Imperial College London

Active Location and Emergency Reporting Tool (A.L.E.R.T)

Providing more accurate location information for emergency authorities

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1. Introduction

Emergency authorities in the UK such as the police, fire department, and ambulance service respond to an average of 85,000 calls per day. (British Telecom) In many situations, the time taken to reach the scene makes a difference between life and death. Active Location and Emergency Reporting Tool (A.L.E.R.T) seeks to reduce the response time of emergency responders by providing more accurate location information. The main technology involved is Assisted Global Positioning System (A-GPS), which pinpoints the origin of an emergency call more accurately than does the current technology of Cell Identifier (Cell-ID). A.L.E.R.T can be implemented either through the control plane or the user plane. We propose to conduct a feasibility study of A.L.E.R.T within London using the user plane to quantify its benefits. Subsequently, a more informed decision can be made regarding a nation-wide implementation of A.L.E.R.T and the choice of technology involved.

2. Current System and its Limitations

Our proposed solution can be integrated into the current emergency reporting system and yet be able to address its limitations by accurately pinpointing the location of the call from a mobile phone. Presently, when 999 is dialled in the United Kingdom (UK), the call will be first routed to an operator from British Telecom (BT) or Cable and Wireless (C&W) who will ask whether police, ambulance, or fire service assistance is required. The operator (commonly known as the Public Safety Answering Point or PSAP) then redirects the call to the appropriate EA that manages the area where the call originated. For example, a call from the London area requesting for police assistance will be redirected to the Metropolitan Police Service (MPS). Location information is stored in an emergency service database and available to EAs through BT's Enhanced Information Service for Emergency Calls (EISEC). C&W operate a similar service database system as well. Due to privacy concerns, this information is only available to authorized users of the EA for about 30 minutes.

There are two different ways of obtaining location information. If the call originates from a landline, the location is mapped to its registered address which is accurately known. However, if the call is from a mobile phone, location is mapped through a technology called Cell-ID, which is not as accurate as other technology available today.

According to the Global Standard for Mobile communication (GSM), a cell is the geographical area that a Base Transceiver Station's (BTS) transmission covers and each cell has a unique Cell-ID that identifies it. By identifying which cell the phone is connected to, the physical location of the phone can be deduced to be within a radius of the BTS.

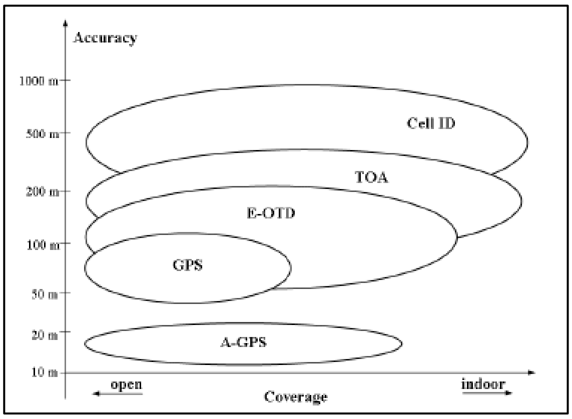

Figure 1: Qualitative comparison of the accuracy and coverage of various location techniques. Cell-ID, Enhanced Observed Time Difference (E-OTD) and Time of Arrival (TOA) are strictly control plane techniques; GPS and A-GPS can be used as both user and c and control plane solutions. (Trevisani and Vitaletti 2)

Cell-ID-based location is simple and inexpensive but inaccurate because of several factors. Firstly, the physical size of a cell varies significantly, ranging from tens of metres to several kilometres in radius. Hence, the location is only deduced to be within a certain radius of the BTS. Generally, in the downtown part of a city with many BTS, Cell-ID tends to be more accurate than in rural areas where one BTS covers a large geographical area. However, the exact location of the caller is still unknown. Also, location from Cell-ID is based on the assumption that the mobile phone is connected to the nearest BTS which is not always true. Thus, in situations where the mobile phone is not connected to the nearest BTS, the accuracy of the location information is seriously affected. (Trevisani and Vitaletti 1-4)

Figure 1 illustrates that Cell-ID has very poor accuracy, especially as compared to the other location techniques. This is important because, according to BT, 62% of emergency calls originate from mobile phones today. (British Telecom) Although very accurate location information is not needed when redirecting the call to the relevant EA, it can help the EA reduce their response time since emergency responders will know exactly where to go. Hence, we propose using A-GPS to relay more accurate location information during an emergency call.

