Application Specific Secure Grouping of Vehicles in Vehicular Ad-hoc Network

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Application Specific Secure Grouping of Vehicles in Vehicular Ad-hoc Network

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by

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Dedicated to my family

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Certificate

This is to certify that the work in the thesis entitled ***Application Specific Secure Grouping of Vehicles in Vehicular Ad-hoc Network*** submitted by ***Ambuj Kumar*** is a record of an original work carried out by them under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of *Master of Technology* with specialization of *Information Security* in *Computer Science and Engineering Department*, National Institute of Technology, Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Ashok Kumar Turuk
Professor
Computer Science and Engineering, NIT Rourkela

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Abstract

Providing efficient, secure and reliable communication among vehicles is complicated and challenging problem. Vehicles communicate with each other (V2V communication) and Road Side Infrastructure (V2X communication) unit to provide convenient, safety and commercial service to the travelers. Similar information shared by each vehicle within close proximity creates huge network congestion. Grouping of vehicles reduces dropping of packets due to collision of sending large number of duplicate packets. Grouping concept is used in our thesis to provide different applications of VANET in a better way. We have modified grouping of vehicles according to our applications requirement and proposed an approach for vehicles to select real-time adaptive path. Vehicles choose congestion free and shortest time path to their destination. In the next section, grouping of vehicles are used to transmit event-driven safety message in emergency situations. Grouping of vehicles is efficient in this case as it needed to be very fast and highly reliable. We have added different parameters for transmitting the message to neighbors which makes it more efficient. It uses decentralized environment as it needed to works both for highway and urban scenario of the city. It helps to improve security in the message and privacy of entities in an efficient manner which are major concern in achieving robust vehicular network.In testing phase, we evaluated the performance of our proposed approach with help of VANET simulators (OMNET++, SUMO, Veins) and compared ours proposed approach with other existing methods.

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Chapter 1

Introduction

1.1 VANET and Group Communication

Wireless communication has influenced ours lives in many ways by making our life more convenient, easier and comfortable. VANET is a type of Mobile Ad-hoc Network in which vehicles move rapidly through the road and topology changes very frequently. VANET helps to provide safe, secure and more comfort travel to travelers. Different application of VANET includes Cooperative collision warning, giving a warning message about steep curve, accidents etc., Congested Road Notification, Traffic Probe, Parking spot locator etc. i.e. VANET in addition to safety, security, applications also provide convenient, and infotainment services. Vehicles uses the Road side infrastructure in different applications which are less prone to high latencies.

Vehicles information optimization while sharing information to other vehicles is not an easy task. For example, Vehicles communicate their local edge information to other vehicles but this information will not be relevant to vehicles moving on different edge or vehicles moving in opposite directions. It is required to ensure that information to be delivered at the right place. Data from large number of vehicles in close geographical region create huge packet having similar/duplicate information. Since vehicles moving in a close geographical region have similar mobility pattern and there is a correlation among data so each vehicle need not require to rebroadcast the data sent from neighbor's vehicle. To solve the problem vehicles form a group with other vehicles having a similar mobility pattern as depicted in figure 1.1. The group contains one Group leader (GL) which control the group and all other vehicles send the information to it. GL of the group changes frequently due to high mobility of vehicles or path changes at intersections. Group can be static or dynamic depending on different conditions. Many paper has been proposed for group formation with least ID as GL or GL having maximum neighboring vehicles in the group. We have modified group based concept depending on different applications. In the first scenario, GL receives the information of its edge from moving vehicles which it aggregates and summarize. The summarize information is used by vehicles to select adaptive path with the

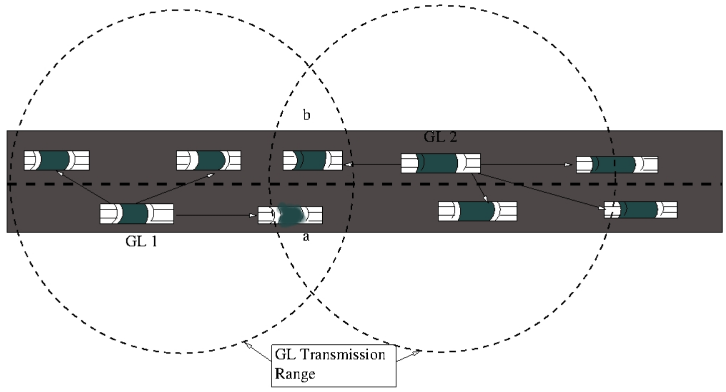


Figure 1.1: Group Communication among vehicles

help of the RSU. In the second scenario, dynamic group has been created in which GL collects information within the transmission range of vehicles and it uses group communication for efficient transmission of event-driven safety message (ESM) among its members and nearby groups.

1.2 Problem Definition

In our work, it has been given more focus towards the integration of group communication with different applications. Group communication has been used previously in the area of VANET. It has been integrated with different areas e.g. safety and security to solve the different problems efficiently. Previously work has been done to optimize the group communication by choosing the GL in different ways and forming Group static and Dynamic. We have optimized different applications based on group communication. We have used it to optimize the path selection and event-driven safety message transmission (ESM) by the vehicles. Vehicles dynamically select optimized path to their destination based on the traffic congestion. We have added various parameters to ESM protocol to minimize network packet and make it more reliable. We improved group communication for ESM message so that it could work both for urban scenario of the city and the highway.

1.3 Motivation

This work has been motivated to the systematic analysis of different applications of VANET based on networking point of view. Our motive is to use the connection among different networking based VANET applications and the standard VANET protocols to create a better traveling. The main goal of our work is to determine the making the applications of VANET more convenient, safe, secure and efficient with the help of grouping. Grouping of the vehicle reduces the number of packets in the network. Simultaneously we ensure not to important data loss in packet sent from vehicles to GL. Grouping of vehicles with or without the help of V2X communication works efficiently depending on different application. Vehicles finding their shortest path route use group formation from every edge where GL sends the aggregated information to the nearest RSU. In the event driven message transmission vehicles grouping helps to send data with fast,efficient and safe way.

1.4 Objective

In our work there are two main basic objectives using the Group communication.

(1) Adaptive optimal path selection by vehicles.

(2) An efficient event-driven safety message transmission by vehicles using VANET.

1.5 Thesis Organization

The organization of the rest of the thesis is as follows. Chapter 2 throws brief discussion about Vehicular Ad-hoc Network, its different applications, protocols, and Group communication between vehicles. Chapter 3 describes the existing work and proposed work in details that includes Real-time adaptive path selection using grouping of vehicles in VANET. Chapter 4 describes the existing and proposed work about event-driven safety message transmission protocol for

VANET. Experimental results are also included in chapter 3 and chapter 4. The work presented is summarize in chapter 5.

Chapter 2

Background

VANET Introduction
Applications
VANET Protocols and Recent Projects
Main Challenges of VANET
Mobility Models

2.1 VANET Introduction

Communication Technologies have become an essential part of our life to get different kind of services. Wireless communication in vehicles has fascinated researchers since the 1980s. In the last few years, there has been increased large number of research in this area. IEEE 802.11 standard has been setting the standard for vehicular manufacturer to address the safety and comfort issues of vehicles. Now a separate wireless spectrum has been allocated for vehicular wireless communication. With the introduction of Global Positioning system (GPS) and wireless transceivers in 1990s, further stimulated the research in the field of inter-vehicular communication. Millions of people across the world die and even more injured due to vehicles accident in a year. A vehicle collects the safety and other information and re-distribute to other vehicles with the help of V2V and V2X communication, as for example the warning message is sent to drivers about the danger before they actually face it. Most available wireless communication relies on base station as it helps to synchronization and other services; however using RSUs covering throughout the road network is very expensive and difficult to deploy. If VANET is successfully implemented on the road then it will form the biggest ad hoc network ever implemented, but still stability, reliability and scalability are a major concern of it. Intelligent Transportation Systems(ITS) have been stimulated the development of Vehicular Ad-hoc Network (VANETs). In this type of network vehicles are equipped with equipment through with they communicate with each other through V2V and V2X communication.

VANET mainly contains following essential entities which are required to support it:

(1) Vehicles: vehicles are moving node able to communicate in V2V and V2I mode. Vehicles on-board (OBU) are equipped with GPS device, sensors, wireless omnidirectional antenna and a digital map of the network.

(2) RSU: RSUs are fixed infrastructural unit placed near to the roadside. RSUs collect the information from one network and forward the information to

another network. RSUs contain wireless antenna which collect information from wireless transceiver. A RSU is assumed to be connected with other RSU and trusted third party by secure fixed infrastructural network.

(3) Data Server: Different roadside infrastructure are connected through a data server which collects the data from vehicles. RSU uses these data for taking future decisions.

Similarity between the MANET and VANET are as follows:

(1) VANET is a subgroup of MANETs

(2) Both are characterized by the self-organization and movement of the nodes.

(3) Both MANET and VANET are more prone to physical security threats in compare to the infrastructure based networks.

MANET provides voice and infotainment services to passengers but they are not well suited directly to V2V and V2X communication. Differences between MANET and VANET are as follows [2]:

(1) MANET contains nodes which have un-controlled moving patterns. In VANET, movement of vehicles is restricted by factors like roads, traffic regulations. Nodes propagation model in VANET is not assumed to be free space because of presence of buildings, trees, vehicles and other obstacles.

(2) Services of vehicles in VANET are supported by Fixed Roadside Infrastructures. Fixed infrastructures are deployed at certain locations in network.

(3) Vehicles communicate with each other with DSRC standard that uses IEEE 802.11 standard for wireless communication.

(4) Vehicles are not subject to be strict energy, space and computing capability which are normally adopted in MANETs. Nodes are assumed in VANET to have ample energy and computing power.

(5) High speed vehicles (up to 250 km/h) and large dimension of the VANET are more challenging problems.

(6) Due to high speed of nodes, network topology changes very frequently. Vehicles are moving at the speed of 60-75 kmph(25 m/sec) and if radio range between two vehicles is 125m then the link between the two vehicles would last at most 10 sec.

(7) In VANET, frequent disconnection of network occurs due to link between vehicles changes quickly. This problem is further worsening due to difference of vehicles density in highway and urban scenarios. Also, vehicles frequency decrease in non-rush hours causes frequent disconnectivity.

2.2 Applications

Vehicles in VANET with the help of network protocol stack and system integration, provide different applications. A vehicular generic class of applications most likely to have a similar set of protocols and mechanisms in the network stack due to similar application characteristics and performance requirements. Network designers should be able to maximize the re-usability of common mechanistic 'building modules' for a specific class of applications with similar application characteristics and performance requirements. Research on VANET has driven network support of various application development. Research on deployment of RSUs are carried out by DSRC research community helping future deployment in V2X applications to provide safety/warning applications and highway traffic management for commercial applications. Applications of VANET are roughly organized into three major categories based on costumers benefit of applications [3].

