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EMERGENCY REPORTING SYSTEM BASED ON AIRBAG TRIGGERING

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Abstract. *The objective of this research was to create a model for an emergency reporting system that utilized both hardware and software components. The hardware elements were composed of four parts: accident detection, global communication, local communication transmitter and local communication receiver. Accident detection would be initiated when an airbag triggering signal was implemented and was employed, as it produced a low false alarm. Following the activation of the accident detection, then the communication aspect was prompted. Communication was proposed to be conducted at two levels: global and local. Global communication transmitted the vehicle's information and accident location to a central server through a cellular network, whereas local communication informed nearby vehicles to avoid the accident location, so to prevent a rescue team from reaching the scene. Thus, Zigbee is an IEEE 802.15.4-based communication system that was used for a local purpose. On the other hand, the software elements were located on the central server, which the database collected and accumulated the retrieved information. Therefore, the rescue service personnel would employ a web server to reveal the information regarding the tasks that the rescue team would need to undertake at the accident scene. A prototype of this system has already been implemented and tested in a laboratory environment emphasizing on efficiency of the local communication. The result indicated that the effective range of the local communication is more than 200 m adequate for slowing down a vehicle.*
Keywords: Emergency reporting, Airbag triggering signal, Microcontroller, Short message service, Zigbee, Web application

1. **Introduction.** Every year, road incidents kill approximately 1.35 million lives worldwide. The main cause of death is the 8th, which is also the dominant cause of death among children and young people aged 15-29 years. In addition, approximately 20-50 million people experience suffering from accidents that result in lifelong disabilities. This in turn has an effect on most countries' Gross Domestic Product (GDP) of as much as 3% [1]. With regards to Thailand, in 2019, there were approximately 1.5 million calls nationwide that contacted the universal emergency care hotline requiring emergency medical services [2]. This number was followed by 180 thousand cases that utilized radio communication and another 15 thousand cases that used other alternatives.

In most cases, the incident was reported either by a surviving victim or a bystander, which depending on the location could take some time before a rescue service arrived.

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In addition, the surviving victim or bystander would need to know the severity of the incident in order for the rescue team to prepare the necessary emergency care equipment to facilitate the required assistance. However, if the emergency care system could be centrally located with a modern IT system, then it could easily link to the rescue team, thus providing improved efficiency of emergency care.

The number of losses in terms of victims not cured at a hospital is another value worth considering in terms of statistics from National Institute for Emergency Medicine (NIEM). At the accident site, 4,233 victim deaths were reported, while 548 deaths occurred during transport to a hospital facility. Meanwhile, late ambulance response results in roughly 700 deaths each year in Ireland [3]. For Thailand, an NIEM official noted that at least 20% of emergency cases ended in death prior to arrival at hospitals. Traffic issues and ignorance of drivers who block ambulances trying to get to specific locations in emergency cases have been cited as a major cause.

The central purpose of this paper involves the design and promotion of an emergency reporting system for traffic accidents to solve the problem. Four hardware components have been created. One is for accident detection using airbag triggering signal. The other three components are global communication and the two main local communications of receiver and transmitter. The global communication system relays accident information to solve this in situ accident reporting obstacle. Accident data can be displayed on a web application, so staff can dispatch rescue workers after they get the information from the database server. Employing local communication between vehicles can also help enhance traffic flow. To communicate and receive accident-related information in local areas, hardware can also be used.

An Arduino UNO micro-controller is used as the main processor to put the four hardware components into service. For the accident detection element, a vehicle's airbag triggering signal is used, which can be triggered with the deployment of the airbag, thus diminishing the risk of false positives. For global interaction to send short messages to the central server and the assigned number, a UC20-G module with a 3G shield module attachment is used on the microcontroller. The time of accident and victim details are provided in the message. An XBee Pro module consistent with the Zigbee IEEE 802.15.4 standard is used for local transmission to announce the accident event continuously. To advise nearby vehicles to avoid blocking the rescue team's vehicle, Zigbee-based signals can keep broadcasting from the rescue team's vehicle. This paper suggests the design and application of hardware components and supporting software components to enable these facilities.

