Developing a SIoT compatible novel traffic simulator to evaluate and execute complex SIoT based algorithms in typical road traffic scenarios

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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at BRAC University.

2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.

3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.

4. We have acknowledged all main sources of help.

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Abstract

In recent years, Traffic Congestion has become a serious problem both for the developed and developing countries. Averting Traffic congestion's preemptively would provide maximum benefits to commuters all around. Wireless communication between vehicles, which is nowadays accessible with smarter cars coming out more and more frequently, is the right path in coming up with a solution for traffic congestion. Vehicular communications seek out to reduce congestion's and improve road safety by adopting VANET and IoT based solution systems. VANET systems create dynamic node-node connections between vehicles to create a network of communication. SIoV promises new dimensions to the traffic congestion issue of the world by introducing social network concepts to the realm of SIoT, but this technology is still quite emerging. Therefore SIoT and the SIoT of vehicles that is SIoV has only been explored in the hands of able simulators. This paper proposes a novel Unity Engine based simulator to utilize complex SIoT traffic mapping algorithms and simulate traffic scenarios once the connections between vehicles has been established. Furthermore the simulator produces observations of the traffic congestion judging from the vehicular connections, producing suggestions that help to avert further traffic congestion's for a 4-way intersection on a busy street. The simulator maps vehicles as nodes and runs a scenario to observe the traffic scenarios created within the parameters. The idea is to avoid traffic congestion by utilizing pre-existing concepts of SIoT and design a simulator that can be fed SIoT algorithms and would produce satisfactory results.

Keywords: SIoT, Traffic congestion, SIoV, Traffic Simulator, VANET, MANET, Unity, IoT, Gephi, SIoT Simulator, IoV, Social Networks.

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Nomenclature

The next list describes several symbols & abbreviation that will be later used within the body of the document

CSV Comma Seperated Values

GUI Graphical User Interface

IoT Internet of Things

ITS Intelligent Traffic Systems

$MANET$ Mobile Ad-Hoc Networks

$SIoT$ Social Internet of Things

$SIoV$ Social Internet of Vehicles

$VANET$ Vehicular Ad-Hoc Networks

Chapter 1

Introduction

1.1 Background

Traffic congestion is a problem that needs immediate attention for the long run of active urbanization. The complete automatic analysis of traffic congestion is complex because of the interconnected and congested roads. Many technological approaches have been adapted recently to develop a long term solution. The most recent sector is Social Internet of Things (SIoT). SIoT is the integration of social networks on the Internet of Things (IoT)[1][2]

Internet of Things (IoT)[3] has been known for its burgeoning technology which guarantees a world of smart interconnected devices through the internet with sensing and self-commanding abilities to communicate and exchange data within the network without any influence of human beings. SIoT shares similar goals as IoT. SIoT evolved from IoT to create a better world for humans by integrating intelligence and consciousness into smart objects that share mutual interests and necessities to socialize, communicate and work together to resolve a specific situation[4]. The main difference between IoT and SIoT is that SIoT not only connects the devices together like IoT but also enables cooperation and builds up a socializing relationship among the devices to attain liable solutions to the problems[4][2]. SIoT enables interconnected transport infrastructures from which some real time data can be acquired which can be useful to reduce congestion providing a smart traffic management system.

SIoT has flourished in the transportation system when vehicles were associated with it and merged into the Social Internet of Vehicles (SIoV). It is a social network in which all the vehicles connected within the network associate and form social relation with each other and the transportation infrastructure automatically [5]. The proposed research suggests a system to detect traffic congestion by implementing the concept of SIoV and Vehicular Ad-hoc Networks (VANET). The traffic area is converted into a vehicular network in which the vehicles imitate human nature and behaviour in social media[1]. Each vehicle is considered to be a node in the network. Emergency information such as on-road accidents, road maintenance, or congestion management issues is exchanged among vehicles or passengers[6].

VANET is the growing technology that renders wireless inter-vehicular communication networks connecting nearby vehicles. VANETs share real-time information through beacon transmissions consisting of vehicles location, speed, road accidents, or construction information in the swarm of connected vehicles[7][8][9] SIoT, SIoV, VANETS are paradigms that can help to better traffic management by communicating information with

improved speed and ensuring reduced congestion and safe driving.
In order to minimize the occurring losses due to traffic congestion, the system should find the possible factors that can reduce congestion. Based on the stated ideology, the paper proposes an open-source simulation system to analyze a traffic network. SIoT and VANETs are applied to simulate a traffic scenario of the four-way intersection of Bijoy Sarani. The simulator provides a limited simulation system built specifically for SIoT related analysis to test the impact of SIoT based algorithms. It has the capability to pull data or plug new SIoT data such as a car to car distance, location of cars, speed of cars, different variable data, etc. and decisions, or regulations into the vehicles. VANETs are best suited for autonomous cars since effective perceiving of SIoT based data from autonomous cars is easier. Also, many futuristic works are related to autonomous cars. However, in the simulation manual cars were considered too.
There are other available simulators that are complicated and inconvenient for SIoT or VANET connected cars. The data from VANET needs to be interpreted using other applications to ensure easy perceiving of data by the network analysis tool. Therefore we created a simulator that takes SIoT based information rapidly and then directly plots the results using Gephi. The system analyzes the output in an iterative way as the outputs are fed into the simulator and run repeatedly testing the changes or factors that give positive feedback in controlling traffic management. Therefore based on the simulation we can detect the overall impact of the algorithms and the betterment of the simulator.

1.2 Research Problem

Traffic congestion is known to be one of the most common daily phenomena of the cities and a leading threat to transportation management in the world. One-quarter of the population resides in the urban parts of the world[10]. Recently traffic congestion is increasing at a higher scale especially in urban areas affecting the people living there the most. The population of the urban areas is estimated to be doubled by the year 2050 predicted by the United Nations [10].Whether the country is developed or underdeveloped, traffic congestion will in fact keep on getting worse day by day in this era of urbanization and in the future.
Dhaka, the capital of Bangladesh, one of the most crowded places is known to be one of the most traffic chaotic cities. When the year 2050 is reached the urbanization rate is estimated to increase from 30 to 50 percent [11]. Bangladesh occupying 993 people per sq kilometer, has been identified as one of the populous countries [12]. The swift increase in population elevated the transportation demand. Now the high population with a high transport requirement gave rise to an extensive number of vehicles at a frightful rate. Dhaka has a lack of transportation infrastructure planning for which the vast increase in the number of vehicles exceeds the capacity of the roads thus leading to traffic jams[13]. Moreover, the sudden increase in personal transport, mainly private cars and motorcycles contributes to the increase of vehicles.Other vehicles including rickshaws, and huge buses are in excessive quantity too. Rickshaws and buses are a cheap transport medium that are popular and in high demand among the public transports.
The core reason for traffic congestion is mainly because of the increased number of vehicles as well as poor traffic regulation and car parking systems [14] . Parking cars along roadsides due to incapacity of parking systems inside shopping malls, schools, universities and multi-complex buildings further narrows down the road. An estimation of barely 9% of the roads and 6% of sidewalks remain free [15]. This reduces the space for other

cars to travel freely hence leading to congestion. Pedestrians are compelled to walk on roads as cars are parked on sidewalks which increases the scope of road accidents.

Traffic congestion not only causes disruption of daily human lives but also affects environmental, societal and economic progress [16] . Traffic congestion contributes to air pollution due to excessive gas and fuel consumption releasing carbon dioxide, carbon monoxide, nitrogen oxides into the air thus affecting the environment as well as human health. In addition to that traffic jams participate in noise pollution that also has an adverse impact on both the environment and human health. About 60% of the polluted air comes from the exhaust gases from the vehicles. As a result, there are about 80-230 million respiratory tract disease victims and 1200 to 3500 people die due to polluted air particles [10]. Traffic congestion not only affects human lives but also affects the economic sector. An annual estimation of 3.2 million working hours is wasted due to traffic jams everyday[17]. Traffic jams are severe at the busiest hours of the day mostly in the morning, afternoon and late evenings that is at the office and school starting and departure time. About 16% of the people use personal transport and 84% use public transport [18] which means that a higher percentage are dependent on public transport. Therefore a larger part of the population are wasting an immense amount of time due to traffic jams hence leading to economic losses. An annual estimation of the economic cost of traffic congestion is about $3.8 billion [18]. Bangladesh is not in a position to sustain such an economic or environmental loss as a developing country.

Furthermore, other reasons for traffic congestion are uneducated drivers and rash driving [18]. This scenario is most common among bus drivers. There is no coordination among the busses and the drivers fail to follow the bus schedule causing waste of time. The drivers tend to compete with other busses in order to surpass them. Therefore this reckless driving and car speeding contributes to the rates of on-road accidents making it extremely dangerous and unsafe for both passengers on board and also people on other vehicles. Traffic accidents are the preeminent global reason behind death and severe injuries. It is also reported that 72 percent of the road accidents occur due to the drivers' fault [15]. An estimated average of about 3000 accidents take place in a year, out of which 2700 people die and 2400 people face injuries [10]. The accident rate crossed 4900 incidents of accidents in the year 2017.

The governments intensively struggle to find a solution to the problem as the prediction of traffic congestion is a very challenging task [16]. The government and experts tried and failed in their efforts to shape up the situation by building flyovers, introducing automatic traffic signal lights and also prohibiting rickshaw pullers on high roads and trucks during the day [18]. The congestion on the roads blocks emergency vehicles such as ambulances, fire engines, police cars, etc. to pass through. This further aggravates the situation making casualties more susceptible. If this issue is not solved as fast as possible then there will be more death casualties in the near future as vehicles are the reason behind road accidents. A sudden blockage of roads due reconstruction of roads or construction of flyovers or accidents can also add to the reason behind congestion. Therefore things would be much easier if such information were known to every vehicle traveling on the road and people would know which alternative path to take or be alerted beforehand. However, it is actually possible when the technology is merged with the vehicles.

Recently various technological advances with the convergence of vehicles are evolving in several research works. Moreover, technological approaches are found to have effective solutions over reconstruction of the transportation infrastructure [19] according to the London School of Economics and Political Science (LSE). Communication among vehicles focusing on the new reign of autonomous cars are reported to mitigate on-road casualties[23]. US Energy Information Administration (EIA) reported that traffic accidents will decrease along with the decrease in congestion since about 25% of the reason behind traffic jams are road accidents [20]. Similar research works using SIoT in vehicles have been successful in reducing the travel time by 33% by minimizing congestion [21]. Therefore the integration of technology into vehicles has been setting its standard to reduce death casualties and to preserve the environment. Our research emphasizes on the testing of SIoT algorithms continuously by means of feeding the SIoT data into the proposed simulator in an iterative way ensures solutions to minimize traffic congestion

1.3 Research Objectives

The main purpose of this research is to develop a limited traffic simulation to test the effect of SIoT algorithms in minimizing traffic congestion. It uses the concept of SIoT and VANET. Both SIoT and VANET set up a communication between vehicles. The objectives are:

- Deeply understand the concept of SIoT and VANET
- Develop a simulator for a specific traffic scenario and that is convenient for running SIoT algorithms
- Develop a simulator that can pull and plug of SIoT based data or information easily, also conveniently
- Evaluate the result and accuracy of the simulator
- Recommend improvements of the simulator

1.4 Scope and Limitations

SIoT is a technology that has scopes of improvement since it is still evolving in its collaboration with vehicles. The vehicles have a randomized variable multiplied to their speed and agility to imitate a natural traffic scenario and their random movements to some extent. Although this made the simulator dynamic to a great extent, this approach to give every vehicle its unique characteristic is very simple. Thus the simulator does not always imitate the natural response of vehicles in traffic. However, the performance can be improved by including more complex traffic models and making the vehicle more responsive and intelligent. The factors should be derived from the scenario the particular vehicle is in and then take discussions accordingly rather than taking random factors to calculate speed and other characteristics of the vehicle.
The SIoT simulator also has some limitations compared to the conventional full-fledged simulators. It is challenging to provide accuracy and spontaneity due to the sudden malfunction of the sensors or willingness of all vehicles to share its data. This type of system fails to be scalable. As a result, the system can generate faulty data.

1.5 Document Outline

The rest of the section of the paper has been organized as follows. Chapter 2 is the literature review along with the related works of relevant and existing approaches based on the proposed research and broad explanations about the works that are already familiar. Chapter 3 describes the methodology of this research. It includes details about the explanation of the proposed model and the procedure of the simulator construction by the concept of SIoT. It also includes the implementation of the SIoT algorithm. The data generation and the result analysis section is in chapter 4. This section gives detailed information about the data-set structure and how the data-set was fetched. It also includes a comparative study of the acquired data. Finally chapter 5 talks about the conclusion of the paper which summarizes the whole research and in which future work is discussed about the future extension or implementation of this paper.

Chapter 2

Literature Review and Related Work

This chapter introduces the concepts of IoT communications and intra-vehicular communications that were used for this thesis work. It also introduces the mechanics of the simulator used and the graphing tools used to conduct the simulations for obtaining the results. Furthermore the related works to this project are also analysed for a closer understanding of the impact of this simulator system. This chapter explains SIoT and VANET showcasing how these communication systems were used in successful establishment of the algorithm on which this simulation is based.

2.1 IoT

2.1.1 Description of IoT

Internet of Things or IoT is one of the largest and most ambitious leaps in technological of the last decade. It is a a new technology paradigm visioned as a global network of machines [22]. IoT introduces a system and network of connectivity between devices previously handled manually, it establishes connectivity between machines and helps them communicate vital information that helps automate tasks in large scale establishments like factories and such. The true advantage of the IoT for companies can be fully realized as connected devices can communicate with each other and interact with vendor-managed inventory systems, customer support systems, business intelligence applications and business analytics.