It can be categorized and classified the applications based on the application related characteristics. There are different classification of applications like the entities participated in the application, the geographical region in which the application works when the applications will be triggered, end-to-end communication, the network protocol used, and kind of security used etc. The message packet format varies with the type of applications. Normal safety and convenience applications use lightweight short messages while commercial applications on the other hand, generally prefer the traditional heavyweight IP format to be compatible with existing commercial Internet services. Application classification is conducted at various levels, depending on design granularities. High level classification is helpful to distill the major concepts and identifying the synergy among various applications [3].

V2V/V2I applications classification based on network design are mainly divided in two parts:

(1) Short Message Communication: Applications using short message communication use both broadcast and unicast communication. Broadcast communication are used for event-driven, scheduled and On-demand applications while unicast is used for secure and non-secure routing.

(2) Large-Volume Content Download/ Streaming: These applications generally use unicast communication. It is generally used for file download and video streaming.

2.3 Protocols and Recent Projects

There has been improvement in Intelligent transport systems (ITS), due to investment from the government, academia, and industry, leading to the development of safety and traffic management technologies in vehicle and road infrastructure. There has been proposed different protocols to meet the standard to support ITS but recently proposed WAVE standards on the dedicated short range communications (DSRC) is the only standard that meet the requirement for road safety messaging and control. But still there are several social and technical challenges with DSRC protocol to dealt with large scale deployment.

WAVE system supports two classes of devices: on-board unit (OBU) and roadside unit (RSU). It supports two classes of communication : V2V and V2I.

In the united state , 75 MHz of spectrum in the 5.9 GHz frequency band has been allocated for DSRC applications. This 75 MHz frequency band is divided into seven 10 MHz channel and the rest 5 MHz is reserved as the guard band [4]. In seven channels available spectrum is configured in to one control channel (CCH) and six service channels (SCHs). The CCH is reserved for high-priority short message or management data, while others are transmitted on the SCHs as shown in figure.

The IEEE 1609 family, IEEE802.11p and the society of Automotive Engineers (SAE) J2735 collectively form the key parts of the WAVE protocol stacks [5]. The major component of WAVE protocol stack and its associated standards are shown in figure 3.2.

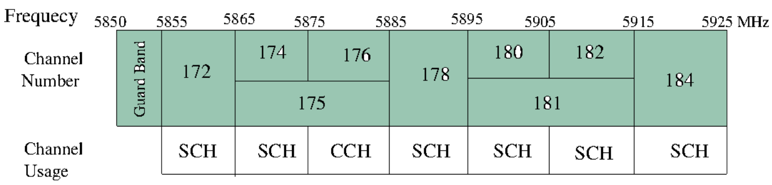


Figure 2.1: The DSRC Frequency Allocation in US

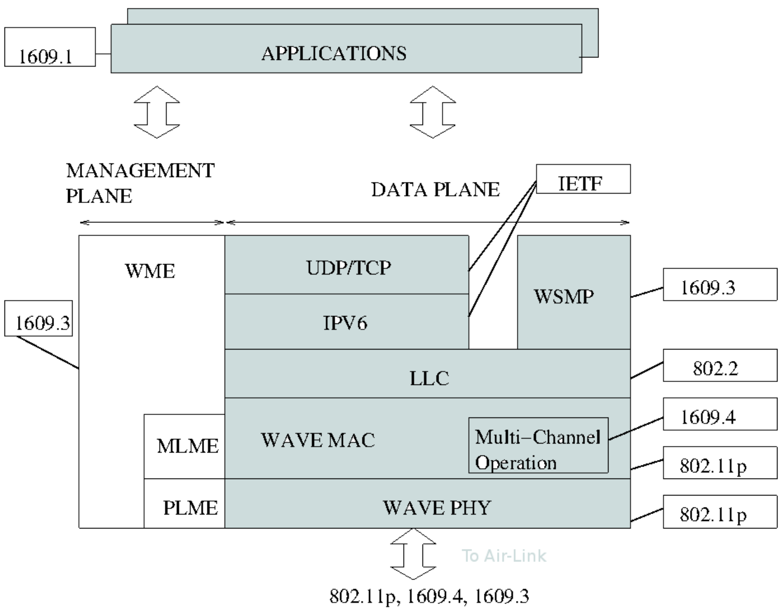


Figure 2.2: The WAVE Protocol Stack and Its Associated Standards

Important VANET project based on th research related to VANET and ITS research are as follows [6]:

- CAR 2 CAR Communication Consortium: It is a nonprofit European organization supported by equipment suppliers, research organizations, and other partners. Objective of this project is to further increase road traffic safety, and efficiency by means of cooperative ITS with V2V communication supported by V2I communication.
- CARLINK Consortium: The aim of this project to develop an intelligent wireless traffic service platform between cars supported by wireless transceivers beside the road.
- GeoNet: It uses the basic result of CAR 2 CAR Communication Consortium and take it the next step. It create a baseline software implementation interfacing with IPv6.
- iTETRIS: It develops an evaluation platform for large-scale, long-term simulations of cooperative traffic management applications. It performs detailed analysis of effects and performance of cooperative applications on traffic flow, travel time, emissions etc.
- NOW: Network On Wheels NoW is a German research project which is supported by the Federal Ministry of Education and Research. The main objectives are to solve technical key questions on the communication protocols and data security for Car-2-Car Communications.
- SEVECOM: Sevecom is an EU-funded project that focuses on providing a full definition and implementation of security requirements for vehicular communications.

2.4 Main Challenges of VANET

The main challenges of VANET are divided in to two categories: Technical challenges and Socioeconomic challenges [5].

2.4.1 Technical Challenges

First and central challenges of VANET is that no communication coordinator can be assumed to be possible. In all the area of the network roadside infrastructure deployment is very difficult. Although some applications are needed infrastructure like traffic signal violation warning, toll connection and optimal path selection.

Design of the medium access control (MAC) layer is the key issue in the design of the VANET. Now, the main focus of VANET on using the IEEE 802.11 carrier sense multiple access (CSMA)- based MAC for VANETs. This is due to availability and cost considerations and accepts the random elements of such a MAC. The bandwidth of frequency channel varies in the range of 10 to 20 MHz and with such a high vehicular density, these channels easily could suffer from channel congestion. If more than one channel used then it leads to multi-channel synchronization problem especially in the case of a single transceiver per vehicle and co-channel interference problems.

Other challenges of VANET are the highly dynamic network topology due to high speed movement of vehicles and the consequences of it the environmental impact on their radio propagation. The lower antenna heights and attenuation/reflection of all the moving vehicles' metal bodies make the condition worse. VANET should work in large area, for sparse and dense vehicles traffic region and should be scalable. Adaptive transmission power and rate control is strongly needed to achieve a reasonable degree of reliable and low latency communication.

In VANET, achieving security and privacy is also a major challenge. Receiver must sure and trust the source of information, privacy requirement of a sender and, data must be confidential.

2.4.2 Socioeconomic Challenges

Market adoption is also a major challenge. Convincing costumer to purchase the vehicles equipped with VANET technology is difficult job. If number of vehicles equipped with VANET technology will be very less on roads then the benefits of it cannot be achieved. Deploying RSUs is also a costly approach in initial stages. Still various major issues are yet to solve before deployment like backhaul connectivity, IT-management issues, road operators etc.

2.5 Mobility Modeling

In VANET, there is a strong interaction between the network protocol and vehicular mobility. Mobility is influenced by data traffic. There is a need for simulation study of VANETs for a mobility model reflecting the real behavior of vehicular traffic. It is required to be dynamically reconfigurable in order to reflect the effect of communication protocol on vehicular traffic. After several years of research, now a large number of mobility models are available from most trivial to realistic ones. But, still it is difficult to select a good mobility model because of their difficulty in understanding of each model's characteristics and their benefits and drawbacks [7].

The mobility model is usually classified in two types as macroscopic or microscopic. Macroscopic mobility model are helpful to search gross qualities of interest, such as vehicular density, mean velocity etc. Microscopic modeling considers each vehicle as a distinct entity, which result the behavior in a more precise way but computationally more expensive way. The Microscopic modeling model are helpful in identifying functional block like motion constraints, traffic generator, and time and external influences. Microscopic simulation model deals with properties like the inter-vehicular distance, acceleration, breaking, overtaking. Mobility model intended to generate realistic motion patterns includes the building block like accurate and realistic topological maps, obstacles, vehicles characteristics (speed, acceleration, deceleration, speed compatibilities), trip motion, path motion, smooth deceleration and acceleration, human driving patterns, time patterns, external influence etc [8].

Chapter 3

Real-time Adaptive Path Selection by Vehicles in VANET

3.1 Introduction

VANET helps to provide safe, secure and more comfort travel to travelers. Vehicular Network can be used to reduce travel time by alerting drivers about potential traffic jams and alternate available routes. India has 142 million registered vehicles in march 2011. The area occupied by roads and streets in Class-I cities (population more than 100,000) in India is very less compared to the United States of America (India-16.1%, USA-28.19%) of the total development area[9] which results in increased traffic accidents and traffic jam at rush hour in cities. The 2007 Urban Mobility Report stated that traffic congestion causes 4.2 billion hours of extra travel every year in the US, which almost accounts for 2.9 billion extra gallons of gas. Infrastructure growth as compared to increasing vehicles on the road is not possible due to cost and space constraint. Intelligent Transportation System (ITS) can mitigate the problem of traffic congestion by providing the information about road traffic status and, efficient utilization of transportation resources.

VANET assisted ITS have capability to develop traffic control applications with collaboration of vehicles with road side infrastructure (RSU). Vehicles are able to select an alternate path to cop traffic congestion with the help of ITS in urban areas of a city. Vehicles can use Dijkstra algorithm to calculate shortest paths with the help of city map but this selected shortest path is usually not be a shortest time path in an urban scenario. Vehicles need to travel path having shortest time to reach their destination in place of the shortest distance path to avoid traffic congestion. The optimal path selection by vehicles also reduces the amount of CO_2 gas emitted by vehicles, fuel consumption, travel cost, and travel time and improve the spatial utilization of road network.

The main objective of our proposed scheme is to design an algorithm for real-time adaptive path selection by vehicles. The goal of this study is twofold:

(i) We intend to minimize the travel time of vehicles.

(ii) Vehicles avoid creating congestion by selecting real-time non-congested path in their route.

