**ROAD INCIDENT REPORTING SYSTEM**

**BY**

**BIBEK ITANI**

**A Thesis Submitted in Partial Fulfillment of the Requirements**

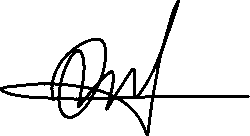
**For the Degree of Bachelor of Science in The**

**Department of Mathematics and Computer Science**

**Claflin University**

**Orangeburg, South Carolina**

**May, 2022**



**4/5/2022**

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**Date: 03/31/2022**

1. **ACKNOWLEDGEMENTS**

First and foremost, I would like to thank Claflin University’s Computer Science Department for providing me with knowledge and skills that has prepared me for this research and for my career.

I would also like to express my gratitude to my professor, academic advisor, and thesis advisor Dr. Ramaier Sriram for his invaluable advice, support, and guidance. I wish to extend my special thanks to Alice Carson Tisdale Honors College for awarding me the Honors College Scholarship and providing me with opportunities to build my skills and knowledge.

Likewise, I would like to thank my professors/ committee members Dr. Abdelrahman Desoky and Dr. Shrikant D. Pawar for their valuable input to the thesis.

Lastly, I would also like to thank my friends, family and colleages who have supported me and offered deep insight into the study.

1. **THESIS STATEMENT**

The timely information can be shared with the drivers in case of any mishaps ultimately helping them in figuring out what the best route is. Existing technologies can be leveraged to send that information.

1. **ABSTRACT**

The increase in driving population and the want to drive cause increasing driving mishaps. Due to the lack of timely or live information on such events, traffic jams occur. Such information can be provided via navigation or traffic updates. However, current navigation systems are unable to create or receive live traffic updates in the direction of travel. This capstone research focuses on vehicle to vehicle communication, via smartphones, to inform live events, to enable a driver to evaluate alternative routes and minimize inconvenience.

1. **KEYWORDS AND ABBREVIATIONS**

|  |  |
| --- | --- |
| **Abbreviations** | **Meaning** |
| CCP | Connected Citizens Program |
| CIFS | Closure and Incidents Feed Specifications |
| CV2X | Cellular Vehicle to Everything |
| DSRC | Dedicated Short-Range Communication |
| FCC | Federal Communications Commission |
| GPS | Global Positioning System |
| IoT | Internet of Things |
| ITS | Information Technology Systems |
| IVC | Inter-vehicle communications |
| JSON | JavaScript Object Notation |
| LDPC | Low Density Parity Check |
| MANET | Mobile Ad Hoc Network |
| NHTSA | National Highway Traffic Safety Administration |
| OBD-II | On- Board Diagnostics II |
| OBU | On- Board Unit |
| PHY | Physical Layer |
| RBs | Resource Blocks |
| RTA | Real-Time Application |
| RSU | Roadside Unit |
| SOS | Systems of Systems |
| TA | Trusted Authorities |
| TGbd | Task Group 802.11 bd |
| URL | Uniform Resource Locator |
| USDOT | United States Department of Transportation |
| VANET | Vehicular Ad Hoc Network |
| V2I | Vehicle to Infrastructure |
| V2V | Vehicle to Vehicle |
| XML | Extensible Markup Language |

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**Figure 1.1 *Transmission of the information to Waze Maps***

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**VII. INTRODUCTION/ BACKGROUND**

Traffic accidents are very frequent resulting in traffic congestion. Traffic congestions impart both economic and social costs. Road congestion is a major challenge in transportation that requires immediate innovative solutions. Washington drivers waste nearly two weeks of their year stuck in traffic caused due to traffic accidents. Traffic congestion results in an annual drain of $87.2 billion on the US economy, including 4.2 billion hours and 2.8 billion gallons of fuel spent while sitting in traffic, which is equivalent to almost one work week every year (Riva, Garvey & Pietrucha, 2006). Needless to say, the emission of carbon dioxide while sitting in traffic is insane. In general, the stationary vehicle emits more than a moving vehicle. This figure can be reduced drastically if the accident is reported immediately and autonomously using Inter-Vehicle Communication (IVC). This research came out of the desire to provide live or timely information regarding driving mishaps to the drivers following the same route. Most of the drivers can take a nearby exit avoiding the accident spot once they receive the alert.