The organization of this paper is as follows. The literature review and the research gap are discussed in Section 2. The overview of the proposed system is introduced in Section 3. The implementation details are explained in Sections 4 and 5. Sections 6 and 7 give the experimental results and discussion. Finally, the conclusion and future work are discussed in Section 8.

2. Literature Review.

2.1. **Survey of the existing models/work.** In [4], they proposed eCall, which uses the sensor for detecting vehicle crash and notifying road vehicles. When the accident happens, the system sends characteristics of the vehicle, accident coordinates to an emergency service unit. It is also possible to press a button installed in the vehicle if the driver has suffered a heart attack or witnessed another accident. In [5], this system uses the in-built vibration sensor in the airbag to detect the immediate vibrations when accidents occur. The airbag is enabled, the system operates to send data such as location, characteristics of the vehicle to the emergency service. From [6], they developed a system called Accident Detection and Reporting System (ADRS), that detects accidents and notifies to the nearby service provider for necessary assistance. This ADRS is mounted in a vehicle that consists of a sensor, a microcontroller, and an RF transmitter module. When an accident occurs, the system sends accident data to nearby emergency service providers within 100 meters for an ambulance and reports the incident to the police. In [7], they have created a smartphone application that can be downloaded and installed on smartphones. This application uses the smartphones' sensor capabilities to detect accidents, and gathers important data such as location, and phone number for notification.

In [8], there is an automatic notification of an accident. Use a Global Positioning System (GPS) sensor, an accelerometer sensor, and a microcontroller to detect a critical incidence and send the coordinates to the cloud. The system of [9] has rapid accident detection processing time. The system can also send the car accident location information to hospitals, police stations, and the accident victim's relatives. This system used Arduino UNO to connect with an accelerometer and impact sensor for accident detection. It connects to the Internet via Raspberry Pi. The system also focuses on road participants' safety, which can notify when meeting accidents using an emergency push button.

The system in [10] consists of Internet of Things (IoT) and various modules such as shock sensor, GPS, Near-Field Communication (NFC) reader, Cellular 3G, and navigation mechanism. This developed device using the shock sensor can be integrated with the car's bumper, lateral structure, and airbag. When airbags are enabled, the system will accurately calculate the coordinate of location from the data of the GPS module. Then, the system sends the exact vehicle location to the server via the cellular 3G module. This system has identification passengers and drivers via detecting their ID numbers of NFC reader. In the process of routing from the location of rescue teams to the point of the accident, this system uses the Haversine function. The system in [11] provides early warning to drivers about road conditions to improve road safety. Vehicles on the same road can exchange information and alert each other. It was using wireless integrated with microcontroller for communication. A mobile application-based incident reporting system was proposed in [12]. The system also provides road conditions and accident information for drivers who are on the corresponding route and use the application.

2.2. **Summary/research gaps.** The systems mentioned above share the same purposes, but there are a few gaps in these systems that are listed as follows. The methods in [4, 5, 10] used an in-built vibration sensor in an airbag to detect immediate vibration when an accident occurs. When an airbag is triggered, the systems operate to send data such as location and vehicle characteristics to an emergency service. This method improved the systems by decreasing false alarm rate. From the above work, the vehicles on the same road cannot communicate with each other. The system in [9, 11] has exchanged information between each other but it notifies as a short distance. A smartphone application was developed in [7] to utilize a smartphone's in-built sensor capabilities for an accident report. An accelerometer is the main sensor used for an accident detection as well as the systems in [8, 9]. However, a use of acceleration measurement on a smartphone or acceleration sensor is less accurate compared with a direct measurement on an airbag. Moreover, the system in [10] provides a route from a current rescue team location to the location of an accident. The work in [6] developed a system to detect accidents and notify nearby service providers for necessary assistance. It has an accurate accident detection, but it notifies only rescue services within a short distance.

2.3. **Contributions.** Since a false alarm wastes time and efforts of victim's relatives and rescue service staff, the first contribution is that the proposed system produces a lower false alarm rate by using a direct measurement on an airbag than the systems in [6, 7, 8, 9]. The second is that the proposed system notifies rescue services into a broader distance than the systems of [4, 5, 6]. Finally, the proposed system will notify the nearby vehicles to an occurring accident to avoid blocking the rescue team's vehicle which this function could not be found in [4, 5, 7, 10].

