

PAPER 17 – Modelling Internet of Things Architecture for Accident Detection and Reporting for Emergency Medical Assistance

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ABSTRACT

This research work focused on accident detection system for emergency medical aid; the study identifies the society's slow response to medical emergencies as a major problem. In order to enhance and maximize the anticipated reaction time, this system aims to provide an early detection of accidents and transmit the information promptly to the emergency unit. The study was carried out in Benin city, Nigeria utilizing a test bed methodology that included a wireless embedded system, a cloud platform, and several electronic sensors and modules, including a Global system for mobile communications (GSM) module (SIM8001), a Global positioning system (GPS) module (NEO-6M), an accelerometer (ADX335), a shock sensor, an Atmega328p microcontroller, etc. The developed device was connected to the cloud platform via GSM module, which also served as the device's GPS receiver and shock sensor. The accelerometer and shock sensor were utilized to identify crashes. The detection rate provided by the created accident detection algorithm served as the metric for the system's accuracy. The response time ranges between 9 and 12 seconds was obtained as time taken to identify the accident and alert the closest hospital. This verifies the systems' degree of accuracy when used in real-time. Keywords: Cloud Platform, database, internet of things, web application, wireless system.

1. INTRODUCTION

The internet of things (IoT) is a term used to describe physical objects that can be connected to a network and exchange data with other objects and systems via the internet or other communication networks. Its main focus is on information that is gathered in real time and decision-making based on this information (Mouha, 2021). The emergence of IoT holds potential for the creation of intelligent systems and applications, such as smart farming, smart homes, among others. Its use in transportation management or systems is receiving a lot of attention from academia and business, and, it is considered as a way to improve road safety in smart cities (Gomathy et al., 2022). Vehicles equipped with a variety of sensors make it possible to not only keep an eye on the surroundings and the vehicle itself in real time, but, it also makes incident detection easier. The current trend in the death rate from road accidents made the use of this technique necessary. Despite the significant efforts made by international road safety organisations to reduce the number of deaths related to road accidents by organising awareness campaigns, discouraged drinking and driving, promoting the use of seat belts and airbags, and other innovative traffic solutions, accident crashes still remain high.

The problem of false alarms emerges because the majority of these works primarily focus on the accidents detection with little or no technique for accident reporting (alert system). The majority of these road fatalities occur as a result of emergency management authorities' and medical personnel's poor reaction times (Devi and Anila, 2018; Adelabu, 2017). If emergency medical care is offered at the scene of an accident, an accident victim's odds of survival may rise dramatically (Aloul et al., 2014). Getting to collisions faster is one of the most efficient strategies to reduce road traffic deaths. Several tools, like e-Notify, are available to aid in the detection and reporting of road traffic accidents (Aloul et al., 2014 and Bhatti et al., 2019). Each vehicle must have an on-board unit (OBU) to use the e-Notify system. Even though this might be a good option, it is pricey and not all vehicles might have on-board devices. The eCall system was created by the European Commission, who also mandated its installation in every vehicle created after 2015. The emergency number 112, 999 in the UK, and some other countries are alerted when the eCall system discovers an accident (Zhao, 2000; Ali and Alwan, 2015).

The goal of this project is to combine low-cost devices, several sensors, a database of hospital profiles, an effective detection algorithm, and IoT infrastructure to increase the accuracy of accident detection and emergency response times for traffic incidents in Benin City, Nigeria. According to a recent World Health Organization (WHO) report, Africa has the highest annual death and injury rates at 1.35 million and 50 million, respectively (WHO, 2018).

Furthermore, Nigeria recorded over thirty nine thousand (39,000) fatalities from these statistics. Road accidents are the eighth leading cause of fatalities globally, according to the Association for Safe International Road Travel (ASIRT), and it is projected to be the fifth leading cause of fatalities in the near future unless significant changes are made with the aid of technology and increased public awareness (ASIRT, 2020).

According to ASIRT, managing road accidents and the resulting social harm costs every country a significant amount of money—about two percent (2%) of its annual budget (ASIRT, 2020). In response to the depressing figures listed above, researchers have developed strategies to address the issues of accident collisions and fatalities, including drivers monitoring systems, smart traffic systems, establishing road management agencies, emergency management devices etc.

The objective of the study is to: - enhance and maximize the anticipated reaction time to road crashes thereby reducing mortality rates associated with road crashes in the society. A test bed methodology that included a wireless embedded system, a cloud platform, and several electronic sensors and modules were adopted.

