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Fuzzy Logic based Cluster Head selection by enhancing Aggregated Relative Velocity in VANET

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Approval sheet

This Independent Research entitled "**Fuzzy Logic based Cluster Head selection by enhancing Aggregated Relative Velocity in VANET**" has been read and approved as meeting the preliminary research requirements of the School of Computing in partial fulfillment for the award of the degree of Master in Computer Networking, Jimma University, and Jimma, Ethiopia.

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Dedication

I dedicate this thesis to my family members. And also friends, and teachers who shared their words of advice and encouragement to finish this study.

Acknowledgment

First, I would like to thank the almighty GOD, who helped me in every aspect of my life. I am extremely thankful to my main advisor Assistant Prof. Mr. Kebebew Ababu and My co-advisor Mr. Werku Brhan , whose sincerity and encouragement I will never forget. They have been an inspiration as I hurdled through the path of this Master's degree. Each of the members of my Thesis Committee has provided me with extensive personal and professional guidance and taught me a great deal about both scientific research and life in general. This thesis would not have been possible without the guidance of all teachers and friends. I am thankful for the extraordinary experiences they arranged for me and for providing opportunities for me to grow professionally. I am grateful for my parents whose constant love and support keep me motivated and confident. My accomplishments and success are because they believed in me. Deepest thanks to my siblings, who keep me grounded, remind me of what is important in life, and are always supportive of my adventures.

Finally, I owe my deepest gratitude for all supporting me in my thesis. I am forever thankful for the unconditional love and support throughout the entire thesis process and every day.

Lealem Telele

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Acronyms

AC: Access Categories

AIFS: Arbitration Inter-Frame Spacing

ANFIS: Adaptive Neuron-Fuzzy Inference System

AU: Application Unit

ARV: Aggregated Relative Velocity

BSM: Basic Safety Message

CALM: Continuous Air-interface Long and Medium range standardization

CCH: Control Channel

CH: Cluster Head

CM: Cluster Member

CG: Cluster Get way

CSV: Comma-Separated Values

CW: Contention Window

DSRC: Dedicated Short-Range Communication

ECDSA: Elliptic Curve Digital Signature Algorithm

EDCA: Enhanced Distribution Channel Access

EDR: Event Data Recorder

ETSI: European Telecommunication Standards Institute

EU: Europe Union

FCC: Federal Communication Commission / USA

FCFS: First Come First Served

FDCL: Fuzzy Dependency and Command Language

FIFO: First-In-First-Out

FIS: Fuzzy Inference System

GNU: GNU's Not Unix

GPS: Global Positioning System

GUI: Graphically User Interface

HRTZ: History Relative Time Zone

IPv6: Internet Protocol version Six

ISO: International Organization for Standardization

ITS: Intelligent Transportation System

IVC: Inter-Vehicle Communication

LLC: Logical Link Control

MAC: Medium Access Control

MANET: Mobile Ad hoc Network

MATLAB: MATrix LABoratory

Mbps: Megabits per second

MHZ: MegaHertZ

MLPQ: Multi-level priority queue

MOVE: Mobility model generator for Vehicular networks Environment

NHTSA: National Highway Traffic Safety Administration

OBU: On-Broad Unit

OFDM: Orthogonal Frequency Division Multiplexing

PLCP: Physical Layer Convergence Procedure

RCP: Resource Command Processor

RSA: Ron Rivest, Adi Shamir, and Leonard Adleman

RSU: Road Side Unit

SAE: Society of Automotive Engineers

SAQ: Safety Area Queue

SCH: Sub-Cluster Head

SIMULINK: MATLAB based graphical programming environment for modeling

TCL: Tool Command Language

TCP: Transmission Control Protocol

UDP: User Datagram Protocol

UI: Unnumbered Information

V2I: Vehicle to Infrastructure

V2V: Vehicle to Vehicle

VANET: Vehicular Ad-hoc Network

WAVE: Wireless Access in Vehicular Environment

WLAN: Wireless Local Area Network

WSM: WAVE Short Message

WSMP: WAVE Short Message Protocol

XML: extensible markup language

Abstract

Vehicular Ad hoc Network is one of major area in the technology of Mobile Ad hoc Network. Making a vehicular network more robust and scalable is one of main issues in Vehicular Ad hoc Network. Since vehicles are high amount of mobility and unpredictable situation, it's a major issue to manage vehicles in the certain network. So we have to find a way to communicate in stable and robust method of cluster head selection.

Clustering is of crucial significance in order to cope with the dynamic features of the Vehicular Ad hoc Network topologies. Dividing in different cluster and assigning one head for certain number of cluster member is the method of the whole process. The challenge we face is how to select the reliable and efficient vehicle for to be a cluster head. And what factors to use in order to differentiate the best node among others. The prominent parameters speed, acceleration, distance, aggregated relative velocity and direction information are taken into account as inputs of the proposed cluster head selection algorithm. Those inputs will be fuzzified by the fuzzy logic by depending on the rule initiated we can give them the value to be a head or a member.

Fuzzy logic can handle multi-valued truth by using membership function which will measure the degree of inputs. This mechanism supports in effectively way to get and assign the cluster head.

In general, the finding in this research is better decision making system than recent works. By tolerating the instability of vehicular ad hoc network behavior. Recent works in such problem suggested fuzzy logic base decision making means. But we also enhance the parameter of the inputs to our fuzzy inference engine which is called aggregated relative velocity. Using MATLAB software we illustrate what have been done. SIMULINK is the package that facilitates the simulation method.

Key words: VANET, Cluster Head, Cluster Member. Fuzzy logic, Membership Function, MATLAB, MANET

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Chapter One

Introduction

1.1 Background

A network of vehicles connected with each different nodes and sharing data is called VANETs. VANETs are Sub group of MANETs with some specific characteristics and challenges. For instance high mobility, swiftly altering topology and unbounded network dimension are some of areas the place VANETs are extraordinary from MANETs. [1]

The VANET is referred to the ad hoc manner community in which shifting automobiles and different gadgets come into contact with the wireless medium. The transferring car share beneficial data with the other devices. In the network, other devices behave like a node which transfers beneficial facts to the different nodes. After acquired the beneficial facts or records from the transferring vehicles, the nodes generate useful data from them and transferred to different nodes. [2] [15]

Due to the high vehicle mobility condition the VANET is suffering from rapid network topology change and variable network connectivity. Above said issues are resolved with the clustering topology built in the VANET. All the nodes combined in a group during clustering process. A cluster has three main parameters cluster head (CH), cluster member (CM) and cluster gateway (CG). [2]

The Vehicular Ad Hoc Network (VANET) plays a crucial position in the improvement of smart cities, especially in ensuring vehicles' safety on roads. However, VANET wireless-based networks face some challenges such as stability, communication, and reliability.

VANET indulge Intelligent Transportation System (ITS) services to the end users for transferring data exchange and safety. It provides a wireless communication between moving vehicles using different standards like Dedicated Short Range Communication (DSRC) and Wireless Access in Vehicular Environments (WAVE). [4]

ITS propose to manipulate car traffic, help drivers with safety and different information, and furnish some offerings such as automatic toll collection and driver aid structures [2]. In essence, VANETs provide new prospects to improve superior solutions for making reliable verbal exchange between vehicles. VANETs can be defined as a part of ITS which goals to make transportation systems faster and smarter in which motors are geared up with some short-range and medium-range wireless communication [3].

Cluster based routing protocol is one of the most famous routing scheme in VANET. This routing protocol is suitable for large networks. One of the merits of cluster based routing protocols is dividing a large area network into smaller chunks and make in charge one of the members. This behavior of the protocol is counted as merit for the networked environment. In addition to the above advantage cluster based scheme has high scalability. [8] Adding and dropping nodes is not that much difficult when it compare with others. [2] On the other hand, there are some demerits of the clustering approach. Increasing latency is the headache of cluster based approaches. Since the dissemination of data passing through the cluster head it's obvious to delay the time of package delivery. [4]

Clustering in VANET's desires to choose a cluster head (CH) to synchronize the communication between clusters. The rest knobs in the cluster are called cluster members. [3] In Cluster based routing the entire geographic area is divided into clusters. In this protocol, the vehicles that are close together form a group. Each cluster has one cluster head which is responsible for intra and inter-cluster communication [8]. Our task in this new proposal is writing an algorithm which is be able to select head of the cluster depend on the following parameters

- Position of the node
- Speed of the node
- Direction of flow of packages
- Acceleration of the node

This selection of CH is called fuzzy logic-based, because the assignment is can be done when another head is performing but not as demanded. So we will go through the fuzzy logic based selection of cluster head. In general, all the current schemes provide the means of better selection of CH, but we will try to add the feature like membership functions before the assignment of cluster head up to some characters.

1.1.1 VANETs characteristics

1.1.1.1 Highly dynamic topology

The topology in VANETs is highly dynamic due to fast moving vehicles, drivers behavior and link lifetime (the time in which vehicles are in communication range of each other). *Patterned mobility*. In MANETs, the nodes move in a random way while in VANETs the vehicles mobility is constrained to road pattern and layout. Vehicles move in a predictable manner and obey traffic rules and regulations.

1.1.1.2 No power or storage constraints

Unlike other sensor networks, the power and storage limitations are not a major issue in VANETs due to continuous availability of battery power in vehicles [32].

1.1.1.3 Dynamic network density

The network density in VANETs is highly variable depending on time and location. Sometimes the density may be very high in traffic jams or very low at some points due to no congestion at certain points as well certain times. [31]

1.1.1.4 Large scale

The network may be very large in size covering a whole city or even a country having thousands of vehicles and RSUs.

1.1.1.5 No computational power constraints.

Vehicles are equipped with high performance processors and other resources [33].

A cluster-based network is a kind of distributed network where the underlying nodes are categorized into different types.

1.1.2 Types of Nodes

These are the following types of nodes that can be found in any vehicular cluster model. [10]

1.1.2.1 Cluster Head (CH)–this is the node that is the coordinator or head of the cluster. It takes responsibility for the discovery and maintenance of the routing paths. All the intra-cluster and inter-cluster communication takes place using this node.

1.1.2.2 Secondary Cluster head (CSH)—this is the node selected by the CH on the basis of different parameters. This node acts as a backup or as a subordinate to CH and assists it in the clustering process. CSH may or may not be present in the cluster based on the algorithm being used for clustering and the application of the algorithm.

1.1.2.3 Cluster Member (CM)—the node which is not CH or SCH is a cluster member. These are the nodes which broadcast messages to each other for information exchange.

1.1.2.4 Gateway Node (GW)–this is the node which helps in communication with RSU. It is not necessary that this is present in every cluster.

A cluster architecture based vehicular ad hoc networks can be modeled into two different ways, i.e., single-hop or multi-hop. Both models have their own advantages and disadvantages based on the applications they are used for. A single-hop model is one where every node is directly connected to CH. A multi-hop model is one where the distance between the CH and the CM can be n-hop. Depending on the distance the multi-hop can be 2-hop, 3-hop, etc. This distance is predefined by a maximum hop count. Multi-hop effectively expands the coverage of a cluster, which can lead to less change in CH and ultimately stable clusters.

According to experts clustering the vehicles is the best way to handle the dynamic and stochastic environment of the transportation.

1.1.3 Background of Fuzzy Logic

Fuzzy logic was first proposed by Lotfi Zadeh in a 1965 paper for the journal Information and Control. In his paper, titled "Fuzzy Sets," Zadeh tried to replicate the type of facts used in statistics processing and derived the elemental logical policies for this variety of set.

"More frequently than not, the classes of objects encountered in the real physical world do no longer have precisely defined standards of membership," Zadeh explained. "Yet, the fact remains that such imprecisely defined 'classes' play and vital function in human thinking, Particularly in the domains of sample recognition, conversation of information, and abstraction."[43]

Since then, fuzzy logic has been efficiently applied in laptop manipulate systems, image processing, artificial intelligence, and different fields that depend on alerts with ambiguous interpretation.

1.1.3.1 Components of Fuzzy Logic

Fuzzy logic is often described as having four components (Figure 1)

- Fuzzification. The process of converting specific input values into some degree of membership of fuzzy sets based on how well they fit.
- Fuzzy rules / knowledge base. These are the If-Then rules to follow, often derived from expert opinions or via more quantitative approaches.
- Inference engine. The way of obtaining the final fuzzy conclusion, according to the degree of membership of input variables to fuzzy sets and the detailed fuzzy rules
- Defuzzification. The process of converting the fuzzy conclusions into detailed output values.

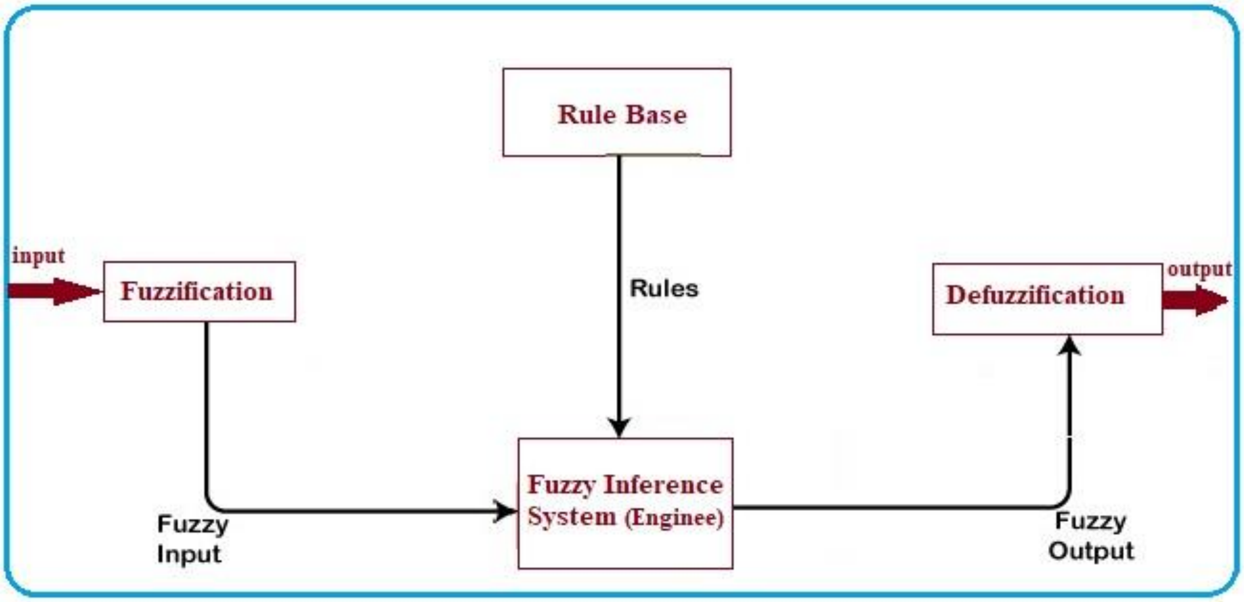


Figure 1: Components of FUZZY Logic

Artificial intelligence-based decision making systems, such as fuzzy logic, perform well in pattern classification and decision making systems. Accordingly, in this work, we propose a fuzzy logic-based intelligent scheme for more realistic clustering of the inter-vehicles coordination control. Fuzzy logic is a decision making process based on some input membership functions and a group of fuzzy rules. Its principle is based on mimicking the way the human brain operates. Hence, fuzzy logic presents itself as an appropriate solution to handle uncertainty in tuning for the best beacon exchange rate with other vehicles. Many intelligent clustering schemes for VANETs were elaborated.

Fuzzy logic is an effective tool for solving various computing problems in the world. This technique has been applied in different machines and applications to control actions based on certain pre-defined conditions. In the future, fuzzy logic will be applied to diverse products and systems. The scope of fuzzy logic applications will increase due to technological advancement and digital transformation. [43]

1.2 Statement of problem

As discussed previously there are different approaches of VANET protocol. Cluster based routing protocol is one of them. Cluster based approach has some problems and which can be resolved and enhanced as much as possible using the proposed solution of the thesis. We will address problems one by one and suggest the solution for each of them.

