Real-Time Communication and Location Tracking System for Vehicular Emergency using IOT Based Smart System

G. Naganandhini[1], K. Sowndarya[1], K. Rini Catherine[1], M. Anitha[1]
[1]*Department of Electronics and Communication Engineering*
NPR College of Engineering and Technology
Natham, Dindigul, Tamil Nadu

Abstract - *Internet of Things is an emerging technology having the ability to change the way we live. In IoT vision, each and every 'thing' has the ability of talking to each other that brings the idea of Internet of Everything in reality. Numerous IoT services can make our daily life easier, smarter, and even safer. Using IoT in designing some special services can make a lifesaver system. In this paper, we have presented an IoT enabled approach that can provide emergency communication and location tracking services in a remote car that meets an unfortunate accident or any other emergency situation. Immediately after an accident or an emergency, the system either starts automatically or may be triggered manually. Depending upon type of emergency (police and security, fire and rescue, medical, or civil) it initiates communication and shares critical information e.g. location information, a set of relevant images taken from prefixed angles etc. with appropriate server / authority. Provision of interactive real-time multimedia communication, real-time location tracking etc. have also been integrated to the proposed system to monitor the exact condition in real-time basis. The system prototype has been designed with Raspberry Pi 3 Model B and UMTS-HSDPA communication protocol.*

Keywords – *Semiconductor Optical Amplifier (SOA), Punctured Difference Set (PDS), Encoder-Reuse Technique (ERT), Cross Gain Modulation (XGM), Cross Phase Modulation (XPM).*

I. INTRODUCTION

Right now we are living in the era of Internet and rapidly moving towards a smart planet where every device will be connected to each other. Internet of Things (IoT) [1] is the technology helping us to achieve the goal of a smart world. IoT and Cyber Physical system [2] have the ability to change the vision of our way of living. All developing countries are aiming to transform their cities into Smart City [3] by taking several projects. For example, the government of India has taken an initiative called Digital India [4] to connect the nation to Internet.

A. Necessity of Vehicular Emergency Communication System in Smart City Perspective

In a smart city every device or better to say every 'thing' is connected 24 × 7 to the Ubiquitous network [5]. They can communicate to each other regardless of their communication protocols and hardware / software infrastructure. Machine to machine (M2M) communication [6] is rapidly growing to make the machines more intelligent and shared in nature. In this paper, we have used the concept of a smart city to provide a life savior system for a smart vehicle in any kind of emergency situation occurred on road. Most of the modern cars are well equipped with several sensors, mechanical devices, software, embedded hardware etc. to pre-detect collisions or crashes and avoid them. 'Safety and security' is one of the most important criteria of a vehicle. These kinds of modern safety systems are very much useful and reliable for car drivers as well as passengers on road. But those safety systems have one major limitation. These systems can only be used to avoid crashes. But unfortunately, if the system fails to avoid an accident or there is any other emergency situation other than accident, those systems have no provision to deal with them. If the driver gets sick while driving or some road blockage occurs or some mechanical problem occurs, those systems can't help. A study says that in India 141,526 people were killed on road in 2014 by different types of road accidents [7]. Most of them were killed due to late arrival of rescue teams to the accident location. So it is obvious that if the accident information can be sent to the respective authorities immediately after a situation has occurred some of the lives could be saved.

B. Novelties of the Proposed System

In this paper, we have introduced an emergency communication and location tracking system for any type of vehicular emergency. This system aims to minimize the damages after a vehicle meets any unfortunate situation like an accident by sending automatic message to the nearest hospital and police station. It is also helpful for other emergency situations such as medical emergency, criminal problem, civil emergency and also for mechanical problem in the car. When a car meets any emergency situation the system starts automatically or manually according to the type of the situation and sends emergency message to the control room. The control room then forwards the message to the nearest rescue center (hospital, police station, govt. office, car workshop) according to the emergency type and situation. The features of the system include the followings.

1.
t has a wide verity of emergency situations that could occur on road.

2.
here are some cameras in the car in different angles that can send pictures automatically to the control room to describe the condition more specifically.

3. The control room can forward the message to right and nearest authority for that emergency automatically or manually.

4. Real-time multimedia (voice and video) communication feature also integrated to the system that helps the rescue authority to understand the real scenario of the victims any time.