The existing assistance system in the event of a car accident focuses mostly on one sensor (Amin et al., 2012). Researchers Vinod et al. (2019); Rajkiran and Anusha (2014) and Vinod et al. (2019) presented a system that uses GPS to automatically detect accidents and alerts all nearby hospitals and law enforcement agencies. This hardware-based system only uses one sensor to identify accidents; if this sensor malfunctions, the entire system fails. Some technologies detect accidents and alert rescue crews using the gravitational pitch. These systems, like those described in Bhatti et al. (2019), suffer from the same issue of using just one sensor. Relying on a single sensor increases the possibility of false positives, or the reporting of an accident when none actually occurred. Some systems, described in Suo et al. (2012), employ accelerometer data as a trigger to alert emergency services of a collision.

The result obtained showed that the system was able to react quickly to accident crashes. Finally, the results show that the emergency response time - the time it takes to locate the accident and notify the closest hospital is between 9 to 12 seconds. This demonstrates the accuracy level of the technologies when utilized in real-time.

2. THEORETICAL ANALYSIS

In this research, four layers model design namely: perception or sensory layer, network layer, intermediate layer, and application layer was adopted in order to achieve the intended goal (Bhatti et al., 2019; Pathik et al., 2022). The IoT architecture used is graphically depicted in Figure 1.

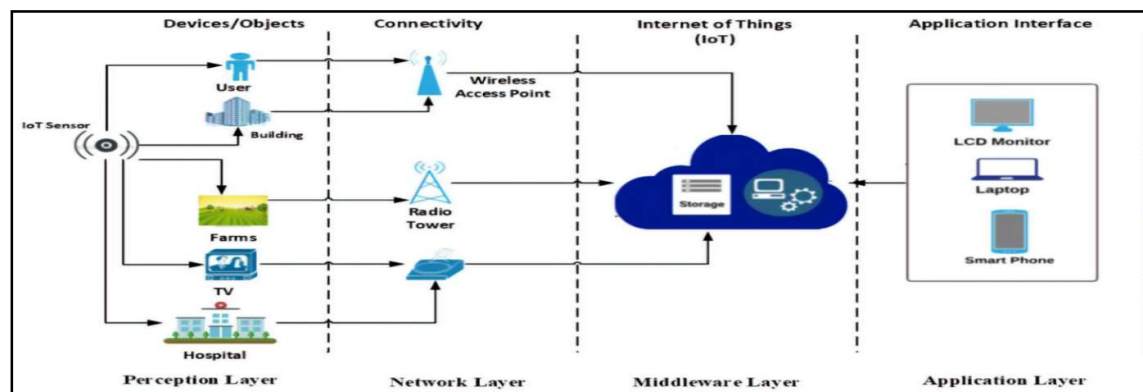


Figure 1: Internet of Things Architecture Adopted

3. MATERIAL AND METHODS

3.1 Methods

In order to decrease the reaction time for rescue operations, a novel IoT technology was created to identify accident crashes and notify the required personnel. The cloud system and the wireless embedded device were linked to function as one unified entity from the designed methodology. Figure 2 depicts the system's architecture modeled from (Ali and Alwan, 2015).

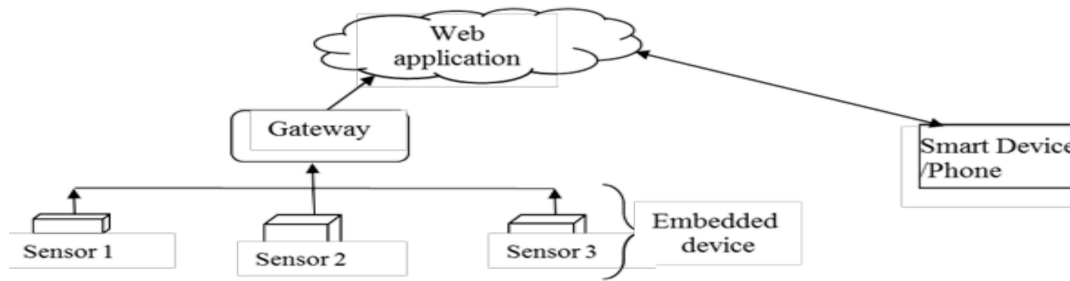


Figure 2: IoT Architecture for Intelligent Accident Detection System

3.2 Development of the wireless embedded device

The GSM module, GPS module, accelerometer, shock sensor, and other types of modules and sensors were used to create the wireless embedded device. To create the working system, these components were interfaced with a microcontroller as illustrated in the block diagram of Figure 3.