This research started with understanding the current status of information that is provided to the drivers once such events occur. In the last decade, various car manufacturers have been developing solutions for vehicle-to-vehicle (V2V) communication that would allow the redirection of other drivers away from an accident. Alerting the drivers approaching an accident scene could prevent further accidents by warning them to slow down, as well. IVC are designed for specific cars or a consortium of cars which makes it inefficient for the drivers who don’t drive cars from those specific manufacturers.

**Overview of Mobile Phones and Car-Play System**

Mobile phones have become an integral part of our life. Mobile devices have been used to monitor and report accidents. The integration of “Internet of Things” into modern electronics, embedded sensors in smartphones have contributed to the design of various systems such as guiding, reporting human behavior in situations like road accidents, falls, etc. Mobile devices are easily accessible and building a software that detects an accident comes at a cheaper price than building and integrating additional hardware to the vehicle. In addition, smartphones are immediately available to most of the users. This paper talks about a solution to alert the drivers traveling in the direction of accidents motivating them to reroute accordingly. This will result in less traffic congestion.

This research focuses on implementation of smartphone based IVC systems with the help of a central server. Vehicle-to-Vehicle communications can be enabled through WiFi or cellular networks. The smartphone based technology can be very effective due to the portability and wide accessibility of smartphones.In addition to that, smartphones can be easily connected to the CarPlay System which reduces the frequent usage of smartphones while alerting the vehicles on the back.

Research Questions

This study was guided by the following research questions:

1. What is the social impact due to traffic congestion?
2. What is the current state of V2V/V2I communications?
3. How can we leverage the existing technology to send out alerts?

In short, the study that was directed and the design that was proposed are laid out in the following document. The analysis begins with a background on the current state of inter-vehicle communication. A thorough research on smartphone based IVC systems is discussed.

**VIII. LITERATURE REVIEW**

This section comprises different subsections as follows: analysis of current state of inter car communications, ways of data collection on traffic mishaps and how it is broadcasted, and discusses communication delays between two vehicles.

**Overview of Current state of Inter Car communications**

Inter Vehicle Communications (IVC) is defined as a system where two vehicles communicate autonomously enabling the sharing of information such as live traffic updates, stopped vehicles, etc. The primary objective of Fanca *et al.* (2018) was to present a study on mobile terminal solutions for detecting accidents while doing systematic comparisons with existing systems. Throughout history, various companies have adopted their own form of IVC and various integrated automatic accident detection and notification systems have been experimented. For example, OnStar, which is a form of IVC and is only available to Opel and Vauxhall car owners. One of the major downsides of this system is the inability to cancel the call to the first responders once the SOS button is pressed, even when accidentally pressed. The other downside of this system is: it comes in hefty cost and is unavailable for older vehicles. Likewise, there are various IVC experiments like FleetNet, CarTALK 2000, INVENT, etc. that have been practiced throughout history.

IVC networks have been frequently studied in many forms like mobile ad hoc network (MANET) where vehicles form a vehicular ad hoc network. Jawhar *et al.* (2013) talks about how a lot of the research in IVC systems is focused on particular applications. It’s imperative that research is conducted in designing protocols, services that can be used by most of the IVC applications. Harding *et al*. (2014) discusses that cost estimation for vehicle-to-vehicle hardware deployment will range from $81 to $291. The research was conducted by NHTSA researchers. The major conclusion from these articles are: it is hard to implement these systems as they are very particular and there is no guarantee every vehicle will adopt it.

