

Software Design Study

'Final Report'



UNIVERSITY OF BIRMINGHAM

Emergency Systems Team

George
Matthew Flint - 1247903 - mxf203@bham.ac.uk
Deyan
Martin
Robert

This work was conducted as part of the requirements of the Module 06-15500 Software Design Study of the Computer Science department at the University of Birmingham, UK, and is submitted in accordance with the regulations of the University's code of conduct.

April 29, 2015

Contents

1	Abstract	3
2	Introduction	3
3	System Overview	3
4	Modules	3
4.1	Emergency App	3
4.1.1	Video Streaming Rationale	3
4.1.2	Chat System Rationale	5
4.1.3	Automatic Video Sending Rationale	5
4.2	CPR System	5
4.2.1	Rationale	5
4.2.2	Project SMS-livrddare	6
4.3	API	7
5	Specification	7
5.1	Common Technologies	7
5.1.1	Google Cloud Messaging	7
5.1.2	Database	12
5.2	CPR System	13
5.2.1	Iteration 1 - Basic Functionality	13
6	Project Management	23
7	Personal Reflections	23

1 Abstract

The software design study gives the student the opportunity to work in a team (typically 5 or 6 students) on a challenging and substantial software design project. This will normally include mainly the early phases of the software lifecycle (requirements analysis and software design), but may also include the further development of prototype software and/or demonstration software.

2 Introduction

3 System Overview

4 Modules

4.1 Emergency App

4.1.1 Video Streaming Rationale

Video calling is not a recent development, but one that has been processed throughout time [33]. It has finally emerged and is making quite the splash in the technology world. Mobile phones with video calling capabilities provide instant face-to-face communication with anyone, anywhere. In order to have this capability, the phone must have a camera and a stable internet connection.

Nowadays, most mobile phones have built-in cameras [34][35] with the capability of capturing images with a resolution of at least 2 MP, which is of HD quality or transferred into pixels: 1600x1200. Some mobile phones provide even more than 41 MP resolution of a single image. These cameras, however, record video with a lower quality than single images. Older phones with older 2 MP camera sensors can record video with resolution of 240p, which is equal to 320x240, at 15 frames per second. With the advances of technology, this has changed a lot. Nowadays, most mobile phones can record videos with at least 480p (640x480) resolution and at least 30 frames per second. The newest models from 2014 even have the possibility of recording video with 4K resolution (4096x2160) at 30 frames per second. Apart from high quality of the video, modern mobile phones can exchange quality for speed and capture video with 720p (1280x720) at 120 fps or some even reach 240 fps.

Another feature that is required in order to make a video call and all mobile phones with built-in cameras have is mobile or wireless internet connection. Mobile connection is usually slower, starting with 2G, 3G and reaching the newest and the most advanced 4G. As of June 2014, the 2G and 3G coverage of the UK premises is 99.7% and 99.5%, respectively [36]. Nevertheless, further technology improvements are being developed. 4G coverage has already reached 73.0% of UK premises and researchers has began work on 5G, which is believed to be introduced in the early 2020s [37].

Based on statistics by Skype [38], a normal internet call requires a minimum of 30 kbps of download and upload

Technology	Coverage	Speed
2G (GPRS)	99.7%	56 to 115 kbps
2G (EDGE)	99%	up to 237 kbps
3G	97%	0.2 to 28 Mbit/s
4G	73%	100 Mbps

bandwidth. In order to be able to conduct a simple video call using a smartphone, a bandwidth of minimum 128 kbps upload and download speed is needed, whereas 300 kbps is recommended. For higher quality of the call the speed requirements rise to 400kbps and 1.2 Mbps for the highest quality. Youtube suggests similar network requirements for

its streaming service [39]. Taking into account the use of newer encoding techniques, the network requirements can be compared with the network speed that mobile technology provides. Using 2G, a simple video call can be made, with low quality settings. However, 3G speeds are enough in order to perform a medium to high quality stream and 4G will be able to provide even better streams.

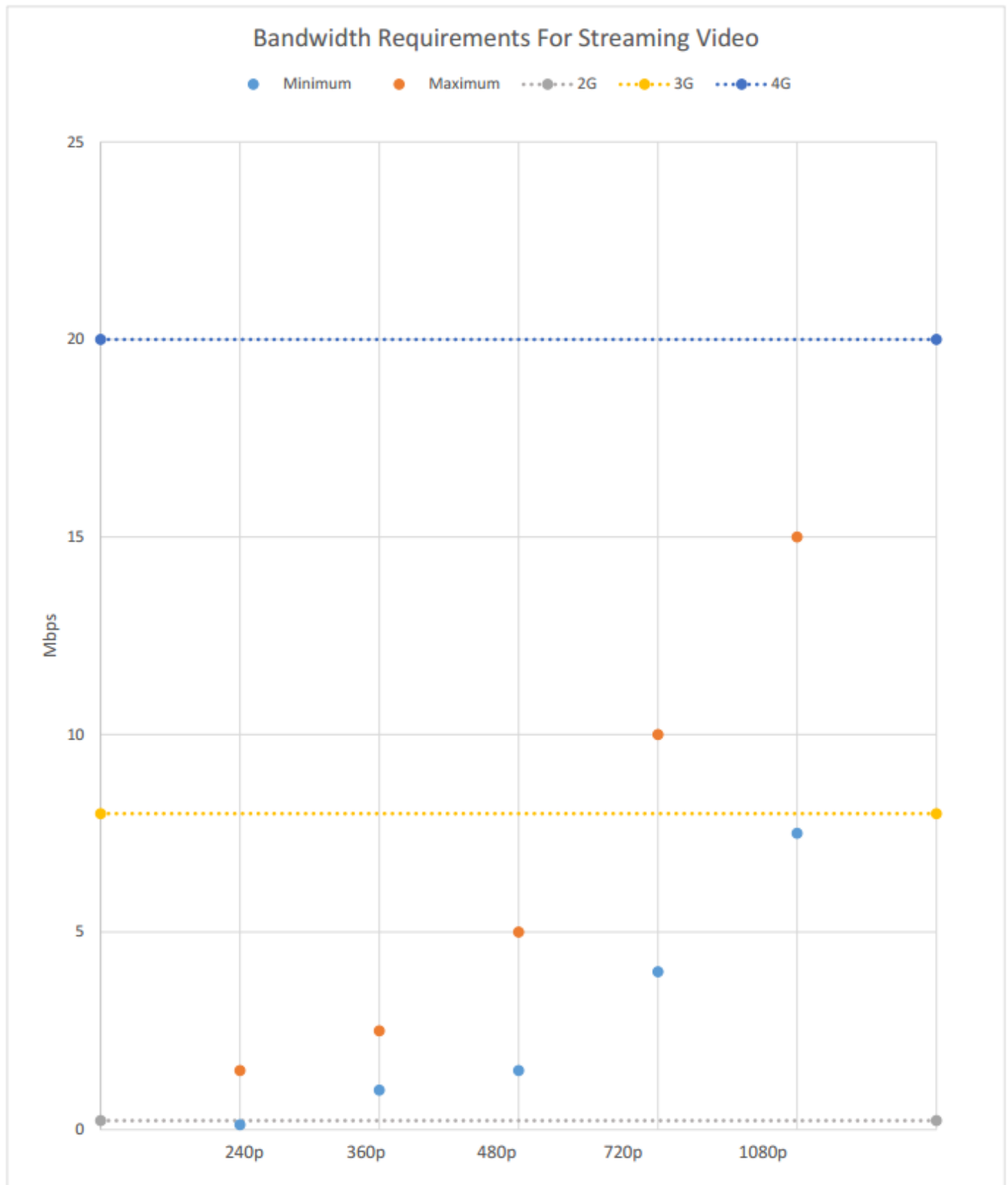


Figure 1: The bandwidth requirements for video streaming.

Wireless internet connection can be compared to the same network requirements. As it can usually provide better and

more reliable internet connection, it would be the preferred way of transferring the video stream data. However, free wireless internet connection is available in limited places, thus, a combination between wireless and mobile internet connect is required, in order to provide internet access of the highest quality and coverage.

Thanks to the low bandwidth requirements and fast mobile network that is available almost everywhere, it is now possible to make video calls using your mobile phone wherever you are. Furthermore, with the technology evolving so fast, it is likely to be able to make High Quality video calls from everywhere in the near future.

