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Tesi di Laurea Magistrale in Informatica

On Supporting Ethical Decisions in Connected and Autonomous Vehicle Scenarios

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Dreams are not what you see in sleep; it is the thing which doesn't let you sleep.

- Dr. A.P.J. Abdul Kalam

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Abstract

Intelligent transport systems are developed at a larger scale in recent times, which has revolutionised the role of transportation. In this modern era, applications like navigators, toll booths, roadside communication devices, speed cameras, parking sensors and so on have become an essential part in transportation. The concept of Internet of Vehicles (IoV) has been playing an immense role in generation, storage and analysis of information related to communication between vehicles. In this report we are going to introduce the concept of ethical decision making, in both connected and autonomous vehicle scenarios.

Contents

List of Figures

Acronyms

DSRC Dedicated Short Range Communication Systems

GDPR General Data Protection Regulation

ITS Intelligent Transport System

VANETs Vehicular Ad Hoc Networks

Chapter 1

Introduction

In recent times, various methods of vehicular communication involving cars and humans have been proposed. Introducing messages of ethical content in the communication is the major highlight of this thesis.

The beginnings of vehicular communication go a long way back to the 1970's. The systems initially designed were used to transmit traffic information and safety warnings. They were *Dedicated Short Range Communication Systems (DSRC)* which had a very small area of coverage. Over the years, the communication has advanced as there was development in wide range of devices and long range communication systems. This led to lot of concerns regarding the usage, transmission and privacy concerns of data shared between the different components. This report presents research work involving creation of an architectural framework considering the ethical aspects of communication.This setup consists of vehicles, humans and other systems pertaining to inter-vehicular and intra-vehicular communications.

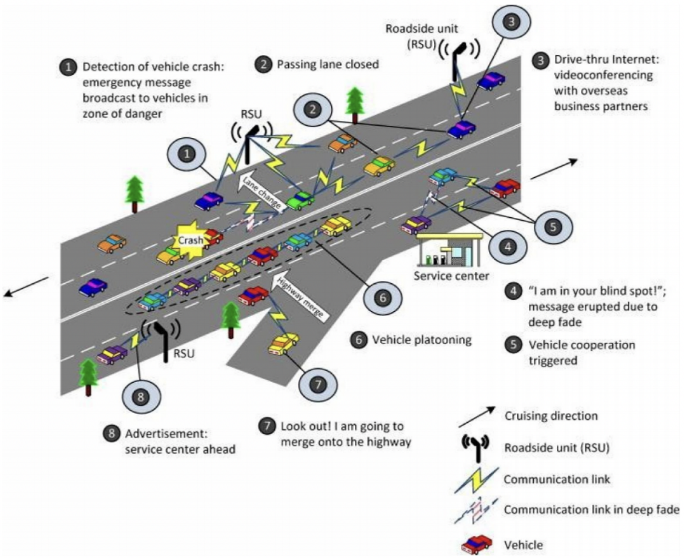


Figure 1.1: Sample VANET architecture, adopted from [13]

Technology has advanced at such a rapid rate especially in the automotive industry causing the use of cars tremendously. This has lead to communication between vehicles and humans to become more complex which also involving huge data exchange. *Vehicular Ad Hoc Networks (VANETs)* are being used to establish communication between vehicles, humans and other stakeholders. A sample architecture of VANET is illustrated in figure 1.1. This thesis investigates the existing Vehicular Communication Methodologies and also demonstrates a simple use case illustrating the use of ethical messaging framework for vehicular communication.

1.1 Motivation

These days, cars are able to exchange messages for various reasons such as navigation, traffic related communications , emergency situations and so on. This thesis introduces a ethical framework that is able to support communication between humans, vehicles and other roadside infrastructure components.The motive is to bring an ethical angle to the communication. The details of the structure of the ethical engine will be discussed in the future chapters.

1.2 Scope of the Project

The scope of the project is illustrated through a simple use case where communication between two cars involving a person with medical condition in one car and another person in other car. The communication happens through ethical engines present in both the cars. This is being realised by a simulation using network tools.

1.3 Research Goal

The main goal of this thesis is to propose a software architecture for autonomous vehicle scenarios that deal with ethical messaging involving cars and people on board to exchange messages. In this use case we have considered a scenario wherein a passenger communicates with another passenger using the ethical engine of the vehicle.

1.4 Research Questions

- What is the kind of architecture which might support ethical messaging services?
- What are the categories of ethical content that can be transmitted?

1.5 Research Findings

- Factors influencing ethical communication
- Messaging patterns that support ethical messaging

1.6 Structure

The structure of the thesis is as follows:

The first chapter deals with the introduction. The second chapter details the background of the research whereas the third depicts the literature review. The forth chapter illustrates the methodology of the simulation. The fifth chapter deals with the implementation. The sixth chapter details the results and the seventh chapter deals with the conclusion.

Chapter 2

Background

This chapter gives a brief overview of the important concepts, the standards and the ethical aspects involved in autonomous car communication. The first subsection deals with VANETS whereas the second subsection illustrates the Intelligent Transport Systems. The third subsection describes the ETSI standards used in the simulation whereas the final subsection describes the ethical concerns.

2.1 VANETS

One of the dreams of modern vehicle manufacturer's is to make vehicles communicate to each other. In this direction, Vehicular Ad Hoc Networks (VANETs) were introduced. VANETs are a group of vehicles that are in motion or stationary which are connected by a wireless medium or a network [11]. There are 3 important regimes in broadcasting a message through VANETs. They are dense vehicle regime, sparse vehicle regime and regular vehicle regime. The establishment of a vehicular communication must follow the IEEE 802.11p or 802.16 (WiMax) standard.

There are two major types of VANETs based communications [11]. They are the Short Range Communication (SRC) and the Long Range Communication (LRC). The range of SRC ranges from around 10 metres to 1 km whereas the range of LRC range from 10 km to several kilometers depending on the bandwidth and other factors. In our experiment we are making use of the SRC for vehicular communication.

Furthermore, there are 2 major division in VANETs [11]. One is the pure adhoc network where communication between vehicles takes place without the help of additional infrastructure. The other important type is where communication between vehicles and roadside infrastructure using different algorithms takes place.

Each node in a VANET consists of two units. One is the On Board Unit (OBU); which is responsible for the communication whereas the Application Unit (AU) is responsible for executing the programs associated with making the OBU functional.