3. Proposed Solution

Two approaches can be used to relay more accurate location information to EAs; namely, the control plane or user plane. In the control plane solution, the network operator (e.g. O2, Vodafone, and Orange in the UK) would need to upgrade their current signalling equipment to implement the SS7 protocol defined by the International Telecommunication Union Telecommunication Standardization Sector (ITU-T). The equipment needed is a Serving Mobile Location Centre (SMLC) to determine the position of the mobile phone and a Gateway Mobile Location Centre (GMLC) to relay the position data. After installation, the system will be able to obtain location information through a variety of methods such as those listed in Figure 1. While the control plane solution is reliable, secure, and backward compatible with older 2G mobile phones, it poses significant cost and complexity for network operators to interface with the different technology standards (e.g., 2G GSM, 3G UTMS, and 3G CDMA).

The user plane solution avoids costly and complex modifications to network signalling equipment by using a data connection to send the location information to a server. This involves installing third-party software onto the mobile phone which will control the formatting and uploading of the data. The disadvantages of this solution are that it is incompatible with older mobile phones and requires a data connection.

3.1 Similar Solutions

The design of A.L.E.R.T is based on similar solutions that have been implemented in other countries such as Japan, South Korea and the United States of America (USA). However, it can be adapted to the unique circumstances in the United Kingdom.

3.1.1 Case Study of Japan

There are 122 million 3G subscribers in Japan, translating to a 95% 3G penetration rate with at least 95% of them having Global Positioning System (GPS). (Meeker) As a result, a large number of emergency calls are made from mobiles that are 3G and GPS-enabled. In Japan, the law is such that phones must to send the callers' location information to the emergency service, unless the dialled number includes the prefix "184". The Ministry of Information and Communications (MIC) has also set a non-mandatory target for the mobile network operators to provide location information of 15 metres accuracy with Time-To-First-Fix (TTFF) within 15s under open sky. (Mott MacDonald, "Japan Case Study" i)

In order to achieve this target, network operators need to use both network-based and GPS-based techniques to send location information. They use a hybrid method which chooses the best positioning method depending on the emergency caller's current situation. For example, if both mobile internet and GPS signals are available, A-GPS is used. If only GPS signals are available, then standalone GPS solution would be used instead. For non-open sky condition, Cell-ID and Observed Time Difference of Arrival (OTDOA) methods are used. (Mott MacDonald, "Japan Case Study" 1) By intelligently choosing the positioning technique, the location information sent is optimised in terms of accuracy and reliability for all physical conditions. This hybrid solution is implemented through Qualcomm's gpsOne chipset. (Miyazono)

NTT DOCOMO, the largest mobile network provider in Japan, implemented "advanced emergency call functions." This includes two main functions: initial position function and location searching function. The initial position function reports the caller's location information to emergency services when the call is initially made. It is implemented in a two-step response as follows: during the first step, approximate location information obtained by Cell-ID is sent; in the second step, more accurate GPS-based location information is sent. (Aso, Nakao and Sokei 38)

When an emergency call is made, the Local Mobile Multimedia switching system (LMMS) determines the caller number identification and sends a request to the emergency service concerned. LMMS then confirms the caller's intention to report location information and requests the Radio Network Controller (RNC) to perform cell level positioning. When this information is received, LMMS sends the LoCation Services (LCS) Client ID to both the emergency attendant board and External Business user Service Control Point (EBSCP). EBSCP forwards the location information to the EAs who acknowledge with a receipt signal of the information. LMMS determines whether the mobile phone supports precise positioning. If so, it requests the RNC for GPS positioning; if not, it requests for cell level positioning again. When precise location information is available, RNC requests the phone to perform A-GPS positioning and the information is relayed back to LMMS via RNC. The step is repeated, similar to how cell level location information was previously obtained. The two-step response terminates when LMMS gets the receipt from EBSCP again. (Aso, Nakao and Sokei 39)