<u>A. Speed and oscillatory:</u> Speed of the vehicles is the headache of in the vehicular ad hoc network world. Because of each drivers intention and capability of the vehicle there is always an oscillatory which makes difficult of transferring data whether inter-vehicular or intra-vehicular communications. During the change of topology the assigned cluster may go far away from most of members so this type of events make hard to transfer the data from members to the cluster head. [1] Most of the time, the drivers' behaviors and how they estimate the inter-vehicle distance and other factors such as the rapid changes in vehicular traffic conditions and characteristics are subjective and not predictable. [1, 31, 36, 44]

In this general situation obtaining a single cluster head statically makes more complicated and difficult to achieve the demanded flow of data. Changing the cluster head as wanted as possible makes less of the dropped packets.

B. Instability of the cluster: clusters in VANET faces instability. Obviously high speed and different intentions of drivers will make the formed cluster to be instable. Unlike MANET the VANET clusters have less lifetime and most of the time spans are difficult and unpredictable environment. [1, 6]

To create and avoid as much as possible instabilities assigning the head of the cluster fuzzy logic inference system is one of the solutions. For example the driver of the head node can isolated with certain amount of distance from the whole crew in this state the cluster may resign and assign another node as a cluster head which is on the comfortable position to manage the rest of the members. This helps to make the cluster more stable.

C. Loosing CH: once the cluster is formed and started performing usual tasks it may not continue in that manner. The head node may lost due to traffic or it may stop somewhere. If the cluster head is not communicating the member tries to be a head by itself or may be the cluster members will be join another neighbor cluster. [3]

But if we can assign the CH based on fuzzy logic methodology. We can cast other members to the head while the current head communication is coming weak and going too lost from the cluster.

So far we have tried to express deeply each problems faced by in cluster based routing protocol. Once the cluster head is assigned and waiting it until resigns by itself consequences those type of problems. We must have propose the fuzzy logic-base assigning method or scheme to deserve a better communication as such efficient and effective dissemination of data whether in between each members or with the neighbor clusters and the outside environment.

In general we will try to solve the above problems and to address this questions

- Φ How to assign a make a stable cluster by extending the lifetime of network?
- Φ What is the impact of cluster making without multivalued data type inputs?

- Φ How to take over the position of CH while the current head is assigned?
- Φ How to process the multi-valued inputs to get the better decision making for CH selection?

1.3 Objectives

1.3.1 General Objective

The general objective of this thesis is proposing effective and efficient cluster based routing protocol approach during dissemination of data using head of the cluster.

1.3.2 Specific Objective

- ☞ To achieve our general objective, we have specific objectives. Those objectives are:
- ☞ Reviewing the existing VANET technology
- ☞ Reviewing the Existing Cluster based routing protocol scheme in VANET
- ☞ Design algorithm of assigning cluster head
- ☞ Design algorithm for fuzzy logic based selection of head in a specific cluster
- ☞ Propose new fuzzy inference scheme to assignment of cluster head
- ☞ Test and evaluate the new scheme in simulation environment
- ☞ Compare and contrast the new scheme with existing dissemination scheme

1.4 Methods

We have to use some techniques to optimize and get of ride those problems and to achieve what we want in our objectives. Those are the following methods.

1.4.1 Literature Review

To achieve the objectives listed above we review deferent papers about the general VANET technology for understanding the overall technology as well as the existing method of selecting and affiliation method of cluster head of the cluster. We have to dig out what has been done in that area.

1.4.2 Design and Implementation

In this phase, the proposed architecture and algorithms to cast the new head, resign the current CH and assign new one. All the detail architecture of the proposed work is designed in this phase. Because of the difficulty of implementing VANET in a real environment we, implemented the proposed system in network simulation environment. We implement via a realistic simulation MATLAB and Simulink.

1.4.3 Evaluation of the Proposed Work

We conduct experiment in simulation environment and evaluated our work in terms of network parameters like network overhead, data delivery ratio and number of notified vehicle. After evaluating our work we compare and contrast with the existing works done on static cluster head selection cluster based routing protocol scheme.

1.5 Scope and limitation

Our proposed system focuses on developing a type of cluster which be able to assign using fuzzy logic its head cluster. We will give more attention for developing algorithms those can handle the stochastic environment of the vehicular fast and accelerated behavior by giving dynamic solutions based on fuzzy logic inference system like assigning the head and resign when its performance degraded.

What we won't cover or address are

- Security issues during transition from one head to the other
- Nodes unwillingness being CH
- Machine learning aspects

1.6 Significance of the study

The different way using fuzzy logic based CH selection has the following significant points.

- Developed cluster head selection algorithm is modelled using MATLAB software. The network model employing the proposed algorithm and the example scenarios are implemented in MATLAB/SIMULINK Modeler simulation software. During the simulation, both parts work concurrently for more realistic estimation and substantiation.
- A new multi-criteria CH selection system, which has the ability to adapt its structure according to the application requirements and network conditions, is proposed.
- The proposed CH selection algorithm is different from one of the last studies.[35] [36] [37] [38] due to direction parameter taken into account (for two-way multilane highway) and the CH selection process aimed with RSUs.
- To the best knowledge of authors, using direction, speed, distance and acceleration parameters for decision making of cluster head in order to optimize CH selection process is the first time.

Chapter Two

Literature Review

2.1 Overview of VANET Technology

Vehicular ad hoc networks (VANET) are a subcomponent of mobile ad hoc network (MANET).[33] Each node act as a router can freely move any direction and every vehicle fitted out communication power and communicates with every different and interlinked to create a network in ad hoc nature. Vehicles in VANET to shape the topology which is sometimes terribly dynamic and extensively no uniformly distributed. The frequent disconnection of a link due to the highly dynamic topology nature of VANET does not adapt to MANET routing protocol.

Commonly, VANET architecture services two types of communication devices namely OBU and RSU (Road-Side Unit). OBUs are installed in vehicles, and RSUs are stationary devices and placed on roadsides. The RSUs act similar to an access point and capable of providing communications with infrastructures (i.e., 2G, 3G, fiber optic, or microwave). The OBU provides travel assistant safety applications (i.e., accident warning systems) between vehicles and also communicate with RSU for getting specific applications from wireless network technologies (i.e., downloads and emails). Also, the data in VANETs are classified into real-time (i.e., video streaming) and non-real time (i.e., traffic and weather information) traffics [42].

As mentioned before, two main units, RSU and OBU standards in VANETs have been developed by IEEE which is referred to as Wireless Access in Vehicular Environment (WAVE) [6]. WAVE consists of IEEE 802.11p and IEEE 1609.X protocols [7]. Physical and MAC layers of WAVE are dealt with IEEE 802.11p and the upper layers are designed by IEEE 1609.X. RSU and OBU systems use 10 MHz bandwidth in 5.9 GHz band and supported 3 to 27 Mbps data rates depending on the modulation scheme [8]. In IEEE 802.11p protocol, CSMA/CA is used for medium access control.

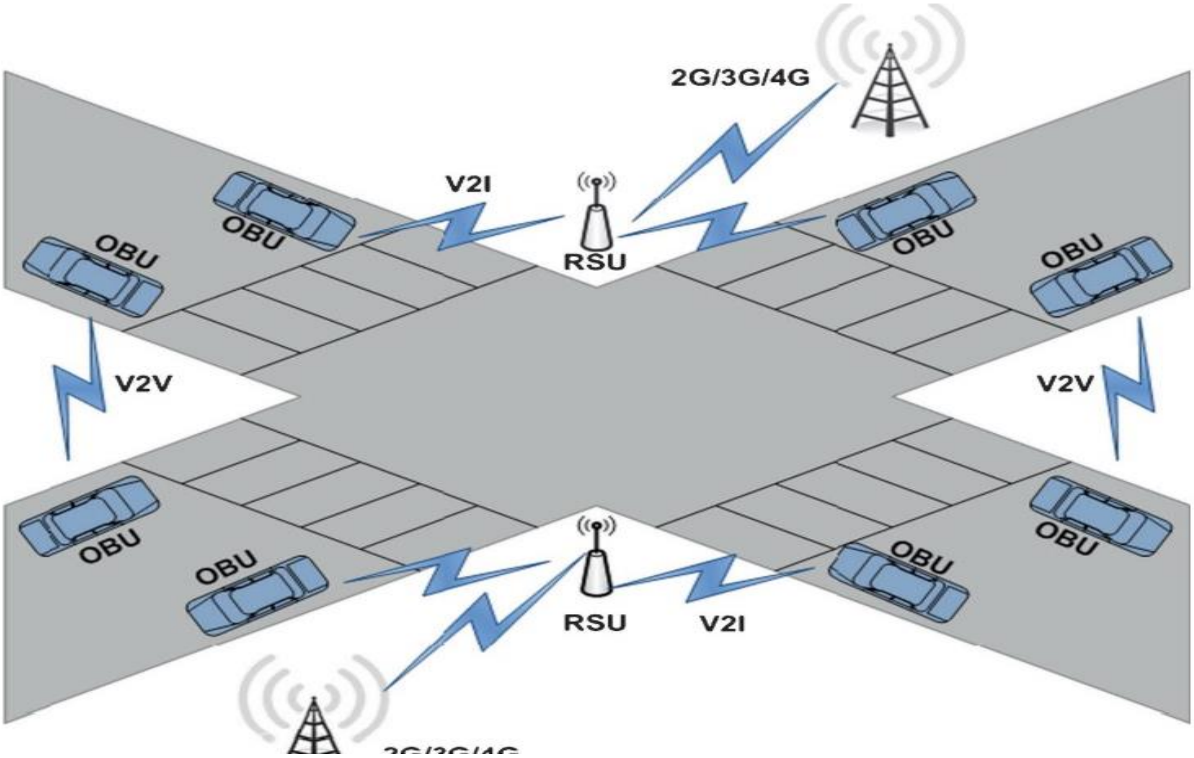


Figure 2 VANET structure

2.1.1 Road side Unit

A VANET is also formed by a collaboration between vehicles and fixed infrastructures called roadside units (RSUs), which help with data transmission. RSU is a fixed device along roads that is equipped with at least a network device for short-range wireless communications based on IEEE 802.11p [9], with 75 MHz of a Dedicated Short Range Communication (DSRC) spectrum at 5.9 GHz [10]. Within their coverage area, an RSU plays an important role for collecting and analyzing traffic data generated by smart vehicles. Additionally, RSUs can serve as a gateway to other communication networks, such as the Internet [11]

In a VANET, information can be relayed from a vehicle to the next toward its final destination through direct (i.e., instant) forwarding or through carry-and-forwarding. VANETs also allow vehicles to connect to Roadside Units (RSUs), which in turn are connected to the wired Internet and may also be interconnected with each other via a high capacity mesh network. The RSU wired and wireless backbone network can be used to bridge network partitions in the VANET.

Recent works (such as [12]) proved the impact of good RSU placement on the dissemination of both safety and comfort information. Algorithms have been used [16], [19] to geographically position the RSUs in the most effective locations around the city.

2.1.2 On Board Unit

On-Board Diagnostics (OBD-I) standard adopted in the USA for vehicle emission testing. However, it was only with the OBD-II [18] that full diagnosis capabilities and standardization were achieved. Topics of the standard are: structure of the diagnosis connector, protocols for the electrical signals, messages format, and a list of readable vehicle parameters.

Figure 3 Onboard Unit Vs RSU

There are two sample applications for our OBU device. The first application can be included in the set of driver safety and assistance ones. In this case in-vehicle data must be sent within a constrained time to a control room, the effectiveness of the develop OBU device in such a scenario has been proven by means a delay time analysis in sending in vehicle data to roadside networks. The second application belongs to the resource efficiency set, and the use of an OBU device able to gather car-related parameters is discussed in respect of the fuel level estimation problem. The classification of both presented applications is according to the taxonomy reported in [19].

2.2 Standards and architectures for wireless communications in ITS

The first attempt to propose standardized wireless solutions for ITS systems date back to the year 2001 when the Technical Committee 204, Working Group 16 of the International Organization 4 for Standardization (ISO) started to develop a basic set of ITS communication standards under the name Communications Access for Land Mobiles (CALM) [14]. The main goal of the Working Group 16, according to the CALM concept, is to define a family of international standards for a common architecture, protocols and interface definitions related to wireless-based, interoperable access technologies for ITS applications and services. The CALM standard establishes three possible communication modes for ITS: vehicle-to-vehicle, vehicle-to-infrastructure and infrastructure-to-infrastructure, while considering a large set of wireless communication standards (WLAN, LTE, WiMAX, UMTS, EDGE, GPRS) in its reference system architecture(Figure2) [4].

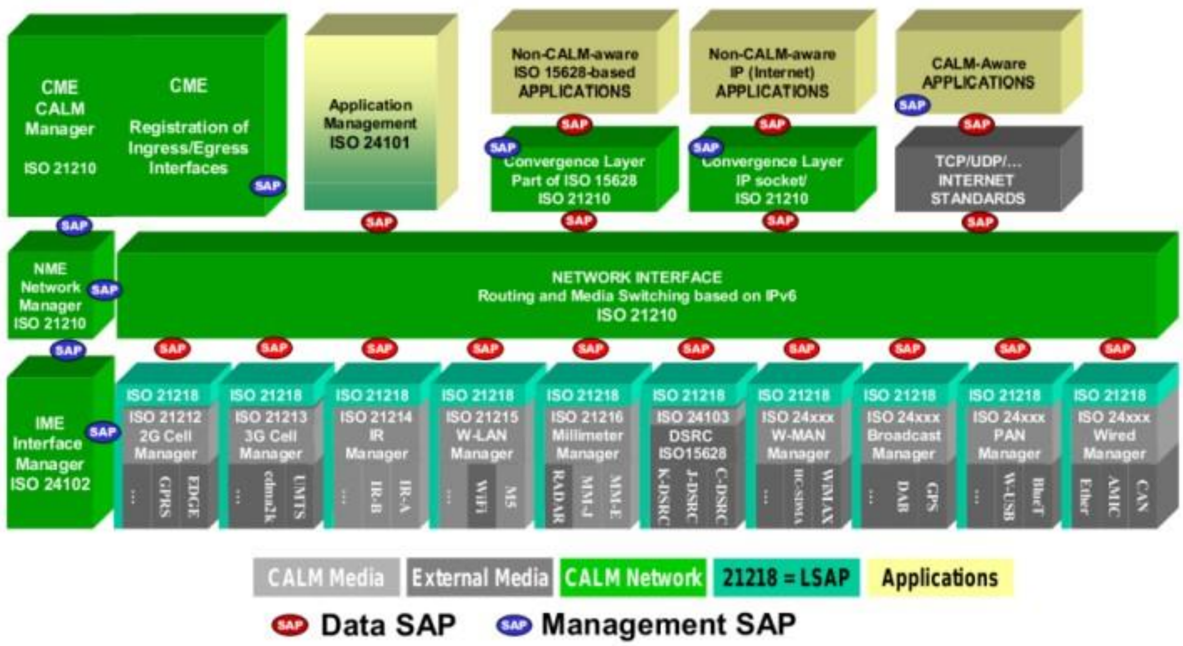


Figure 4 CALM system architecture from. [14]

Intelligent transportation machine (ITS) can successful to relay the data between the automobile based totally on geographical region and get the neighbor information thru the navigation gadget fitted in every vehicle. On the geographic routing, primarily based on geographic information to pick out the neighbor, which is close to the destination to ahead the packet to the destination. So the site visitor’s video display unit’s offerings and navigation provider to end up on hand in the vehicle. The ITSs in the wireless get right of entry to in vehicular environments (WAVE) standards that decide distinct types of communication, for example, vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle (I2V). [14]

2.2.1 Vehicle-to-Vehicle (V2V)

It is multi-hop multicast/broadcast communication used to transmit traffic related information over multiple hops to a group of receivers. ITS is generally concerned with the road ahead and not on the road behind. ITS mainly used two types of message forwarding techniques, Nave Broadcasting and Intelligent Broadcasting [13].