In this section, we propose a real-time dynamic path selection protocol by vehicles with the help of the RSU. RSU aggregate the information of network which is used by vehicles to select their path. We have optimized the data dissemination in network about current traffic details by using Group communication between vehicles. GL is selected from each group which communicates with RSU through multi-hop broadcast communication. Additional parameters have been considered like the addition of value added services, maximum allowable speed limit on a road, obstacles on a particular road like traffic signals, accidents to further improve path selection by vehicles. RSU sends message to vehicles if found route congestion in vehicles path. Finally, we have simulated to our scheme to evaluate the effectiveness and efficiency of proposed protocol. Simulation of the proposed Scheme confirms that vehicle chooses the alternative path according to the set of rules of proposed scheme when they find congestion on the current route. We have considered both grid-network map and real-scenario map simulation environment in which random number of vehicles are generated which moves at various road segments to create road congestion. We have taken various parameters as discussed above to simulate the scenario. Simulation is performed by using OMNET++ which is free network simulator for academic use, microscopic traffic simulator SUMO to handle road traffic mobility and Veins.

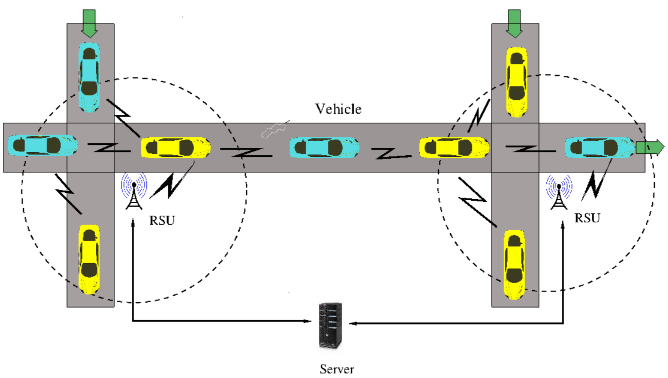


Figure 3.1: V2V/V2I communication

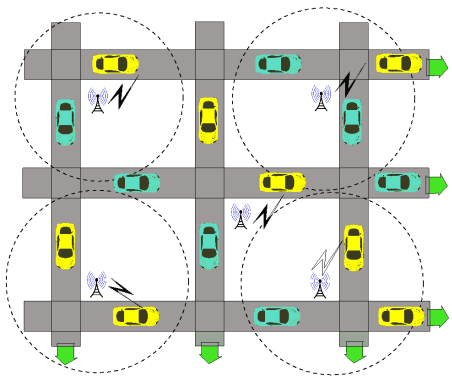


Figure 3.2: RSU distribution in VANET Network

3.2 Literature survey

Lin et al. proposed in [10] to select path by vehicles from an origin point to a destination point such that total wireless connection- capacity is maximized keeping minimum driving distance. Verroios et al. [1] proposed dynamic path selection by the vehicle based on estimations received from fellow travelers. It presented a distributed protocol that allows for vehicles to exploit selective information obtained from others traveling ahead in a trajectory towards a destination. Dobre et al. proposed in [11] a system by using additional sensors within the roadside infrastructure. It has considered only the speed of vehicles on a particular lane to avoid traffic congestion. Vehicles moving ahead exchange information that allows route selection of vehicles moving behind it. Bai et al. [**?**] proposed indexing method which uses view-based hierarchy search method for optimal path detection. Eggenkamp et al. [12] used extended Dijkstra Algorithm to find optimal path. Lam et al. [13] presented a system by dividing the area in to cells and in each cells it caches the data item of the database. Vehicle traffic information in decentralized structure is proposed in [14, 15, 16, 17] based on inter-vehicular communication.

We cannot aggregate the full network simultaneously to evaluate the network details, so group formation is required to aggregate the local details. Several Groups/ Cluster based Algorithm has been proposed in recent years to reduce the packet transmission in the Network. Caballero-Gil et al. [18] proposed algorithm to reduce communication overhead in VANETs. Paridel et al.[19] proposed context-based grouping for efficient collaboration in VANETs. Ohta et al. [20] presented clustering-based data transfer scheme using positions and moving direction of Vehicles for VANETs. Luo et al. [21] designed a new routing protocol for VANET, based on cluster-based routing. Song et al. [22] proposed a cluster-based directional routing protocol in VANET.

3.3 Proposed Protocol Model

3.3.1 VANET Architecture

In VANET, Vehicles communicate with other vehicles (V2V communication) and with Road Side Infrastructure (V2I communication) as depicted in figure-3.1. RSU exchange traffic information to moving vehicles, which uses by drivers to adjust their routes to avoid congestion. The entire network is divided into segments by RSUs which collects information on a particular area as depicted in the figure- 3.2. Distribution of area by RSU helps to decentralize processing of the traffic data, and prevent spreading of irrelevant data.

The road network is considered as an undirected graph with road junction as a node and road as a segment of an edge between two consecutive junctions. Vehicles move to the different edge and change their path at the node of the graph. Vehicles take the help of GPS device to know about the current edge and distance of nodes. The vehicle PDA device takes input data from a GPS device and stores it as a directed graph. Figure-3.3(b) shows the sub graph of their corresponding road network Figure- 3.3(a).

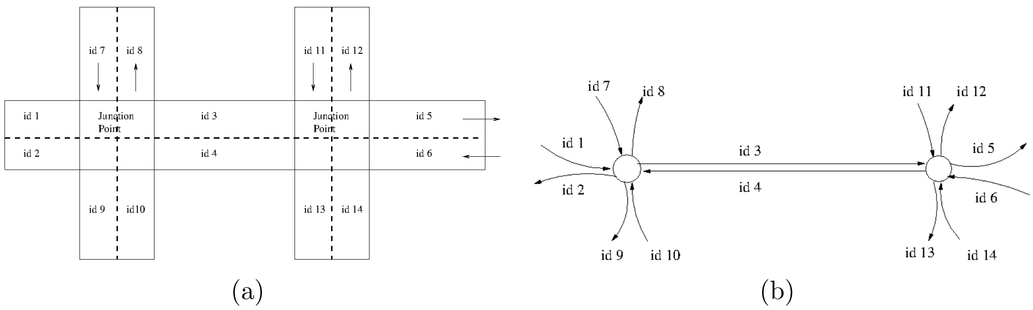


Figure 3.3: PDA obtains data from GPS device and stores it as a directed graph [1] (a) A road network and,(b) Corresponding directed graph

3.3.2 Assumptions

We have considered transmission range are same for vehicles, GL and RSU. Mobility of vehicles possesses some constraints to provide safety and security applications. Vehicles move with constant speed and maintain a definite gap between each other to prevent accidents. Vehicle movement also depends on the vehicles moving ahead of it. Vehicles maintain their lane and obey traffic signals during movement. RSUs are placed near to the different roadside at intersections.

3.3.3 Network Model

RSU exchange traffic information with moving vehicles, which allows Drivers to change their route to avoid congestion. RSUs are placed at different intersections which monitor the data sent from vehicles. Different RSUs helps to decentralize processing of data, and prevent spreading of irrelevant data. Urban area of a city consists large number of vehicles in close proximity. If each vehicle sends data to each other then it will create huge network congestions.

To reduce network congestion modified group concept is used for vehicles. Vehicles moving on a single edge segment form one group. A GL is selected from each group which receives the information of vehicle speed, queue length and position received from vehicles in the group about the road segment. GL aggregates the speed of vehicles. GL finds the nearest RSU from the geographical location of RSU from digital map obtained by GPS device and transmit the gathered data to RSU.

We have considered a case in which GL 'x' is near by two RSUs, A and B as shown in figure- 4.7. Let the geographic location of GL 'x' is (x, y) and that of RSU 'A' and RSU 'B' are (x_1, y_1) and (x_2,y_2) respectively. Vehicle 'x' measures the distances and direction of flow from RSU 'A' and RSU 'B'. R_1 and R_2 are distances from RSU 'A' and RSU 'B' respectively. It follows algorithm- 1 to decide whether to send data to RSU 'A' or RSU 'B'.

The group consists of a set of vehicles moving in a close geographical area nearly having same mobility patterns. Each group chooses a GL among its members who can communicate with its own Group members, summarizes the information about the Group and communicate with the RSU. Group reduces information exchange between vehicles and RSU. In the absence of the group, each vehicle broadcasts its

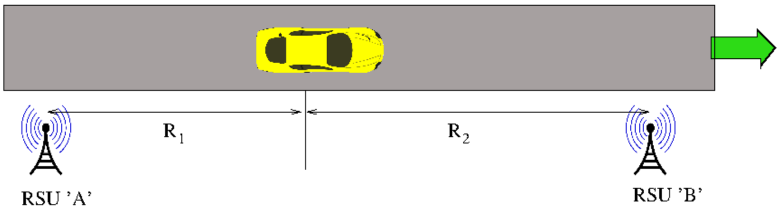


Figure 3.4: Measurement of nearest RSU by vehicles

$R_1 = \sqrt{(x - x_1)^2 + (y - y_1)^2}$

$R_2 = \sqrt{(x - x_2)^2 + (y - y_2)^2}$
α_1 =*Angle of direction of vehicle and RSU 'A' with vehicle's flow of direction*
α_2 = *Angle of direction of vehicle and RSU 'B' with the vehicle's flow of direction*
if $\alpha_1 \leq \alpha_2$ **then**
  Vehicle is heading towards the direction of RSU 'A'
else
  Vehicle is heading towards the direction of RSU 'A'
end if
if *vehicle is heading towards the direction of* R_a **then**
  if $(R_1\text{-}R_2) \geq 0$ **then**
    Send message to R_a.
  else
    if $(R_1 - R_2) \leq 0$ *and* $R_1 \leq \frac{3(R_1+R_2)}{4}$ **then**
      Send message to R_a
    else
      Send message to R_b
    end if
  end if
else
  Send message to R_b
end if

Algorithm 1: Selection of RSU by vehicles

information and uses multi-hop communication to send its information to RSU. It creates a large number of duplicate packets or packet having similar information as vehicles moving near-by location have correlation about speed, acceleration etc. Consequences of it, packet dropping is increased due to collisions and it reduce the network throughput.