The location searching function acquires the caller's location information for the EAs. Due to privacy and security issues, this acquisition of location information is only available within 20 seconds of the emergency call being completed. The acquisition procedure is similar to that of the initial location service. However, it differs in that the function is initiated by the emergency service sending request to the EBSCP which forwards the request to LMMS after initial position function has occurred. The LCS Client ID is used to identify the concerned mobile phone. (Aso, Nakao and Sokei 40)

3.1.2 Case Study of South Korea

South Korea has the fastest network and one of the most advanced Location Base Services (LBS) in the world. Its 4G LTE network presently has a market penetration of more than 30%. South Korean law requires that all mobile phones sold in the country must support GPS, and all of its three mobile operators use the same GPS-based LBS technology – gpsOne. gpsOne is available on the control plane for emergency services to pinpoint a caller's location to within 5-10 metres accuracy in the outdoor conditions. (Mott MacDonald, "Korea Case Study") Moreover, the Korea Electronics and Telecommunications Research Institute has been tasked by the Korean government to start research into a location technology that can improve the location accuracy to within 5 metres. (Tan)

3.1.3 Case Study of USA

In USA, the E9-1-1 system has been implemented to “improv[e] the reliability” and the “accuracy of the location information transmitted with a wireless 9-1-1 call.” (Mott MacDonald, “Assessment of Mobile Location Technology” 41) The Federal Communications Commission (FCC) has mandated the mobile operators to provide a location accuracy of within 50 meters for 67% of the time for handsets. The Public-Safety Answering Point (PSAP) has to obtain the location information of emergency callers within 3-5 seconds. (Mott MacDonald, “USA Case Study” 1)

There are two key solutions used in USA to obtain location data, namely the A-GPS and the Uplink Time Difference of Arrival (UTDOA). In USA, similar to the case in Japan, a hybrid solution is usually used to obtain location data, where A-GPS is the primary solution and UTDOA is the back-up solution (used when less than 4 satellites are found, rendering A-GPS useless). All these are implemented in the control plane. (Mott MacDonald, “USA Case Study” 9)

Most of the cost of the E911 system was incurred by mobile operators to upgrade the equipment and handsets in their respective networks. For example, UTDOA requires installation of network equipment at base station in order to triangulate and obtain location information of callers. Hence, this solution is very expensive for operators and it struggles to achieve FCC’s requirements for 3G (W-CDMA) networks. (Mott Macdonald, “USA Case Study” 8) Within CDMA operators, 98% of the handsets have GPS chipset as they were mandated to replace handsets without GPS. Emergency services also had to spend US$5.4 million to upgrade 74 PSAPs in the initial round of funding.

The FCC mandate has driven technology which can further improve future methods of determining location. Technologies such as RF fingerprinting techniques may allow location accuracy to be achieved indoors. The development of UTDOA and other network-based positioning systems are also a direct result of this mandate. (Mott MacDonald, “USA Case Study” 27-28) There are also future solutions being planned in USA such as using Femto cells with GPS receivers to get a handset’s position and using WIFI and WIMAX for positioning. (Mott MacDonald, “USA Case Study” 12)

3.2 Proposed Implementation in the UK

We have decided to conduct a feasibility study to explore if a similar system can be implemented in the UK because UK is currently at the same stage of technological development as the countries we have looked at and is thus capable of supporting such a technology.

The solution used in other countries is implemented on the control plane and emergency authorities have expressed their preference for the control plane approach through location-based services (LBS) rather than the user plane approach. (Mott MacDonald 33) At the same time, mobile operators are reluctant to provide this platform as it involves a large capital investment of at least £9m per operator. (Mott MacDonald 50) This makes the control plane an unfeasible solution for the near future. A solution using third party software is still plausible despite it being theoretically less reliable.

Our proposed solution to incorporate GPS location accuracy in emergency response is a mobile application (app) designed specifically for emergencies and freely downloadable from app stores for most platforms. There is a market for A.L.E.R.T to be implemented as an app in smartphones because of the high penetration of smartphones (50.3%) in the UK. (Kantar Worldpanel, “Over half of GB population owns a smartphone”) As this number has been increasing over the years from 11% in 2010 to 27% in 2011 and 39% in 2012 (OFCOM), the potential for this solution is likely to become more viable in the near future.