**Ways of detecting traffic mishaps**

Traffic updates are regularly provided via navigation applications to the drivers. The world is indeed headed towards making everything autonomous and convenient to the human. Traffic data are primarily collected via satellite that tracks the amount of congestion in a particular road/highway. However, the lack of live information encourages the drivers driving through the accident spot to add up to the existing congestion. In recent years, research has been conducted on visual surveillance systems that basically monitor traffic at the intersections. It is aimed to decrease the fatality rates caused due to the lack of first aid treatment, which is vital. The problem with a visual surveillance system is: it cannot precisely detect the accident if it is out of the vicinity of the lens, or if the weather conditions like fog, heavy rainfall, or snowfall obstruct the view of the camera. Almaadeed *et al.* (2018) talks about the incorporation of audio based surveillance systems to improve the accuracy of accident detection. The imaging system has a limited depth-of-field. Audio based surveillance can be used to complement the visual surveillance system ultimately improving the robustness of traffic mishaps detection. This research comprises an excellent architecture for audio analysis and classification: extraction of temporal and spectral features, extraction of joint (t, f) - domain features, feature selection and classification ultimately yielding the accurate information regarding mishaps. This will help minimize the false detections, as well. The result from the experiment can be leveraged in the mobile-based traffic mishap detection system to provide the accurate information on the traffic to the drivers traveling through the same route.

The vehicle- to- vehicle (V2V) communications are found to be a useful tool required for automated solutions, facilitation of early detection and prediction. It is even possible to improve road safety by reducing road congestion and helping in the smooth flow of vehicles in the road. Data exchange in V2V communication and raging systems can ensure the connection and communication between two moving vehicles present at a distance. The primary purpose of *Ameen et al.*(2019) was to review and analyze the exchange of data in vehicle-to-vehicle (V2V) communications systems. Various databases such as ScienceDirect, Web of Science and IEEE Xplore from 2008 to 2018 were used out of which 140 articles were selected to review. This study was divided into six categories: real-time development, simulation development, real-time and simulation development, framework and architecture, survey and review and studies. Automatic detection of V2V is also promoted. The result analysis mapped new directions and a discussion of the data exchange in V2V in hardware and software techniques were presented to identify the gap in future directions that focused on driving behavior, which achieved a higher accuracy rate than the other techniques used. The identification of aspects of motivation, open challenges of the technology utility, authors’ recommendations and substantial analysis on several aspects such as devices, number of scenarios, test location, type of sensors, number of vehicles and evaluation technique used and softwares used. However, research efforts in this direction are still ongoing. Three phases were designed to meet the demands for detecting and notifying drivers from collisions with high accuracy rate. The proposed methodology has four phases: investigation phase, development of hardware for V2V, study and analysis, and evaluation phase. In conclusion, V2V communications could open opportunities to accurate detection, prediction and exchange of data and fill in the identified gaps.

Smartphones are the most fascinating object compared to PC or laptop as they are much smaller with a similar processing power, easily customizable and an extension of the individual. Response time in an accident is very critical for timely availability of medical services in case of medical emergency. The delay of transfer of information during an accident and immediate unavailability of first aid, usually resulting in the demise of an individual, is a problem yet to be solved. The use of a system that detects and reports the occurrence of the accidents and reduces the time between an unfortunate and unforeseen event of accident and sending emergency respondents to the scene of accident is a solution to the problem. The primary objective of Fanca *et. al.* (2018) is to review the research on mobile terminal solutions based on smartphones for the detection and prevention of accidents and to compare it to the existing solutions focusing on how it works, operating system on which it is running, its pros and cons. Mobile devices especially smart phones have been used to monitor, detect, guide as well as report through various applications as it is available immediately to the users, easier to determine the speed, location, and other traffic at a cheaper cost in comparison to the use of loop detectors that was being used traditionally. The smartphones can also update their softwares more frequently than vehicles, and have integrated sensors of rich data variety. The objective of SARGS is the detection of accidents automatically using the sensors embedded in the smartphone. Reporting the occurrence of the accident as soon as possible using the real-time system and the correct records is also important. The system needs to be able to send the warnings automatically. While doing so it is very important to minimize the false positives in smartphone detection and reduce the false rate of detection and reporting of accidents. Therefore, the possibility to cancel the false reporting of false accidents should also be an option. OnStar is one of the integrated automatic detection and notification systems developed at the time of vehicle traffic accidents and has been running since the 1990s in the USA. However, the impossibility of the system is to cancel the call to the emergency incase SOS button is accidentally pressed is its limitation. One methodology used to eliminate the false positives of an accident is by integrating the data provided by the smartphone sensors (accelerometer, microphone, GPS, gyroscope, camera and so on) with data collected through the vehicle (airbags, GPS position and so on) using wireless form of communications (Wi-Fi, Bluetooth, OBD-II platform and VANET) or an additional use of Kalman filter.It has been found that the Android operating system is open source, more permissive that uses embedded sensors, and phones with this operating system are much cheaper than iPhone smartphones. Android is the main platform for designing and deploying the demonstration application, for implementing services, accident detection, emergency event reporting, and testing the functionality of the proposed system. Thus, the desired phone’s operating system, the inbuilt sensors for detection and additional features of the application can be used by the user for detecting an accident using smartphones.