These technology innovations could change how emergency situations are handled. Being able to send real time video footage to an emergency operator or an emergency team, could help them assess a given situation better and give better instructions to the people requesting help. In a phone conversation we held with a personnel of an emergency department, we asked to express what are her thoughts on introducing video streaming feature to an emergency call. That would be very useful. One of the issues we always have, when we take a 999 call, is that we are blind. We are going on what our caller is telling us, so to be able to see it, would make things a lot easier and we could assess the severity a lot quicker. - Dawn Whelan. This was also confirmed by a survey that we have conducted, which showed that 82% of the people, who participated, think that they could benefit from such a feature.

4.1.2 Chat System Rationale

As of 2012, there are more than 32,000 registered phones with the Emergency SMS service [52]. However, according to statistics [53] there are more than 10 million people with some kind of hearing loss and 800,000 of them are severely or profoundly deaf. That means that only about 4% of the people, who might experience the need to use the Emergency SMS service, are registered. Including a live chat feature in the emergency application will greatly reduce the difficulty of using such a service and will make it more accessible to a greater part of the population.

Using a live chat requires a minimum amount of internet access, which means that the chat will be available for use even in regions where mobile network coverage is poor. Moreover, such chat will be able to deliver messages in the same order they were sent, keep track whether a message has been delivered and read by the operator and will make requesting more information easier and faster. A single message will take only milliseconds to be delivered, rather than the slow speed of delivering SMS messages. If a message fails to be delivered, the application can keep trying or notify the user that it was unable to send the message. Giving such information to the users, rather than suggesting to them to resend the message if no response has been received in 3 minutes, gives them the opportunity to react faster.

4.1.3 Automatic Video Sending Rationale

A problem that may arise during a 999 call is that the caller may not be able to describe in details where he is located. This could be due to him being in an unknown place or just confused because of stress. The results of such a problem can be that the emergency team head in the wrong direction or arrive to the place of the emergency, but are unable to find the exact location of the accident. In order to help with transferring the exact location of the person, requesting emergency, mobile phones can be used.

As already stated, nowadays, all mobile phones have the ability to access internet, through various technologies. Apart from that, most mobile phones have GPS sensors [34][35] and are able to locate themselves within seconds. The acquired location can either be exact, within a few meters, if a GPS sensor is available and a good GPS signal is present, or at least identifying the correct region, based on mobile network reception. This information is also very small, in terms of data size, which means that it can easily and quickly be sent over the network. Including such a feature in the emergency application can greatly reduce the time needed for the emergency team to head in the right direction, thus, the team will be able to arrive faster.

4.2 CPR System

4.2.1 Rationale

Cardiovascular diseases are one of the leading causes of death in the western world [1]. They come with an increased risk of cardiac arrest, of which there are an estimated 60,000 [2] incidents out of hospital annually in the UK - about 1 ev-

ery 9 minutes. In fact, across the whole of Europe, 1 person per 1000 population will suffer a cardiac arrest in any year.

The truth however, is that in most cases of out of hospital cardiac arrest the chances of survival are depressingly low. The average overall survival rate for England is just 8.6% [2] and in some parts of the country, just 1 in 14 people survive an unanticipated cardiac arrest [3]. This is poor by international standards, with some of the highest survival rates being Norway (25%), Holland (21%) and Seattle (20%) [2] which shows clear potential for improvement in the UK.

The most effective way to increase a persons chances of survival from cardiac arrest is to perform immediate CPR, whether that be only chest compressions or mouth to mouth. Evidence suggests that where CPR is attempted, survival rates are doubled [5] and this could be expected to save around 300 lives per year. This is because the chance of survival after a cardiac arrest reduces by around 10% every minute without proper care [6] due to the lack of oxygen the body (and especially the brain) experiences. Early CPR until paramedics arrive is very important to maintain blood circulation to the heart and brain, which also increases the chance that treatment with defibrillators is successful [6].

One of the main reasons that the fatality rates of the UK are so high is because of a low rate of initial CPR by bystanders: Fewer than one in five people who suffer a survivable cardiac arrest receive the life-saving intervention they need from people nearby [3]. Compare this to 73% in Norway [4] and it is clear that this is an area for major improvement. There are several factors thought to be responsible for low levels of bystander-initiated CPR, including lack of training and fear of litigation [5]. In addition, the number of population trained in CPR is currently 3.8m [5] (out of 60m). This small proportion means the likelihood of someone being nearby when an individual suffers a cardiac arrest is very low, and furthermore, training new people to give CPR will only help in the long term as it will take some time before any difference to this likelihood is noticed. In the meantime, a better way is needed to link those trained to give CPR to those in need of it.

So few recoverable cardiac arrests are survived mainly due to the time it takes between the arrest occurring and the rescue attempt beginning. With the average waiting time currently around 8 minutes [7], and recent news of longer response times from emergency services [24], we need to look into ways of helping those affected before emergency services arrive.

4.2.2 Project SMS-livrddare

There is an ongoing research project in Sweden called Project SMS-livrddare [6], which aims to improve cardiac arrest survival rates by getting trained civilians to start CPR early, before the ambulance arrives [6]. Currently active in the entire capital city of Stockholm, the trial started in May 2010 and has seen massive uptake from the public, with 9,600 residents currently registered [9]. This has resulted in SMS-livrddare-volunteers reaching victims before ambulances in 54% of cases and has helped increase survival rates from 3% to nearly 11%, over the last decade [8].

The system works by having willing civilians trained in CPR register to help if a cardiac arrest happens in their vicinity. When an emergency call is received, the geographical position of the caller is determined. If there is suspicion that a cardiac arrest has occurred the emergency operator activates a positioning system that locates the mobile phones of helpers connected to the service. In cases where a lifesaver is nearby, they are alerted via their mobile phone. Meanwhile ambulance and emergency services are alerted. The alarm to the SMS-lifesavers mobile phone comes as an SMS. The text message contains information from the emergency services about where the suspected cardiac arrest has occurred and the message also includes a map link which can be used to more easily find the location. The SMS-lifesaver also receives an automatically generated phone call to alert the user that an SMS arrived on the phone [6].

This is the basis for our implementation of this feature. We believe that this project has done incredible work and shown people a new way of being a part of first aid assistance, but that there are areas which could be refined and improved. For example, the project currently has users register two areas that they will likely be, one for day and one for evening, then uses these areas to determine people to contact. This, and other problems like it, will be what we intend to address in our implementation of the system.

5 Specification

This section contains the technical specifications of the modules and how we have designed them throughout the iterations.

5.1 Common Technologies

5.1.1 Google Cloud Messaging

5.1.1.1 Design Overview For our system we intend to utilize push notifications as the main way of initialising contact between our server and the users phone. As our system is initially being developed for the Android platform, we are going to implement the Google Cloud Messaging (GCM) [10] system as the main method of sending and receiving these notifications.