- Naive Broadcasting: believes in periodic broadcasting of messages at regular intervals. If the message comes from behind then the vehicle ignores the message, but if the message comes from a vehicle ahead then the receiving vehicle send its own broadcast message to the vehicles behind it. The limitations of naive broadcasting method is that large numbers of broadcast messages are generated, hence increases network overhead. [13]
- Intelligent Broadcasting: overcomes the above limitation by using acknowledgements, hence limiting the number of message broadcasts. If the event-detecting vehicle receives the same message from behind it, it assumes that at least one vehicle in the back has received it and will be responsible for further transmitting the message. [13]

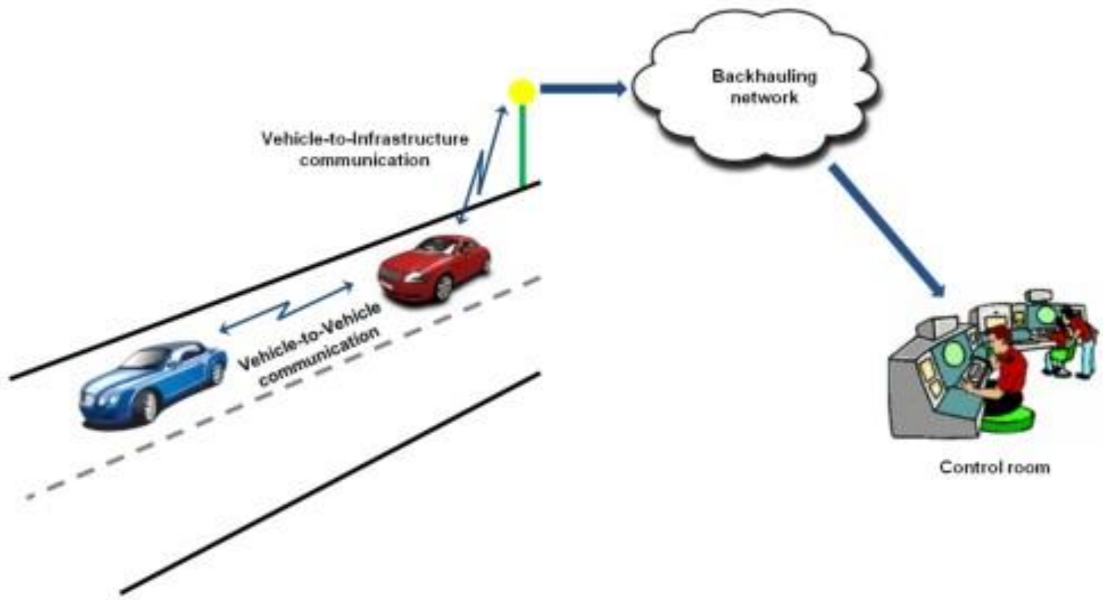


Figure 5 V2I and V2V communication

2.2.2 Vehicle-to-Infrastructure (V2I)

In both standardization (Europe and US) initiatives introduced in the previous section, the key wireless technologies for enabling data transmission from vehicles to roadside networks, and vice versa, are: GPRS, UMTS, WiMAX, LTE, and WLAN. Considering their use in ITS applications targeted to the vehicular environment each one of them shows advantages and drawbacks.

V2V and V2I communications, the IEEE Working Group 1609, established in 2006, started the development of the Wireless Access in Vehicular Environment (WAVE) standard [16]. In the suite of WAVE protocols, the IEEE 802.11p standard for Physical and Data Link layers, is derived from IEEE 802.11a, aiming at conforming the WLAN specifications with the vehicular environment: it guarantees a seamless communication between two network nodes with a relative speed up to 200 km/h [17] in the 5.9 GHz frequency band. Although the standard definition started in 2006, the first official document has been released in July 2010 only; today several wireless transceivers compliant with IEEE 802.11p are available on the market.

2.3 Communication Standards for VANET

Dedicated Short Range Communication (DSRC) It is developed by USA and is a short to medium range communications service that is used for V2I and V2V communication. The United States Federal Communications Commission (FCC) had allocated 750 MHz of spectrum i.e from 8.5 GHz to 9.25 GHz to be used by DSRC. [20]. DSRC spectrum has 7 channels with each channel 100 Mhz wide. Out of 7 channels, six channels are used for service purpose and remaining one for control purpose. The following figure 5 shows the bandwidth allocation of DSRC Spectrum.

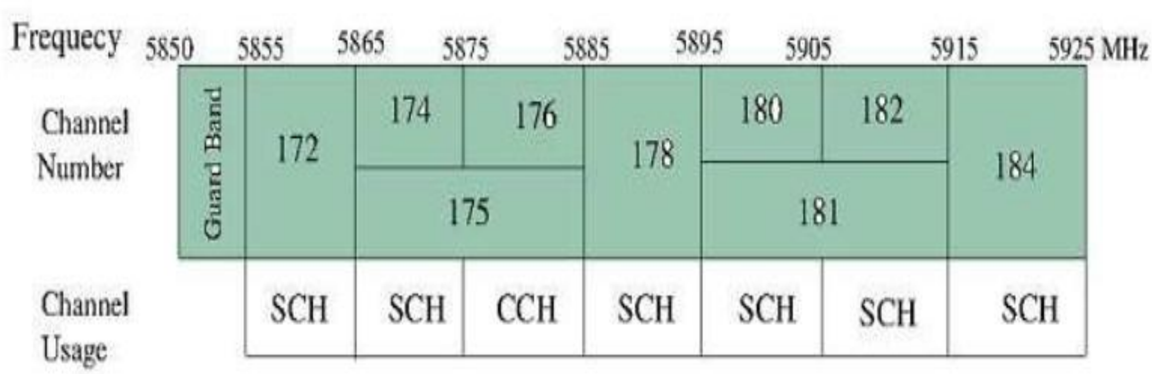


Figure 6 DSRC Bandwidth Allocation [20]

Wireless Access in Vehicular Environment (WAVE) (IEEE 1609.11p) in 2003, American Society for Testing and Materials (ASTM) sets ASTM-DSRC which was totally based on 802.11 MAC layer and IEEE 802.11a physical layer [20]. The main problem with IEEE 802.11a with Data Rate of 54 Mbps is it suffers from multiple overheads. Vehicular scenarios demands high speed data transfer and fast communication because of its high topological change and high mobility. For this the DSRC is renamed to IEEE 802.11p Wireless Access in vehicular Environments (WAVE) by the ASTM 2313 working group. This works on MAC layer and physical layers. WAVE consists of Road Side Unit (RSU) and On-Board Unit

(OBU). WAVE uses OFDM technique to split the signals. The following figure 6 shows the WAVE, IEEE 802.11p, IEEE 1609 and OSI model.

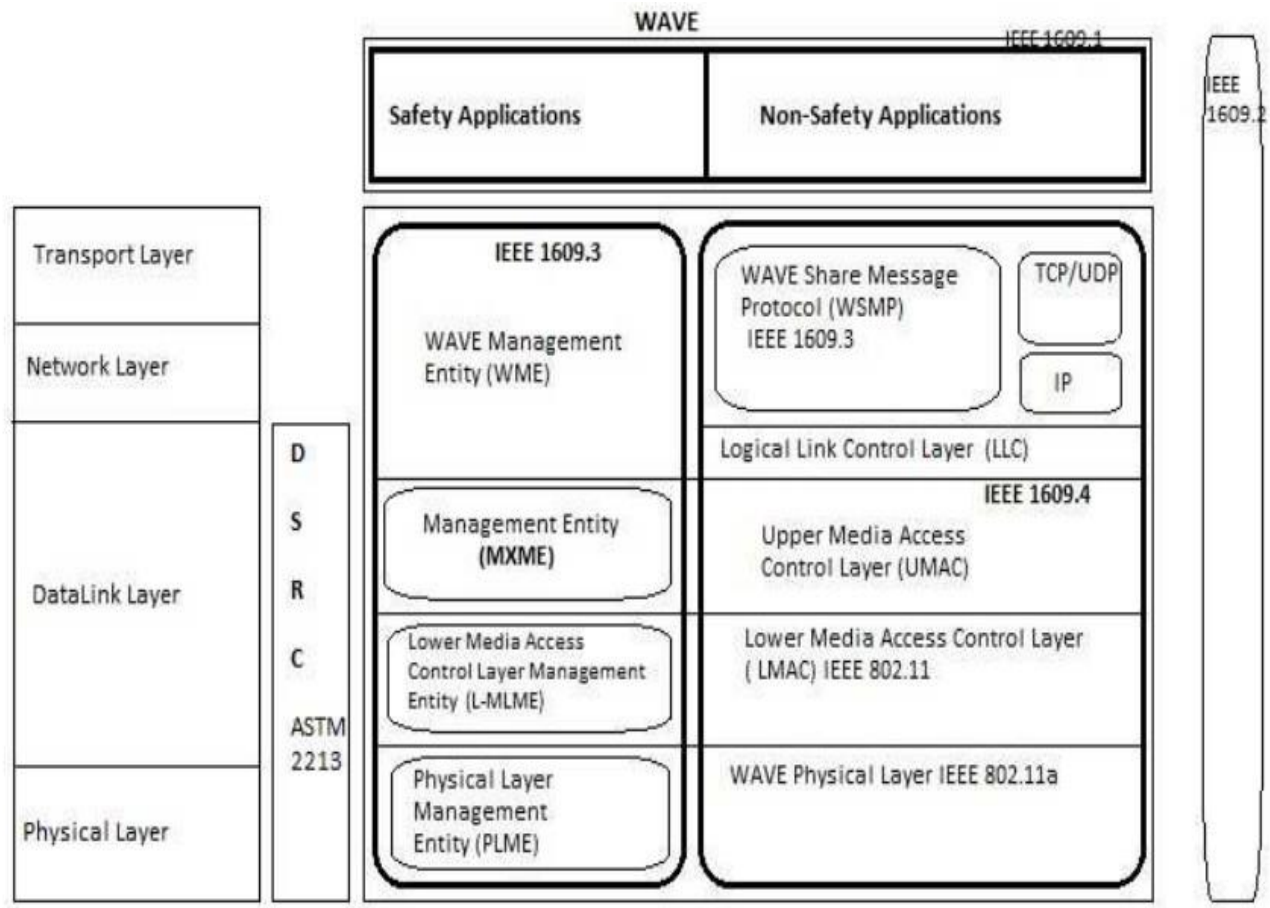


Figure 7 WAVE protocol Stack [20]

2.4 Overview of Fuzzy Logic

"In fuzzy logic, the truth of any statement becomes a matter of degree." Kaufmann, A

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects without crisp, clearly defined boundaries. In such cases, membership in a set is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalued logical systems. [21] [22] [23]

Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, this mechanism is provided by the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the toolbox, it is effectively one of its principal constituents. In most of the applications of fuzzy logic, a fuzzy logic solution is, in reality, a translation of a human solution into FDCL. [22]

Fuzzy logic approximates human reasoning and does a good job of balancing the tradeoff between precision and significance. For instance, when warning someone of an object falling toward them, being precise about the exact mass and speed is not necessary. [23]

2.4.1 Why Use Fuzzy Logic?

Here is a list of general observations about fuzzy logic:

- ☞ Fuzzy logic is conceptually easy to understand. The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far-reaching complexity.
- ☞ Fuzzy logic is flexible. With any given system, it is easy to layer on more functionality without starting again from scratch.
- ☞ Fuzzy logic is tolerant of imprecise data. Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.

- ☞ Fuzzy logic can model nonlinear functions of arbitrary complexity. You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox software.
- ☞ Fuzzy logic can be built on top of the experience of experts. In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.
- ☞ Fuzzy logic can be blended with conventional control techniques. Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.
- ☞ Fuzzy logic is based on natural language. The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use.

The last statement is perhaps the most important one and deserves more discussion. Natural language, which is used by ordinary people on a daily basis, has been shaped by thousands of years of human history to be convenient and efficient. Sentences written in ordinary language represent a triumph of efficient communication.

In general, fuzzy inference is a method that interprets the values in the input vector and, based on some set of rules, assigns values to the output vector. [23]

2.4.2 Fuzzy Sets

Fuzzy logic starts with the concept of a fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. To understand what a fuzzy set is, first consider the definition of a classical set. A classical set is a container that wholly includes or wholly excludes any given element. For example, the set of days of the week unquestionably includes Monday, Thursday, and Saturday. It just as unquestionably excludes butter, liberty, and dorsal fins, and so on. [21]

The plot (Graph 7) below shows the truth values for weekend-ness if you are forced to respond with an absolute yes or no response. On the right is a plot that shows the truth value for weekend-ness if you are allowed to respond with fuzzy in-between values. [21]

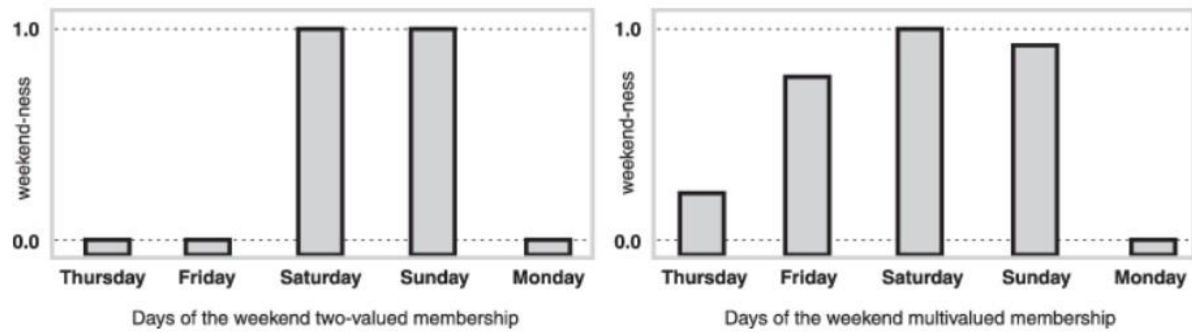


Figure 8 Two-valued and multivalued formation of the weekend-ness of the date [21]

2.4.3 Membership Functions

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept.

The curve is known as a membership function and is often given the designation of µ. For example, the following figure (figure 8) shows both crisp and smooth tall membership functions.

