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Efficient Communication System based on Multiple Access Techniques for VANETs

A Thesis

Submitted to the Department of Computer Science, College of Computer Science and Information Technology University of Anbar as a Partial Fulfillment of the Requirements for the Degree of Master of science in Computer Science

By

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Dedication

This thesis is dedicated to:

My Father's Soul

My Great Mother

My Lovely Husband

My Little Angel

My Brothers

My Sisters

My Friends

Tasneem Alani

2020

Abstract

Road traffic accidents are perceived as a serious problem in societies and one of the main reasons for fatalities, disability, and injuries that inflict humans all over the world. To minimize the hazard and ruthlessness of a road traffic accident a series of new safety applications can be achieved by employing wireless communication among vehicles travelling near each other or among vehicles and particularly installed Road side units (RSUs), a technology widely known as a Vehicular Ad Hoc Network (VANET). Most of the vehicular ad hoc network supported safety applications mainly rely on transmitting safety messages either by the means of vehicles or Road-Side Units, whether it is a periodical action or in the case of an unexpected event, such as detecting unsafe road condition or hard brake cases.

This thesis presents a multi-channel Time Division Multiple Access (TDMA) protocol and Code Division Multiple Access (CDMA) protocol which are designed specifically for supporting high priority safety applications in a vehicular ad hoc network scenario. Computer simulations are performed by the use of MATLAB. The scenario of a virtual city is simulated and various metrics for performance are evaluated, comprising protocol overheads, good network mode, channel usage, fairness of protocol, potential transmission collision, and delay delivery of the safety message.

The Cross-Layer design's performance in a multi-channel vehicular ad hoc network is evaluated in a highway scenario, principally in connection with delaying end-to-end package delivery. Queuing packages in each relay vehicle are considered in end-to-end delay analysis. Furthermore, the numerical results are provided to study the impact of different parameters, where CDMA provides a smaller transmission collision rate that leads to a significant rise in efficiency, where the E2E delay in TDMA has 37.026 sec and the CDMA has 36.3 sec. The scheme has a 94% packet delivery ratio in CDMA while has 92% in TDMA. The tested techniques can be seen as a promising tool for Medium Access Control in vehicular ad hoc networks, which is able to achieve various unconventional safety applications to boost the standards of public safety and enhance safety for passengers, pedestrians and drivers on roads.

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List of Abbreviations

Abbreviation	Description
ACK	Acknowledgement
BSM	Basic Safety Message
CTMAC	CSMA and TDMA Based MAC Protocol
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access/ Collision Avoidance
CSMA/CD	Carrier Sense Multiple Access/Collision Detection
CDMA	Code Division Multiple Access
DSRC	Dedicated Short-Range Communication
FDMA	Frequency Division Multiple Access
GPS	Global Positioning System
ITS	Intelligent Transportation System
IVC	Inter Vehicle Communication
IRC	Inter Road-Side Communication
IFS	Inter Frame Space
LANs	Local Area Networks
MAC	Medium Access Control
MANETs	Mobile Ad-Hoc Networks
OBU	On Board Unite
PHY	Physical Layer
RSU	Road Side Unite
RSI	Road Side Infrastructure
SDMA	Space Division Multiple Access
TMC	Traffic Management Center
TTU	Travel Time Updates
TUM	Traffic Updates Message
TDMA	Time Division Multiple Access
VANET	Vehicular Ad-Hoc Network
V2V	Vehicle-to-Vehicle

V2R	Vehicle-to-RoadSide Unite
V2I	Vehicle-to-Infrastructure

Chapter One

General Introduction

Chapter One

General Introduction

1.1 Introduction

The world's road safety report 2015, which includes information from 180 nations in the world, specified that the overall number of deaths in the road accidents was 1.25 million yearly, while the mortality rates were considered to be maximum in the low-income developing nations [1]. The majority of accidents leading to death were because of children’s safety systems, motorcycle helmets, high-speed, safety belts and drunk driving, indicating that humans are the major cause of accidents [2]. Thus, there is a need for using a lot of technical approaches for controlling such causes and reducing them [3]. The most important challenges that faced the emergency response domain are traffic congestion and the delay in the arrival of the emergency vehicles to the accident site. The emergency vehicles include police cars, fire trucks, or other more specialized vehicles.

Vehicular Ad Hoc Networks (VANETs) are a subgroup of Mobile Ad Hoc Networks (MANETs) with the distinguishing property that the nodes are vehicles like cars, trucks, buses and motorcycles. These nodes are highly mobile, and they are able to communicate with each other by Vehicle to Vehicle (V2V) communications and to connect to the infrastructures by Vehicle to Infrastructure (V2I) communications for services. The main goals of implementing VANETs are efficiency, safety and environmental friendliness.

The communication system plays an important role to deliver control data, important information, and cooperative awareness messages from source node to destination node. However, data transmission is always travelling through what so called “channel”. In this case, the fundamental problem of interference is raised spatially after the dramatic expansion of communication users. Thus, researchers have paid efforts for addressing this communication challenge. The concept of multiple access came into image to allow all users to share the radio resources without causing harmful effects to each other. These technologies are working at trade-off bases; in other words, at applications where a large band is required with no concern to time. The available frequency is very limited to intake of all spectrum users at once in the normal conditions; However, researches are conducted to study multiple access technologies as method to tackle the frequency deficiency. Such techniques are permitting users of the spectrum to share the bands without congestion or interference. The basic structure of communication infrastructure of vehicles can be seen as in Figure (1.1).

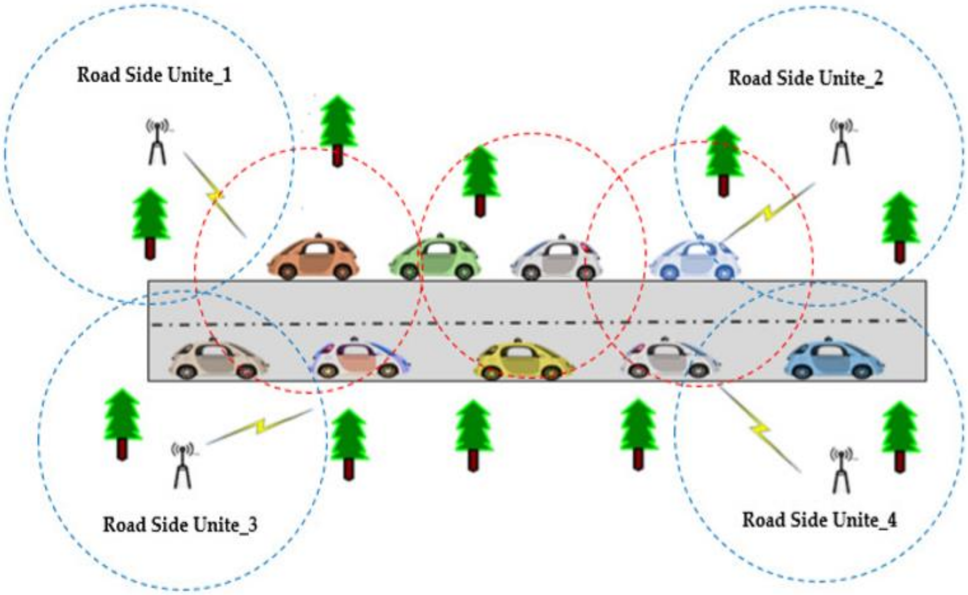


Figure (1.1). The basic communication infrastructure of vehicles [4].

We can easily notice that Figure (1.1) contains four road side units (RSUs) and vehicles. These RSUs play a significant role in providing sufficient radio signals which help in exchange control data, notification, and cooperative awareness messages as well as information.

In this thesis, the proposed system is considered as a flexible communication system with the ability to communicate between the main center and moving license vehicles taking into account the problems in the environment. In addition, communication system design according to Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) approaches for being more secure and flexible. The suggested system was carried out via a high-way environment concept for realizing high capacity, high quality of service, high security, and robustness. The systems is tested with the number of metrics and measured parameters to proves the efficiency of the communication system.

1.2 Motivation

Vehicular communication systems are defined as the communication networks in which roadside units and vehicles are communicating. Traffic information and warning messages are the transferred information in such communication type. Also, vehicular communication systems are of high importance in reducing traffic congestions and accidents. Because of the recent significant of road safety, the studies on Vehicle-to-Road Side Unit (V2R) and Vehicle-to-Vehicle (V2V) communications were increasing.

Typically, there are two networking types (V2R and V2V) related to wireless access in vehicular environments. The vehicular communications were specified as being part of Intelligent Transport Systems (ITS). Also, vehicular communication networks are offering a lot of applications including traffic management with real-time data to respond to the congestions of the road. At the same time, find an excellent path via accessing real-time data might be another benefit of the vehicular communication systems that result in saving fuel and time, along with many economic benefits. Yet, the road awareness message is considered the major aim of such a network.

In Figure (1.2) VANET consists of vehicles and RSUs that exchange awareness messages to give Vehicle the time to respond to events that threaten human life [5].

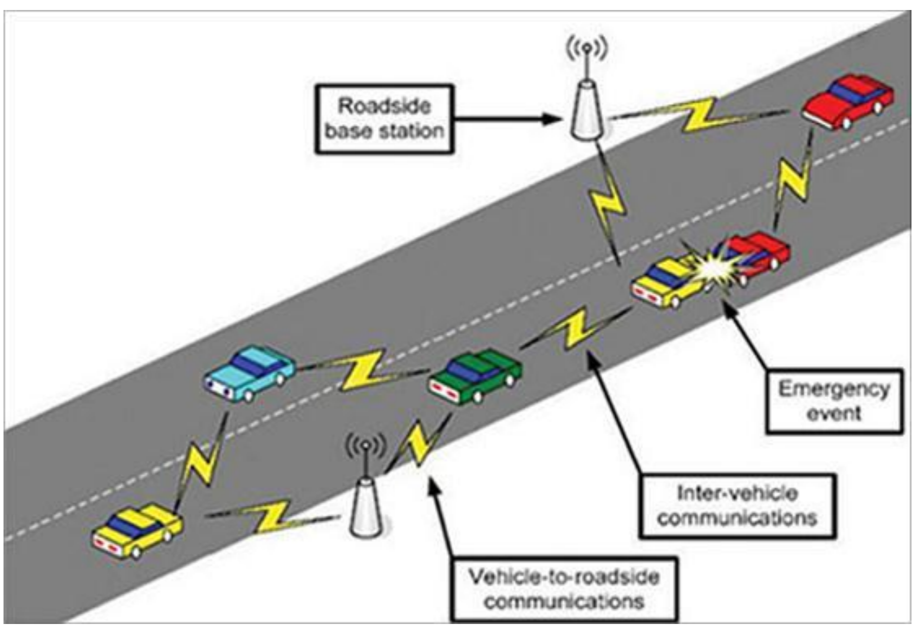


Figure (1.2). VANET Components [5].

1.3 Problem Definition

VANETs are suffering a lot of obstacles in traffic congestion, collision, secure communication between emergency vehicles and RSUs /other vehicles, and road safety, which are the cause of thwarting/delay the arrival of emergency vehicles (ambulance or police) to the danger area in time. Traffic jams and awareness messages between vehicles are one of the main issues in the modern urban areas causing a lot of road accidents in cities and deaths since the ambulance cars are not arriving at the right time. The Communication system is subjectable to various performance degrading factors such as noise, etc. These factors are acting against the performance and system quality of service. On the other hand, communication systems have dramatically expanded where the number of communication users (vehicles) is far increased. The problem of congestion in signal and send/receive awareness message has become more prominent, where not all vehicles are able to get service at the same time.

The methods of Multiple Access (Multiplexing) can be defined as the process used to combine multiple signals as well as transmitting them in a common channel, also it is an approach utilized to allow the communication over a single common channel via multiple users (vehicles). There are a lot of types related to multiple access approaches, such as Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), and Frequency Division Multiple Access (FDMA).

1.4 Literature Survey

The vehicles were majorly based on their communication systems which were external/internal systems for sensing the surrounding environments and move between the points. Concerning such condition, a lot of studies specified that the communication systems are of high importance to develop and. Yet, a lot of projectors have the aim of improving present communication systems of the vehicles. Also, the performance related to the vehicles was improved by enhancing their external communication systems. A few current associated studies are indicated in the next paragraphs.

In 2013, Hassan Aboubakr Omar, et al. a new multichannel TDMA MAC protocol specifically suggested for VANET. Also, the VeMAC is supporting effective single-hop as well as multi-hop broadcast services on the control channel with the use of implicit acknowledgments as well as removing hidden terminal problem, while the protocol is reducing transmission collisions because of the node mobility on the control channel through allocating disjoint sets of time slots to the vehicles which are moving in the opposite direction and to the road-side units. Simulation and analysis results in city and highway situations were provided for evaluating the performance of VeMAC as well as comparing it with ADHOC C, current TDMA MAC protocol for the VANET, [6].

In 2014, Muhammad A. Javed, et al. suggested space division multiple access (SDMA) approach along with an adaptive rate control method for improving the effectiveness of BSM transmissions. With SDMA for reducing the interferences between vehicles and addressing hidden node problems, just vehicles sufficiently located far apart were allowed for reusing the same time slot for sending their BSM. In addition, the developed SDMA method is permitting multiple transmissions for each one of the road segments and using CSMA/CA in each of the segments, to develop better use of bandwidth and space, [7].

In 2015, Mohamed Hadded, et al. provided the significance of utilizing the collision free medium access control paradigm in the VANET, and after that showed a new topology-based classification as well as providing a summary of the TDMA based MAC protocols which were suggested for VANET. The study focused on the properties of such protocols, also their drawbacks and advantages. Lastly, providing qualitative comparisons, and discussing a few of the open issues which must be handled in future researches to improve the performance related to the TDMA based MAC protocols with regard to V2V communications, [8].

In 2016, Nyoman W. Prasetya, et al. suggested clustered based TDMA through a traffic priority in the VANET. Also, the clustered traffic was specified as low and high traffic priority and embedded in the TDMA MAC Header, while the evaluation results are showing that the suggested method is performing better in the high density of nodes, [9].

In 2017, Jiawei Huang, et al. designed a CTMAC, which is considered as a MAC protocol that is synthesizing the current approaches; including, the arbitral reserving channel (utilized in TDMA based protocols) as well as the random accessing channel (utilized in CSMA style protocols). Also, the CTMAC is swiftly changing its approach based on the density of the vehicle, while its performance was better in comparison to other modern protocols. It is evaluating the CTMAC with the use of at scale simulations, the results of their work specified that the CTMAC is reducing channel completion time as well as increasing the goodput of network by 45% for a lot of network settings and application workloads, [10].

In 2018, Khattab M. Ali Alheeti, et al. proposed an external communication system of autonomous vehicles that utilizes CDMA scheme to improve its communication performance, to reach high capacity, high quality of service, high security, robustness and overcoming the obstacles in TDMA. The significant contribution in this paper is enabled autonomous vehicles to exchange essential information and control data between vehicles and RSU in that radio converge area. It enables vehicles to communicate in waste communication cases, such as; low bandwidth, accident, and jamming, [4].

In 2018, VanDung Nguyen, et al. suggested a modified packet which is transmitted in the TDMA period to reduce the transmission overhead within a hybrid TDMA/CSMA multi-channel MAC protocol. In addition, the simulation results are showing that a MAC protocol with a modified packet is supporting effective packet delivery ratio related to the control packet in CCH. Furthermore, the study analyzed hybrid TDMA/CSMA multi-channel MAC protocol with modified packets within saturated throughput situations on the service channels (SCHs), while the analysis results are showing that the number of neighbors has an insignificant impact on the establishment regarding the number of time slots in the TDMA periods as well as on the SCH within saturated throughput situations, [11].

In 2018, Khattab M. Ali Alheeti, et al. suggested a system for intrusion detection for protecting the communication systems regarding self-driving cars; combine hierarchical models based on of log parameters and cluster developed for detecting Sybil and Wormhole attacks in the high-way usage situations. It is according to clusters, utilizing TDMA for overcoming a few of the problems of VANET including high mobility and density, also limitations of bandwidth to exchange messages, each one of the vehicle logs is calculating and storing various parameter values following receiving cooperative awareness messages from the close vehicles, [12].

In 2019, Amrit Suman, et al. present MAC protocol embeds automatic size adjustment of contention window according to network capacity, channel allocation for each node based on TDMA and SDMA, priority assigning for each type of messages and security checking for each packet using CRC. The proposed MAC is compared with the conventional MAC protocol on two parameters, speed of the nodes and number of nodes .The results show that the proposed MAC performs better with respect to conventional MAC protocol. The proposed MAC can be used in V2V, V2I, and V2RSU communications, [13].

In 2020, Jinbin Hu, et al. present a MAC protocol TDMA based on motion-prediction is proposed to choose the forwarding node in the next time frame according to the moving direction, speed and geographical location of the vehicle nodes. It also propose a collision resolution strategy based on the changing rate of the number of neighbor nodes to reduce the accessing delay. The experimental results show that the motion-prediction TDMA protocol effectively reduces the multi-hop transmission delay and transmission count, thus enlarging the effective transmission range and improving the transmission efficiency, [14].

1.5 Thesis Objectives

The main objective of the presented work is to design and building a communication system based on multiple access techniques that is used to exchange information between vehicles (V2V) and vehicles/RSU (V2R). The suggested system was carried out via high-way environment scenario for reaching high capacity, high quality of service, high security, and robustness. The communication system was improving the performance of network transmission by using TDMA and CDMA MAC protocol with the ability of providing adequate broadcast service required for supporting quality of services requirements related to VANET periodic as well as event-driven safety application.

Lastly, comparing the two approaches and getting the results of the suggested communication systems according to certain performance metrics with the use of MATLAB.

1.6 Thesis Outline

The content of this thesis is divided into five chapters:

Chapter One: gives introduction of the study, Motivation, Problem Definition, thesis Objectives, and survey about the related works.

Chapter Two: presents the theoretical background of VANET, VANET challenges, characteristics, and application. Also, we will focus on the Self-driving cars, Multiple access techniques.

Chapter Three: presents the general description of the proposed system with details of design and the algorithms used in designing and implementing it.

Chapter Four: shows discussions and results based on the number of parameters metrics.

Chapter Five: presents future works and conclusions.

Chapter Two

Theoretical Background

Chapter Two

Theoretical Background

2.1 Introduction

VANETs are defined as novel network technologies obtained from the Ad-Hoc Networks and providing wireless communications between vehicles (nodes). It has many possible important applications. VANET is an advanced application of MANET, which can enhance road safety, essential emergency alerts, traffic management, and infotainment facilities for drivers and passengers with increased efficiency of the transportation systems [15]. VANETs are technologies of high importance for the future smart vehicle systems as well as being an essential component of Intelligent Transportation Systems (ITSs), which involves a lot of state-of-the-art technologies including wireless communication devices, video cameras, GPS, and sensing devices. It provides important in-time information related to road conditions for drivers as well as the systems of traffic management for enhancing traffic efficiency, reducing traffic congestions, waiting time, and the consumption of fuel.

VANETs communications can provide three techniques, they are Inter Roadside Communication (IRC), Inter-Vehicle communication (IVC), and/or communication between vehicles and fixed roadside equipment (V2R) communication as can be seen in Figure (2.1) [16]. In VANETs, each vehicle acts as a communication node (sender and/or receiver) to share the information either directly between vehicles as single-hop connection, or vehicles can be capable of retransmitting messages, in that way enabling multi-hop communication [17].