There are several uses of VANETs in vehicular communication [4]. They are categorised into user based applications and safety related applications. Some of the examples for used based applications are peer connectivity between vehicles and internet connectivity. Similarly, examples for safety related applications can be the collision avoidance system, co-operative driving and traffic optimisation systems.

2.2 Intelligent Transport Systems

Intelligent Transport System (ITS) have been one of the fastest growing research areas over the last few decades as population in the world increases and people look out for deployment of modern technologies in the field of vehicular transport. However, there are several concerns to the communication between vehicles, humans and other infrastructural elements. Some of the most important aspects are the ethical aspect of data and the privacy.

Let us begin with a quote on ethics by Potter Stewart: "Ethics is knowing the difference between what you have a right to do and what is right to do". We today live in a digital world where personal data is captured by a range of devices and social media. The EXOSOUL project [8] has been at the forefront to establish a exoskeleton to monitor, analayse and control the flow of data through various digital platforms. Firstly, let us discuss some of the stakeholders which influence the relationships between the human rights, technologies, markets and business models.

- Autonomous systems: "They are systems that have the ability of substituting humans in supplying (contextual) information that the system may use to make decisions while continuously running.Depending on the nature, property, and use of this information, an autonomous system may impact moral rights of the users, be they single citizens, groups, or the society as a whole" [8].
- The harmful side of the digital society: Due to the rapid usage and exploitation of personal data by different agencies and technologies, the western society thought of bringing in regulation regarding the storage and distribution of data. In this regard *General Data Protection Regulation (GDPR)* was constituted across Europe. It is a comprehensive set of guidelines that governs the usage, reproduction and sharing of personal data. SImilarly in the US there have been privacy laws that have been passed and are somewhat similar in nature to GDPR.
- The need for digital approach: For years, Europe has called for a more comprehensive approach that encompasses privacy and addresses ethical issues in the scope of the digital society. The European Data Protection Supervisor has called for inclusion of a ethical dimension in data protection in the year 2019. Furthermore, in March 2018, the EGE released a statement on "artificial intelligence, robotics, and 'autonomous' systems" in which it urges an overall rethinking of the values around which the digital society is to be structured. The human dignity is considered as the main principle and it must not be violated by autonomous technologies[8].

The sharing of information between vehicles and other roadside infrastructure also have a great risk in terms of tracking the geographic location of the vehicle and exposing it to unknown networks [14]. In the US there has been a legislation enacted with respect to privacy in vehicular communication. It has been stated in the law that all vehicles must provide owners or lessees the ability to stop the data collection, except for data essential for safety and post-incident investigations, and manufacturers are prohibited from using the collected data for marketing or advertising without consent from the owners or lessees.

2.3 ETSI Standards

ETSI has proposed a set of standards for communication in Information and Communication Technology (ICT) devices, systems and services. These are prominent all over the world but strictly implemented and followed in Europe. These standards provide a platform that ensures safety, reliability and compatibility to various software systems.

Firstly, let us discuss the idea of ITS as published in the ETSI standards. ITS supports a wide variety of existing as well as modern technologies for deployment and usage. Our focus in this project is on ethical communication through messages between cars, humans and Road Side Infrastructure (RSI). The follwing points highlight the support provided for the implementation of the messaging between vehicles and RSI:

- Intelligent Transport System Conference (ITSC) proposes an open system architecture which is not proprietary.
- Communications between mobile ITS stations (vehicles), and between mobile ITS stations and fixed ITS stations (roadside installations), with single-hops or multiple hops between the source and destination ITS stations.
- Access to public and private (local) networks including the global Internet, Infrastructure and satellite broadcast.

Secondly, we are interested in exploring the design principles with respect to the ETSI standards. There are two major categories. They are the ITS domain and the generic domain. The ITS domain focuses on the ITS based communication whereas the generic domain focuses on the other elements used in ITS systems.

Taking into consideration the above introduction of ETSI stadards, we will introduce the concept of ethical messaging. Today, as the world is connected by internet and there is lot of information exchange, doubts have creeped up regarding the usage, sharing and deletion of personal data. This is where ethical messaging plays a role in communication.

We are extending this concept into the messaging in the autonomous and vehicle communication scenarios. Let us start with a quote by Isaac Asimov "ethical implications are paramount and would be required to enable vehicles to operate safely in an autonomous manner, with or without the causal interaction with human beings" [7]. We see that vehicles are evolving and able able to make decisions regarding data usage of passengers, drivers and also contact emergency services with a little bit of human assistance. This ability is explored in our experiment and a simple use case is experimented with. The details of the experiment are given in the upcoming chapters.

2.4 Supporting ethical concerns in autonomous systems

Europe has been calling for a digital society where the human being with fundamental rights remain at the center. Therefore, there is a need to rethink the roles of several stakeholders in the digital world by empowering them when they operate as citizens as well as individuals.

The concept of human being able to control the flow of data and decisions made through different autonomous systems on behalf of them was the main point of focus. This in turn leads to a autonomous system being able to respect human's decisions and beliefs.Therefore a system's autonomy is a direct consequence of the amount and kind of respect of the individuals they interact with. The more individuals the system interacts with the less autonomy may be given to potential conflicts of respect.This is clearly understood in the scope of privacy where different individuals may have different privacy concerns about their personal data both in general and also depending on given contexts[8].

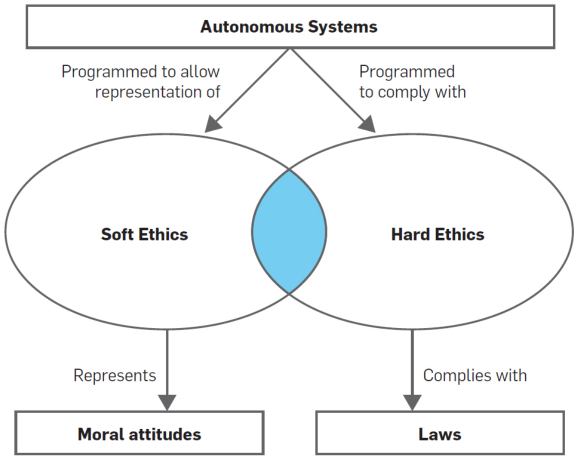


Figure 2.1: Relationship between digital ethics and autonomous systems , adopted from [8]

2.4.1 Digital Ethics

Digital governance is the practice of establishing and implementing policies, procedures, and standards for the proper development, use and management of the data through different systems [5]. A branch under this field is the digital ethics. Digital ethics is the branch of ethics associated with the study of moral problems relating to data and information. This field deals with the generation, recording, curation, processing, dissemination, sharing and usage of information. Moreover, it also relates to the usage of algorithms in the field of AI, machine learning and robots. The practises and infrastructures to support morally good solutions also come under its scope.