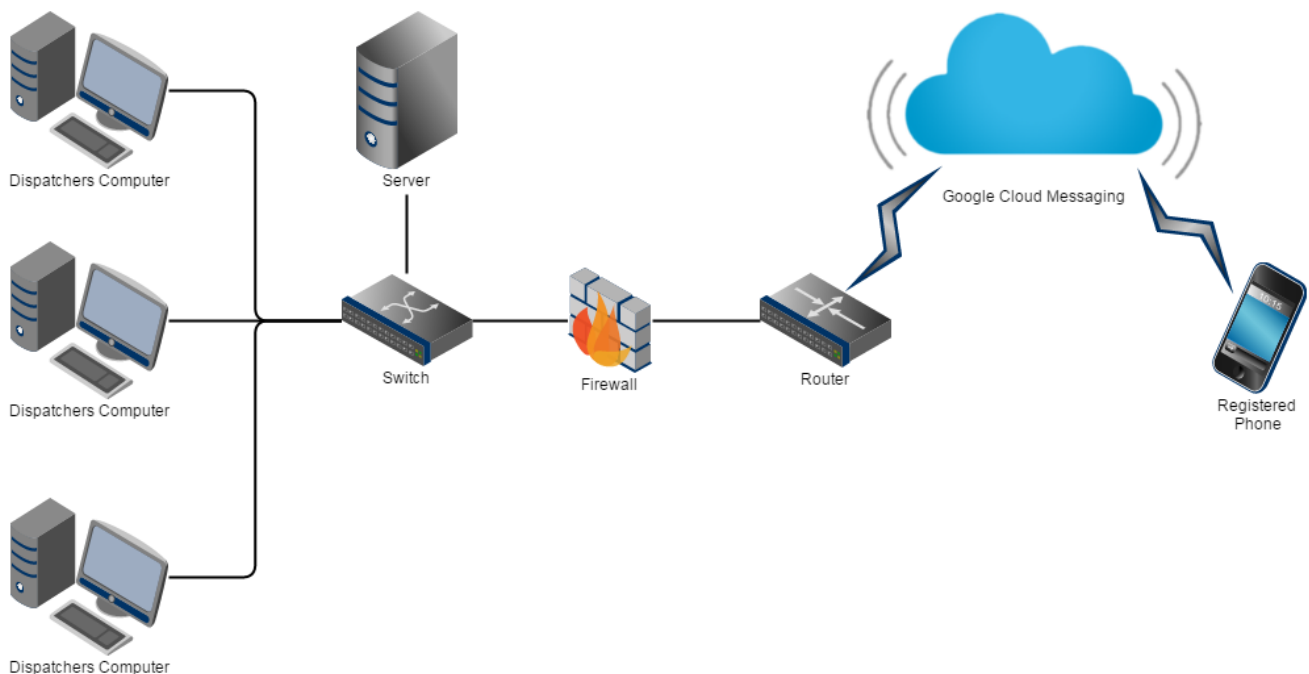


Figure 2: Network map of how our system will communicate between devices and the server

We have chosen to use this system for a few reasons. Firstly as our app is initially being developed for Android (due to current limitations with IOS) so using GCM is advisable as it is heavily embedded with the operating system and so reduces strain (such as power usage) [11]. GCM also allows the notifications to be received when the app is not running which is of huge benefit to the user who then does not have to keep the app open to offer their help. Other notable reasons include that it is free to use, can handle large scale push notifications [11], notifications can be canceled at a later time using a collapse key and that you can send data (up to 4096 bytes) as a payload to be used by the app. GCM can also be integrated with ISO push notifications [13] which could be useful if, in the future, an IOS app was being developed.

As a result of deciding to use GCM, we need to keep a database of the registered app users. This is because GCM uses a registration ID system to send a message to a specific phone, we need to store and relate this ID to a user of our system.

5.1.1.2 GCM Setup We intend to use GCM primarily for its ability to push notifications to a clients device. There are several things which we need to have set up before the notifications can be sent. Firstly, each phone will have a unique key associated with it which is used to identify an individual’s phone so messages can be sent to it. This is obtained by the app when it registers with the GCM service. In order for our server to send messages to this device we need to know and store this registration ID, therefore the device will need to send it to our server to be stored in a secure database. The detailed setup instructions are available directly from google and have example code to assist in the setup [14].

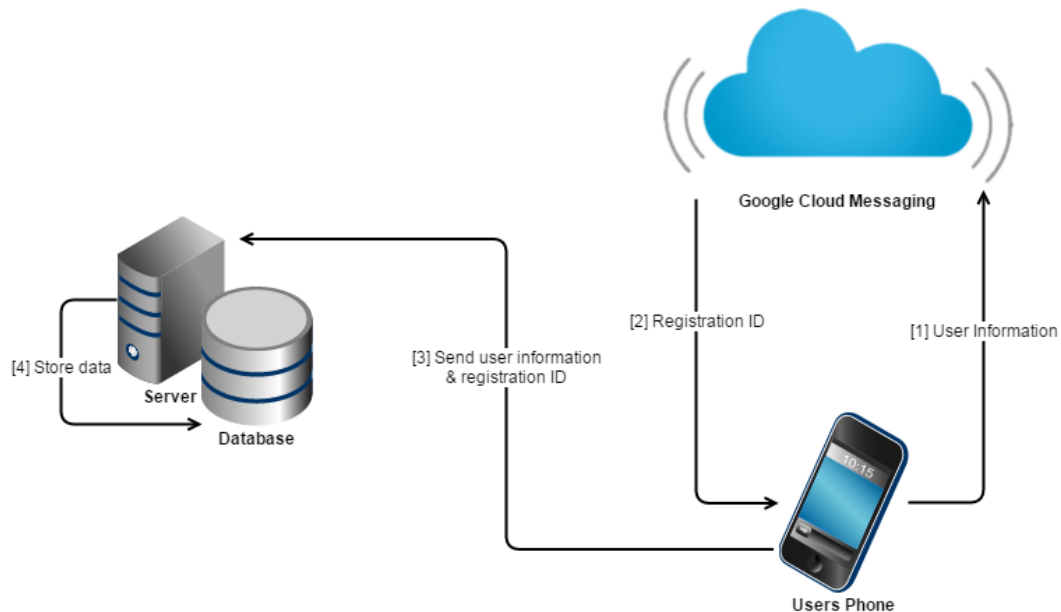


Figure 3: Diagram of the initial setup and registration with Google Cloud Messaging

We will also have to setup the database to store the information of the user that the phone is registered to along with the Registration ID (token) obtained from GCM. This design is detailed in the database section.

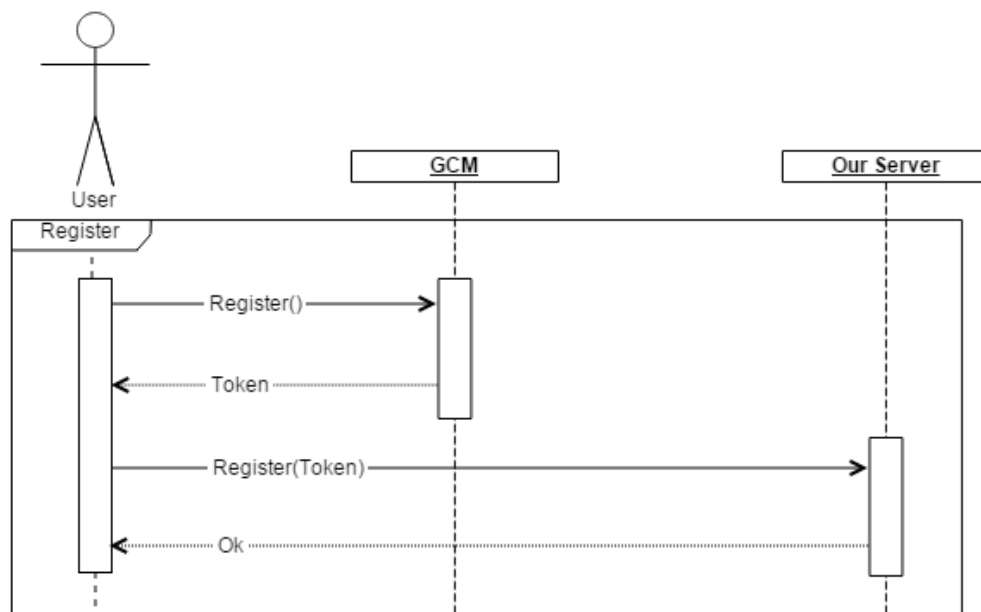


Figure 4: Sequence diagram showing interactions when registering a device

5.1.1.3 Sending Downstream Messages Once the initial setup is completed we can focus more on the message sending and receiving parts of the application. In order to push a notification to our users phone our server needs to send a request containing the registration ID and the message to Googles Messaging Server which then sends it directly to the device associated with that ID.