3. **The Proposed System.** In this work, we develop an architecture for an emergency reporting system. The architecture consists of two levels of communication including global and local communications. Figure 1 presents the overall information passed through the architecture. Once an accident occurs, the communication modules are activated. The current GPS coordinates are acquired and combined with the registered information regarding the vehicle, i.e., the user detail, the vehicle make and model, the contact of relatives. The combined information is then sent via a cellular network in two ways. One is sending the accident information to the relatives contact using Short Message Service (SMS). The other way applies the IoT concept by sending the accident information to the central server using cellular data. Then the collected information will be displayed to the information center to cooperate with a rescue service.

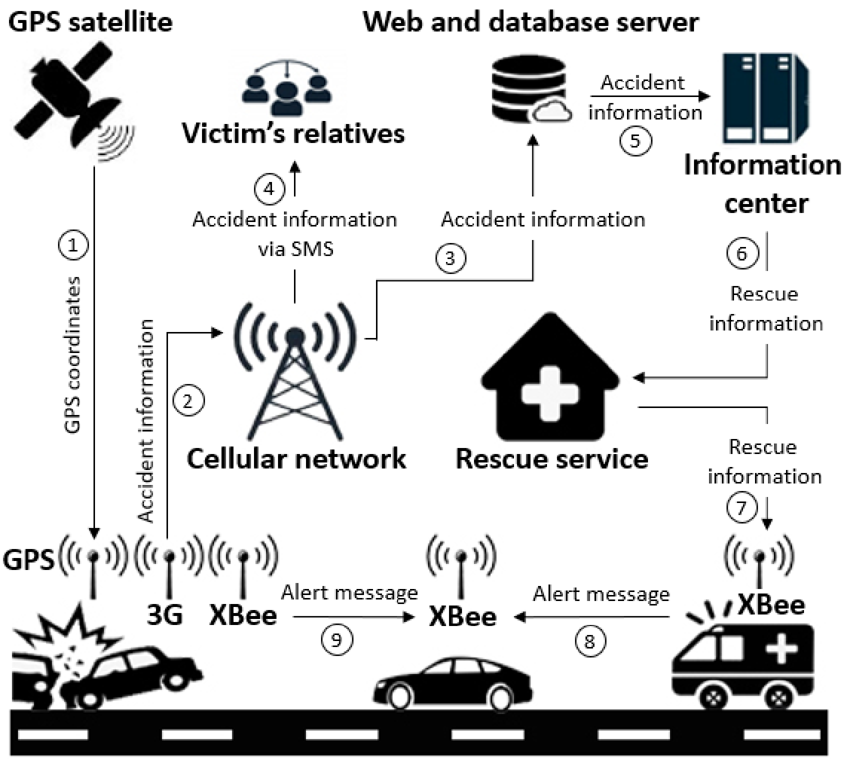

FIGURE 1. The proposed system

In the meantime, the local communication module in the victim's side is also invoked. It keeps broadcasting the alert message to other nearby vehicles to avoid traffic accident. Not only the message from the victim but also the message from an emergency vehicle are broadcasted. So design and implementation of this system could improve the rescue efficiency and traffic safety level by a smooth flow for the emergency vehicles to reach the hospitals in time.

4. **Hardware Components.** To achieve the system requirements, four hardware components serving the needs have been developed. One detects an accident using an airbag triggering signal. The rests are for global and local communications. All vehicles are equipped with these modules related to effective responses as the receiver (nearby vehicles) or transmitter (victims). The hardware components and the associated data are depicted in Figure 2.

