An IoT Approach to Vehicle Accident Detection, Reporting, and Navigation

Elie Nasr, Elie Kfoury, David Khoury
Computer Science Department
American University of Science and Technology
Beirut, Lebanon
enasr@aust.edu.lb, ekfoury@aust.edu.lb, dkhoury@aust.edu.lb

Abstract— **One particular concern that Public Safety Organizations (PSO) must account for whilst engaging in many activities is decreasing the effect of vehicle accidents, aiding as many injured people as possible and providing 24/7 on the spot rescue. The Red Cross humanitarian organization is one of the most known PSOs to be present on-site whenever an accident or a disaster takes place. However, some of the rescue teams face difficulty in reaching the injured people to due late alerts and insufficient information of the specific accident location. The advent of the mobile phone and Internet of Things (IoT) industries reshaped the way people communicate and brought a paradigm shift to public and private services [1]. This ever-evolving technology marked the beginning of new era affecting the lives of people and various businesses. This paper conveys a smart and reliable IoT system solution which instantly notifies the PSO headquarter whenever an accident takes place and pinpoints its geographic coordinates on the map. When an accident takes place, a shock sensor detects it. Then, an algorithm is applied to process the sensor signal and send the geographic location along with some ancillary information to the PSO headquarter, indicating accident occurrence. This is a promising system expected to aid in the tedious rescuing process by reporting ~~in a matter of seconds~~ the location of an accident, the passengers injured, blood types, thus lowering death's rates. The geographical data collected from this system could be relied upon as admissible evidence or indicator of the road state and conditions.**

Keywords— Public safety organization, accident, rescue, IoT, sensor, geographical coordinates.

I. INTRODUCTION

According to the Association for Safe International Road Travel (ASIRT), nearly 1.3 million people die in road crashes each year, 20-50 million are injured or disabled. Road crashes cost USD $518 billion globally, costing individual countries from 1-2% of their annual GDP. Currently, Road traffic crashes rank as the 9th leading cause of death and account for 2.2% of all deaths globally. Unless action is taken, road traffic injuries are predicted to become the fifth leading cause of death by 2030 [2].

The challenges imposed to local PSOs in saving human lives resulting from vehicles accidents have become a crucial concern due to the huge aforementioned number of departed people. As far as many injured could lose their lives, and since no on-site medical assistance has been provided promptly as a result of: (1) late accident reporting, (2) inaccurate geographic location, and (3) lack of injured medical information, the need for automated and intelligent mobile solution tackling this burden becomes a must.

The current existing solutions that provide assistance to passengers in case of vehicle accident occurrence are mainly concerned with user interaction after the incident happened. Those mobile solutions require that the injured must launch the app and request help manually and that would not be possible if he/she is under critical or serious non-vital situation. The situation becomes even worse if passengers went under unconscious state.

Our proposed solution is a smart IoT system consisting of architecture, design, and implementation. This system requires no user interaction during or after the accident; consequently, it provides instant automated vehicle accident detection and reporting. This method is applicable for any vehicle used in transportation and mainly for cars accidents. The primary users of this solution are the public safety organizations rescue teams (like Red Cross, Emergency Management Agencies, Law Enforcement Agencies, Fire Departments, Rescue Squads, and Emergency Medical Services, etc…).

The main contributions of this paper are: (a) Developing a new smart IoT solution which helps the community in reducing the death rate resulting from vehicle accidents. (b) Ensuring that no passenger (injured) intervention is required during or after the accident. (c) Transmitting automatically the basic medical information needed by the rescue teams to the PSO headquarter. (d) Collecting geographical data which can be fed to a data mining engine to extract roads conditions, and to generate descriptive statistics reports about vehicle accidents. (e) Implementing a navigation system to find the closest rescue team to the crash.

This paper starts with descriptive statistics about car accidents delivered by ASIRT, the challenges imposed to local PSOs in saving human lives resulting from car accidents. Sections II, III, IV, and V describe the related work, the proposed method, design and architecture, and implementation consecutively. Sections VI and VII expose results, conclusions, and future work.

II. RELATED WORK

This section overlooks similar existing solutions and examines their advantages and disadvantages.

Auto Accident App, developed by PlatinumPeak LLC [3], is a mobile phone application to offer free, assistance to accident victims. It provides one-button access to emergency personnel and step-by-step guidance through the information gathering process to ensure that no critical information or evidence is missed. The main disadvantage is that it serves only as a form of manual reporting about the accident after it is being taken place. Hence, it doesn't really provide any form of rescue for the passengers.