In VANET environment, each vehicle has its structure in a device called On Board-Unit (OBU) / Radio interface that facilitates them to communicate with other vehicles and RSUs and also enabling short-range wireless ad hoc networks which receives security messages such as unexpected break warning from other vehicles, essential emergency alerts and non security messages such as comforts & amusement related information [18]. In general, OBU helps the vehicle to be warned with critical situations such as accidents, traffic jams, and predicting the movements of the nearby vehicles through the dissemination of traffic associated messages with information related to the current time, speed, position, acceleration/deceleration, direction and so on. The draft reference communication architecture of the VANET is indicated in Figure (2.2).

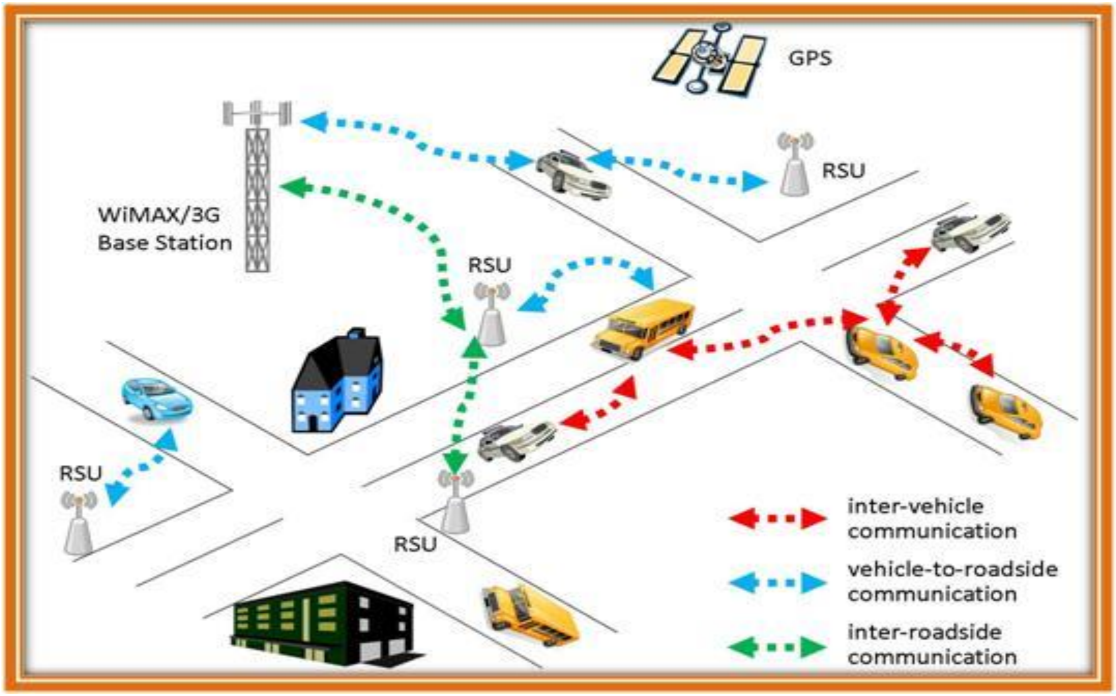


Figure (2.1). Vehicular Ad hoc Networks [16].

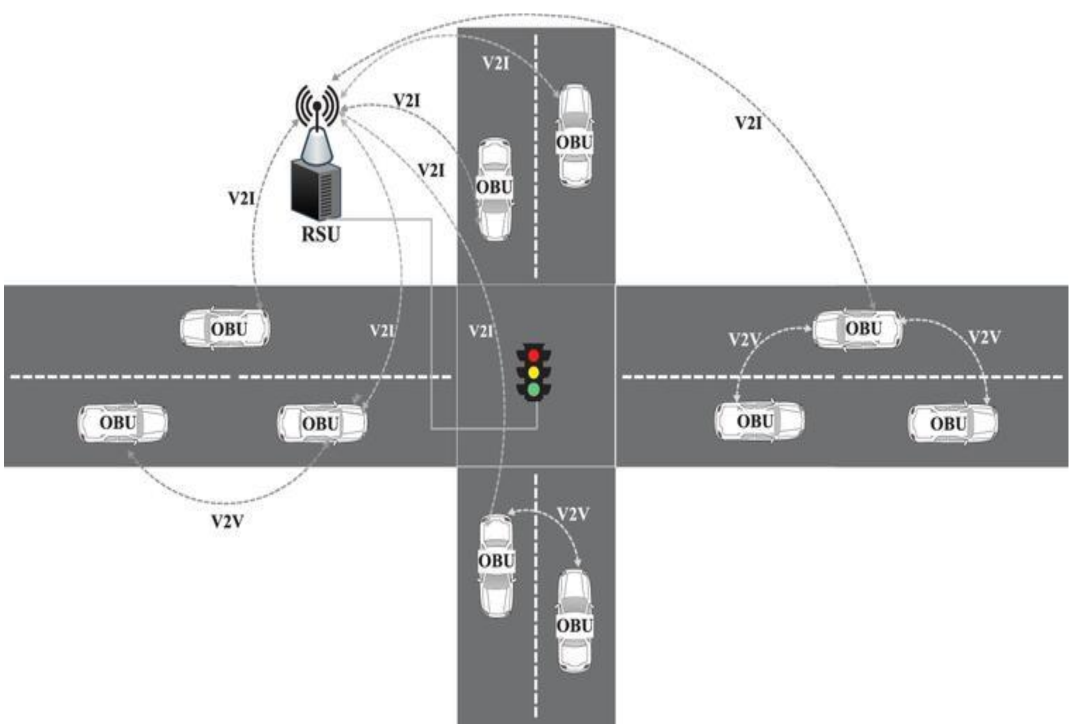


Figure (2.2). The communication architecture of the VANET[19].

2.2 Characteristics of VANETs

There are some similarities between MANETs and VANETs self organizations, infrastructure-less, low and variable bandwidth, and short-range connectivity, VANETs are characterized with some characteristics such as highly dynamic topology and reliable channels by which to distinguish them from MANETs. Moreover, most of the MANETs routing protocols might not be utilized in VANET, as they are suffering from bad performance because of the high mobility of vehicles. VANETs have unique and significant properties impacting the protocol security and the design related to communications systems, such characteristics are summarized as follows [20][21]:

1. Highly Dynamic Topology: VANETs have a highly dynamic environment because of the random movement and high-speed of vehicles, while the topology is frequently changing since the links between the nodes are connecting and disconnecting and the time duration for exchanging the data packets remains small. Furthermore, each one of the vehicles might be directly communicating with other vehicles in the case when they have a line of sight to each other in the radio range. In general, the radio domain of vehicles is about 300 m.

2. Large number of nodes: Generally, VANETs as a technical basis with regard to envisioned ITS. Thus, it is anticipated that a large part of vehicles is going to be equipped with abilities like GPS for vehicular communications in addition to fixed road-side infrastructure units.

3. Frequent disconnecions: In VANETs, the highly dynamic topology leading to the occurrence of frequent disconnections between 2 vehicles as they are exchanging information, such disconnections between the vehicles often occur in the high-ways because of the low density of vehicles. In city scenarios, huge buildings and trees often weaken the network signals, which may lead to a breakdown in communication between vehicles. Vehicles will have the highest probability of changing their directions on urban roads.

4. Unlimited storage and computational power: Smart vehicles consist of electronic chips with enough power and storage capacity, so they can store routing information, drivers and vehicles identity confirmation, and other information. Vehicles itself is providing continuous energy to their computing as well as communication devices.

5. Interaction with onboard sensors: Vehicles can use the onboard sensors like GPS device to provide the information like their location, direction, moving speed of nodes, and other vehicle-related information, such information might be utilized for routing decisions and efficient communication.

6. Communication Environment: VANETs are divided into two types of environment sparse network (like highways) and dense network (like urban areas) according to the difference of traffic densities. In a dense network, there are many objects such as buildings, trees & other objects that act as obstacles. This obstacle may reduce signal bandwidth and data transfer speed among vehicles and RSUs. In a sparse network, all these obstacles are less prone and do not impact the connection between vehicles.

7. Restricted and predictable mobility patterns: Dissimilar to the MANET's random mobility, the VANET mobility model is maintaining connectivity via restricted rules such as traffic flow, speed, road maps, etc., that make them predictable as a minimum on short-run.

8. Hard Delay Constraints: In some of VANETs safety applications, emergency messages must be provided with high-priority and should be provided to relevant nodes (e.g. disasters, accidents) on time, such applications have high requirements with the reliability and real-time. Thus, end-to-end delay related to even a single second can impact negatively the importance of emergency information meaningless.

9. Network connectivity: In VANETs can measure the degree of network connectivity depends largely on two important aspects are:- the range of wireless links as well as the portion of participant vehicles(nodes). Therefore, just a portion of vehicles on the road might be equipped with wireless interfaces.

2.3 VANET Challenges

In recent years, traffic jams and accidents increase due to an increase in traffic volume. Thus, VANETs face many challenges that require further study and discovery to get the best solutions for VANET infrastructure, safety, applications, and services. There are some salient challenges are summarized as follows [16][17][21]:

1. High Mobility: In general, each node in the ad hoc network is mobile that can move from one site to another within the coverage area, but still the mobility is restricted. In VANET, each node in the network is a vehicle that can move from one location to another very quickly. Due to the high speed and random movements of vehicles, connections are quickly created or discrete.

VANET mobility model built on vehicle speed, communication environment (sparse or dense network), driver's behavior, and road structure.

2. Volatility: In VANETs, the connectivity between vehicles might be for a short period. Vehicles traveling within the coverage area working a connection with other vehicles, these connections will be missing due to the high mobility of vehicles and/or traveling in the opposite direction.

3. Security: is a big challenge for vehicular communication that needs to be carefully assessed and addressed in the design of the vehicular communication system. In the VANETs environment, if there is no fixed infrastructure, vehicles will depend on other vehicles that are unreliable to propagate data. There are a lot of risks like fake messages, leaking of private information, etc. Therefore, it is necessary to detect fake messages that cause traffic congestion and enforcement of unknown behavior for unreliable individuals to avoid vehicle tracking and identification.

4. Privacy: is a major issue used to authenticate messages, keep the data of the drivers, and location private from unauthorized pepole. This data such as trip path, speed, real identity, etc. The privacy might be applied for tracking the movement of vehicles and revealing the permanent identities of vehicles. Privacy can be achieved through the exchange of temporary keys between vehicles, these keys will be changed constantly as each key might be utilized just one time and expire following usage, and therefore will do not let unknown parties track driver's movement.

5. Authentication: In VANETs, every message must be authenticated with ensuring the authenticity of communication within entities, thus the vehicle must be reacting to events just with the disseminating messages created via authorized senders. Due to repeat messages, every message must be signed digitally and verified for the signature before transmission with utilizing authenticated timestamp in the message.

6. Network Scalability: In the world, the number of users and/or vehicles is in continuous increase, leading to traffic jams and this will affect the performance of the network or maybe network outages and without changing the system components and protocols, for example, the size of this network in the world approximately exceeding the 750 million nodes, and there is no a global authority, rule the criteria for this network.

7. Routing issues: Due to rapidly changing network topology, there is no fixed route of the packet. Based on the carry and forward concept in vehicular communication networks, a packet was carried via a node until it could be forwarded to a node being closer to the destination.

8. Integrity: The integrity service is addressing unauthorized access to information and the disclosure of data manipulation by unauthorized parties, this is ensuring that the messages were received as sent, with no insertion, modification, replays, or reordering.

2.4 Applications of VANETs

VANETs applications are divided into classes for each one there is a set of protocols. Without classification, development, or designing a separate protocol for each application will be difficult work. The advantages of that classification are [22]:

1. Developing a little number of applications in one class will give benefits validation and simulation for most applications that are classified under the same class.

2. Defining key of performance metrics related to each class of applications that enable from evaluating whether the designed application meets the specifications of that class.

3. For each class, there is a network protocol stack that has important consideration in improving, development and reusability of network protocols.

2.4.1 Safety Applications

These types of applications are designed for driver assistance in handling incoming events in a nearby environment by message exchanges. Following examples of this type of application [22]:

• **Intersection collision warning:** this type of application warning users from probability collision happen on an intersection by using RSI (Road-Side infrastructure) and OBU (On-Board Devices Unite) that issue warnings to the certain vehicle or all the near drivers based on warning strategy.

• **Post Crash Warning:** in this application, a message about a crash appears to transmit it either V2I or V2V.

• **Emergency Electronic Brake Lights:** this application is sending a message to the vehicle behind in the case that suddenly breaking or the front vehicle of him that breaks hard.

• **Road Condition Warning:** these messages about road conditions such as the road ahead was icy or slippery.

2.4.2 Traffic Management Applications

These applications are increasing the driver's convenience with sharing traffic information between (V2V) and (V2I) as following [22]:

• **Congested Road Notification:** vehicle in this application reports to other vehicles for congestion in front of it to allow other vehicles to take detour in advance.

• **Parking Availability Notification:** vehicles are receiving availability parking in a certain geographical area.

• **Parking Spot Locator:** this application enables drivers to allocate a slot in parking.

2.4.3 Commercial Applications

These applications provide comfort for drivers by providing with communication services, following some of these applications [22]:

• **Service announcements:** these applications broadcast information periodically to the vehicle, for example, the announcement of food malls.

• **Map download:** the vehicle can update the existing map or can be access to map providers.

2.5 Vehicular Communication Layers

Data transfer between vehicles is accomplished in three ways: multi-hop, single-hop, and bidirectional, with each of them is utilized for certain applications. The bidirectional was considered as conventional communication in 2 directions, while the other regimes were 1-way communications; faster communications. For transmission all vehicular information, the need for a protocol which is handling the messages transmitted and attempts on avoiding message collisions will be necessary. So, the Medium Access Control (MAC) layer will be responsible for that. Physical channel(s) with a dedicated frequency range used to transfer information called the physical layer (abbreviated PHY). A routing layer is needed for moving the data from source to destination, the architecture indicates "fundamental organization related to a system embodied in its components, the relations to each other, and environments, as well as principles guiding its evolution and design" [23].

Figure (2.3) shows the application layer which arises on top of vehicular communication layers. All layers below it in the communication system from high-level to the down were provided, such layers: Routing, MAC, and PHY. Orthogonal to these is the security layer.

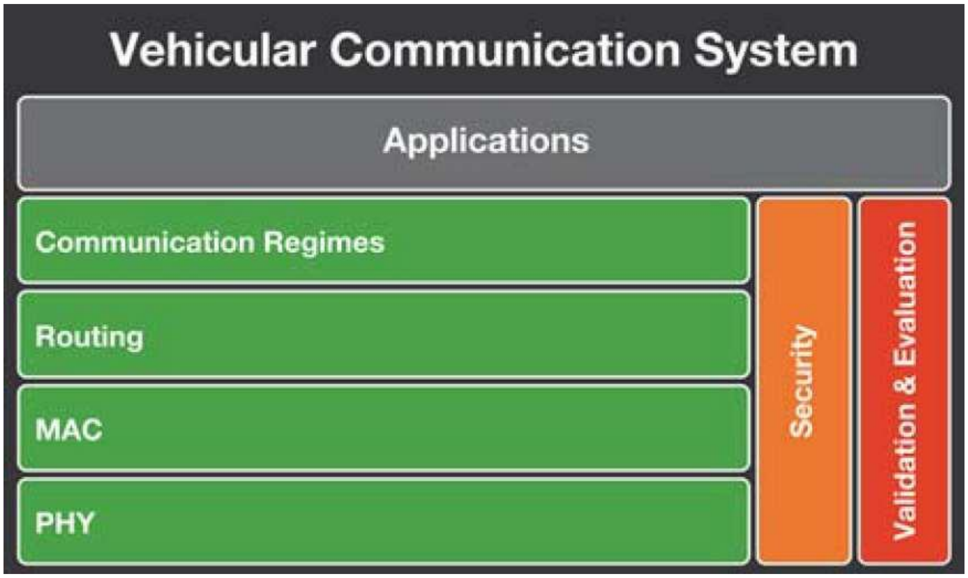


Figure (2.3). Vehicular communication layers [23].

2.6 Intelligent Transportation Systems (ITS)

Intelligent Transportation Systems (ITS) is an innovative technology to provide safety and reduce congestion in road traffic scenarios. Different services and applications are being developed and studied to make transportation safer and efficient. Wireless communication of vehicles to road-side units or between vehicles is the key element to enable the ITS services. ITS uses communication technologies and information to make various modes of transportation more efficient, safer, smarter, and cleaner. With regard to surface transportation, VANETs were frequently utilized for providing wireless communications between at least 2 systems. Also, a VANET includes vehicles which are equipped with wireless device (with a range of transmission up to some hundred meters) communication with fixed road-side units and with each other with no requirement for infrastructures like base-stations or access-points [24]. In addition, the dissemination related to VANET's safety messages was a major ITS aspect. In 2011, the European commission indicated over 30,000 deaths in road accidents [25]. With regard to highway accidents, distributing accident warning messages in an efficient and timely way to surrounding vehicles might be saving a lot of lives as well as reducing the congestion of traffic. Furthermore, the ITS is providing multi-hop wireless communications for distributing messages beyond the sender's transmission range, which is achieved via enabling forwarding the messages via the vehicles in the network.

2.7 Self-driving vehicles

These vehicles represent a technological advancement which might be providing solutions to existing transportation issues and considerably changing how individuals are approaching mobility. High rates of traffic accidents, more congestion, and increasing emissions of carbon were some results of auto use. In addition, the self-driving vehicles are offering alternate types of individualized transportations which might be used for reducing the bad effects. Whereas the self-driving vehicles will be possibly enhancing sustainability, efficiency and safety of our auto-oriented transportation system, a lot of obstacles remain, especially with the perception of the public regarding safety, control, and liabilities. Also, the capability of self-driving vehicles in affecting transformative changes are largely depending on how effective the vehicles are to attract the driver from private auto-mobiles. As soon as establishing critical mass regarding the self-driving vehicles, network benefits as well as other economies of the scale enable environmental, safety, and travel time enhancements. The attitude of the public towards self-driving vehicles is more and more significant as the public is shaping the demands and market for cars, policies handling them and, and future investments in infrastructure [26].

Recent works on vehicular systems are exploring encouraging future for the vehicular communications, they are considered novel applications which are reducing road fatalities, resulting in greener transportations, and enhancing the driving experience. Apart from safety, autonomous vehicles are providing a lot of advantages. For persons who lost their driving privilege due to disability or age, the autonomous vehicles are going to be removing the spatial barriers preventing their interaction with community, friends, and family. This isn't only applicable for society, yet also commercially as it is increasing the number of individuals who might be considering buying automobiles, while the environmental effects of driving will be reduced via autonomous vehicles. Furthermore, the autonomous trucks and cards might be tuning their deceleration and acceleration profiles for reducing wasted fuel. Since the autonomy technologies are becoming ubiquitous, the manufacturers have the ability to reduce the mass of vehicles since a large part of the mass was used to protect occupants. Due to the linear relation between fuel consumption and vehicle mass, there will be a possibility for trading intelligence for the mass of the vehicle, thus increasing fuel efficiency and safety. The prospects regarding such applications are according to the presence of predictable communication infrastructures for the dynamic networks [26].