5. To find out the nearest rescue center we have used Haversine [8] formula to calculate the distance by coordinates. The automatic nature of the system makes it unique and probably the best in its kind.

The objective of this paper is to develop IOT enabled real time communication and location tracking for vehicle Emergency. The paper is organized as follows. In Section II, Related work and research is discussed. In section III, Proposed system is described. In Section IV, Simulation results are presented. In section V, concludes the paper.

II. RELATED WORKS

Internet of Things and Smart City are emerging research topics recent days in Internet oriented technologies grabbing the attention of researchers. The exponential growth of this field is taking us rapidly towards a smart planet, well-equipped with smart objects everywhere. Not only in theory but Padova smart city [9] has actually proved that a fully IoT enabled (smart) city can be achieved in reality. Some of the researchers have also studied on traffic and road security in a smart city. In [10] authors have proposed a GPS based location tracking system able to collect location information and send it through SMS. But the main problem of this system is, it is not a fully automated system. The user has to start the system manually. In [11] the authors have discussed the impact of Intelligent Transportation System (ITS) for future intelligent vehicles.

Thompson, Chris, et al. in [12] have introduced a system that can detect an accident by a smart phone's sensors, e.g. accelerometer sensor etc. and the phone uses its 3G connection to transmit accident information. But the system is not integrated into the vehicle and also not fully automated and sometime needs third party reporter to send complete emergency information along with photos.

OnStar from General Motors [13] provides smart assistance to their vehicles by providing driving assistance, route direction, and navigation service to its customers. It also provides emergency communication services through its always connected 4G connection. But with OnStar, the user can Ionly contact the vehicle's manufacturer or emergency numbers (e.g.911) and not to the local emergency rescue centers that can cause a delay in rescue.

Ford also provides similar types of facility by their Ford Sync [14] app on their cars. When a user needs emergency assistance the app shows the emergency phone numbers from his smart phone on the screen so that the user can contact them immediately. The system can also contact the emergency 911 number for emergency situations. But this app is completely dependent on the user's smart phone.

Authors of [15] introduced ARRS that can automatically detect an accident and report it. They have used image processing approach to detect a vehicular crash from CC Camera videos. But the main problem of this kind of system is the accidents can't be detected in absence of a camera.

Most of these kinds of systems are dependent on the users' smart phones and are not always automated. Some of them are entirely proprietary product for their own cars and on emergency; they can connect to their call centers only. There is no provision for those solutions to contact nearest police or hospitals directly for emergencies that causes delay in rescue mission.

III. PROPOSED SYSTEM

The proposed system is divided in three major parts, an on-board embedded device (situation node), emergency control terminal room and rescue center terminal. We have divided vehicular emergencies into five different types according to their characteristics. The details of each part are discussed in the following sections.

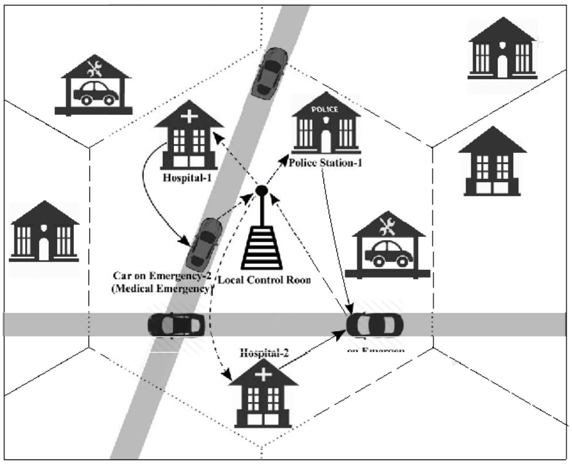

Fig. 1: Architectural diagram of the proposed system for existing infrastructure

A. *Details of the System*

A vehicular emergency system is highly necessary and is an integral part of any smart city for proper safety, security, and reliability of smart living. Most important feature of this system is when a vehicle meets an accident the system starts automatically and track its location and takes some of its initial photos with the preinstalled cameras and send them immediately to the emergency control room. The control room system automatically finds the nearest hospital and police station and forwards the message to them. Now the hospital and police station authority analyze the situation with the help of initial photos and send rescue teams to the accident location. We have divided emergency situations in five different categories as follows.

