Road Accident Monitoring System and Dynamic Insurance Pricing Using Fog Computing

Ajit Singh
School of Computer Science and Engineering
Vellore Institute of Technology
Tamil Nadu,India
ajitofficial0702@gmail.com

Akshita Kapur
School of Computer Science and Engineering
Vellore Institute of Technology
Tamil Nadu,India
akshita.kapur2019@vitstudent.ac.in

Anshul Anand
School of Computer Science and Engineering
Vellore Institute of Technology
Tamil Nadu,India
ansshul.anand2019@vitstudent.ac.in

Dhruv Vaidh
School of Computer Science and Engineering
Vellore Institute of Technology
Tamil Nadu,India
dhruv.vaidh2019@vitstudent.ac.in

Gunik Luthra
School of Computer Science and Engineering
Vellore Institute of Technology
Tamil Nadu,India
gunik.luthra2019@vitstudent.ac.in

Boominathan P
School of Computer Science and Engineering
Vellore Institute of Technology
Tamil Nadu,India
boominathan.p@vit.ac.in

***Abstract*—The emergence of Cloud Computing and the exponential evolution of the Internet of Things (IoT) have thrown up new key challenges like - Latency, Security, and Performance. Fog computing provides a solution at addressing these issues. The architecture of Fog computing is such that it helps bring the computational power of Clouds at nodes situated much closer to the IoT device, helping to improve the overall Quality of Service parameters. The quick latency, response time, bandwidth constraints and improved resolutions of privacy and security concerns have led Fog computing to find its way into Health care monitoring systems. Another application of Fog computing can be found in traffic accident emergency systems, where every second of response time lost can be the difference between life and death, the quick repose time of fog nodes comes into play. This paper aims at proposing a monitoring system installed in cars that will aid law enforcement agencies and health care facilities respond quicker to emergencies leveraging the improved latency of Fog nodes and also a cloud computing system for using the data gathered from individual cars and drivers to determine the insurance rate of the car.**

Keywords—Cloud computing, Fog computing, Nodes, Sensors, Accident emergency system, Insurance pricing

I. Introduction

Even though there is drastic progress in technology and its use, the technology used in accident response systems still needs a lot of improvement because even today world records around 1.3 million deaths each year due to road accidents [13]. Occurrence of accidents can happen anytime, anywhere, within a fraction of a second with no prior notice. The accidents are obviously fatal but many lives can be saved if the time delay from the time of the accident to the time when the people receive medical help is reduced by a few minutes or seconds. Leveraging real-time IoHT applications has helped to advance the healthcare system [8].

The mechanism that exists today is not as quick as per the requirement. As most of the existing models require someone to manually contact the required departments for help. In some scenarios the accident is huge and the victim himself cannot call for help and there is no one to help at the accident site in such a situation we require a fully automatic system to inform the concerned departments.

The advent of FOG computing has opened new spectrums of methods to reduce this time delay. Fog computing also known as Edge Computing is an expansion of cloud computing and is more near the edge devices. The important features of FOG computing are adaptability, real-time communication, less latency, and compatibility [9]. The quick real-time data collection, processing, and transmission of signals is another feature that is useful in creating a network of nodes.

Although there exist some proposed architectures that have used FOG computing keeping the time delay in mind. However, these fail to address the major issue of reporting the accident via an app [2,10], hence requiring third-person support to call for the emergency services. The proposed methodology in the paper addresses this issue and puts forward an automatic road accident emergency system that uses both FOG computing and cloud computing to minimize this delay and save precious lives.

The study [4] proposes the use of a Global Positioning System (GPS), GSM modules to help track vehicles during accidents, a Light-dependent resistor, an LCD screen, and an accelerometer that would help to spot the vehicle at night by sending an SMS. The proposed system in this paper automates this process during an accident and does not rely on sending of an SMS during an emergency.