As we know, self-driving vehicles are modern fully automated vehicles that involve directly with carrying people, so it is very important to be safe with these vehicles. Thousands of people die every day because of traffic accidents and most of these accidents are caused by humans. Recently, many expectations realize that self-driving vehicles will be ready on the road by 2020. External communication has a few properties which are causing its inherent performance problems: car speed, high-dynamic topology, non-existence of fixed security system, the density of vehicles, and open medium wireless communication. All these obstacles made autonomous vehicles expose big challenges before explicitly on roads. Many car industries and companies expected that driverless vehicles will be ready on the road by 2020. Self-driving Vehicles will generate powerful benefits as shown in Figure (2.4) [27-31]:

- **Reduce accidents:** If committed to applying self-driving vehicle laws, so accidents have been reduced to the lowest possible. About 1.2 million individuals are dying yearly from traffic accidents and about 94% of those accidents, are caused by human error.
- **Increase productivity:** self-driving vehicle improves human productivity that results from leaving thinking about driving.
- **Congestion avoidance:** Congestion is a big problem experienced by many of the streets and the self-driving vehicle is equipped with techniques that enable them to choose the best ways to help ease congestion.
- **Fuel saving:** Electric self-driving vehicle is considered very economical because it needs only continuous charging which does not cost.
- **Reduce pollution:** Since the electric self-driving vehicle relies on electric power, it does not cause any pollution compared to other cars.

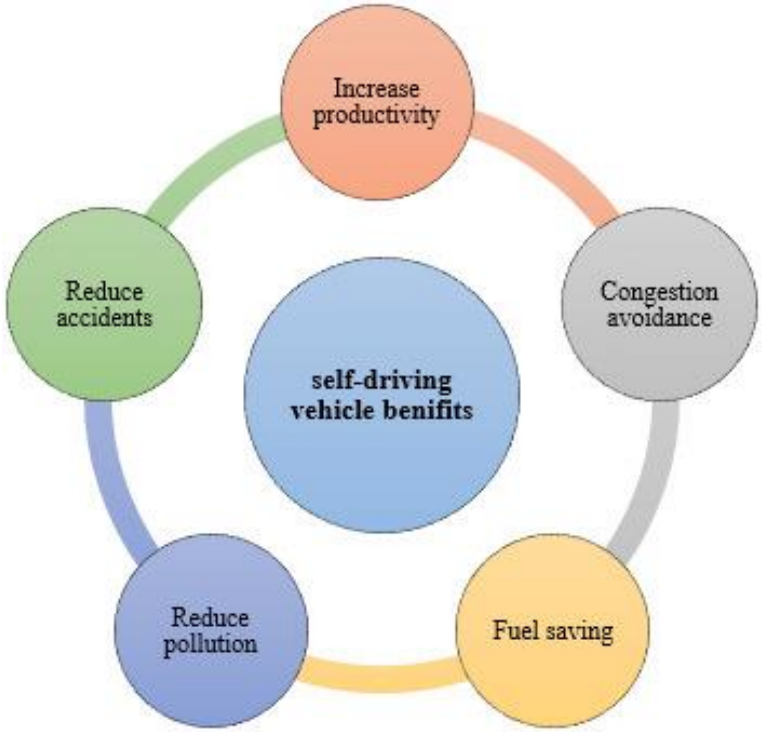


Figure (2.4). Powerful benefits of self-driving vehicle[4].

2.8 Multiple Access Protocol

The Medium Access Control (MAC) is used to transmit data between two nodes, its major functions as [32]:

1. Data Link control

The data link control was accountable for adequately transmitting the messages over the transmission channel with the use of certain approaches such as flow control, error control and framing.

2. Multiple Access Control

When there is a dedicated link between receiver and sender, then the data link control layer will be adequate, otherwise multiple stations might be simultaneously accessing the channel. Therefore, multiple access protocols were needed for decreasing collisions and avoiding crosstalk. For instance, in a classroom which is full of students, as the teacher is asking a question and all students (or stations) are simultaneously answering (sending the data at the same time), then the chaos will be made (data lost or data overlap), then it will be the teacher's job (multiple access protocols) to handle students and making them answer the questions one by one. Therefore, protocols were needed to share data on non-dedicated channels. Also, the multiple access protocols might be categorized as in Figure (2.5).

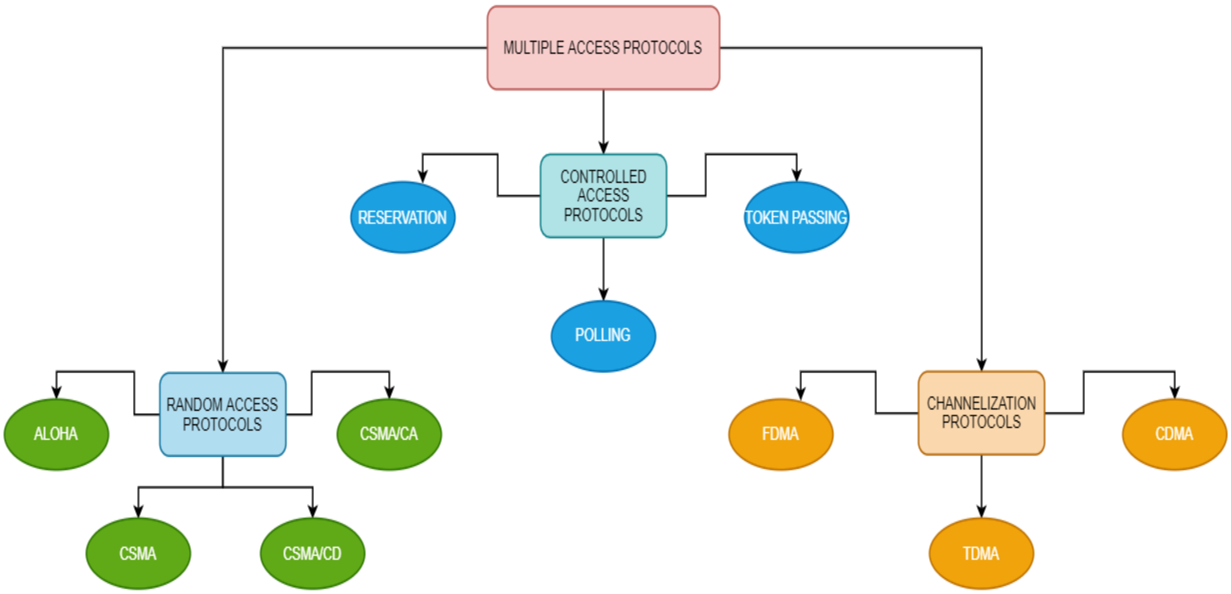


Figure (2.5). Classification of Multiple Access Protocols[33].

2.8.1 Random Access Protocols

The same superiority exists in all stations, in a way that there is no one of the stations has more priority compared to others, while any of the stations has the ability of sending data according to the state of medium (busy or idle). It has two features [32]:

1. There isn't fixed sequence of the stations sending the data
2. There isn't fixed time for sending data

Random access protocols might be additionally sub-divided as follows:

2.8.1.1 ALOHA

It is developed for wireless LANs, yet it can be used for shared medium. Actually, multiple stations might be transmitting the data at the same time and might thus result in collision and the data will be garbled [32].

Pure Aloha: In the case when a station is sending data, then it will wait to receive acknowledgement. In the case when acknowledgement does not come withing the allocated time, then the station will be waiting from random amount of time referred to as back-off time (Tb) and resending the data. As a lot of stations are waiting for different amount of time, there will be a decrease for the probability of more collision.

Slotted Aloha: It is considered to be comparable to the pure aloha, apart from the time will be divided into slots and sending of data will be enabled just at the beginning of such slots. In the case when a station missed out the allowed time, it should be waiting for the next slot, thus the probability of collision will be reduced.

2.8.1.2 CSMA

Carrier sense multiple access (CSMA) is ensuring less collisions since the station is needed to initially sensing the medium (busy or idle) prior to transmitting the data. It will be sending the data when it is idle, or else it is waiting until the channel become idle. Yet, there remains a possibility for collision in the CSMA because of propagation delay. For instance, in the case when station A want to send the data, it will be initially sensing the medium. In the case when the channel is idle, then it will send the data. Yet, after the data's first bit is transmitted (delayed because of propagation delay) from the station A, as station B is requesting to send data and sensing the medium, it will also find it idle and is going to be sending the data, this is going to lead to data collision from station A and B. The access modes of CSMA are as follows [32]:

1.Persistent: The channel is sensed via the node, it will send the data when the channel is idle, or else it will keep checking the medium for being idle and unconditionally transmits (with 1 probability) when the channel is identified for being idle.

2.Non-Persistent: The channel is sensed via a node, the data will be sent when the channel is idle, or else it will be checking the medium following random amount of time (not continuously) and transmit the data when the channel is idle.

3.P-persistent: The medium is sensed via the node, data with p probability will be send when the channel is idle. In the case when the data isn't transmitted ((1-p) probability), then it will be waiting for certain amount of time and checking the medium again, then it will send with p probability when the medium is idle, such process will be repeated till the frame is sent. It is utilized in packet radio systems and WIFI.

4.O-persistent: Node's superiority will be decided earlier and transmission happen in such order.

The node will wait its time slot for sending data in the case when the medium is idle.

2.8.1.3 CSMA/CD

In Carrier sense multiple access/collision detection(CSMA/CD), the stations have the ability for terminating data in the case when collision is identified [32].

2.8.1.4 CSMA/CA

In Carrier sense multiple access/collision avoidance(CSMA/CA), the collision detection process includes the sender receiving acknowledgement signals. In the case when there is only 1 signal (its own), then the data will be effectively sent, yet when there are 2 signals (its own along with the other one that is collided), it indicates that a collision happened. For the purpose of distinguishing between such 2 conditions, a collision should have an effect on the received signal. Yet, it isn’t in wired networks, thus the CSMA/CA will be applied in such case, collision is avoided via CSMA/CA via [32]:

1.Interframe space: The station will be waiting for a medium to be idle, and when the medium is found to be idle, then it doesn’t directly send data (for avoiding collisions because of propagation delay), or else it is waiting for a period of time referred to as IFS. After such time, it will be again checking if the medium is idle. The duration of IFS is according to the station’s priority.

2.Contention Window: This is considered as the amount of time which is divided into slots. In the case when the sender is ready for sending data, it will be choosing random number of slots as wait time that will double each time the medium isn’t idle. Also, in the case when the medium is busy, then it will not be restarting the whole process, yet it will be restarting the timer in the case when the channel is idle again.

3.Acknowledgement: The sender is retransmitting the data in the case when acknowledgement isn’t received prior to time-out.

2.8.2 Controlled Access Protocol

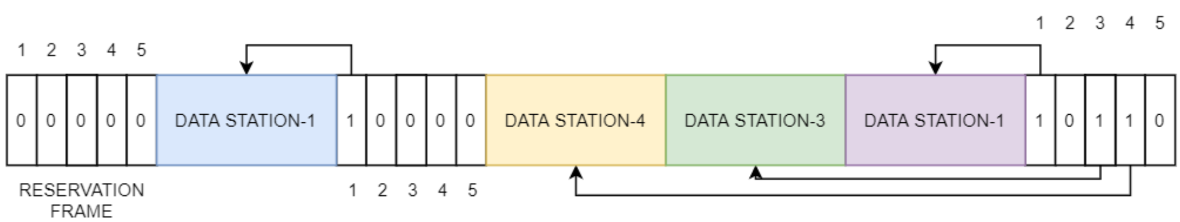
In controlled access, the stations attempt to gain the information from each other for finding the station that has the right of sending. It permits only a single node for sending each time, for avoiding the collision of the messages on the shared medium [32].

2.8.2.1 Reservation

In this approach, a station is required to be making reservation prior to the sending of data. The timeline has two period types:

1. Fixed time length interval of the reservation.
2. Variable frames' data transmission period.

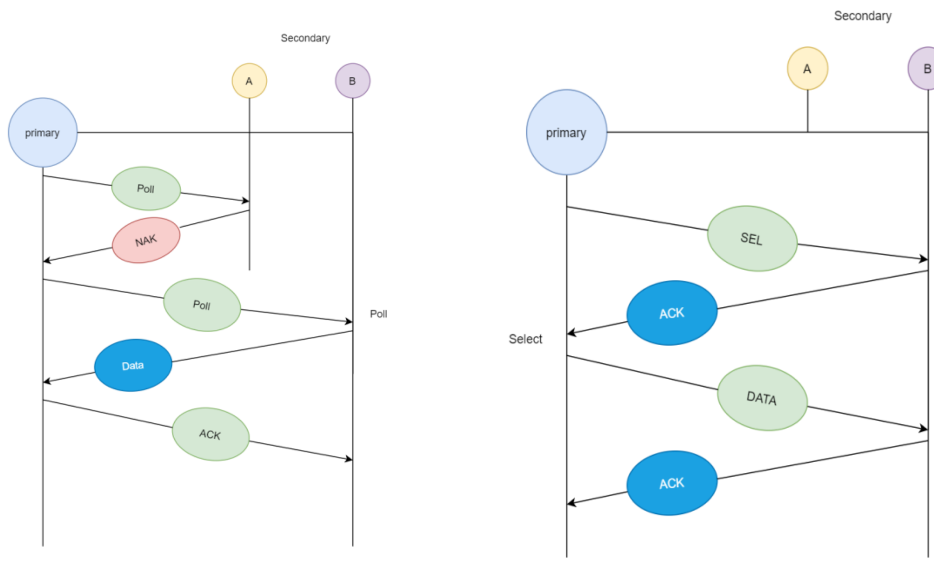
Considering that there are M of the stations, this interval of reservation is split to M slots, and every one of the stations has a single slot. Supposing that the station 1 has a frame to be sent, it will transmit one through slot 1. None of the other stations is permitted to be transmitting through that slot. Generally, i the station may be announcing that it has a frame that needs to be sent through the insertion of a 1 bit in the i slot. After checking all of the N slots, every one of the stations will know the stations that require transmission. The stations that reserved their slots will transfer the frames in this order. Following the period of the data transmission, the next interval of reservation will begin. As everyone has agreed on the one that will go next, there won't be any collision cases [32]. Figure(2.6) below illustrates a case with 5 stations and a 5-slot reservation frame. In the 1st interval, stations 1, 3, and 4 reservation made the reservations. In the 2nd interval, station 1 only made the reservation.



Figure(2.6). The procedure of reservation[34].

2.8.2.2 Polling

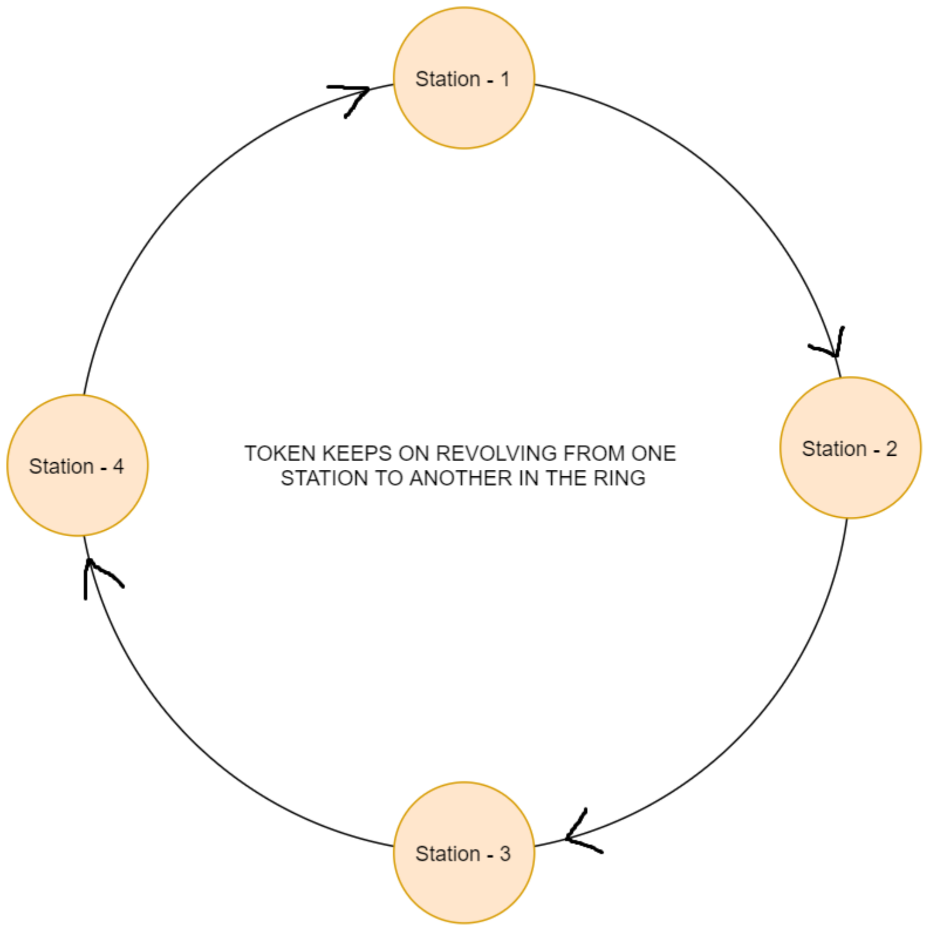
The procedure of the polling is similar to roll-call which is done in the classroom. Similarly to a teacher, the controller will send a message to every one of the nodes in turn. In which case, one plays the role of the primary station (i.e. the controller) and the rest will be the secondary stations. All of the data exchange operations have to be carried out via the controller. The message which is sent by controller includes the address of node which has been chosen to grant the access. Even though all of the nodes get the message, however, the addressed node will respond to it and then send the data, if there is any, otherwise, often a "poll reject" (NAK) message will be transmitted back. The issues include high polling message overhead and high dependence on the controller's reliability [32], as shown in Figure (2.7).



Figure(2.7). The procedure of polling[34].

2.8.2.3 Token Passing

In this method, as shown in Figure (2.8), stations are logically connected to one another as a ring and station access is regulated by the tokens. The token can be defined as a small message or a special bit pattern, circulating from a station to the next in the predefined manner. In the Token ring, the token will be passed from one of the stations to the other neighboring one in that ring, while in the case of the Token bus, every one of the stations utilizes the bus for sending that token to the following station in a specific order. In those two cases, the token will represent permission for sending. In the case where the station has a frame which has been queued for the transmission when receiving a token, it becomes capable of sending that frame prior to the point where it passes that token to the following station. In the case where it does not have any queued frames, it will simply pass the token. Following the frame sending, every one of the stations has to wait for all of the N stations (and that includes itself) for sending the token to their neighbours and the rest of the N – 1 stations to send a frame, if there is any. There are issues such as the token duplication or loss or new station insertion or removal that require being addressed for the reliable and suitable process of this method [32].



Figure(2.8). The procedure of token passing[34].

2.8.3 Channelization Protocols

In this, the available link bandwidth is shared in frequency, time and code to several stations for the simultaneous access into the channel.

2.8.3.1 Frequency division multiple access (FDMA)

FDMA provides frequency spectrum chunks which will be utilized in the data transmission. Data is produced at baseband and will be modulated at a variety of the radio frequency values. The guard band is proposed for avoiding the interference, as shown in Figure (2.9), where ”f” is the frequency and ”t” is the time. FDMA is utilized in the first generation analog the systems of communication. It is also utilized for providing every one of the users with a duplex channel [35].

The advantages are listed as

• Network timing not required.

• Compatible to existing hardware.

The disadvantages are listed as

• Intermodulation products cause degradation and poor power utilization.

• Uplink control power required.