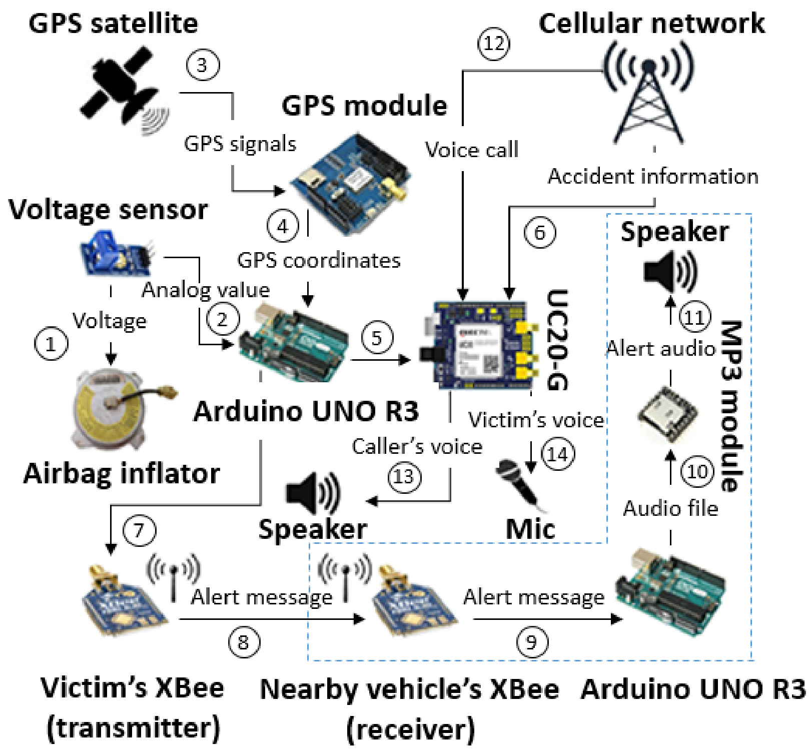

Figure 2. The detail of the hardware components

In this work, we assume that activation of automotive airbags is triggered by crash sensors. A circuit bridging an airbag inflator and a vehicle's power supply is connected, so that voltage between the VCC and ground pins of the inflator rises ①. The accident detection component utilizes this voltage change to determine whether an accident occurs by simply comparing with a pre-defined threshold. A voltage sensor is applied to measuring voltage between two pins. The output voltage value pin is connected to an analog input pin ② of an Arduino UNO R3 board which is the main processing unit of our proposed system.

Once an accident has been detected, the global communication procedure is activated ⑤-⑥. Information regarding the accident will be sent through a cellular network. The GPS coordinates based accident location needed to be updated continuously ④ with Arduino board to avoid timing delays at the initial stage of GPS satellites in acquisition ③. Without initialization, it may take a longer time to acquire satellite signals and get the correct GPS location. This associated data retrieved is commanded to UC20-G module and automatically sents it via SMS to the registered emergency contact numbers. In the meantime, the data packets are transferred to a central processing server via 3G Shield (UC20-G).

The two local communication components, transmitter ⑦-⑧ and receiver ⑧-⑪ are developed for mitigating delay in rescue operations. Both transmitter and receiver are deployed to a vehicle but for different objectives. Messages from a victim are emitted from a transmitter to inform nearby vehicles which obtain messages using a receiver. This kind of messages helps driver receive a message decision to avoid traffic at an accident location or to rapidly approach the location if a driver is able to perform first aid treatment. On the other hand, a transmitter installed in an emergency vehicle broadcasts messages for cooperation purpose. Drivers who receive the messages can early prepare to clear the way for incoming emergency vehicles. An Arduino UNO R3 board in the receiver side selects different alert audios based on what type of message it receives ⑩. An alert audio is then played using an MP3 module connecting with a speaker ⑪.

The XBee Pro module equipped in victim's vehicle received accident detected messages from the Arduino UNO R3. The main issue is the use of XBee Pro module to implement the vehicle-vehicle communication by sending the message as an alarm to alert the nearby vehicles whenever an accident occurs. This action enables rapid entry of the rescue teams as well as public in radius around the accident location (driven less than 220 m, from the experimental results). Therefore, nearby vehicles may notice that victim is in need.

In case if the victim at accident site is connected from others, then an incoming call will be answered on loudspeaker mode automatically through UC20-G (cellular network is mandatory). The victim may be able to answer the call via microphone inputs ⑫-⑭.

5. **Database and Web Application Designs.** A relational database designed for the system consists of two tables which are a user table and an incident table. The user table contains information of dispatchers as follows: (i) User ID, (ii) Username, (iii) Password, (iv) Name, and (v) Title. The attributes of the incident table are (i) Incident ID, (ii) Date time, (iii) Vehicle description, (iv) GPS coordinates, (v) Relative's contact, (vi) Victim's contact, (vii) User ID, and (viii) Status where the User ID attribute in this table refers to as a dispatcher. Most fields are intuitive, but the Status field indicates the current situation regarding an accident having four values:

(i) Accepted – The case is accepted by a dispatcher.
(ii) Ambulance sent – An emergency vehicle has been on the way to the accident location.
(iii) Victim picked – The victim has been on the way to a hospital.
(iv) Victim arrived – The victim has arrived the hospital.