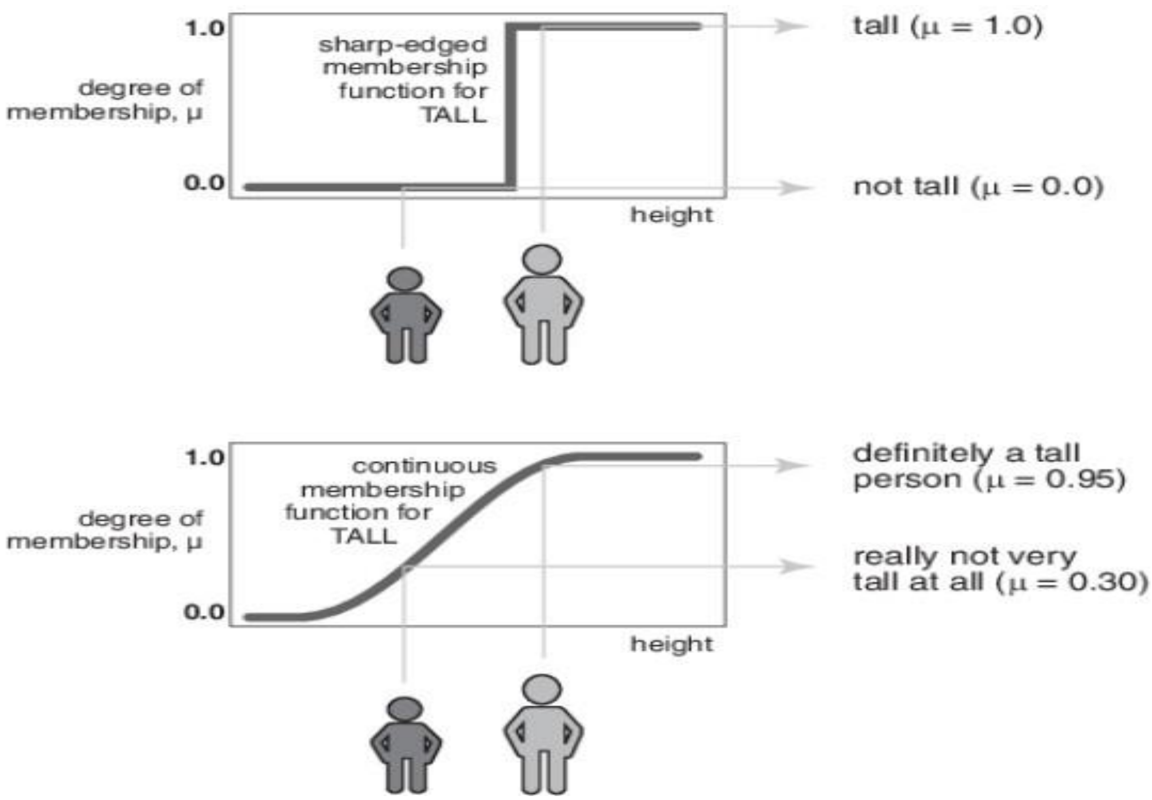


Figure 9 the membership function shape

A membership function must really satisfy is that it must vary between 0 and 1. The function itself can be an arbitrary curve whose shape we can define as a function that suits us from the point of view of simplicity, convenience, speed, and efficiency.

A classical set might be expressed as

$$A = \{x \mid x > 6\}$$

A fuzzy set is an extension of a classical set. If X is the universe of discourse and its elements are denoted by x, then a fuzzy set A in X is defined as a set of ordered pairs.

$$A \quad \{x, \mu A\ (x) \mid x \in X\}$$

$$A = \{x, \mu A\ (x) \mid x \in X\} \quad [21]$$

μA(x) is called the membership function (or MF) of x in A. The membership function maps each element of X to a membership value between 0 and 1.

Basic membership function types. [24]

- Piece-wise linear functions:
- Gaussian distribution function:
- Sigmoid curve:
- Quadratic and cubic polynomial curves:

2.4.4 If-Then Rules

Interpreting if-then rules is a three-part process. This process is explained in detail in the next section:

1. *Fuzzify inputs:* Resolve all fuzzy statements in the antecedent to a degree of membership between 0 and 1. If there is only one part to the antecedent, then this is the degree of support for the rule.
2. *Apply fuzzy operator to multiple part antecedents:* If there are multiple parts to the antecedent, apply fuzzy logic operators and resolve the antecedent to a single number between 0 and 1. This is the degree of support for the rule.
3. *Apply implication method:* Use the degree of support for the entire rule to shape the output fuzzy set. The consequent of a fuzzy rule assigns an entire fuzzy set to the output. This fuzzy set is represented by a membership function that is chosen to indicate the qualities of the consequent. If the antecedent is only partially true, (i.e., is assigned a value less than 1), then the output fuzzy set is truncated according to the implication method.

2.5 Fuzzy Inference Systems

- Mamdani systems
- Sugeno systems

Fuzzy Inference System	Advantages
Mamdani	• Intuitive • Well-suited to human input • More interpretable rule base • Have widespread acceptance
Sugeno	• Computationally efficient • Work well with linear techniques, such as PID control • Work well with optimization and adaptive techniques • Guarantee output surface continuity • Well-suited to mathematical analysis

Table 1 Mamdani systems and sugeno

2.5.1 Defuzzify

The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified to obtain a single output value from the set.

There are five built-in defuzzification methods supported: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum. Perhaps the most popular defuzzification method is the centroid calculation, which returns the center of the area under the aggregate fuzzy set, as shown in the following figure 9. [21]

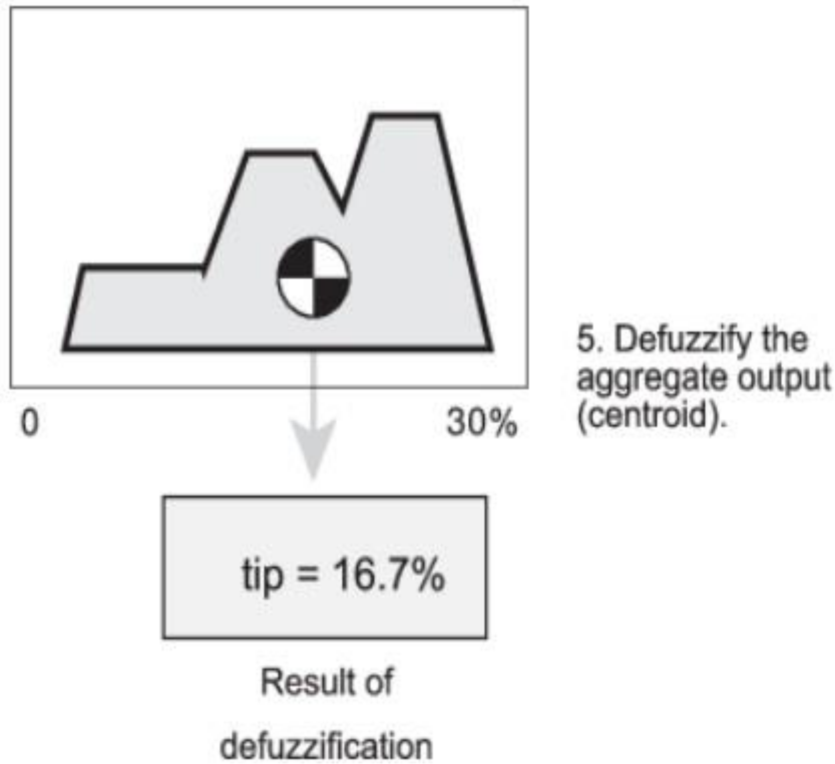


Figure 10 Defuzzification example

2.6 Cluster Models

A cluster architecture based vehicular ad hoc networks can be modeled into two different ways, i.e., single-hop or multi-hop. Both models have their own advantages and disadvantages based on the applications they are used for. A single-hop model is one where every node is directly connected to CH. A multi-hop model is one where the distance between the CH and the CM can be n-hop. Depending on the distance the multi-hop can be 2-hop, 3-hop, etc. This distance is predefined by a maximum hop count. Multi-hop effectively expands the coverage of a cluster, which can lead to less change in CH and ultimately stable clusters.

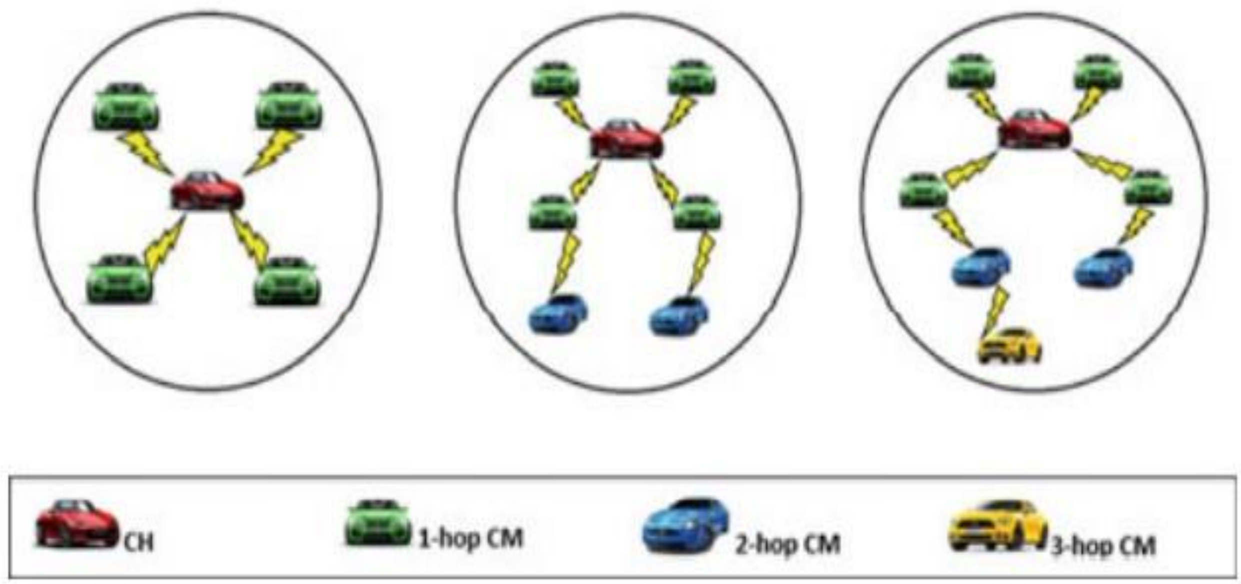


Figure 11 Multi-hop clustering

There are a number of issues which need to be addressed to have a global view of clustering in VANETs:

- What are the parameters that decide the role of cluster nodes?
- Which device will be selected as a cluster head?
- Are the selected CH evenly distributed?
- Which model is suitable for highly dense networks-single-hop or multi-hop?
- Is there any requirement of cluster merging?
- Who will initiate cluster merging?
- Cluster splitting is required and when it is required?

2.7 CH Selection Schemes

There different types of protocols depends on the fuzzy logic in VANET. We will discuss some basic protocols in this session. There are a number of research articles available that have given the classification of clustering algorithms used in VANET. But in this paper, the cluster-head selection algorithms for VANET are being discussed. (Figure 11)

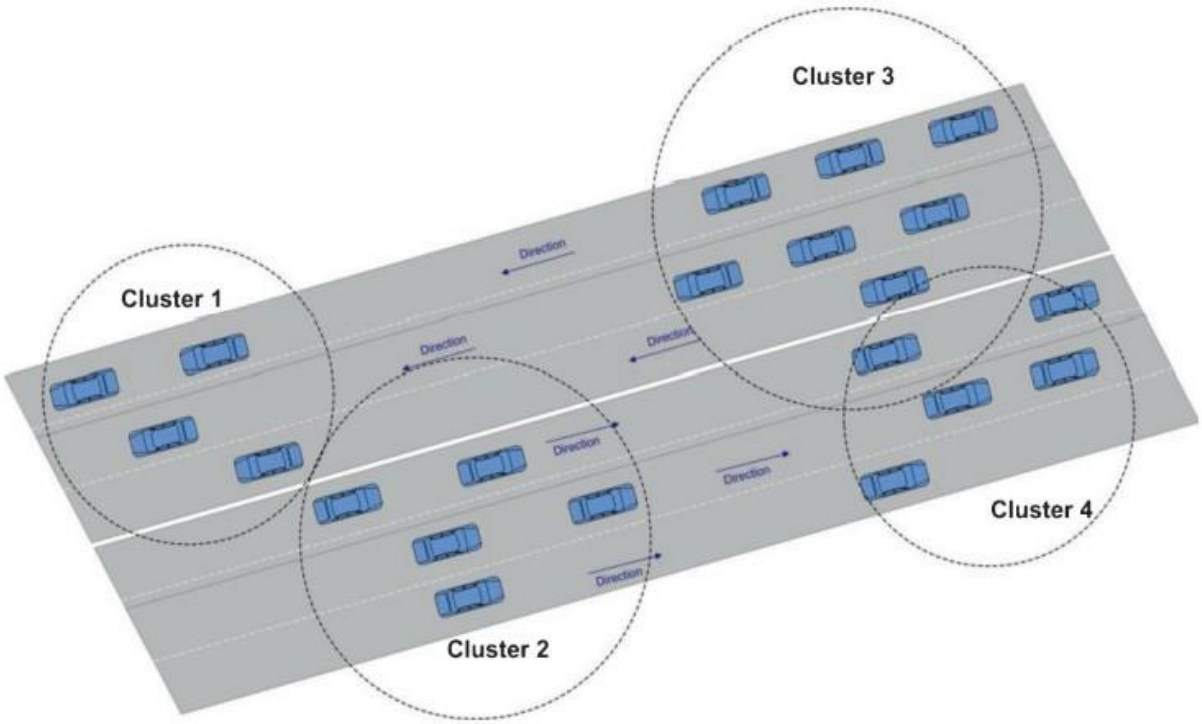


Figure 12 Clusters in VANET

2.7.1 Weight-Based Cluster Head Selection Algorithms

In this category of algorithms, the CH is selected on the basis of weights being assigned to each of the vehicles under consideration on the basis of various parameters like distance, velocity, speed, direction, mobility,[26] etc. The vehicles can be decided as CH by using the highest weight or lowest weight as a decision factor.

An enhanced weight-based clustering algorithm is given in [26], where the CH is the node with the highest weight calculated on the basis of speed, distance and connectivity level. In [27], an algorithm is proposed which calculates the total force of a node as based on that decides the CH. The total force is calculated as a sum of force along X-axis and Y-axis.

2.7.2 Priority-Based CH Selection Algorithms

Under this category comes the algorithms which used the priority of the vehicles as the means for CH selection. In [28], an algorithm is proposed which is a passive clustering approach for clustering during the route discovery process. The priority of the node is determined based on multi-metric election strategy based on various metrics like node degree, transmission count, link lifetime. In [29] other priority-based clustering technique is proposed, where the metrics like link lifetime, velocity, distance is used for prioritizing the node for CH selection.

2.7.3 Nature-inspired CH selection

In this category of algorithms, the CH selection is done using the strategy of various nature-inspired algorithms like ant colony optimization, particle swarm optimization, bee, etc. in [30] an ant colony optimization algorithm is proposed which selects the CH using the probability of all the nodes available for clustering.

2.7.4 Fuzzy Logic Based CH Selection

In this category of CH selection algorithms, fuzzy logic based on multiple attribute decision is used for selection of CH [31]. In [34], a fuzzy logic based algorithm is proposed for improving the performance of the vehicular ad hoc networks. They have optimized the CH selection procedure by using speed, acceleration, distance, and direction. In this algorithm, CH is elected and re-elected in a distributed manner. The algorithm is highly stable due to its adaptability to driver's behavior and its learning process to predict the future speed using a fuzzy logic interference system.

Generally Clustering is the technique which has been used in ad hoc networks for a number of different applications like routing, data dissemination, tracking of target, etc., the most important characteristic required for any cluster is stability which is dependent on the CH of the cluster since CH is the coordinator of the cluster which controls all other nodes. Above, we have discussed different categories of CH selection algorithms based on which we have found the following points:

1. Most of the CH selection algorithms have used speed, distance, velocity as the major parameters for deciding a CH.
2. CH selection is done using various techniques like priority based selection, weight-based selection, fuzzy logic based selection,
3. A stable CH can lead to a stable cluster and ultimately improves the overall stability and reliability of the network.

4. Techniques of cluster maintenance like cluster merging, cluster splitting, and use of subordinate/secondary CH is required for improving the cluster stability.

2.8 Applications

The applications of clustering include the following:

1. Routing in VANET and selecting a standard routing protocol.
2. Improved efficiency of VANET.
3. Target tracking in vehicular ad hoc networks.
4. Load balancing and reduced communication overhead.
5. Efficient message dissemination in various VANET applications.
6. Improved scalability of the large dynamic vehicular ad hoc networks.