GL - Group leader
LEAVE_MSG - Message when GL leaves the group
ϵ *- GL transmission range*
V_d*- Vehicles with same flow of direction*
f_d*- Vehicles with same flow of directions with other group members and highest degree of neighbors*
if *GL leaves Group* **then**
  GL broadcasts LEAVE_MSG packet
  LEAVE_MSG packet is received by Group Members
end if
if *GL selects new GL before leaving the group* **then**
  vehicle V_{fd} is selected as new GL within the transmission range of ϵ
else
  Group Members select leading vehicle Vd as next GL
end if

Algorithm 2: New GL Selection when GL leaves the Group:

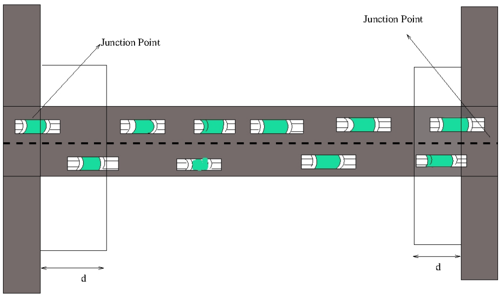


Figure 3.5: Area excluded for measurement of speed

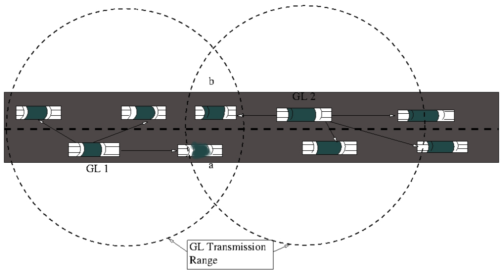


Figure 3.6: GL message Transmission

Group Leader Selection

Different algorithms have been proposed to select and change GLs among its group, e.g. Least ID in group, node having highest degree in group, etc. GL changes with time as GL leaves the group due to movement of the vehicle. It joins as a member of another group after leaving the present Group. An intelligent GL selection increases Group stability and maximize Group Lifetime.

A vehicle waits for time interval τ during which if it found beacons transmitted by GL then it joins the corresponding group otherwise it forms a new group with itself as new GL.In next beacon interval vehicle selects GL as a highest degree neighbor. If more than one vehicle is present in the group which has equal highest

GL - Group leader
τ*- Time Interval after vehicle transmit Beacons*
ϵ *- GL transmission range*
χ *- Information received by vehicles from the same road segment*
ttl=0
repeat
  if *GL is in the transmission range of sender vehicle* **then**
    GL receives the beacons transmitted by vehicle at every time interval τ.
  else
    ttl=ttl+1
    Vehicle selects the next hop vehicle in the communication range of it in the direction of GL.
  end if
until *Vehicle is in transmission range of* ϵ *and ttl¡3*
t=0
repeat
  if $\chi == true$ **then**
    Accept the packet and aggregate the information with the information received from other vehicles.
  else
    Drop the packet.
  end if
until t $\leq \tau$
if $t == \tau$ **then**
  1. GL sends the aggregated information to RSU through one hop or multi-hop communication.
  2. RSU receives the packet and stores it in the data server.
  t=0
end if

Algorithm 3: Group Communication by Vehicles:

degree neighbors then vehicle select new GL which is nearer to the middle of the Group.If GL leaves the group then the process for new GL selection is depicted in algorithm- 2.

Group Communication

Vehicles periodically broadcast their information in the form of beacons about a position which contains information about current speed, acceleration, edge id, lane number, geographical position i.e. vehicles's latitude and longitude. Routing of this information is performed by vehicle only through the same road segment as of GL. Intra road segment routing is performed with the help of RSU through which it collects information from one road segment. This information is used by vehicles moving on other road segments in the network. It also helps to prevent huge packet routing in the network. Vehicle forwards the packet to GL depicted in figure- 3.6 by using the Algorithm- 3. If road segment size is larger than the GL transmission range then vehicle selects an intermediate vehicle in the direction of GL to which vehicles send its information.

Vehicles move slowly or stop at the junction point due to traffic light. vehicle's speed is not considered in range of 'd' from the junction point for calculation of average speed of the edge as depicted in figure- 4.2.

$$d = \frac{u^2}{2a} + average\_queue\_length \tag{3.1}$$

Where, u = speed of vehicle to which it starts deceleration. a = the declaration of vehicle.

3.3.4 Route Selection Algorithm

RSU is deployed at some important and busier route intersection where the route selection of vehicles is important and significantly affects the travel time of the vehicle. RSU performs periodically one-hop broadcast about the current neighbors' route traffic information which receives by vehicles nearby intersection. When the vehicle reaches in the transmission range of RSU it requests route inquiry to RSU by sending current location, road id, destination road id and optional value added information, which in reply RSU sends back the current optimized route for destination. The value added information contain the query about location of the parking lot, petrol pump, restaurant etc. in the area, which the vehicles want to avail this services in passing by the routes through the destination. Nearest RSU receives the data sent from vehicles, collect and aggregate the relevant data from data server and sent back to the vehicle about optimized route information to vehicles. Whenever vehicles enter in to RSU region, RSU detects the vehicle through its periodic broadcast of beacon information. If the vehicle has already registered it route details then it finds out from the data stored in the server whether vehicle following the route is congestion free and shortest time route or not. If the alternate shortest route is available then RSU sends the warning message to the vehicle to change its route.

Two types of messages are transmitted by RSU for route selection:

1. RSU periodically broadcasts the local information: RSU periodically broadcasts the aggregated local information receives from GL in the form of beacons. The local information contains the information about paths having congestion. Vehicles receive the path information and change its routes accordingly.

2. RSU reply vehicle's request about route selection: Vehicle within its transmission range of RSU near to the intersection sends request to the RSU which contains information about destination and additional services that it requires during their most optimal path searches.

RSUs use the aggregated information stored in data server that has obtained from vehicle's GL to find the optimal time path. The optimal path calculated by RSU is used by vehicles to dynamically determine the path it will follow. Vehicle in the network is able to cope with traffic congestion in an urban environment by selecting an alternative route to their destination. It also helps to remove traffic congestion and ensure proper utilization of roads in the network. The output of the Algorithm discussed in next section is to find out the average time required by vehicles to traverse by each route and the average time is used to calculate the optimal time route for vehicles.

Time Taken to cover the distance of each alternate path

RSUs placed at the junction point measures the distance of each alternate path from vehicles current edge to the destination edge.RSU gets the length of each traversing lanes and their average speed sent from their GL, stored on the data server. Vehicles are moving on different path having different speed.It measures the time taken by vehicles from each edge and sums it to find the total time taken by it in the entire route. E.g. vehicle is assumed to be passing through three edges having a length d_1, d_2, d_3 and their respective speed on those edges are v_1, v_2, v_3 respectively. Total time taken by vehicle is T_{total}. Where,

$$T_{total} = \frac{d_1}{v_1} + \frac{d_2}{v_2} + \frac{d_3}{v_3} \tag{3.2}$$

Time taken due to the addition of value added services

When vehicles have to travel from source to the destination by covering the particular edge containing a restaurant, petrol pump, parking area etc. then RSU measures the total time taken by vehicle throughout the journey by dividing into two parts. In the first part, it measures the total time taken up to the edge where the vehicle avails the services and in the second part it measures the total time from particular edge to destination. RSU considers the edge where vehicle gets the service as a first destination. In this case T_{total} is calculated as follows.

$$T_{total} = T_{total1} + T_{total2} \tag{3.3}$$

Where,

T_{total1}= Time taken by vehicle from current edge to edge where it avails services.

T_{total2}= Time from edge where it gets serviced to destination edge.

We have not considered time elapsed to avail the services.

Time taken due to Traffic Light in Path

The number of traffic lights in path add the delay in the path traversed by vehicles to reach their destination. RSU counts the number of traffic lights and gets the stop time due to red signal for each traffic light in the vehicle route. Let, T_{tf1}, T_{tf2}, T_{tf3} be assumed as delay occurred due to three different traffic lights. A total time delay occurs due to traffic light is T_{tf}. Where,

$$T_{tf} = T_{tf1} + T_{tf2} + T_{tf3} \tag{3.4}$$

Vehicles add the time delay occurs due to traffic light. Traffic signals increases the path travel time as vehicles have to stop at red signals. Improper traffic light time at junctions also increases the queue length at junctions. To remove this problem we have used coordinated traffic light at different junctions. We have considered special case for emergency vehicles, when it enters into new edge, the traffic light turns green in the direction of movement of it to avoid queues and waiting time for a traffic signal. But it increases the waiting time for other vehicle coming from other directions.

Time taken due to queue in the path of vehicles

Vehicles arrive at the junction point; make a queue and waits for a traffic light to be green. Vehicles also make queue due to accident or abnormal stop in the path of a vehicle. Waiting time for vehicle at junction point is the time duration between the time of arrival and time at which traffic light turns green. GLs send the information about the queue length occurred at every edge in each route which is updated at each beacon interval. GL uses this information to calculate the time delay occurred due to queue. A Vehicle which is in the queue gets service on first come and first serve basis. We have assumed a point where there are 'n' numbers of vehicle in the queue then time consumed by the vehicle is in the queue is the time taken by each vehicle to reach their maximum speed from rest plus waiting time due to red light. If we consider a case in which vehicle reaches at queue end point of length 'q' with maximum speed 'v' and if the queue is not present there then the time taken by vehicle to reach at junction point is T_n. Where,

$$T_n = \frac{q}{v} \tag{3.5}$$

In second case, if queue is present and vehicle stops due to queue at a distance of q from the junction point then number of vehicle in the queue from junction to vehicle is (say) N.

$$N = \frac{q}{x+y} \tag{3.6}$$

Where, x= Length of vehicle
y= Distance between each vehicle.
z= Safe distance from junction point.
It has been taken assumption that the length of every vehicle is same and it stops at equal distances with each other.Time delay by vehicle to reach at a junction point from the queue endpoint depends on the number of vehicles ahead of it. The distance of the first vehicle from junction point is by then the time taken by vehicle to reach to the junction point is T. Where,

$$T = \sqrt{\frac{2z}{a}} \tag{3.7}$$

When the vehicle starts at queue point, its initial speed is zero. It reaches with maximum speed with acceleration 'a'. Time taken by rest (n-1) vehicle to reach their junction point is T.

$$T_1 = \sqrt{\frac{2((n-1)(x+y)+z)}{a}} \tag{3.8}$$

We get total time consumed by a vehicle from the queue end point to junction point is (say)

$$T_2 = T + T_1 \tag{3.9}$$

Total time delay by vehicle to reach the junction point due to queue is T_d. Where,

$$T_d = T_n - T_2 \tag{3.10}$$

From Little Theorem mean queue length is determined as, N=λ T. Where,

λ = Average Costumer Arrival Rate

T = Average Service time of a costumer.

The queue at a junction point depends on the arrival rate and service rate. We have calculated the service rate T_2 for each vehicle at the junction point. Vehicles queue service rate depends on the vehicle's speed, and number of vehicles waiting ahead in the queue. Vehicles arrival rate is a Poisson process as the number of vehicles moving on the road in urban scenario is very high so a vehicle is considered as very small in road resources, and decision taken by vehicle to enter a particular road is totally dynamically taken by Driver. We have calculated vehicles arrival rate as the difference of the vehicle entering to the lane to the vehicle leaving the lane.