3.2.1 High Level Design

A.L.E.R.T is designed to be integrated into the current system (as described in section 2 – Current System and its Limitations). On top of the current method of using Cell-ID, GPS location data will be obtained by the mobile phone and sent to a server via a data connection while the call is in progress or even after the call has been completed. This server will be integrated with the current EISEC system so that the GPS location will be easily available to the emergency dispatcher and responders.

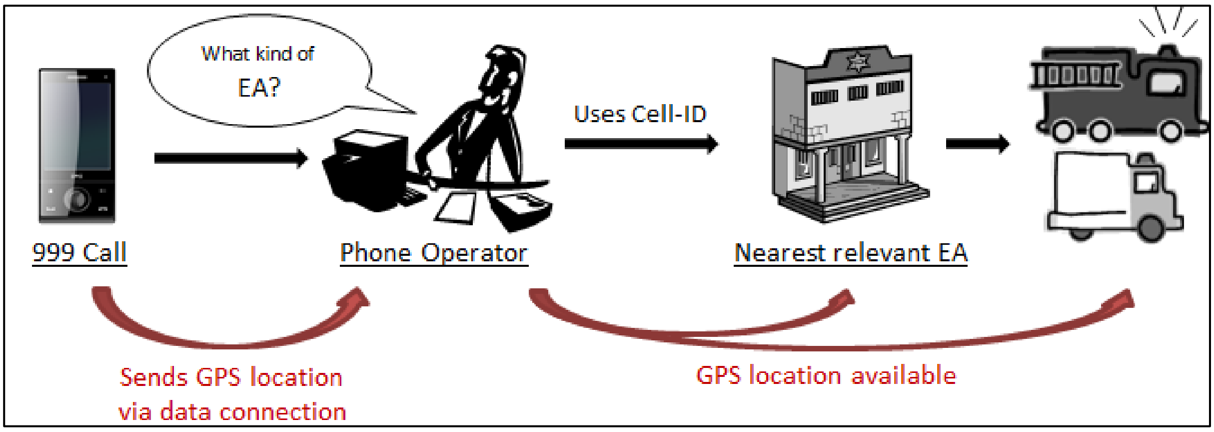

Figure 2: High-level design of ALERT where the new solution (in red) is integrated into the existing system (in black)

3.2.1.1 Obtaining More Accurate Location Information

A.L.E.R.T addresses the issue of imprecise location information by using new technologies such as GPS and A-GPS. GPS is a satellite-based navigation system operated by the US Defence Department and made available for civilian use since the 1980s. GPS signals are constantly transmitted to Earth by navigation satellites. The civilian GPS signal, dubbed L1 frequency, operates at 1575.42 MHz. (National Coordination Office for Space-Based Positioning, Navigation, and Timing) Each GPS signal contains information regarding the satellite from which the signal came from, exact orbital position and current time and date of the satellite (ephemeris data), and orbital information about the other satellites in the system as well (almanac data). A GPS receiver calculates the distance between itself and the satellite by observing the time difference between the signal's transmission from the satellite and its reception. With distance information from at least three satellites, a GPS receiver can calculate its two-dimensional location in terms of latitude and longitude by triangulation. (Garmin) However, because civilian GPS signal is transmitted by the satellite with a maximum power of only 50 watts and bit rate of less than 25 bits per second (bps), received signal is often weak, and downloading almanac data can be very slow. Slow almanac data download increases the TTFF, which defines how fast the receiver can calculate its position after it is first switched on. To overcome this problem, A-GPS was developed.

A-GPS is largely acknowledged as the standard in GPS-enabled smartphones, which widely use the gpsOne chipset by Qualcomm. For a gpsOne-enabled smartphone to calculate its position, the smartphone collects measurements from both GPS satellites and the mobile network. Ephemeris and almanac GPS data are downloaded from a location server when available, reducing TTFF. (Qualcomm CDMA Technologies) The A.L.E.R.T app will make use of gpsOne available in the smartphone to determine the precise location of the call. The technical details of this are described in the section 3.2.2 – Low Level Design.