Fog computing bundled with Cloud computing can play a huge role in managing and tackling emergencies. The cloud framework provides immense manageable resources, storage and virtual network connectivity which gives the opportunity to monitor the driver's driving skills and give driver ratings [6]. This can be used to incentivize safe driving with lower premiums on car insurance and ultimately make the roads safer for everyone. In the study [7], monitoring drivers help keep them alert and focused on road eliminating the three major forms of issues that play a major role in accidents – a) drowsiness, b) Texting, and c) distractions on road.

A simulation of the proposed accident alert system was run and the effectivity of Fog nodes in accident prevention was displayed.

The paper is organized as follows section II is related works, section III has proposed methodology which is further divided into two sub-sections – A) Emergency Alert System, B) Dynamic Insurance Pricing, and section IV concludes the paper with future work that can be done.

II. Related Work

In the paper, Umakant Dinkar Butkar et al. [1] emphasizes to devise a plan that includes a warning and detection of the incident. The backbone of the system, which aids in message transmission to various scenarios, is the microcontroller node MCU. Accidents will be sensed by the device's core module, the impact sensor. The impact sensor activates in the case of an accident, and data is sent to the registered number through the GSM module. A GPS-based national location tracking system can be used to change position. Smartphones are equipped with inbuilt sensors like accelerometers that can identify indirect dangers, enhancing the usage of automated accident detection and reporting systems. There are several obstacles to be addressed, namely the risk of negative consequences from accidentally dropped phones. Reducing the false level of smartphone accident detection is crucial due to the high number of phantom (accidental) calls made to emergency services. Risk detection systems may be developed to guard against erroneous assumptions using a mix of contextual data, such as knowing when the user is in the vehicle, sensor data, such as accelerometer and audio information, and filtering sensitive sensor data. For instance, airbag shipment doesn't begin until an acceleration of 60G’s.

In this paper Mohammad Aazam et al. [2] have realized that the emergency notification interface should be quick and efficient. To achieve this goal they utilized the concept of fog computing with already existing cloud computing. In most of the mechanisms existing today require the user to realize the type of emergency and call the required departments. Introducing the concept of fog computing will help complete this whole process with just a click of a button. According to the evaluation performed end to node fog communication is quick from end-to-node cloud communication for transferring both multimedia files and bulk data further to this cloud communication also has synchronization delay. So, they concluded that using fog computing will be beneficial.

The authors Zubaida Alazawi et al. [3] Proposed a model called intelligent disaster management system. The paper suggests a three-layer system. The cloud layer provides the environment for the system to work. The intelligent layer consists of various algorithms and models to process the best strategy for response according to the data provided. Finally, the data is provided by the system interface which consist of various gateways. According to the evaluation performed by the authors they concluded that this system is an advancement over traditional disaster management system.

The study discussed by Yifan Huang et al. [5] is a ratemaking framework for UBI, and its efficacy is evaluated in two scenarios—risk categorization and claim frequency prediction. From this study, several inferences may be derived. First, sophisticated machine learning algorithms work well in some cases for issues involving risk categorization, with the XGBoost model often having the greatest prediction accuracy. Second, driving behavior characteristics play essential roles in pricing automotive insurance. Regardless of their forms and the models being employed, the incorporation of driving behavior variables in risk probability models may always increase the forecast accuracy. The large gains show a more robust and direct causal association between these factors and the driving risk. But even so, claim frequency models should be more careful when utilizing factors related to driving behavior. Third, both theoretical and practical considerations support the framework that use the binning approach to create distinct tariff classes. Using binned variables in GLMs will ultimately be preferable to using original variables, regardless of whether the model is for risk probability or claim frequency. This suggested framework not only has a high prediction accuracy but also complies with the insurers' and regulators' criteria for interpretability, suggesting that it may have some practical UBI pricing applications