Auto Accident App, developed by the Murphy Battista [4], is a useful application for individuals who commonly or even occasionally find themselves behind the wheel of a vehicle. It features time saving forms that allow users to clearly collect accident information. Not being automated is considered a drawback of this application.

Accident Report, developed by Dr. Apps [5], lets you create an accident report (a PDF file) in a simple and organized way, as required by insurance companies and the police, without missing important details during an accident situation. The main disadvantage of this app is that it focuses on reporting and doesn't provide any sense of rescue.

All the solutions lack an automated smart approach to accident detection, reporting and navigation. This paper proposes a new method which overcomes the above stated applications' weaknesses.

III. METHOD

In this section, we elucidate our proposed system at a high level scope. The system is composed of the following phases: (a) Vehicle registration and preparation, (b) Passengers' registration, (c) Monitoring accidents through a web interface located in the PSO headquarter.

Vehicle Registration and Preparation: This phase deals with the process of vehicle registration. The vehicle's owner must prepare the vehicle for this system by installing the IoT device. After installing the device, the owner gives the Vehicle ID to the operator responsible for vehicles registration in the headquarter's database. This would lead the PSO to recognize that the registered vehicle satisfies the pre-conditions to be integrated in the system.

The IoT device encompasses four modular components: shock sensor, GPS, NFC reader, and cellular IoT. Those combined modules altogether spontaneously notify the rescue organization headquarter whenever an accident takes place, pinpoint the exact location, and recognize the passengers inside the vehicle on the headquarter map. The triggered sensor signal reports the vehicle's identifier along with the accident's location which appear on a web-based interface in the rescue center. This enables the rescue teams to respond immediately.

Passengers' Registration: The mobile application aims at providing a one-time only registration form for passengers' personal data. The personal data include: (a) Full name, (b) Blood type, (c) Phone number, (d) Email, (e) Medical history, (f) Date of birth, (g) Reference phone number.

The whole record of passenger's information is uploaded to the headquarter's database once the registration process is complete.

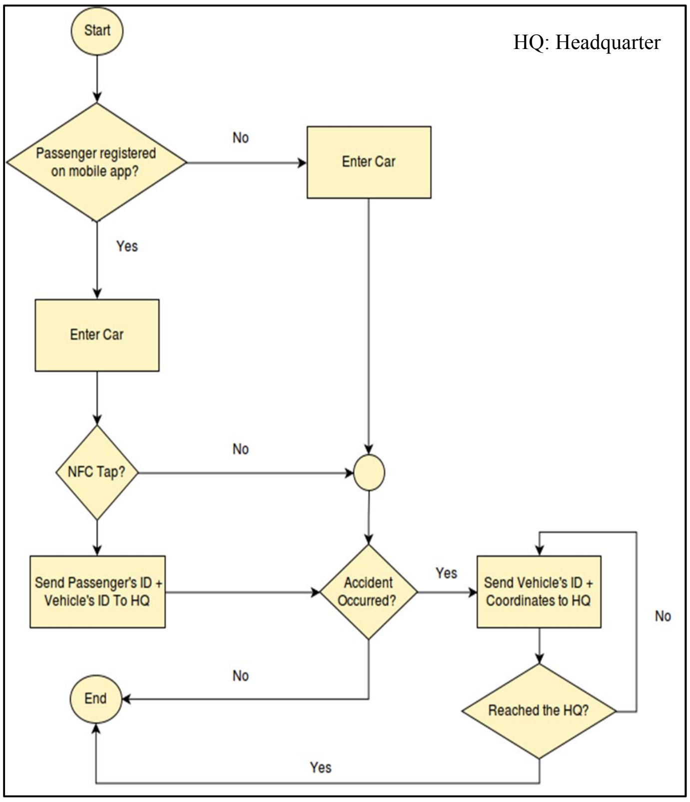


Fig. 1 – System Flowchart

Monitoring Accidents: When a passenger gets in the car and taps the Near Field Communication (NFC) handheld device (mobile phone), the passenger's ID and the vehicle's ID are transmitted and stored into the headquarter's database (see Fig. 1). Consequently, the database server establishes the mapping between the pre-registered personal information and the passenger's ID. As a result, the headquarter can recognize exactly the information of the passenger inside the vehicle.