Broadly classifying the digital governance there are two main categories.One of them is the digital regulation. The digital regulation specifies the rules which explain the do's and don't with respect to the management and usage of data. On the other hand, the digital ethics help the society in making the morally right decisions in different environments and contexts.

The concept of ethics in autonomous systems was categorised into hard ethics and soft ethics as represented in figure 2.1.

Hard Ethics

The process of formulating the regulations which govern the values, duties and responsibilities to do a morally right or wrong action. Some of the examples are the legislation in Iceland where equal pay is given to employees irrespective of the gender. The hard ethics are rules or regulation that have been formulated by various government or non governmental bodies. In the EU, the implementation of the Universal Declaration of Human Rights (UDHR) and The Charter of Fundamental Rights of the European Union act as the starting points for the formulation of regulations in this regard.

Soft Ethics

Soft ethics can be used in situations where there is a divide between the moral and immoral actions. In the EU the soft ethics has also been given equal preference over the hard ethics. It is currently being exercised, to help individuals, companies, governments and other organisations to take more and better advantage, morally speaking, of the opportunities offered by digital innovation. But there is scope for lot of improvements in the legislation and the competing values and interests need to be balanced. This point is leading companies to incorporate the policy of good corporate citizenship.

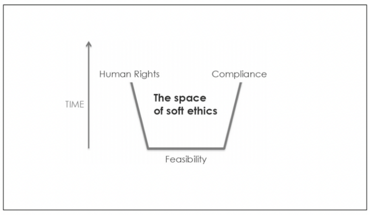


Figure 2.2: The space of soft ethics , adopted from [5]

Chapter 3

Literature Review

This chapter gives a brief overview of the various communication systems for cars that were developed over the years. Several studies have been conducted in this field and several organisations have designed, developed and deployed various systems.

3.1 Vehicular Communication Systems

There has been a lot of research to make the communication between cars open source. In this regard android based systems have been designed and developed by various equipment manufacturers. Android systems are open source systems which can be customised and the various functionality are deployed using apps. Two of the android based communication systems are highlighted in this section.

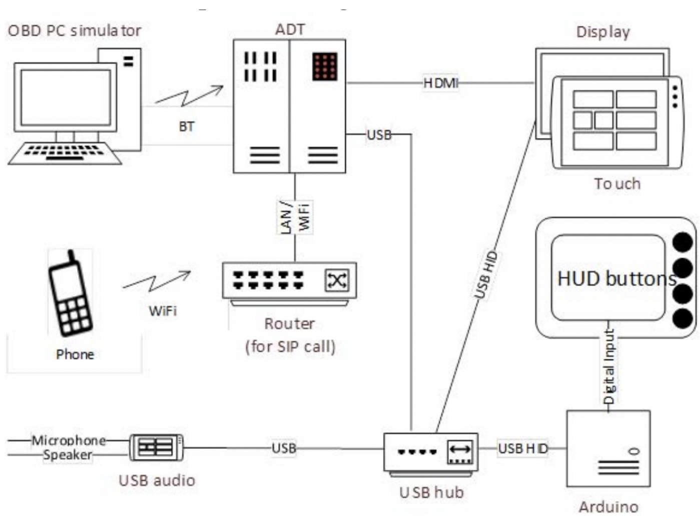


Figure 3.1: Implementation Architecture , adopted from [9]

1. An Android based system used to integrate Android to vehicular communication is simulated in this research project [9]. A Java based protocol is deployed to communicate between the broadcasting station to the cars. The traditional car infotainment system was modified to accommodate the message notifications. The system was simulated using components available easily. The system consists of a commercially available device with Android OS installed, a PC device for simulation of Vehicle events, an IP router for IP phone usage, a USB

sound card for external microphone and speakers connection, a USB hub for interconnection between all components, an Arduino device for UI navigation with physical buttons (jog shuttle use case), and a TV monitor with touch foil, connected to the HDMI output connector of an Android device.

2. One of the important goals of using technology in driving is to avoid accidents and improve the driving experience [3]. In this regard, a smartphone based system has been designed and prototyped to inform drivers regarding the conditions of the road, weather and curves. It also gives information regarding the emergency contacts in case of emergencies. The two major scenarios handled by this system are the accident handling and the message flow to prevent accidents. The architecture shown describes the 2 scenarios listed. The accident handling system consists of a simple messaging system which consists of a road side transmitter. It also consists of an emergency service that co-ordinates the messaging services. The road condition notification system consists of mobile based interface for the sender and receiver cars.

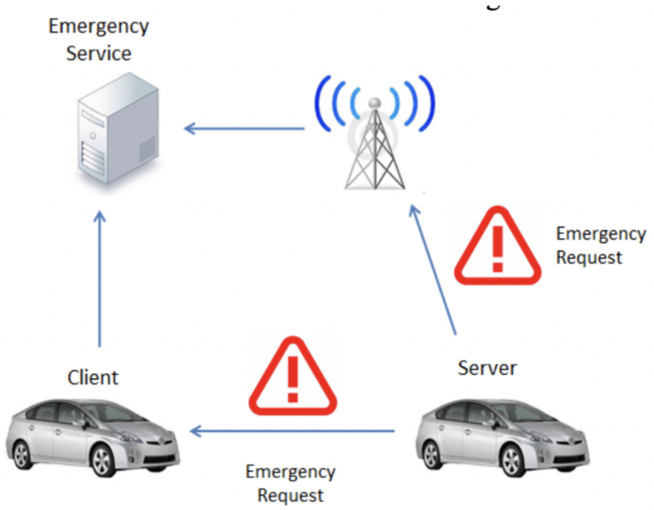


Figure 3.2: Accident Handling System , adopted from [3]