2.9 Challenges in Fuzzy-logic based CH selection

The most important problem is the overhead presented to select the Cluster Head (CH) in the clustering process and to continue the connection in a fast changing and highly dynamic network topology (i.e., VANETs). Those are main challenges and headache for experts in CH selection

- Stochastic environment of transportation
- Behaviors of drivers
- Over head of CH

Chapter Three

Related works

There are many clustering algorithms in the literature used in wireless networks especially for Sensor Networks, however, there are only a few researches on clustering techniques about VANETs. In this section, a review of CH algorithms separately for VANETs was given.

The CH algorithm [31] was based on vehicles' distance from other vehicles within their neighborhood and their relative signal strength. The authors aimed to solve the problems which were encountered aforementioned studies in the literature with using fuzzy logic based CH selection algorithm.

In the [31] the researchers have try to solve the stability and reliability issues by selecting CH using fuzzy logic-based system. To resolve the reliability problems they proposed a fuzzy cluster head selection scheme in Cognitive Radio (CR) VANET, which uses the CR technology for the spectrum sensing algorithm. And also the have used Signal Noise Ration and Signal Energy as the parameter to the fuzzy inference system. The gap of this paper we reviewed is the latency and security problems. Since the parameters are limited with the strength of the signal the velocity deference will make latency and also get the others signal around crowded city roads.

[34] A. Calhan. This paper proposes the fuzzy logic based cluster head selection which depends on speed, acceleration and distance parameters. They tried reduce the overhead of re-clustering and provide an efficient hierarchical network topology. During the election of CHs in VANETs, cluster head candidates select one candidate to be the CH. Fewer CH changes provide a more stable cluster. For this purpose [34], cluster candidates must choose a candidate that has the potential to be a CH longer than other cluster head candidates. Each vehicle is able to communicate with its CH directly and the vehicles are able to communicate with the others either directly or, via their CH.

The study in [35] presents the fuzzy logic-based technique for creating clusters with long lifetimes. Three parameters are taken into account in this approach. First, it combines node relative speeds with their associated CHs. Second, it examines a node's number of available links inside a cluster, and third, it considers node security. This method can still be used in uni-directional highway scenarios. In a bi-directional highway scenario, however, selecting member nodes with the same speed as its CHs may be ineffective because they could travel in different directions. This reduces the time it takes for the node to be associated with a cluster.

[36] This one tries to build the new model by assigning IDs for each cluster members and evaluate them using the records during the tournament. This novel model is best but it require more centralize type of system that can control and command each vehicle. This is the gap with the model.

This [37] work Proposed a method in VANETs by Fuzzy logic based k-hop distributed clustering. The proposed approach was compared with the CMAC, PPC by using OMNET and SUMO simulator. The performance is evaluated between the average numbers of state change, number of clusters, and average cluster lifetime vs. transmission range. And gives safe clusters.

The following table shows the basic method of related papers have had used. And the new parameters those are invented and try to explain the contribution done by each related works. Pros and cons of the papers are exhibited in the table.

Proposed work	Parameters used for CH selection	Clustering logic	Network model	Contribution	Limitation	Year
[35] Bylykbashi	-Relative speeds -Number of available links	Fuzzy Logic	-Multi-hop -Bidirectional highway scenario	Manage in better way the stability of CH	Message safety, and latency	2019
[37] Aissa, M.	-The safe distance between a CH and its adjacent vehicle, average distance between vehicle,	Fuzzy Logic-based k-hop distributed clustering	Multi-hop	Improve effective decision making to select CH	Don't include emergency situations	2020
[31] Saleem, M. A	-SNR (Signal to Noise Ratio) -Signal Energy	Fuzzy Logic	Single-hop	A fuzzy cluster head selection scheme in Cognitive Radio (CR) VANET	Don't address highway schemes	2019
[34]A. Calhan	-Speed -Acceleration -Distance -Direction.	Fuzzy Logic	Single-hop	Increased stability, less communication, and coordination overhead	During Low speed of vehicles	2015
[36] S. Harrabi,	ID based	Fuzzy Logic	Single-hop	Performs well compared to MAODV routing in terms of throughput, end-to-end delay, packet delivery ratio	-	2016

CHAPTER FOUR

DESIGN OF THE PROPOSED SOLUTION

A fuzzy abstract thought system with crisp inputs and outputs implements a nonlinear mapping from its inputs house to output house. This mapping is accomplished by variety of fuzzy if-then rules, every of that describes the native behavior of the mapping.

4.1 Model

Specifically, the antecedent of a rule defines a fuzzy region within the input house, whereas the resultant specifies the output within the fuzzy region. Primarily a fuzzy abstract thought system consists of 5 purposeful blocks as shown in Figure 12. The Structure of the Fuzzy abstract thought system is delineate as follows.

- A rule base containing variety of fuzzy if-then rules.
- An info that defines the membership functions of the fuzzy sets employed in fuzzy rules. They each are combined as knowledge domain. A decision making unit that performs the reasoning operations on the principles.
- A fuzzification interface that transforms the crisp inputs into degrees of match with linguistic values.
- A defuzzification interface that rework the fuzzy results of the reasoning into a crisp output.

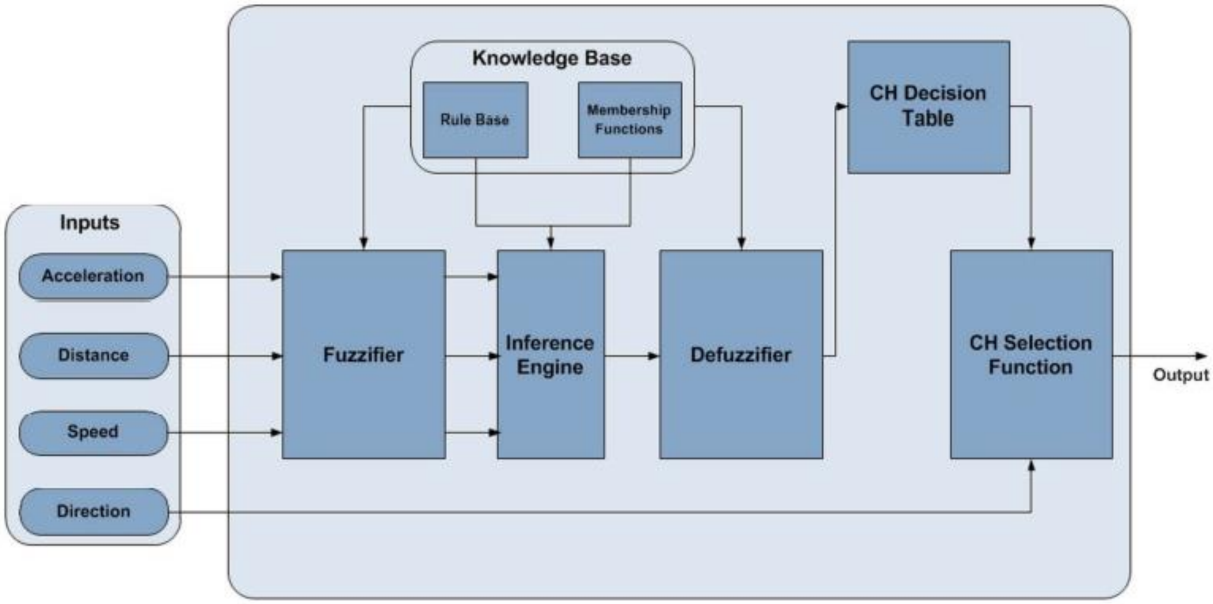


Figure 13 Block diagram of the proposed fuzzy logic based CH selection system.

4.2 Establish Rules

The rule base and also the information square measure put together spoken because the mental object. Fuzzy if-then rules or fuzzy conditional statements square measure expressions of the form: If x may be a Then y is B. where, x and y square measure input and output linguistic variables. A and B square measure labels of the fuzzy sets characterized by acceptable membership functions. A is that the premise and B is that the sequent elements of the fuzzy rule. Fuzzy values A and B square measure delineated by the membership functions. The styles of membership functions square measure completely different and downside depended. The most common sorts of fuzzy reasoning that are introduced within the literature and applied to completely different applications are Mamdani and Sugeno sort models[39], [40]. The foremost basic distinction between Mamdani-type FIS and Sugeno-type FIS is that the method the crisp output is generated from the fuzzy inputs. Mamdani-type FIS uses the technique of defuzzification of a fuzzy output, whereas Sugeno-type FIS uses weighted average to calculate the crisp output. Hence, Mamdani FIS has output membership functions whereas Sugeno FIS has no output membership functions. Mamdani sort is wide accepted for capturing skilled information. It permits describing the experience in additional intuitive, a lot of anthropomorphous manner. Hence Mamdani sort model is applied for the projected system.

The projected FIS for the analysis of routing consists of 3 inputs: period of time of the vehicle, share of vehicles occupation same direction and range of close vehicles. The system has one output that provides the suitable route. Figure 12

Figure 12 illustrates the essential components of the fuzzy based CH selection system. The first phase of the CH selection system is to give the measured parameters into a fuzzifier. The task of the fuzzifier is transforming the actual quantities into fuzzy sets. For instance, if the acceleration is considered in crisp set, it can be represented as decelerate, same or accelerate in the corresponding fuzzy set. The membership values (μ) are generated by mapping the values obtained for a specific parameter into a membership function. Then, the fuzzy conversions are performed by utilizing a reverse engine (i.e., defuzzifier) to produce output. In the last phase, the calculated output is exploited for choosing the best candidate CH.

In the proposed fuzzy logic based clustering algorithm, membership functions of the fuzzy logic scheme inputs are shown in Figures 13, 14 and 15, respectively. Trim and trapezoid are preferred as the fuzzy membership functions owing to their capability of achieving better performance for especially real time applications [41].

4.3 Flow chart

The basic flow of the cluster based routing protocol is explained in figure l3. This is the current scheme of sequential stepwise approach. This step includes the following tasks as the flow chart shows. Neighborhood Discovery, development of cluster, anatomy of a Clustering Algorithm, selection of cluster head, and including Affiliation, which means it is approach the

node will communicate the neighbor it determined to be the best CH (cluster head) from its individual viewpoint.

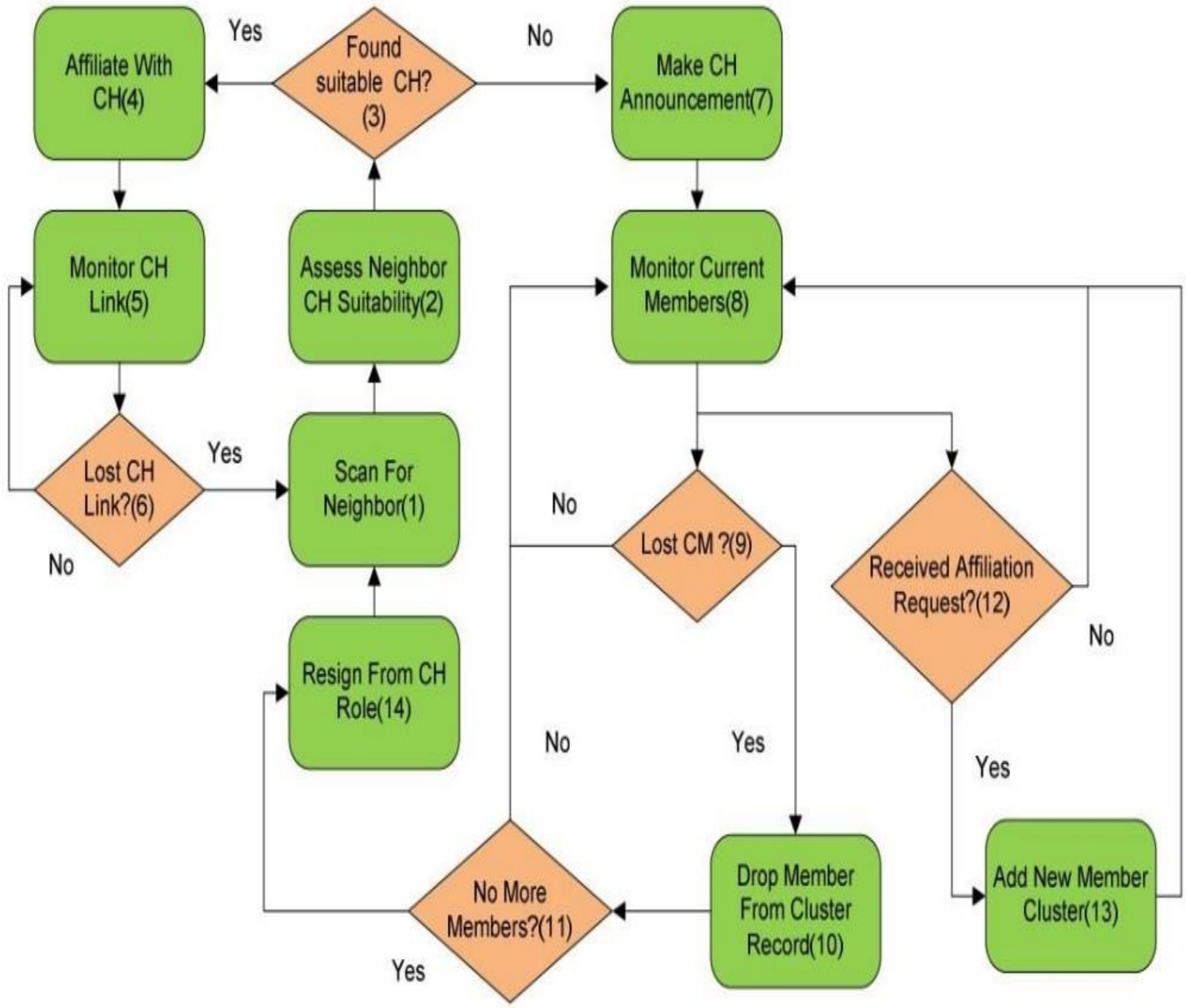


Figure 14 Flow chart of Clustering Algorithm

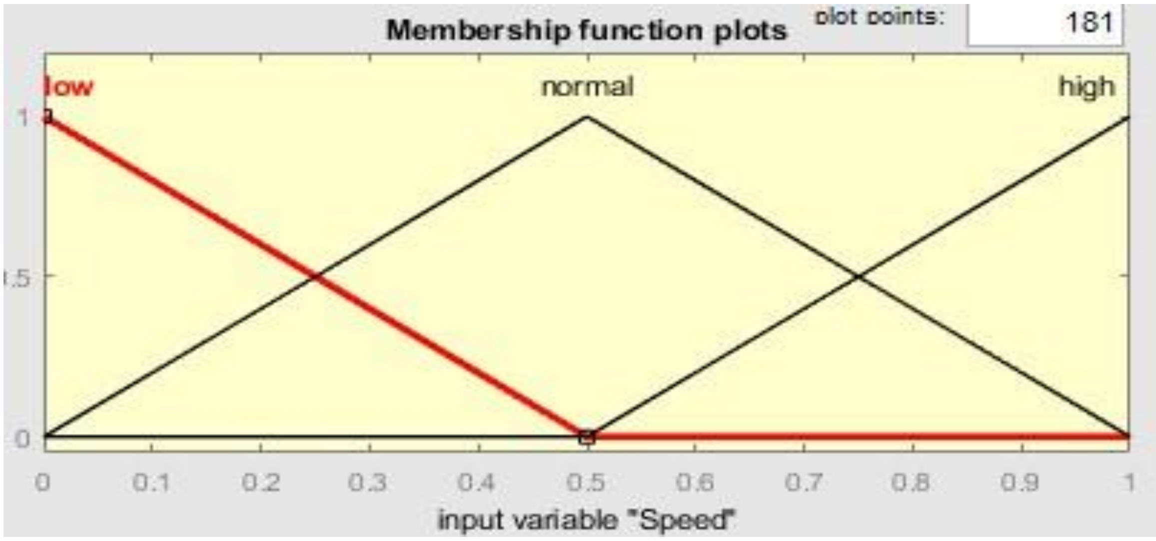


Figure 15 Fuzzy membership functions for speed (S).