Total time taken by vehicle from source to destination depends on the current average speed of each road, the number of traffic signals crossed, the maximum allowable path of a road and, the queue length of the selected path. RSU get the above information from vehicle's GL and through the GPS device at junction point and calculate the average time taken through each path segment.

$$T_{travel} = T_{total} + T_{tf} + T_d \tag{3.11}$$

Vehicle selects the path dynamically with minimum average time T_{travel}. At each junction point containing RSU, vehicles get updated values and vehicle's PDA device updates its route information.

Other parameters which are used by vehicles to select an alternate route as follows.

1. Vehicles prefer to select the main link way to reach their destination. If two ways take the comparable time then vehicles select the main linking path between source and destination.

2. Vehicle considers the maximum supportable speed on the road to reach their destination. If the route contain residential area and schools then vehicle's speed on that path is very less and vehicle avoid to that path in the dynamic selection of paths.

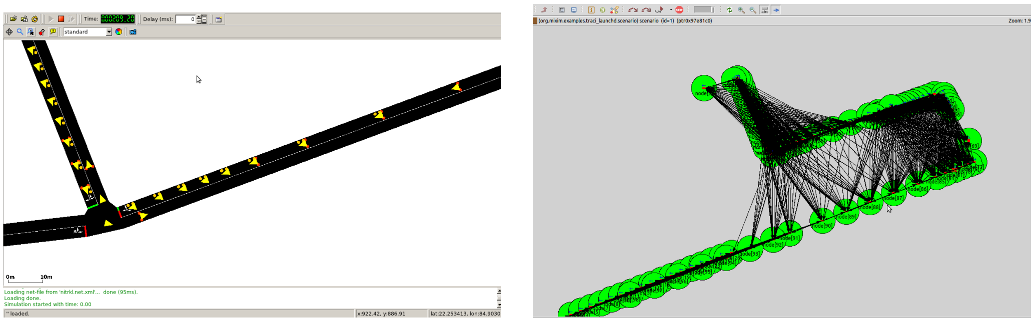
3.4 Results and Discussion

We have used OMNET++ for network simulation, SUMO for microscopic road traffic simulation and Veins (Vehicles in Network Simulation) for the coupled simulation framework which integrates OMNET++ and SUMO. The major advancement of using Veins is that it is able to generate the real time interaction between network simulation module and road traffic simulation module. It is also able to affect road traffic simulation module based on the network simulation module.

OMNET++ [23] is a discrete event simulation framework which is suitable for modeling wireless vehicular network. Vehicles communicate with each other through message passing. OMNET++ supports are limited to simple mobility patterns like a random way-point model. Since VANET simulation requires road traffic which mobility pattern is much different from the mobility pattern supported by OMNET++ so it is used microscopic road traffic simulation tools SUMO [24].

Mobility of the vehicles is modeled according to trace file generated from real world scenarios. SUMO provides the microscopic model for traffic simulation which is required for accurate traffic modeling for each vehicular activity and interaction like position, speed, and radio transmission between nodes etc. OMNET++ sends command to SUMO to control road traffic simulation and SUMO returns the position and other information about the map and traffic mobility to OMNET++. OMNET++ and SUMO are integrated with the traffic control interface, TraCI which provides TCP connection between each other [8]. Figure- 3.7(a) and Figure- 3.7(b) shows the vehicles movement in SUMO and Veins framework respectively.

We have simulated our proposed work in both grid topology and real street map of the NIT Rourkela, India with the help of Veins. We have extended Veins command to support our proposed work. In both the scenarios we have compared cost metric of our proposed work with Dijkstra shortest path Algorithm and vehicle moving randomly from source to destination. Vehicles moving on the road adjust



(a) (b)

Figure 3.7: Snapshot from Graphical user interface of network and road traffic Simulators(a) Vehicles in OMNET++/Veins and (b) SUMO

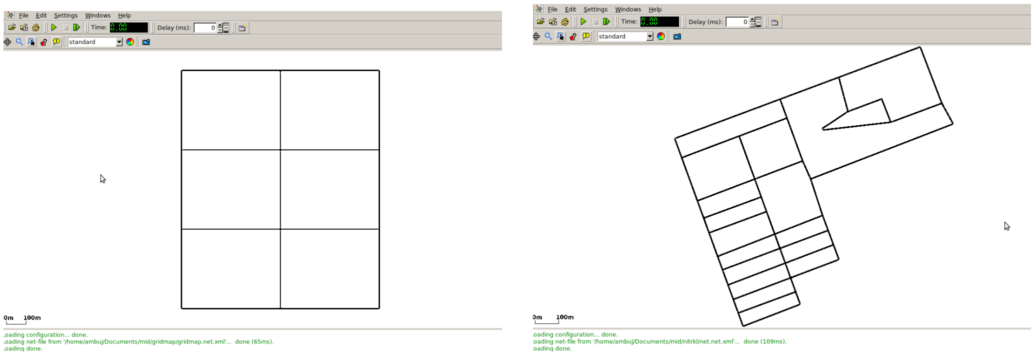
their path dynamically after getting alternate most suitable routes from RSU. Travel time from each road is computed by vehicle and it selects the path having least travel time to their destination.

Simulation of our proposed scheme is performed with the different road traffic and Veins parameters depicted in table 4.3.1. SUMO command randomtrips generate a fixed number of vehicles moving through different routes in the map. Certain vehicles are added to the map varies with area and type of network which move from source to destination. After certain time when vehicles spread through out the map, we add ten vehicles of which five of them follow dynamic path and rest move using Dijkstra algorithm. Simulation result of both grid map and realistic road map scenario is described below.

Parameter	Values
Maximum vehicle speed	20m/sec
Maximum acceleration	0.8m/s2
Maximum deceleration	4.5m/s2
vehicle length	3m
gap between vehicle	2m

Parameters Used for Veins	VALUE
Mac.queuelength	5
Mac.maxTxAttempts	14
Mac.txpower	100mW
Mac.contentionWindow	20
Mac.slotduration	0.04sec
Phy.usepropogationDelay	False
Phy.sensitivity	-80dBm
beaconInterval	0.1 sec
maxoffset	0.5 sec

Table 3.1: Parametes under which simulation is performed (a) SUMO simulation parameters for vehicles and (b) Module parameters for Veins



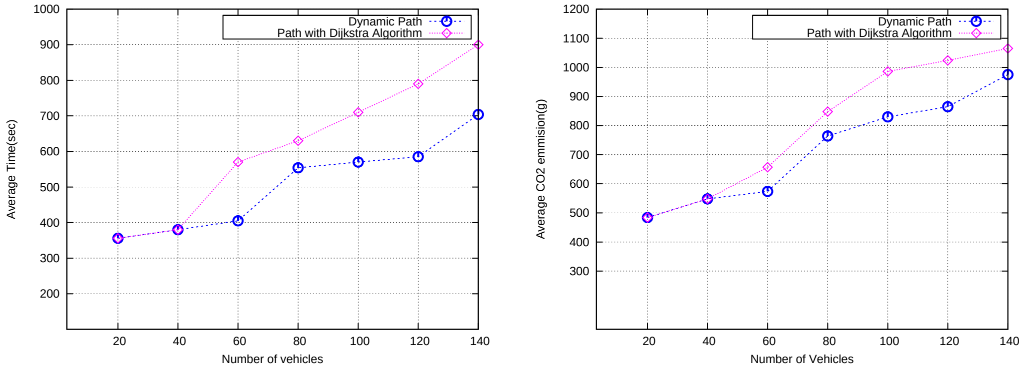
(a) (b)

Figure 3.8: Screenshot of map to which vehicles moves(a) single lane road of 2 x 3 cells on Grid Scenario, and (b) Realistic Road Traffic Map of NIT Rourkela, India obtained from OpenStreetMap Project

3.4.1 Grid map Scenario

To evaluate our results we used a simple Grid scenario of 2 x 3 roads which contain single lane road which are spaced 500 m apart in horizontal direction and 400 m in the vertical direction as shown in Figure- 3.8(a). A a random trip of vehicle is generated (20 - 150 vehicles) throughout the map using SUMO command. At the different time stamp of simulation we added the vehicle on the map which enters at bottom left corner of the map as the source and destination is set as top right corner. The traffic light is placed at each intersection. As shown in figure- 3.9(a), when the least number of vehicles is present in the network then average time taken by vehicle is same with vehicles which cover path due to no congestion in network, and vehicle selects shortest route from source to destination. Vehicles have to cover the longer path when vehicles in the network increases which also increase the travel time. Figure- 3.9(b) shows the average CO_2 emission by vehicle in moving from source to the destination.

Traffic light obstructions for the entire map are kept as constant i.e. changes at regular interval of 90 sec except for emergency vehicle. When an emergency vehicle enters into the lane traffic light turns green irrespective for its time interval. We manually created traffic jam by stopping of vehicles or creating accident in the lane. If the vehicle gets no traffic congestion in shorter route than it chooses the shortest route from source to destination. The result is obtained after vehicle performs inter vehicle communication and with communication with fixed infrastructure.



(a) (b)

Figure 3.9: Results obtained for vehicles route selection following Dynamic path and Dijkstra Algorithm in Grid Scenario (a) Total time taken and, (b) CO_2 emission based on movement from source to destination by vehicles

3.4.2 Realistic Road Traffic- NIT Rourkela Street Map

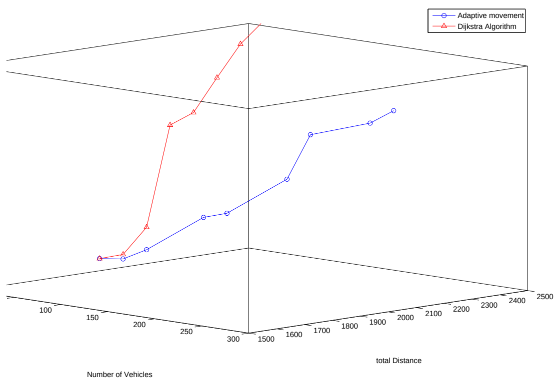
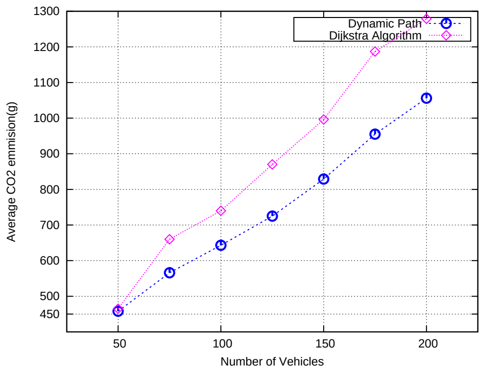
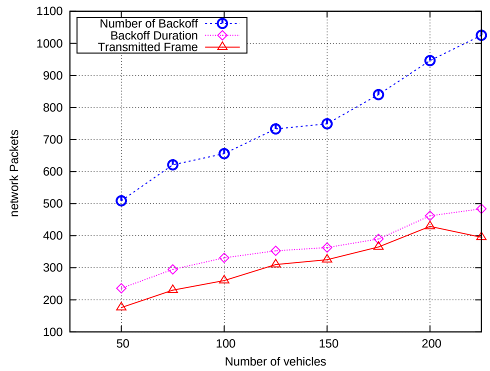