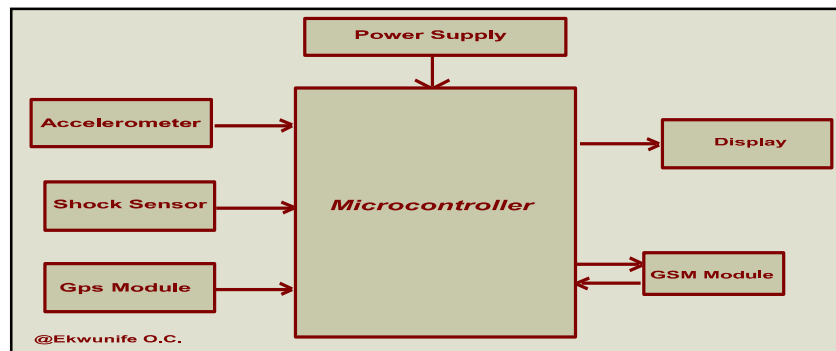


Figure 3: Wireless embedded device

The various wireless embedded device modules were created to carry out their specific tasks in order to accomplish the predetermined objectives as shown in the system circuit diagram in appendix A.

3.3 Development of web application for accident detection

An approach for identifying, outlining, and organizing system requirements is called a use case. The web application that is being created to complement the device is referred to in this context as the "system." Unified Modeling Language (UML), a common notation for modeling actual objects and systems is realized by adopting use case diagram in Figure 4 which depicts steps needed by an accident detection device, commencing with driver registration and ending with emergency or crash notification.

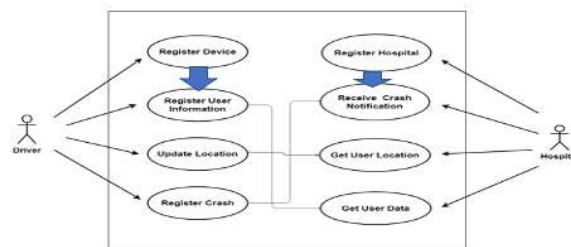


Figure 4: Use Case Diagram

3.4 Software development methodology

The Waterfall Model was the software development approach employed. The waterfall model divides a project's operations into a series of linear phases, each of which is composed of specialized tasks and is dependent on the previous phase's deliverables. The method is common in some branches of engineering design. Although progress moves mostly in one direction ("downwards" like a waterfall) through the phases of conception, initiation, analysis, design, construction, testing, deployment, and maintenance, it tends to be among the less iterative and adaptable approaches in software development. Given that the software system needs to connect with the hardware sensing device and other software systems, it is employed here to enable optimize the architecture of the development process. The process' most frequent steps are shown in Figure 5.

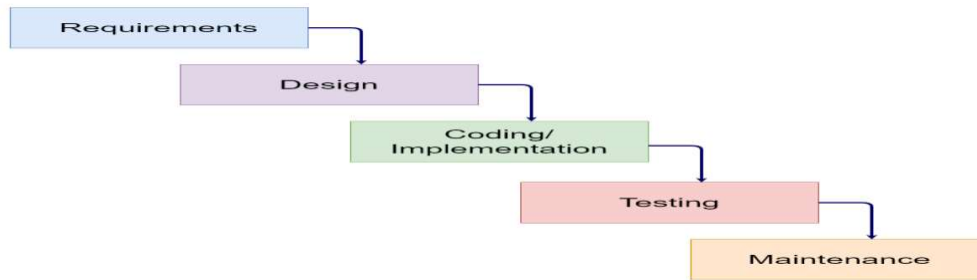


Figure 5: System architecture

The connections between the various system components are shown in Figure 6. The GPRS gateway transmits data from the embedded device to the web application. Figure 6 depicts the data movement diagram that explains how data moves throughout the cloud system, from the wireless electronic device to the backend, database, webpages (frontend), and google map. Static Maps API and Locations API were used to create the web application. Google offers a consumer application and web mapping platform called Google Maps. It provides route planning for walking, driving, flying (in beta), and taking public transportation, as well as satellite imagery, aerial photography, street maps, 360-degree interactive panorama views of streets (Street View), and real-time traffic conditions.