- **Type-1(Accident):** This is the most important emergency type for a vehicle on road. When a vehicle crashes or meets any accident the system sends the emergency message to the nearest hospital and police station. Also, the preinstalled cameras activate only for this type of emergency to help the rescue teams to understand the real scenario of the situation from the base station and act accordingly.
- **Type-2 (Medical):** Sometime it happens that a passenger or the driver of a car suddenly becomes sick and is unable to go to the hospital or find any hospital nearby. In that case, they can start the system manually and define the emergency type to medical issue. For this type of emergency the control room sends the message to the nearest hospital as emergency medical situation and the hospital acts accordingly.
- **Type-3 (Criminal):** If a car meets some criminal issue, they can also contact the control room for help. For this case the nearest police station is informed.
- **Type-4 (Civil):** If there is any natural calamity, and the road is blocked by some barrier, the nearest government civil service office and police station are informed.
- **Type-5 (Mechanical):** If a vehicle meets some mechanical problems, nearest car workshop is informed.

Table I summarizes different types of emergencies, respective rescue authorities and emergency priority.

TABLE I: Emergency Types and respective contact Authorities

Emergency Type	Mode of Activation	Emergency Message	Contact Authorities	Emergency Priority
Type-1	Automatic / Manual	Location, Photo, Type, Car Info.	Police Station, Hospital	High
Type-2	Automatic / Manual	Location, Type, Car Info.	Hospital	High
Type-3	Manual	Location, Type, Car Info.	Police Station	High
Type-4	Manual	Location, Type, Car Info.	Police Station, Govt. Office	Medium
Type-5	Manual	Location, Type, Car Info.	Car Workshop	Low

B. *Database*

To store all necessary information on car, control room, and rescue centers we need very well structured databases to perform correctly. Any kind of delay whether it is commu-nication or response delay could be dangerous for someone who is on road and needs immediate help. So the structure of the database should be simpler and we should avoid complex queries to retrieve data from database. In our system, we have used three databases to design the prototype as follows.

- **Car Database:** The vehicular database contains all very essential data about the vehicle. Here the car's registration number, owner's details etc. are pre-installed. Also for emergency contact, the owner's family or friends contact information are also stored here.
- **Control Room Database:** To provide immediate service, the control room needs to know all nearby rescue centers' location and their services within its locality. So, in the control room database details of all the nearby hospitals, police stations, govt. offices, workshops etc along with their locations and respective emergency services are stored. Whenever an emergency message comes to the control room, it automatically finds nearest rescue center from the actual emergency location for that particular emergency type and forwards the message to them immediately.
- **Rescue Center Database:** Individual rescue centers have their own databases to store all the records of emergency messages coming from the emergency control room. In this database, all incoming messages coming from control room are stored with the relevant information about the emergency situations, i.e. emergency location, type, images etc.

TABLE II: Example of an on Car database table

Car Id	Owner Name	Registration No	Owner Address	Emergency No	Emergency Location	Emergency Image
U1	User-1	U-xxx-1	UA-xxx-1	xxxxxxxxx1	[initially empty]	[initially empty]

TABLE III: Example of an on Rescue Center database table

Emergency Id	Car Id	Emergency Location	Emergency Type	Emergency Image	Rescue Team
17	U1	22.555034, 88.3075927	Accident	[BLOB- 102.3 KiB]	h1, p1

C. *Situation Node*

For our system, the vehicle needs to be equipped with some hardware equipments. For example, to track the exact location of the car, there should be a GPS device that will return the exact location information of the car. But if GPS is not available, we can use some other techniques to get location, like network location, Geolocation service [16] from Google etc. For our prototype, we have used Google's Geolocation [17] service to get the location (latitude, longitude) in a real-time basis. Other very important feature of the system is the emergency camera in a car. For this purpose, we need to install some cameras in the car in different angles to make the car's full interior part visible. Also, it is very important that if someone meets any accident or other emergency situation, his family / friends need to be informed. For this purpose, there should be a database in the car where the car, its owner, and emergency contact information is stored that will also be sent to the control room. The prototype of the vehicular part has been designed with the following hardware devices.