The re-clustering procedure is executed periodically, which generally leads to the less stable cluster structure. Clustering procedure can be difficult to apply any Mobile Ad-Hoc networks, but in VANETs, there are several advantages of applying clustering; firstly, the network topology is constrained by highways and then secondly, the vehicles are moving in groups naturally on roads. These benefits give a chance to develop the clustering algorithms for VANETs.

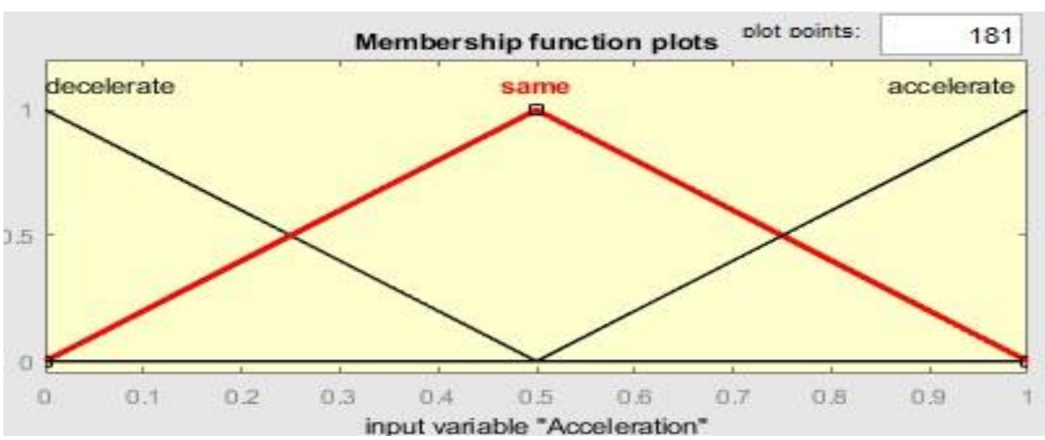


Figure 16 Fuzzy membership functions for acceleration (A).

In the proposed fuzzy logic based clustering algorithm, membership functions of the fuzzy logic scheme inputs are shown in Figures 13, 14 and 15, respectively. Trim and trapezoid are preferred as the fuzzy membership functions owing to their capability of achieving better performance for especially real time applications. Our fuzzy logic system has totally 27 fuzzy rules and some developed fuzzy rules are illustrated in table 3.

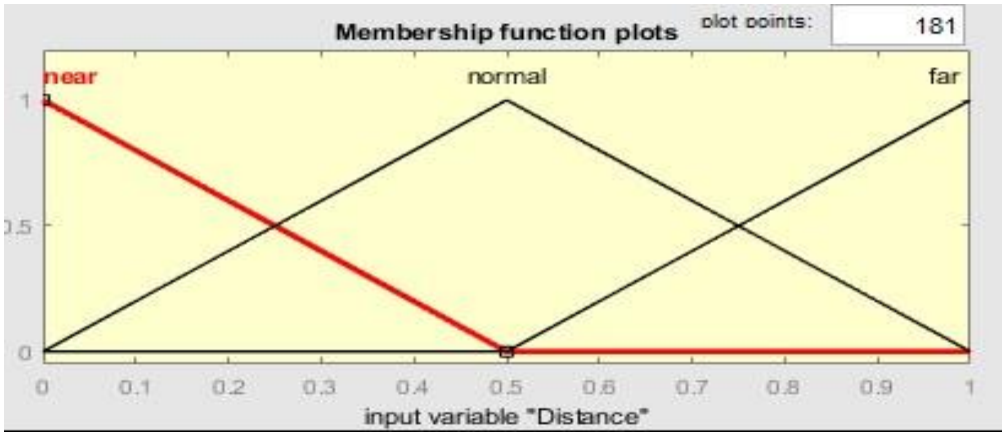
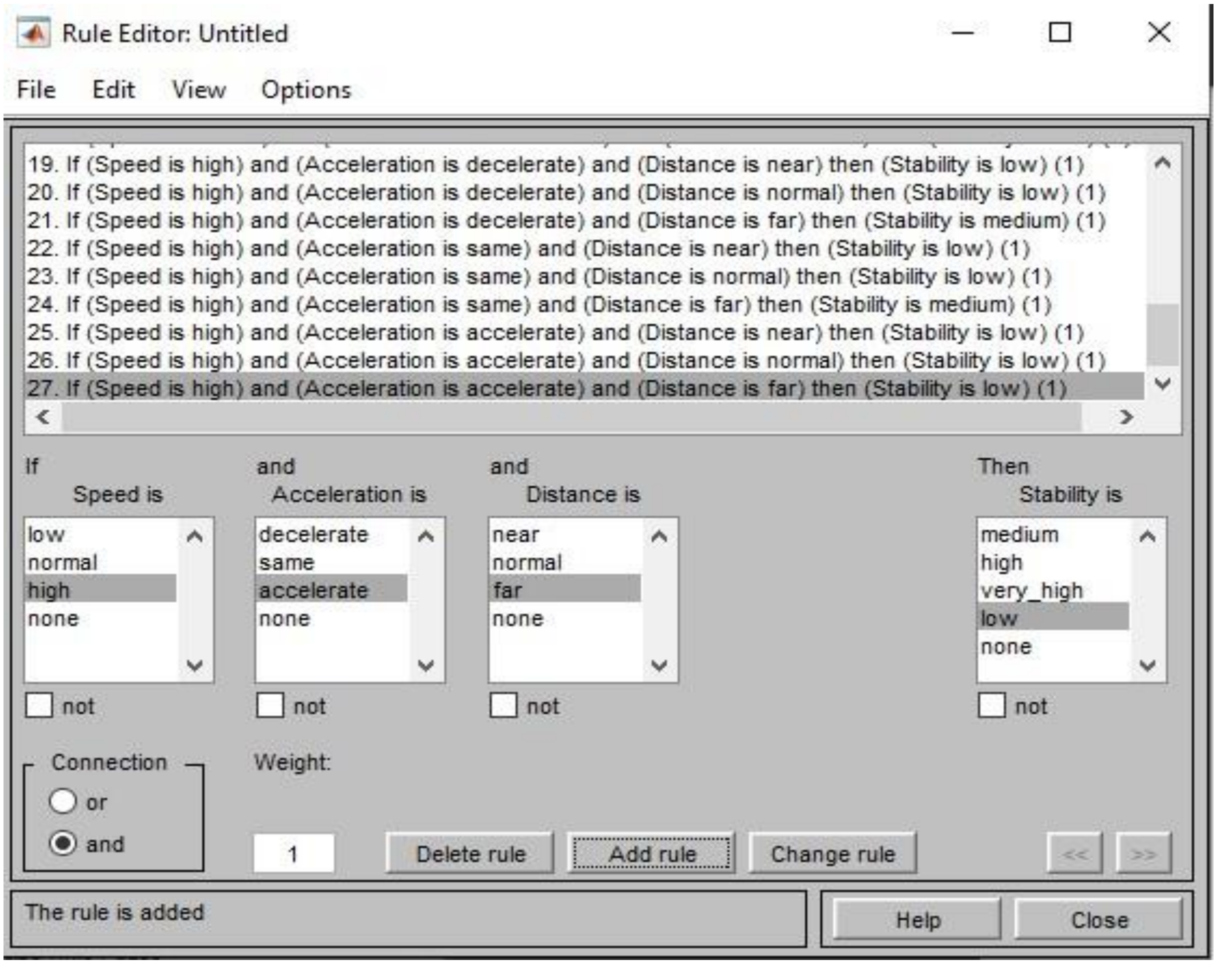


Figure 17 Fuzzy membership functions for distance (D).

Table 2 If-then rules base

Rule no.	**IF (AND)**			**Then (Output)**
	Speed	*Acceleration*	*Distance*	
1	Low	Decelerate	Near	Medium
2	Low	Decelerate	Normal	High
3	Low	Decelerate	Far	Very high
4	Low	Same	Near	Low
5	Low	Same	Normal	Medium
6	Low	Same	Far	High
7	Low	Accelerate	Near	Very low
8	Low	Accelerate	Normal	Low
9	Low	Accelerate	Far	Medium
10	Normal	Decelerate	Near	Low
11	Normal	Decelerate	Normal	Medium

12	Normal	Decelerate	Far	High
13	Normal	Same	Near	Low
14	Normal	Same	Normal	Medium
15	Normal	Same	Far	High
16	Normal	Accelerate	Near	Very low
17	Normal	Accelerate	Normal	Low
18	Normal	Accelerate	Far	Medium
19	High	Decelerate	Near	Very low
20	High	Decelerate	Normal	Low
21	High	Decelerate	Far	Medium
22	High	Same	Near	Very low
23	High	Same	Normal	Low
24	High	Same	Far	Medium
25	High	Accelerate	Near	Very low
26	High	Accelerate	Normal	Very low
27	High	Accelerate	Far	Low



Three-dimensional pattern vector (input of the fuzzifier) for candidate access points is:

$$PV_C = [S_C; A_C; D_C], \quad (1)$$

Where S is speed, A is acceleration, and D is the Distance value of vehicle.

Three-dimensional fuzzy pattern vectors (output of fuzzifier and input of inference engine) for candidate cluster head is:

$$PV_F = [PF_1; PF_2; PF_3] \quad (2)$$

Since the product inference rule is utilized in the fuzzy inference engine, then, for a new pattern vector, the contribution of each rule in the fuzzy rule base is computed by:

$$C_r = \prod_{i=1}^{3} \mu_{F_i}(P_i). \tag{3}$$

4.4 Sequence Diagram of Selecting CH

The proposed scheme mainly consists of two main sections. First, the cluster configuration section decides which cluster the vehicles will be joined, because a vehicle can participate in any cluster in both directions. A vehicle must be in only one cluster at the same time. So, in the proposed simulations, each vehicle in an RSU coverage area takes a cluster affinity value in an information packet from the RSU. This value indicates the vehicles' affinity levels of a cluster which is proportional to the distance from RSU. A vehicle can join a cluster owing to the affinity level that defines the proximity of the vehicle to RSU. For example, if a vehicle is in the coverage area of two RSUs, one of them is 100 m away from the vehicle, and the other is 300 m away from the vehicle, finally, the affinity level of the first cluster is bigger than the second one. Therefore, the vehicle decides to join to the clusters in the first RSU's coverage area according to affinity level. RSSI (Received Signal Strength Indicator) values of RSUs are used for affinity level.

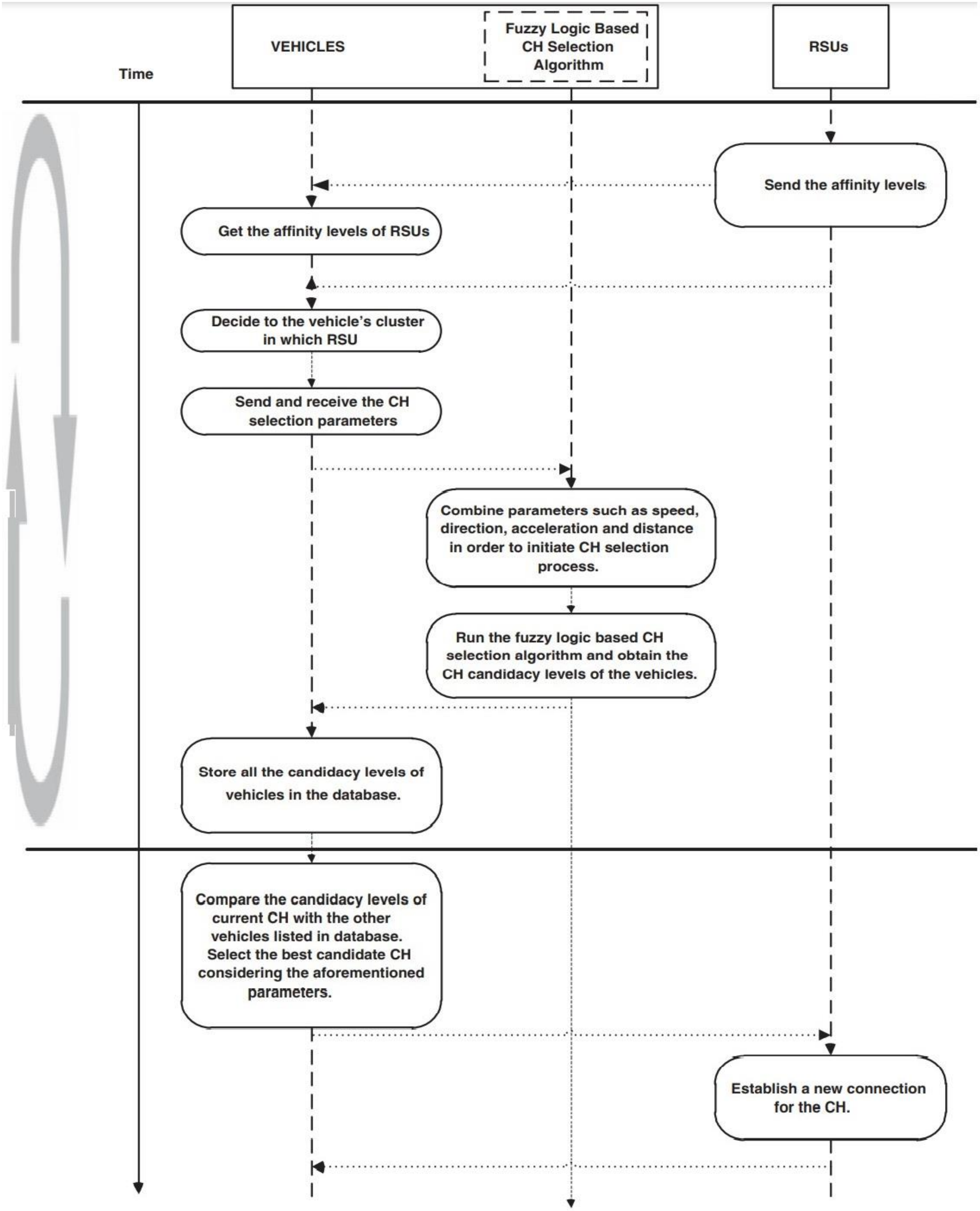


Figure 18 Sequence diagram of the proposed fuzzy logic based CH selection system.

4.5 Algorithm

Fuzzy Logic Based CH Selection Algorithm

Algorithm (1)

START

1. Scan For neighbor
2. Assess neighbor suitability

    If found suitable CH

        Affiliate with CH

    NOT

        Make CH announcement

3. Transform to Fuzzy set
4. Add parameters Speed, Distance and Acceleration

    $PV_C = [S_C; A_C; D_C]$,

5. Fuzzification the inputs
6. Add membership function

    Multivalued Logic:

        Y = sigmf(X, [a b]);

    END

7. Defuzzify the fuzzy sets in order to apply
8. Apply if …. Then Rule

    27 Rules we established depend on the parameters

9. Give the best candidate to be cluster head of the cluster

END

Generally, the proposed model solves the latency problem and can learn the stochastic environment of vehicular movements. Cluster head selection process is one of the major challenges in Vehicular Ad-Hoc Networks since there are various parameters must be considered and it is a crucial issue that the algorithm satisfies all vehicles which have diverse speeds. A fuzzy logic based cluster head selection algorithm is proposed which is able to combine direction, speed, acceleration, and distance parameters in order to select the most appropriate vehicle as cluster head in this study. The simulation results show that the proposed algorithm can select the vehicle as cluster head with the optimal parameters in case studies, and also, the proposed algorithm satisfies both low speed and high speed vehicles on two-way multilane highway.