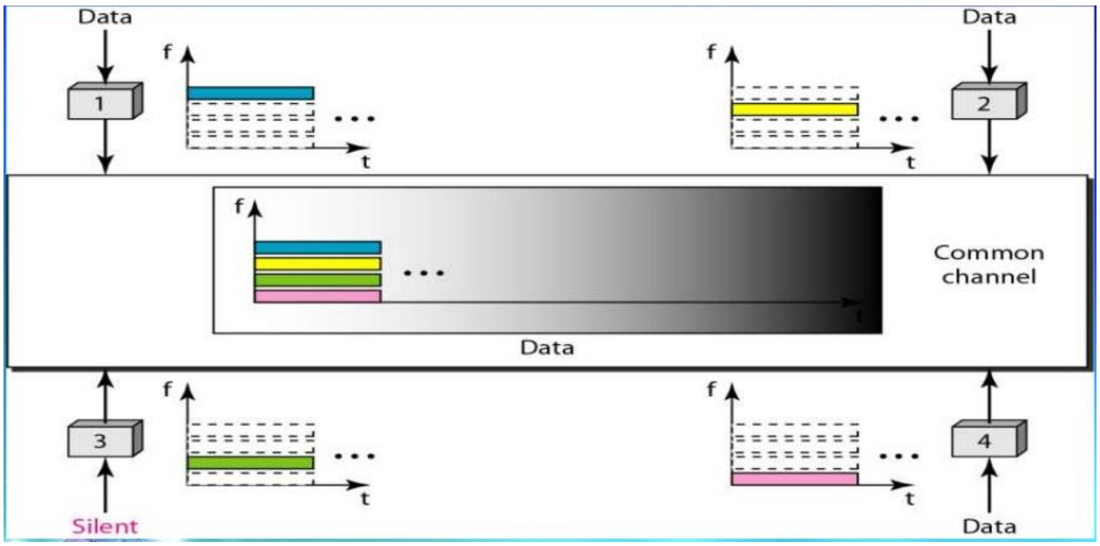


Figure (2.9). FDMA [36].

2.8.3.2 Time division multiple access (TDMA)

TDMA permits multiple user from sharing a frequency band through the allocation of various time slots. The signals which come from every one of the users are sent at intervals depends on multiplying number channels into time slot, as shown in Figure (2.10). TDMA technology has been utilized in second generation communication systems. Every one of the users is provided by 1 of 8 slots of the TDMA in a 200 KHz bandwidth. Dynamic resource allocation meant that more users could be support only 8 active users at a time [37].

The advantages are listed as

• No mutual interference between accesses.

• Requires no uplink power controls.

The disadvantages are listed as

• Network control required.

• Large peak power transmission for the earth station.

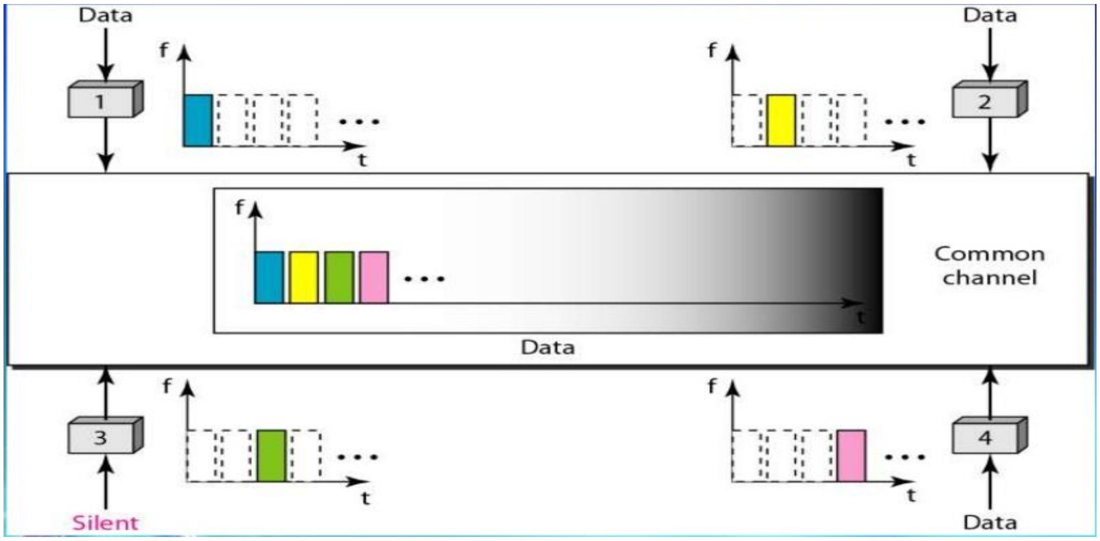


Figure (2.10). TDMA [36].

2.8.3.3 Code division multiple access (CDMA)

CDMA is a method where data bits undergo modulation by orthogonal sequence of high frequency bits like the Walsh code or the pseudo random code like the gold code. Those codes have been utilized for spreading signals through a large band of frequency. Several of those signals from various users will be transmitted afterwards through this same band of frequency, as shown in Figure (2.11), where ”c” is the code and ”d” is the data. The receiver has to have an identical sequence of spreading, multiplied by composite signal in a procedure which is referred to as the dispreading. Making the CDMA highly robust and secure. The code of the spreading has been designed for scrambling data signal. The spreading code changes with a considerably higher speed compared to the data signal which has meant considerably higher frequency that data signal. CDMA has been utilized in the communication systems of the3rd generation [38].

The advantages are listed as

• Network timing not required.

• Anti-jamming capability.

The disadvantages are listed as

• Requires wide band-width for each user.

• Requires strict code sync.

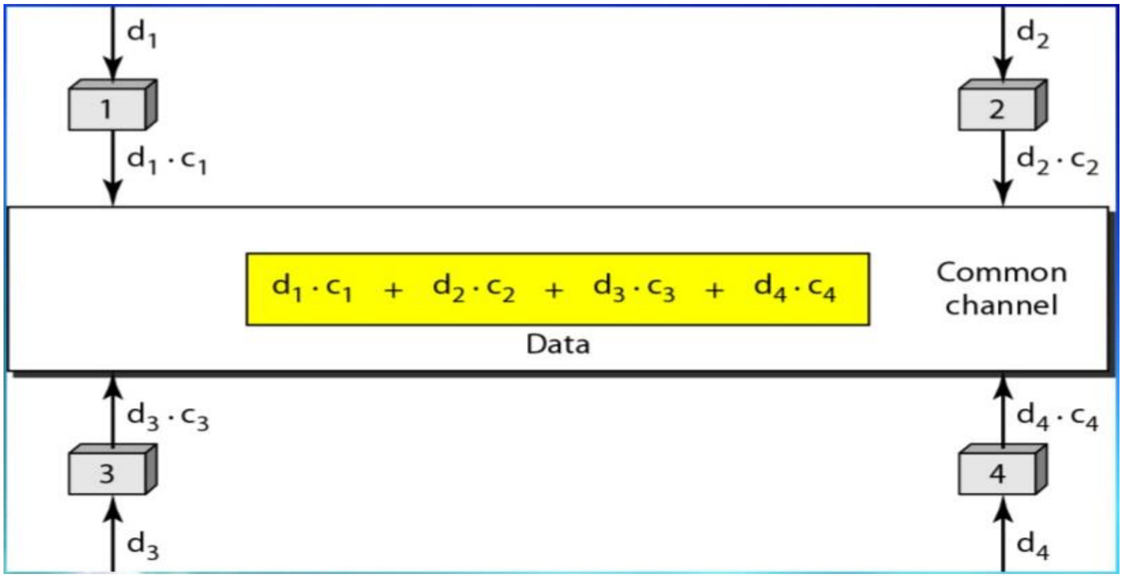


Figure (2.11). CDMA [36].

2.9 Comparison between FDMA,TDMA and CDMA

Multiplexing can be defined as the procedure that is used to combine several signals and transmit that in a shared channel. Then multiple access is the technique that has been utilized for allowing several users to have communication over one shared channel. There are many types multiple access approaches, Here in Table (2.1) will be reviewed a simple comparison between these methods: FDMA, TDMA and CDMA [39].

Table (2.1). Comparison between FDMA,TDMA and CDMA [40].

Feature	**FDMA**	**TDMA**	**CDMA**
Terminals	All terminals are active for short periods of time on the same frequency	Every terminal has its own frequency, uninterrupted	All terminals can be active at the same place at the same moment, uninterrupted
Spectrum utilization for a single station	It does not use full bandwidth	It uses full bandwidth within allocated time slot	It uses full bandwidth throughout operation
Analog/Digital	Generally analog	Digital	Digital
Interference	Interference may occur	Interference may occur	Interference is eliminated
Synchronization	Difficult in demand assigned	Difficult in demand assigned	Easy
Flexibility	Poor	Better	Best
Secrecy	Almost insecure	Betterthan FDMA	Fully secure

Chapter Three

The Proposed System

Chapter Three

The Proposed System

3.1 Introduction

Road accidents are one of the daily problems that occur all over the world. The evolution of vehicles manufacturing is to provide connectivity between vehicles with the broadcasting of safety messages. (ITS) technology now widely used to monitor traffic and to respond quickly to accidents by dispatching emergency services. Vehicular networks require a minimum number of vehicle to be good connected and functional, which can fail to achieve due to either low numbers of vehicles on the road or insufficient radio- equipped vehicles [41].

In this chapter, we will design the proposed system and implement it by using the protocols of TDMA and CDMA in VANET and discuss the results by using MATLAB language for representing the road network and traffic demand.

3.2 The Methodology

The purpose of our proposed approach is to apply the time-division multiple access (TDMA) and Code-division multiple access (CDMA) for optimizing the connection among vehicles and RSUs, minimizing the losing packets and decreasing the trip time of a vehicle. Both Figure (3.1) and Figure (3.2) show this approach conducted in three diverse protocols. Each component is in charge of performing its special tasks and to communicate with other components for transmitting /receiving information when needed. The key function of each component is considered as follows:

1. Traffic Management Center functionality: Traffic Management Center is in charge of analyzing the traffic depending upon the information that was conveyed to the RSU. It also calculates the road measurement by the use of average travel time and intersecting roads delay factor. The Road-Side Unit is in charge of evaluating the group of road segments, using algorithm the 'Edge to RSU association' that stores the correlation dictionary in the database of traffic Management Center database for using the RSU. Traffic Management Center (TMC) also cleans up old information from the database to

reduce RSUs' query time.

2. Vehicle functionality: Each vehicle is responsible for calculating travel time for every section of the road that has traveled and for transmitting it. Furthermore, route planning to determine the desired route should be conducted separately by the OBU for each vehicle autonomously.
3. Road-Side Unit functionality: Road-Side Unit is in charge of collecting travel time updates (ttu) from the vehicles and transferring updates to the Traffic Management Center database. The transferred travel time in Traffic Management Center is aggregated through transit Road-Side Units. Each RSU inquires about the segment of road metrics for which the Road-Side Unit is in charge of and broadcasting them for vehicle use.

Both Figure (3.1) and Figure (3.2) illustrate the structure of a high-scale interaction among the major components. Interactions between three: Road-Side Unit, their massage format and vehicles for communication are shown on the right the map container.

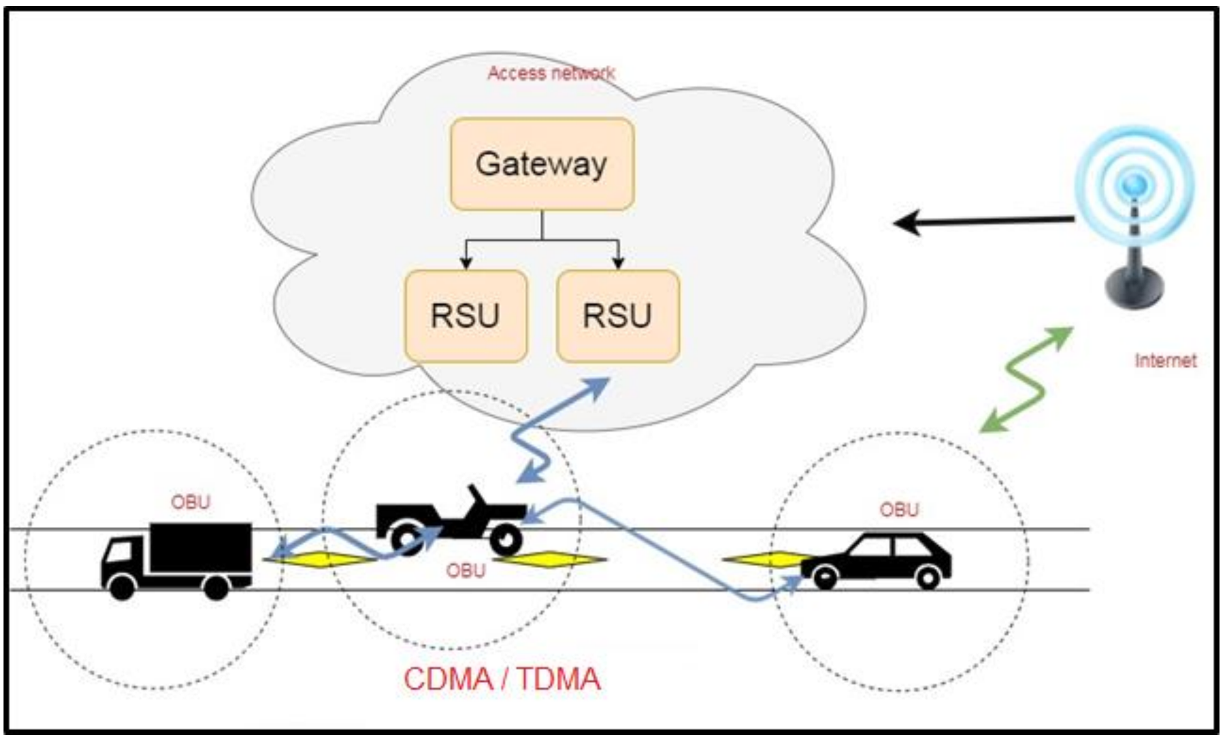


Figure (3.1). Structure of proposed approach.

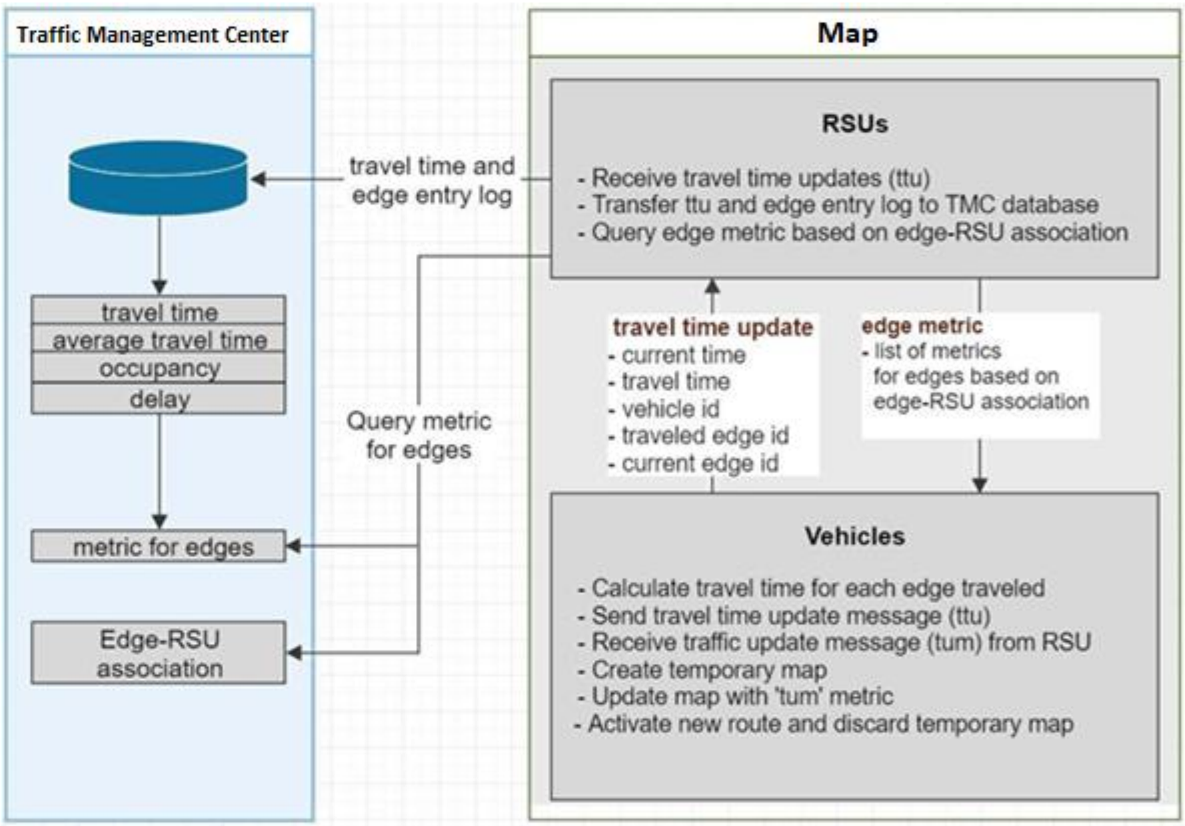


Figure (3.2). High-level overview of the proposed approach.

3.3 Traffic Management Center (TMC) Functionality

In this method, the Road-Side Units do not build the path of the vehicles, but the vehicles perform that from getting the edge cost information of a specific neighboring area around the particular vehicle. Consequently, it is significant to determine the volume of edge cost information that is transmitted through a specific Road-Side Unit, and in particular, the group of an edge where the information transmission cost should be related to the neighboring area of the vehicle receiving the transmission. Furthermore, it maintains diverse schedule updates demanded by Road-Side Units and clearing out old information for reducing dissimilar dynamic schedule entries to reduce query time.

Hence, the algorithm (3.1) indicate to create a relationship among an edge and a group of Road-Side Units where RSUs are in charge of transmitting metrics for a certain edge. When specifying the edge "e" that can be linked to a group of Road-Side Units "R" the presented RSU 'r' intersecting roads is taken as the center point "c" where the outbound edge of "c" is "e", concerned in adjacent junctions that is "n" It jumps away from "c" which can reach "c" using its outward edges. An "n" is created depending on the request of a user to set for the required number of the hops. The higher number of hops, the more Road-Side Units can send the distinctive edge metric. In Figure (3.3) Road-Side Units in color will transmit the metric value of the expected edge "e" with the starting node "j" for the neighboring vehicles to effect on a planning process for the path.