- For our prototype design we have used Raspberry Pi 3 Model B [18] single board computer as main development board for the vehicular sub-unit design.
- An USB 4G/LTE [19] Dongle is used to track location of the car and also for communication unit.
- An USB Webcam is also used to capture images of the inner parts of the car and also for real-time video communication.
- A microphone and a speaker are also there for voice communication from the car.

EMERGENCY MESSAGE

Emergency Type	Location (Latitude, Longitude)	Emergency Image (only for Type-1)	Car Info. (Emergency Contact)

Fig. 2: Emergency Message Structure.

As discussed earlier, system triggering can be done both automatically and manually. Automatic triggering can be done by several modern mechanical and electronic devices by detecting collision break failure etc. If the system is triggered automatically, the type of the situation is set to Type-1 (accident) by default. For this case, the driver need not do anything. The emergency cameras start taking initial photos and system tracks the location automatically. Finally, the message is generated with all required information. The emergency message contains emergency type, location, initial photo, and car's information, including emergency contact details. The emergency message structure is shown in Fig.2 the entire architecture for a situation node is shown in Fig.3.

If the system is triggered manually by the driver, it asks for the type of the emergency. Here a Watchdog timer [20] has been integrated that waits for 10 seconds for type specification. If type is specified within time, emergency type is set to the specified type; otherwise it treats the situation as an accident and activates the auto mode. For example, a driver gets sick suddenly while driving. If he could manage to turn on the emergency system and specify the emergency type, the system immediately treats the situation as a medical emergency and acts accordingly. If the driver could manage to activate the emergency system but could not specify the emergency type, the watchdog timer of the system waits for
10 Seconds for type specification; if not, it treats the situation as an accident and starts acting accordingly. After generating the emergency message the car's system delivers the message to the emergency control room. The algorithm situation node is discussed in Algorithm 1.

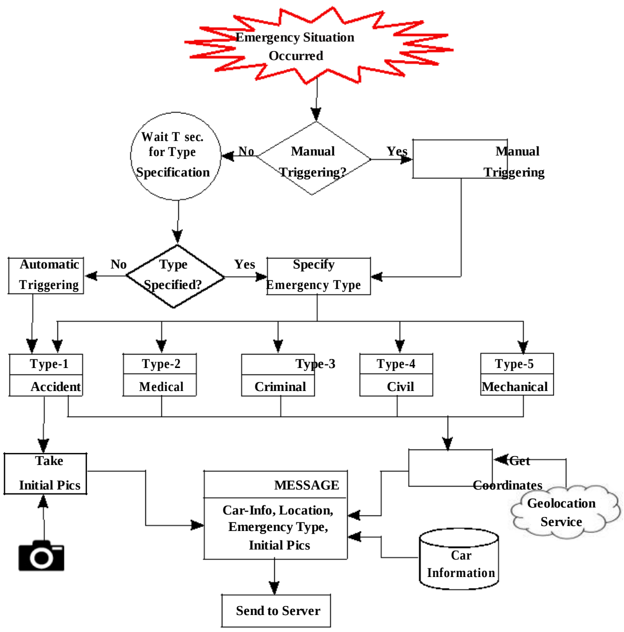

Fig. 3: Architecture of remote vehicle.

D. Control Room

The emergency control room is the central control center to manage and rescue any kind of vehicular emergencies on road. The main task of the control room is to receive emergency messages from a vehicle, locate the nearest rescue centers for that kind of emergency from the actual emergency location, and forward the message to them. Control room server has all information of different types of rescue centers (i.e. hospitals, police stations, car workshops, govt. offices etc.) and their locations stored in its database. So whenever an emergency message comes to the control room, it immediately starts finding the nearest rescue center for its kind from its own database. To measure the distances from situation node to the rescue centers, we have used Haversine formula. The control room system is fully automatic in nature. So there is no human delay. Actions are taken immediately after receiving emergency message. Also, there is a feature of manual control by the control room operator. If he thinks that any other action should take for a particular emergency, he could manually take the actions by forwarding the message to some other rescue center and check the status of the rescue mission. This can supersede the functioning of the automated mode. The structure of the control room is shown in Figure 4 and the algorithm is shown in Algorithm 2.