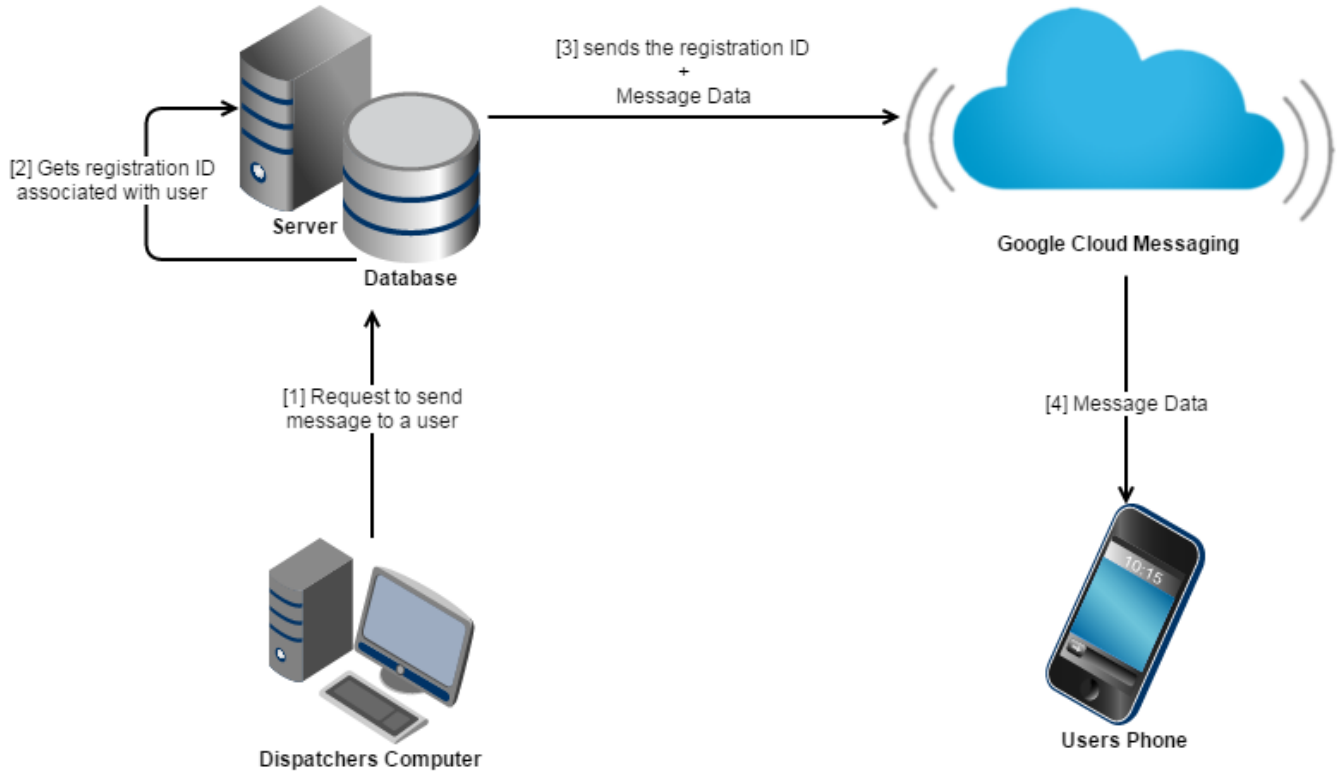


Figure 5: Diagram illustrating sending of a message to a clients device

We have decided to use the XMPP protocol as the connection between our server and GCMs server. This was chosen (over HTTP) for a few reasons. Firstly, the XMPP protocol is faster than HTTP and so would allow the system to send messages to users quickly which is a crucial aspect of any emergency system. It also uses the existing GCM connection on the device to receive the data, saving battery usage as you don't have to open your own connection to the server. XMPP does not however allow broadcast messages to be sent to multiple devices, instead you have to send a new message for each device you wish to contact. This should not present a problem in our system as we will only need to send a message to one device (in this iteration) and even if a later iteration was to require sending to multiple devices, it would be a small number.

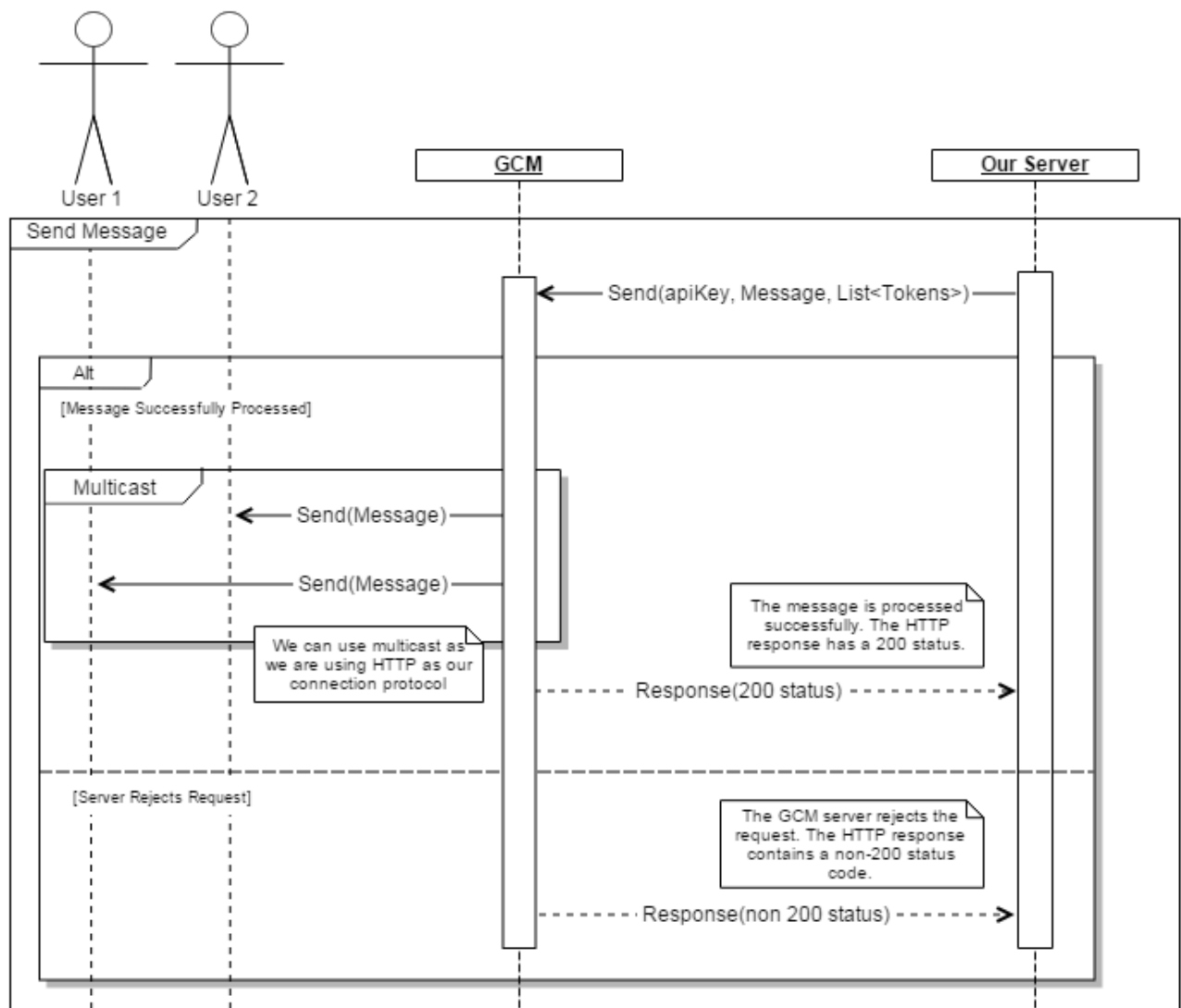


Figure 6: Sequence diagram showing the interactions when sending a message to the client device

Once a XMPP connection is established our server can use normal XMPP `message` stanzas to send a JSON-encoded message. For this iteration our message will contain five components, the registration ID of the device we are sending the message to, a message ID to uniquely identify this message, a collapse key we can use to overwrite the message later, a time-to-live after which the message will expire and not be sent, and the payload data we wish to send. The format of the message will look like this :

```

<message id="">
  <gcm xmlns="google:mobile:data">
    {
      "to": "REGISTRATION_ID",
      "message_id": "UNIQUE_MESSAGE_ID",
      "collapse_key": "UNIQUE_COLLAPSE_KEY",
      "time_to_live": "TIME_IN_SECONDS",
      "data": {
        "KEY": "VALUE",
      }
    }
  </gcm>
</message>
  
```

For each device message your app server receives from GCM, it needs to send an ACK message. If you don't send an

ACK for a message, GCM will just resend it. GCM also sends an ACK or NACK for each message sent to the server. If you do not receive either, it means that the TCP connection was closed in the middle of the operation and your server needs to resend the messages[10].

These response messages will need to be dealt with according to their responses. The ACK will be sent if the message was successfully delivered however there are two types of error messages (NACK and Stanza error) for situations such as Invalid JSON, bad registration ID or Device Message Rate Exceeded. Each of these messages contains an error ID and message which informs you of what the problem is so that it can be dealt with [15].

In some situations, we will include a payload of data that will be sent (in the message) to the clients device. This payload is easily incorporated into the message and forms part of the JSON-encoded message string. This payload data has no limit to the number of key-value pairs however there is a total limit of 4kb maximum message size. String values are recommended to all other data types would need to be converted to strings before sending them to the device [15].