Road safety can be prioritized using the Vehicular communications networks from the as it forms the backbone of cooperative transport system that supports the user by providing safety and instantaneous information amongst the users. Dedicated Short Range Communications (DSRC) and Long-Term-Evolution-Vehicle (LTE-V) are the two technologies of Device to Device (D2D) communications which are expected to have progressed in the developments and evaluations worldwide. However, both the technologies have their own limitations. The main objective of the article *Ansari K (2020)* was to investigate the components and workings of spectrum sharing between Dedicated Short- Range Communications and Cellular Vehicle-to-Everything for deployment in a common region and review the background and functionality of both technologies. According to the author, the Vehicle to Everything platform also provides spectrum sharing at the ITS band and at the same time provides instantaneous and concurrent propagations of Dedicated Short-Range Communications and Cellular Vehicle-to-Everything messages. DSRC is designed primarily to operate in ITS band while C-V2X is capable of operating in both ITS band and cellular licenced bands. DSRC usually takes a decentralized approach for the utilization of spectrum. Meanwhile, C-V2X supports both centralized and decentralized approaches to control radio resources. Both technologies have been enhanced to make it more reliable, have lower latency and higher throughput. The DSRC’s PHY and MAC layers underlying communication technology is IEEE 802.11p that specifically operates in the 5.9 GHz frequency range. C-V2X modes 4 utilizes SC-FDM and supports channels with 10 and 20 MHz of bandwidths with each channel divided into sub channels in the frequency domain and sub frames. Each sub-channels are further divided into Resource Blocks (RBs). The IEEE Task Group 802.11 bd (TGbd) aims to add additional modes of operations to DSRC and increase its throughput offered by the technology. Next gen DSRC is intended to include double the throughput at MAC and enabling longer communications ranges by reducing the noise sensitivity. PHY layer of the next-gen DSRC includes the inclusion of OFDM numerology of IEEE 802.11 ac for better efficiency and adoption of Low Density Parity Check ( LDPC) forward error correction codes enabling higher coding and improved channel estimation, reliability and mitigation of multipath fading. The comparison of DSRC and C-V2X is multidimensional as they have many technical dissimilarities. The adjacent- channel interference test results of various studies showed the potential problems in simultaneous operation of DSRC and C-V2X on adjacent channels incase of transmitters being in close proximity. In conclusion, the nature of the hybrid V2X environment will challenge the concept that each vehicle consists of at least a single V2X radio, making the current multisystems channels no longer valid. Also, both technologies in the same channel for concurrent transmissions in absence of a mutual synchronizer solution would cause harmful co-channel interference. Adjacent channel interference problems in hybrid V2X systems are the areas of research in this field that need to be studied elaborately.

**IX. METHODOLOGY AND DESIGN**

Based on the literature review, the feasibility analysis was done amongst the technologies that are currently available in the market. A thorough analysis on the future states of those technologies are also discussed. This section talks about how technologies like V2V, V2I, and the current Navigation systems can be useful in transmitting the mishap information from the observer’s end to the receiver’s end.