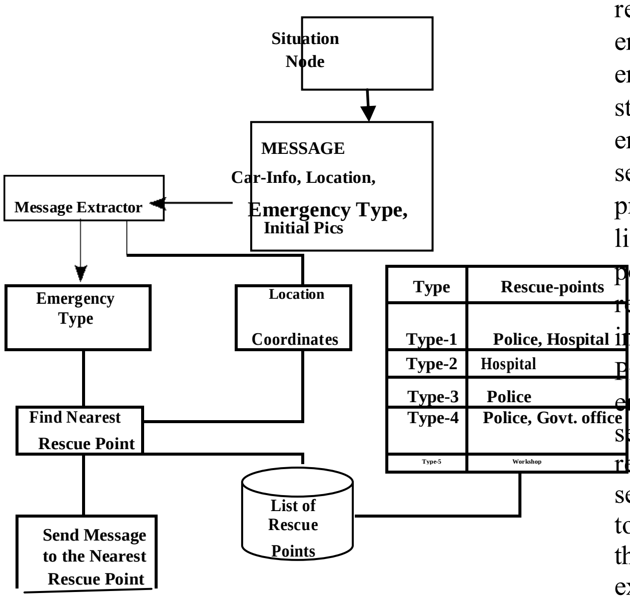

Fig. 4: Architecture of the Control Room.

Distance Calculation: Distance calculation is one of the important parts of the system. A unique feature of this system is the automatic finding of the nearest rescue center. To provide this facility in real-time basis, we have inserted all the information of rescue centers in the server database. The location of the rescue centers are stored in coordinates (latitude, longitude). When a car sends message, the location (latitude, longitude) is extracted from the message and then distance comparison is done according to the type of emergency. The distance between two points (X1, Y1) and (X2, Y2) can be calculated.

Algorithm 1: Algorithm for situation node.

```
Data: location, type (optional), image (optional), car info
Result: Emergency Message to Control Room
Emergency Situation Occurred;
if mode of activation = AUTOMATIC then
  | SET type = type1;                          /* type1 = Accident */
else if mode of activation = MANUAL then
  | START watchdog timer;
  | Wait time = 10 seconds;
  | if type SPECIFIED then
  |   | SET type = new type;                   /* Enter Emergency Type */
  | else
  |   SET type = type1;
  | end
  | END watchdog timer;
  | SET type = new type ;
else
  | SET type = type1;
end
GET location FROM GPS/ Network/ Geolocation ;   /* Enter Emergency Start location tracking system */
SET location (lat, long) = current location (lat, long);   /* Get location */
image = no image;                              /* Initially no image */
while type = type1 do
  | GET image; /* Turn on cameras and take pictures */
  | SET image = new image;
end
GET car info FROM database ;
MESSAGE = (type, location, image, car info) ;   /* Emergency message building */
CONNECT available wi-fi/ Bluetooth/ network ;   /* Only for not IoT enabled vehicles */
Send MESSAGE to control room ;
```

E. Rescue Center

Rescue centers are categorized with their mode of rescue and emergency services. For medical emergency, all nearby hospitals are listed with their emergency service details and locations. Police stations are listed for both accidental and criminal emergencies. For civil emergencies government civil service offices are listed. And for mechanical problems, all nearby car workshops and garages are listed. Emergency mobile vans (ambulance, mobile police van etc.) are also listed here as emergency rescue centers. The complete framework for an individual rescue center is shown in Figure 5.

Primary task of a rescue center is that whenever an emergency message comes from control room they send rescue team to the emergency location and rescue the victims. The original message that was sent to control room is forwarded to the rescue center to analyze the situation more specifically and locate the emergency location. Rescue center system first extracts the message. If there are any photos of the situation, they can immediately understand the real scenario of the victims. The emergency location is shown in map in their system with route direction and navigation service [21] provided by Google so that they could send rescue team to the location by the shortest route.