Figure 3.10: Total distance and time taken by vehicles to move from source to destination in a scenario where fixed large number of vehicles are moving in network

We also simulated our proposed work on a real street map of NIT Rourkela(Figure- 3.8(b). Road layout of NIT Rourkela is publicly available from the OpenStreetMap project. The data obtained from the OpenStreetMap are not suitable for processing in SUMO so map is modified through Java OpenStreetMap



(a)



(b)

Figure 3.11: Results obtained for vehicles route selection in realistic road traffic Scenario (a) CO_2 emission based on vehicles following Dynamic path and Dijkstra algorithm and, (b)Frames transmitted for Dynamic path

Editor "JOSM" which makes the map suitable for the work of osm files and it also adds building, trees etc. obstacles on the map. We used NETCONVERT in SUMO to generate map and adds traffic light at the intersections. RandomTrips in SUMO is used to create the random trips of vehicles. We have simulated for different number of vehicles randomly distributed across the map. Vehicles are added at a regular certain intervals which originate from the fixed point from the map and goes through to the destination. We compared the result obtained from Real-time vehicle movement with Dijkstra algorithm from source to destination.

Figure- 3.10 shows distance covered and time taken by vehicle in movement from source to destination for both dynamic path and Dijkstra algorithm. Average CO_2 emission for vehicles is shown in figure- 3.11(a). Results obtained from figure- 3.10 and figure- 3.11(a) clearly shows time taken and average CO_2 emission by vehicles which follows dynamic path are less than the vehicles which follow Dijkstra algorithm. Figure - 3.11(b) shows the number of transmitted frame, back-off duration, and number of back-off by a vehicle for our proposed scheme.

Chapter 4

An Efficient Safety Message Transmission Protocol for VANET

4.1 Introduction

In VANET, vehicles broadcast beacons periodically which contain vehicles common characteristics like position, velocity and lane number. Receiver Vehicle uses this beacon information to predict the movement of sender vehicles. Vehicles trigger event safety messages when any abnormal changes occurs in vehicles behavior which breaks the normal continuity of movement of vehicles such as hard braking, sudden lane change, break failure, engine breakdown or any other vehicle malfunction. If any such incidents occur, abnormal vehicle sends ESM to all endangered vehicles to prevent collisions. These messages must reach to endangered vehicles in real time. The main objective our proposed scheme is to design an efficient and reliable routing algorithm. Goal of this study is of twofold:

1 We intend to minimize the network congestion by reducing participating vehicles in information transmission. Large number of vehicles is present in close proximity create huge network congestion.

2 Use of Context-based grouping.

We propose a Group based communication mechanism to optimize ESM information transmission. Vehicles form groups and select a Group Leader (GL) within its transmission range. GL summarizes the information and broadcast it within the group and to the next GL. We have also considered impact of velocity of nodes during the transmission of ESM packets because as vehicles speed increases or decreases, frequent link disruption occurs. We have used context-aware inter-group transmission of packets to reduce network congestion. The main objective of context-aware grouping is that only relevant vehicles will receive packets which are affected by accidents. We have simulated the scenario by using network simulator and road traffic simulator. We have used OMNET++,a free network simulator for academic use. It helps to model realistic communication between vehicles. For traffic simulation we have used microscopic road simulator sumo.

Trust is an essential requirement of VANETs when one vehicle sends ESM message to another. ESM messages have highest priority so a user will feel comfortable only when he can trust the ESM messages he receives. A VANET becomes trustworthy when all the vehicles within it are trustworthy. Only in this condition, user can believe on network components. If an adversary deliberately broadcast false ESM message, or send old or expired information (Replay Attack) then this information can misdirection the road traffic and it will become major cause of impairment in traffic safety.

If RSUs are not protected, deployed near to roadside, without any physical protection then it can easily compromised. RSU is also under attack by adversary for sending false, modified, expired or misleading information that may cause dangerous consequences to OBU. In grouping, an untrusted vehicles within the group may also sends false information.

To overcome the above discussed risk factor, it is compulsory to verify the identity of message sender, as well as maintaining integrity of the message. This can be achieved through suitable secure protocol. Identity verification is a tough task in VANET due to high and variable velocity of nodes, variable node density and also it operate on roads with nonuniform characteristics. Its also a problem for a single controller which can not handle thousands of vehicles at a time.

It is important to limit the wireless traffic intensity to avoid packet collisions at the Medium Access Layer (MAC) layer. Increased collision rate impair the performance of vehicular communication. Since, WAVE standard can not handle with many high priority messages in a dense network scenario. We are needed a trust scheme that has low computational complexity, high scalability, as well as reliable and quick verification mechanism.

4.2 Literature survey

Protocol applied in MANET cannot be directly implemented on VANET due to high mobility. We cannot aggregate the full network simultaneously to evaluate the network details, so we require group formation to aggregate the local details.

Bo Xing et al. [25] discussed the problem of varying reliability needs and fast broadcast of critical data over Ad-hoc networks. Guan et al. [26] proposed two algorithms for low priority safety messages to improve channel utilization and channel availability for high priority emergency messages. Suriyapaiboonwattana et al. [27] proposed an adaptive alert message dissemination protocol for VANET to improve road safety. Ma et al. [28] proposed and justified the design for control channel in DSRC for vehicle-safety-related applications. Peksen et al. [29] proposed multi-hop safety message broadcasting in VANET by relying metrics. Various papers [30], [31], [32] have been proposed on different issues of Safety Related Messages.

Paper [33] create the group offline and each group messages includes with it an authentic group ID .It generate a group signature on each of its message. Vehicle in the group can send data only inside the group. Group Managers (GMs) have the responsibility to admit new vehicles and to evict attacker/malicious vehicles. Paper [34] proposed the model for trusted grouping using TPM Hardware. It provide hybrid cryptography scheme. The IEEE 1609.2 industrial standard as well as most of the earlier works in the literature [35], [36] propose the use of digital signatures (such as ECDSA and NTRU) and public-key infrastructures (PKI) in the provision of message authentication services. To ensure user privacy, each vehicle is preloaded with a large set of short-lived pseudonym certificates used for message signing at the expense of storage. As opposed to these works which rely solely on PKC, we use much more efficient symmetric-key techniques for data communication. For instance, the TESLA protocol [37] uses symmetric-key techniques for broadcast authentication and relies on time to create the asymmetric knowledge between the sender and the recipient. Studer et al. [38] observed that TESLA is subject to memory-based DoS attacks against the recipient in VANET settings due to the storage of previously received messages. Therefore, they proposed TESLA++, a modified version of TESLA, which requires the recipient to store a self-generated MAC of the message's MAC received. The message itself as well as the key will not be revealed until the key expires. However, the property of delayed key disclosure inherent in TESLA++

hampers the readiness of message data and therefore limits its use in time-critical VANET applications. GHAP protocol proposes the privacy preserving group communication scheme for VANETs (PPGCV) to satisfy forward and backward secrecy, authentication, protection against collusion, and privacy.

4.3 Proposed Protocol Model

4.3.1 Group Formation

Group consists of a set of vehicles moving in a close geographical location. When Vehicles find more than one Group within its transmission range it calculate distance and flow of direction from each GL. If vehicles have a similar flow of direction with GL then Group stability increases. In figure 2, two Groups are formed where GL_1 and GL_2 are GLs of Group 1 and Group 2 respectively. A vehicle is in the similar flow of direction with other vehicle if their angle of direction $\alpha \leq \frac{\pi}{4}$.

Notation	Description
v_i	i_{th} neighboring vehicle
ζ	Number of neighbors
α	Angle of direction between two vehicles
n_i	Sum of neighboring vehicles
ϵ	Transmission range of GL
R	Transmission range of vehicles
D_{v-GL}	Distance of vehicle to GL
τ	Vehicles beaconing interval
M	Mode of operation
P	Priority of message
SID	Source ID of message
GID	Group ID of message
ID	Intermediate vehicles
TTL	Time to live of a message
RLOC	Source location if message

Table 4.1: Notation used for the Algorithm

Vehicles uses following steps to form the groups:

Step 1: A vehicle periodically receives beacons transmitted by the neighboring vehicles and calculates the number of neighbors by $n_i = \sum_{i=1}^{n} v_i$.

Step 2: Vehicles set a threshold for n_i. It checks at τ interval whether $\zeta \geq n_i$. If ζ is greater than n_i; then go to step 3 else go to step 8. ζ for all vehicles are considered to be same.

Step 3: If two or more GL are moving within transmission range of each other i.e. $D_{GL} \leq \epsilon$ and they have similar flow of direction then they merge two Groups with common GL. Where, D_{GL} is distance between two GL.

Step 4: Vehicles check whether they are in transmission range of GL. If vehicles find itself in GL's transmission range and in similar flow of direction with GL then go to step 5. If vehicle founds it is in transmission range of a group but not in GL's transmission range as shown in Fig. 4.7 then go to step 6

Step 5: Vehicles joins as a group member. Go to Step 9.

Step 6: Vehicles calculate the distance from neighbor GL to itself. If D_{V-GL} is in between $\frac{3R}{2}$ to 2R then the vehicle creates new Group. This condition reduces overlapping of Groups. In figure 6, vehicles within radius R receives packet sent from vehicle B but within this region there is not any Group. In this case vehicles creates new Group. Go to step 9.

Step 7: Repeat from step 1 after τ time interval.

Step 8: No Group creation occurs till next beacon interval.

Step 9: After getting the next beacon repeat from step1.

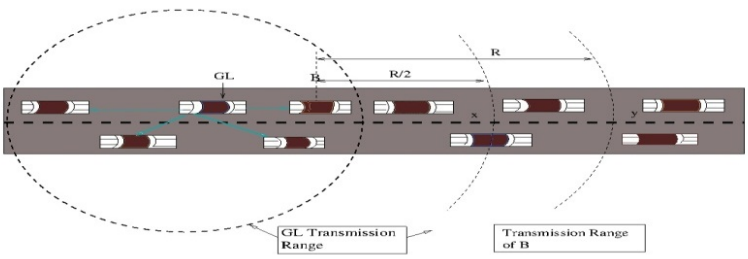


Figure 4.1: Creation of new group

4.3.2 Group Leader Selection

Several algorithms have been proposed to select and change GLs, e.g. Least ID in group, node having highest degree in cluster, etc. GL changes if present GL leaves the group or it changes its path at intersection. GL joins as a member of another group after leaving the present Group. An intelligent GL selection increases group stability and maximize group life time.