The design section basically contains three main components:

* Initiation of the message
* Transmission of the message
* Receipt of the message

**Initiation of the message**

Here, the mishap information like nature of event, severity of the event, time are considered as messages. Generally, the observer or the witness initiates the information. Information can be initiated in multiple ways. Observer can use the voice commands, touch screen, or the camera can be used to initiate the information. Each has its pros and cons.

Voice commands will enable drivers to initiate the messages easily using the advanced technology. At the advanced level, a driver may describe the mishap information without taking their eyes off the road or their hands off the wheel. There are available In-Car Speech Recognition Applications which we can leverage to initiate the messages. Apple CarPlay has Siri, Google has rolled out Google Assistant driving mode that can be paired up with either Apple CarPlay or Android Auto. These Voice Assistant systems are programmable and we can leverage these systems to initiate the messages. In order to make the initiation process shorter considering the attention of the driver towards the traffic, we can assign a specific number to the severity of an accident, nature of an event. For example,

1 → Low Severity Accident

2 → High Severity Accident

3 → Undecided

This way, it will be a lot easier for the voice assistant to process the voice since the signal processing for numeric values is easier than a word or sentence. Similarly, the nature of an event can be recorded too. Voice processing is still being researched on a larger scale in terms of its efficiency. Different accents can lead to the mis-input as the system might not recognize the untrained voice. However, various researches have been going on to make it better and accurate.

Touch screen of the car can be leveraged to initiate the message by a passenger sitting next to the driver. Driver can allow the passenger to record the information if any driving mishap is observed. This process will be quicker in comparison to voice commands as the system will have an old-fashioned form to record the road hazards and its severity.

Information is packaged and sent as information packets through the network. Just like, how sending mail works. For mail to be sent - we require the sender's address, receiver’s address, and the postal stamp. Similarly, for an information packet to be sent, we will require the sender's address, the intended receiver’s address, number of the particular packet, etc. This is the procedure for initiation of a message and packeting it.

**Receipt of the message**

The message, once received, can be displayed using multiple ways. As discussed, advanced built-in car systems like CarPlay can be used to display push notifications like in a phone. Push notification serves as a quick communication channel enabling systems to convey messages. The notification information sent includes text alerts. Later on, the text can be converted into a voice thus enabling distraction free driving. There is an existing system of a CarPlay that reads out the notifications to the driver.

After the initiation of the message, messages are supposed to be transmitted for the receiver to receive it. The middle component of the design is as follows:

**Transmission of the message**

**I) Using navigation app like Waze as an interface**

Waze is a satellite based navigation software that is popular in sharing real-time information that translates into traffic conditions and road structure. Using the navigation app like Waze as an interface, the information on mishaps can be sent to the driver’s traveling through the accident spot. Once the message is initiated using Vehicle’s system, that information can be sent to the Waze server, which will then display the hazards using their platform for the Waze users. As of now, Hazards that appear in the Waze are added and updated through the primary sources:

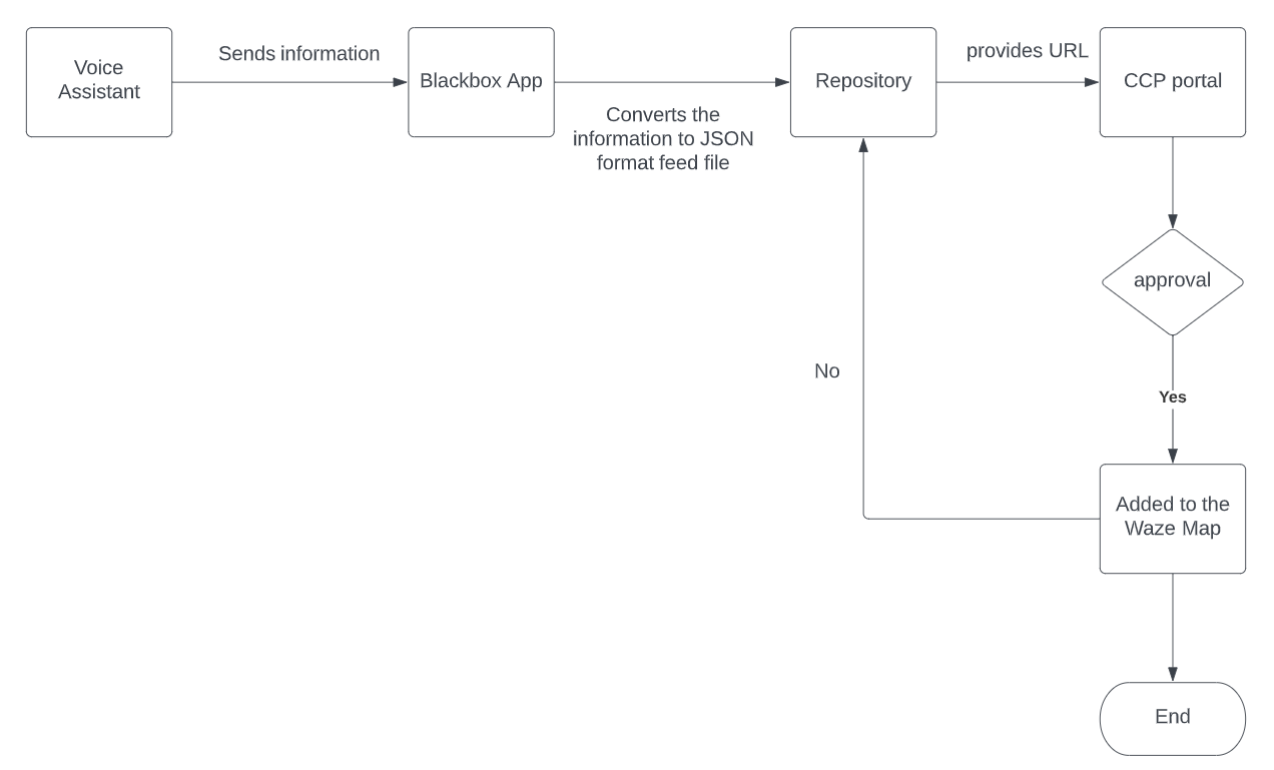
1. Driving and map editing community
2. Feeds provided by their partners

Partner data feed lets Waze partners independently upload and share traffic alerts, road closure information with the Waze drivers traveling on the same route in real time. The feeds can be created as follows:

* By creating a XML or JSON format feed file consisting the data for incidents, closures, or hazards.
* By providing the URL to the data via CCP ( Connected Citizens Program) Portal.

Feed file has a specific acceptable structure of a Closure and Incidents Feed Specifications (CIFS) feed. Once the data is sent, Waze has to further verify the file and the data is automatically fetched and added to the Waze maps.

Once the blackbox application that is built to receive the initiated message is done, it can serve as a middleman for the Waze server and In-Car System. That will easily allow drivers to initiate the message and broadcast it using waze. The design for the system using Waze is shown below:

****

*Fig 1.0: Transmission of the information to Waze Maps*

**II) Using V2V/V2I as an interface**

Vehicle-to-Vehicle is a communication platform that enables accessing information about the speed and position of other V2V enabled vehicles. It uses VANETs ( Vehicular ad hoc networks), which comprises a wireless network where vehicles can communicate with one another and share information about their driving behaviors. The information shared includes speed, position, braking, stability, the direction of travel, among others. Vehicular ad-hoc networks play an essential role in the development of the Intelligent transportation system (ITS). VANET has three main components: the Trusted Authority (TA), Roadside Unit (RSU), and On-Board Unit (OBU) ( Mohamed et al., 2021). TA is a third party that issues/revokes vehicle certificates and provides RSUs and OBUs with security parameters such as key pairs ( public/private) ( Lim & Manivannan, 2016). In VANETs, each region has a RTA that controls a designated area ( Jiayu Q. *et.al.*, 2020). OBU is a transponder that is used for exchanging information with other OBUs. OBUs can exchange information with RSUs using dedicated short-range communication ( DSRC). RSUs are installed by TA in a specific location on the road, such as parking spaces or road junctions. RSUs provide traffic information to legal vehicles on the road. RSUs can additionally be communicated through the RTA. This distributed architecture has the advantage of low communication and computational overheads ( Jiang, Ge & Shen, 2020). This architecture is comparable to Edge-Fog-Cloud computing architecture that solves many issues related to IoT services. The distributed architecture improves the overall end-to-end delay and security by shifting data processing to units closer to nodes.

VANETs can be classified into two main types ( Al-Sultan et al., 2014). The first type is the entertainment applications and second being the safety applications. Safety applications include: intersection collision avoidance, traffic sign violation warning (Al-ani et al., 2020). Safety applications have hard real-time constraints; it must be sent and received within 100ms ( Hu & Laberteaux, 2006). An extra blackbox application that records the ‘ severity of an accident’ can be built as a safety application. This will allow the drivers driving through the accident route to decide on whether to take an exit or stay in the traffic ( that gets cleared up fast, considering it’s a low severity accident). Since, the communication between OBUs and RSUs is done using DSRC, there is a low latency and high reliability with DSRC. The weather has no adverse effect on communication. It is also protected by the FCC.

Thus, once the message is initiated, we can leverage VANET or DSRC communication to send out information packets to the RSU and RSU to the vehicles. Receipt of the message can be done as discussed above.

The aforementioned technologies can be used to transmit the information packet to the receiver’s end. All of these technologies have their pros and cons. By taking an account on the state of technology for 5 years, this report has been prepared. The RSU deployment is still very debated due to the funding issues and it is unclear whether private/public organizations are going to fund it.

**X. DISCUSSIONS**

This section discusses the advantage of one technology over other and its challenges for the deployment.

If we decide to go through the Waze route, there are some parameters that need to be accounted for. The data feed file and scheme has to be validated by Waze. In case of any significant flaws, the file is sent back for our correction. The data is fetched automatically every 2 to 6 minutes, and after data is fetched, it may take up to an additional 4 minutes for the information to appear in the Waze app. Also, in case of any flaws with the file feed; which will be rejected, extra delays can occur which will delay the process.

There are some disadvantages with the V2V or V2I technologies, as well. There is a chance a hacker might direct the signal or send faulty information to the receivers, which might increase the chance of an accident. Along with that, faulty communications can occur due to equipment malfunctions. RSUs are not fully deployed, yet and it is still in the process. Looking at the data, for RSU to be deployed everywhere, it will require a huge amount of money. The pilot deployment site for the deployment of RSU was chosen to be New York City by USDOT in September 2015. It took almost five years to get it up and running ( The Future Begins with the Roads Side Unit, 2020). The biggest challenge for the deployment of RSUs is not technology. It’s rather “Funding”. The cost per device can range from $1300 to $18,000 along with the maintenance that can cost $2,000 to $3,000 a year [5]. The cost will vary depending on location, usage, and what is inside the roadside unit, but it will be an expensive investment considering the amount of RSUs that has to be deployed on road.

If we decide to go with the existing platform ( Waze ), it will be easier to associate with them. The facilitation of the process will not face challenges when compared to the other as there are existing challenges for the deployment of RSUs. Thus, going with the existing platform is more of the reality.

**XI. CONCLUSION**

In conclusion, to realize this concept in 5 years, working with waze to include the features necessary is the best way. However, considering the timeline, if deployment of RSU takes an unpredicted peak, the other option can be considered.

Future works remaining to be completed include the deployment of the blackbox application that will act as an interface between sender and receiver. Additionally, the application must be applicable in In-car Systems. Finally, future work also includes recording information using Siri or natural translation systems available in the car to initiate the message.

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