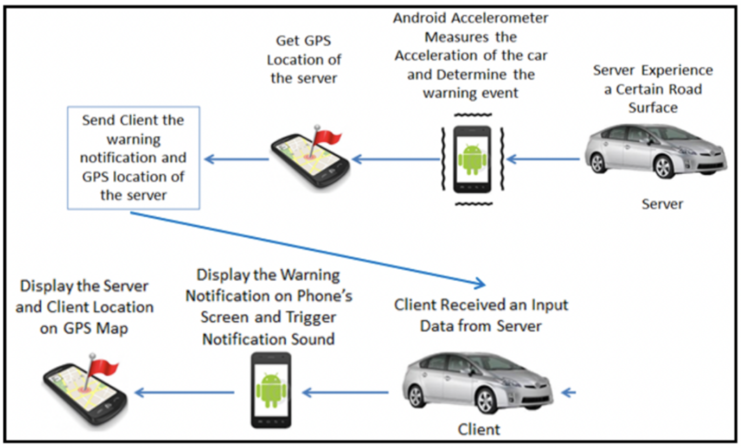


Figure 3.3: Road Condition Notification System , adopted from [3]

3.2 EXOSOUL Exoskeleton

Interacting with digital world brings in a lot of concerns regarding the usage, sharing and marketing of user data. In the modern era, people use a variety of applications that capture the user history, personal information and other types of records. The following research work presents an architecture which highlights the importance of ethical usage of user data through various applications.

1. The innovative idea of presenting an exoskeleton which governs the usage, sharing and destruction of user data is the major highlight of this research. There are two major aspects taken into consideration here; one is the regulation set by the government and the other one is the ethical aspect of the user.

   The major challenge highlighted in this research work was to identify the space of ethics, privacy preferences for users, to assess their compatibility with regulations, and to orchestrate interactions of users endorsing different preferences, so as to prevent deadlocks and to promote best ethical practices in digital societies [1]. This architecture presented in this thesis is based on the issues highlighted in this research work.

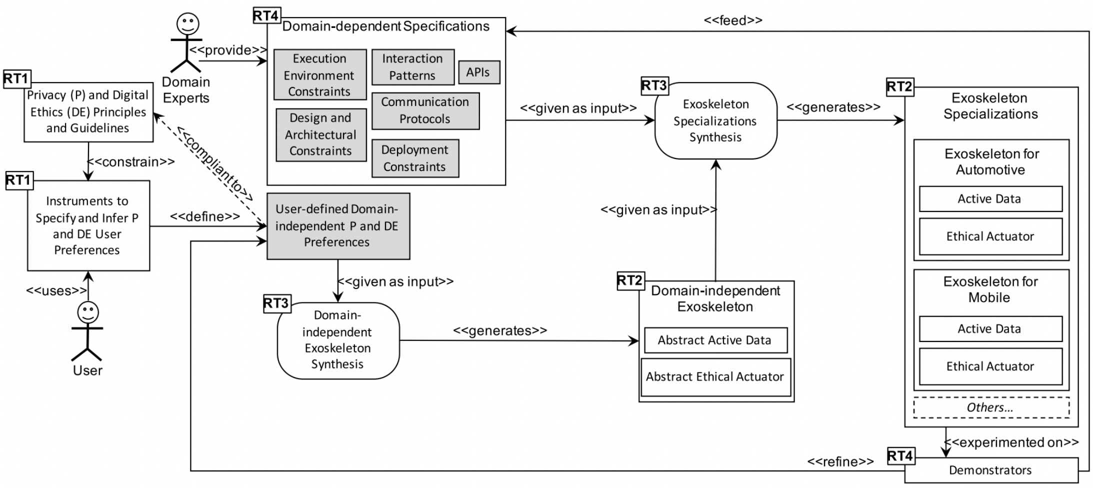


Figure 3.4: Generic Exoskeleton Architecture , adopted from [1]

   The exoskeleton specifies in the figure 3.4 specifies the mechanism that can enable machines to respond to various ethical challenges in both the simulated and real environments. There are two major approaches listed in this work namely the top-down approach and the bottom up approach. The top-down approach follows the policy of specifying the ethical theories that make explicit ethical judgements and organize them in categories whereas the bottom-up approach follows the feedback mechanism where users understand the rules, regulations and then provide a feedback to the system to learn and improve. The iterative mechanism is implemented to make the system learn the ethical aspects and evaluate them. In case there is an unknown scenario the priority of the ethics is assigned to the default priority. The scenario is handled with the help of external sources and then the machine is given the feedback.

   An exoskeleton is made up of two main parts: the active data and the actuator. Active data is a wrap around personal data which adds the logic required to access personal data and manage their life-cycle, from creation to destruction, sharing and usage, according to the specified privacy preferences. The ethical actuator on the other hand translates the ethical principles into concrete statements for decision making.

The exoskeleton presented in this research work is a generic one. The domain specific exoskeleton is designed for the use case of this thesis and is explained in the next chapter. The automotive domain is chosen for the implementation and simulation purposes in this thesis.

Chapter 4

Methodology

This chapter gives an overview of the use case selected for this research work. It also gives a brief description of the flow of data in the architecture through the sequence diagrams and state diagrams.

4.1 Use Case

- **Setting:** A parking lot in a big mall
- **Resource contention**: Two autonomous connected vehicles (named A and B hereafter), with one passenger each, are competing for the same parking lot. Passenger of vehicle A is pregnant.
- **Context**: A and B are rented vehicles, therefore, they are multi-user and have a default ethics that determines their decisions.