The study done and method proposed by Harit Sharma et al. [10] give us an insight into road accidents happening and how to tackle this issue. The paper suggests a method to bring a simple app that could alert the authorities with the help of an algorithm and MEMS-grade sensors which are provided in smartphones like an accelerometer, gyroscope, etc. The application S-Car Crash collects data from the smartphone sensors and gives it to the crash detection algorithm which compares it to the data provided by the NHTSA crash database and then according to the results forward it to the authority. The main work of this app is to balance out the limitations of a normal smartphone crash detection app as the sensors provided in them are only able to record a certain amount of acceleration and the crashes have a lot more acceleration compared to the measures of the smartphone. The application also uses microphones to eliminate the false positives in a crash as many of the medium crashes have an acceleration of 40 g which would not be equal to the standard of the crashes. That’s why it is a very good app that reduces the probability of crashes.

Harpreet Singh et al. [11] discussed the development of driver behavior profiling, i.e., rating/categorizing drivers into distinct categories depending on how they drive, has resulted from this paper's focus on recognizing unsafe and non-economical driving maneuvers. The PRISMA procedure is utilised in this article to shortlist the parameters used to profile the drivers. Speed, Acceleration, Braking/Deceleration, Jerk, Sudden Lane change, Sudden maneuver, Cornering, Idling, Engine speed, Throttle position, Mileage, Traffic flow, Traffic violation, Spatial, Variation, Temporal Variation, Distraction, Time Headway were the 17 parameters used to classify the drivers in this study. Aggressive, Distracted, Risky, Conservative/ Calm, Safe, and Saver drivers are categorised (mainly based on fuel consumption). The studies utilised for assessment classify their drivers using the following approaches: K-Means clustering, Recurrent Neural Networks, Long Short-Term Memory, and Fuzzy Interference Systems are some of the techniques used. Data is collected via GPS, OBD, Inertial Navigation systems, In-Vehicle Telemetry, and Smartphone sensors.

Roel Verbelen et al. [12] in their paper proposed a different approach for calculating insurance premiums on cars. The existing approach to perform the task mentioned above is by using the driver’s age, license age, postal code, engine power, use of the vehicle and insurance claim history. The approach discussed in the study focuses on the usage of the vehicle, this is approach is termed as Usage-Based Insurance (UBI). UBI focuses on the data gleaned by the black-box device installed in a vehicle to return its real-time telematic information to the insurance companies. This device measures the speed, harsh or smooth braking, aggressive acceleration or deceleration, cornering, and parking skills the driver is applying while driving. The data acquired from the car along with the insurer information is being utilised to calculate the UBI. For model training purposes, the researchers use the Belgian telematics insurance dataset. The model incorporates the usage of a regression framework of Generalized Additive Models (GAMs). GAMs provide an important advantage of interpretability which is instrumental in calculating the insurance premiums making it easier for the policyholders as well as the insurance companies to understand.

III. METHODOLOGY

The primary aim of the paper is to propose an architecture that provides a solution to the time delay that exists between the accident and the time to initiate a response, furthermore automates the process hence removing the need to use an app or other forms of an emergency button and allow direct initiation of emergency protocols and save lives that are lost due to few precious seconds. A road accident is any event that is recorded on the pressure sensors on the frontal and sides of the car that trigger the opening of airbags and other safety measures in the car. A similar model using an app and fog is presented in [2] which this paper further improvises. Moreover, this paper also aims at making the road safer by monitoring the drivers.

A. *Emergency Alert System*

The proposed architecture makes sure in case of an accident or a car crash when the other safety features of the car activate like airbags etc. the sensors in the car transmit signals to locate the nearest Fog node and send an emergency SOS from the car to the nearest FOG node. The FOG node is located at every traffic signal or street light depending on the availability and requirements. The car sensors at the same time try to communicate with the central cloud server to reduce delay, in the event the fog node is not found. The cloud server receives the SOS message and waits for a further signal from the sensors.

Fog nodes are of three types server, gateway, and fog devices. The fog node that receives the SOS signal acts as a gateway to the servers at the emergency centres. It pre-processes the signal received and identifies the location of the car and pins in it's own location to the stack and forwards the SOS signal to the emergency center servers. By avoiding time delays to send the message to a central cloud and the time of pre-processing and buffering of information at the cloud center, the FOG nodes avoid delays in sending SOS messages to the centers.