5.1.1.4 Sending Upstream Messages We can also use GCM to send upstream messages from the clients device to the server via Googles CCM (Cloud Connection Service). This works by embedding the servers registration ID (obtained when registering for the GCM service) into the clients software and passing this ID along with a message to the GCM service to be forwarded to the server.



Figure 7: Diagram showing the sending of a message from the client device to the server

This will once again use the XMPP protocol for the reasons stated in Sending Downstream Messages and then we can use normal XMPP `<message>` stanzas to send a JSON-encoded message in the following format[25] :

```

<message id="">
  <gcm xmlns="google:mobile:data">
    {
      "category":"com.example.yourapp", // to know which app sent it
      "data":
      {
        "KEY":"VALUE"
      },
      "message_id":"UNIQUE_MESSAGE_ID",
      "from":"DEVICE_REGISTRATION_ID"
    }
  </gcm>
</message>
  
```

This message is then forwarded by GCM to our server and the message is parsed for its data. The device uses the `send()` method from the GCM API to construct and send the message. This takes the following format:

```
gcm.send(GCM_SENDER_ID + "@gcm.googleapis.com", id, ttl, data);
```

Where `GCM_SENDER_ID` is the stored GCM ID number of the server, `id` is the unique message ID, `ttl` is the time to live of the message (seconds) after which the message will expire and not be sent and finally the data to be sent [25]. This will produce a stanza in the format described above and send it to the server ID specified.

After the message is received from CSS by our server we are expected to send an ACK message back to google. This should be in the following format [25]:

```

<message id="">
  <gcm xmlns="google:mobile:data">
    {
      "to":"DEVICE_REGISTRATION_ID",
      "message_id":"MESSAGE_ID_OF_RECIEVED_MESSAGE"
      "message_type":"ack"
    }
  </gcm>
</message>

```

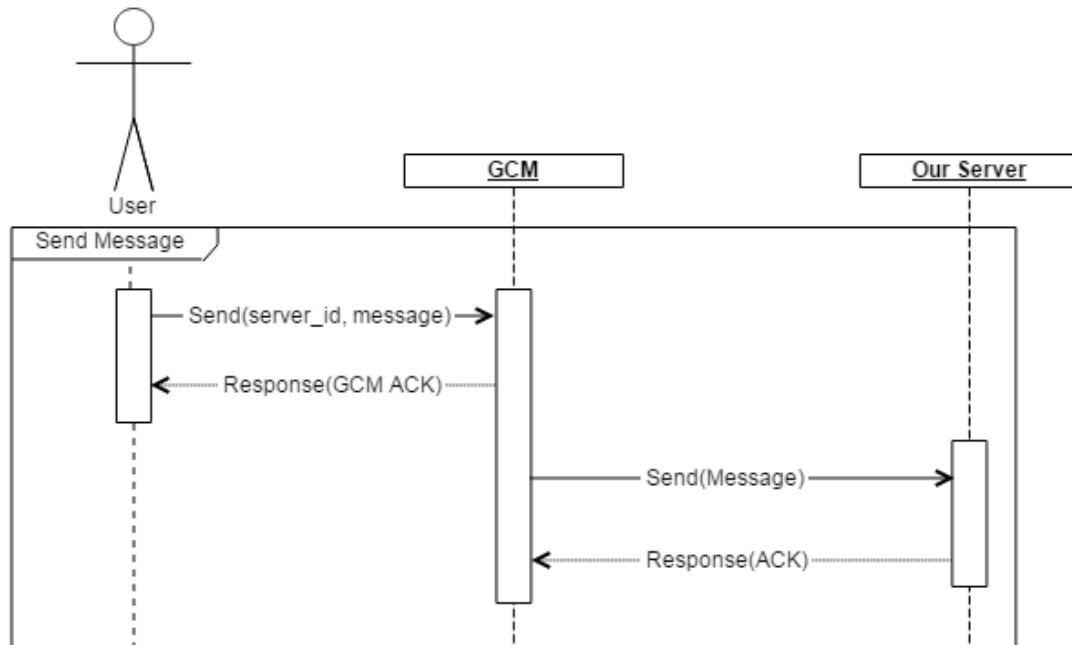


Figure 8: Sequence diagram showing the interactions when sending a message to the server from a client device

5.1.2 Database

It was immediately apparent that both the Emergency App and CPR System would need a database backend. To ensure we chose the best system, we investigated the three most prolific database management systems (DBMSs): MySQL, Oracle, and SQL Server.

Almost immediately, we discounted MySQL as being immature compared to Oracle and SQL Server. Transactions and stored procedures are a relatively recent addition to the system, and both are technologies that we will rely on heavily to ensure data is consistent and intact. It also has far fewer features relevant in enterprise environments, lacking fine-grained access control, table partitioning and disaster recovery.

Next, we scrutinised the remaining contenders. Ultimately, there isn't a lot of difference between them; SQL Server has a marginal advantage with in-memory tables and better performance in write-intensive environments, while Oracle is supposedly more suited to applications with equal read and write traffic due to its locking system.

In the end, we decided to go for SQL Server due to its Spatial Data extensions, which would be used particularly heavily in the CPR System. This functionality allows us to do accurate geometric calculations, like finding the distance between two sets of coordinates, within the database itself. In addition, SQL Server is renowned for its stability, with a transaction and journaling system that detects and automatically fixes errors, preventing corruption and increasing uptime - all of which are desirable traits in such life-critical applications.

5.2 CPR System

5.2.1 Iteration 1 - Basic Functionality

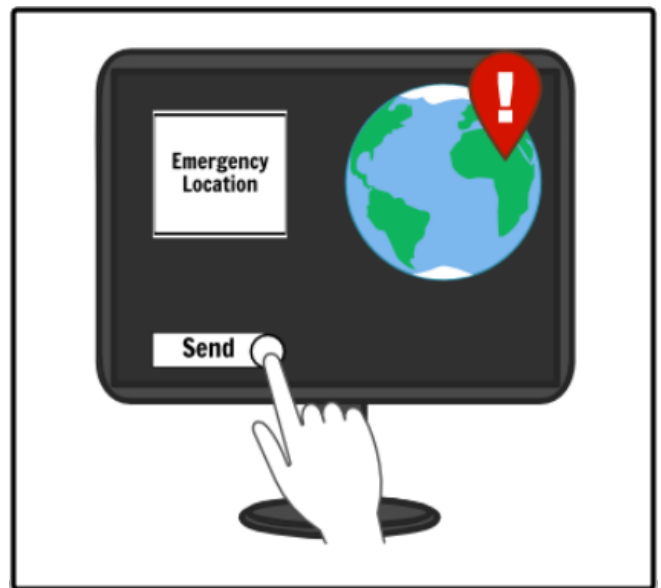
5.2.1.1 Aims This iteration develops the core functionality of the CPR system; it is intended to be the simplest application possible that has the required functionality. Subsequent iterations will refine and build on top of its services and components.

At its most basic level, the system needs to be able to send a message to a responders devices to notify them of the location of an emergency. This individual should be the closest person in the database to the incident. They are then expected to attend the emergency location and provide assistance where necessary. The individual is assumed to have the appropriate qualifications and training which has been verified, and have willingly signed up for the service.

5.2.1.2 Storyboard This is a storyboard to help visualise the intended functionality of the system.



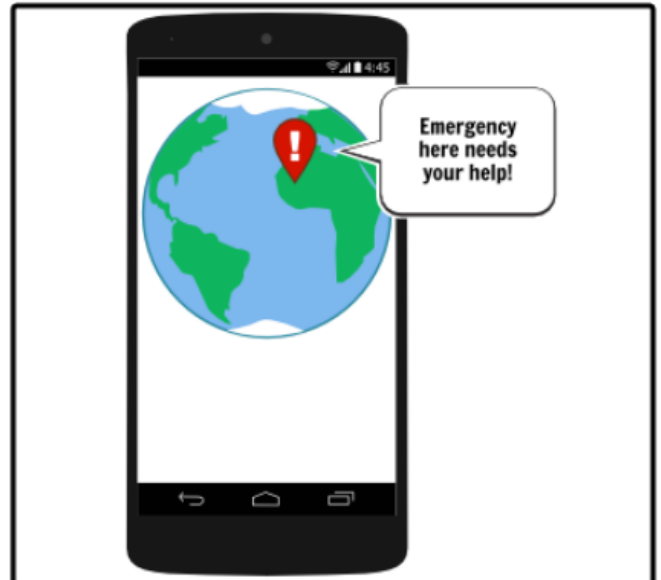
The emergency Dispatcher gets a call about an emergency situation.