2.1.2 Components of IoT

Essentially IoT can be simplified under 5 major groups of communication technology[22]:

- **Radio frequency identification (RFID)**: Radio Communication between sensors, tags and readers for automatic data collection and recognition of devices through radio waves.
- **Wireless sensor networks (WSN)**: A distributed system of interconnected autonomous devices to capture physical and environmental data through sensors and communicate with RFID to monitor geolocation, thermal temperature and so on [23]
- **Middleware**: A mediator between software and physical sensor-laced devices that provides software developers and users to communicate and handle input/output.

- **Cloud computing**: Provide exemplary back-end support for massive streams of data that get collected every instant from vast of number of interconnected IoT devices.

- **IoT application software**: Establish user-specific software and applications to support the large amount of IoT devices used in a scenario, managing the device-device and human-device connectivity in a well arranged form.

2.2 VANET

Vehicular Ad-hoc Networks **VANET** creates a mobile internet system by converting moving cars into nodes around a certain network, this is an application of wireless multi-hop networks. More and more cars are nowadays equipped with highly capable communication modules and sensors, these sensors and modules are used in inter-vehicle communications for a range of applications. Starting from basic road safety VANET can be used for dynamic route scheduling, prevention of collisions, blind crossing, traffic signal coordination and real-time traffic condition monitoring, VANET provides the grounds for all of that to be put into work in smart cities[24]. VANET is the child of Mobile Ad-Hoc Networks or MANET holding the similarity of movement and self-organization of nodes, containing constraint of fast topology changes due to high node mobility[24][25]. VANET essentially creates temporary Ad-Hoc networks with fast moving vehicles around a certain hub, this allows the mobile network created to share and receive information about road conditions and traffic congestion and so on. VANET creates two types of communication, Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) connections, where messages are either relayed to vehicles or the infrastructure governing node which then relays the message to other vehicles in the network.

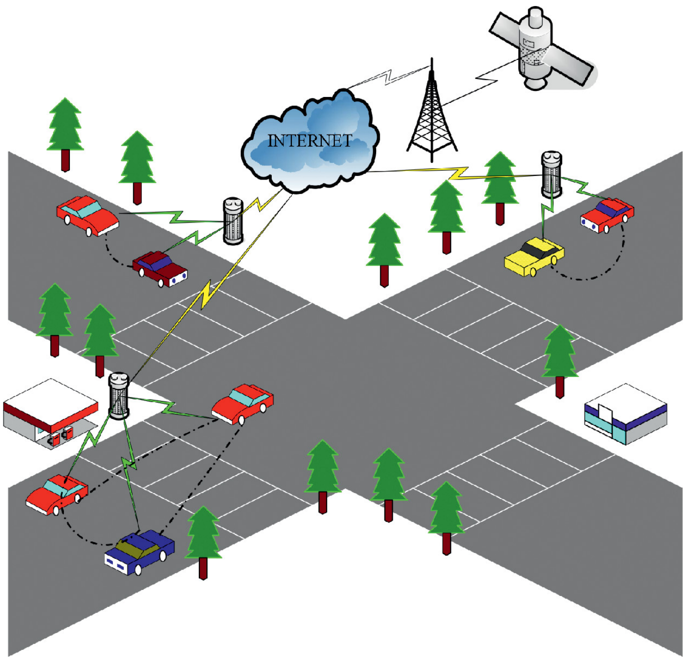

Figure 2.1: VANET V2V and V2I network scenario [26]

VANET is a one to one communication between nodes, this is an example of a distributed network system although in cases of V2I communications VANET can be centralized as well. Since VANET is a form of MANET mobility is inherited by VANET, nodes or vehicles are constantly changing location and speeds making the network extremely dynamic. Fig 2.1 shows an illustration by [26] that demonstrates an example of a common VANET scenario and how the mobile network looks like.
The downsides of VANET are that it can only establish a connection to a node so long as the node stays within range, if the car moves away the node-node connection is then broken and information transfer stops as the vehicle steps out of the network. Additionally VANET has a multitude of security risks as replicating a node and infiltrating a network would require minimal efforts. VANET also has little data processing capabilities, since the network established is so dynamic, large number of data is being received from various nodes at any given time. This omits the ability to fine-tune, secure, find patterns in data and many more data processing techniques that otherwise could be possible by different vehicular communication methods.

2.3 SIoT

Scientific evidence stands to prove that a large number of individuals in a social environment can produce much greater accuracy solutions to a certain problem faster than a single individual regardless of how capable that individual might be[27]. This concept has been implemented in several systems that propose to achieve solutions for traffic congestion issues and internet search relate issues[28]. IoT establishes numerous connections and integrates mass numbers of devices with each other for inter-device communication to share and collect data. The devices are able to communicate with each other over various protocols and cooperate with fellow devices to reach a mutual solution.
Scientists and experts have come to a more advanced consensus though that a merge between ”Social Network” and IoT is advised and much more profitable benefiting with much larger solutions that regular IoT systems struggle to provide[28]. Merging these two concepts provide us with the following beneficial outputs:

- **Network Scalability**: The SIoT system can be molded in the way that scalablity and network navigation is guaranteed as is with human social networks.
- **Security**: Trustworthy connections can be can created between devices established as *freinds* maximizing security in the system.
- **Research**: Social Media analysis models can be reworked slightly to fix IoT related issues.

2.3.1 SIoT and Social Structure

In this part, we take a more in depth look into how SIoT really brings the social benefits to IoT. Much like a human social system a basic form of social relation is the **Parental obeject relation**(POR) wherein the relationship is established at the moment of manufacture. Objects created at the same time by the same manufacture establishes this relationship and is unchanged through the product life cycle only updating when a disruption is noticed[29]. Secondly objects can establish **Co-Work Object Relationship**(COR). This relationship is created when similar objects(eg. RFID tags, sensors, vehicles) are sharing location and are situated close to each other on a regular basis. These objects communicate useful information to each other that can potentially help them come to a solution much quicker. For vehicles, multiple vehicles sitting at a traffic stop can share vital information such as, time waiting, traffic up ahead and so on, which can help the vehicles behind it avert traffic congestion more efficiently[30]. Lastly, we have **Social Object Relationship**(SOR) a relationship which is established when objects come into contact continuously with each other solely based on their owners. This relationship forms a *trust* or *friendship* amongst objects as they work together to create solutions for *friends*[29].

2.3.2 Vehicles and SIoV

Based on the aforementioned relationships vehicles can create a decentralized SIoT network by communicating amongst *friends* and gather information as humans do in social networks[30]. As such an evolutionary step of SIoT in vehicles has led to a new paradigm of **Social Internet of Vehicles**(SIoV). SIoV steps into the realm of the Intelligent Transport Systems(ITS) and provides more elegant changes and solutions to the existing ITS solutions[5]. Following these ideas, we can deduce that SIoV has a dual nature deriving from SIoT fundamentals, one where the vehicles themselves are the main players and active connections and social relations are built around them, and the other where the drivers/passengers of the vehicles are used to build social relations and circles. This can be seen more detailed in Fig 2.2 as the architecture was demonstrated by [31]. To understand SIoV better we can take a look at the social network interactions between humans in comparison to how a social network of vehicles might operate. Starting from the node types to the way the two interactions take place.

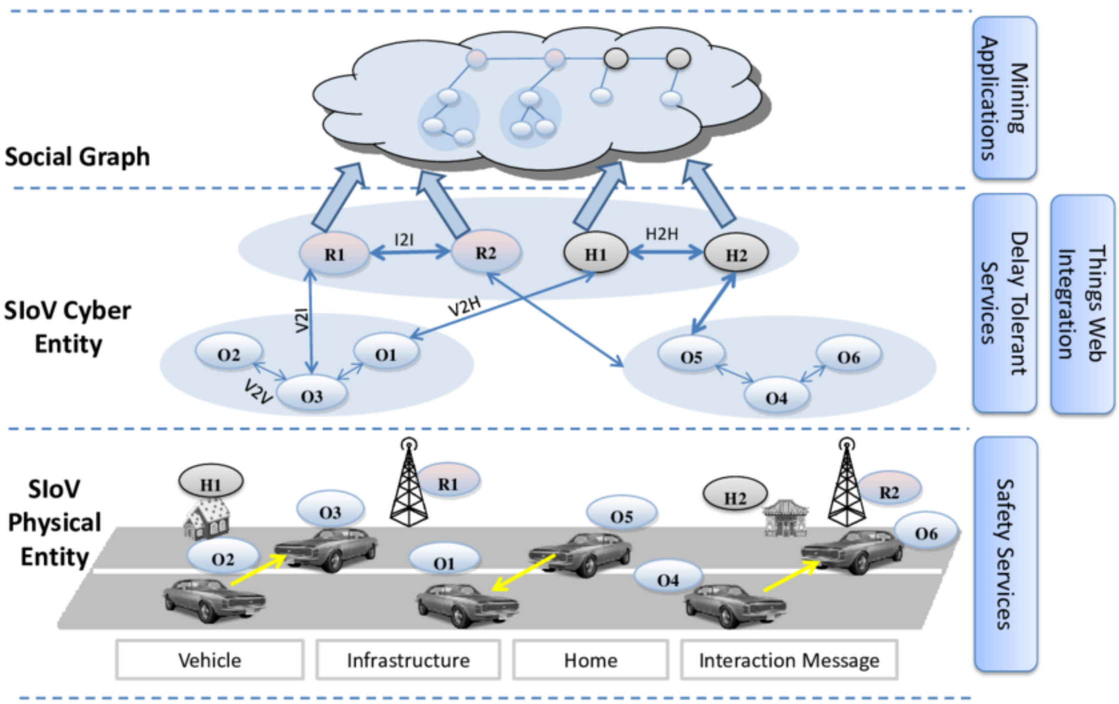

Figure 2.2: Architecture of SIoV[31]

2.3.3 SIoT to SIoV

We now look at how we got to SIoV from SIoT. Internet of Vehicles or IoV rose from the idea that vehicles of the future are going to be riddled with sensors, communication modules, autonomous features and social networking capabilities. So the IoV consists of cars, autonomous or otherwise constantly communicating with other cars in a network to relay road conditions and avert congestion and so on. SIoV then rises from the merger of the networking capabilities of SIoT and the communication modules of IoV, social ties are made with vehicles in a network and the data collected from the vehicles can be used to improve travel times and conditions as well as offer quality of life improvements for drivers/passengers[5]. For example, COR based communications in a network of cars can exchange information with each other about road conditions broadcasting the information and reducing congestion on the road, SOR based network can preemptively help reduce travel times as *friend* vehicles in a network can relay conditions about similar routes. To understand SIoV better we can take a look at the social network interactions between humans in comparison to how a social network of vehicles might operate. Starting from the node types to the way the two interactions take place. This can be best illustrated in Fig 2.3 by [31]

Property	**Social Network of Humans**	**Social Network of Vehicles**
Dynamic Nature	Mostly static and grows based on real life relationship.	Highly dynamic and nodes join or leave extremely fast.
Basis of Relation	Connection links are based on real life relations, similar personal interests, career paths, locations, etc.	Connection links are based on travel route, similar configurations, similar owner interests, same manufacturer etc.
Social Interactions	Tweet, comment, like, share, chat, tagging, follow, poke etc.	Message exchange, sensory data consumption, status update subscription, status reputation score.
Anonymity	Mostly not anonymous since connections exist between real life friends, or with people of some common interests.	Mostly anonymous since the identity of the vehicle and the vehicle owner is hidden.
Trust	Social relationship grows through continuous interactions and authenticity. Trust among peers increase with more interactions.	Mostly anonymous relationship unless otherwise specified and there is direct and indirect trust due to high speed topology change.
Topology	Mostly stable. Slowly changes with addition or deletion of friends.	In a vehicular social network topology updates very fast because of the ad-hoc wireless technology range and high speed of vehicles.
Privacy Settings	Privacy is generally maintained or customized by the social network owner.	Some information is publicly shared for the safety issue and others are private to the vehicle owner. Owner should be able to customize privacy.
Activity Concentration	Most activities occur among real life close friends, or in a group of professionals of similar interests.	Interactions occur mostly within anonymous neighbors.
Usage	Online social network is a virtual network which is valued by human interactions and social engagement.	An overlay network on top of the physical vehicular network and mostly used as a knowledge base of vehicle usage and experience.

Figure 2.3: Social network of Humans vs Social Network of Vehicles [31]

2.4 Gephi

Gephi is an open-source network analysis visualization software platform developed with Java on netbeans. Network graphs of past were only left to those who truly had mastered complex mathematical formulas and had a grasp over difficult to maneuver software, but Gephi changed this scenario by bringing easy to navigate and use network graph visualization. Graphs consist of nodes and edges simply put [32]. We can from edges figure out how well nodes are connected to each other, a node-node connection is referred to as *neighbors* and one node can have many edges to it. Gephi has the capability to support *directed* and *undirected* edges within a graph. An undirected graph means that the nodes have a symmetrical link-up, directed graphs on the other hand are asymmetrical also characterised by arrows pointing to and from start and end nodes. Gephi labels nodes and edges with scientific identifiers offering range of color customization and so on. The author here [32] talks in their book about Gephis integration to accommodate all its features and shows the gross overview of Gephi, this material gave this papers research a boost in workflow as Gephi was primarily used for all data visualisation and analysis. The material was used as reference material to navigate Gephi and its features.