3.2.1.2 Sending the GPS Data via EISEC

A.L.E.R.T will send the information through a two-step response similar to that in Japan's case study. A-GPS is activated to find the caller's exact location when the smartphone app is used to make an emergency call. As the emergency call connects, Cell-ID information is available, similar to making an emergency call the regular way, allowing the PSAP to route the call to the relevant EA. Cell-ID can be used for the routing of the call because exact location information is unnecessary at this point; also, A-GPS may be delayed in obtaining the exact location. After the A-GPS has acquired the location, the app will automatically update the location information in the emergency service database with the more accurate location as the call is in progress or even if it has ended. The EA will obtain the caller's location through EISEC as per normal, but be able to obtain the more accurate GPS location rather than just the Cell-ID information. This solution allows the EA to receive timely, accurate GPS location without additional steps for both the caller and the EA.

3.2.2 Low Level Design

To illustrate the low level design, we created a user plane solution demonstration that is fully operational. The app runs on the Apple iOS mobile operating system and was developed using the iPhone SDK and XCODE. We have chosen to test this solution on this platform because iPhones make up nearly 30% of the UK smartphone market. (Kantar Worldpanel, "GB markets drive Apple growth")

When the A.L.E.R.T app is started, it immediately invokes the iPhone location manager which starts the smartphone's A-GPS hardware and returns the user's location. The inbuilt Apple maps kit is used to display the location, which is continually updated and shows the area of accuracy. A reverse geocoding request to Google's map servers translate the longitude and latitude data into a street address which is also displayed in the app. The map and data fields are updated whenever the user moves more than 5 metres.

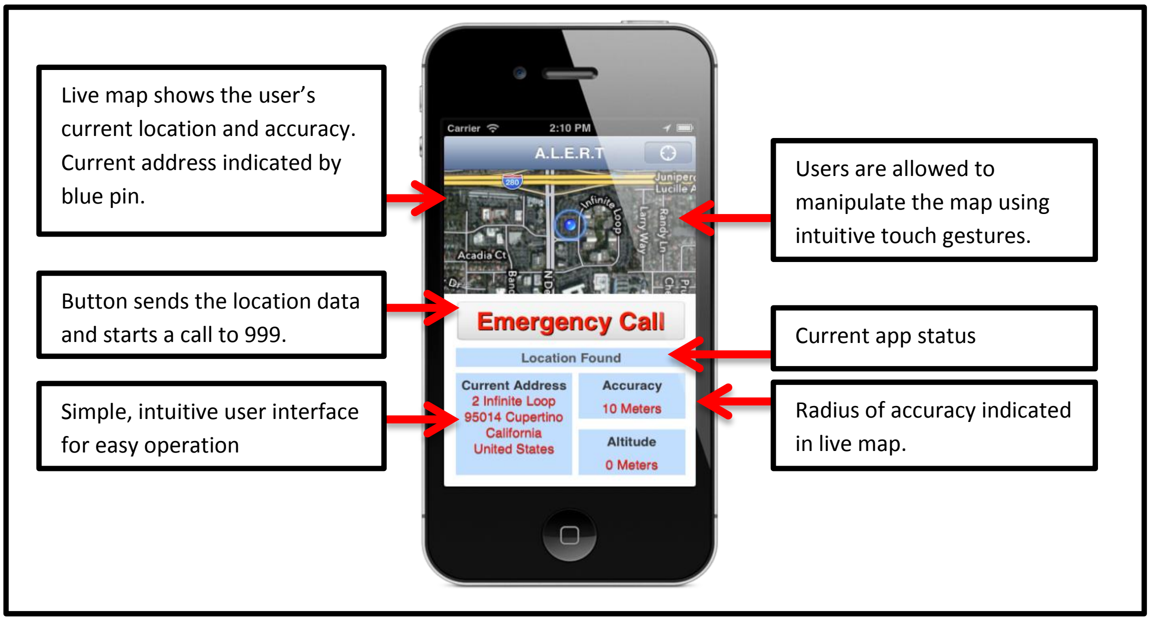

Figure 3: User interface of ALERT app

When the "Emergency Call" button is pressed, the app sends the location data to a remote webserver using a PHP: Hypertext Pre-processor (PHP) post method. This submits the data to the server to be stored in a database containing phone numbers and their latest locations. The database used for the demonstrator was a simple text file, and the data was submitted in less than a second. Simultaneously, the smartphone will call the local emergency services.