It is an appropriate emergency to ask for help from anyone nearby. The dispatcher sends the help request.



The closest person to the emergency is alerted to the situation.



They are shown the location.



If the responder is available to help they make their way to the emergency.



Once they arrive they help as appropriate.

1. The emergency services receive a call detailing a medical emergency which is triaged.
2. While waiting for a response vehicle to arrive, the dispatcher has the option to send the emergency location to a trained responder (first aid or CPR) who may be able to attend quicker than the emergency services. This option to request this responders assistance should be limited to certain situations and locations so that responders are not sent to potentially dangerous environments.
3. Once the request has been sent, the responder is notified that an emergency requires their presence. The notification shows the responder the location of the incident
4. The responder then decides if they are able to attend the emergency to help the situation and makes their own way there.

In theory, the responder gets to the location quicker than an emergency response and they are able to provide first aid to those who need it until the ambulance arrives.

5.2.1.3 Sending Notifications In order for responders to attend an emergency, they need to know where it is. The standard way of doing this is to send a latitude and longitude, which we will include in the payload section of a GCM message. This information can be directly passed to all mapping applications to plot the location. The structure of the message data should be as follows:

```
...
"data":
{
    "message_type":"new_emergency",
    "longitude":"VALUE",
    "latitude":"VALUE"
}
...
```

In this message the `"message_type"` field describes what kind of message this is. To send a new emergency to the user the value of this field should be `"new_emergency"`. This is checked when the message is received and the appropriate action is taken (i.e. a new emergency alert is created). The alternative is `"close_emergency"` as the value and this is used when the dispatcher wishes to cancel the assistance of the user either because they are no longer required or the casualty has been dealt with and the emergency case closed (see App CPR pane for more details).

The other data we need to send is a coordinate pair corresponding to the location of the emergency, (where longitude and latitude values are in the range of [-180, 180] and [-90, 90] respectively [16]) as this is a standard way of referencing a location and is the coordinate system major map applications use. This will allow us to parse the coordinates directly into a map app on the device to show the user where to go. This can be easily done in two ways, one is opening the default maps app with the location entered into a geo-URI [17] and opening it. This URI contains the coordinates and when called opens the default map with the location shown as a drop point (Example: `"geo:0,0?q=34.99,-106.61(Emergency)"`). The second option is to incorporate the Maps API into our app, this would allow us a greater degree of control on what the user can see and also disable features (such as removing the emergency marker). The implementation of this is relatively easy and adding a marker simply uses the `LatLng` data type [18].

```
public void onMapReady(GoogleMap map) {
    map.addMarker(new MarkerOptions()
        .position(new LatLng(10, 10))
        .title("Emergency"));
}
```

Integrating a map into our app is the route we have decided to go down as this allows us greater granularity and control over what the user sees and is able to do. This should be shown to the user when they click on an emergency notification.

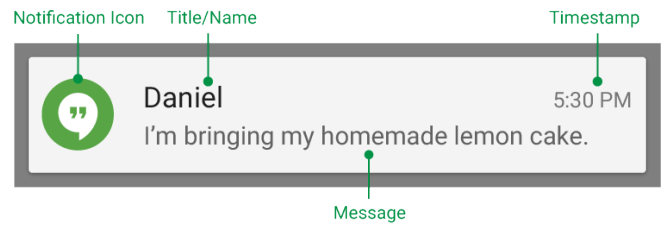
5.2.1.4 Notification Interaction and Alert When an emergency is sent to the phone the user will need to be notified immediately so that they can attend the scene as quickly as possible. The first step towards doing this is to create a popup notification so that the user can immediately see (either on top of other applications or on the lock screen) that their assistance is required.

There are two main factors of information that the user needs to be informed of, the first is that their assistance is required, the presence of this notification does imply this however it should also be stated somewhere in the notification that this is an emergency situation. The second is the location of the emergency, for this we have identified two main points of information that are useful to the user. The first is the address of the emergency location, this should be present so that if the user knows the area around them they can instantly recognise where they are needed and start making their way towards it. It also allows them to give directions, say to a taxi driver, directly from the notification without having to open the app at all. The second is the distance to the emergency that the user is currently. This information is very useful to the user as it allows them to instantly gauge how long they will take to attend the scene and make decisions based off this such as the best mode of transport.

To provide both of these points to the user we will need to use Androids built-in location API, as the information provided to the device is in coordinate form. There are several features which will allow us to obtain the required information, the first is in the Geocoder class of the location API [19]. The method `getFromLocation()` returns a list of addresses, the first is in the Geocoder class of the location API [19]. The method `getFromLocation()` takes a coordinate pair (latitude and longitude) and returns a list of addresses which are known to describe the area immediately surrounding

the coordinates. Upon calling this we can then extract the address line by line using the associated methods with the `Address` class [20] and insert them into our notification. We can also use the `Location` class of the location API to get the `distanceTo()` a destination [21]. This takes a location as a parameter (which we can set the longitude and latitude of) and returns the distance in meters to the destination from the users current location.

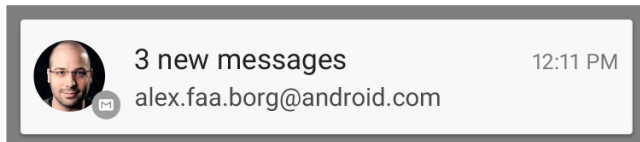
Android supports a variety of notification formats [22] however they all have four common features, a Title/-Name, Notification Icon, Timestamp and a Message. Our notification should also have these features, the title should be a common one (for all emergency notifications) which relates to the fact that the users assistance is required at an emergency. A title similar to Medical Assistance Required should both inform the user of what the notification is for and grab their attention.



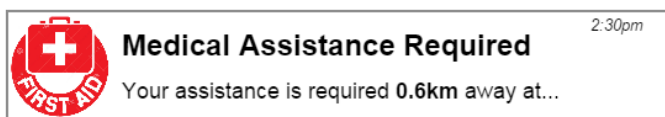
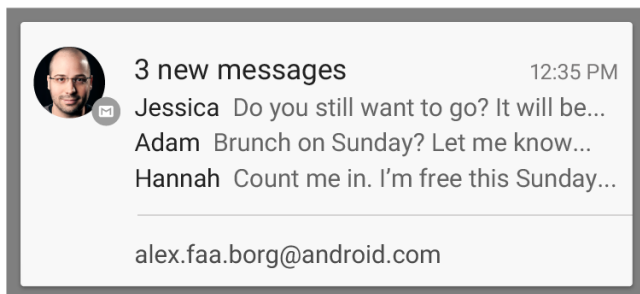


The notification icon should also be striking to grab their attention, and also needs to be unique to the app and tell the user, at a glance, the nature of the notification. Something similar to this image would be best as the image is striking and so should catch the users attention while being unique among other notification icons and being related to the theme of the notification.

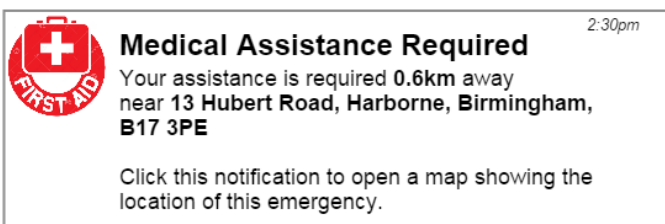
The timestamp of the notification should be set to the time that the push notification was received and the message body should contain both the distance to and the address of the emergency. Android allows expandable layouts [22] which allows the notification to be minimal initially and expand when clicked on. The minimal layout still contains both the title and the icon (along with a line of text) which means the user can still instantly see what the notification is about and can click on it to expand the description (which contains the address).



EXPAND ↓ ↑ CONTRACT



Minimal notification



Maximized notification

This is a design shown how our notification might look to the user on either the lock screen or while actively using the phone. Upon clicking this notification the app will be launched and show a CPR pane which would not be normally accessible. This pane contains a map with the location of the emergency shown clearly with a marker, the users current location and a directions button which will plot a route to the emergency from the users current location.