CHAPTER FIVE

IMPLEMENTATIONS AND RESULT EVALUATION

The proposed model was developed by MATLAB/Simulink. In this session we implement and try to represent the results in tabulated, graphical and in written form.

5.1 Simulation setup

The simulation was done the most handy and comfortable MATLAB. Simulink is used to develop the mode.

Table 3 Simulation parameters.

MAC Protocol	CSMA/CA Based
Frequency	5.9 GHz
Modulation type	QPSK
RSU transmitting range	1000 m
OBU transmitting range	300 m
Channel bandwidth	10 MHz
Simulation area (for each RSU)	1000 m x 60 m
Simulation time	40 sec
Vehicles speed	30–120 km/h

The case studies consist of a 5 km highway with six lanes, three of each direction, 5 RSUs with 1000 m coverage area and vehicles as shown in figure 17.

The vehicles move with a constant or variable speed ranging from 30 to 100 km/h according to trajectory attribute of mobile terminals in SIMULINK. The RSUs are placed every 1 km. Each RSU sends an information packet every ten milliseconds to the vehicles which are in its coverage area during the simulation runtime. The information packets synchronize the vehicles according to the directions of the vehicles. Firstly, the vehicles are grouped into two clusters in each RSU coverage area according to the directions as illustrated in figure 17. A number of clusters can be in a RSU's coverage area. Secondly, the fuzzy based CH selection algorithm runs on the vehicles' OBUs. Each vehicle sends its own information packets to other vehicles with aforementioned parameters. Direction parameter of the vehicles directly affects the CH selection process.

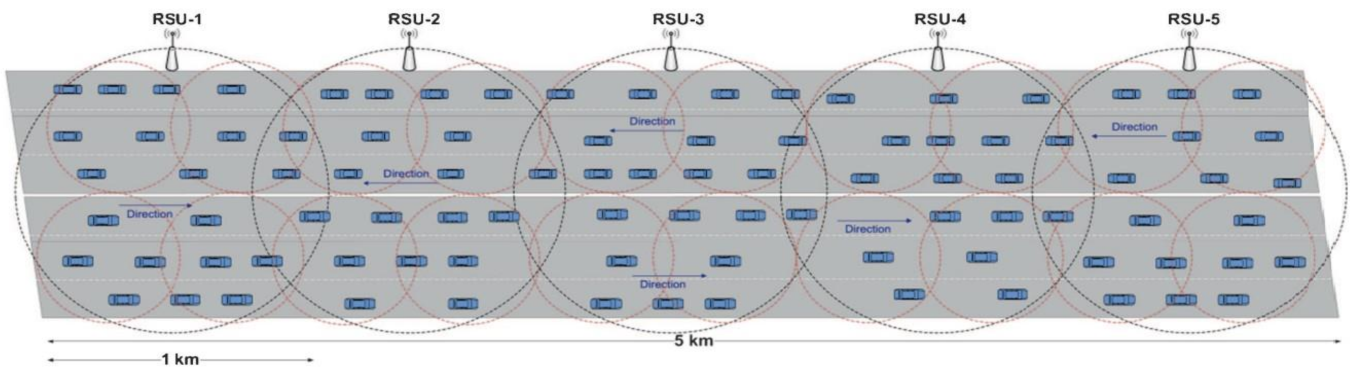


Figure 19 VANET architecture in the implementation

5.2 Fuzzy Logic designer

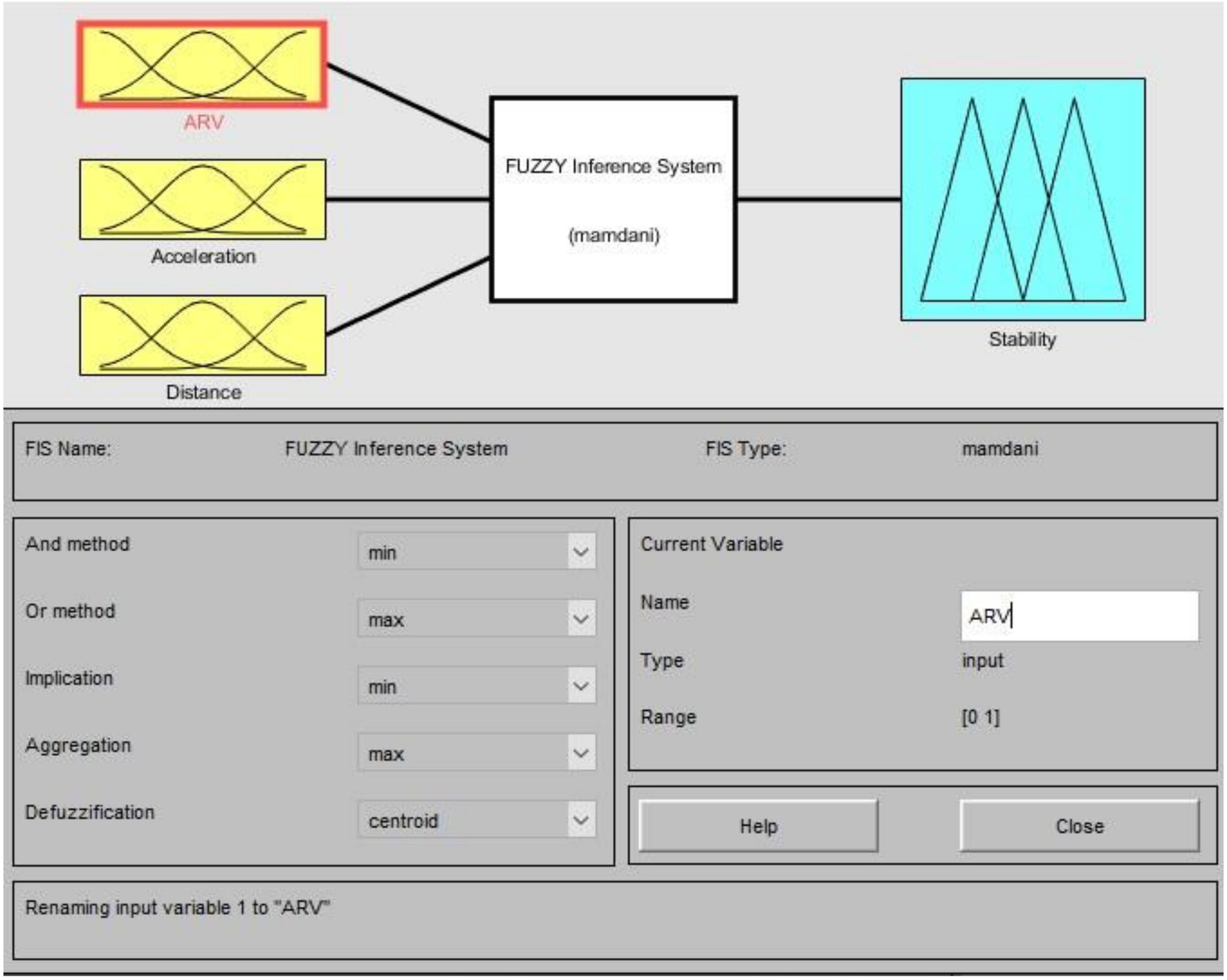


Figure 20 fuzzy logic designer

5.3 Simulating the Cluster Head Selection

Each RSU saves the ID of the vehicle which is in its range and makes a cluster of such vehicles. A cluster head for energy efficient data transmission is selected using fuzzy logic. Three vehicle properties network connectivity, average distance, and average velocity are input this fuzzy logic.

5.4 The Results

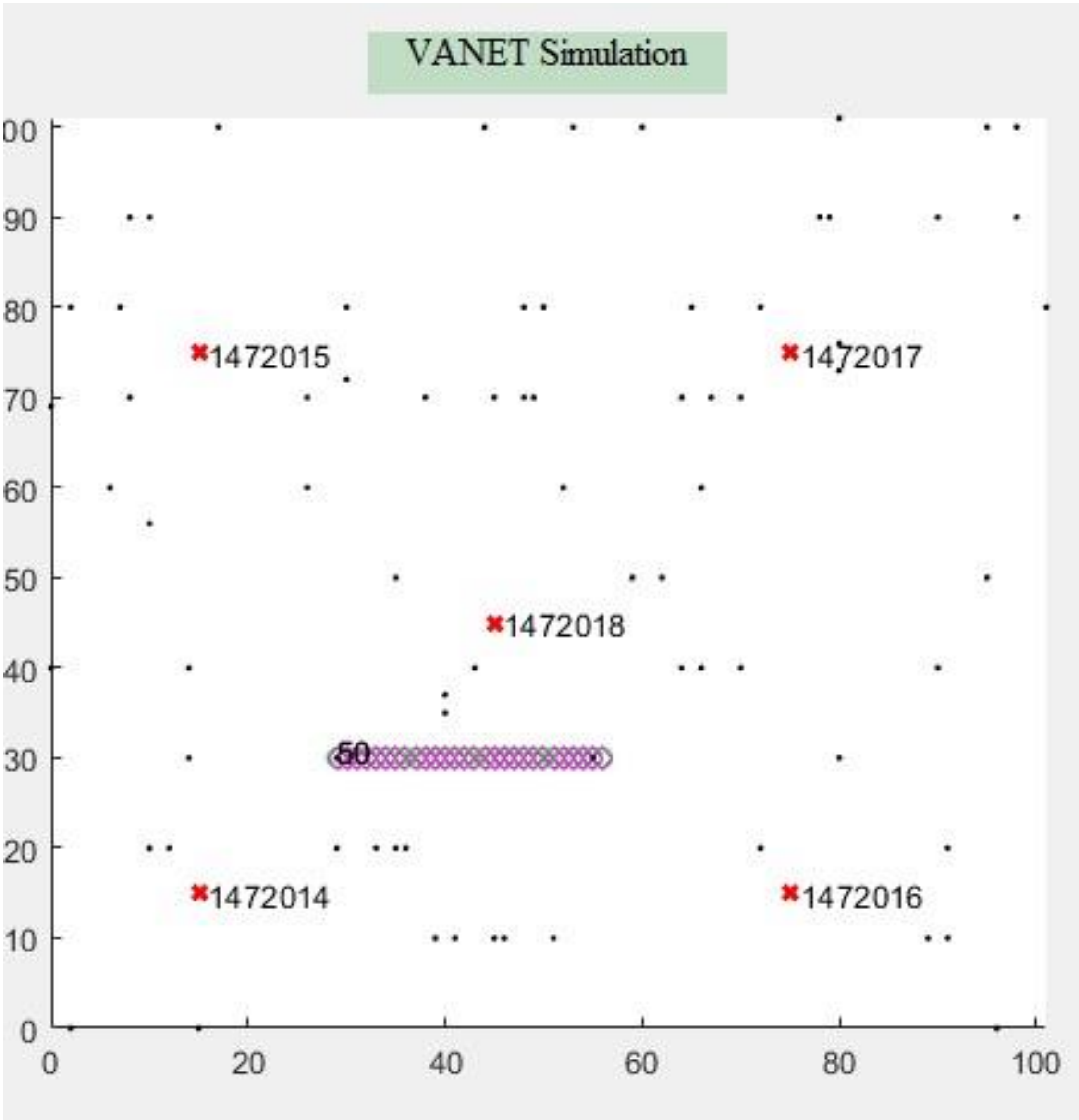


Figure 21 Distribution of nodes and connectivity each other

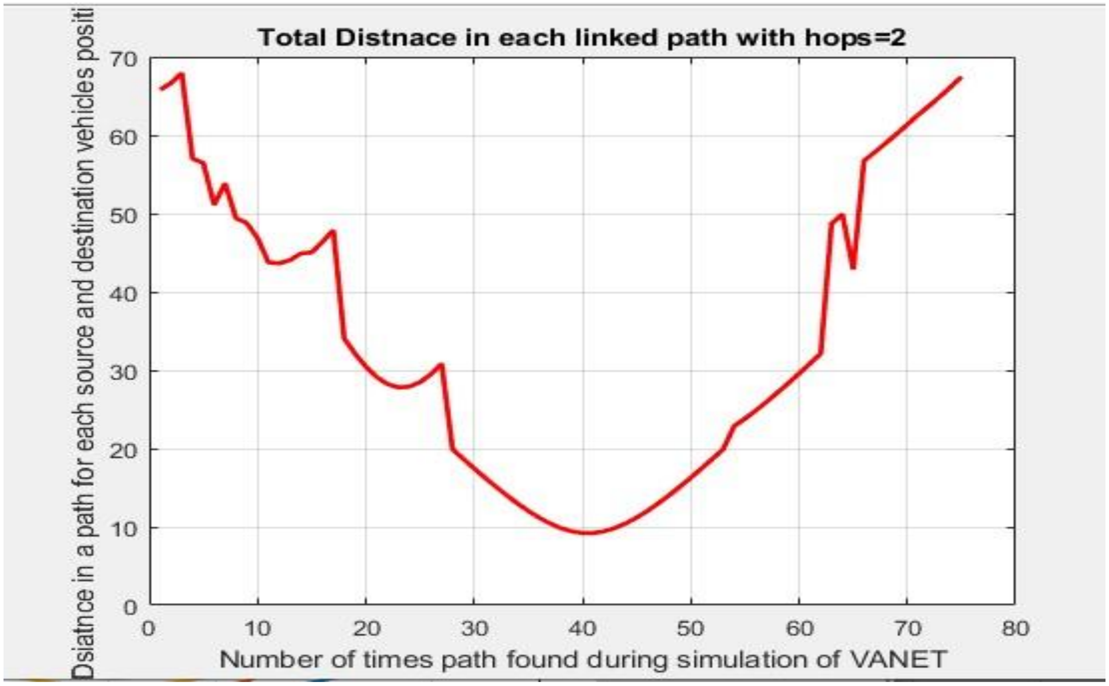


Figure 22 Distance in each linked path

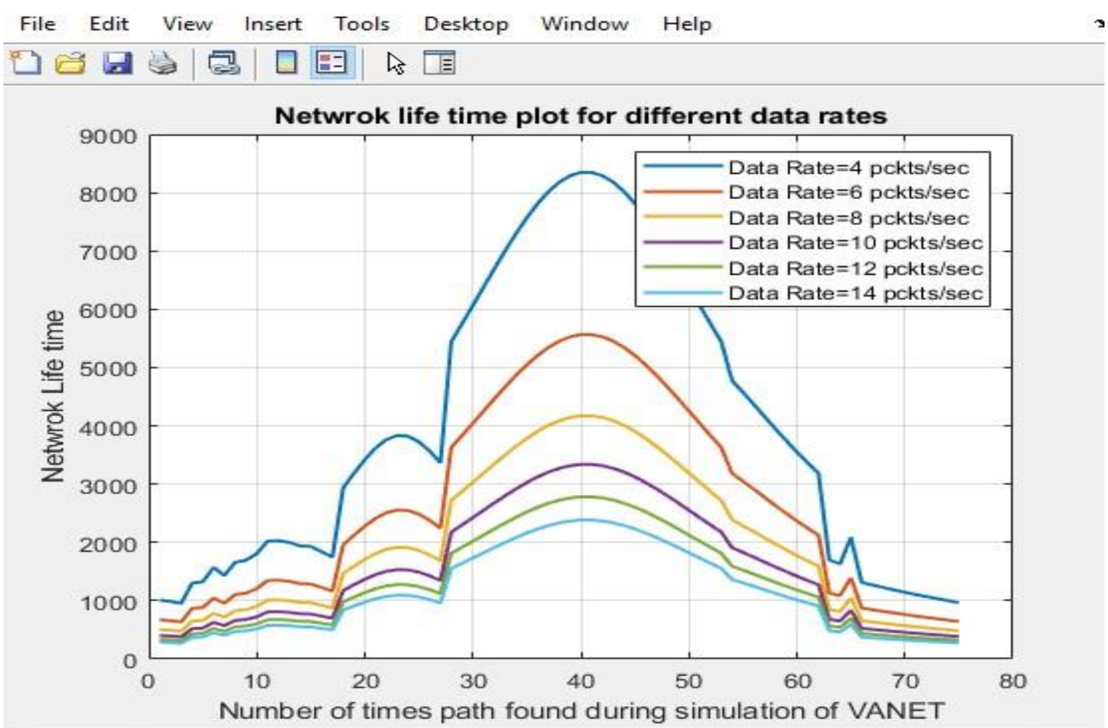


Figure 23 Network life time

The final method that evaluate our model is the implementation use by SIMULINK simulator.