This process can be applied to all passengers in the car. The IoT Bluetooth Low Energy (BLE) communication protocol can be used as an alternative to NFC, to signal the presence of the passenger inside the vehicle.

In case of vehicle's accident, the airbag, or any shock detection mechanism triggers the shock sensor and consequently a Hypertext Transfer Protocol (HTTP) request alerting the occurrence of an accident and its geographical location is sent to the server. Since the server has previously recognized the passengers inside the vehicle, it can now spot the passengers that are in danger.

A rescue team can then be sent immediately to the acknowledged location carrying out appropriate medical support since pre-medical info have already been identified by headquarter's operator.

IV. Design and Architecture

The below system architecture is the conceptual model that defines the structure, behavior, and more views of our proposed system.

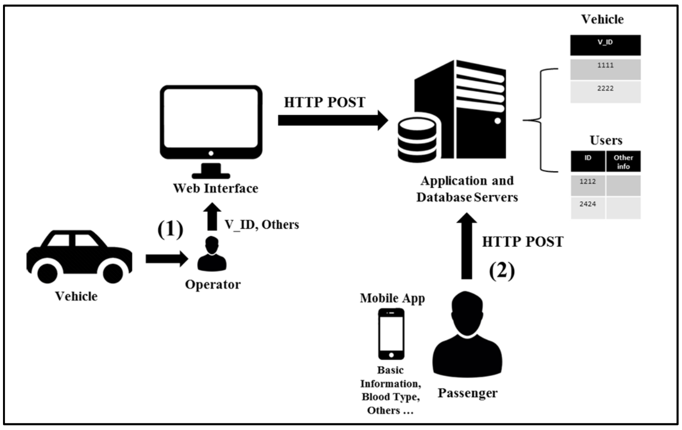


Fig. 2 – Registration Phase Architectural Diagram

The preparation/registration phase discussed earlier is illustrated in detail in Fig 2. The operator registers the vehicle using its vehicle ID through a web interface connected to the database server. As a result, the *Vehicle* table in the database now comprises records pertaining to all registered vehicles.

On the other hand, the passenger registers himself/herself on the server through the corresponding mobile interface. This would make a passenger eligible to get into any equipped vehicle and benefit from the rescue facilities provided by the system.

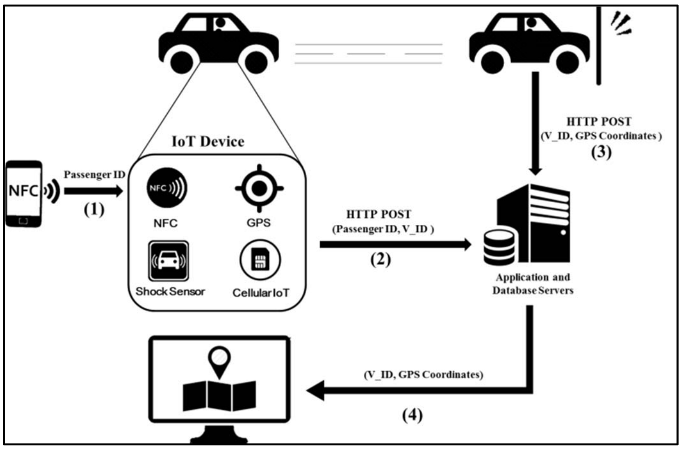


Fig. 3 – Monitoring Phase Architectural Diagram

The monitoring phase discussed in section III is illustrated in Fig 3. When the user taps the NFC enabled device (mobile phone) to the IoT node, an HTTP request holding the passenger's ID and the vehicle's ID, is sent through the IoT cellular network to the application/database servers. If a passenger decides to leave the car, he must tap again the NFC enabled device for the record to be removed from the database. Another alternative could be to store the information locally in a memory, thus, reducing the number of transactions on the server.

On the server side, a table containing the current trips is maintained. Each trip consists of its passengers and the vehicle's ID.

In case of accident, another HTTP request containing the vehicle's ID and the GPS coordinates (longitude and latitude) is sent to the server in which all records' attributes are stored in the database and inserted to an XML file simultaneously (see Fig. 4).