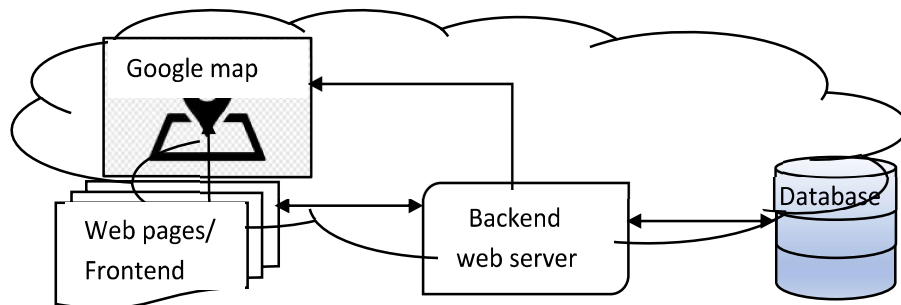


Figure 6: Cloud structure showing data flow (Ali and Alwan, 2015)

3.5 Database development

In this work, the database system was implemented using MongoDB. Instead of using tables and rows like standard relational databases, it employs collections and documents. The system's database was modeled using the embedded data model, which MongoDB offers in addition to the normalized model. With this method of data modeling, the designer has the option of including all relevant data in a single document. The MongoDB collections for the hospitals providing ambulance services near Benin City were carried out showing its: - hospital name, address, location, phone numbers and number of ambulances and other data available.

3.6 Working principle of the system

The system is designed to function in a manner that the device's end-user sensor values are communicated to the backend web server using an HTTP POST request (every 10 seconds). These readings include the device's latitude and longitude as determined by the GPS receiver, the shock sensor, and the accelerometer. This device data is supplied into the body of the request in the JavaScript Object Notation (JSON) format. When the web server receives this data, it analyses it to determine whether an automobile crash has been detected or not. In the event of an unplanned system reboot, it is also possible to quickly access the last device location by storing the received data in a database system. In order to compute the route between the location of the device at the moment and the closest hospital, the backend additionally connects to the Google Maps API platform (all hospital locations are to be stored on the database). The affected person's information is then transmitted by SMS to the closest hospital providing ambulance services. Figure 7 shows the working principle of the system.

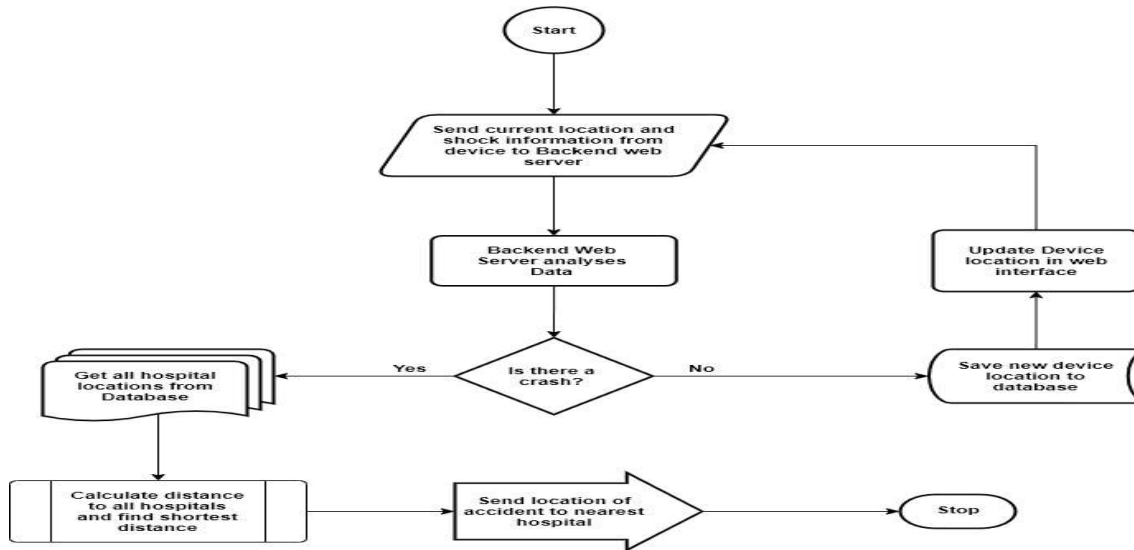


Figure 7 Functional Flow Chart of the System

4. RESULT AND DISCUSSION

The hardware device's circuit prototype was created using the proteus simulation software, implemented on a breadboard, and then transferred to a Veroboard, Figure 8. The code was written using the Arduino IDE, and the Atmega328p microcontroller was programmed using the TL866 universal programmer.