The FOG nodes in the vicinity of the accident receive an emergency SOS signal from the car sensors, pre-process them and then finally relay the SOS message, base location of the FOG node to the pre-defined disaster response centers 1st being a police station, 2nd being a hospital, and lastly a fire station. The information of the nearest centers in these categories is pre-fed in the FOG node to avoid delay in sending the SOS message to the centers. The Fog node also sends an acknowledgment message back to the sensors of the car which on receiving the message forward the same to the cloud's main server.

The SOS message being sent from the car contains the GPS location and an emergency help signal. The message relayed from the FOG node contains both the GPS location of the car as well as the base location of the FOG node to eliminate any hassle that might occur during the transfer of the SOS signal and GPS location and make it easy for the responding departments to act quicker. The extensive location information in the SOS messages plays a key role in the identification of location as the major time is spent in figuring out the location of the accident site. Figure 1 represents the Architecture of the emergency alert system.

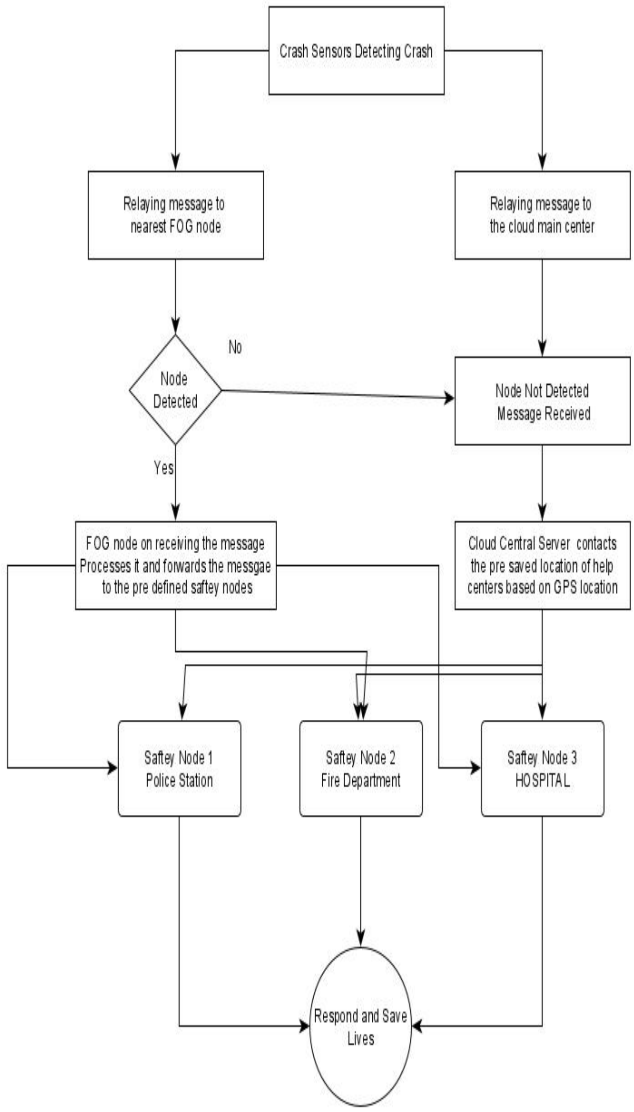

Fig. 1 Architecture of the emergency alert system

The pre-fed centers are equipped and connected to their respective network of FOG nodes, on receiving the SOS message the respective departments send their emergency response teams to the site and this efficient architecture will prove to have a quick accident to a response time that will save precious lives of people. The main center reads the message from the FOG node and displays the detail on their screens. Several FOG nodes create a network of safety that enables fast response and help save victims' lives. Using a FOG-enabled network reduces the time to communicate essential information by a significant amount.