2.5 Related Works

SIoT based ITS solutions are on the rise of late, [30] in their work describe an algorithm for mapping a decentralised SIoT network. They create the connections between vehicles from a manually collected map from various sources on the internet. While their work mainly focuses on the connectivity and mapping no simulation was done to test the mapping in a real time dynamic scenario, which we have done as later discussed in the paper. The core concepts of the two papers are quite similar as both deal with SIoV based vehicular network mapping but this paper proposes a novel simulator created through unity to test real time car conditions to reduce traffic congestion.

Authors in [33] have made an in-depth research on monitoring traffic congestion in smart cities that consist of smart cities. Their work primarily consists of using aerial drones that map and monitor traffic conditions using a behavioral algorithm. Our paper differs it by having an SIoV network within objects in the road that provides a more current world solution and does not require use of smart cars as most cars come with sensors that can be used to create SIoV networks.

Another work [34] determines the State-of-the-art vehicles are enhanced with advanced technologies. These features eventually allow them to communicate with nearby vehicles by forming VANETs [35]. However, our proposed simulator not only creates a communication amongst the vehicles, it gathers the SIoT data to create a network in such a way that it can contribute to analyzing different characteristic of a traffic.

A work [36] described mobile Ad Hoc networks (MANETs) in which nodes are capable of interchanging messages independently without relying on a basic technical structure. The development of a large, pervasive network in which mobile smart devices are connected through communication, which is wireless. With the assistance of this kind of created networks, users can provide services in any particular scenario. The next generation of MANets established by moving vehicles which are named Vehicular Ad Hoc Networks (VANETs), were further analyzed by the authors where they use the perceptions of complex networks [37][38][39]. This is a revolting technology that allows the cars to become self regulating without any technical structure needed as per these related works [40], [41]. It is being used in recent applications to increase the flow of traffic on roads [42], [43]. Vehicles communicate with each other in these systems, where they share information like distance and position. Softwares, algorithms and Protocols can be able to access real time locations of vehicles across the street considering them as nodes, since the global positioning system (GPS) can be conveniently mounted in vehicles of all kinds [38].

In [44] the author has discussed about the advantages of unity engine as a tool for game development. Having a feature-rich interface and very flexible editor. The author has described Unity as an all-in-one editor that supports multiple operating system. It also supports 3D and 2D development which along with other features has enabled the proposed simulator to be versatile.

Chapter 3

Methodology

3.1 Methodology

A SIoT compatible simulator had to be built with the SIoT algorithm to be used and tested and for that, a platform was selected. A platform with maximum freedom of asset selection and adding versatility was selected. The Simulator was created in a modular way so that quick changes can be made and source code can be modified according to need. The simulator was created in a 3d environment with low-resolution objects to ensure lower resource consumption in case of computational power. Traffic signals and lane changes were implemented. Access to variables from GUI was implemented to easily test the simulation for changed scenarios. Outputs were generated to be used directly in network analysis tools using the SIoT algorithm as the determining factor of how the conversion will happen and how the traffic data will be interpreted by the network analysis tool. After the simulator was made multiple tests were done to create different traffic situations and generate SIoT related files. Later on the generated files were tested using a Network analysis tool. With the network analysis tool the Traffic domains in the simulations could be converted into a Complex network. Multiple statistical and analytical tools were used on the data to visualize and determine network related values which could be used to know different characteristics of the traffic domain. Comparing the value with the simulation input and simulation picture the efficiency and accuracy of the simulation and evaluation process was determined as a whole process to evaluate SIoT based traffic interpretation and analysis approaches.

3.2 Building the Simulator

3.2.1 Platform, tools and asset selection

For building the simulation different platforms were tested and considering various advantages unity was selected. Unity is a renowned and robust game engine that has elements like physics formulas as components to use as elements while making a game or simulation. Alongside, there is a large community and marketplace for unity with a variety of basic assets available for non-commercial use. To build a realistic traffic simulator everything has to be done from scratch. Availability of useful assets proved very useful while texturing and modeling different elements of the simulator. As hardware resources were limited unity tools to optimize the simulator played a vital role. Thus Unity Engine was selected as the Building Platform. Unity provides documentation support for all of the features and the community is very responsive and helpful in terms of problem solving or getting any insight if any error occurs. Visual Studio Code comes as a default IDE for all the scripting and coding which is a very powerful tool. Unity Engine by default used C as programming language. The primary goal was to implement a road junction in a 3D environment with routes and traffic lights functioning as Real life. The simulator settings also had to be accessible by Graphical User Interface and thus tools for User Interface creation in unity were used. As assets low-poly models were selected for 3d representation of Simulator objects. For car and route creation, a prefab to object creation method was used which provided cloning facilities for different objects rather than creating or designing every object individually.

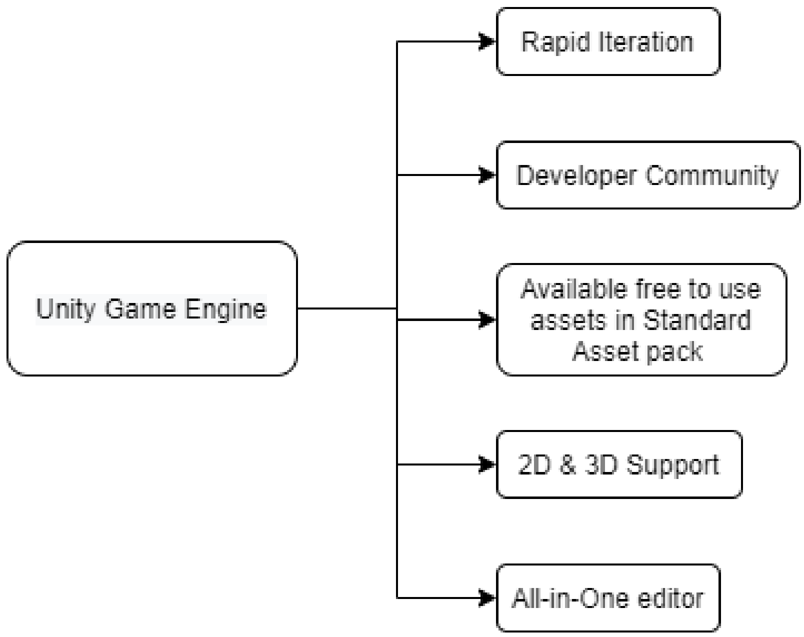

Figure 3.1: Unity Features

3.2.2 Setting up the map and vehicles

As the map, a four-way intersection road was selected as a traffic junction for the Simulator. For creating the map a 3d plane was selected with adjusted roughness to create necessary friction with the wheels of the vehicles for realistic vehicle movement. As a visual template for the road design and as road terrain visualization a Satellite image of Bijoy Sarani was used. Roads and routes were created accordingly. Name fields for different roads and routes were created so that later the position of the vehicles according to route names can be determined. The whole map was created on a square 3d plane with a 1:4 ratio to the real size of the component and elements. On this map, later routes and paths were created as per the visually available reference of the texture map of Bijoy Sarani.The map overview is shown in Fig 3.2

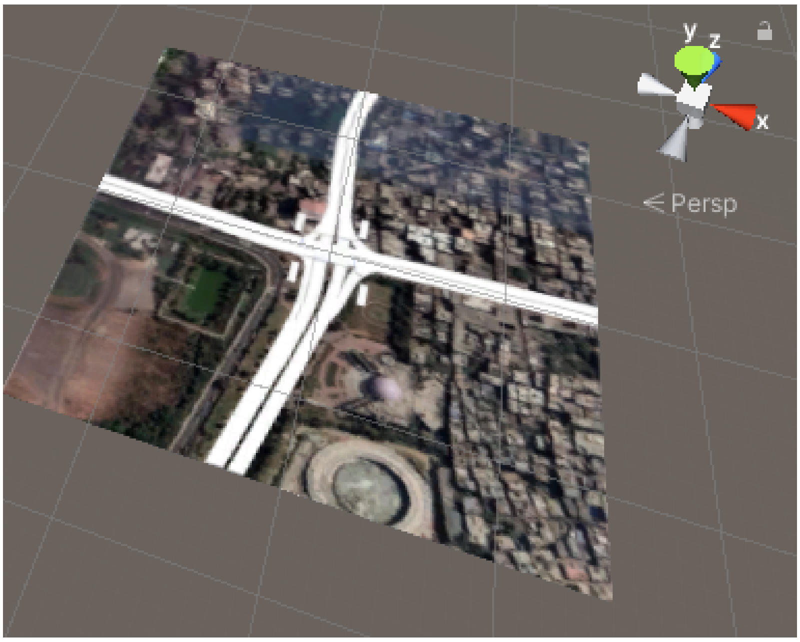

Figure 3.2: Map Design

Vehicles were designed with limited but complex decision-making skills with respect to obstacle avoidance, lane changing, route finding, and configurable attributes such as source, target, turning speed, max speed, and braking co-efficient in accordance with the vehicle type. Apart from these weighted random factors were multiplied with attributes such as speed and acceleration to give the simulations a natural like vehicle movement in the case of manual cars and replicating different driving styles.
As 3d models of vehicles of different types, a single low-resolution 3d model of a hunchback car was used with different colors of the car representing different vehicles.Vehicles are demonstrated in the image shown in 3.3

Figure 3.3: Car Design

3.2.3 Routes and traffic rules

Routes were created with the way-point tools of unity which creates connecting paths for game objects to follow. Every way-point can work for a single vehicle to follow the route so to implement lanes 3-4 way-point routes were created for each road. For replicating the signal another set of routes were created in the junction area to connect between different roads. 36 routes using way-point were created for the whole system. Connections between parallel roads were also made to implement lane changing. Lane changing was a very important factor for the traffic to achieve natural behavior and vehicles taking decisions to reach their destination facing less amount of obstruction. Lane change was programmed for most of the routes including turns and connecting routes to test scenarios with variable strictness in traffic rule enforcement.taking U-turn was not considered and implemented in the system. Maximum and minimum speed of any lane and lane connection as well as lane changing speed all are kept as variables and can be changed manually. Road design is shown in Fig 3.4

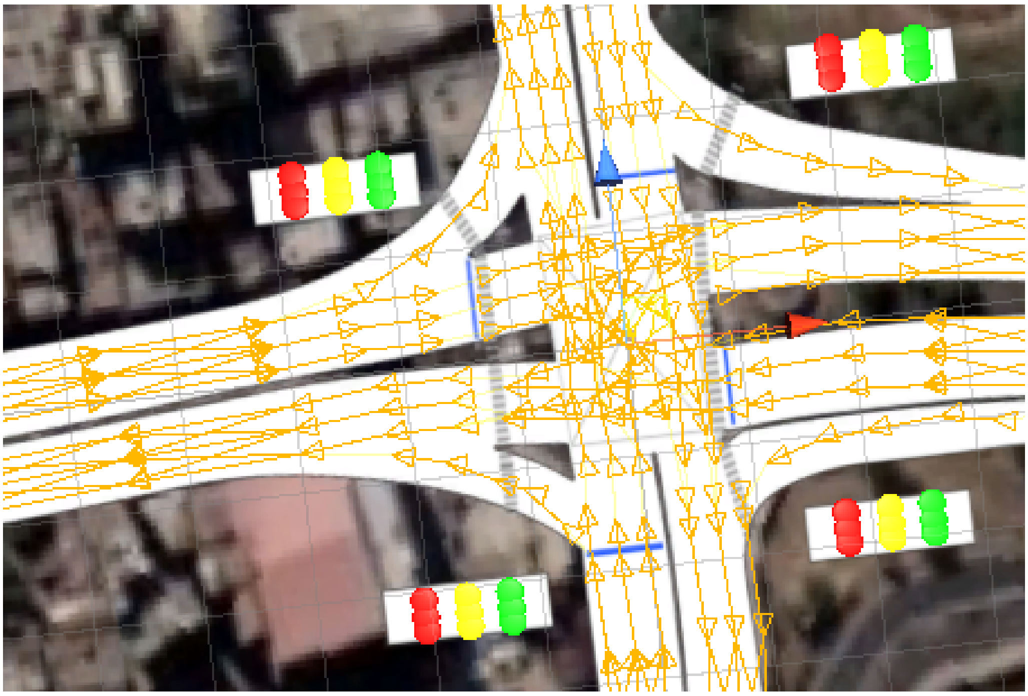

Figure 3.4: Routes and traffic rules

In the 3.4 the way-point routes that are used to define the lanes and lane change paths are visible, There are more connecting routes for giving the vehicles alternative ways to approach towards their destination in case of network congestion. Also different parameters are set with the routes to be passed to vehicles on them to control their flow according to preset rules.

Algorithm 1 Collision Avoidance and Lane Change

```
Result: Avoid collision with other vehicles by braking or changing lane
while Vehicle speed is greater than 0 do
    if Distance with the vehicle in front is less than safe distance s then
        if Speed of the vehicle in front is 0 then
            Decrease speed by 40%
            if Lane change is enabled and any adjacent lane is free then
                Change lane and accelerate to normal speed
            else
                brake
            end
        else
            if Vehicle in front is less than critical distance c then
                Decrease speed by 40%
                if Lane change is enabled and any adjacent lane is free then
                    Change lane and accelerate to normal speed
                else
                    brake
                end
            else
                Decrease speed by 10%
            end
        end
    else
        Keep going at normal Speed
    end
end
```

For lane changing and braking 1 algorithm was implemented in Unity engine, for finding route to destination and interacting with traffic signal few other algorithms were implemented as well. To make the simulation run there were a lot of scripting to be done and real life traffic rules were defined through similar approach of algorithms as shown in the pseudo code shown in 1.

To Reach their destination the vehicles also had to take decisions in traffic signal and connected routes to find the optimal path. This was implemented through route find algorithm. In that algorithm if any vehicle had a destination to the directly connected left hand route. then lane change was disabled for those vehicles for that simulation and those vehicles will only approach through leftmost lane.