A web application was designed as presented in Figure 3. To develop a web application prototype, the Personal Home Page (PHP) language in conjunction with Hypertext Markup Language (HTML) and Google Maps API were adopted for map display and navigation. The web application framework consists of Apache, PHP, and MySQL.

In this work, we will explain only the main web page used by a dispatch center. The user interface sketch of the web application is presented in Figure 4. The right table

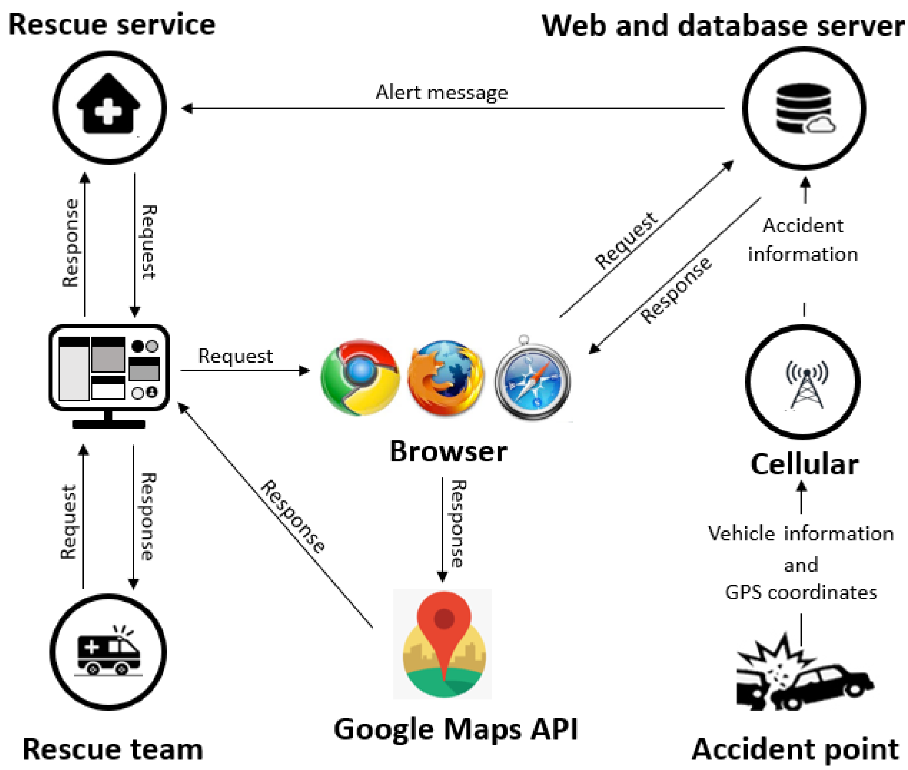

FIGURE 3. Web application architecture

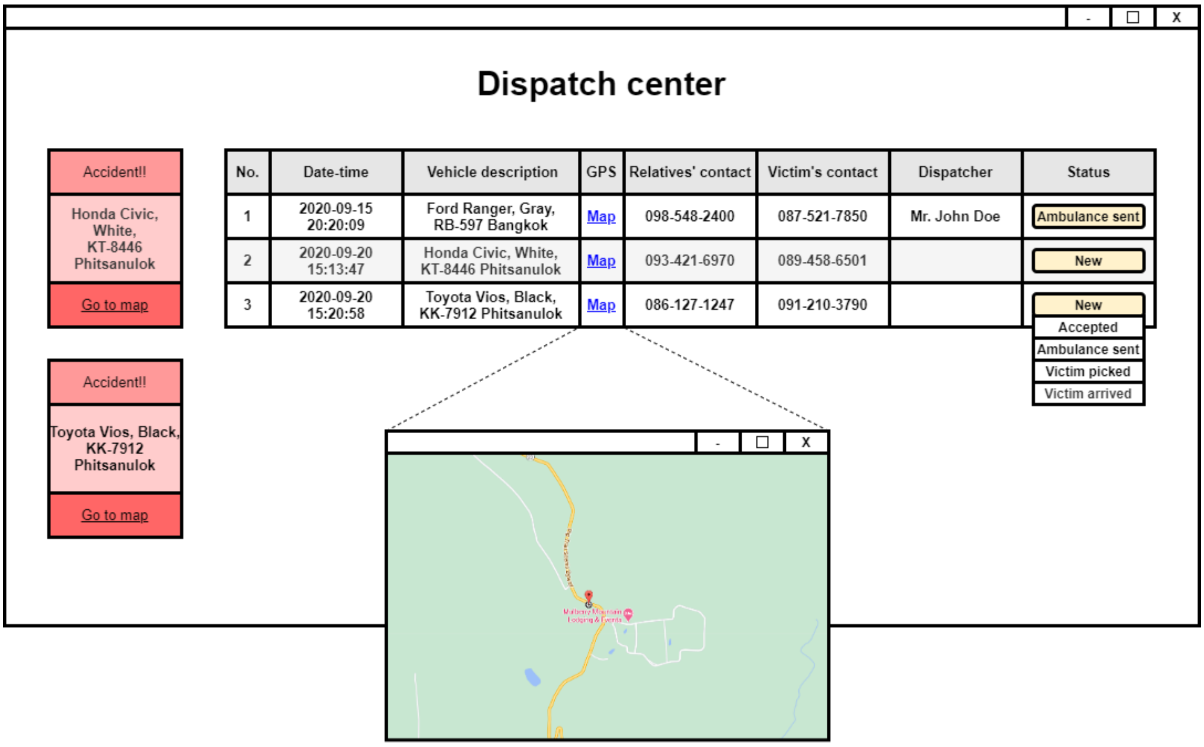

Figure 4. The user interface sketch of the web application

displays the information of accidents. It corresponds to the fields of the incident table. The GPS column contains links to Google map displaying accident locations. Statuses of accidents can be updated using drop-down menus in the rightmost column. Once an accident has been reported, its information will be popped up by a red box on the left side. It also has a link to display the accident location. However, in this stage, a user must refresh the page to let the new incident appear in the right table.

6. **Preliminary Experiment.** In the proposed system, the local communication using XBee Pro modules can be very prone to errors. To check whether the designed system is working properly or not, each vehicle would be equipped with an XBee Pro module. The XBee Pro module's efficiency test was conducted by implementing site-vehicle communication.

From numbers ① and ② of Figure 2, the main signal sender is the airbag inflator. The signal is an airbag triggering status as analog values. This signal is probed by the voltage sensor connected to the Arduino UNO R3 board. This board can robustly detect an accident since a voltage difference between a normal situation and an airbag triggering situation is large. Therefore, the false alarm rate is very low in theory.