Technically, the webpage is reading asynchronously from the XML file the child entries "*marker*", and updating the map without having to refresh the page repetitively.

```
- <markers>
    <marker status="Pending" car_id="263463_O" lat="33.88497" lng="35.52343"/>
  </markers>
```

Fig. 4 – XML File Containing Current Accidents

While reading the XML file, a pin pops up on the map indicating the location of the accident.

When the operator browses the map, locates and clicks on the pin, a popup window is displayed, showing all passengers' information. This allows the rescue team to prepare the required medication, treatments, and toolkits beforehand.

V. Implementation

Hardware Components

In our implementation we have used an IoT device containing different components and modules as well as communications capability. The main components of this device are:

1. Shock sensor

Shock sensor can be integrated in various ways to match the vehicle requirements. It could be activated by vibration or triggered by highly effective safety system airbag. This airbag system contains several components and mechanism which all work together to ensure the physical integrity of the passengers to the highest degree [6]. The sensitivity of the employed sensor is adjusted to meet the standards adopted in safety airbag systems.

2. Global Positioning System (GPS)

GPS navigation is a component that accurately calculates geographical location by receiving information from GPS satellites. [7] The SKM53 GPS module device is used to send to server the exact vehicle location.

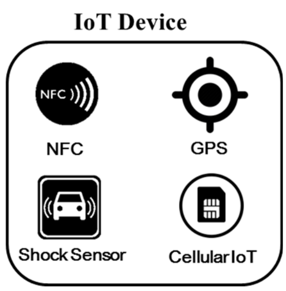


Fig. 5 – IoT Device Components

3. NFC Reader

Near field communication (NFC) is a set of communication protocols that enable two electronic devices, one of which is usually a portable device such as a smartphone, to establish communication by bringing them within 4 cm (2 in) of each other (tapping) [8].
An NFC reader is used to identify each passenger by detecting his/her ID. Then the IoT device sends and matches this ID with the corresponding remote database entry.

4. Cellular IoT

It is required to implement cellular IoT 3rd Generation Partnership Project (3GPP) technologies: Extended coverage Global System for Mobile communication (ECGSM), Long Term Evolution (LTE), Long Term Evolution Machine to Machine LTE-M, and the new radio access technology Narrowband IoT (NB-IoT) specifically tailored to form an attractive solution for emerging low power wide area (LPWA) applications. [9]
As for the higher layers in the IoT protocol stack, the emerged protocols, the Constrained Application Protocol (CoAP) over User Datagram Protocol (UDP), Datagram Transport Layer Security (DTLS) can be used to overcome the limitations of the IoT devices' constraints.
Our system uses the cellular 3G module to establish all kind of wireless communications from and to the server.

Software Components

The mobile application is built using Android ™ Operating System. Hypertext Preprocessor (PHP) is used for server-side scripting, Raspberry Pi open-source prototyping platform for data and signal processing. In addition, a near field communication (NFC) component is used to read the user's data from the mobile. The Raspberry Pi board was programmed using the Python programming language. A GPS component is used to send the exact location of the vehicle that had the accident. Finally, MySQL is used as the Database Management System (DBMS).

Navigation

In our proposed system, a navigation mechanism is implemented using the Haversine function to determine all distances between the accident location and all widespread rescue teams. The Haversine formula is an equation important in navigation, giving great-circle distances between two points on a sphere from their longitudes and latitudes. [10]

```
Require: Points – A list of points identifying the location of rescue teams
Require: AccPoint – A point representing the accident's location
Output: Sorted list of distances in ascending order
  DistanceList← empty
  i ← 0
  for CurPoint in Points do
    DistanceList { i++} ← Haversine (AccPoint, CurPoint )
  end for
  Sort (DistanceList)
  return DistanceList
```

Fig. 6 - Pseudocode for Determining the Nearest Point

Fig. 7 illustrates the rescue teams' distributions and the calculated distances to accident location.