In case the FOG node is not found, the cloud server waits for 90 seconds to receive an acknowledgment from the car sensors regarding the SOS signal reaching the node. If no response is received an automatic sequence is started and the nearest police station and hospital are contacted via the cloud network. The cloud main server works to locate the nearest departments during the waiting period using the GPS location received from the car. And if a response is received by the cloud main server, then no action is taken by them. Figure 2 shows the communication pattern of the emergency response system.

A simulation was performed to calculate the expected time of sending and receiving the message and dispatch time by the emergency services. This has been discussed in section IV.

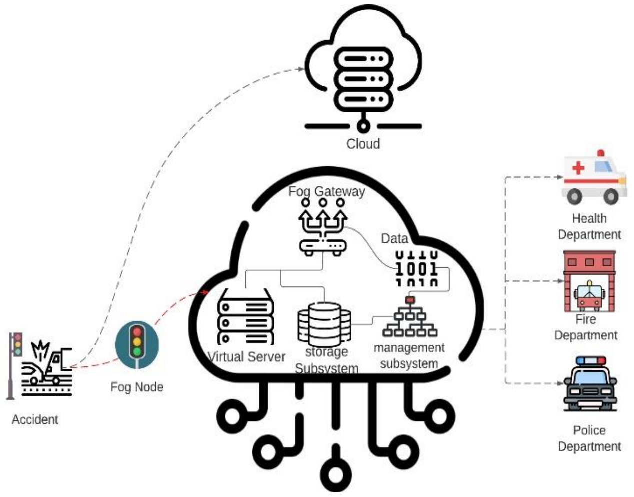

Fig 2. Accident Detection Communication Model

The proposed architecture not only reduces the time taken to respond to the immediate emergency that arises due to the accident and saves lives but also will help bolster the public perception of emergency services in the country. With the proposed architecture the need for an app especially in cases where the driver fainted during the impact of the accident, is eliminated. Hence this will prove to be more effective than previously proposed systems.

The pressure sensors used to detect a crash on the frontal and sides that help open airbags play a huge role in detecting a crash and triggering an SOS signal. On receiving a trigger a Wireless Sensor network records the GPS location of the vehicle and relays it in order to find a fog node and also to the cloud server. The WSN also waits for a response from the fog node. The frontal and side crash sensors being already in place and effective in detecting crashes will help add this additional feature without extra cost. A WSN has two radio modules that transmit and receive messages and hence serves the purpose of transmitting an SOS message. And a GPS locator is mandatory on all cars these days and is also accurate in providing the location of the car. The WSN sensors in the car will make use of the Vehicle ad hoc Network (VANET) and Intelligent Transport Systems (ITS) already present in most vehicles and also the Global Positioning System (GPS) to send SOS signals to the FOG nodes and the cloud network.

B. Dynamic Insurance Pricing

Along with the FOG safety model the proposed architecture also helps in making our roads safer. It plans to monitor the driving skills of the driver in real-time with the use of pressure sensors and other algometric methods and place them under the Accelerator, Brake, and Clutch of the cars. It has been studied that drivers that know their behavior and skills are being monitored tend to drive much more safely as compared to other drivers [11].

The paper proposes adding pressure sensors to record sudden braking or high-speed acceleration or prolonged pressure on the clutch to determine the ranking of a driver and using the data collected to determine the amount of insurance money a driver should pay as a premium for his car insurance. Figure 3 represents the architecture of the dynamic insurance model.