Other simple automation and rules were implemented by coding in *C*. For setting the waypoints in a manner that they create a route and guide traffic over them to their destination basic conditional statements were used in all the algorithms. All this algorithms as a whole is responsible for creating the simulation with moving traffic.

3.2.4 Traffic signals

Traffic lights were placed and the timing interval was made accessible from the simulator settings to test different combinations of timing in different scenarios of traffic. Traffic lights are connected to the main routes and directly connected routes for the side lanes were kept uninterrupted as real traffic. Visual representation of the traffic light is made by placing a traffic signal beside the respective road it is assigned to. Four traffic signals were placed in total controlling a total of 24 lanes to control the flow of the traffic. The time interval of each of these traffics can be set separately. The signals represent their state by color illumination tool in unity.

3.2.5 Variable inputs and factors of simulation

The simulator was enabled with multiple customization and configuration features from outside the source code. Vital settings were made available to manipulate from the Simulator interface. These variable inputs help the system to generate dynamic traffic scenarios through traffic simulation to evaluate various decisions and measure the impact on traffic behavior. For Roads, the variables are the maximum and minimum speed of each lane, lane changeability, Vehicle spawn number. For Vehicles, the variables are top speed, acceleration, source, destination, braking distance, and braking torque. For traffic lights, the variables are interval and Serial in which roads will be opened and closed. There are various random factors to be multiplied with different other variables to make spontaneous minor changes that can be enabled or disabled. Fig 3.53.6

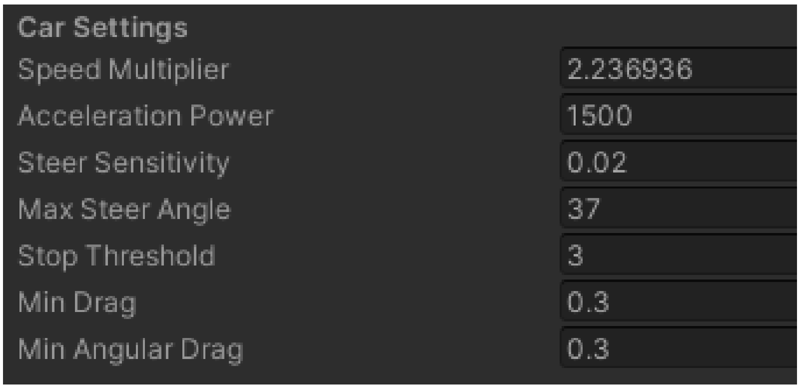

Figure 3.5: Variable inputs and factors of simulation

Figure 3.6: Variable inputs and factors of simulation 2

3.2.6 Simulator GUI implementation

All the Variables and Factors can be changed from the unity platform interface before loading the simulator without accessing source code or scripts as they are made public variables. Public variables are directly available to edit from text input interfaces in unity to be manipulated. However, there are several prime factors that are made available to manipulate while running the simulator from a Graphical User Interface. Vehicle speed of different categories of vehicles is one such factor, along with vehicle speed, traffic light interval, and lane changeability can also be set, Number of total vehicles is another one. For each of the settings, the simulator requires a particular time to configure and check for errors in given values. Dynamic manipulation of these values can be used to generate thousands of scenarios in the Simulator and present a number of opportunities to test and research Traffic congestion-related issues. Fig 3.7

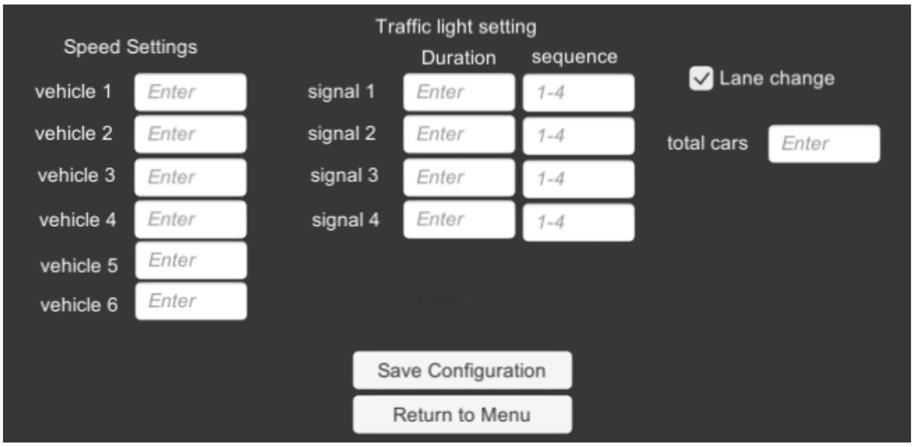

Figure 3.7: Variable Input Interface

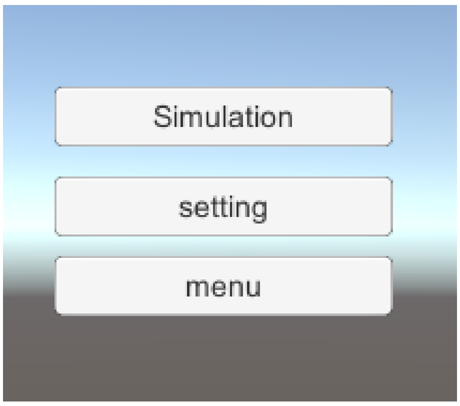

Figure 3.8: Start or main menu Interface

Figure 3.9: In Simulation pause Interface

3.2.7 Measurement of the augmented V2V distance

While the simulation runs a background script continuously keeps track of the distance between adjacent vehicles within a range using vector calculation. As the Simulator Environment is a 3D area position of different vehicles are given in *x*,*y*,*z* vector values. In this vector space, *y* represents the elevation of an object. The difference between the object's position in 2D space is calculated from a unity function called "Magnitude" which takes references to two object's position as a variable to be passed and calculates the distance in-between then in 3d vector space. As y position of all the vehicles are same so the calculation only gives the vector distance that is derived from the *x* and *z* positional value of the vehicles. The data is then stored in an array of lists which keeps a record of adjacent cars and their distance in-between. This value is important for configuring SIoT algorithm and *VANAT* related simulations. VANAT and SIoT both uses vehicle to vehicle distance to determine if there should be a communication or connection between them or parameters should be passed or not. All the vehicles are checked in an iterative process frame by frame to keep the distance arrays updated. This calculation alone is responsible for the Unity Engine using more resources while running the Simulation.

3.2.8 Adding Vehicular Ad hoc Network (VANET) features

As the main purpose of the simulator is to be able to communicate with network analysis tools via output formats that are acceptable by network analysis tools the vehicles in the simulation system had to be capable of sharing parameters in a methodology used in VANET. For VANET implementation the cars need to communicate which is implemented in the simulator by storing necessary properties in public arrays so that the vehicles can access each others relevant information such as position, route, connections etc from the public arrays of data. Data to be shared is defined through the scripts and algorithms. VANET is easier to implement in simulation than real life as to implement VANET in real life, hardware implementation to ensure connectivity creates most of the complexity. Whereas, in simulation to pass parameters and value from vehicle to vehicle does not increase complexity and can be implemented just by defining variables to be shared as global and passing their parameters in required algorithms.

3.2.9 SIoT algorithm implementation

There are multiple SIoT algorithms to convert a traffic scenario into a social network of nodes and edges. Traffic to Network domain conversion is generally applied by thinking of nodes as vehicles and their connection to other cars near them as edges. The edge weight is calculated by the distance between the vehicles or the signal strength. As signal strength has an inversely proportional relationship with distance. To implement in scenarios where signal strength data is not available due to inaccessibility or the connection being augmented, taking the vehicle to vehicle distance as hop to hop distance of the converted network is a general approach. For determining variables that will be required for traffic to network domain conversion the system was incorporated with SIoT based Algorithm[30] The Algorithm keeps on iterating over distance values between two vehicles for each vehicle and considers two adjacent vehicles with no vehicle in-between as a one-hop distance and creates an edge of weight 1 between them. While doing the calculation the algorithm also considers whether the vehicles are going in the same or opposite route.

The algorithm first checks whether the vehicles are on the same route or not. If on the same-route then the algorithm checks if the two vehicles are in a position that they can be connected directly with no other vehicle being between them, if so, then it checks whether the distance between the two vehicles is lower than the primarily set maximum hop distance. If all these criteria are met then a connection is set between the vehicles with an edge weight of 1 if they are side by side or closely placed, otherwise, the value is set as per their distance in a selected scale.
If the routes are different then the algorithm checks if the routes are connected, for connected routes only and for vehicles with a one-hop distance of lower than maximum hop distance a connection is made with an edge weight of their distance in a selected scale.

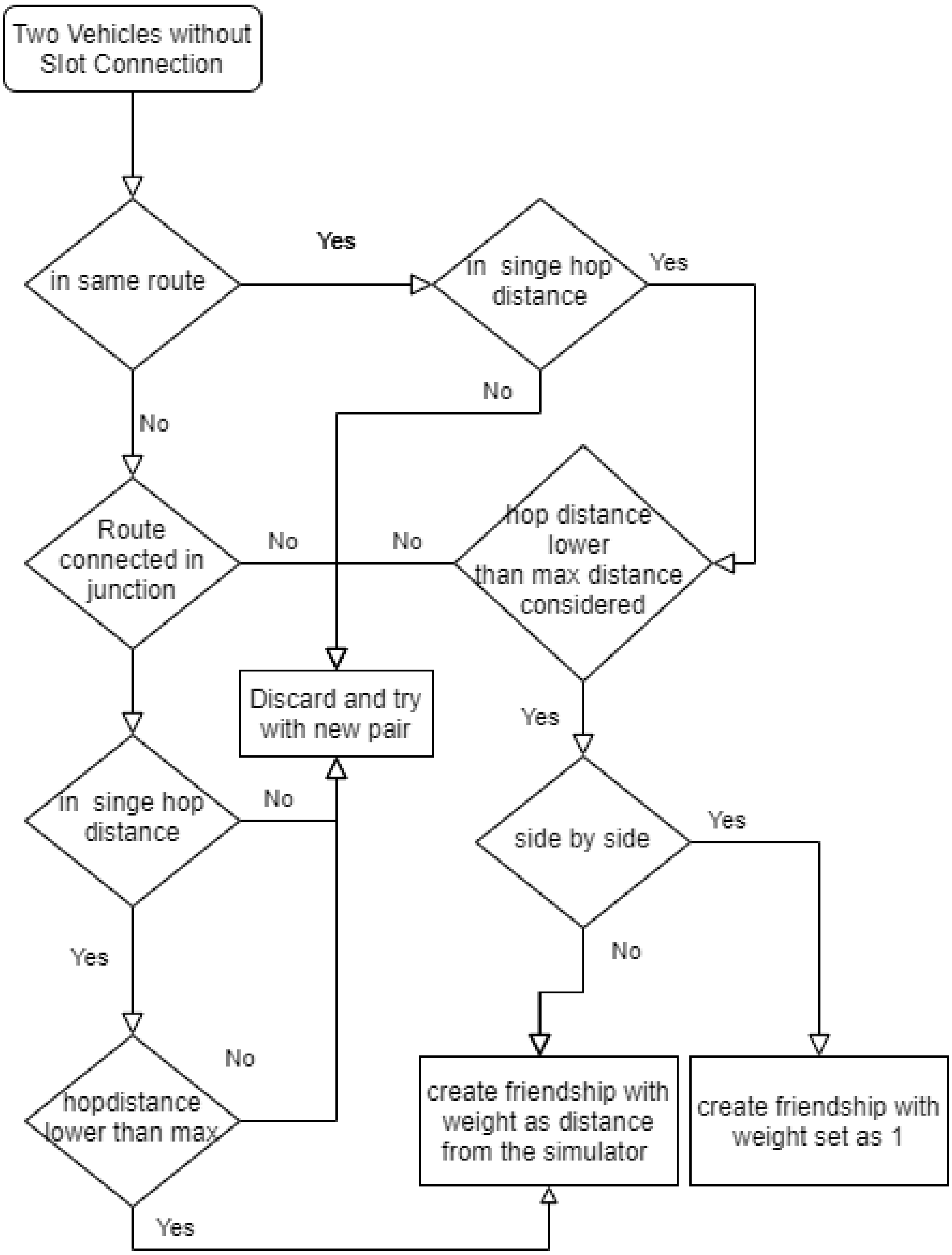

Figure 3.10: Visualization of the selected SIoT algorithm in flowchart

3.2.10 Output configuration and format

For generating an output file the simulation has to be paused in any certain state after the simulation begins and calculation of vehicle to vehicle distance for all the vehicles is calculated to avoid getting null values. For SIoT based traffic mapping into a network domain, two tables are required by any network analysis tools with some fixed attributes to each column. The table and data format names are Node Table and Edge Table. For the Node table, the column names are ID, Category, Label, Route. And for the Edge table, the column names are source, target, type, weight, calculated by distance, Label Route, weight distance. For network analysis tools to be able to parse the data, there are some fixed file formats. Comma Separated Values (CSV) file format is a generic and widely used one and these files can easily be edited ad parsed data from. Considering the advantages of CSV file formats the simulation supports only data output as CSV files. The simulation after processing the data and running the selected SIoT traffic to the network conversion algorithm requires a unique test input to name the output CSV files. Two CSV files are generated, one containing Edge value and the other containing Node Values. Fig 3.11 and Fig 3.12 shows the output file contents.

```
Nodejjjjjjjjjjj.csv - Notepad
File Edit Format View Help
Id,Category,Label,Route
0,cng,0,K_B
1,bus,1,T_B
2,car,2,B_K
3,bus,3,T_B
4,cng,4,T_B
5,pickup,5,B_F
6,pickup,6,B_T
7,pickup,7,B_T
8,cng,8,J_B
9,cng,9,K_B
10,car,10,J_B
11,pickup,11,T_B
```

