. These discussion and conclusions will show the results and relate them to the research question and hypothesis made. The project will then be discussed to what could have been done differently due to the limitations of this project.

## 7.1 Project Resume

Indoor Location App on smartphone devices has seen recent trend in both supply and demand. This can be due to the recent pandemic however before this, its popularity could have been indirectly attributed to the spread and convenience of outdoor LA of the past decade. With the increased development of Indoor Location, there is a likelihood that more mainstream services are developed that utilise Indoor Location technology. However, there is still an issue of indoor location being inaccurate due to the signal being disrupted by obstructions such as walls, roofs and even trees. Another issue with this technology is privacy, whether if it will perversely track our location and even some who wonder if we need this technology in are daily lives. A Literature and Technological Review was done to investigate the technology behind Location Awareness, the current methods to achieve Indoor Location, other Indoor Location Applications and whether to consider the security principles of a mobile application. The other areas of the Literature and Technological Review was used for the implementation of the application such as which platform to use for development, programming language used, and other tools needed for implementation.

The aim of the project was to answer the following research question:

**Can an Android Application be made to locate your current location on campus using Wi-Fi signals with API’s converting them into coordinates and plot your location on a map to send to another student via SMS?**

By having this research question as the focus, the main objective of the project was to create an android application that located the current position of the user by using the existing infrastructure of Wi-Fi access points. Therefore, this project will use an develop and test approach by creating the application and evaluating the application in the format of a live test. The original test was to include live testing, questionnaires and an informal interview, however this was cancelled due to unforeseen circumstances and a new test was done which consisted of the researcher doing an in-depth test of the location finding capability of the application and brief comments from the researchers family were gathered about UI of the application. An iterative agile lifecycle was used for the implementation of the projects prototype. Requirements and design features were identified by doing in-depth research into other android applications. An initial wireframe was made to shows conceptual design of the UI based on the requirements. The Indoor Location Application was developed on Android studio in Java. A Web API was used to allow the Trilateration to work and Google Maps was used to display the current location of the user. When the application was complete, the initial test was cancelled due to the lockdown, so alternative testing was done.

The quantitative results and the pseudo qualitative evaluation contributed to the conclusion of the initial hypothesis in the primary research:

By using the Indoor Location App, individuals should be able to locate each other more efficiently and with ease in comparison to individuals who use vague directions to locate others by using the App for its accurate location information and its delivery of near-instantaneous speed.

## 7.2 Discussion of Results

The main objective of the project was to create an android application that located the current position of the user. The results from the initial investigation of section 2.2 in the literature and technological review implied that there many ways to achieve indoor location awareness and how they were able to achieve that. The investigation concluded that the Trilateration method is the more favourable of these methods as although it bit inaccurate when compared to the other methods, it is also less costly in terms of resources and its key use of utilising the existing infrastructure. The issue about obstructed signal strength can be mitigated by using the “Free-space path loss formula”. The conclusions made in the literature and technological review helped support the hypothesis and allowed for the proper execution of the application being developed and to see if it was possible to find the current location of a person indoor. Alternative test had taken place due to unforeseen circumstances, these tests involved the researcher to test the accuracy of the markers placed on the map and showing the application to his family, to gather their opinions of the UI. The results from the evaluation were proven to be positive which supported the hypothesis.

## 7.3 Project Limitations and Future Works

The findings form this project were justified and had aided in answering the hypothesis in the execution phase of this project. Nevertheless, there were several factors that may have contributed towards the limitations of this project. The 3-month timescale allocated for the implementation of the application would cause the application to be more on the prototype side rather than a fully released product. These limitations may have influenced the evaluation of this project however, it also leaves further development for this topic area. The Indoor Location App is mainly focused on the GCU campus but there is scope to have global coverage of the application.

During the implementation phase, the use of Google Geolocation API could have been used instead of the free Public Wi-Fi database to allow mapping capabilities between floors however as mentioned it was not used due to its costs. Another consideration would be to use another Indoor Location strategy such as Wi-Fi fingerprinting or Wi-Fi RTT however they were not suitable for the project as it would be too costly in terms of resources or storage capability.

For the evaluation phase, the main limitation was that proper testing could not be conducted. Although alternative testing had taken place, the tests would not be able to fully appraise the application and may have skewed the results of the evaluation of the application. A future topic suggestion could be to adjust the algorithms used to give a more accurate location.