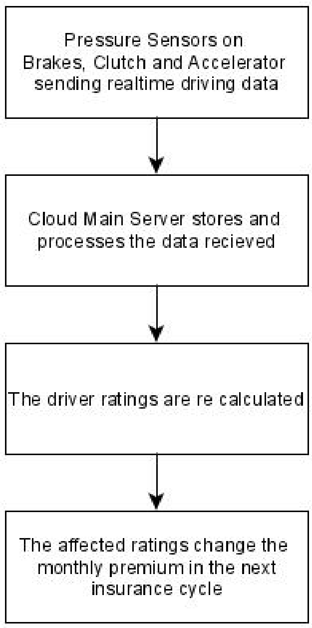

Fig. 3 Architecture of the dynamic insurance pricing model

The data from these sensors send real-time information to the cloud main server leveraging the already existing VANET and ITS technologies. The cloud main server stores the data and uses it for re-calculating the driver ratings at the end of each trip. The data being relayed will provide insight into the driving skills and it could be used in more ways to improve the safety of the roads and save precious lives. Figure 4 displays the clouds data collection and usage of data collected via cars.

The paper also proposes that the driver with better ratings can be asked to pay a lesser monthly premium for car insurance than those with poor ratings. This not only improves the consciousness of the driver but will in turn prove to be a good business model for insurance companies. This incentivizes careful and safe driving and in turn discourages callous and rough driving on the streets where the safety of the driver and everyone present on the roads are at risk

The cloud-native platform that is proposed to monitor the driver uses the data from the driver using a V2C (Vehicle to Cloud) communication [ ] and the VANET and ITS systems. The data is stored and processed and the driver ratings are calculated in the following manner. The negative and the positive impactors are recorded and sent to the cloud. The cloud pre-processes and checks for the factors that will help it either subtract, add or do nothing to the driver ratings based on the drivers' performance. The factor may include a) drowsiness, b) texting during driving, c) distractions from the road, d) rash acceleration and e) abrupt breaking.

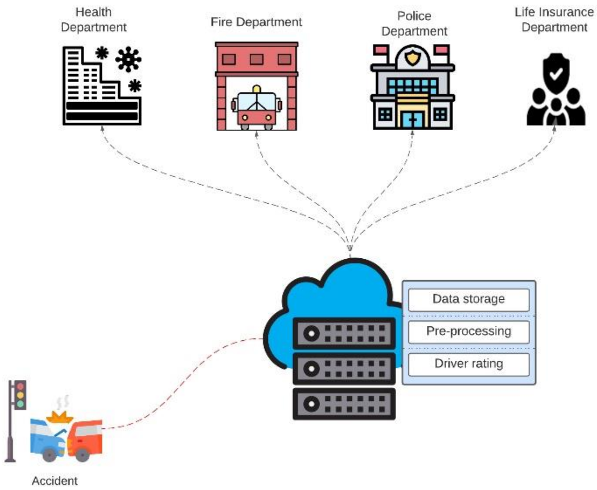

Fig. 4 The cloud communication pattern and usage of data collected

The driver ratings are calculated based on the way drivers drive. By monitoring drivers during overspeeding, abrupt and heavy braking, rash driving and being drowsy while driving, and texting on the phone. These can be monitored using a dashboard camera, pressure sensors under the brake and accelerator pads, and also capturing speed during different times of the day. All these activities can have a negative or positive impact on your driver points, hence enabling the creation of a central driver rating system.

The novelty of the methodology proposed in the paper is as follows:

- The proposed automatic emergency signaling system using Fog nodes which has been missing in previous related works.
- Cloud-connected network that relays auto SOS messages to the concerned departments in case the Fog node is not found.
- The collection of driving data and using it to rate drivers that can be used to monitor drivers.
- Proposing to incentivize good drivers with cheaper premiums on car insurance hence making roads safer.

IV. Results and Discussion

A simulation of the proposed accident alert system model was created on Omnet++. The models had 1 alert sensor to transmit the message and the GPS location, 1 Fog node to receive, pre-process and forward the message and 3 pre-defined Fog emergency centers in Hospital, Police Station and Fire Department. The simulation also contains a cloud server. This helps to simulate and evaluate the model on a real-time basis.

The data from these sensors send real-time information to the cloud main server leveraging the already existing VANET and ITS technologies. The cloud main server stores the data and uses it for re-calculating the driver ratings at the end of each trip. The data being relayed will provide insight into the driving skills and it could be used in more ways to improve the safety of the roads and save precious lives. Figure 4 displays the clouds data collection and usage of data collected via cars.