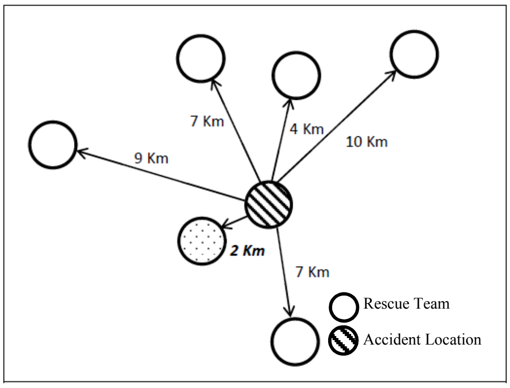


Fig. 7 – Points Distribution Example Scenario

For any two points on a sphere, the Haversine of the central angle between them is given by

$$\mathbf{hav}\left(\frac{d}{r}\right) = \mathbf{hav}\,(\varphi_2 - \varphi_1) + \cos(\varphi_1)\,\cos(\varphi_2)\,\mathbf{hav}(\lambda_2 - \lambda_1)$$

where
hav is the Haversine function:

$$\mathbf{hav}\,(\theta) = \sin^2\left(\frac{\theta}{2}\right) = \frac{1-\cos(\theta)}{2}$$

d is the distance between the two points (along a great circle of the sphere; see spherical distance),
r is the radius of the sphere,
$\varphi\mathbf{1}, \varphi\mathbf{2}$: latitude of point 1 and latitude of point 2, in radians
$\lambda\mathbf{1}, \lambda\mathbf{2}$: longitude of point 1 and longitude of point 2, in radians
The list of all calculated distances is sorted in ascending order to determine the second nearest rescue team whenever the former team is not available. (see Fig. 6)
A push notification of the accident's location is sent to the closest available rescue team which can now use the Google Map service to determine the shortest route to destination.

VI. Results

This section shows a simulation of some important features implemented in our system. (1) On the headquarter side, Fig.6 illustrates a pin instructing the occurrence of an accident.

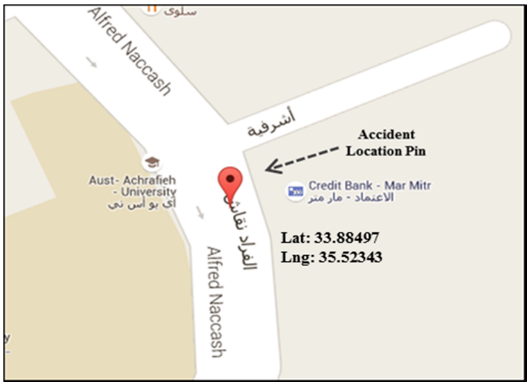
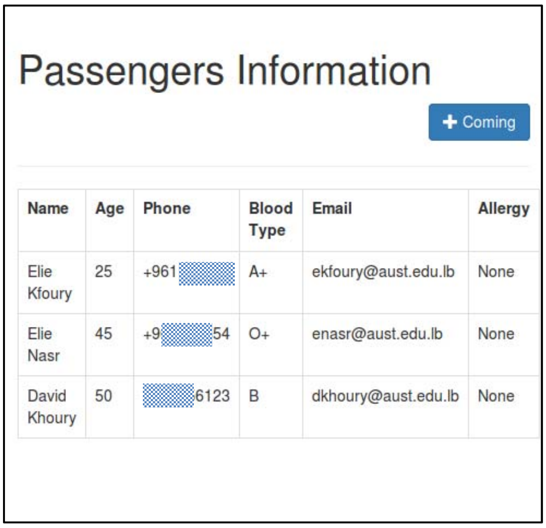


Fig. 8 – Detecting Accident

The map also shows the geographical coordinates (longitude, latitude) of the accident location. (2) When the operator clicks on the pin, a popup window is displayed, showing all passengers' information. This allows the rescue team to prepare the required medication, treatments, and toolkits beforehand as shown in Fig. 9.



Passengers Information

+ Coming

Name	Age	Phone	Blood Type	Email	Allergy
Elie Kfoury	25	+961[redacted]	A+	ekfoury@aust.edu.lb	None
Elie Nasr	45	+9[redacted]54	O+	enasr@aust.edu.lb	None
David Khoury	50	[redacted]6123	B	dkhoury@aust.edu.lb	None

Fig. 9 – List of Passengers and their Information

(3) In Fig. 9, when the operator press on the *"+ Coming"* button, a new popup windows is displayed showing a sorted list of all rescue teams along with the calculated distances to accident location (see Fig. 10).

Team Number	Location	Distance from Accident
Team 1	Ashrafieh	02 KM
Team 3	Hazmieh	05 KM
Team 2	Broumana	08 KM

Fig. 10 – List of PSO's Rescue Teams

(4) In Fig. 10, when the operator select "Team 1", a push notification is sent instructing Team 1 leader to route to the accident location as shown in Fig. 11.