4.2 Architecture

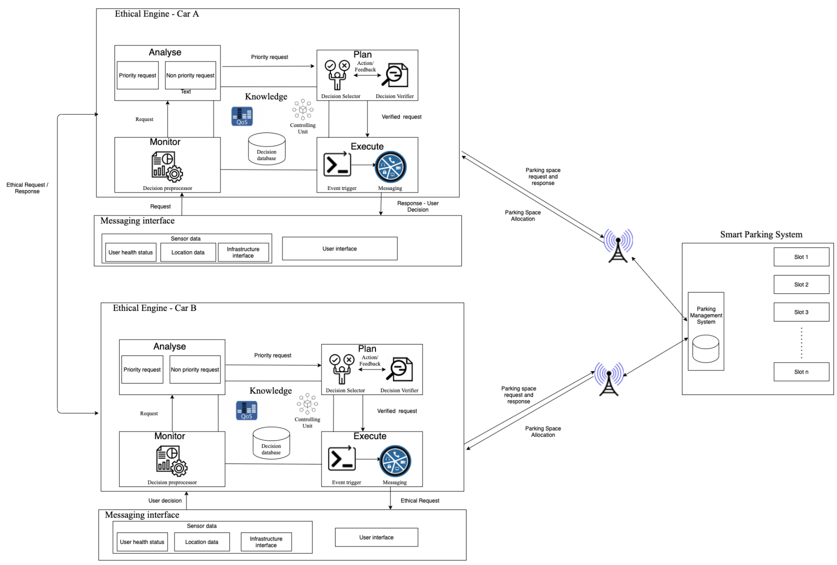


Figure 4.1: Generic Architecture for Ethical Messaging in Autonomous Vehicle Scenarios, some components inspired from [2]

The generic architecture of the ethical messaging system is designed using the famous software architectural pattern MAPE-K. It is appropriate for rapidly changing situations.The role of MAPE-K is discussed in the final section of this chapter. The major components in the architecture are the messaging interface,ethical engine(decision preprocessor, analyser,selector, verifier, decision database, controlling unit), roadside infrastructure and parking management system. The details of the ethical engine are discussed using the state diagrams later in this chapter.

The scenario details two cars which are autonomous and rented vehicles. Both the cars are competing for a parking lot near a hospital. Each vehicle has an ethical engine which assists the passengers to send ethical communication in the form of messages. The range of the communication in this scenario is considered to be 500 metres. It can be extended based on the usage of modern technology such as satellite based communication. In this scenario we have decided to make use of radio waves based communication system.

In this use case we have considered 3 levels of priorities for passengers. They are as follows:

- Level 1: Critical priority: Disorders like heart ailment, accident related issues, blood loss issues, pregnancy
- Level 2: Important priority: Old age issues, physically handicapped, mentally handicapped
- Level 3: Normal priority: All other ailments

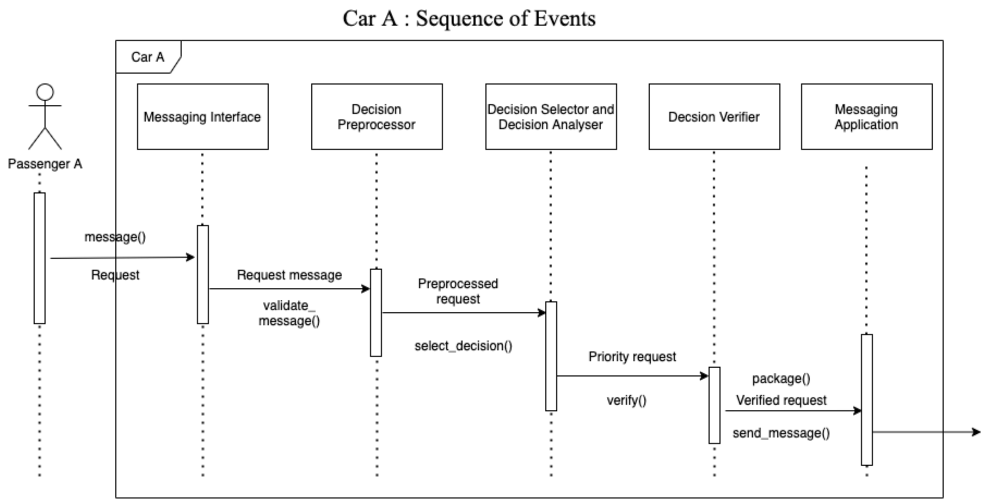


Figure 4.2: Sequence of events in Car A

The sequence diagrams listed in the figure 4.2 enlists the sequence of processes that take place in car A. The processes are as follows:

- The passengers places a request through a messaging interface.
- The messaging interface sends the message to the decision preprocessor for validating the message.
- The decision selector selects the priority of the request and analyses the decision.
- The decision is verified by the decision verifier.
- The ethical request is sent to passenger B by the messaging application.

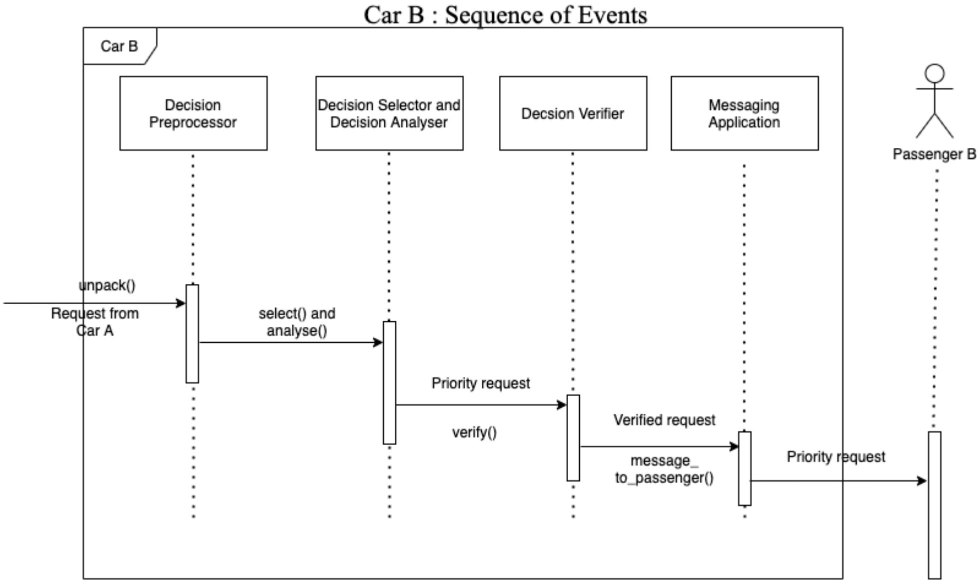


Figure 4.3: Sequence of events in Car B

The sequence diagrams listed in the figure 4.3 enlists the sequence of processes that take place in car B. The processes are as follows:

- The ethical engine of car B receives the ethical request and unpacks it.
- The messaging interface sends the message to the decision preprocessor for validating the request.
- The decision selector selects the priority of the request and analyses the decision based on the priorities of passenger B.
- The decision is verified by the decision verifier.
- The ethical request is sent to passenger B by the messaging application for decision making.