New GL Selection when GL leaves the Group:

Step 1: GL broadcasts LEAVE_MSG when it changes path at intersection point or stops. LEAVE_MSG packet is received by all members of the Group.

Step 2: Before leaving the group, GL selects a new GL within a transmission range of threshold ϵ, where $\epsilon \leq \frac{R}{4}$ and it selects that vehicle which has a highest neighboring nodes and similar flow of direction. Group members wait for new GL selection for a time interval 2τ. If GL does not select new GL before leaving the Group, then go to step 3.

Step 3: Group Members select nearest leading vehicle as GL having highest neighboring nodes and similar flow of direction with GL.

Merging of Groups:

When two Groups merges then GL_1 and GL_2 selects a new GL between them. GL_m (x,y) is selected by:

$$GL_m(x, y) = (\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}) \tag{4.1}$$

Where, (x_1,y_1) and (x_2,y_2) are geographical location of GL_1 and GL_2 respectively. In figure-4.2 GL_1 and GL_2 forms common Group according to above equation.

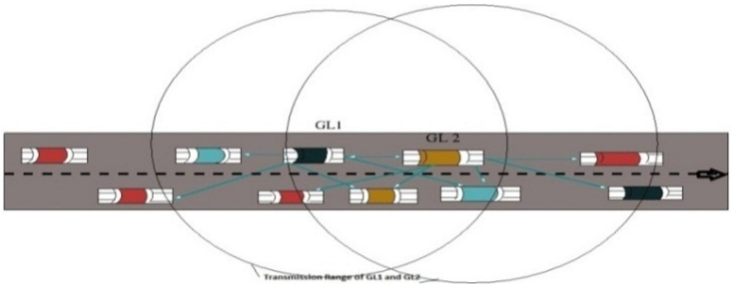


Figure 4.2: Creation of new group

4.3.3 ESM Message Transmission

Selection of communication range:

GL forwards the packet to the farthest node of the Group to reduce multi-hop communication and achieve faster communication. Message broadcasting is performed by considering the mobility effect in the network. Vehicles send periodic beacons to find their neighboring vehicles and GL. Due to the high mobility ESM message forwarding by the vehicle to GL fails. In [39], speed of each vehicle is a random variable following normal distribution with mean μ and variance. We have taken n samples in τ time interval in a Group to find the speed difference of GL with other vehicles. These samples are independent of each other and we calculate the difference in speed between vehicles in group by using the following eq. 2.

$$\triangle\bar{v}_{i+1} = \frac{1}{n}\sum_{j=1}^{n}\triangle v_{(i+1)j} \tag{4.2}$$

Where, $\triangle v_{(i+1)}$ is the difference of $(i+1)^t h$ vehicle to GL while $\triangle\bar{v}_{i+1}$ is the average velocity difference.

Maximum transmission range of GL depends on the maximum transmission power. Maximum transmission range of vehicle is d_{max}, where

$d_{max} = \sqrt{(x_u - x_v)^2 + (y_u - y_v)^2}$.

Packet Format in normal mode is shown in figure 4.3 and figure 4.4 shows the packet format in safety mode. In Safety Mode, GID and Payload are same as normal mode packet. Set IN if IN is present else put default value as 0.

Normal Mode				
M	GID	LID	Timestamp	msg

Figure 4.3: Packet format in normal mode

Safety Mode								
M	RLOC	SID	GID	P	Type	IN	TTL	msg

Figure 4.4: Packet format in safety mode

ESM Message Transmission Phases:

Vehicles follow three different kinds of communication based on group formation. There are three cases according to which the ESM message is send to the destination. The cases are described as follows:

Case 1: Vehicles are within the communication Range of GL in which it directly receives ESM messages from the vehicles.

Case 2: Vehicles are in the communication range of Group but not in GL. Vehicle selects intermediate vehicle (say χ) within the communication range R_1 in the similar flow of direction to send the message to the next Group. Where,

$$R1 = d_{max} - \triangle\bar{v}_{i+1} \tag{4.3}$$

It decreases the TTL by 1 and forwards the packet to next GL. Case 3: No next

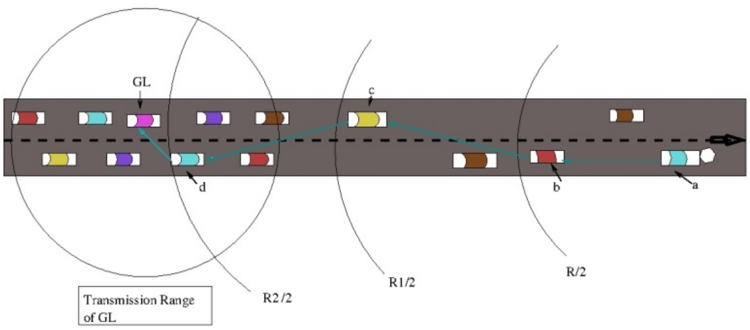


Figure 4.5: Packet format in safety mode

Group found in the communication range of the GL. In this scenario, due to less number of vehicles in the road (in highway scenario), there is a chance of dropping of packets. For this reason, vehicle selects next hop vehicle near to $\frac{R}{2}$ as shown in Figure 4.5. In this case, each vehicle within $\frac{R}{2}$ and R will receive ESM packet twice i.e. they receives duplicate packets and they just ignore it. If they do not receive duplicate packets, there must be a packet dropping and vehicle retries to send the packet by changing next hop vehicle. Duplicate packet increases redundancy but improves reliability.

4.3.4 ESM Message Transmission Using Priority and Context- based communication:

The three cases discussed in the above part uses priority and context-based communication to send the message. If GL receives more than one packet simultaneously then GL selects the packet from the queue which has highest priority among them and forward it to next GL. GL maintains a priority table to decide priority of a message, e.g. vehicles give higher priority to that ESM message which is generated from an accident, rather than the vehicles applying sudden break or moving in a high speed. Priority reduces queuing time delay of highly sensitive ESM messages. If any accident occurs, then GL generates ESM message and sends only to those groups which are really endangered by the accidents. It helps to reduce the generation of redundant packets and reduces the network congestion. Context-based communication forwards the packet based on various types of accidents:

1. If some vehicles break fails or vehicle is moving speedily then GL sends ESM to those groups which are moving ahead with similar flow of direction to it.

2. If an accident occurs then vehicles moving forward to it is not affected. Vehicle sends ESM message to those groups which are behind of it similar flow of direction.

3. If traffic light fails or an accident occurs at junction point, GL forwards the packet in all directions.

4. When GL receives the message, it checks whether alert message is still useful

to forward and check whether TTL ≥ 0 or not. It drops packet if any of the above conditions fail.

4.4 Ensuring ESM message security

4.4.1 Security Requirements

Following security goals are required for group-based VANET applications.

1. No any untrusted node can join any group.
2. To ensure message authentication by verifying that received messages are generated from one of the group member.
3. Group members must maintain forward and backward secrecy, Any group member that already has left the group should not able to get new key and also after joining to new group it should not be able to use the previous group key.
4. To provide non-repudiation so that the receiver of data can later proof the identity of sender if required.
5. To provide minimum delay for ESM message due to addition of cryptographic techniques.

4.4.2 System Assumptions

OBU is considered as non-trusted entity, RSU as semi-trusted entity and Certification Authority(CA) as a secure entity. A revoked node must be instantly detected by key server CA. CA is responsible to distribute the keys to all the vehicles in the network.

security framework for secure grouping has been proposed by us using Trusted Platform Module (TPM) hardware. Since RSU has been considered as semi-trusted entity so vehicles do not disclose its identification to it. Certification

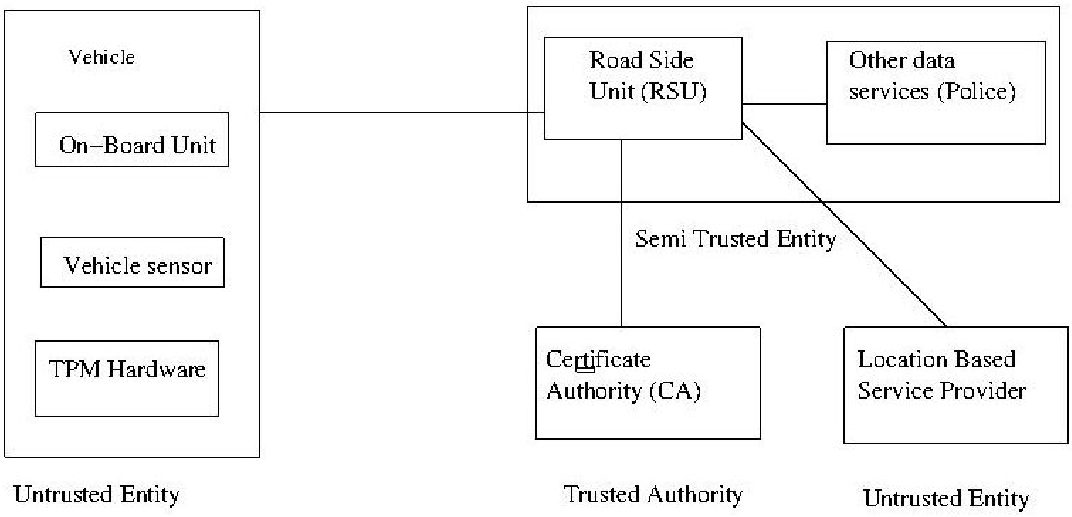


Figure 4.6: VANET basic infrastructure

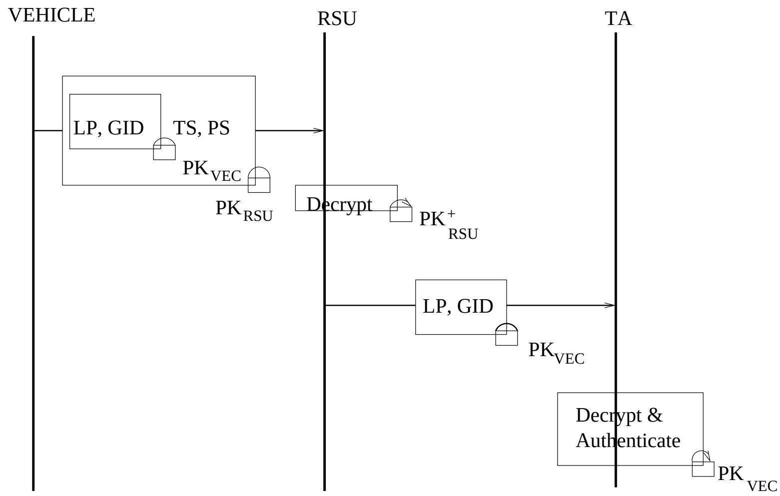


Figure 4.7: Vehicle Authentication by TA

Authority are considered to be fully secure and stores all the private key of the network.