5.2.1.5 Cancel Notification The dispatchers should also be able to cancel the assistance request remotely for a variety of reasons such as the emergency has been dealt with or paramedics have already arrived to name a few. To do this we will utilise the collapsible feature of messages sent over GCM [23] which allows us to overwrite

previous messages with the same `collapse_key`. We can combine this with the field in the payload of the message `"message_type"` which is set to `"new_emergency"` when the dispatcher wishes to ask for assistance. The new message should have a `"message_type": "close_emergency"` so that, when the message is read the message type should be checked and the appropriate action taken, in this case it should, if its currently accessible, hide the CPR pane and clear any associated data. A message field should also be present which will be displayed in the message field of the notification.

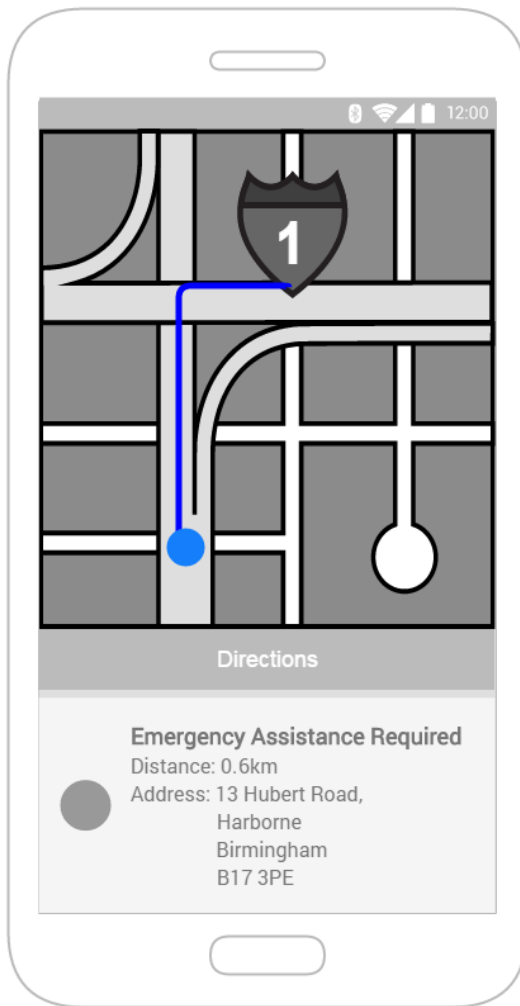
```
...
"data":
{
```

```
    "message_type": "close_emergency",  
    "message": "Emergency resolved"  
  }  
  ...
```

5.2.1.6 Notification Sound of the App This was the first thing which we thought the user would like to customize as this has been commonplace among phones for years and our users would expect to be able to do this with our app. However, after some discussion we thought about how this might negatively affect the users ability to be alerted to incoming emergencies. For example, if a user was allowed to set their own notification sounds and they chose one that was the same (or similar) to their message alert or ringtone then they might be more inclined to ignore the phone for a period of time believing it was just a regular notification. This is more likely as our app is likely to be only used occasionally when the individual is the closest responder to an emergency, it will be a case of setup and forget for most users who might even have forgotten they installed it until they are being asked to help.

For this reason we have decided against allowing the user to change the notification sounds. We intend to use a custom alert noise which is unlike any other provided by default on the phone. We believe that keeping this sound is more beneficial than allowing the user more personalisation as they will not recognise the sound and therefore are more likely to check why their phone is making a noise.

5.2.1.7 CPR App Pane This is the design prototype for the CPR pane of the application. By default (i.e if its opened without an emergency) this shows a blank map and information pane which, when an emergency notification is received from the dispatchers, changes to display the information for that emergency. Upon receiving the notification (with the payload data) the coordinates are sent to this app and become the destination marker of the map.



The associated information is displayed at the bottom third of the pane which can be obtained (as in the Notification Interaction and Alert section) from coordinates provided using the location API. The distance measurement should be re-calculated at a set interval so that the value is updated while moving.

The map also contains a Directions button which, when pressed, will start navigation assistance from the users current location to the emergency.

We have decided to implement an in-app map view rather than opening the directions in the default map app because it gives us a greater degree of control over what we can show the user and allow them to interact with. For example it allows us to disable the draggable state of the marker [18] so that the user cannot accidentally move it to the wrong location and then delay their response time. It also allows us to display our own content on the screen (in the lower third) at the same time that the user is getting directions to the emergency. This is currently displaying the address and distance of the emergency from the user however it could be used to display extra information as appropriate.

There are two ways for this information to be hidden once again. The first is that the phone receives a new notification from the dispatchers which contains the same `collapse_key` as this emergency (detailed in Cancel Notification) in this case it should clear any associated data from the app (the destination marker and info pane). The second way is when the app is first loaded a timeout timer should be started which contains a reasonable amount of time to allow the user to attend the scene, but once expired should hide this pane from view and clear any previous emergency data. A timer of 60 minutes should be enough time for any first responder to attend a scene and

pass the casualty over to the emergency services (this time should in fact be more than enough). This is so that if, for some reason, the collapse message is not received the information will be removed on its own accord

5.2.1.8 GPS Location We need to maintain a database of registered users locations so that we can target an individual who is the closest person to the emergency and send a notification directly to them via GCM. There are a number of ways which we could implement this, however we decided to (for this iteration) push the location from the device to our servers on a regular time interval. A time period of 1 hour is what we will use initially, this should be enough to maintain a reasonably accurate location of the user (more accurate when they are stationary for a while and less accurate while traveling) while not heavily impacting battery usage or performance of the device with more frequent updates. While not being a very complex or clever system this will be enough for us to get started and will be sufficient for this iteration.

An alternative implementation would have been to push the location of all emergencies to all phones registered on the service. It would then be upto the phone to determine if they were close enough to alert the user to the emergency. We decided against this method for a few reasons, firstly it does not scale well with a large user base. If this was to be rolled out nationally you could easily be sending hundreds of emergencies to thousands of phones on a daily basis. This would also drastically affect battery life of the users device as it would then have to process each emergency received to determine if it was near them, possibly leading to increased user dissatisfaction and uninstallations of the

app. Finally, there would be a lot more data being sent and received in this implementation. Rather than sending each clients location once every 1 hour (for example) you would have to send each emergency to every registered phone which would quickly rack up with multiple emergencies per day.

Other ideas we thought about were having the user subscribe to an area that they are likely to be in (possibly one for work and home) then using this location to send messages to people who are likely to be in the area. This is currently how the Swedish project Project SMS-livrddare [6] is contacting its users. We feel however, that this is not accurate enough as there will be situations when they are not around the area (e.g traveling to another city) and using the GPS location of the phone would allow us to contact users with greater geographically accuracy.

To send this data to our server we decided to use GCMs upstream message feature to send the message via Googles CCM (Cloud Connection Service). We chose this over establishing our own connection for a few reasons but primarily for increased efficiency. GCM upstream messages are sent over the same connection used for receiving, which is managed by the operating system and is left in an always open state. It makes sense to utilize this connection rather than use excess resources which would decrease performance (such as battery) [26]. It is also very easily implemented as the API provided does most of the work that would have to be managed if we were to implement our own connection (e.g. checking if the network is available) [27]. It is also not necessary to establish our own connection as the only data we will be sending to the server (in this iteration) is a GPS coordinate pair for the users location, this can be easily converted into string format and sent as a payload GCM message.

The message should be sent according to the specification detailed in the GCM justification section under Sending Upstream Messages. This details that the sent message will have the users registration ID attached which the server can use to associate this sent location with a registered user. The structure of the message data should be as follows:

```
...
"data":
{
  "message_type":"location_update",
  "longitude":"VALUE",
  "latitude":"VALUE"
}
...
```

This message, when received by our server, will then be able to parse the message type to see that it is a new location that's being sent and add it to the database appropriately. The longitude and latitude values are the devices current location and can be obtained by the `getLastLocation()` method of the Location API [28]. Android's Network Location Provider determines user location using cell tower and Wi-Fi signals, providing location information in a way that works indoors and outdoors, responds faster, and uses less battery power. This method returns the most recent location currently available, if another app has recently updated the devices location then this will be used otherwise it will be updated before the most recent value is returned.

5.2.1.9 Database Design The simplicity of this iteration means that it does not require a complex database. We fully intend to have to make sweeping changes to this design in future iterations, however it should form an easily-expandable base on which to build.

The DBMS used for this system will be Microsoft SQL Server 2014, due to its prevalence in professional applications, spatial data types and comprehensive high-availability features, including redundancy and failover, which are critical for a system as important as this.