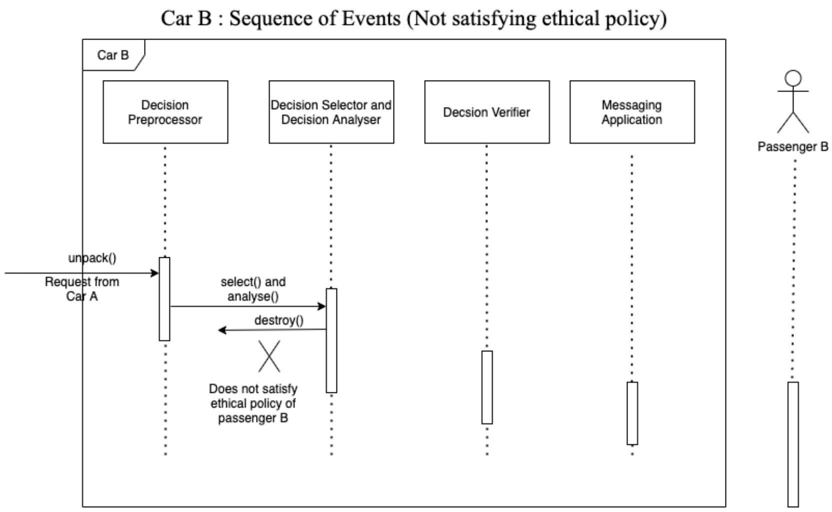
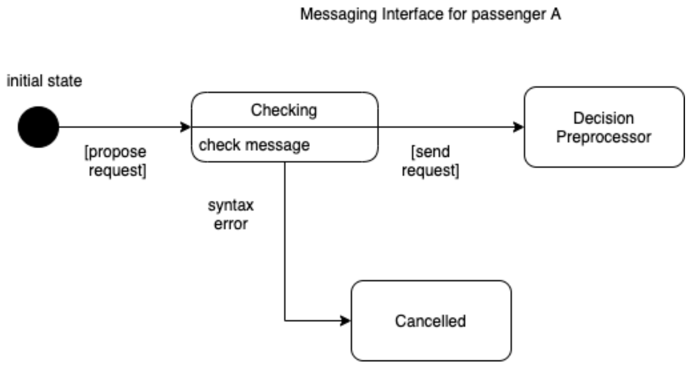


Figure 4.4: Sequence of Events in Car B - Not satisfying ethical policy

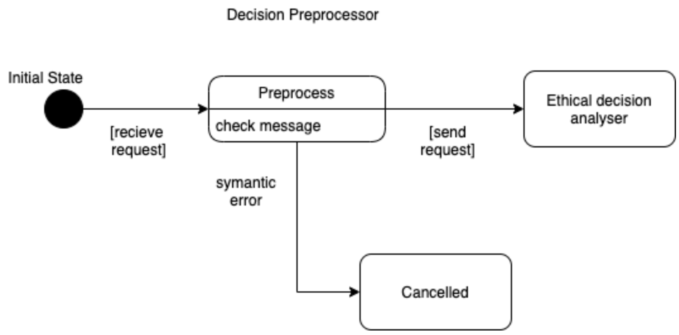
Each of the passengers have the liberty to set the priorities the moment they enter the car. The priorities can be customised according to the user. The sequence diagram in figure 4.4 shows the scenario where passenger B rejects the ethical request from passenger A.

4.3 State Diagrams

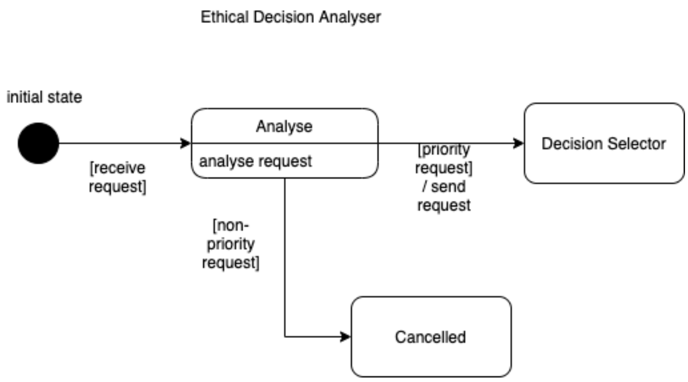
The state diagrams describe the functionality of the components in the architecture (fig 4.1). The flow of information is depicted through various states. The state diagrams were designed based on the principles followed in Martin Fowler's UML distilled book [6].



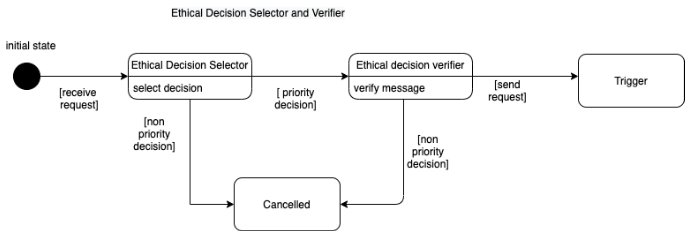
The messaging interface of passenger A has 2 states. Once the passengers places a request through the interface the message is checked and then sent to the decision preprocessor. In case of errors it is sent to the cancelled state.



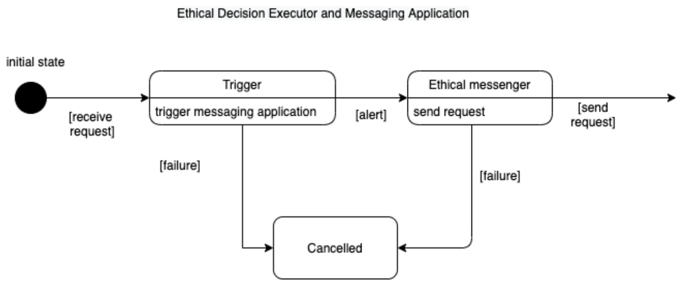
The preprocessor unpacks the message and is the first phase of the ethical engine. In case of semantic errors the message is cancelled.