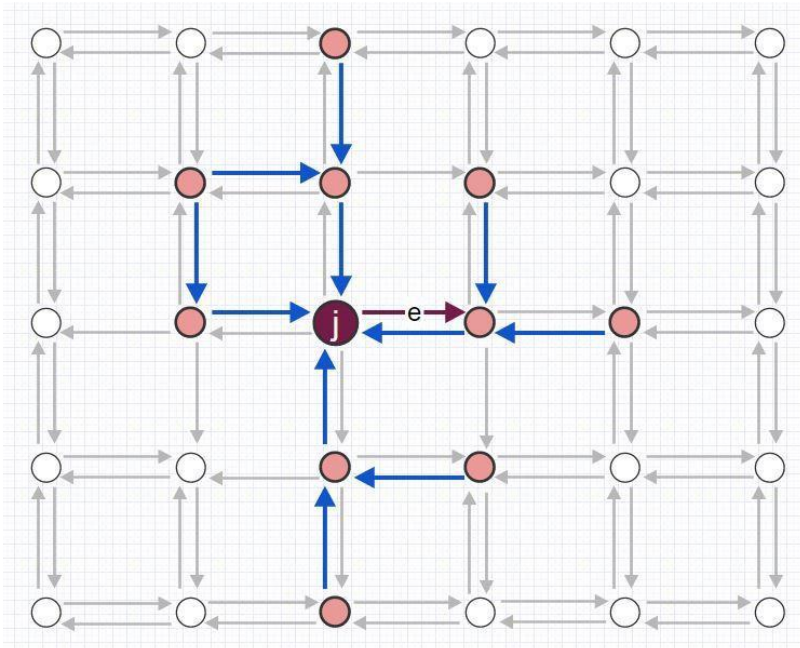


Figure (3.3). Edge-RSU relationship.

Algorithm (3.1). Edge- Road-Side Unit Relation
Input: Node set, V Edge set, E Graph G = (V, E) Max_hops = n O = connection
Result: For any particular directed edge e (v1, v2), finding node set A, such that ∀v ∈ A, v can lead to v1, in n hops, by the use their outgoing edges if there is such an edge. The node set is similar to the Road-Side Unit set here
initialize dictionary is empty, for edges as key and set of associated nodes as value loop each node Node set belong to Node Initialize outgoing edge set, Find conntion foredge set loop for each outgoing edge Initialize queue Q

```
while Q is not empty do
        current_node = Q.front.first
        hop_count = Q.front.second
CHECK  if hop_count less than Max_hops then
            Q.dequeue ()
loop the for each edge egde (v1, v2) belong to  E, do
Check  if v2 equal the  current_node
              Q. enqueue (v2)
```

3.4 Vehicle OBU Functionality

In this section we will describe the Send Travel Time Updates and Update Vehicle Route.

3.4.1 Send Travel Time Updates

When the vehicle is entering an edge, the "start-time" is stored on that edge, which is subtracted out of the "end-time" while the vehicle finishes the travel on that edge to calculate the travel time. Eventually, it creates a “Travel Time Update " package that stores travel time to the last completed edge and broadcasts it through the dedicated short-range communications medium. The travel time calculation for that edge is ignored when the last edge is empty where the vehicle just started its journey, or the last edge is an internal edge adjacent to the intersections. The vehicle also tracks idle time on any edge to see if it waits longer than the queuing delay threshold. When the vehicle waits over this threshold at the edge, it will instantly build a Travel Time Update message without completion travel on that edge. While constructing the 'Travel Time Update' package, it determines the delay by identifying the ' validity-bit ' of the package. In a situation like this, travel time equivalent to time spent on that edge in an idle and mobile situation is also set.

3.4.2 Update Vehicle Route

It generates a copy of its map (i.e. graph) and updates the cost of edge cost as recovered from the " tum" message in the copied map when the vehicle obtains a "tum" message from Road-Side Unit. It submits the path as active in traffic control and ignores the graph that is copied. The new path stays active till the vehicle receives the latest traffic update message with a new edge metric. Figure (3.4) shows a flow chart for the high-level process of the vehicle application.

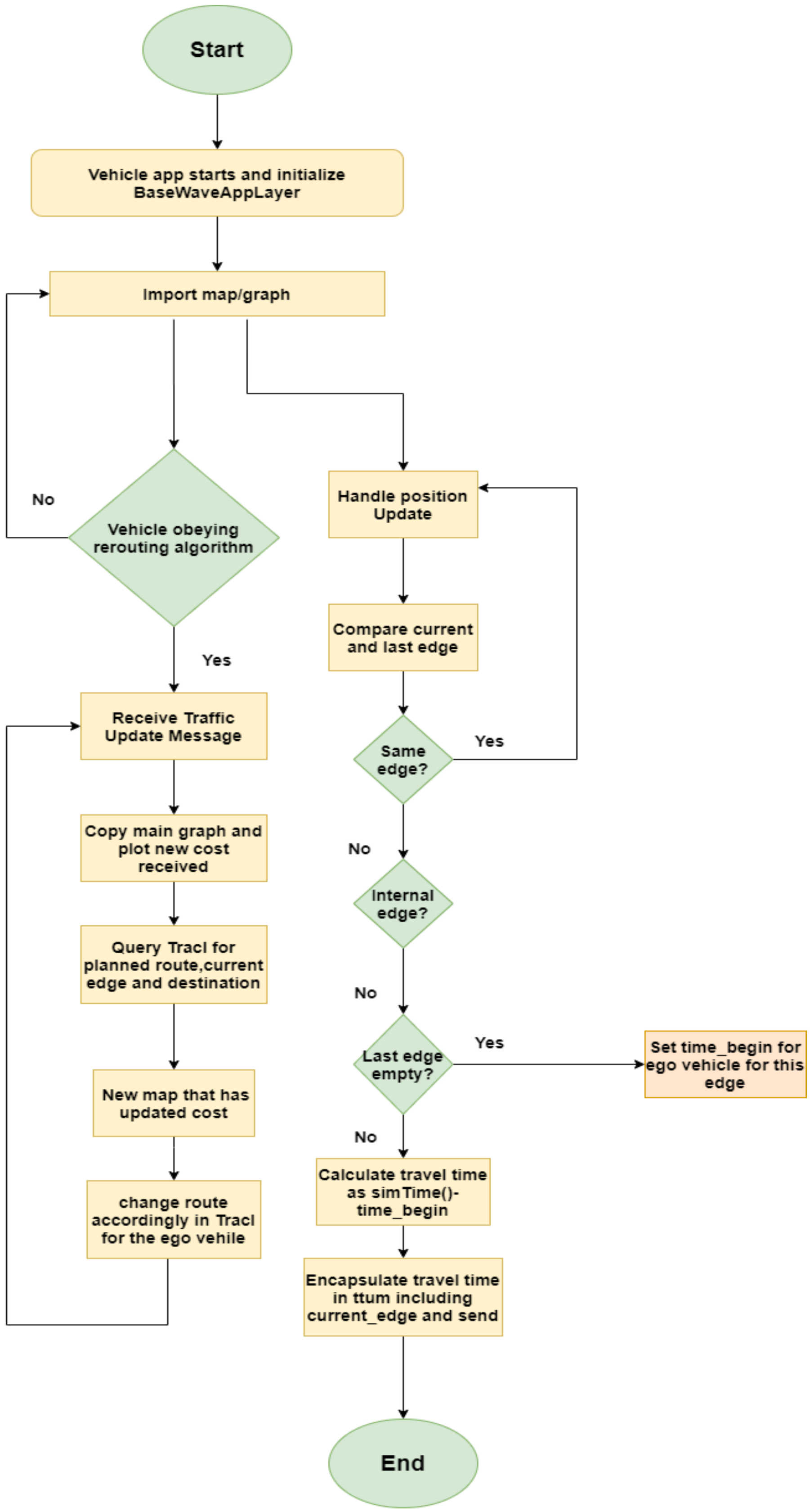


Figure (3.4). Vehicle application flowchart.

3.4.3 Time Division Multiple Access (TDMA)

TDMA protocol that improves on Vanet by considering the relative speed and traffic flow of each vehicle , Like Vanet, the resource allocation of each vehicle is divided into two sub-frames and resources are allocated to the vehicles according to their moving directions (left and right). As we just discussed, if vehicles moving in the same direction have different speeds, a merging collision problem may occur. Each vehicle calculates its relative speed from the difference between its own speed and the average speed of neighbor vehicles. If the relative speed is lower than the standard deviation speed, it is set to have a "low" phase. If it is higher than the standard deviation, it is set to have a "high" phase. However, when traffic density is high in one direction, vehicles may experience many merging collisions due to finely divided resource allocation units as shown in Figure (3.5). The algorithm (3.2) indicate to the TDMA operation in our scenario.

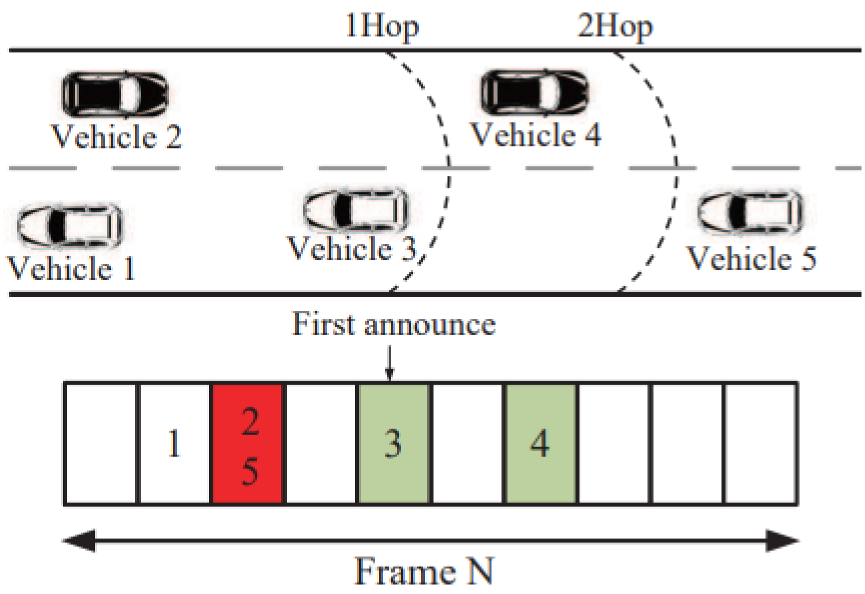


Figure (3.5). Collision prediction of prediction-based Time Division Multiple Access.

Algorithm (3.2). TDMA
Input: the vehicle sent signal to RSU
Output: For any particular directed edge e (v1, R) , finding node set A, such that ∀v ∈ A, v can lead to v1, in n hops, by the use their outgoing edges if there is such an edge. Node set is similar to Road-Side Unit group set here
- The two vehicle generate the signal (random zero and one with 16bit)   Vehicle1_data= random (16,1)   Vehicle2_data= random (16,1)   - Modulation :The two signals embedded to TDMA, where   - The first slot in bandwidth of TDMA carry the first frame in the first signal (Vehicle1_data).   - The second slot in bandwidth of TDMA carry the first frame in the second signal (Vehicle2_data).   - The third slot in bandwidth of TDMA carry the second frame in the first signal (Vehicle1_data).   - The forth slot in bandwidth of TDMA carry the second frame in the second signal (Vehicle2_data).   - and so on.

3.4.4 Code Division Multiple Access (CDMA)

It is a multi-vehicle technology with various codes. The same bandwidth is used in this approach for various vehicles. Every vehicle shall have its own spreading code assigned to it. To describe the CDMA let consider the following example the transmitted data is distributed on the spreading code of eight bits in both Vehicle 1 and Vehicle 2, so it will be 16 bits as shown in Table (3.1). These two values are XORed to generate the output of the transmitter. Bit zero is represented by +1 and bit one is represented by -1. At the transmitter side of vehicle1, the data bits to be transmitted is XORed with the spread code of Vehicle 1 and Vehicle 2 as shown in Figure (3.6). At the receiver side, the received bits will be XORed with the same spread code to generate the received data that is exactly the same as the transmitted data as shown in Figure (3.7).

Table (3.1). Spreading code for bits in CDMA.

Transmitter	**Vehicle 1**								**Vehicle 2**							
Data bit	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0
Data value	+1	-1	-1	+1	+1	-1	-1	-1	-1	+1	+1	-1	-1	+1	+1	+1
Spread code	1	1	0	0	1	0	1	0	1	1	0	0	1	0	1	0
code value	-1	-1	+1	+1	-1	+1	-1	+1	-1	-1	+1	+1	-1	+1	-1	+1
X-or bit	1	0	1	0	1	1	0	1	0	1	0	1	0	0	1	0
X-or value	-1	+1	-1	+1	-1	-1	+1	-1	+1	-1	+1	-1	+1	+1	-1	+1
Receiver	**Vehicle 1**								**Vehicle 2**							
Received bit	1	0	1	0	1	1	0	1	0	1	0	1	0	0	1	0
Received value	-1	+1	-1	+1	-1	-1	+1	-1	+1	-1	+1	-1	+1	+1	-1	+1
Spread code	1	1	0	0	1	0	1	0	1	1	0	0	1	0	1	0
Code value	-1	-1	+1	+1	-1	+1	-1	+1	-1	-1	+1	+1	-1	+1	-1	+1
X-or bit	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0
X-or value	+1	-1	-1	+1	+1	-1	-1	-1	-1	+1	+1	-1	-1	+1	+1	+1

Structure Considering 8 bits of spreading code, this leads to 256 separated users (vehicles) with unique code. All active users were sending their spreading data into the channel. These data will be summed to form the composite signal that transmitted to all users through the channel as shown in Figure (3.6). The sending data of the first channel (four bits) is spreaded into 32 bits according to the spreading code of 8 bits. The same thing has occurred for the other channels with their unique spreading code. All these spreading signals are summing to shape the composite signal to be transmitted in a channel.

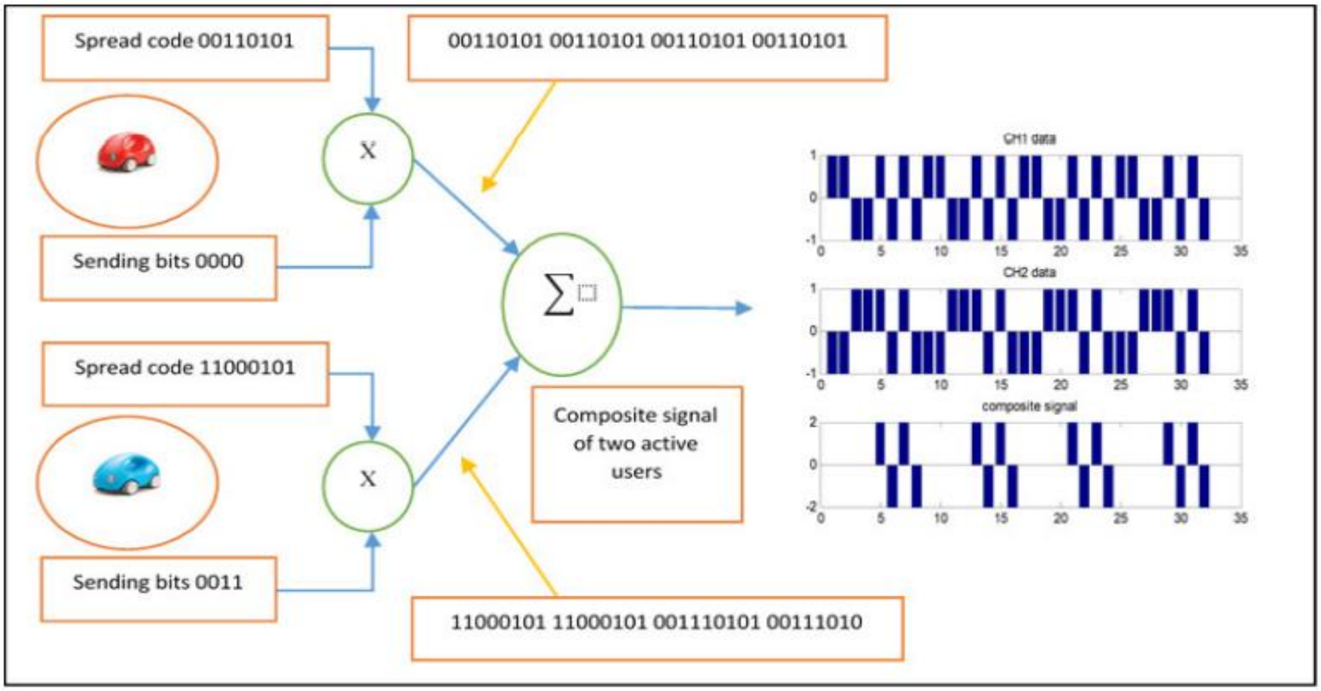


Figure (3.6). The transmitter in CDMA.

On the other hand, the receiver structure is implemented to extract the original data signal of each channel as shown in Figure (3.7). The composite signal is received by the receiver, and then this signal is spreading by the unique spread code of the indicated channel. After that, the channel bits are extracted, and then these values are compared. When the value is greater than zero, so it is represented by a positive bit and when the value is less than zero, so it is represented by a negative bit.

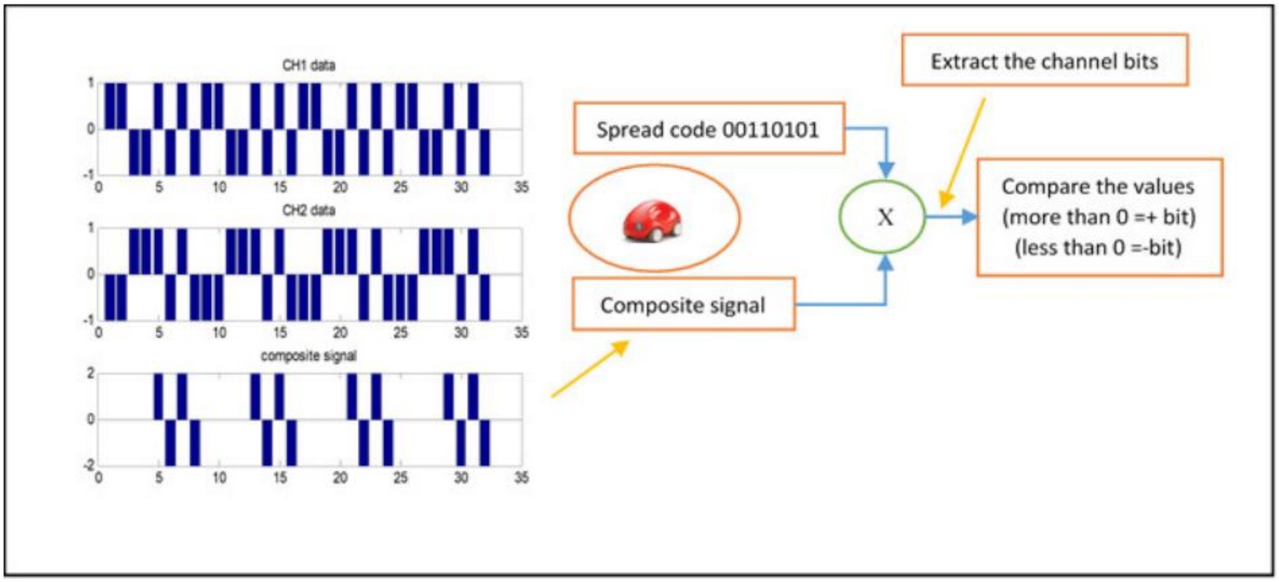


Figure (3.7). The receiver in CDMA.