A receiver site with an XBee Pro module installed was firstly located, and then a vehicle equipped with an XBee Pro and a GPS modules moved away from the receiver site. The modules were on the vehicle's roof to provide a clear signal reception and transmission. Our experiment used a 20 km/h vehicle to move in the four directions drawn by the black line segments in Figure 5. The transmission rate was 2 seconds to measure the maximum distance that the XBee Pro modules can communicate.

The experimental results showed the first route from the starting point to the endpoint in the experiment. The last signal received was approximately 615.42 meters, shown in Figure 5 (1). In the remaining route, the same measurement method was conducted. In the second route, the vehicle moved to the left of the starting point. The maximum distance was approximately 347.32 meters, shown in Figure 5 (2). In the third route, the

FIGURE 5. The effective range experiment

vehicle moves to the opposite with the first route. The maximum distance was approximately 337.98 meters, shown in Figure 5 (3). And in the last route, the vehicle moves on the right of the starting point. The maximum distance was approximately 247.36 meters, shown in Figure 5 (4).

7. **Result and Discussion.** To check whether the designed system is working properly or not, each vehicle would be equipped with an XBee Pro module. The XBee Pro module's efficiency has been tested to implement vehicle-vehicle communication by sending an alarm message to notify the nearby vehicles whenever an accident occurred within 900 meters or less. The communication between emergency vehicles to many vehicles nearby has been investigated under three different situations as listed in Table 1.