## 7.4 Conclusion

This project goals were to determine if indoor location could be implemented using the Wi-Fi access point already installed in the existing infrastructure. The project started with the Literature and technological review which was used to research the underlaying technology used in this project. A follow-up investigation was done to identify the requirements needed for this project and initial wireframes were made. Then, an Android application centred on the Glasgow University Campus was developed to locate a person location using the Trilateration Algorithm used in the application. Alternative tests were undertaken which results supported the hypothesis. The hypothesis stated that the android application for indoor location would be more advantageous than using vague written directions to locate a person. Alternative evaluation methods were used to answer the hypothesis and research question. These evaluation methods include an in-depth test into the accuracy of the android application and gathered opinions from the researcher family. The evaluation phase has concluded the execution of the project.

To conclude, the project proved successful despite the use of alternative testing due to the evaluation results, confirming that indoor location on an android device is possible using the Wi-Fi infrastructure. User feedback from the family of the researcher also confirmed that the android app is an effective tool to find a person location indoor rather than written directions.

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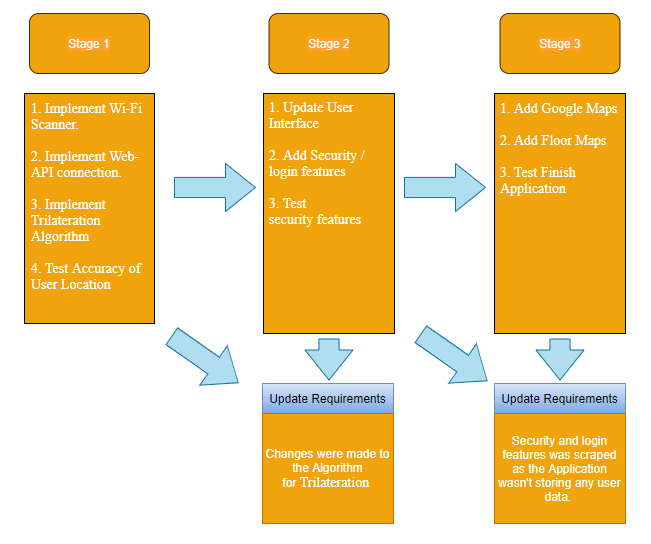
# 10.0 Appendices