Vehicles contain secure hardware which store vehicles unique license plate number, public key of TA, RSU,vehicle and vehicle's private key. RSU contain its public and private key and public key of Trusted Authority. Security between group members between vehicles are achieved using the help of RSU.

Table 4.2: Notification used for this Algorithm

Notation	Description
PK_{VEC} Public key of vehicle	
PK_{RSU}	Public Key of RSU
PK^{+}_{VEC}	Private key of vehicle
PK^{+}_{RSU}	Private key of RSU
SSK	Shared Symmetric key between vehicles within Group
RN	Random number Generation by vehicles
LP	Vehicle unique license number
PS	Previous pseudonym
PS^{+}	Present Pseudonym
TS	Time stamp
GID	Group identification number
msg	Message sent by vehicles

4.4.3 Vehicle Authentication and key generation

Vehicles are authenticated by RSU with the help of CA. Vehicle sends request to RSU for authentication and association with other vehicles in the group. After authentication pseudonym and symmetric key are generated which are used by vehicles to communicate with other members. When vehicles change their group their previous pseudonym is authenticated by RSU and CA generates new pseudonym for vehicles. Pseudonym are just like unique identity of vehicle used to maintain the privacy of vehicle.

Step 1: vehicle to RSU

Phase 1: Before joining to the group vehicles select the group id to which it want to join.

Phase 2: It send authentication request to RSU by encrypting LP number with the public key of itself. This encrypted key is added with group id to which it wants to join, time stamp and previous pseudonym/random number. Time stamp is added by vehicle to prevent replay attack. RSU does not store any key so it is not able to decrypt the information. vehicle original identification is kept hidden from RSU.

ve_i : (PK_{VEC}(LP,GID),TS,PS)

Phase 3: Vehicles encrypt the authentication request with public key of RSU and send the generated message ve_i^+ to RSU.

ve_i^+ : PK_{RSU} (ve_i)

Step 2: RSU to TA

Phase 1: RSU decrypts the message ve_i^+ with its private key and stores it in rs^+.

rs^+: $PK^+_{RSU}(ve_i^+)$

It checks the time stamp to prevent replay attack and extract the pseudonym for future use.

Phase 2: RSU forward the rest encrypted message to TA.

Step 3: TA to RSU

Phase 1: CA decrypts the received message from RSU by using private key of vehicle PK^+_{VEC}(LP). It extracts LP number from the message.

Phase 2: If the decrypted value matches with the stored value in database of CA then it authenticate the vehicle. TA reply back RSU with symmetric key of that group and new pseudonym encrypted with vehicles public key.

ver_i^+: PK_{VEC}(SSK, PS)

Step 4: RSU to Vehicle

Phase 1: RSU adds the current TS and stored PS to the message and encrypt with its private key. Encryption provides message authentication. It sends back the message to the vehicle.

vev_i^+: $rs^+(ver_i^+$, TS, PS)

Phase 2: Vehicles wait for 2τ time from the request time. Where, τ is the total delay occurs due addition of security. If it get reply from RSU within the time interval then Vehicle decrypt the message and get symmetric key and new pseudonym otherwise it again sends request.

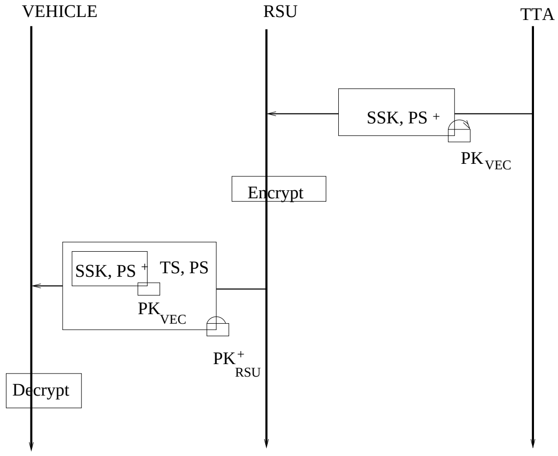


Figure 4.8: Key transmission from TA to vehicle

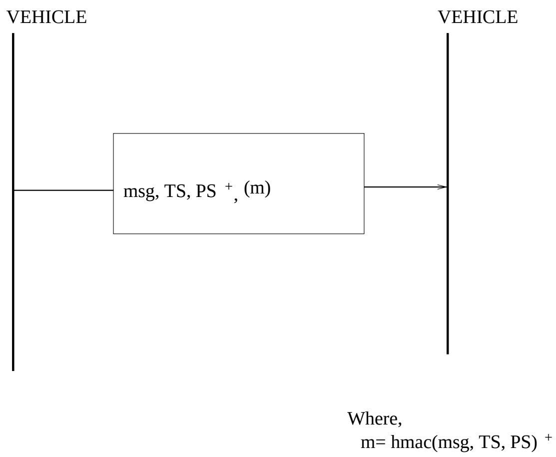


Figure 4.9: Secure communication between vehicles

4.4.4 Secure Communication between vehicle

Phase 1: Vehicles apply hmac function to the message and stores it in v_{msg}. Where, v_{msg}=hmac(message‖TS‖PS^+). Vehicle broadcast the message with (msg ‖ TS ‖ PS^+ ‖ v_{msg}).

Phase 2: At receiver end vehicle extracts the packet with other details and apply hmac to the received message. If both hmac are same then GL accepts the packet otherwise discards it.

Phase 3: If vehicle change the group then vehicle send the request to new group with its old PS and its previous GID. New GL confirms about the membership of vehicle based on reply from old GL and it provide new PS. It sends new PS of vehicles to the RSU for update.

4.4.5 Result

Table 4.3: Comparision with different broadcast algorithm

Scheme	Authentication	Non Repudiation	DoS prevention	multi hop comm.	Symmetric key verification	Symmetric key msg transmission
TESLA	√	×	×	×	√	√
TESLA++	√	×	√	×	√	√
VAST	√	√	√	×	×	×
proposed algo	√	×	√	√	×	√

Chapter 5

Conclusion

Conclusion

VANET group formation and using standard protocol specific for VANET enhance the quality and efficieny. Vehicles uses the group communiaction to reduce number of packets in the network. Which reduces packet collision. Vehicles use the benefit of group with or without the help of RSU depending on applications. RSU utilization increases the ifficiency but highly expensive RSU can not cover the large area of VANET.

Vehicles optimal path selection helps to reduce traffic congestion in urban environment. In our approach vehicles do not require any external hardware like sensors. We have followed the basic structure of VANET in which vehicles communicate with each other and road side units to share the information. Group based approach reduces the packet collisions in the network. GL sends the edge details to nearest RSU. RSU's placed near to roadside collects the information,aggregate, take decision and return back the optimized route to the vehicles. Our simulation results shows the dynamic path selected by vehicles due to congestion in path reduces the traveling time of vehicles. It also helps to reduce CO_2 emission by vehicles and fuel consumption.

We illustrated the design of a Group-based ESM message transfer Protocol. Various methods of Group formation are used in our proposed scheme, which varies with different scenarios. We have considered various parameters like priority of messages, context-based communication and velocity of nodes in our communication protocol to make it reliable and efficient.

Scope for Further Research

We will use coordinated traffic light for various junction. Traffic light duration at various junction varies with queue level at different edges. We also go for stochastic approach for optimized path selection for vehicles. We will further add various parameters to optimize the transmission of event-driven safety message. Security analysis will be done to further improve it and make it more secure.

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- Annexure -

Network simulators can simulate the Ad-hoc network but they cannot simulate the huge traffic of the road network. In order to solve this problem, specific VANET simulator is required. We have used Veins framework which is used to run a Traffic (SUMO) and a Network (OMNET++) simulator in parallel.

we have simulated our simulation on the realistic map of nit rourkela, India, and grid map network created with the help of SUMO. It includes TraCI (Traffic Control Interface) to provide communication between sumo and omnet++. Sumo acts as server while OMNET++ acts as client. It permits us to control the behavior of vehicles during simulation runtime, and consequently it provides better understandability the influence of VANET applications on traffic patterns. VANET simulation software can be divided into three different categories: (a) Mobility generators, (b) Network simulators, (c) Software which integrate (a) and (b) able to simulate both mobility and network (VANETs simulator).

Following simulators have been used to simulate our scenario based on different categories:

(1) Network simulators: OMNET++

(2) Road Traffic Simulator: SUMO

(3) Vehicular network simulation framework: Veins

Specifications for the versions that have been used to integrate simulators are as follows which have been used to integrate the simulators are as follows:

(1) OMNET++: version 4.2.2

(2) SUMO: version 0.15.0

(3) Veins: version 2.0

Steps used to integrate the simulators are as follows:

(1) Download SUMO zar files, unpack and install it.

(2) Download and build OMNeT++. Use Command "OMNETPP" to open it after installation.

(3) Download and build the Veins module framework. Import Veins framework in the OMNET++ as a project. After importing build it in the OMNET++.

(4) Make sure SUMO is working properly. Use command prompt to open SUMO GUI and run the sample example given in it.

(5) Make sure OMNeT++ and the MiXiM Framework are working. Run the MiXiM framework which is imported in the OMNET++.

(6) Run the Veins demo scenario by using the python code /c/Users/user/src/veins-2.1/sumo-launchd.py -vv -c /c/Users/user/src/sumo-0.17.0/bin/sumo.exe . Output is stored in trace file which is extracted according to requirement.

Following are the details for the simulator based on the requirements.

1. OMNET++: OMNET++ has been used to support network simulation. OMNET++ also import Veins and provide GUI for simulation. Basic structure of simulation is based on OMNET++. We are required to extends submodule of the given module as per our requirement. Basics of the simulator can be understand with the help of given tic-toc example.

2. SUMO: SUMO is used to generate the real-traffic road network. Roads, vehicles, traffic lights, obstacles near to road-side are generated by SUMO. Grid-map of the network is generated with the help of SUMO-documentation available on SUMO official website. Real-traffic map of NIT-Rourkela is downloaded from the Openstreetmap (Openly available). Downloaded OSM file are modified in JOSM (Java open street map editor) to make it suitable for use. It is modified to make it SUMO compatible.

3. Veins: Veins integrate all the files of SUMO in it. Basic scenario of Veins is run by choosing Run As- OMNeT++ simulation. Before run it, make sure

to allow access to SUMO through any personal firewall you might run. Now, editing of simulator is required as per our need.