5.2.1.9.1 Requirements

- *Registration details of responders*
This need only be a unique identifier and forename and surname for now - it can be trivially expanded later on, so we will not dwell on implementation details.
- *Responders devices*
Each responder can (and should) register as many devices as they have to their account, in order to increase the chances of them being successfully notified that their assistance is required. In order to do this, we need to

store information about responders devices, in particular the push notification key that allows us to tell GCM (or any alternate service, such as APNS) which device to send notifications to.

- *The locations of these devices at any given time*

To be able to find the closest responder to the incident, we need to track the locations of all responders devices in as close to real-time as possible. We could only keep the latest position, however maintaining the full history (or at least a certain amount of it) is a trivial change, and could be used in the future to improve the responder selection algorithm.

- *Incidents, and the responder chosen to attend that incident*

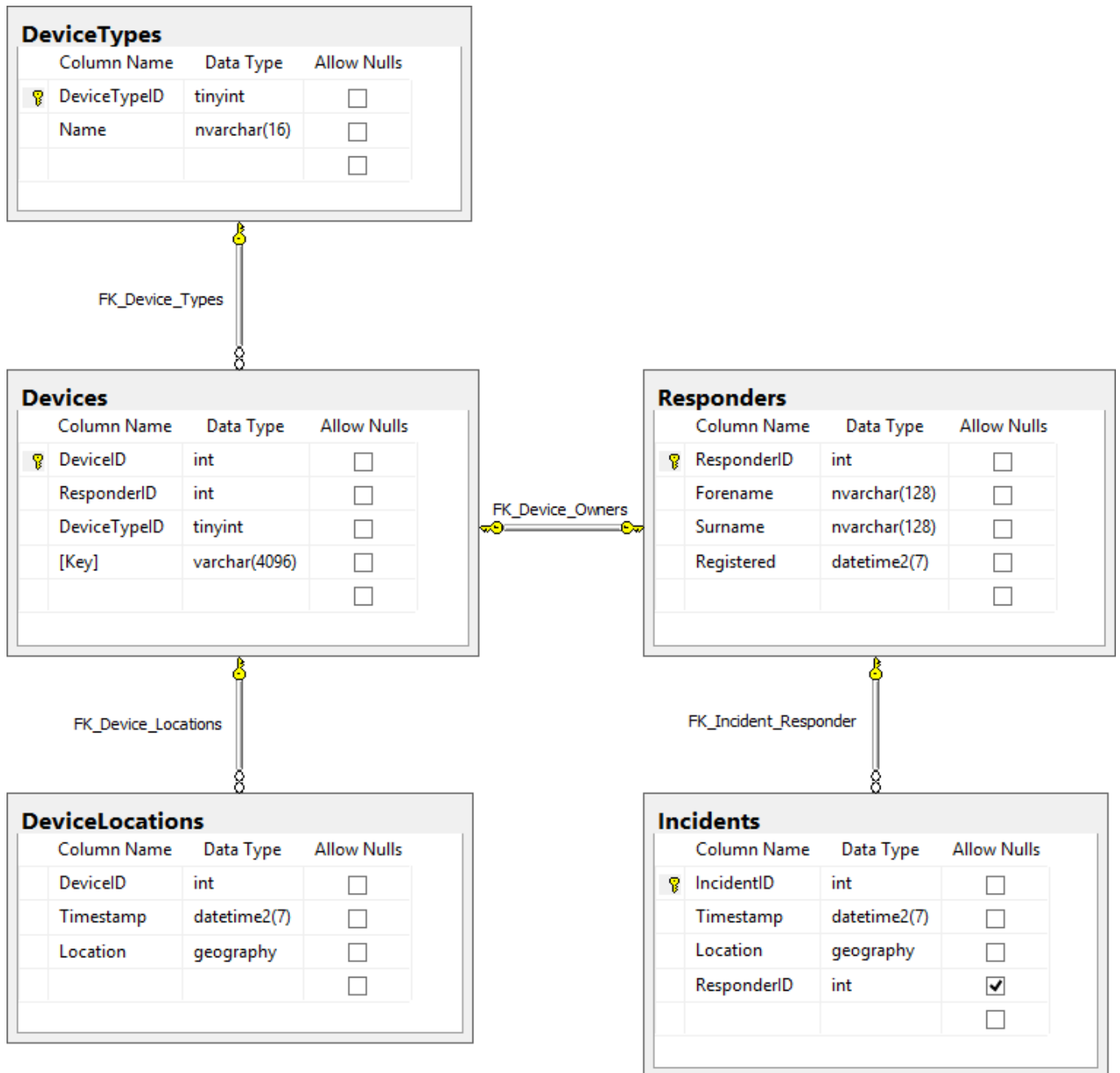
The database needs to be able to store the location of incidents so it can send these to responders. It must also keep a history of which responder attended which incidents for logging purposes.

5.2.1.9.2 Data Types Location data is commonly represented as a latitude and longitude pair, however modern databases have dedicated spatial data types. SQL Server 2014 is no exception; it has the `geography` type for ellipsoidal data. The key `geography` instance type that we will be using is `Point`: a 0-dimensional object representing a single location. We will use it to identify the whereabouts of incidents and responders devices. It has the added benefit of supporting elevation, should we need it in the future to increase accuracy of location data.

Primary keys will be `ints`, unless we can guarantee they will not overflow if a smaller width type is used. Unfortunately SQL Server only supports signed types, so 32-bit integers will allow up to 2,147,483,647 (2³¹ - 1) rows per table. Considering there are roughly 65m people in the UK, this is more than enough to store all possible responders. Even at this limit, the type is large enough to handle each of them having 33 registered devices each - also an infeasible number. As already mentioned, there are an estimated 60,000 [2] incidents in the UK every year that this system could be relevant to. Assuming this figure doesn't exceed, an `int` primary key will sustain the system for 35 millennia. The only exception is device types: there are less than 255 services offering push notification facilities, so a `tinyint` will suffice for this purpose.

Device keys are allowed to be up to 4096 bytes, as GCM `registration_ids` can be up to 4KB in size, however in practice they will be much smaller than this - it is this long to handle edge cases.

5.2.1.9.3 Entity Relationship Diagram Entity relationship diagram of the database.



N.B. `Incidents.ResponderID` is nullable as it is conceivable that an incident might be created, and it take a few moments for a responder to be assigned to it.

5.2.1.10 Selecting the Responder to notify In this iteration, we are simply choosing the single closest responder to the incident. In terms of the above schema, we need to alert the owner of the device whose latest position is closest to the incident.

We have a table of device locations; the first step is to extract the latest location of each device:

```
SELECT LatestLocations.DeviceID, LatestLocations.Location
FROM (SELECT DeviceLocations.DeviceID, DeviceLocations.Location,
ROW_NUMBER() OVER (PARTITION BY Devices.DeviceID
ORDER BY DeviceLocations.Timestamp DESC) AS Rank
FROM Devices
INNER JOIN DeviceLocations
ON DeviceLocations.DeviceID = Devices.DeviceID
```

```

) AS LatestLocations
WHERE LatestLocations.Rank = 1

```

As well as spatial data types, SQL Server also includes operations on these types, one of which is `STDistance`, which returns the shortest distance between two `Points`. We can now intersect this with the known location of the incident, producing a list of `DeviceIDs` in ascending order of distance to the incident.

```

-- will hold the location of the incident
DECLARE @incident geography;

-- look up the location of the incident with identity 'x'
SELECT @incident = Location FROM Incidents WHERE IncidentID = x;

-- sort devices by their proximity to the location of the incident
SELECT LatestLocations.DeviceID,
       LatestLocations.Location,
       @incident.STDistance(LatestLocations.Location) AS Proximity
FROM (SELECT DeviceLocations.DeviceID, DeviceLocations.Location,
            ROW_NUMBER() OVER (PARTITION BY Devices.DeviceID
                               ORDER BY DeviceLocations.Timestamp DESC) AS Rank
      FROM Devices
      INNER JOIN DeviceLocations
        ON DeviceLocations.DeviceID = Devices.DeviceID
      ) AS LatestLocations
WHERE LatestLocations.Rank = 1
ORDER BY Proximity ASC;

```

From here, it is trivial to look up the owner of the closest device and notify all of their devices of the emergency.

6 Project Management

7 Personal Reflections