## Appendix A: Questionnaire

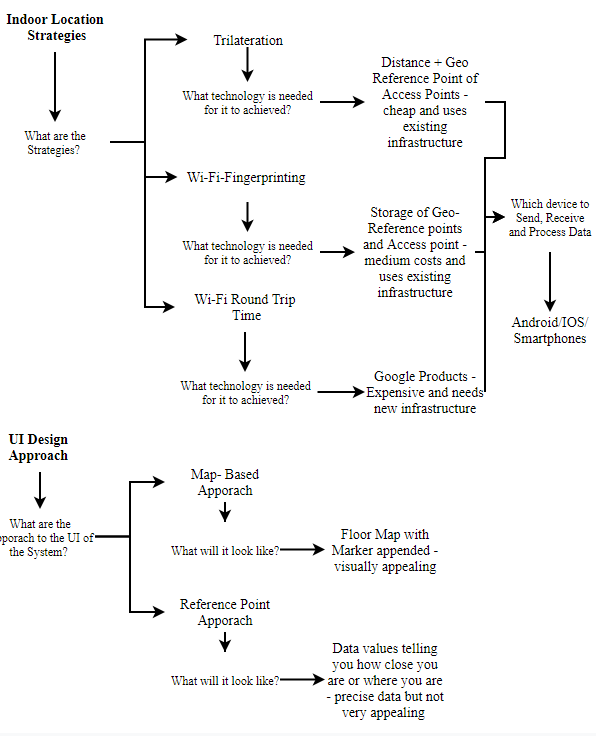
A screenshot of a cell phone

Description automatically generated

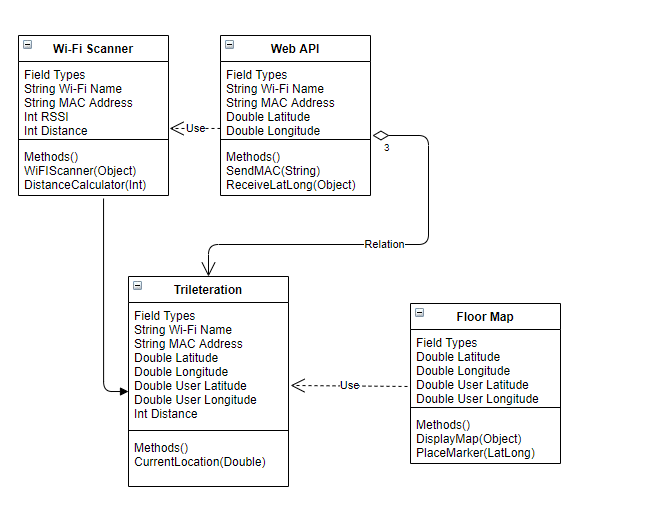
## Appendix B: Lifecycle diagram



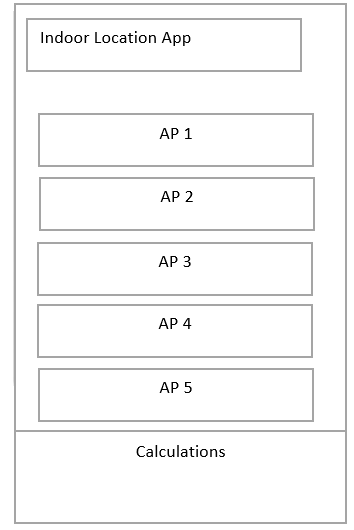
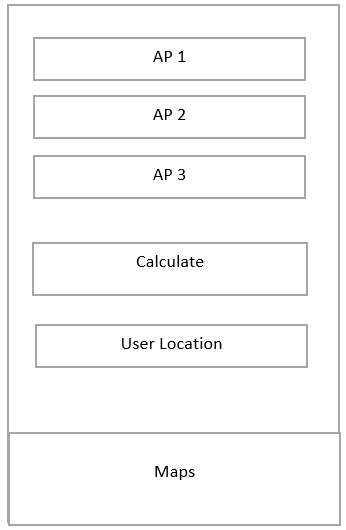
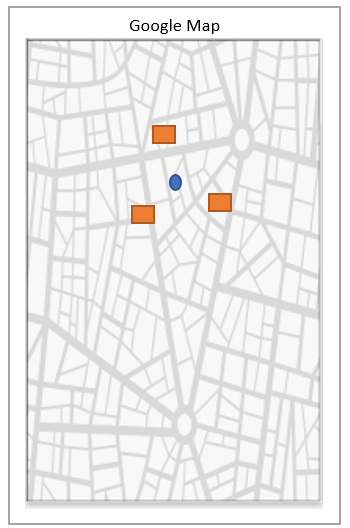
## Appendix C: Research Outline



## Appendix D: Class Diagram



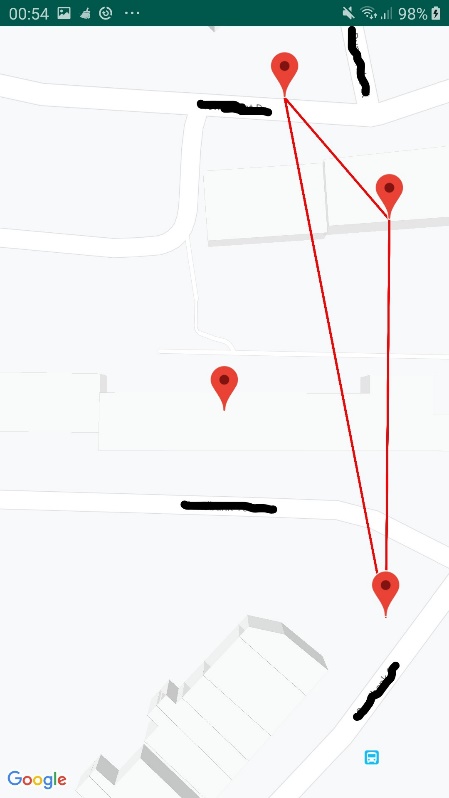
## Appendix E: Wireframes



## Appendix F: Code Listings

<https://github.com/YLEE201/Honour-Project/tree/master/proto>

## Appendix G: Indoor Location App

A screenshot of a cell phone

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Description automatically generatedA screenshot of a cell phone

Description automatically generated

A picture containing text, map

Description automatically generatedA close up of a map

Description automatically generatedA screenshot of a cell phone

Description automatically generatedA picture containing map, text, table, photo

Description automatically generated