Algorithm (3.3). CDMA
Input : the vehicle sent signal to RSU
Result: For any particular directed edge e (v1, R) , finding node set A, such that ∀v ∈ A, v can lead to v1, in n hops, by the use their outgoing edges if there is such an edge. Node set is similar to Road-Side Unit group set here
- The two vehicle generate the signal (random zero and one with 16bit) Vehicle1_data= random (16,1) Vehicle2_data= random (16,1) Then convert the number to(-1,1) - Generate spread code (random zero and one with 32 bit) Spread code = random (32,1) then convert to (-1,1) - Modulation : Caluclate the xor logic operation between vehicle data and spreadcode Transmitter Data = spread code xor vehicle_data - Demodulation : Caluclate the xor logic operation between Transmitter Data and spreadcode Receiver Data = spread code xor transmitter data

3.5 RSU Functionality

The fixed RSU nodes in selected junctions are hosted by RSU application. It represents such a point of contact to receive "ttu" packets from nearer vehicles and transmit them to TMC to be processed. RSU handles two types of messages when initializing the application is and connecting to the TMC database. the first type is a group of self-mapping messages group at predefined regular intervals that require a specific Road-Side Unit to query the TMC database for metric edge updates for which RSU is in charge of. The metrics were encapsulated in a "tum" message and transmitted through the dedicated short-range communications medium if metric updates are ready. The second type is a ‘ttu’ message that is transmitted by an ego vehicle. The "ttu" message includes information about the time stamp of the vehicle entering the present edge, the travel time of the preceding edge and if the travel time that was sent due to the delay in queuing experienced by the vehicle. For further analysis, this information is updated to the TMC database. Figure (3.8) illustrates a high-level flowchart of the application.

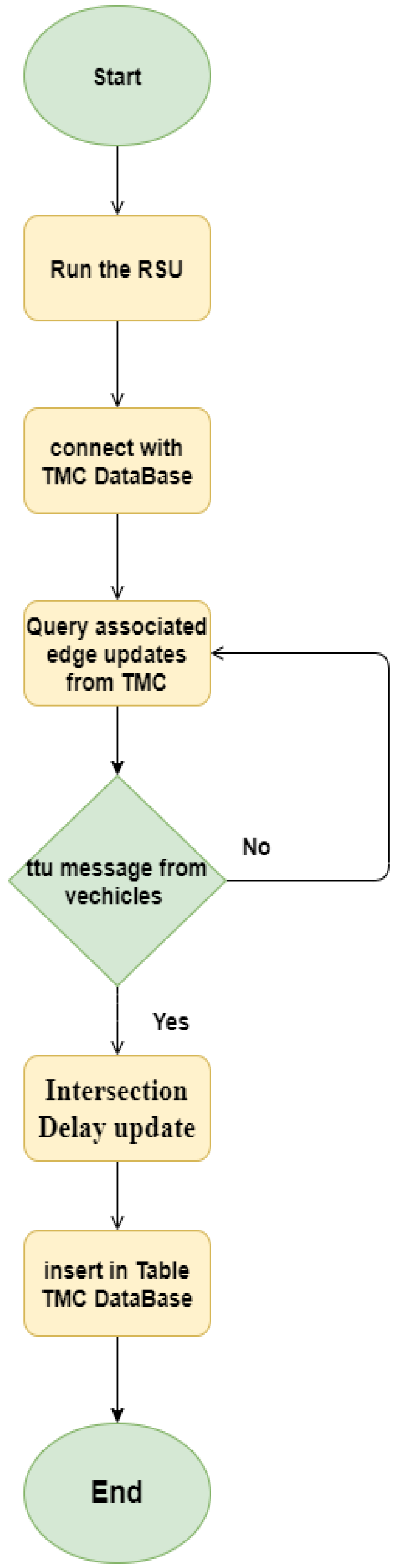


Figure (3.8). RSU application process flowchart.

Chapter Four

Results and Discussion

Chapter Four

Results and Discussion

4.1 Introduction

This chapter presents in detail the performance evaluation through the execution of our scenario in order to examine the efficiency of using TDMA and CDMA protocols, based on the Matlab as a simulator environment. The two protocols will be compared by different number performance metrics to prove the enhancement of the network in the scenario.

4.2 Creation of Scenario MAP

In this work, we create two types of map, first map as a static map that contains a fixed roads and the RSU distributed over the roads and there is more than vehicle moving in and has a specific starting point as shown in Figure (4.1) below.

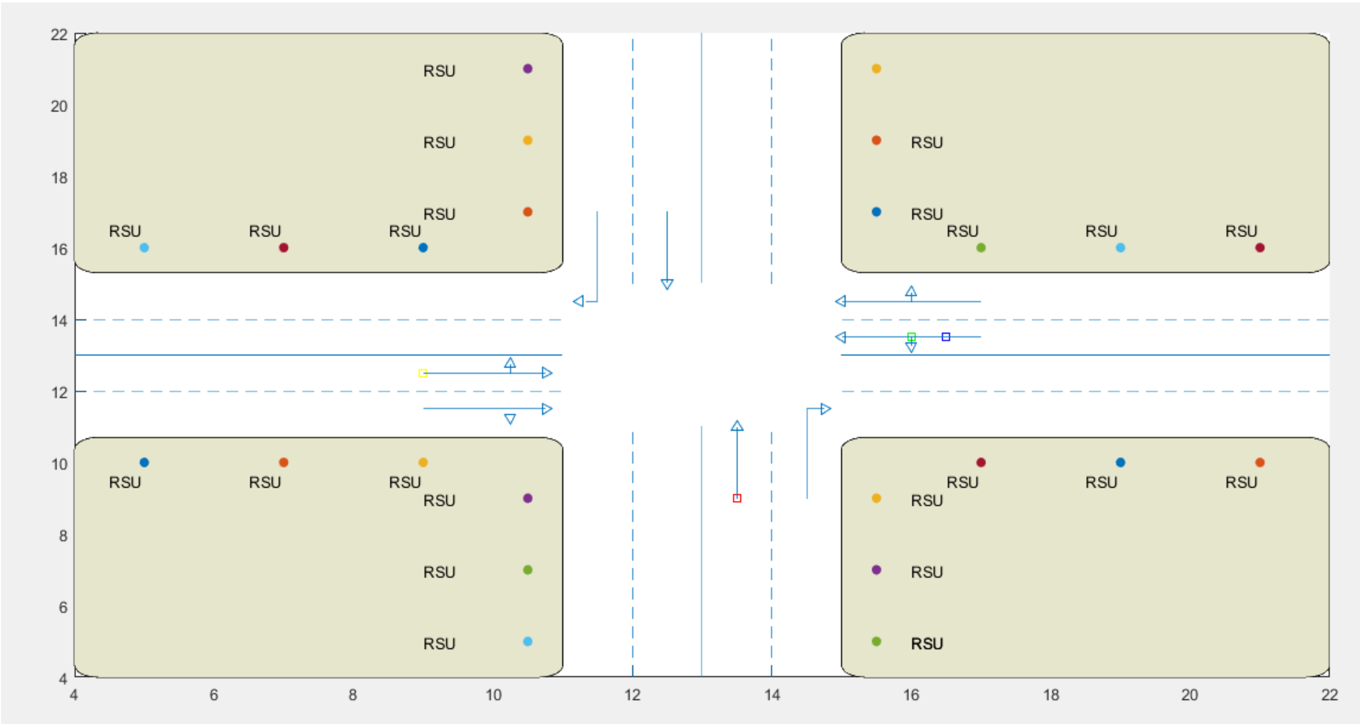


Figure (4.1). Scenario of a static map.

The second type map is the dynamic map that has been relied upon our work where the generated random two separate roads and distribute some of RSUs randomly over them, then applying the TDMA protocol and the CDMA protocol. When press on the start button, the first step build the road as shown in Figure (4.2) and Figure (4.3)

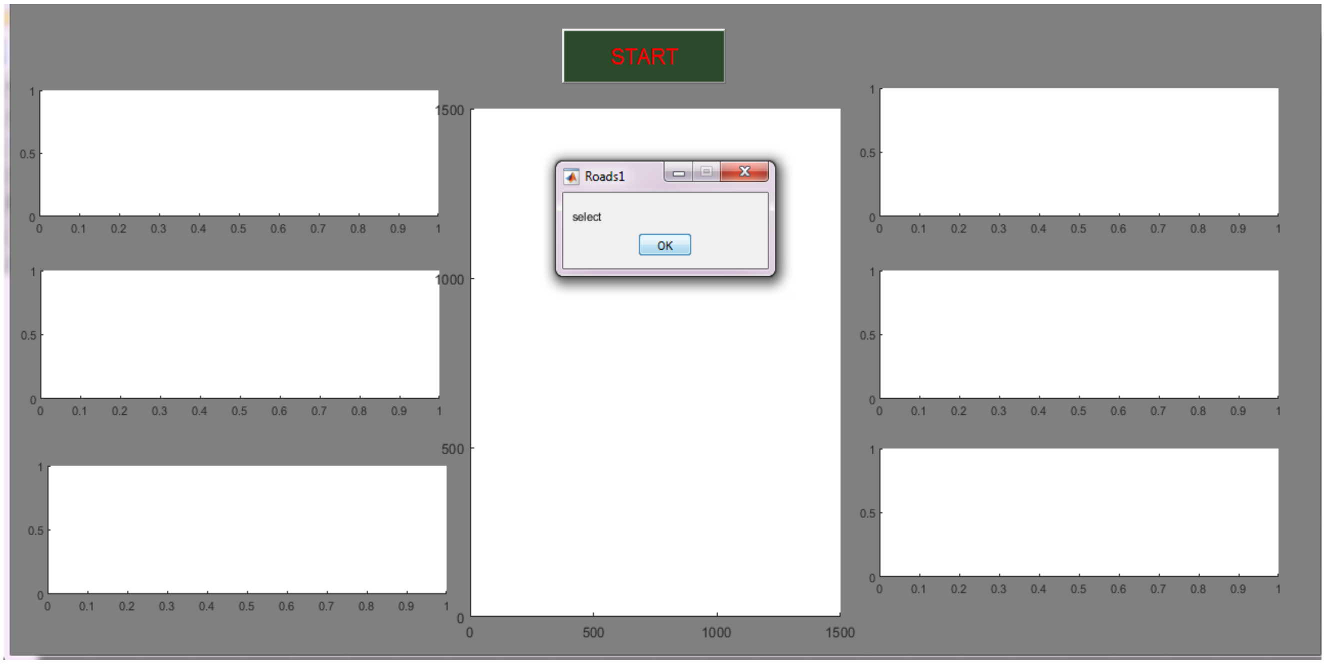


Figure (4.2). Before creating the two roads in scenario of the dynamic map.

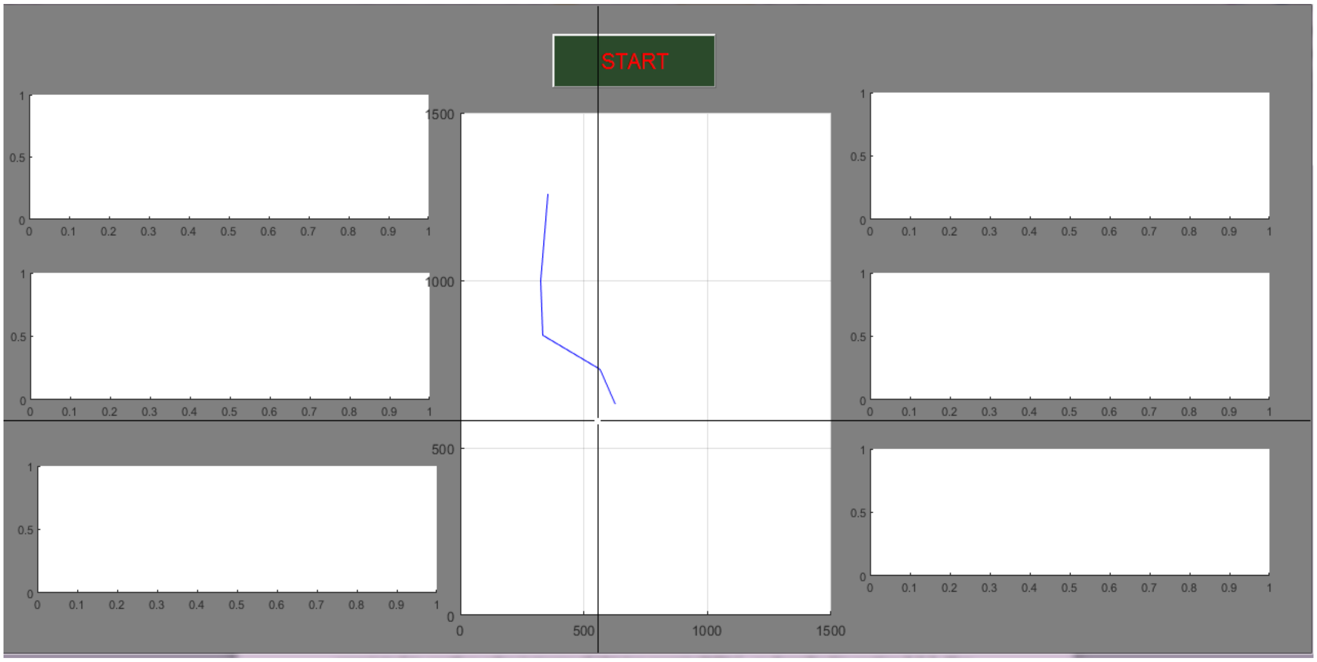


Figure (4.3). Building the first road in scenario of the dynamic map.

In the second step of preparation, the dynamic map builds the second road as shown in Figure (4.4) bellow.

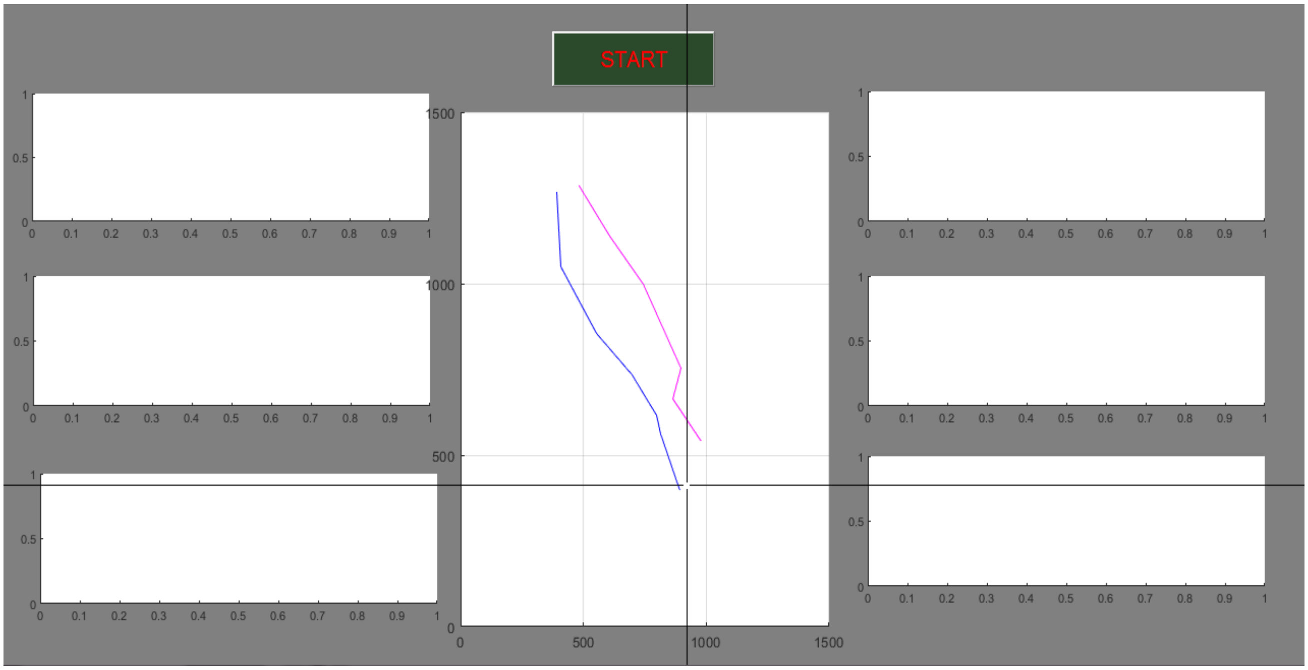


Figure (4.4). Building the second road in scenario of the dynamic map.

In the last step of preparation, dynamic map distrusted six RSUs over the two created roads as shown in Figure (4.5)

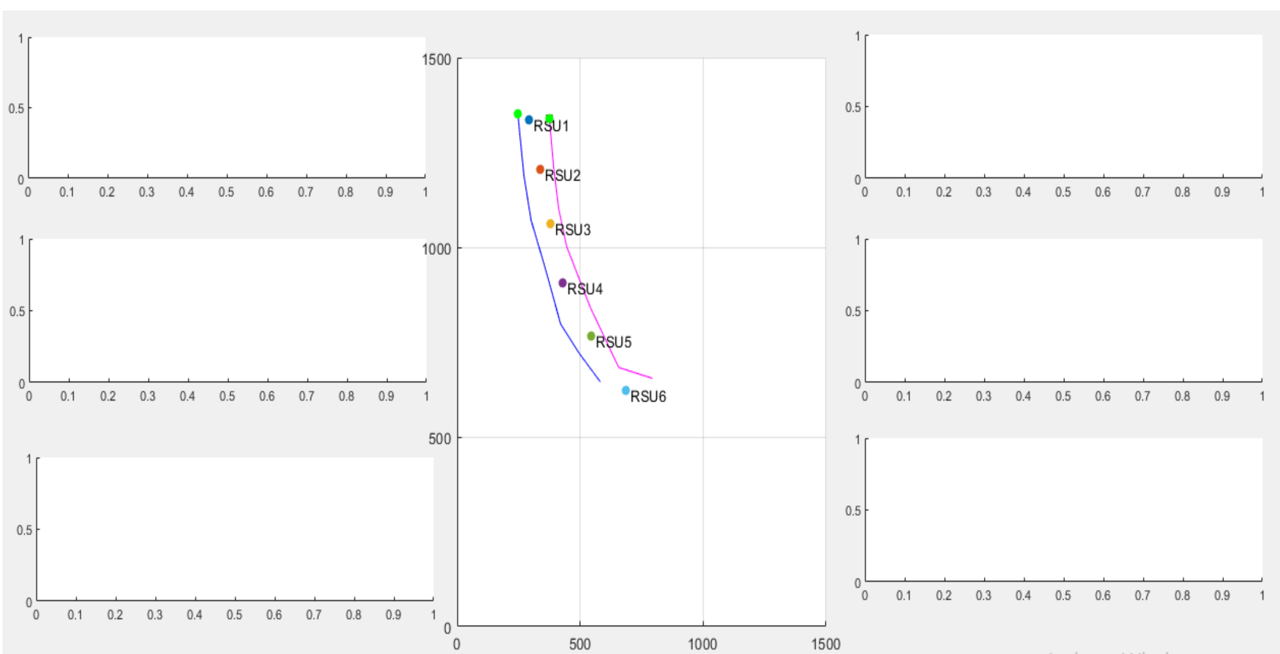


Figure (4.5). Distributed the RSU units over roads in scenario of dynamic map.

4.3 RSU placement selection

Road-Side Unit are positioned in each intersecting roads excluding where the intersecting roads itself represent dead-end edge node, this is conducted in Matlab GUI as shown in Figure (4.1) and Figure (4.5).

4.4 Vehicle setup

Vehicle applications a Matlab program that determines the vehicle's behavior while running simulation. Furthermore, this application also simplifies the extraction of Road-Side Unit position coordinates as they are set differently and have different values.

4.5 Performance Evaluation

We study TDMA and CDMA using MATLAB as simulator. The scenario that has been implemented in the simulation is a network with two vehicles and two roads and RSU distributed in all roads. The simulation area is 1500x1500 with 100m as transmission range between vehicles and RSUs. TDMA will be compared with CDMA to prove the enhancement of the network for some metrics in the scenarios.