Figure 3.11: Data Format in file containing node data

```
Edgejjjjjjjjjjj.csv - Notepad
File Edit Format View Help
Source,Target,Type,Weight,Calc
1,4,Undirected,6,1,1,T_B,2
1,11,Undirected,4,1,1,T_B,1
2,5,Undirected,10,1,2,B_K,10
2,8,Undirected,10,1,2,B_K,10
2,11,Undirected,10,1,2,B_K,10
2,17,Undirected,6,1,2,B_K,2
3,4,Undirected,5,1,3,T_B,1
3,13,Undirected,5,1,3,T_B,1
6,7,Undirected,6,1,6,B_T,2
7,9,Undirected,10,1,7,B_T,10
7,12,Undirected,10,1,7,B_T,10
7,16,Undirected,5,1,7,B_T,1
8,23,Undirected,7,1,8,J_B,3
9,0,Undirected,5,1,9,K_B,1
9,21,Undirected,6,1,9,K_B,2
```

Figure 3.12: Data Format in file containing Edge data

In the Nodes file, the fields are :

- **ID**: Contains one unique id for each vehicle
- **Category**: Defines the category of vehicle. In the simulation, there are 6 categories of vehicles.
- **Label**: Label is the field that contains information to be shown on the nodes in the network simulation graph.
- **Route**: Defines the current route the vehicle is in. For the simulation used in later analysis, the names of the routes are set as T-B, J-B, K-B, F-B and B-T, B-J, B-K, B-F. Where B represents the Bijoy Sarani signal as we have used the Bijoy Sarani map as a reference for the simulator map. T stands for *Tejgaon*, J stands for *Jahangirgate*, F stands for *Farmgate* and K stands for *Khamarbari*.
- Separation of Concern
- Reduced Response Delays

In the Edges file, the fields are :

- **Source**: The id of source vehicle of the connection.
- **Target**:The id of the target vehicle of the connection.
- **Type**: Directed or undirected. The simulation considers all connections to be undirected.
- **Weight**: The distance between nodes/vehicles calculated from the algorithm.
- **Calculated by distance**: Boolean value represented by 0 or 1 that defines how the weight value was calculated.
- **Label**: Label is the field that contains information to be shown on the edges in the network simulation graph.
- **Route**: The route in which the source vehicle is in.

Chapter 4

System Evaluation and Data Analysis

4.1 Data generation

4.1.1 Configuring the simulator

To configure the simulation number of vehicles had to be defined first. The system runs fluently with at max 150 vehicles at limited available computer hardware configuration. The current system the simulation is running on is an intel core i5 laptop with Nvidia 850m mobile graphics on 8GB of ram. The files are run from a conventional Hard Disk Drive. For avoiding any discrepancies the maximum number of vehicles is set to 120 for simulations to be discussed and analyzed. Short intervals were programmed for traffic lights to create traffic congestion with the defined amount of traffic. For comparing the output and the traffic-related data two simulations were considered, In the first simulation, the variables are set keeping in mind a natural situation with a varied number of vehicles. In the second simulation, variables were set as such so that it creates a simulation that would portray a scenario with noticeable change and can be analyzed accordingly.

4.1.2 Extracting SIoT data from simulation

In simulation 1, the simulator was let to run until there is visible congestion in the connecting roads. Selecting a frame the simulation was paused and the "generate CSV" button was pressed. The CSV generation window was opened where the inputs require maximum hop distance and file prefix as input in two separate fields. The same procedure was applied for simulation two. Simulation 1 file name was set as *nodesim1.csv* and *edgesim1.csv*. Simulation 2 file name was set as *nodesim2.csv* and *edgesim2.csv* while generating the files.

4.1.3 Network simulation in Gephi with extracted data

After creating necessary output files for both of the simulations the topology of the converted network was made using Gephi. After importing the data as node and edge values Forced Atlas 2.0 algorithm is used with scaling of 300 to create the network graph. Strong gravity is used to keep the nodes centered and in round shape to have a clear view of the Networks. Then different analysis tools were implemented on the networks to figure out the participation percentage of different vehicles, routes, giant components with weight filters, data from giant components etc. Later the networks were compared in terms of Clustered coefficient distribution and Degree distribution.

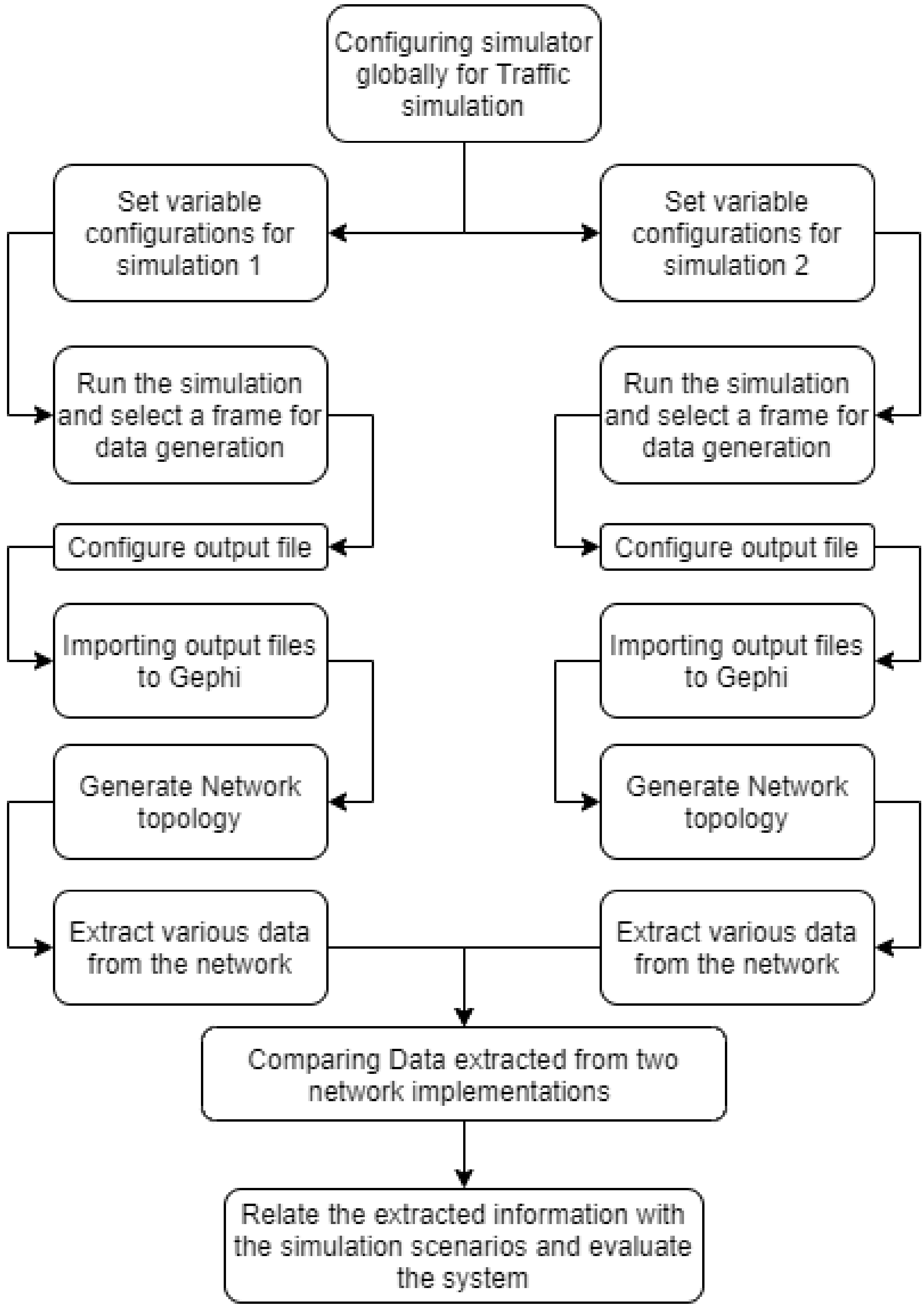

Figure 4.1: Unity Screenshot of Simulation Inputs 1

4.2 Data analysis

4.2.1 Simulation 1

Input variables

Vehicle speed for the simulation as 35,30,25,20,20,20 for 6 of the vehicle category. The signal sequence was also set. The traffic interval was set with short timings as lower as 3 seconds to reduce traffic flow and create a suitable scenario for SIoT implementation on simulation 1. The number of vehicles was set to 120. Lane changing was enabled.

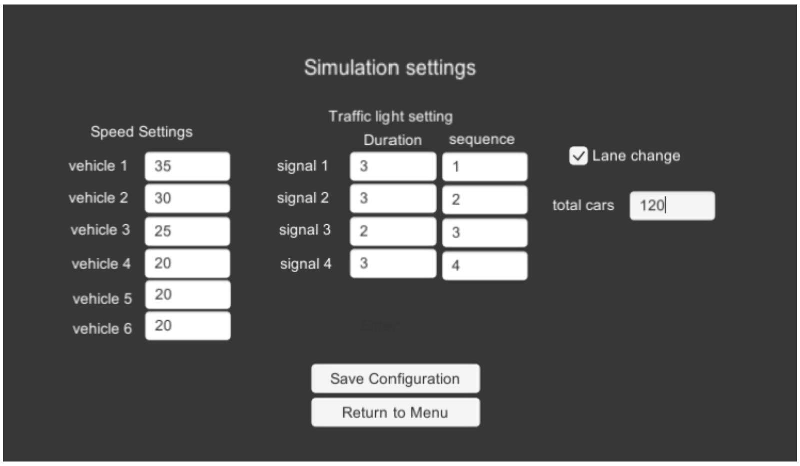

Figure 4.2: Unity Screenshot of Simulation Inputs 1

Picture of the simulation

After a random amount of time to let the vehicles interact with the traffic signal and each other this situation with visibly limited congestion was selected to extract the required data.Fig 4.3

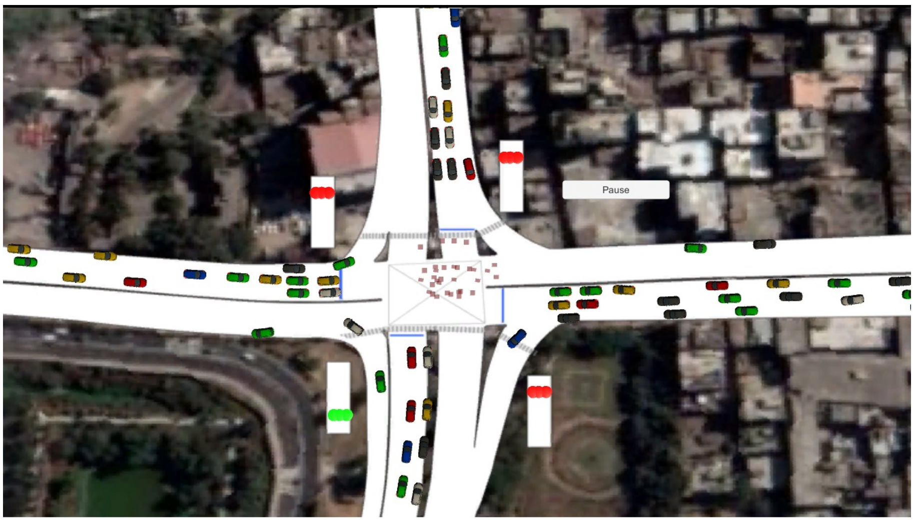

Figure 4.3: Picture of the visible area of the simulation

Converted network

From Gephi we get the traffic data simulated as a network. The total topology of the network provides the necessary insight to analyze the augmented scenario.Fig 4.4

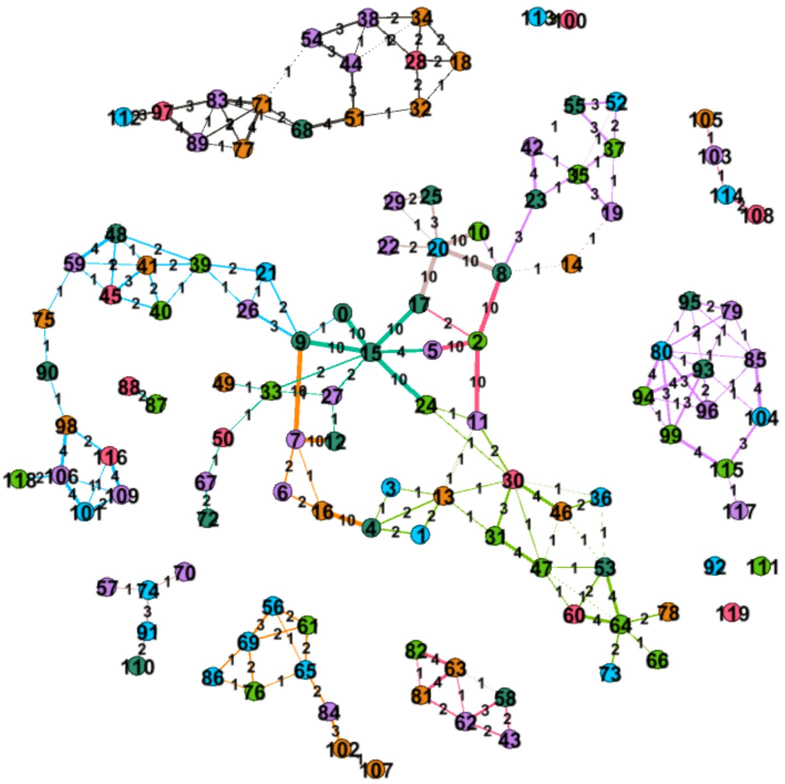

Figure 4.4: Network Conversion

Node/Edge count

The total topology has 120 nodes and 183 edges.Fig 4.5

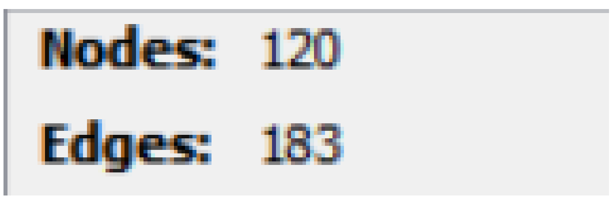

Figure 4.5: Node and Edge count

Vehicle Route information

The percentage of different categories of vehicles in the network can be seen from Gephi. Most of the vehicles are pickup. Then with 17.5% of the total vehicles, there are cars. Fig 4.7