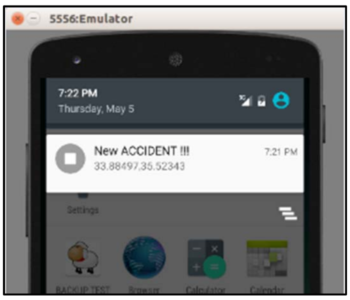


Fig. 11 – Accident's Location Sent to the Rescue Team Leader

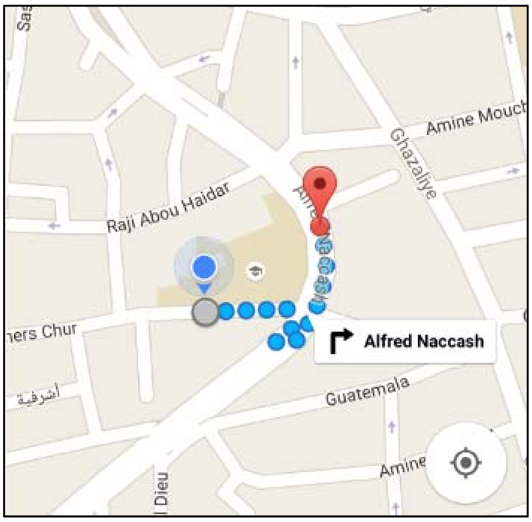


Fig. 12 – Routing from Team Location to Accident

Fig. 12 shows the track that the team must traverse to reach the accident location.

Performance

The load on the server is not considered as enormous as the number of transactions is limited to the number of accidents during a period of time. Therefore, the number of reporting is not immense comparing to any normal application in the market. In the alternative where the passenger information is stored in the car, the number of transactions will be even lower.

Regarding faulty alarms delivered by the sensor, at least three alarms should be sent to confirm the accident. If one alarm is sent, then it is considered as faulty alarm.

VII. Conclusions and Future Work

In this paper, we proposed and implemented an IoT system which may help the community decreasing the death rates resulting from vehicles accidents. Results showed that this solution provided many advantages compared to traditional systems, namely, minimizing injured passengers interaction, providing basic medical information to rescue teams, recognizing exact and accurate accidents locations, and facilitating the routing process. Reliability test showed that the system is robust, that is, available and serviceable specially when the IoT device keeps sending continuous notification of crash occurrence until it makes sure its reception by the headquarter as shown in Fig. 1. Also the data collected from this system can be fed to data mining engine and hence, can serve the PSO in generating statistical reports related to the number of accidents, number of injured, bank of blood donors, and road conditions. Our future vision is to enhance the system and push forward toward integrating it into each vehicle during the manufacturing phase. Also, this system could be managed to get passenger information using a primary key like the Social Security Number (SSN) from a governmental centralized database.

REFERENCES

[1] O. Vermesan, Internet of Things: Converging Technologies for Smart Environments. River Publishers, 2013.

[2] "Road Crash Statistics", Asirt.org, 2016. [Online]. Available: http://asirt.org/initiatives/informing-road-users/road-safety-facts/road-crash-statistics.

[3] A. App and P. LLC, "Auto Accident App dans l'App Store", App Store, 2016. [Online]. Available: https://itunes.apple.com/ca/app/auto-accident-app/id515255099?l=fr.

[4] "Auto Accident App - Murphy Battista LLP", Murphy Battista LLP, 2016. [Online]. Available: http://www.murphybattista.com/auto-accident-app.

[5] "Accident Report for Android", Appsgalery.com, 2016. [Online]. Available: http://www.appsgalery.com/apps/accident-report-34136.

[6] B. AG, "BMW Technology Guide : Airbag/Safety-System", Bmw.com, 2016.[Online].Available: http://www.bmw.com/com/en/insights/technology/technology_guide/articles/airbag_safety_system.html?source=categories&article=airbag_safety_system

[7] M. Grewal, L. Weill and A. Andrews, Global positioning systems, inertial navigation, and integration. New York: John Wiley, 2001.

[8] M. Hendry, Near field communications technology and applications.

[9] "Cellular networks for massive IoT," Ericsson White Paper, Jan 2016

[10] [w. Chris Veness, "Calculate distance and bearing between two Latitude/Longitude points using haversine formula in JavaScript", Movable-type.co.uk, 2016. [Online]. Available: http://www.movable-type.co.uk/scripts/latlong.htm