4.5.1 TDMA

TDMA allows multiple users to share a common frequency band by allocating different time slots. Signals coming from each user will be transmitted at intervals depends on multiplying number channels into time slots. In this work, it is applied the TDMA to control collision between the vehicles and provide routes for vehicles. That is achieved when the vehicle starts moving on the road searching for the nearest RSU to communicate with. The RSU allows several vehicles to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using its own time slot. This allows multiple stations to share the same transmission medium, as shown in Figure (4.6).

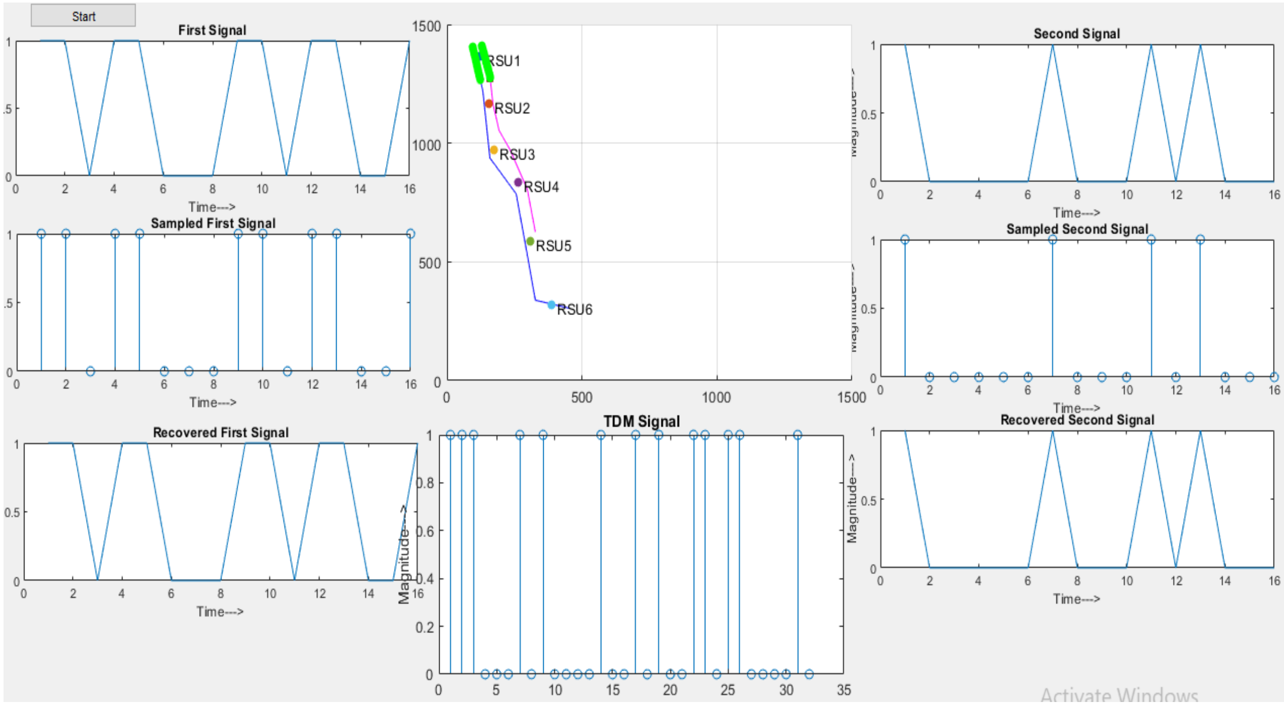


Figure (4.6). The two vehicles connect to the same RSU.

Figure (4.6) shows the two vehicles connect to the same RSU, We generate a random signal in the analog form, then we doing a sampling to the signal to convert it to the digit form (0,1). Then the two signals embedded to TDMA, where the slot1 from TDMA follows the frame1 of the first signal. The slot2 from TDMA follows the frame1 of the second signal. Moreover, the slot3 from TDMA follows the frame2 of the first signal and the slot4 of the TDMA follows the frame2 of the second signal, and so on.

4.5.2 CDMA

CDMA enters within multiple access where several transmitters can send information simultaneously over a single communication channel. This allowed several users to share a band of frequencies to compete for interference between users. CDMA implies spread spectrum technology and a special coding scheme, where each transmitter is assigned to a unique code. To explain the system of CDMA, consider the transmitted data is distributed on the spreading code of eight bits in both vehicle1 and vehicle2, so it will be 16 bits as shown in Table (3.1). These two values are XOR to generate the output of the transmitter. Bit zero is represented by +1 and bit one is represented by -1. At the transmitter side of vehicle2, the data bits to be transmitted is XOR with the spread code of vehicle1 and vehicle2, where the purpose of applying CDMA protocol for build connection between vehicles and RSUs, to determine the rout, and minimize the collision between vehicles.

When each vehicle starts to move, it searches for the closest RSU to communicate with and exchange information, where the maximum connection range between the vehicle and RSU is 100 meters. In Figure (4.7), there is two vehicles move in the two roads and connected to RUS1 (note the green color means the vehicle connects with RSU and red color means connectionless). The left side in the Figure (4.7) shows the transmitted and received signals in CDMA between the vehicle1 and the RSUs. The right side in the Figure (4.7) shows the transmitted and received signals in CDMA between the vehicle2 and the RSUs.

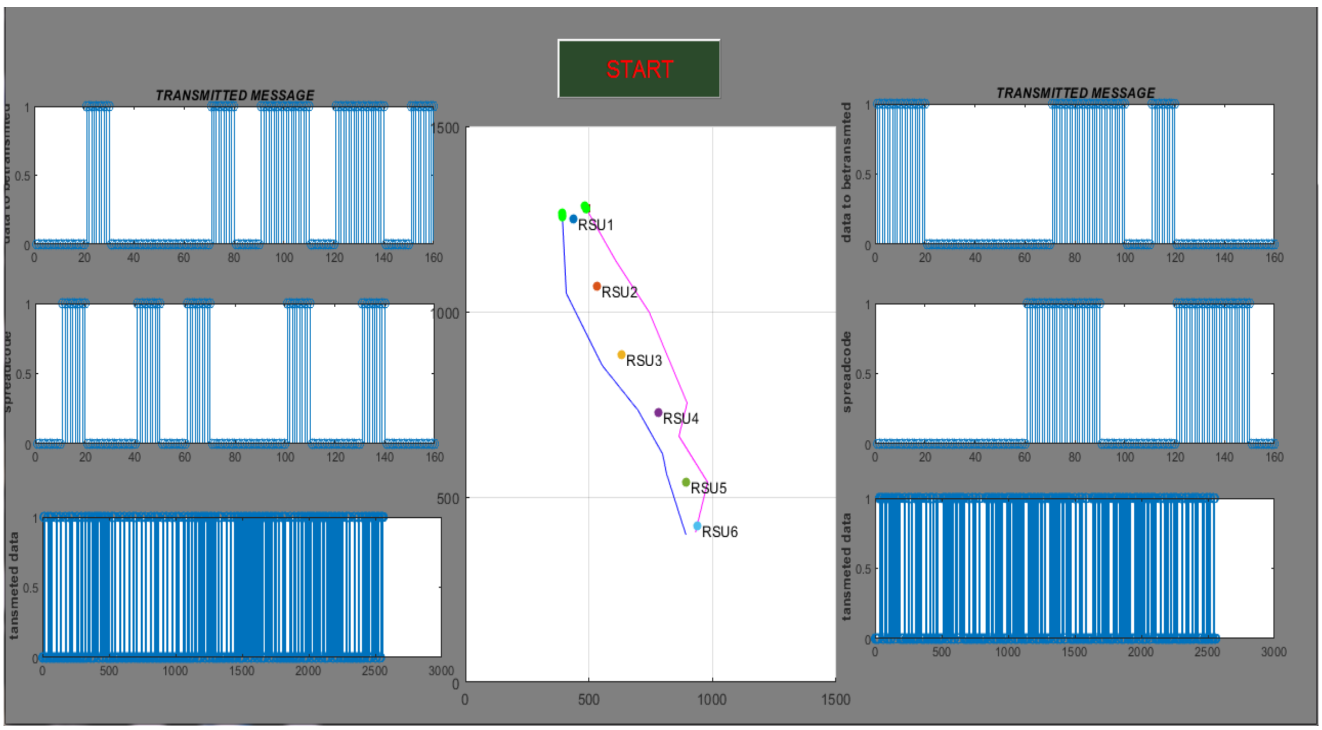


Figure (4.7). The two vehicles connect to the RSU.

The two vehicles continue moving until the distance between the vehicle and RSU1 reach more than 100 meters and lose the connection between them as shown in Figure (4.8). The right side shows there are no data transmitted and received between the vehicle1 and RSUs.

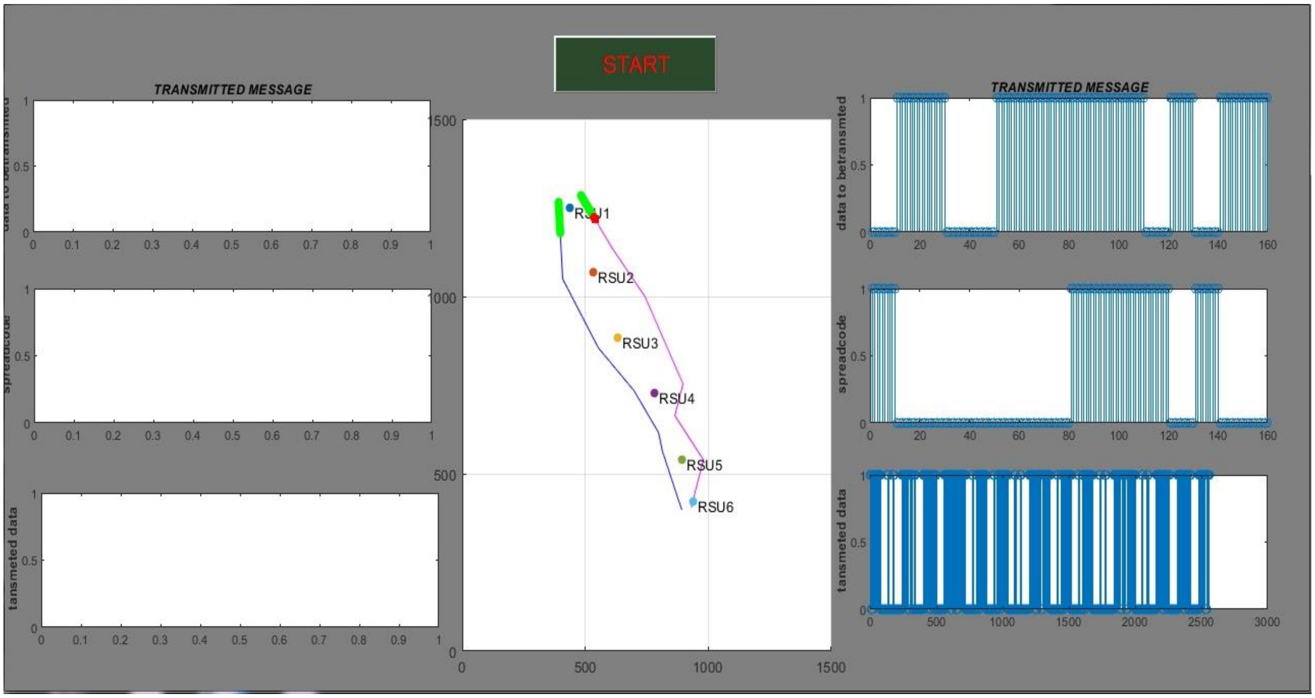


Figure (4.8). The vehicle1 loose the connection to the RUS unit.

The two vehicles continue moving until reaching the end of the roads. The two vehicles connected in the RSU6 as shown in Figure (4.9).

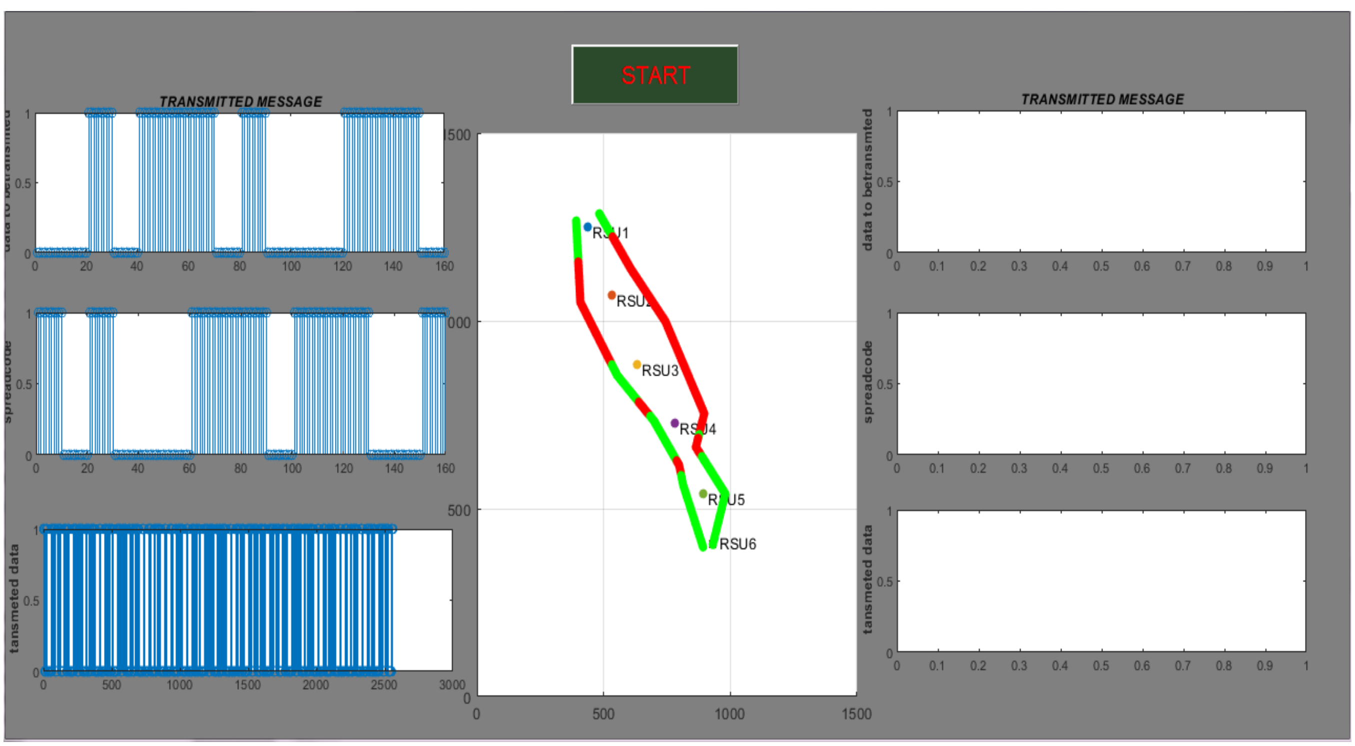


Figure (4.9). The two vehicles reach to end point in roads.

Figure (4.9) shows the data transmitted and received in the left side when the vehicle2 reach to the end of the road before vehicle1.

4.6 Performance Metrics and Results

We have run sets of simulations with the scenario summarized in Table (4.1).

Table (4.1): Summary of simulation properties.

Number of vehicles	2
Total length of roads for vehicles	50000 m
Number of RSUs	6

In this work, CDMA, TDMA and regular communication systems are tested of vehicles to evaluate the performance of the proposed communication system. It was tested under various communication conditions to confirm effective communication. One of vehicles is programmed with the TDMA and CDMA communication system. The communication performance metrics are calculated for vehicles in three cases under the same communication condition. Table (4.2) demonstrates the performance metrics (Transmission Packet, Received Packet, Packet Delivery Ratio, Totally Dropped Packets, Average end to end Delay, Number Of Bit Error Rate), which have been measured for the same vehicle under the TDMA and CDMA communication system, with and without the proposed communication system. The six performance metrics description as following :

A. **Transmission Packet:** The total number of packet sent from the vehicle.

B. **Received Packet:** The total number of routing packets receives at per RSU.

C. **Packets Delivery Ratio (PDR):** Is the ratio of the number of packets received by the destination to the number of the packet sent by the sender. It is the most significant metric that we should consider in packet forwarding. It may affect by different crucial factors such as packet size, group size, action range, and mobility of nodes. The robust message transmission is defined as the 100% packet delivery. The Packets Delivery Ratio is calculated as :

Packet Delivery Ratio = ((Received Packets / Transmission Packets) *100)………… (4.1)

D. Totally Dropped Packets: Represents the number of lost packets from the total number of sent packets. Each packet has a deadline before which it must be executed, and if this is not possible, the scheduler tries to minimize the number of lost packets due to deadline expiry. Totally Dropped Packets is calculated as:

Totally Dropped Packets = (Transmission Packets - Received Packets)……..….. (4.2)

E. Average End-To-End Delay (E2E): The time taken to successfully broadcast data packets from source to destination is called the average end-to-end delay. This metric includes every potential data packet delay from source to destination, such as the propagation delay, queuing at the interface, buffering during the route discovery latency, transfer time, and retransmission delay at Media Control. The average end-to-end delay is calculated as:

Average End-To-End Delay = (Time at which packet received – Time at which packet Sent)……………………………………………………………………………..(4.3)

F. The Number Of Bit Errors: The total number bit dropped in each packet , at per RSU.

The Number Of Bit Errors = (Number of a bit of Totally Dropped Packets *16)(4.4)

Table (4.2): Performance Metrics.

	Without TDMA & CDMA	**TDMA**	**CDMA**
Transmission Packet	50000	50000	50000
Received Packet	41368	46362	47308
Packet Delivery Ratio	82.736%	92.7247%	94.617%
Totally Dropped Packets	8632	3637.67	2691.5
Average end to end Delay	72.6s	37.026s	36.3s
The Number Of Bit Errors	138112	58202	43064

According to Table (4.2), the active role of the proposed communication system can be easily distinguishing in three cases. Conventional communication system needs to be modified, to provide efficient functionality in protecting, increasing the rate of a packet that transmits between sender/ received as well as protecting these types of vehicular networks. The proposed

CDMA and TDMA communication system can enhance the transmission rate of vehicles by increase packet delivery rate in its external communication. It is mainly for dropping any request that targets broadcasting packets. Figure (4.10-4.15), shows the role of the CDMA and TDMA communication in providing slot time for each packet that is sent or received between vehicles in that zone. Where figure (4.10) show the packet transmission in each state, where the amount of packet transmission is equal in all cases.