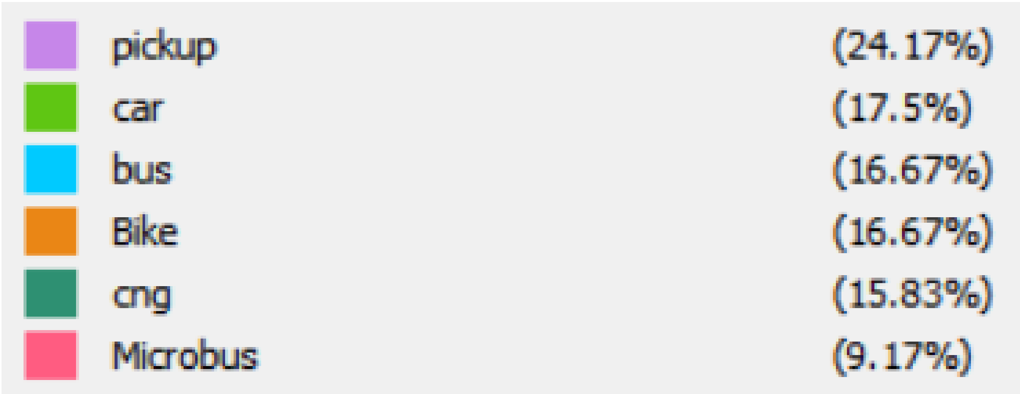

Figure 4.6: Vehicle Route information

The percentage of vehicles in a particular route can be measured from the network and is shown in Fig 4.6

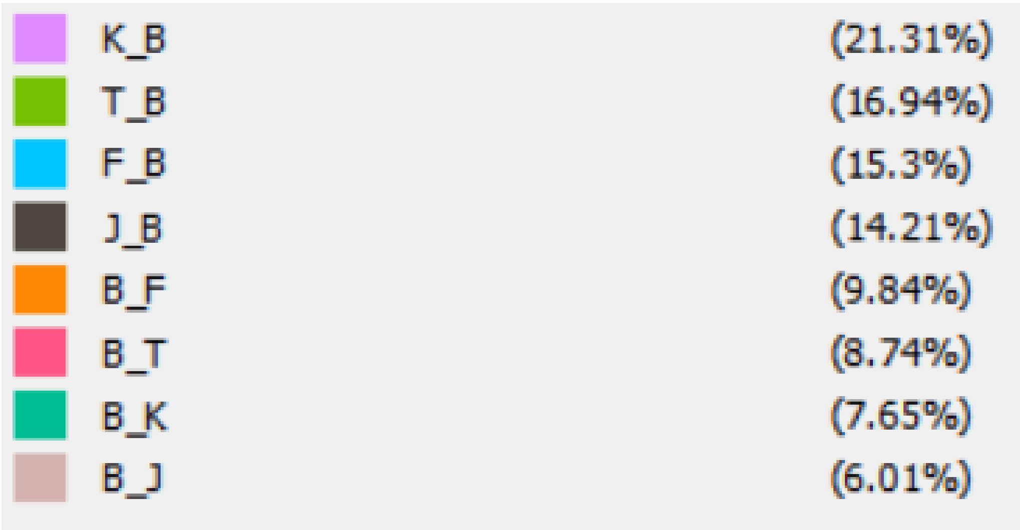

Figure 4.7: Vehicle Route Details and information

Giant component network

The giant component data can be helpful in determining the components that are causing huge clusters or congestion and thus more data can be derived about the causes and nature of the congestion. Fig 4.8 shows the giant component from the network and Fig 4.9 shows the giant component without considering the edges with the highest number of weight, which gives us data on the most closely placed vehicles. For analysis the giant component without considering the edges with the highest number of weight was considered.

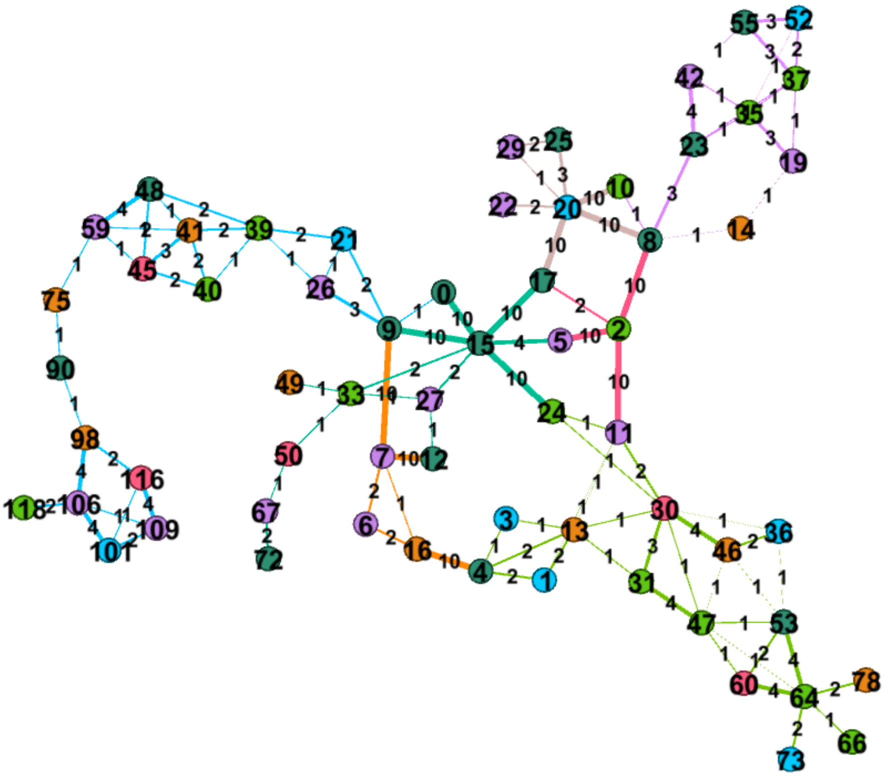

Figure 4.8: Giant component Network

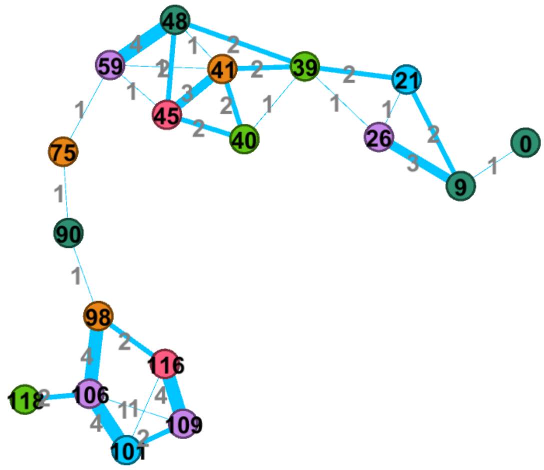

Figure 4.9: Giant component network without considering highest valued weights

Node/Edge count of the giant component

The giant component without considering the highest weight has 18 nodes and 28 edges.Fig 4.10

Nodes: 18

Edges: 28

Figure 4.10: Node/Edge count of the giant component

Vehicle Route information of the giant component

The giant component has more pickup and auto-rickshaw than other vehicles which is shown in Fig 4.21

pickup	(22.22%)
cng	(22.22%)
Bike	(16.67%)
car	(16.67%)
bus	(11.11%)
Microbus	(11.11%)

Figure 4.11: Vehicle Route information of the giant component

4.2.2 Simulation 2

Input variables

Vehicle speed for the simulation as 35,30,25,20,15,15 for 6 of the vehicle category. The traffic interval was set with short timings as lower as 2 seconds to reduce traffic flow further than simulation 1. A similar traffic light sequence was set. The number of vehicles was set to 120. Lane changing was enabled. Fig 4.12

Figure 4.12: Input variables Simulation 2

Picture of the simulation

As traffic lights interval was reduced and the vehicle speed of category 5 and 6 was decreased to 15 this time the roads became more occupied with vehicles. Fig 4.13

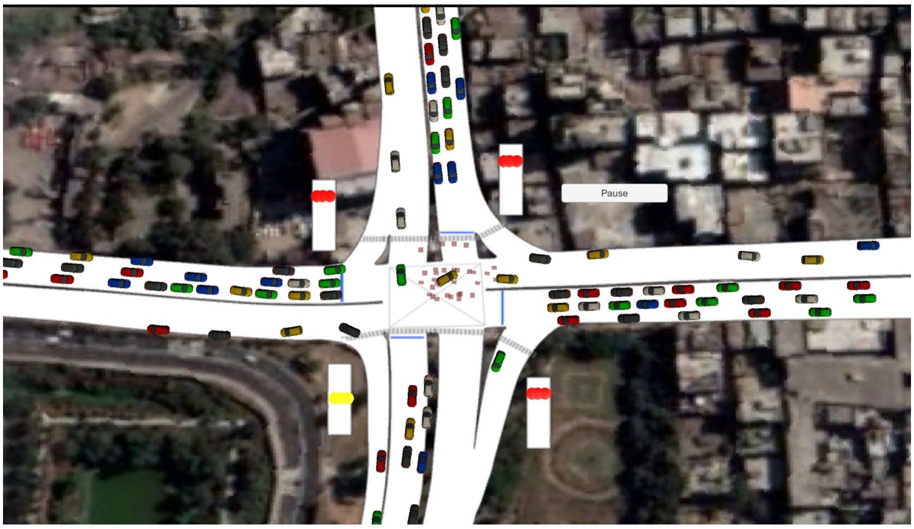

Figure 4.13: Picture of the simulation 2

Converted network

The converted complex network represents the increased number of vehicles on the road by the increase in edges visible in the network.Fig 4.14

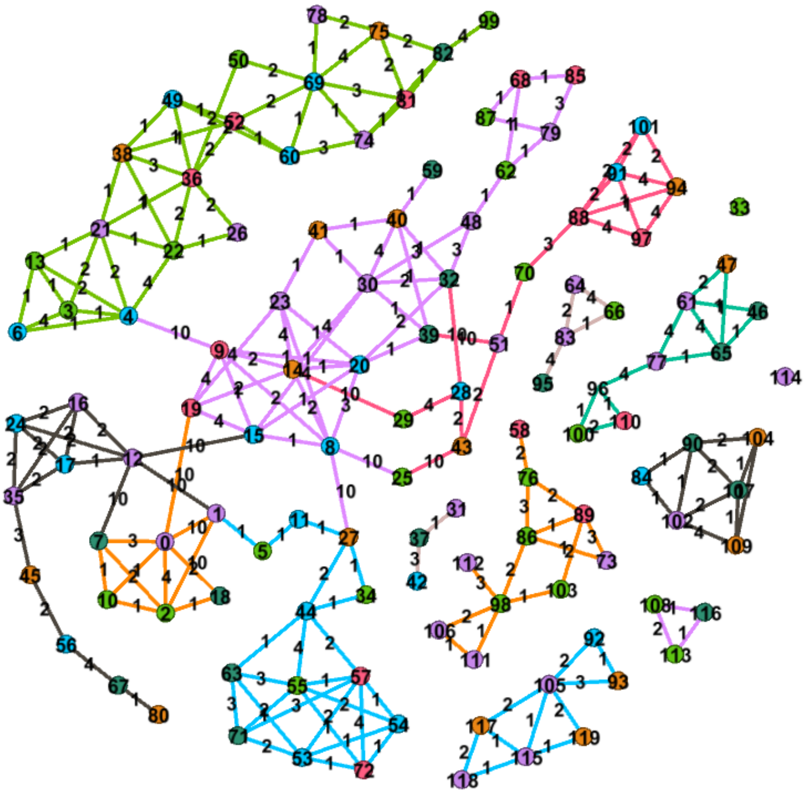

Figure 4.14: Converted network

Node/Edge count

In simulation two the node number remains 120 as simulation 1 but the edge number has changed to 204 as there is more congestion due to change in variables. Fig 4.15

Figure 4.15: Node/Edge count Simulation 2

Vehicle Route information

In this simulation, there is more number of cars than any other vehicle, in the second position, there is pickup and then CNG. Fig 4.16