In the actual system, other important factors such as security, scalability, and reliability will have to be more thoroughly considered. An actual system will require a suitably-secured SQL data server to protect privacy and manage the large volume of data. Also, instead of a PHP post, a more robust uploading protocol can be established to ensure reliability and prevent abuse of the system.

When fully integrated, the emergency dispatcher will be able to retrieve the user's location through the EISEC system as the call is in progress. The GPS location information can then be passed to the emergency responder through the current dispatch system.

3.3 Implementation of A.L.E.R.T

Implementing A.L.E.R.T on a large scale will involve a large amount of resources, especially if the control plane method is used. Thus, a feasibility study to quantify its benefits by implementing on a smaller scale is important in order to determine the best possible large-scale implementation method.

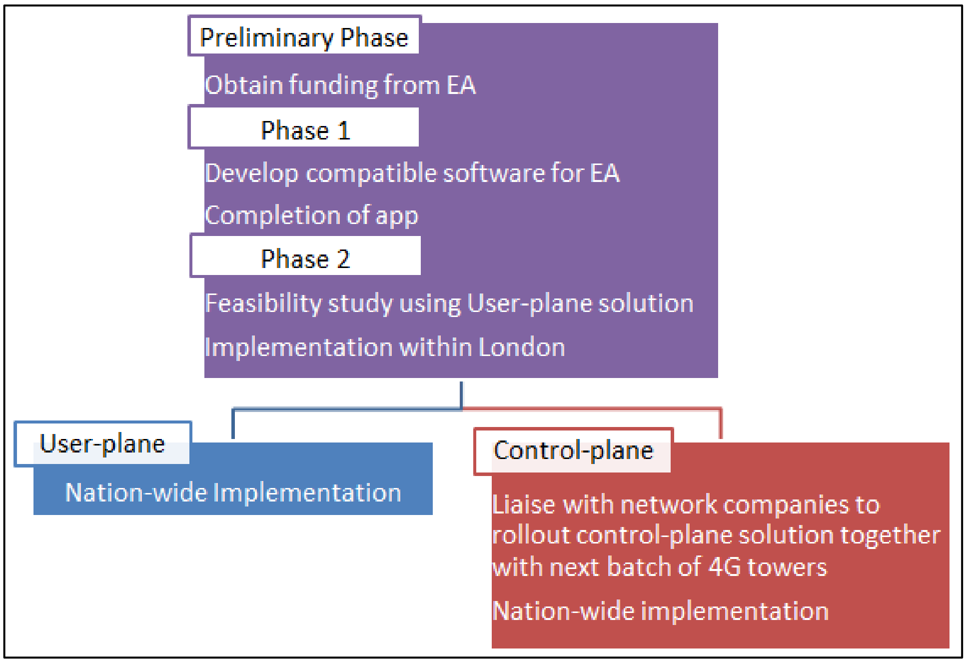

Figure 2: Timeline for implementation of ALERT in the UK

A feasibility study in London involving a user plane solution similar to the demonstration app will be employed because of the lower costs involved compared to a control plane solution. Assistance from the MPS, National Healthcare Service (NHS), and London Fire Brigade (LBF) will be sought for funding, publicity, and integration with EISEC. Once the app and supporting software are developed and tested, the app can be put onto the online stores for the public to download and its impact on response time of EAs can be obtained.

The analysis of the feasibility study's results will help in deciding the best method to implement A.L.E.R.T on a nation-wide scale. If the benefits are significant, the high costs of implementing a control plane solution may be justified in order for A.L.E.R.T to be available to a larger proportion of the population instead of being restricted to only smartphones with the app. To implement A.L.E.R.T on the control plane, coordination with network operators will be needed to roll out the system together with the next batch of 4G BTS. It may also be necessary to liaise with a regulating authority such as the Office of Communications (OFCOM) to mandate a minimum level of location accuracy. However, if the benefits are not very significant, it may be better to roll out A.L.E.R.T to the rest of the UK using the cheaper user plane method. As such, the feasibility study is crucial to allow a more informed decision-making process regarding a nation-wide implementation of A.L.E.R.T and the choice of technology involved.