Figure 8: Circuit prototyping

On the platform, a few hospitals in Benin City were registered, together with the integrated wireless gadget. Figure 9 displays screenshots of the registration page from the web application's graphical user interface.

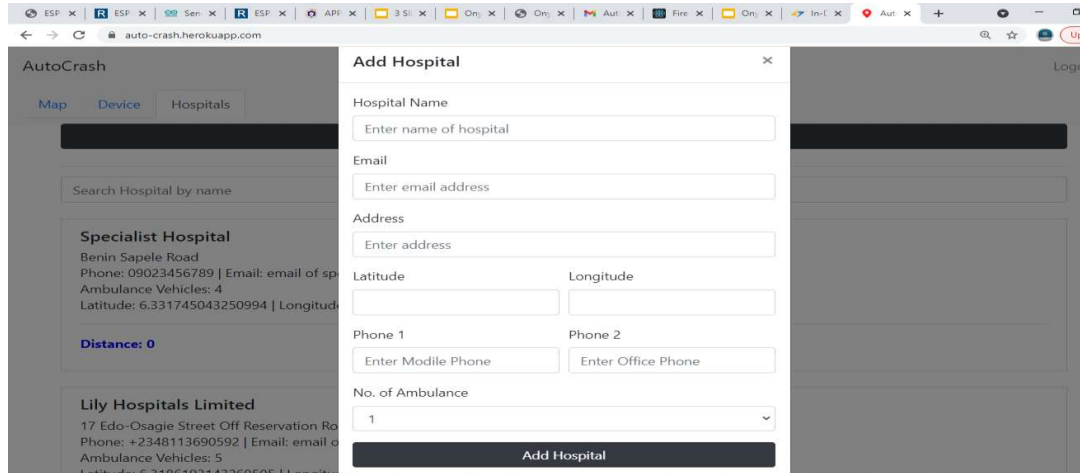


Figure 9: Hospital registration page

The platform for registering the hospitals offering ambulance services is presented in the screenshot above with information relating to the hospitals, such as name, email, latitude, and longitude. These were collected and utilized to find the closest hospital and, call in case of an accident crash.

In an open area, the device was turned on and moved around. The first screenshot, Figure 10, depicts the device's movement on a map, and the second screenshot, Figure 11, depicts the distance between the device and the registered hospitals. The screenshot information in Figure 11 indicates that the University of Benin teaching hospital was the closest hospital location to the device at the time the test was conducted.