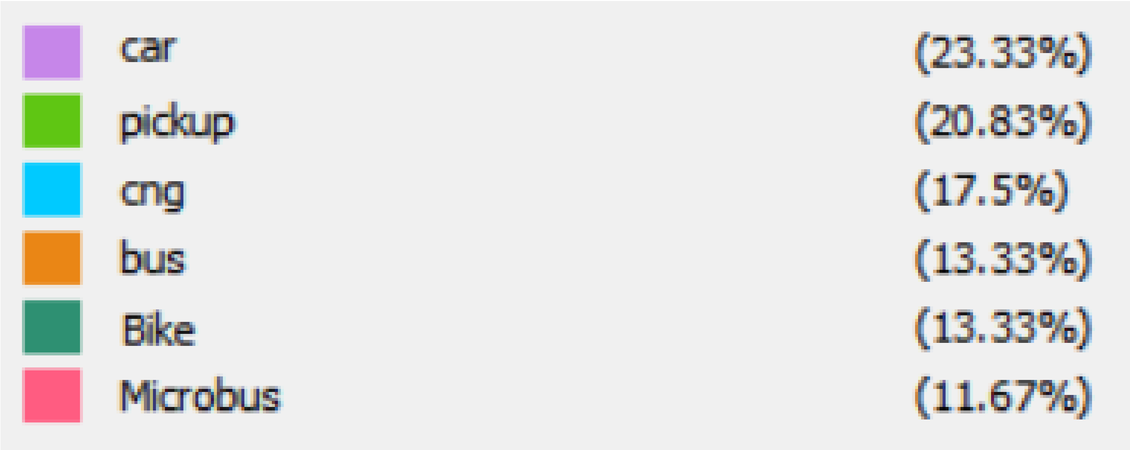

Figure 4.16: Vehicle Route information Simulation 2

J-B route has the most number of presence in the network which means most of the vehicles that are acting as a source of communication are on the J-B part of the node. Fig 4.17

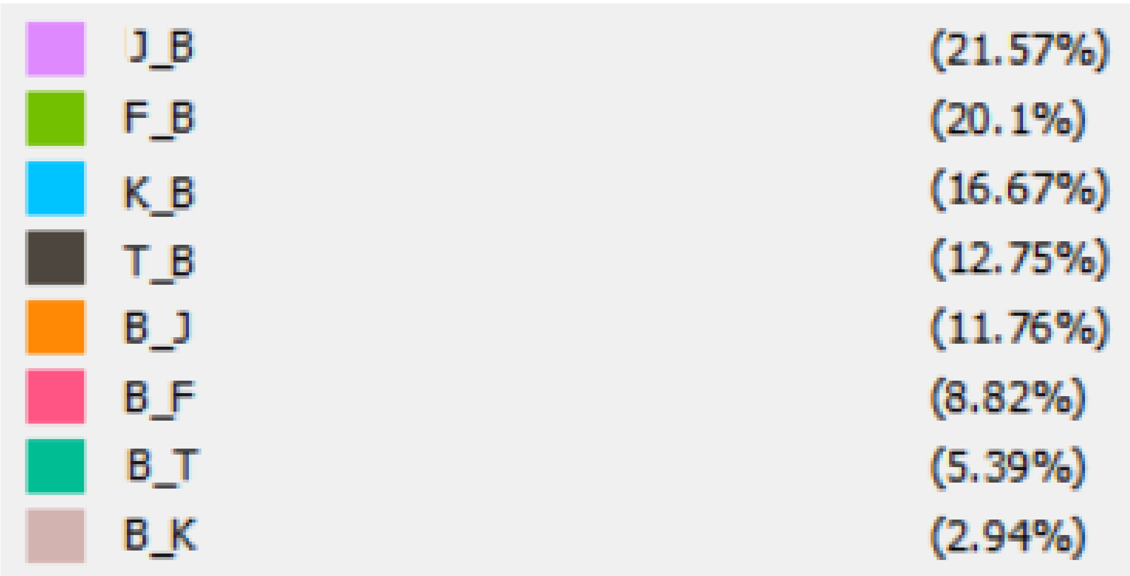

Figure 4.17: Vehicle Route detailed information Simulation 2

Giant component network

Fig 4.18 shows the giant component from the network and Fig shows the giant component without considering the edges with the highest number of weight, which gives us data on the most closely placed vehicles from simulation 2. Fig 4.19

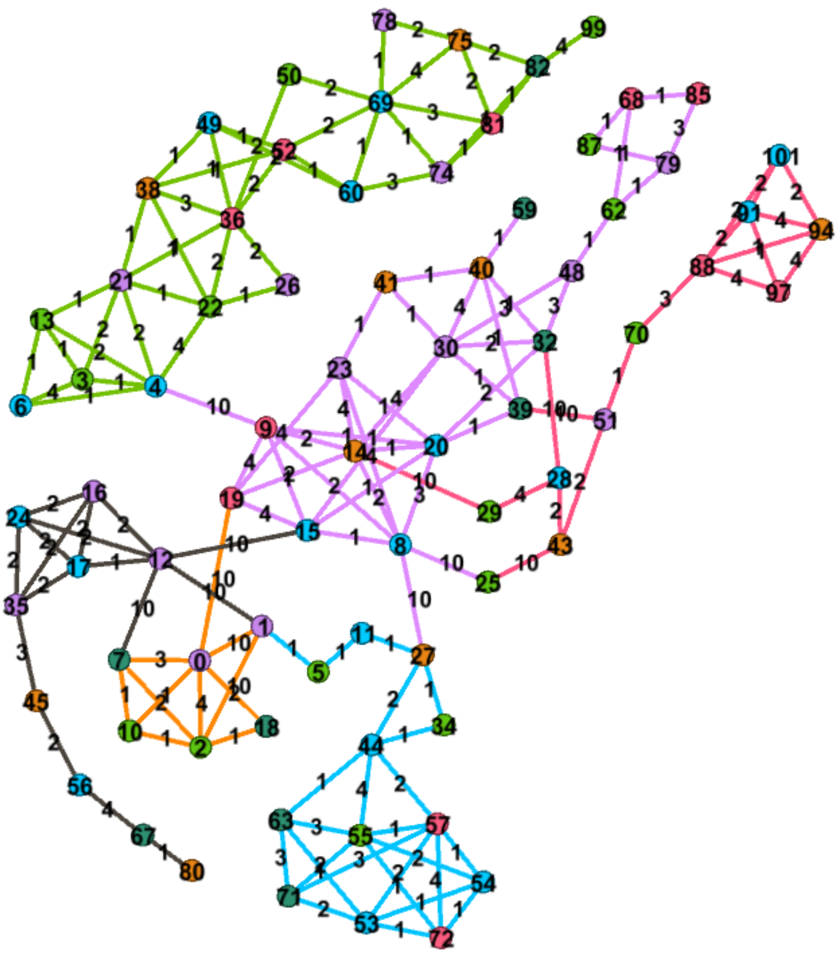

Figure 4.18: Giant component network simulation 2

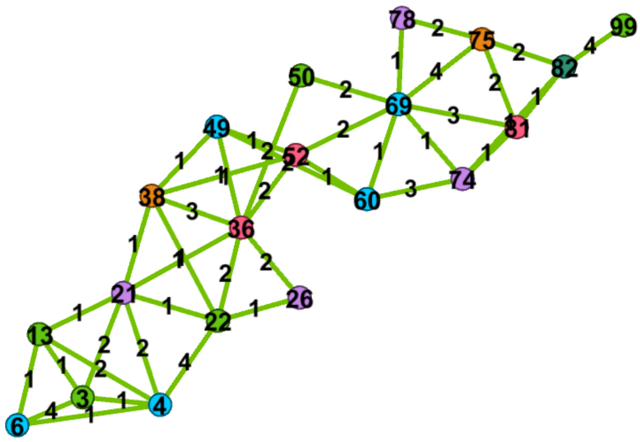

Figure 4.19: Giant network without considering maximum weight available

node/edge count of the giant component

The giant component without considering the highest weight has 20 nodes and 41 edges.

Nodes: 20 (16.67% visible)

Edges: 41 (20.1% visible)

Figure 4.20: giant component node and edge count

Vehicle Route information of the giant component

Fig shows the percentage of vehicles participating in the giant component. Fig 4.21

pickup	(25%)
cng	(25%)
car	(20%)
Microbus	(15%)
bus	(10%)
Bike	(5%)

Figure 4.21: Vehicle Route information of the giant component

4.2.3 Comparison of Acquired data by analyzing network properties

Clustering coefficient

The clustering coefficient, based on the graphical hypothesis, is a metric to what extent nodes in a graph appear to cluster. In network analysis, the clustering graph coefficient is extensively used. The clustering coefficient evaluates the pattern of the nodes and their neighboring interconnections. This pattern is mainly triangular. A high clustering coefficient means that the neighboring nodes have direct links. There are two varieties of cluster coefficients. One is the global version and another is the local version. The global measurement was designed to show the overall clustering in the network, while the local measurement shows the embedding of individual nodes. The idea of the average clustering coefficient is that it calculates the clustering in a network by averaging all its nodes' clustering coefficients. The average clustering coefficient is an efficient measurement of the network topology regarding the local interconnection of the social network. The higher the average cluster coefficient, the more flexible the network can recover from arbitrary damage. In this research, the average clustering coefficient is applied to both simulation 1 and simulation 2.

Average Clustering Coefficient of the network in simulation 1 is 0.430 with a total triangle of 69. The distribution is shown in Fig 4.22

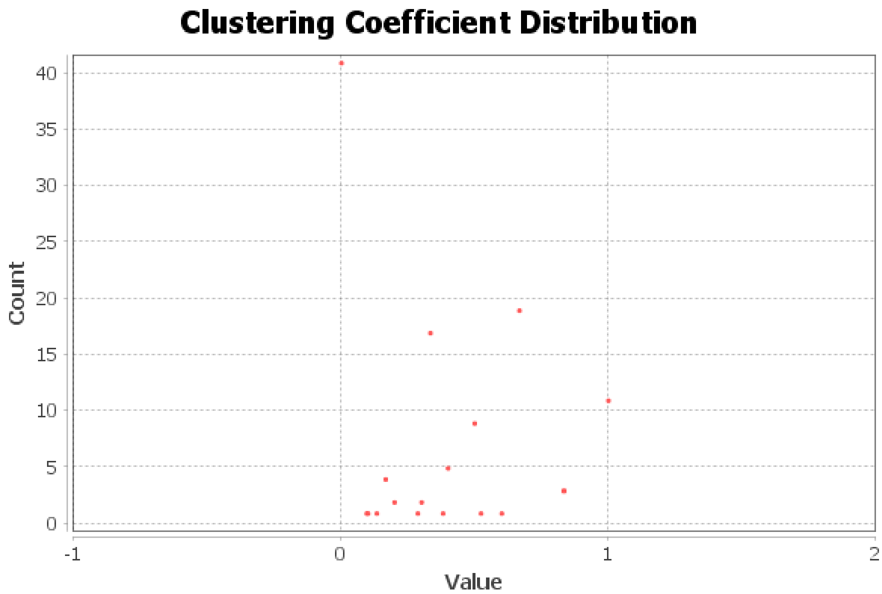

Figure 4.22: Clustering Coefficient Distribution of Simulation 1

The average Clustering Coefficient of the network in simulation 2 is 0.426 with a total triangle of 91. The distribution is shown in Fig 4.23

Degree Distribution

The degree distribution is a network analyzing tool that indicates the probability that a selected node in the network has a particular degree where a degree defines the number of connections a node has with its neighboring nodes. The degree distribution simplifies complex networks by focusing on the connections of single nodes in the network. There

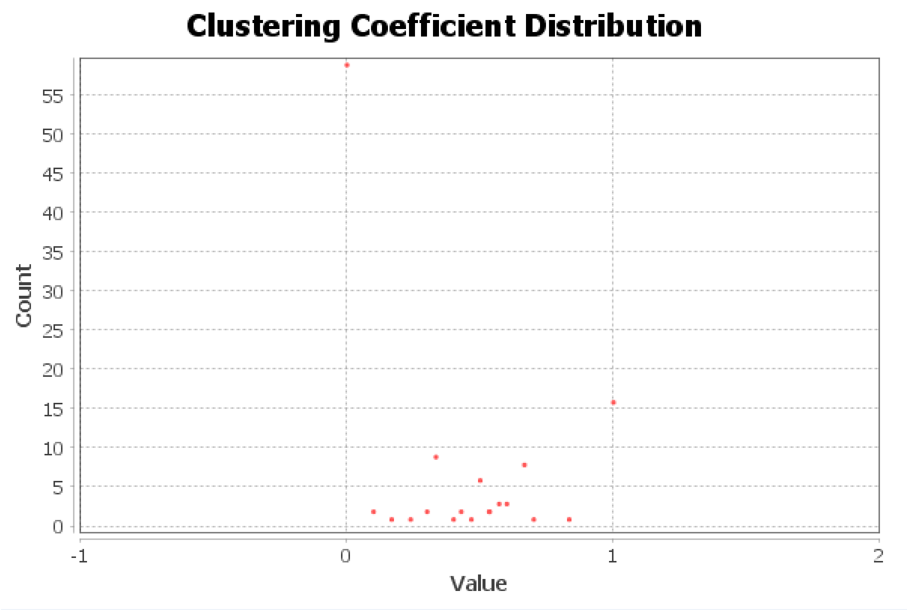

Figure 4.23: Clustering Coefficient Distribution of Simulation 2

are two types of degree distribution graphs: undirected and directed. The directed graphs are more complicated than the undirected graphs. The degree distribution of a graph is said to be skewed when the node degrees of the network is spread over a wide area with a large number of leaf nodes. The degree distribution is applied to simulation 1 and simulation 2 to compare the results in this research.