Algorithm 2: Algorithm for control room.

```
Data: MESSAGE (type, location, image, car info)
Result: Emergency Message to Rescue Center
EXTRACT MESSAGE;
type = new type;
location (lat, long) = new location(lat, long);
image = new image;
car info = new car info;
HAVERSINE (lat, long) ; /* Distance between emergency location and rescue point */
dlong = long1 - long;        /* long1 = longitude of rescue point */
dlat = lat1 - lat;           /* lat1 = latitude of rescue point */
a = (sin(dlat/2))^2 + cos lat × cos lat1 × (sin(dlong/2))^2
c = 2 × arctan2(√a, √(1 − a)) ;   /* c = great circle distance */
d = R × c ;                  /* R = the radius of the earth */
if type = type1 then
    FIND NEAREST police station USING Haversine() and police database;
    police station = NEAREST police station;
    FIND NEAREST hospital USING Haversine() and hospital database;
    hospital = NEAREST hospital;
    UPDATE emergency database;
    SEND MESSAGE to nearest police station AND hospital;
else if type = type2 then
    FIND NEAREST hospital USING Haversine() and hospital database;
    hospital = NEAREST hospital;
    UPDATE emergency database;
    SEND MESSAGE to nearest hospital;
else if type = type3 then
    FIND NEAREST police station USING Haversine() and police database;
```

```
        Police station = NEAREST police station;
        UPDATE emergency database;
        SEND MESSAGE to nearest police station;
else if type = type4 then
        FIND NEAREST government office USING Haversine() and
        government office database;
        government office = NEAREST government office;
        UPDATE emergency database;
        SEND MESSAGE to nearest government office;
else
        FIND NEAREST workshop USING Haversine() and workshop database;
        workshop = NEAREST workshop UPDATE emergency database;
        SEND MESSAGE to nearest workshop;
end
```

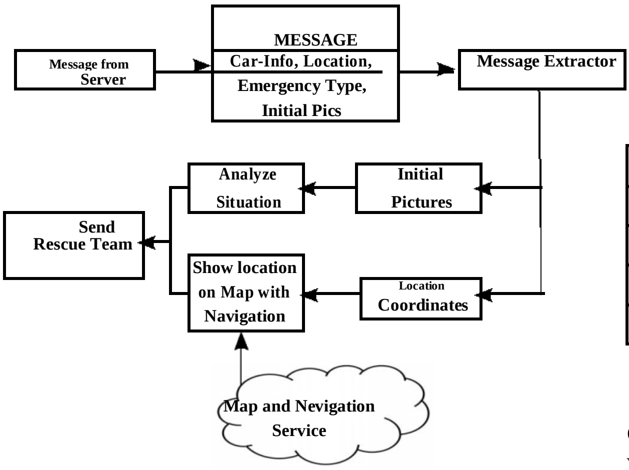

Fig. 5: Architecture of a Rescue Center.

IV. RESULTS AND DISCUSSION

Proposed emergency communication system is able to send automatic message to the control room with all relevant information of an emergency. A snap shot from the emergency control room is shown in fig. where the emergency location is shown in the map that helps the rescue team to reach the location at earliest. All nearby rescue centers are shown in the map and also the nearest one is calculated from the database. An automatic message is sent to them. There are buttons for the control room operator to send the message manually to other rescue centers if he thinks is required. The initial image taken by the car camera is also shown in the interface that can help the authorities to understand the situation. An example screen shot of the control room is shown in Fig.6. Compared to other systems, it is a fully automated system that can automatically find out nearest rescue centers and send emergency message to them. Not only accident, this system provides other four types of emergency options to the driver for other common emergencies that can take place on road. A detailed comparison of the proposed system with existing similar types of systems is shown in Table IV.

Fig. 6: Control Room screen in system prototype.

TABLE IV: Comparison with Existing Technologies.

Emergency System	Automatic/ Manual	On board or not	Type of emergencies	Contact authorities
Proposed System	Fully Automated	Integrated to Vehicle	Five	Directly to the nearest rescue center
OnStar by GM [13]	Partially Automated	Integrated to Vehicle	One	GM Customer Care
Ford Sync [14]	Partially Automated	Synced with Smart Phone	One	Ford Customer Care / 911
ARRS [15]	Fully Automated	Fixed on Traffic Areas	One	Respective Authority

V. CONCLUSION

In this paper, we have proposed an emergency contact and location tracking system for vehicular emergencies on road. The system is fully automatic in nature that can help us to minimize accidental and other emergency damages.

This prototype is mainly designed for smart cities and IoT enabled vehicles. However, this system may also be used with existing infrastructure in any cities. This proposed system is only able to send emergency information from a vehicle to nearby rescue centers, but it can't help to avoid any emergency issues. Also, the system is dependent on several mechanical and electrical devices in a car to detect accident or other emergencies. In future, we would like to include these concerns. Also, we are aiming to design a hardware secured [22] on chip (System-on-Chip / Network-on-Chip) system featuring these services in future.