TABLE 1. Alert message test

Testing area	Alert message type	
	Alert message from emergency vehicle	Alert message from victim
Local street	✓	✓
Crowded local street	✓	✓
Main road	✓	✓

The experiment was repeated 10 times for such situations. It was found that the designed system with all field testing has been successfully broadcasting an alert message warning the nearby vehicles, which acts both as a transmitter and a receiver. With the addition of the above, this system can overcome the problems in traffic operations.

From the preliminary experiment, we found that the effective communication ranges were different because of various environments. The route (1) was an open area with very few trees and buildings. The signal transmission distance was 615.42 meters. The route (2) had dense trees and small buildings along the way. The effective transmission range was 347.32 meters. The route (3) had big and dense trees with branches and leaves covering the road. The signal transmission distance was shortened to 337.98 meters. Finally, the last route had a large building obstructing the starting point and the endpoint which yielded the shortest signal distance at the value of 247.36 meters.

Each area's environment affected the receiving and transmitting distances, such as various building sizes, densities, and tree sizes. These also had effect on signal transmission, as presented in Table 2. In the route (1), 62 signals were transmitted, but 49 signals were

Table 2. XBee Pro communication test

Route	(1)	(2)	(3)	(4)
Distance	615.42 meters	347.32 meters	337.98 meters	247.36 meters
# of transmissions	62 times	49 times	40 times	29 times
# of successes	49 times	34 times	27 times	18 times
# of losses	13 times	15 times	13 times	11 times
Loss percentage	21%	30%	32%	37%

successful, and 13 signals were lost so that the loss percentage value was 21%. Signals were sent out 49 times along the route (2) with 34 successes, 15 failures, and 30% loss percentage. In the route (3) with high dense trees, signals were transmitted 40 times, 27 signals were received, and 13 signals were missing with 32% loss percentage. Signals were sent out 29 times along the route (4) which had a large building obstructing the line of sight between the XBee Pro modules. The numbers of successes and failures were 18 and 11. As a consequence, the loss percentage was the lowest value at 37%.

Enhancing the proposed system could be done as the following. In this experiment, the XBee Pro S2C model was used. It has an urban range of 60 meters, an outdoor range of 1200 meters, and a receiver sensitivity of −102 decibel milli-watts (dBm). However, to increase the communication distance (the urban and outdoor ranges), this could be implemented by using, for example, the XBee Pro XSC model. This is because that it has higher transmit power output parameter than the XBee Pro S2C model.

Moreover, it is because the lower dBm value is the better receiver. Thus, to reduce the signal loss (such as from −102 to −110 dBm), this could be implemented by also using, for example, the XBee Pro XSC model. This is because it has a lower dBm of the receiver sensitivity than the XBee Pro S2C model.

More importantly, both the XBee Pro models above have different frequencies. The XBee Pro S2C model uses a high-frequency radio system at 2.4GHz. This frequency has a reflective manner. This reflective action is difficult for a long-distance transition of signals. Then, this will difficultly penetrate surfaces and coverage areas. In contrast, the XBee Pro XSC model uses 900MHz radio system. It is with a lower frequency than the XBee Pro S2C model. Thus, this will less-difficultly penetrate surfaces and cover larger areas than the XBee Pro S2C model.

8. **Conclusions.** The main idea of this work is to propose the system design for developing prototype of the accident detection and alert system to help the rescue team reach the accident scene at the earliest possible time. The proposed system consists of two main components.

(i) Global communication: an accident is detected and reported by integrating the GPS module-based Arduino UNO R3 micro controller, cellular network with the airbag control module.

(ii) Local communication: vehicle communicates with the other vehicle in the specified range (240 meters) and share the information about the road accidents using XBee Pro module.

The test results showed that the designed system can detect the accident location efficiently as well as highly efficient communication between a vehicle involved in an accident, emergency vehicles and other vehicles. Thus, reduce the time and traffic when an accident takes place. Once it is detected, the designed system can reduce the accident death ratio.

Although the proposed system in this study presents a low false alarm rate, it is not easy to deploy. It is better to apply such a system as an assistant part to reducing false alarms. The development of mobile application design for ambulance tracking systems should be noted for future consideration. As a future work, a practical system will need to collect large volumes of data and grow rapidly. It is inevitable to use big data [13] for efficient data management.

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