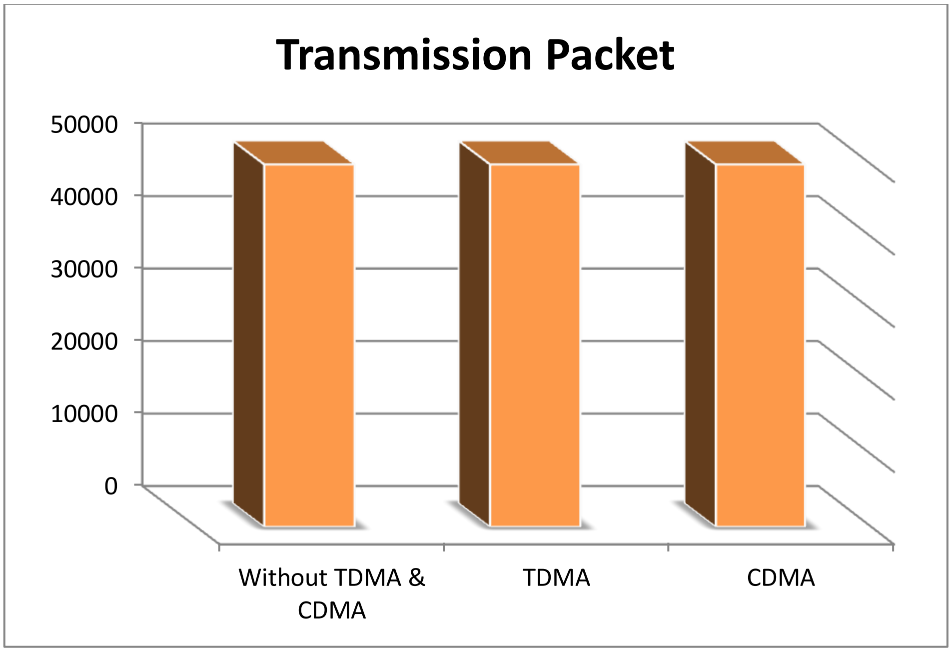


Figure (4.10). The Transmission Packet in each cases.

Figure (4.11) shows the Received packet in each state, where the amount of the Received packet in CDMA is higher than other cases. Through the above figure 4.11, we see in three case that the number of packet transmitted are equal , because the vehicle sends a packet in all cases, regardless of the type of protocol used.

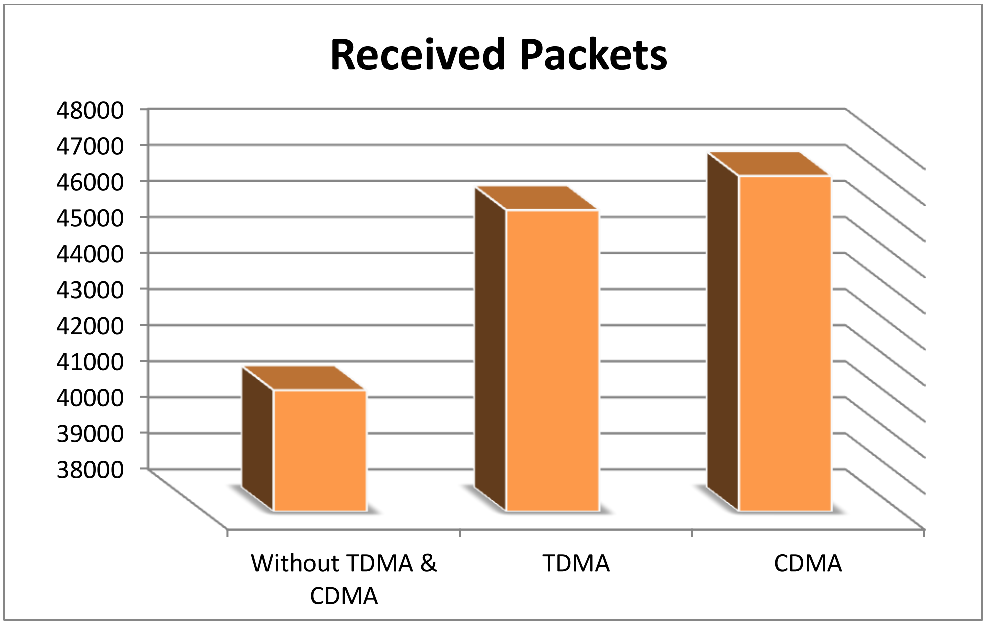


Figure (4.11). The Received packet in each cases.

Figure (4.12) shows Totally Dropped Packets in each state, where the Totally of Dropped Packets without TDMA& CDMA is higher than other cases. Through the above Figure(4.12) we see that the packets received when using a protocol CDMA higher than the rest, because the protocol make can be shared the bandwidth all times that less the drop packet.

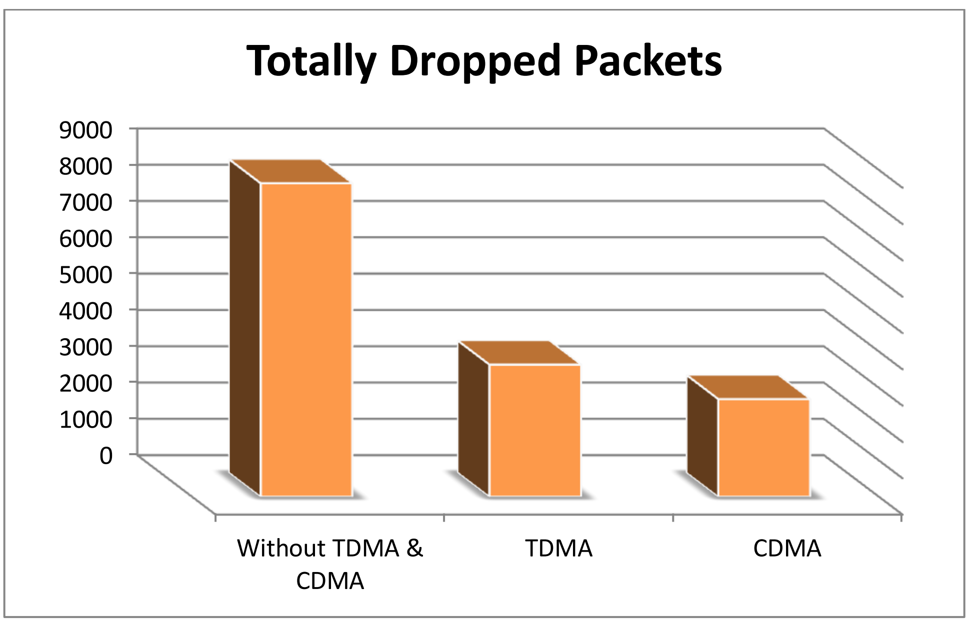


Figure (4.12). The Totally Dropped Packets in each cases.

Figure (4.13) describes the Packet Delivery Ratio in each state, where the Ratio of Packet Delivery without TDMA& CDMA is achieved 82% lower than other cases.

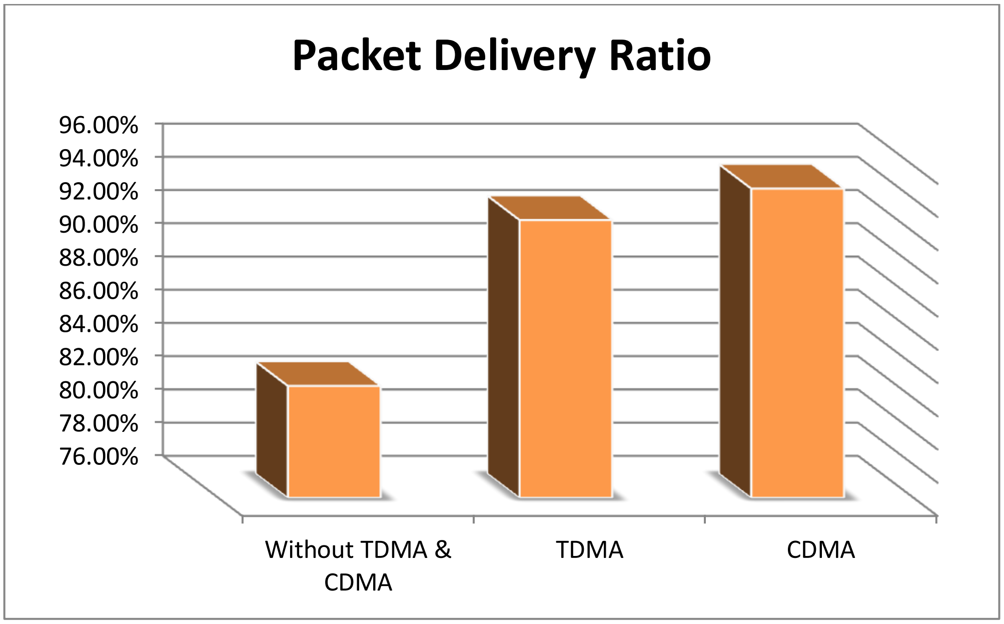


Figure (4.13). The Packet Delivery Ratio in each cases.

Figure (4.14) shows the Average end to end Delay in each state, where the Average end to end Delay in CDMA is better than other cases. When using protocol CDMA, it provides a mechanism for receiving the largest number of packets, which reduces the number of dropping protocols and how much is clear from the above figure.

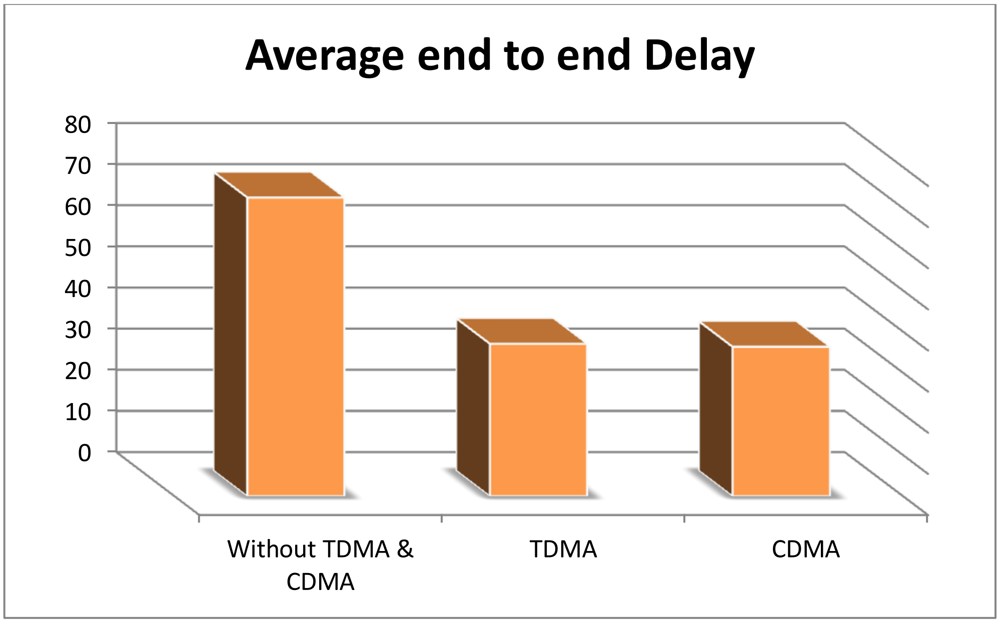


Figure (4.14). The Average end to end Delay in each cases.

Figure (4.15) shows the number of bit errors in each state, where the amount of bit errors is high in first state. We see in the above figure Average end to end Delay in protocol CDMA is less than the rest because it depends on the number of bits received.

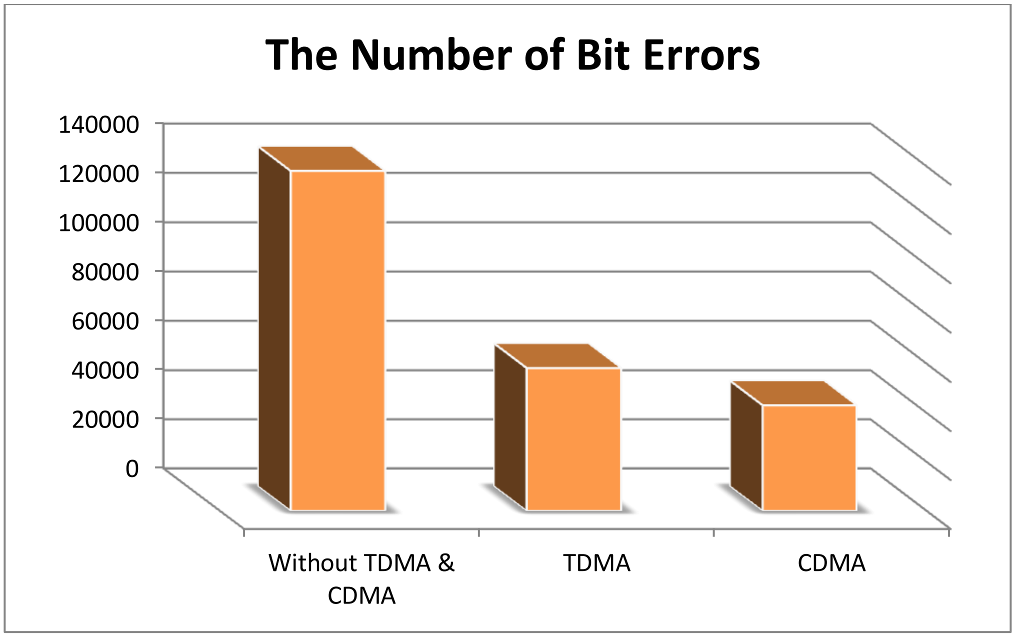


Figure (4.15). The Number Of Bit Error Rate in each cases.

4.7 The Discussion

In this section, we will give a brief discussion about the results and the numerical analysis performed in the previous section. This discussion will further explain the behavior and performance of our TDMA and CDMA protocols. The techniques implemented as mention previously and simulated on a virtual environment

The first technique is TDMA implemented with 2 vehicles and 6 RSUs and CDMA also the same thing, we notice an enhancement on the network performance with CDMA is high from TDMA.

Figure (4.10 to 4.15) shows Performance metrics for TDMA and CDMA communication Systems and reflects a vital role of the TDMA&CDMA system in improving the communication system of VANETs. It was evaluated under two various conditions. The total number of generated packets is 50000 in two scenarios, the average number of received packets is 47309p of VANETs with CDMA system and average drop 2691p. So as, the average number of received packets is 41368p and the average drop packets is 8632p in VANETs with a regular communication system. However, the average number of received packets is 46362p and the average drop packets is 8632p in VANETs with TDMA communication system. It was also found that the robust message transmission in the CDMA was greater than that of the TDMA, so that the amount of PDR was 94.617% in CDMA and 92.7247% in TDMA. Also found CDMA less transfer time that taken to successfully broadcast data packets from sender to receiver where reached to 36.3s while in TDMA reached to 37.026s.

At this point, we can identify a vital role of the proposed communication system in external communication of vehicle, and from the result CDMA provides a smaller transmission collision rate that leads to a significant rise in efficiency.

Chapter Five

Conclusions and Future Works

Chapter Five

Conclusions and Future Works

5.1 Conclusions

Extraordinary and sustained efforts have been dedicated to various automobile-related industries, communication companies and academic fields for manufacturing vehicles. It is expected that these smart vehicles can be equipped with wireless communication technology and sensors appropriately during driving to ensure road safety. This thesis provides broad research on how to identify methods to develop and improve the reliability of vehicles communications.

1. This thesis presented a communication system that improves the performance of the network transmission by using Investigate from the two multiple access (TDMA and CDMA) in a vehicular ad hoc network.
2. We present a comparison between the two techniques which are designed specifically for supporting high-priority safety applications in a vehicular ad hoc network scenario.
3. Shown the simulation in a virtual environment and tested the movement of vehicles programmatically by using GUI MATLAB package.
4. In the comparison, the two techniques (TDMA and CDMA) provide two different results, CDMA provides a smaller transmission collision rate that leads to a significant rise in efficiency.
5. We evaluated our proposed system by measuring some performance metrics such as Receive packets, Drop packets, End-to-End (E2E) delay, Packet Delivery Ratio (PDR), and Bit error rate (BER), where the E2E delay in TDMA has 37.026 sec and the CDMA has 36.3 sec. The scheme has a 94% packet delivery ratio in CDMA while has 92% in TDMA.

5.2 Future Works

1. Implementing and executing the system on a large number of vehicles and the larger size of the area.
2. Implementing the communication system between vehicles (V2V) and not just between vehicles and RSU (V2R).
3. Comparing the CDMA with other types of multiple access protocols such as Space Division Multiple Access Protocol (SDMA) or Interleave Division Multiple Access Protocol (IDMA) to see the advantages and disadvantages of CDMA with other protocols.
4. Applying the protocols on other simulators such as Network Simulator (NS-3), Opnet, and OMNet to ensure from the performance of protocols.

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جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة الانبار

كلية علوم الحاسوب وتكنلوجيا المعلومات

قسم علوم الحاسوب

نظام اتصال فعال يعتمد على تقنيات الوصول المتعددة لـ VANETs

رسالة مقدمة الى قسم علوم الحاسبات- كلية علوم الحاسوب وتكنولوجيا المعلومات- جامعة الانبار وهي جزء من متطلبات نيل شهادة الماجستير في علوم الحاسبات

تقدمت بها

تسنيم احمد رشيد

بإشراف

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١٤٤٢هـ ٢٠٢٠ م

الملخص

تمثل حوادث الطرق مشكلة اجتماعية خطيرة وهي أحد الأسباب الرئيسية للوفاة والعجز البشريين على نطاق عالمي. لتقليل مخاطر وشدة حادث طريق ، يمكن تحقيق مجموعة متنوعة من تطبيقات السلامة الجديدة من خلال الاتصالات اللاسلكية بين المركبات التي تسير بالقرب من بعضها البعض ، أو بين المركبات وخاصة الوحدات المنتشرة على جانب الطريق (RSUs)، وهي تقنية تُعرف باسم إعلان المركبات شبكة مخصصة (VANET). تعتمد معظم تطبيقات السلامة التي تدعم VANETعلى بث رسائل السلامة بواسطة المركبات أو وحدات المنتشره على جانب الطريق ، إما بشكل دوري أو في حالة وقوع حدث غير متوقع ، مثل الفرامل الصلبة أو اكتشاف حالة الطريق الخطرة.

تقدم هذه الرسالة بروتوكولًا جديدًا للنفاذ المتعدد بتقسيم الوقت متعدد القنوات (TDMA) ووصول متعدد لقسم الكود (CDMA) ، وقد تم تصميمهما خصيصًا لدعم تطبيقات السلامة ذات الأولوية العالية في سيناريو شبكة مخصصة للمركبات. يتم إجراء عمليات المحاكاة الحاسوبية باستخدام MATLAB. تتم محاكاة سيناريو مدينة افتراضية ويتم تقييم مقاييس مختلفة للأداء ، بما في ذلك النفقات العامة للبروتوكول ، ووضع الشبكة الجيد ، واستخدام القناة ، وعدالة البروتوكول ، وتصادم الإرسال المحتمل ، وتأخير تسليم رسالة السلامة.

يتم تقييم أداء التصميم متعدد الطبقات في شبكة مخصصة للمركبات متعددة القنوات في سيناريو الطريق السريع ، وذلك بشكل أساسي فيما يتعلق بتأخير تسليم الحزمة من طرف إلى طرف .يتم أخذ حزم الانتظار في كل مركبة مرحل في الاعتبار في تحليل التأخير الشامل .علاوة على ذلك ، يتم توفير النتائج الرقمية لدراسة تأثير المعلمات المختلفة ، حيث يوفر CDMA معدل تصادم إرسال أصغر يؤدي إلى زيادة كبيرة في الكفاءة ، حيث يبلغ تأخير E2E في (TDMA) 37.026 ثانية و CDMA 36.3 ثانية .يحتوي المخطط على نسبة 94٪ لتسليم الحزم في CDMA بينما يحتوي على 92٪ في TDMA. يمكن اعتبار التقنيات التي تم اختبارها كأداة واعدة للتحكم في الوصول المتوسط في الشبكات المخصصة للمركبات ، والتي تكون قادرة على تحقيق العديد من تطبيقات السلامة غير التقليدية لتعزيز معايير السلامة العامة وتعزيز السلامة للركاب والمشاة و السائقين على الطرق.