4. Benefits of Faster Emergency Response Time

A more accurate location of the emergency leads to faster emergency response time, which has several major benefits for the various emergency services, the most important being saving more lives. Also, a shorter response time not only reduces the damage done in cases of fire but also helps to deter crimes.

The requirements set by the NHS for response time of emergency health vehicles demonstrate the importance of a speedy response. Currently, the ambulance will reach 75% of life-threatening emergency calls within 8 minutes. If onward transport is required, 95% of the calls will receive an ambulance capable of transporting the patient safely within 19 minutes (NHS). Presently, ambulance services are currently fulfilling the requirements set by NHS. In spite of this, we recognize that a reduced emergency response time can save even more lives. Several acute disease have survival rate that decreases rapidly if not treated within minutes. For example, the survival rate of cardiac arrests decreases by 7% to 10% every minute if defibrillation is not provided. (Larsen et al.) With A-GPS which is able to achieve a TTFF of 15 seconds and a 15m radius of accuracy, we believe that we can reduce the time required to transport patients to hospitals, thus saving more lives.

Another advantage of faster emergency response time is to deter crimes. The time required to commit certain crimes, such as rape and burglary, are relatively long. From November 2011 to November 2012, there were 3,081 cases of rape and 94,449 cases of burglary in London. (Metropolitan Police, “Crime Figures”) With a faster emergency response time, police officers are more likely to catch these criminals red-handed, thus potentially deterring similar crimes.

Finally, a faster emergency response time would also benefit the fire service in rescuing victims from fire and reducing property damages. From December 2010 to December 2011, there were 12,887 cases of primary fires resulting in 60 deaths and 892 injuries. The average time taken for the first fire engine to arrive is 5 minutes and 22 seconds. (London Fire and Emergency Planning Authority) As fire tends to spread quickly, a faster response time will potentially reduce the number of deaths and injuries, and property damage due to fire.

5. Economic Justifications

The cost of implementation of the user plane solution is minimal because all the software (app and corresponding software for receiving the information) will be developed by our group. Thus, the costs will arise mainly from making the app available for download on app stores such as Google Play for Android and iTunes AppStore for Apple (estimated costs less than US$125 in total per year). Costs will also arise from installing a portable GPS system for the emergency response vehicles or personnel to obtain real-time location information. However, since there is already the Automated Personal Location System (ALPS) available for the Metropolitan Police (The Metropolitan Police “New Tools for Single Patrol”), this system can be extended to all other emergency authorities while our software can be integrated into the existing system. The additional location information provided by our solution can be easily integrated into existing emergency dispatch information systems.

While the estimated costs are minimal, the corresponding benefits of this solution are both tangible and intangible, such as the tangible benefits of property saved in a fire or recovered during theft, but also more importantly in the intangible benefits of saving lives saved or even preventing rape. Using the value of statistical life (VSL) calculations (Sandy et al, 2001), an average person's life in the UK is worth approximately US$6m. The solution thus has the potential to have very high quantifiable as well as intangible benefits.

Furthermore, the solution can be justified by the amount that the emergency authorities have spent on similar projects. For example, the NHS has spent £10,000 on a Drink Tracker app for users to monitor their alcohol intake and £10,000 for an app to help smokers quit smoking (BBC News). Also, the Metropolitan Police intend to deploy more police officers through their new territorial policing model. (Metropolitan Police Authority) Similar apps, such as Crimepush, which allows the user to send an automated message to loved ones in case of emergency, have between 5,000 and 10,000 downloads from Google Play. With more advertising and publicity by the EAs, our app can reach even more people. Thus, in comparison, the estimated cost of the user-plane solution is considerably lesser and is also predicted to have significant returns.

6. Conclusion

A.L.E.R.T is a feasible model because it is based on working models already implemented in other countries. It can be easily integrated into the EAs' existing systems, in particular, using EISEC to send the data to the relevant authorities. By using A-GPS or other relevant technologies, A.L.E.R.T reduces response time of EAs by providing a more precise location of the caller. As discussed, faster response by the EAs leads to many tangible and intangible benefits, of which the most significant would be saving lives. Thus, the system is economically feasible and more research should be conducted to determine the best method for implementing A.L.E.R.T.

Our group would like to thank our mentor, Dr Tania Stathaki, for her kind guidance and support throughout the course of our project.

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