The Average Degree Distribution of the simulation 1 network is 3.050. Fig 4.24

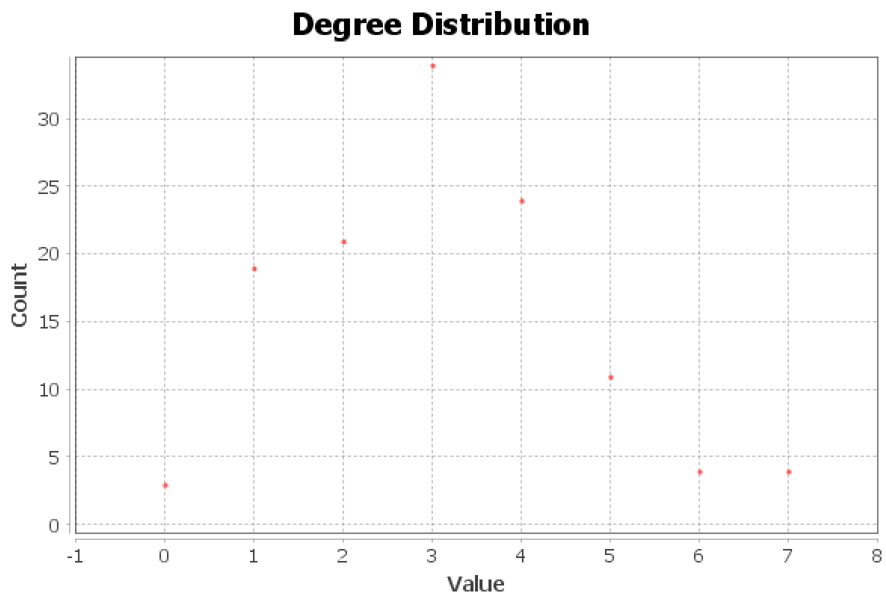

Figure 4.24: Degree Distribution of Simulation 1

The average Degree Distribution of the simulation 2 network is 2.900. Fig 4.25

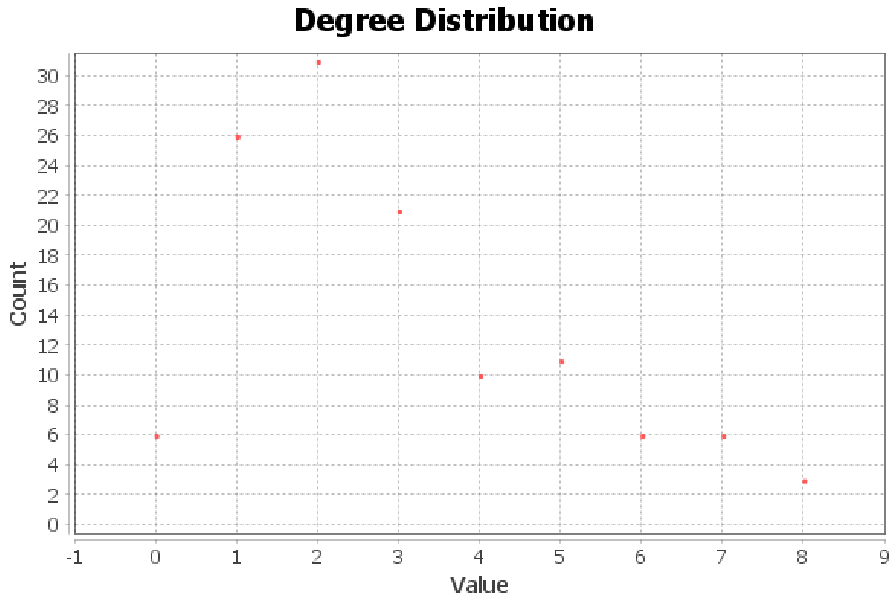

Figure 4.25: Degree Distribution of Simulation 2

4.3 Result Analysis

Using the proposed simulator to implement diverse traffic scenarios were successful just by using limited variables that are made available to be accessed by the Graphical user interface. Traffic responded very similarly to real traffic in case of shorter intervals in signals, Slower movement of vehicles of a certain category and the number of vehicles considered in the simulator. Lane changing and randomized factor as a multiplier of turning and acceleration factor made the simulator interact with each other along with the signal change. Multiple other variables and factors such as vehicle number in a particular route and fixed destinations for vehicles can also be manipulated from the game builder interface of unity. Those changes also result in visible changes in the behavior of the traffic and characteristic of the traffic domain. These responsive and real-life-like outcomes has made the simulator reliable in generating scenarios to Implement SIoT algorithm and exporting data to network analysis tools to plot the data as a complex network. After the network topology was made, different statistical evaluations and network tools were implemented. From the data generated from network analysis tools successful determination of components responsible for traffic congestion was possible. All these things have proved that the simulator can be used as a tool to implement traffic scenarios and also the SIoT algorithm used in the simulator for conversion of the traffic domain into a complex network performed well with promising results. SIoT based analysis of traffic is growing popular day by day to analyze traffic so tools of these kinds and simulations that are directly compatible with network analysis tools are proving to be very useful day by day.In 4.26 the features implemented and evaluated are shown along with limitations in features.

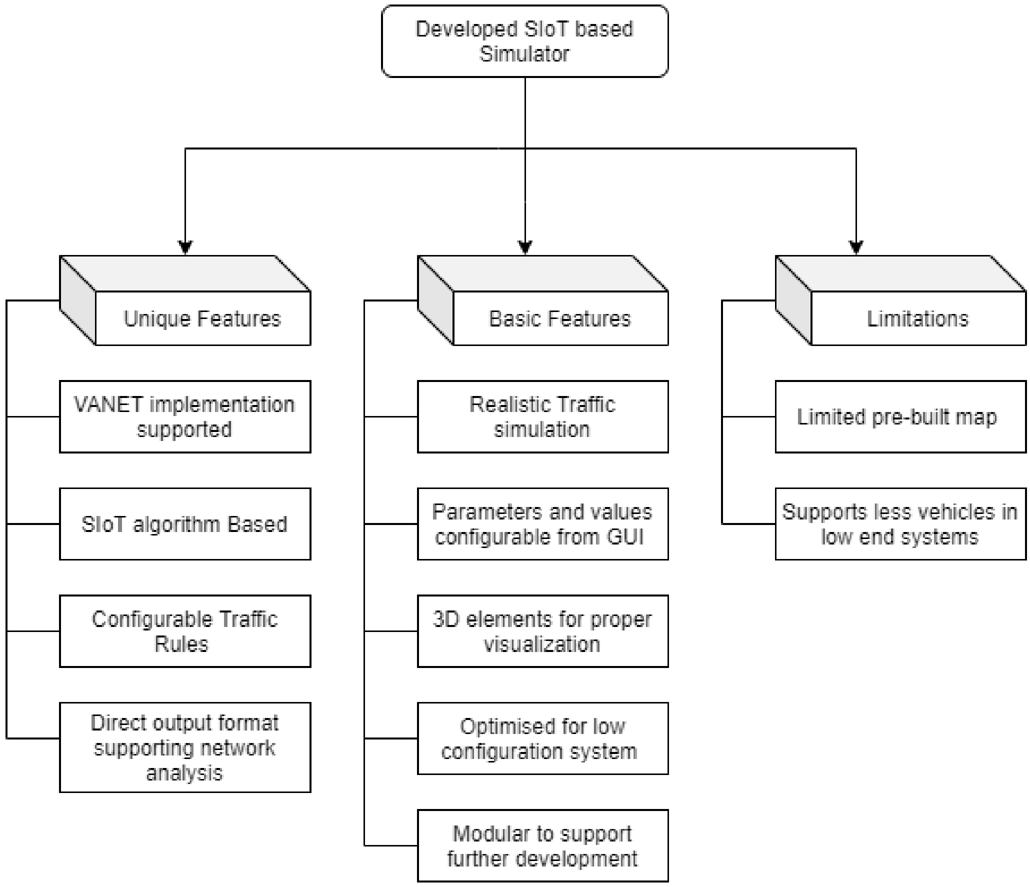

Figure 4.26: Tested Features of the developed simulator

4.4 Research Overview

In this proposed research, the SIoT based simulator which is VANET supported tests of SIoT algorithms in converting traffic domain into complex network to extract information regarding traffic congestion and other related properties. SIoT establishes a social connection among intelligent devices within the network. VANET enables social communication between the vehicles by the idea of SIoV.

The concept of SIoT developed from the concept of IoT(Internet of Things). The first approach of integrating social behaviour among devices and merging it with IoT was initiated by Holmquist et al. back in 2001[4]. The merging of SIoT to vehicles contributed to the advancement of technology in the transportation sector. The proposed traffic simulation system successfully implements the stated principles . The system enables information to pass from vehicle to vehicle. Therefore each vehicle has details about the location, speed, distance, and route of other vehicles in the same area, actively participating to solve the problems of traffic congestion and traffic casualties.

The proposed SIOT simulator is built by configuring traffic rules in the simulated environment to recreate real-like like scenarios . The simulator is designed in such a way that the output of the simulation is directly compatible with the network analysis tool. These features make it unique along with the VANET implementation. It is simplified in 4.26

The basic features are that the simulator provides a realistic traffic simulation. The process of executing various configurations is completely under the control of the Graphical User Interface. The system is built in Unity and enables a 3D visualization of the simulation. Furthermore, the simulator has a limited pre-built map and operates only for a selected or custom-based scenerio. It supports fewer vehicles in the low-end system due to the limitations of resources. However, the system is optimized for low configuration system and has scopes to be modified for further development.

4.5 Research Challenges

SIoT can be implemented in various applications. However, the SIoT based simulator model is a limited simulation system due to the scarcity of hardware resources. The simulation was operated in an intel core i5 laptop with Nvidia 850m mobile graphics on 8GB of ram. As a result, the simulator can facilitate 150 vehicles considering inconsistency. Therefore the system was built on Unity and the optimization of the simulator was majorly dependent on the tools of Unity.

The output data of the simulation is in CSV format in an excel file which is adjusted to be directly compatible with the selected graphical network analysis tool to demonstrate the results. The formatting of the data can not be defined or changed through any preset. The source code has to be edited if any other tool is selected. However, presets can be easily integrated through further development, making the system directly compatible with a range of network analysis tools.

Moreover, the simulator is precisely designed for a four-way intersection (Bijoy-Sarani intersection) so assets are not present to test an SIoT system on any other kind of junction or intersections. In order to verify the efficiency of any SIoT system it is important that the system is capable of testing a few number of traffic scenarios. So, although the simulator does not require heavy resource usage, it can be further optimized and developed in a more efficient and compatible way.

Chapter 5

Conclusion

5.1 Conclusion and Contribution

The main purpose of this research is to test the impact of SIoT algorithms using a SIoT based novel simulator to effectively convert augmented traffic scenarios into complex network. The process is executed by constructing a simulator that is implemented based on the SIoT and VANETs approach. Both are extensions of the Internet of Things. SIoT is a concept that is applied to vehicles introducing the SIoV to address the concern relating the traffic congestion. A vehicular network is formed from a traffic area. This network consists of vehicles that resemble human social relationships. The vehicles are connected in a social relationship and communication within the network where various data, pieces of information, and decisions are exchanged among the vehicles. Firstly the simulation system analyzes a selected traffic scenario of a four-way intersection. Secondly, the impact of the SIoT data or the SIoT algorithms is evaluated by analyzing the output of the simulation.

There are other existing simulators but those are inconvenient and overly complex for the SIoT and vehicular network systems. However, the proposed simulator is designed to be directly compatible with SIoT and the network analysis tool to directly recognize the data without the need for manual conversion. It is built in such a way that pulling or extraction of data and plugging of new data or decisions is much easier. The required output can be obtained by pausing the simulation at a particular moment. Therefore based on the system a real-time scenario of the traffic can be generated. The results are analyzed by applying average clustering coefficient and degree distribution and plotted through Gephi. The findings from network analysis tools can be analyzed to determine necessary steps to be implemented to improve traffic behavior and the steps can also be iteratively fed into the simulator thus identifying the factors that can minimize traffic congestion and also guide to further advancement of the simulator.

Additionally, there is no simulator that can give augmented vehicles a fully real life like characteristics. In the proposed simulator each vehicle is assigned with multiple randomized variables multiplied to parameters assigned to vehicle over different time-frame to emulate the scenario of real dynamic traffic with manual drivers. This can be improved by obtaining factors from the scenario of the specific vehicle instead of taking the randomized multiplication factors for speed calculation and other vehicular traits and thus, making the vehicles more aware and concussions of its surrounding environment. The simulation is executed in Unity. The implemented simulation has limits in terms of scalability as the optimization of the simulator relies on the Unity tools which relies on the configuration of the host system. More trial and learn and better hardware resources would increase effectiveness and scalability of the traffic in simulator to a great extent.

To summarize, the research has set up its standards by showing considerable accuracy in the results. In addition to that, each iteration of the results has shown betterment of the simulator generated scenario and the impact of SIoT algorithms regarding the traffic congestion issue. Thus accomplishing the aim of the research.As VANET is yet to be widely used in physical world, to test and run algorithms and newer approaches on real traffic is not possible and not efficient or safe as well. Building custom simulators which are compatible with new technologies and approach is and will be the optimal way to carry out such researches as this paper focuses in. This can contributes to the advancement of technology and the beginning of an evolution of combining the traffic system of cities with complex traffic scenarios like Dhaka through simulation with SIoT approach that has never been implemented before.

5.2 Future Works

In this research, the SIoT based novel simulator is successfully created with good accuracy on the selected scenario that the simulation was implemented on. However, there is always scope for further extension of this topic in future research. As this research is based on a selected scenario, the simulator can be made compatible with a variety of scenarios along with the addition of more vehicles and routes.Another possibility is The generation of routes and determining the number of vehicles in a simulation can be automatically configured from traffic data from reliable sources. In the proposed system the data inputs are manual. However, it can create a new dimension for study and research regarding traffic and VANET if the process is automated with machine learning approach where the system will start working with a given scenario and generate data and decisions from network analysis approach which could be again fed to the traffic and iteratively improve the traffic flow of the simulation.

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