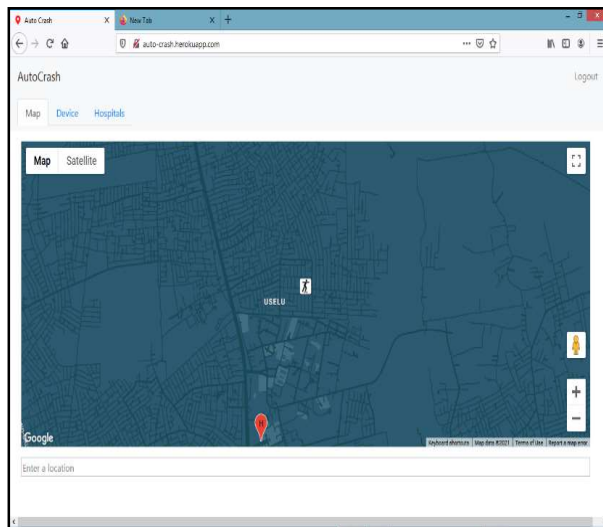


Figure 10: movement of the device on Google map

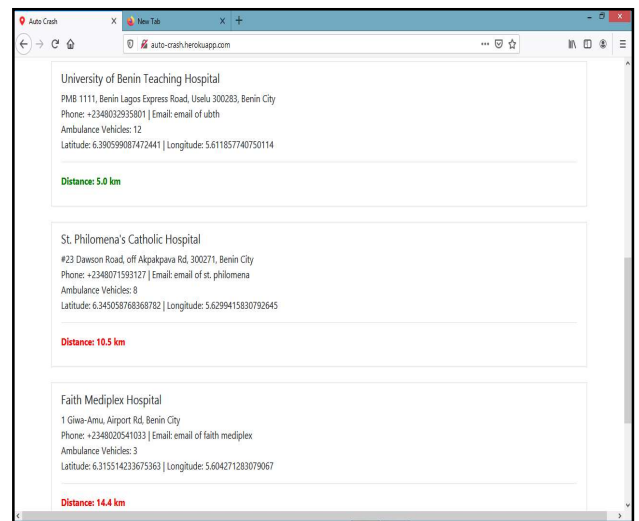


Figure 11: Distances of the registered hospitals from the device

Finally, after the apparatus smashed against a wall while being supported by ball-shaped desk legs, the following observations were noticed on the platform: the shock state that was initially FALSE became TRUE (which showed device has detected an accident). With the information saved on the device, an SMS was sent to the closest hospital. The movement on the map then came to an end. The system was tested for accuracy and the result tabulated as shown in Table 2

Table 2: Accuracy and Response time result

S/N	Accident Time	System Response	System Response Time	Calculated Response Time
1	11:19:09 am	Accident Detected	11:19:19 am	10 seconds
2	11:19:30 am	Accident Detected	11:19:39 am	09 seconds
3	11:19:42 am	Accident Detected	11:19:52 am	10 seconds
4	12:01:00 pm	Accident Detected	12:01:12 pm	12 seconds

Four tests were run on the system to ascertain its reaction and response time based on the results shown in table 2. As an experiment, the system was able to react quickly to an accident crash. The data that were displayed indicate that the response time ranges between 9 and 12 seconds. This is the amount of time it took the system to identify the accident and alert the closest hospital with an ambulance service. Furthermore, the complete circuit diagram for hardware implementation of the wireless embedded device for the delivery of the internet of things architecture for accident detection and reporting for emergency medical assistance is presented in appendix A.

5. CONCLUSION

Finally, the internet of things accident detection and alert system for emergency medical aid was developed employing a variety of current technologies. A profile and database of hospitals providing ambulance services, the development of a web-based platform for accident detection and alert system with integrated emergency alert system, and IOT-based embedded device for the detection and transmission of location and status of vehicular accidents' crashes were all successfully accomplished by the new system. Finally, the results show that the emergency response time - the time it takes to locate the accident and notify the closest hospital is between -9 to 12 seconds. This demonstrates the accuracy level of the technologies when utilized in real-time. The research was successfully implemented and evaluated, and because the design is relatively adaptable, further enhancements in the coverage area can be achieved.

REFERENCES

- Mouha, R. A. (2021). Internet of Things. *Journal of data analysis and information processing*, Vol. 09. No.2, pp. 77-101. <https://doi.org/10.4236/jdaip.2021.92006>
- Gomathy, C. K., Rohan, K., Reddy, B. M. K. & Geetha, V. (2022). Accident detection and alert system. *Journal of engineering, computing and architecture*, ISSN NO:1934-7197, Vol. 12, Issue 3, pp. 32-43. <http://www.journaleca.com/> Page No: 32
- Devi, P. & Anila, S. (2018). Accident Detection and Reporting System using Internet of Things. *International Journal of Current Engineering and Scientific Research (IJCESR)*, ISSN: 2393-8374, Vol.5 (12), pp.57- 61
- Adelabu, W. O. (2017). Design and Construction of a Vehicle Tracking and Accident Alert System Using GPS and GSM Module. *Afribary*. <http://www.afribary.com/works/design-and-construction-of-a-vehicle-tracking-and-accident-alert-system-using-gps-and-gsm-module>
- Aloul, F., Zualkernan, I., Abu-Salma, R., Al-Ali, H., & Al-Merri, M. (2014). iBump: Smartphone application to detect car accidents. *International Conference on Industrial Automation, Information and Communications Technology*, ISBN: 978-1-4799-4909-0, pp.52-56.<http://doi:10.1109/IAICT.2014.6922107>
- Zhao, Y. (2000). Mobile Phone Location Determination and its Impact on Intelligent Transportation Systems. *IEEE Transactions on Intelligent Transportation Systems*, Vol. 1. No.1, pp. 55-64. <https://doi.org/10.1109/6979.869021>
- Ali, H. M. & Alwan, Z. S. (2015). Car Accident Detection and Notification System Using Smartphone. *International Journal of Computer Science and Mobile Computing*, Vol. 4(4), pp. 620–635.
- World Health Organization. (2018). *Global Status Report on Road Safety*. World Health Organization: Geneva, Switzerland.
- Association for Safe International Road Travel. (2020). *Road Crash Statistics*. Available Online: <https://www.asirt.org/safe-travel/road-safety-facts>.