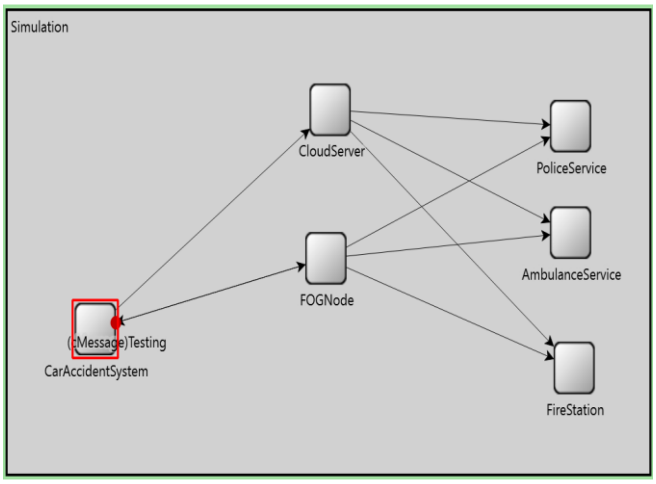

Fig 5. Simulation created to test FOG nodes and their performance

Figure 5 displays the simulation created. The simulation assumes the car to be in an emergency situation and activates the alert systems of the car. The emergency message, seen as a red dot in the simulation, is transmitted by the sensor in the car to both the cloud and the Fog node.

The Fog node, on receiving the message organizes and forwards the message to the emergency services. It also relays the message to the car once it is received. The message forwarded from the fog node contains the GPS location of the car as well as the base location of the Fog node. The emergency services receive the message and deploy the teams as required.

The simulation showed that the time taken for the sensor to relay a message to the Fog node is 4.7 to 5 seconds while the fog node on receiving the message relays it to the emergency services in 5.2 to 5.5 seconds depending on the latency of the nodes.

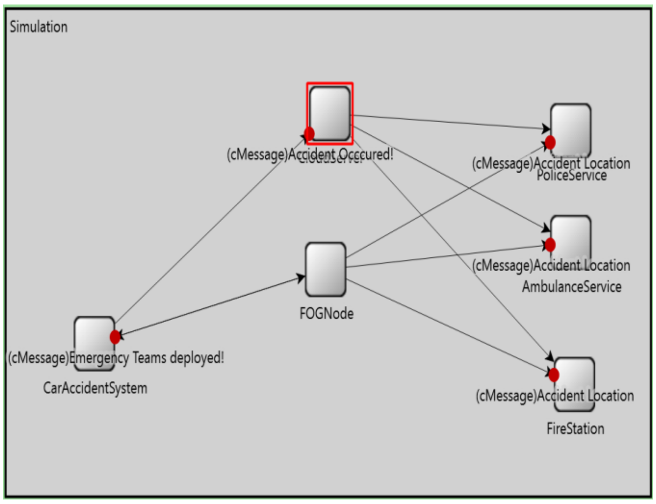

Fig 6. Simulation after all emergency services are notified.

Figure 6. displays the final picture of which emergency services were notified and also shows the message received by the emergency services.

The simulation also helped show how the message from the sensor to the cloud took around 28 seconds and an added delay of synchronization of 9 seconds. The cloud takes about another 28-30 seconds to convey the message to the emergency response center. This shows the advantage of using a Fog based emergency system in place of the conventional cloud-based system as it will save lives in critical situations and make our emergency response system more efficient and reliable.