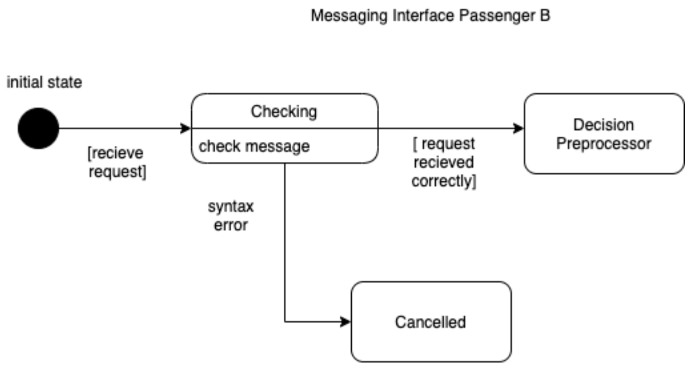
The ethical decision analyser analyses the content of the message and if it is a priority request the message gets forwarded to the decision selector.It is usually used in sending scenarios. In case of non-priority messages, the message gets cancelled.



The ethical decision selector plays an important role in sending scenarios. It helps in selecting the right priority for the request and then verifies it.



The passenger is displayed the message by the ethical messenger in case it satisfies the ethical priorities set by him/ her.



The ethical decision executor consists of a trigger and a messaging application. The trigger is activated when the message is to be sent over the public network. The ethical messenger send the request over the network.

4.4 Scenarios

The following scenarios were considered in this work:

- When an unknown priority request is raised the knowledge base of the ethical engine of the car is updated and the request is given a default priority of level 3. The priority level of the request can be updated at a later stage.
- The passengers can set the priorities before they board the car.

- The priorities of the passenger can be set based on their health status from previous records.

4.5 Role of MAPE-K

- MAPE-K loop plays a huge role in design of adaptable software systems for the following reasons:
- Maintaining the capability to adapt the functionality according to changes in the environment.
- Adapts behavioural changes with respect the security of the system
- Is able to maintain a large, complex system taking decisions at run time
- Interact with several components and make a decision
- Able to enhance security aspects of the design and deployed systems

Chapter 5

Simulation

This chapter gives a brief overview of the prototype of the ethical engine designed for messaging in autonomous car scenarios. We will discuss the purpose, software used for the simulation and the results obtained.

5.1 Prototype of Ethical Messaging System

5.1.1 Motivation

The main goal of the simulation is to explore the integration of ethical messaging with the existing communication mechanisms in cars. The communication was simulated using a open source framework called Artery [12][10].

5.1.2 Simulation Environment

The prototype of the scenario is presented using a software called Artery[12]. It is an open source simulation framework which integrates several software components. The major components are the SUMO software, the VEINS framework and the OMNET++ framework. Vehicular communication is the focus of this framework. We have utilised the VEINS framework to establish a simple prototype of the scenario where cars are able to communicate customised messages. The SUMO software provides the graphical interface for the simulation.

System Details

- Laptop used: ASUS VB704B
- Operating System: Ubuntu 16.04 LTS
- Softwares: SUMO simulator, VEINS simulator, OMNET++
- Software Framework: Artery

5.2 Use Case

The use case discussed in the chapter 4 is the one used for simulation. There were certain assumptions that we had to make. The assumptions are as follows:

- The parking lot is taken as a black box.
- The roadside infrastructure is able to establish communication with vehicles.
- The communication between the cars makes use of the radio waves.
- The range of the communication is taken to be 500 metres.
- The priorities are already set in the ethical engine.

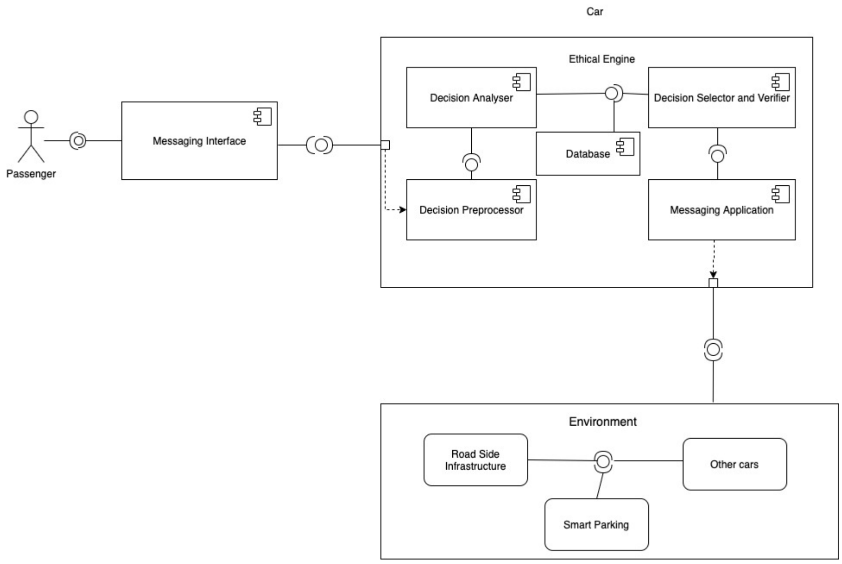


Figure 5.1: Component Diagram

The component diagram depicted in figure 5.1 shows the major components in the use case. The passengers are able to give user priorities through the messaging interface. The cars contain the ethical engine components. The environment consists of the other cars and the roadside infrastructure.

The simulation software supports the communication between cars. The scenario was simulated using the cross road pattern. The junction is considered as the parking lot. Three cars are moving

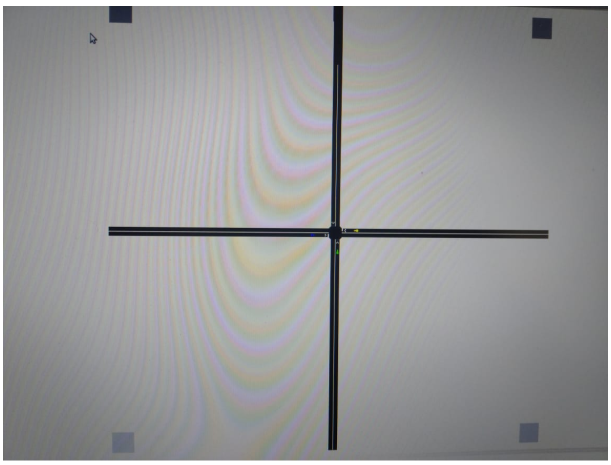


Figure 5.2: Cross Road Simulation - Passengers in Cars A and Car B are communicating with each other using the ethical messaging mechanism

towards the parking lot.The cars are named as Car A, Car B and Car C. The car A places the request to the other two cars for going into the parking lot by using the ethical messaging mechanism. The other cars consider the request and car A is allowed into the parking lot. The software is not able to support a web based or a mobile based interface from the passenger in the current state. Overall the ethical communication between cars was possible by assigning the levels 100, 010 and 001 in binary. It was coded as the priority for each car.