REFERENCES

[1] L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A Survey," *Computer Networks*, vol. 54, no. 15, pp. 2787–2805, 2010.

[2] E. A. Lee, "Cyber Physical Systems: Design Challenges," in *Object Oriented Real-Time Distributed Computing (ISORC), 2008 11th IEEE International Symposium on*. IEEE, 2008, pp. 363–369.

[3] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Ihings for Smart Cities," *Internet of Things Journal, IEEE*, vol. 1, no. 1, pp. 22–32, 2014.

[4] "Digital India," Online, 2015, (Last accessed March 18, 2016). [Online]. Available: http://www.digitalindia.gov.in/

[5] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions," *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, 2013.

[6] M. Chen, "Towards Smart City: M2M Communications with Software Agent Intelligence," *Multimedia Tools and Applications*, vol. 67, no. 1, pp. 167–178, 2013.

[7] NCRB, "Accidental Deaths and Suicides in India 2014," New Delhi: National Crime Records Bureau, Ministry of Home Affairs, Tech. Rep., 2015.

[8] G. Van Brummelen, *Heavenly Mathematics: The Forgotten Art of Spherical Trigonometry*. Princeton University Press, 2013.

[9] A. Cenedese, A. Zanella, L. Vangelista, and M. Zorzi, "Padova Smart City: An Urban Internet of Things Experimentation," in *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2014 IEEE 15th International Symposium on a*. IEEE, 2014, pp. 1–6.

[10] J. Maleki, E. Foroutan, and M. Rajabi, "Intelligent Alarm System for Road Collision," *Journal of Earth Science and Engineering*, vol. 1, no. 3, 2011.

[11] F. J. Martinez, C.-K. Toh, J.-C. Cano, C. T. Calafate, and P. Manzoni, "Emergency Services in Future Intelligent Transportation Systems Based on Vehicular Communication Networks," *Intelligent Transportation Sys-tems Magazine, IEEE*, vol. 2, no. 2, pp. 6–20, 2010.

[12] C. Thompson, J. White, B. Dougherty, A. Albright, and D. C. Schmidt, "Using Smartphones and Wireless Mobile Sensor Networks to Detect Car Accidents and Provide Situational Awareness to Emergency Respon-ders," in *ICST Conf., June*, 2010.

[13] R. A. Young, "Association Between Embedded Cellular Phone Calls and Vehicle Crashes Involving Airbag Deployment," in *1st International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Aspen, CO*, 2001, pp. 390–400.

[14] "911 Assist Overview," Online, 2016, last accessed 15th March, 2016. [Online]. Available: https://owner.ford.com/how-tos/sync-technology/ sync/settings/911-assist-overview.html

[15] Y.-K. Ki and D.-Y. Lee, "A Traffic Accident Recording and Reporting Model at Intersections," *IEEE Transactions on Intelligent Transportation Systems*, vol. 8, no. 2, pp. 188–194, 2007.

[16] M. Graham, S. A. Hale, and D. Gaffney, "Where in The World are You? Geolocation and Language Identification in Twitter," *The Professional Geographer*, vol. 66, no. 4, pp. 568–578, 2014.

[17] P. J. Zehler, "Method for Setting The Geolocation of a Non-GPS Enabled Device," 2013, uS Patent 8,467,990.

[18] S. Monk, *Raspberry Pi cookbook: Software and hardware problems and solutions*. " O'Reilly Media, Inc.", 2016.

[19] E. Dahlman, S. Parkvall, and J. Skold, *4G: LTE/LTE-advanced for mobile broadband*. Academic press, 2013.

[20] F. Vahid and T. Givargis, *Embedded System Design: A Unified Hard-ware/ Software Introduction*. John Wiley & Sons New York, NY, 2002, vol. 4.

[21] D. H. Cho, "Navigation Service System and Method Using Mobile Device," 2014, uS Patent 8,775,067.

[22]S. Koley and P. Ghosal, "Addressing Hardware Security Challenges in Internet of Things: Recent Trends and Possible Solutions," in *12th IEEE International Conference on Advanced and Trusted Computing (UIC-ATC-ScalCom-CBDCom-IoP)*, 2015, pp. 517–520.