Amin, M. S., Jalil, J. and Reaz, M. B. I. (2012). Accident Detection and Reporting System Using GPS, GPRS and GSM Technology. *2012 International Conference on Informatics, Electronics & Vision (ICIEV)*, pp. 640-643. <https://doi.org/10.1109/ICIEV.2012.6317382>.

Vinod, S. Kumar, P. S. & Vimal, V. R. (2019). IOT Based Automatic Accident Vehicle Location Sharing Systema Smart Emergency System, *international journal of scientific & technology research*, ISSN: 2277-8616, Vol. 8, Issue 10, pp.1249-1252,

Rajkiran, A. & Anusha, M. (2014). Intelligent Automatic Vehicle Accident Detection System Using Wireless Communication. *Int. J. Res. Stud. Sci. Eng. Technology*, Vol. 1, pp. 98–101.

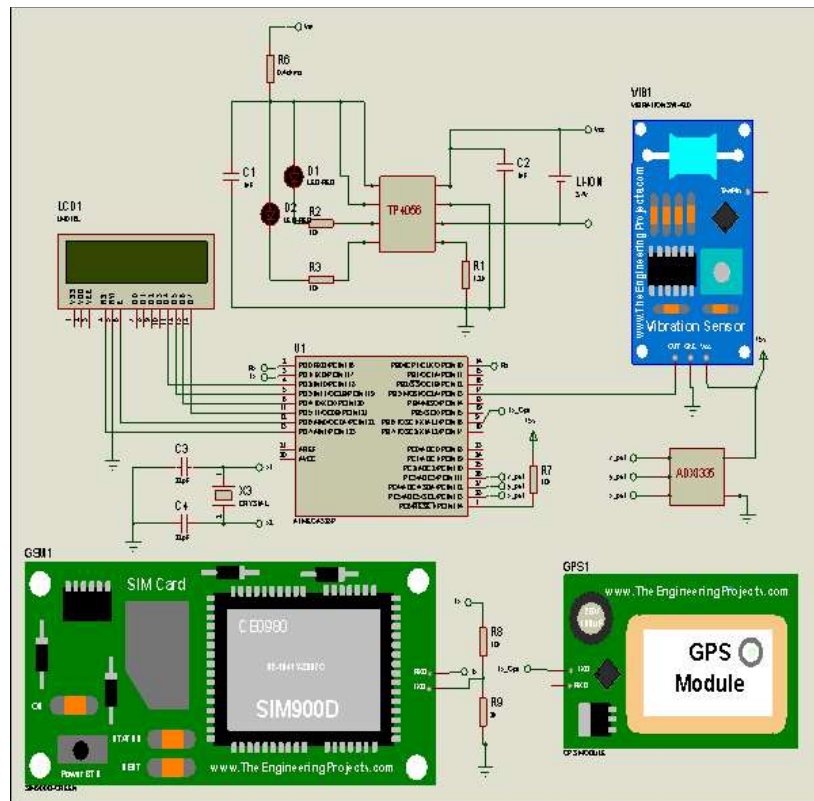
Bhatti, F., Shah, M. A., Maple, C., & Islam, S. U. (2019). A Novel Internet of Things-Enabled Accident Detection and Reporting System for Smart City Environments. *Sensors*, Vol. 19(9). <https://doi.org/10.3390/s19092071>

Suo, H., Wan, J., Zou C. & Liu, J. (2012). Security in the Internet of Things: A Review. *International Conference on Computer Science and Electronics Engineering (ICCSEE)*, pp. 648-651.

Pathik, N., Gupta, R.K., Sahu, Y., Sharma, A., Masud, M., & Baz, M. (2022). AI Enabled Accident Detection and Alert System Using IoT and Deep Learning for Smart Cities. *Sustainability MDPI 2022*, Vol. 14, Issue 13, pp. 1-24. <https://doi.org/10.3390/su14137701>

Appendix A

The appendix A is the complete circuit diagram for hardware implementation of the wireless embedded device for the delivery of the internet of things architecture for accident detection and reporting for emergency medical assistance.



Complete circuit diagram for IOT wireless embedded device