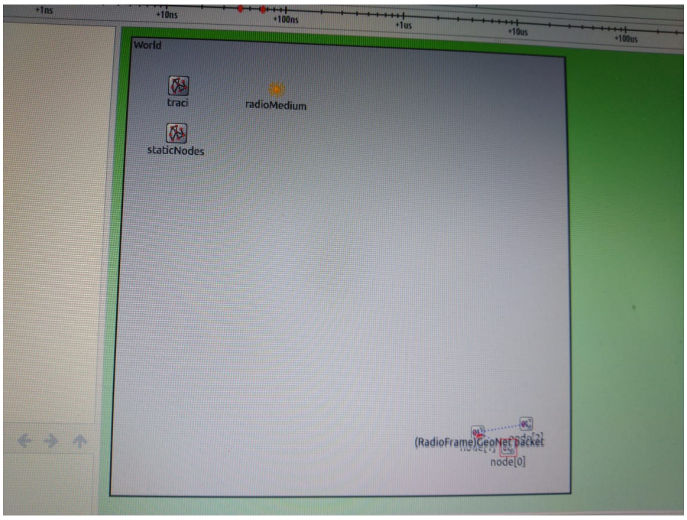


Figure 5.3: Simulation between nodes

The cars are considered as nodes in the simulation. The nodes communicate through the radio wave based mechanism. The software follows the ETSI standards which are implemented across Europe by different car manufacturers.

5.3 Summary of the simulation

The scenario simulated was a simple use case which illustrates the methods to utilise existing methods of vehicle to vehicle and vehicle to infrastructure based communication systems to ethical messaging scenarios. The study was able to explore different mechanisms of messaging already present in the ETSI standards. We have made use of the DENM (Decentralised Environmental Notification Messaging) messaging system. However, there were some issues which the current version of the simulation software does not support. They are:

- The web based interface is not supported for interaction.
- Buttons or options for user configuration are not currently supported.

The simulation was able to establish communication between the cars and send and receive the messages. The services provided by the simulation software currently are the co-operative messaging service, the DENM messaging service as well as car to infrastructure messaging service.

Factors that affect the simulation were the environment, design of the roads and the infrastructure used. Overall the simulation experiment was successful in establishing that open source software can support various additions to current methods of communication in ITS systems.

Chapter 6

Conclusion and Future Work

This thesis report describes a use case illustrating the ethical messaging mechanism involving cars, roadside infrastructure and people on board.The goal was to design, develop and simulate an architectural prototype which is able to utilise this mechanism.

- Firstly, a detailed study was conducted to explore the various communication mechanisms in cars. Later on,it was expanded to study Android based media software and open source software systems in cars.
- Once the literature survey was completed a process to study different architectural patterns that support changes in software at run time was studied. MAPE-K architectural pattern was found to be highly suitable for the use case selected.
- Further, the communication methods described in the architecture were depicted using the state diagrams.
- The use case was simulated using the Artery software and the messaging patterns that were supported was studied.

The learning's from this research work are as follows:

- The opportunity to explore the open source vehicle communication simulator.
- Interaction with web based or android based system was not supported in the current version of software.
- Various plugins were experimented with to install the packages.
- Libraries that support the software were not easily accessible and took a lot of time to install initially.
- Got several opportunities to interact with industrial experts through seminars and workshops.
- The capabilities of the messaging system to be explored with various technologies.
- The real time implementation with web based interfaces is to be explored.

Bibliography

[1] M. Autili, D. D. Ruscio, P. Inverardi, P. Pelliccione, and M. Tivoli. A software exoskeleton to protect and support citizen's ethics and privacy in the digital world. *IEEE Access*, 7:62011–62021, 2019.

[2] J. Cámara, H. Muccini, and K. Vaidhyanathan. Quantitative verification-aided machine learning: A tandem approach for architecting self-adaptive iot systems. In *2020 IEEE International Conference on Software Architecture (ICSA)*, pages 11–22. IEEE, 2020.

[3] A. Djajadi and R. J. Putra. Inter-cars safety communication system based on android smartphone. In *2014 IEEE Conference on Open Systems (ICOS)*, pages 12–17. IEEE, 2014.

[4] D. Eckhoff, N. Sofra, and R. German. A performance study of cooperative awareness in etsi its g5 and ieee wave. In *2013 10th Annual Conference on Wireless On-demand Network Systems and Services (WONS)*, pages 196–200. IEEE, 2013.

[5] L. Floridi. Soft ethics and the governance of the digital. *Philosophy & Technology*, 31(1):1–8, 2018.

[6] M. Fowler. *UML Distilled.* Booch Jabcon Rambaugh, 2003.

[7] N. J. Goodall. Ethical decision making during automated vehicle crashes. *Transportation Research Record*, 2424(1):58–65, 2014.

[8] P. Inverardi. The european perspective on responsible computing. *Commun. ACM*, 62(4):64–64, Mar. 2019.

[9] B. Kovacevic, M. Kovacevic, T. Maruna, and D. Rapic. Android4auto: A proposal for integration of android in vehicle infotainment systems. In *2016 IEEE International Conference on Consumer Electronics (ICCE)*, pages 99–100. IEEE, 2016.

[10] C. Obermaier, R. Riebl, and C. Facchi. Dynamic scenario control for vanet simulations. In *2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, pages 681–686. IEEE, 2017.

[11] R. S. Raw, M. Kumar, and N. Singh. Security challenges, issues and their solutions for vanet. *International journal of network security & its applications*, 5(5):95, 2013.

[12] R. Riebl. Artery framework. `http://artery.v2x-research.eu/`. Accessed: 2021-10-08.

[13] R. Silva and R. Iqbal. Ethical implications of social internet of vehicles systems. *IEEE Internet of Things Journal*, 6(1):517–531, 2018.

[14] A. Taeihagh and H. S. M. Lim. Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport reviews*, 39(1):103–128, 2019.