V. Conclusion

Every second matters when it comes to saving a life during a fatal accident and it will not be possible for the driver or the riders to reach for their phones in every situation and call for help, hence the proposed system eliminates and solves both problems. The proposed solution uses a FOG nodes network that helps relay messages to the respective local authorities to aid in a quicker response to an accident. The automatic transmission of the SOS message when a crash happens means no involvement or dependency on other people to save the victims' lives. Fog computing provides a resource hungry offloading and pre-processing of the data in a more rapid way than conventional cloud computing techniques. It is can be observed even in past work that FOG computing is way faster than traditional methods of communicating information. Hence the idea proves to be an effective one. Moreover, in the second set of the proposed model, the data collected during driving and the cloud main server can be used to help determine differential insurance pricing and in turn, help provide a way to monitor and help drivers be more careful during driving. The future scope of the work is to try to implement and test on the proposed model. The FOG network that will be put in place can also be used in other fields to help improve communication.

Acknowledgment

The authors would like to thank VIT Vellore, and Dr. Boominathan P for his immense guidance and support throughout the paper.

References

[1] "View of Accident Detection and Alert System (Current Location) Using Global Positioning System".

[2] M. Aazam and E. N. Huh, "E-HAMC: Leveraging Fog computing for emergency alert service," in 2015 IEEE International Conference on Pervasive Computing and Communication Workshops, PerCom Workshops 2015, Jun. 2015, pp. 518–523. doi: 10.1109/PERCOMW.2015.7134091.

[3] Z. Alazawi, S. Altowaijri, R. Mehmood, and M. B. Abdljabar, "Intelligent disaster management system based on cloud-enabled vehicular networks," in 2011 11th International Conference on ITS Telecommunications, ITST 2011, 2011, pp. 361–368. doi: 10.1109/ITST.2011.6060083.

[4] A. Halin, J. G. Verly, and M. Van Droogenbroeck, "Survey and synthesis of state of the art in driver monitoring," Sensors, vol. 21, no. 16, 2021, doi: 10.3390/s21165558.

[5] Y. Huang and S. Meng, "Automobile insurance classification ratemaking based on telematics driving data," Decis. Support Syst., vol. 127, Dec. 2019, doi: 10.1016/j.dss.2019.113156.

[6] N. Milanović, M. Milosavljević, S. Benković, D. Starčević, and Ž. Spasenić, "An acceptance approach for novel technologies in car insurance," Sustain., vol. 12, no. 24, pp. 1–15, Dec. 2020, doi: 10.3390/su122410331.

[7] C. M. Nalayini, P. Sreemathi, and B. Nanditha, "Deterrence of Accident Using IoT," J. Trends Comput. Sci. Smart Technol., vol. 4, no. 2, pp. 96–105, 2022, doi: 10.36548/jtcsst.2022.2.005.

[8] V. K. Quy, N. Van Hau, D. Van Anh, and L. A. Ngoc, "Smart healthcare IoT applications based on fog computing: architecture, applications and challenges," Complex Intell. Syst., 2021, doi: 10.1007/s40747-021-00582-9.

[9] H. Sabireen and V. Neelanarayanan, "A Review on Fog Computing: Architecture, Fog with IoT, Algorithms and Research Challenges," ICT Express, vol. 7, no. 2, pp. 162–176, Jun. 2021, doi: 10.1016/j.icte.2021.05.004.

[10] H. Sharma, R. K. Reddy, and A. Karthik, "S-CarCrash: Real- Time crash detection analysis and emergency alert using smartphone," in 2016 International Conference on Connected Vehicles and Expo, ICCVE 2016 - Proceedings, Dec. 2016, pp. 36–42. doi: 10.1109/ICCVE.2016.7.

[11] H. Singh and A. Kathuria, "Profiling drivers to assess safe and eco-driving behavior – A systematic review of naturalistic driving studies," Accid. Anal. Prev., vol. 161, Oct. 2021, doi: 10.1016/j.aap.2021.106349.

[12] R. Verbelen, K. Antonio, and G. Claeskens, "Unraveling the predictive power of telematics data in car insurance pricing," 2017. [Online]. Available: http://europa.eu/rapid/press-release_IP-11-1581_en.htm

[13] "Road traffic injuries" - World Health Organization (WHO) https:// www.who.int› Newsroom › Fact sheets > Detail