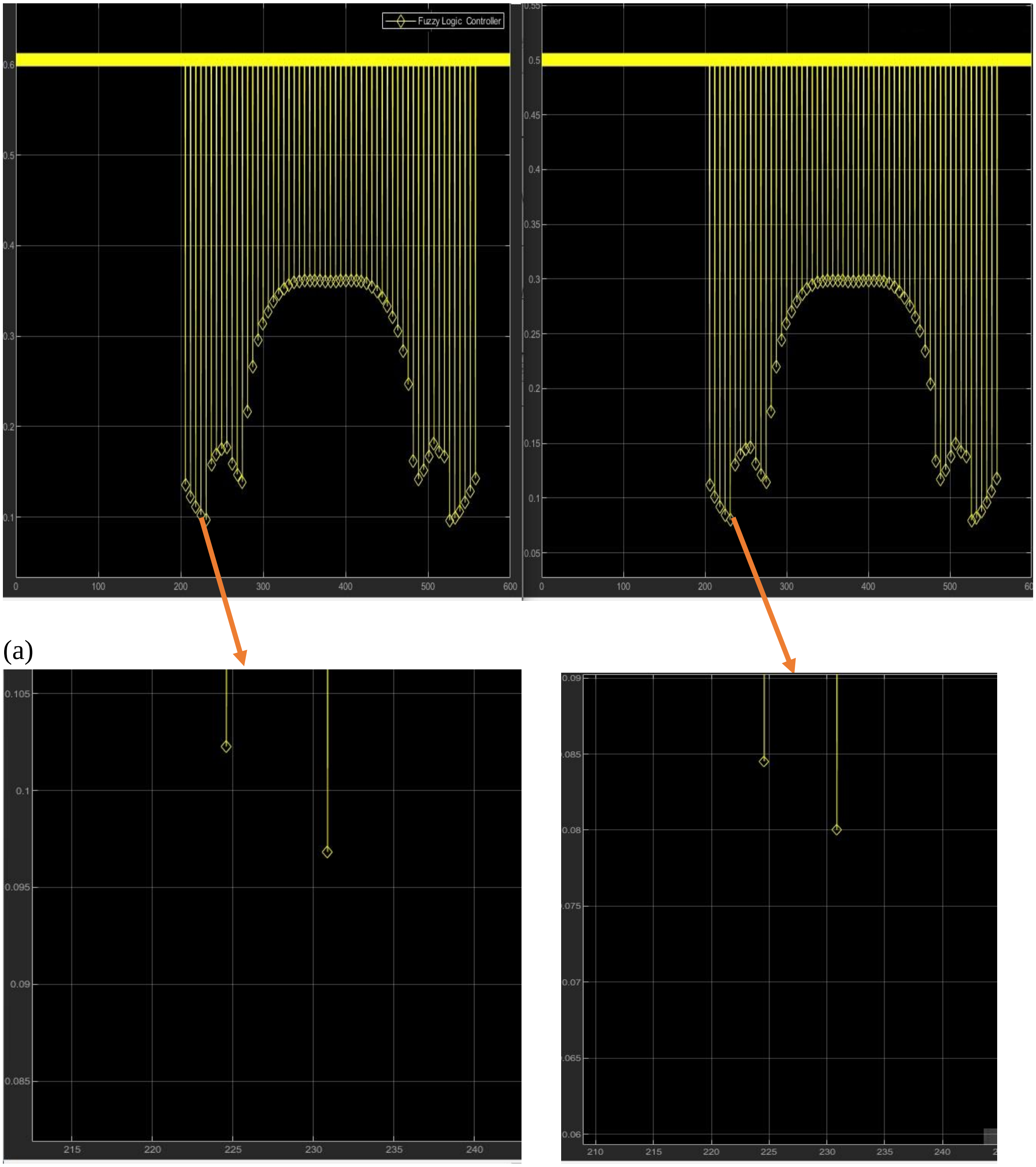


Figure 24: comparing fuzzy logic base with others

CHAPTER SIX

CONCLUSION AND FUTURE WORK

After all, we would like to conclude our paper in this session. This paper introduces the fuzzy logic based CH selection in the dynamic manner by simulating for any amount of vehicles in the road with fixed amount of RSU. On the first session we introduce the concept of VANET and fuzzy logic. We review the current and recent works on the area and we`ve compared them. Of course there are some problems which can be the next assignment.

6.1 Future Work

For the future we would like recommend to give attention on emergency areas. Since crowed traffic is one of the dangerous fields the researchers can concern which way is the best way to send alert messages to the neighbor hoods using fuzzy logic.

In the emergency state using fuzzy logic analysis and conclusion the node can give alerts for RSU or the next node. Adding the knowledge on this problem is the best option.

6.2 Conclusion

Cluster head selection process is one of the major challenges in Vehicular Ad-Hoc Networks since there are various parameters must be considered and it is a crucial issue that the algorithm satisfies all vehicles which have diverse speeds. A fuzzy logic based cluster head selection algorithm is proposed which is able to combine direction, speed, acceleration, and distance parameters in order to select the most appropriate vehicle as cluster head in this study. The simulation results show that the proposed algorithm can select the vehicle as cluster head with the optimal parameters in case studies, and also, the proposed algorithm satisfies both low speed and high speed vehicles on two-way multilane highway.

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APPENDEX

Code to get the Distance Membership Function

```
function nodes= avgDistancelevel(nodes,LW,RSU,clusterNo)
%%
%this function calculates the ADL. The nodes in a cluster are considered
%only

%%
% average distance of all nodes in the vicintiy of each node
indexall=RSU{clusterNo}.all.clusterIndex;
delta=sum(nodes.all.inrange(indexall,indexall).*...
                             nodes.all.dist(indexall,indexall));

% average distance of all nodes in the vicintiy of each node in each
% traffic flow
indexRtoL=RSU{clusterNo}.RtoL.clusterIndex;
zetaRtoL= sum(nodes.RtoL.inrange(indexRtoL,indexRtoL).*...
                    nodes.RtoL.dist(indexRtoL,indexRtoL));
indexLtoR= RSU{clusterNo}.LtoR.clusterIndex ;
zetaLtoR= sum(nodes.LtoR.inrange(indexLtoR,indexLtoR).*...
                    nodes.LtoR.dist(indexLtoR,indexLtoR));

nodes.RtoL.ADL=delta(1:numel(indexRtoL))*LW.RtoL+zetaRtoL;
nodes.RtoL.ADLnorm=normalize(nodes.RtoL.ADL);
nodes.LtoR.ADL=delta(numel(indexRtoL)+1:end)*LW.LtoR+zetaLtoR;
nodes.LtoR.ADLnorm=normalize(nodes.LtoR.ADL);
```

Code to get the Acceleration Membership Function

```
function nodes = avgAcceleration(nodes,LW,RSU,clusterNo)
%%
%function to calculate average velocity
%%
% relative velocity for each vehicle
for ii=1:numel(RSU{clusterNo}.all.clusterIndex)
    for jj=1:numel(RSU{clusterNo}.all.clusterIndex)
        Vrel(ii,jj)=nodes.all.speed(RSU{clusterNo}.all.clusterIndex(ii))-...
                        nodes.all.speed(RSU{clusterNo}.all.clusterIndex(jj));
    end
end
if ~exist('Vrel','var')
    Vrel=0;
end
%overall AVL
sigma=sum(Vrel.*nodes.all.inrange(RSU{clusterNo}.all.clusterIndex,RSU{cluster
No}.all.clusterIndex))...

./sum(nodes.all.inrange(RSU{clusterNo}.all.clusterIndex,RSU{clusterNo}.all.cl
usterIndex));

% AVL in each traffic flow from L to R
speedLtoR_incluster=nodes.LtoR.speed(RSU{clusterNo}.LtoR.clusterIndex);
for ii=1:numel(speedLtoR_incluster)
```

```
    for jj=1:numel(speedLtoR_incluster)
        Vrel_traffic_LtoR(ii,jj)=speedLtoR_incluster(ii)-
speedLtoR_incluster(jj);
    end
end
if ~exist('Vrel_traffic_LtoR','var')
    Vrel_traffic_LtoR=0;
end
% AVL in each traffic flow from R to L
speedRtoL_incluster=nodes.RtoL.speed(RSU{clusterNo}.RtoL.clusterIndex);
for ii=1:numel(speedRtoL_incluster)
    for jj=1:numel(speedRtoL_incluster)
        Vrel_traffic_RtoL(ii,jj)=speedRtoL_incluster(ii)-
speedRtoL_incluster(jj);
    end
end
if ~exist('Vrel_traffic_RtoL','var')
    Vrel_traffic_RtoL=0;
end
% save var Vrel_traffic_RtoL nodes RSU clusterNo
indexRtoL=RSU{clusterNo}.RtoL.clusterIndex;
roRtoL=sum(Vrel_traffic_RtoL.*nodes.RtoL.inrange(indexRtoL,indexRtoL))...
             ./sum(nodes.RtoL.inrange(indexRtoL,indexRtoL));

indexLtoR=RSU{clusterNo}.LtoR.clusterIndex;
roLtoR=sum(Vrel_traffic_LtoR.*nodes.LtoR.inrange(indexLtoR,indexLtoR))...
                       ./sum(nodes.LtoR.inrange(indexLtoR,indexLtoR));

%AVL
% save var
if isnan(roRtoL)     % no traffic flow
    nodes.RtoL.AVL=[];
else
    nodes.RtoL.AVL=roRtoL+sigma(1:numel(indexRtoL))*LW.RtoL;
end
nodes.RtoL.AVLnorm=normalize(nodes.RtoL.AVL);

if isnan(roLtoR)     % no traffic flow
    nodes.LtoR.AVL=[];
else
    nodes.LtoR.AVL=roLtoR+sigma(numel(indexRtoL)+1:end)*LW.LtoR;
end
nodes.LtoR.AVLnorm=normalize(nodes.LtoR.AVL);
```

Main function

```
close all
clc
clear
warning('off','all')
addpath(genpath(cd))
```

```
%%
highwayL=[5000,60];              % road [length,width] in m
laneNo=6;                        % total number of lanes
RSUno=5;                         % no of RSU
RSUrange=1000;                   % RSU transmission range in m
vehicleSpeed=[30,100]*1000/3600;% min and max vehicle speed in m/s
OBUrange = 300;                  % OBU transmission range
nodesno=10;                      % number of nodes
nodes.LtoR.speed=(vehicleSpeed(2)-
vehicleSpeed(1))*rand(nodesno,1)+vehicleSpeed(1); % vehicle speed
nodes.RtoL.speed=nodes.LtoR.speed;
nodes.speed=nodes.RtoL.speed;
clusterNo=RSUno;                 % number of clusters
Tsim=300;                        % simulation time
% read .fis file for CH selection
fuzzystr=readfis('CHsel_fuzzy');
%% road building
figure
axis([0 highwayL(1)+1 0 highwayL(2)+10]);
hold on
for ii=0:highwayL(2)/laneNo:highwayL(2)

rectangle('Position',[0,ii,highwayL(1),highwayL(2)/laneNo],'FaceColor','k','E
dgeColor','g')
    hold on
end
rectangle('Position',[0,highwayL(2)/2,highwayL(1),highwayL(2)/laneNo],'FaceCo
lor','w','EdgeColor','w')
hold on
%% RSU placement
cnt=1;
RSUgap=highwayL(1)/RSUno;                          % distance between two RSUs
for ii=RSUgap/2:RSUgap:highwayL(1)
    RSU{cnt}.loc=[ii,highwayL(2)/2];               % RSU location co-ordinates
    RSU{cnt}.ID=cnt;                               % RSU ID
    fill([ii+50,ii-
50,ii],[highwayL(2)/2+2,highwayL(2)/2+2,highwayL(2)/2+7],'r')
%     [xunit, yunit] = ccircle([ii,highwayL(2)/2],RSUrange);
%     hold on
%     plot(xunit,yunit,'--b')
    hold on
    cnt=cnt+1;
end
% axis off

%% nodes placement

nodes.LtoR.loc=[];                        %location of vehicles moving from L
to R
nodes.RtoL.loc=[];                        %location of vehicles moving from R
to L
nodes_LtoR_loc_y=vehicleinLanedist(nodesno,laneNo,1); % function for
vehicle's y co-ordinate in each lane
nodes.LtoR.loc=[nodes.LtoR.loc;100*rand(nodesno,1),nodes_LtoR_loc_y'];
nodes.LtoR.ID=1:size(nodes.LtoR.loc,1);  % each vehicle ID moving from L to R
```

```
nodes.RtoL.loc=[nodes.RtoL.loc;(highwayL(1)-(highwayL(1)-
100))*rand(nodesno,1)+(highwayL(1)-100)...
                       ,vehicleinLanedist(nodesno,laneNo,2)'];
nodes.RtoL.ID=1:size(nodes.RtoL.loc,1);    % each vehicle ID moving from R to
L
incLtoR=[];incRtoL=[];                     % variable for vehicle position
increment based ypon speed
incLtoR=[incLtoR;zeros(nodesno,1)];
incRtoL=[incRtoL;highwayL(2)*ones(nodesno,1)];

clusterMarker=['*','s','o','^','v','p']; % marker to mark the vehicels in
clusters
clr=['r','y','w','c','g'];
temp=nodes.LtoR.speed;
temp1=nodes.RtoL.speed;
temp2=nodes.speed;
% 1. lane weight
LW=laneWeight(laneNo);

for ii=1:Tsim                              % loop for simulation time
    if rem(ii,100 )==0

nodes.LtoR.loc=[nodes.LtoR.loc;100*rand(nodesno,1),vehicleinLanedist(nodesno,
laneNo,1)'];
        nodes.LtoR.ID=1:size(nodes.LtoR.loc,1);  % each vehicle ID moving
from L to R

        nodes.RtoL.loc=[nodes.RtoL.loc;(highwayL(1)-(highwayL(1)-
100))*rand(nodesno,1)+...
                                            (highwayL(1)-
100),vehicleinLanedist(nodesno,laneNo,2)'];
        nodes.RtoL.ID=1:size(nodes.RtoL.loc,1);    % each vehicle ID moving
from R to L

        incLtoR=[incLtoR;zeros(nodesno,1)];
        incRtoL=[incRtoL;highwayL(2)*ones(nodesno,1)];
        nodes.LtoR.speed=[nodes.LtoR.speed;temp];  % update each vehicle
speed from L to R
        nodes.RtoL.speed=[nodes.RtoL.speed;temp];  % update each vehicle
speed from R to L
        nodes.speed=[nodes.speed;temp];  % update each vehicle speed

    end
    % for vehicles moving L to R
    nodes.LtoR.loc= [nodes.LtoR.loc(:,1)+incLtoR,nodes.LtoR.loc(:,2)]; %
update node's positions
    h=plot(nodes.LtoR.loc(:,1),nodes.LtoR.loc(:,2),'>b');
    incLtoR=nodes.speed;
    % for vehicles moving R to L
    nodes.RtoL.loc= [nodes.RtoL.loc(:,1)-incRtoL,nodes.RtoL.loc(:,2)]; %
update node's positions
    h1=plot(nodes.RtoL.loc(:,1),nodes.RtoL.loc(:,2),'<y');
    incRtoL=nodes.speed;

    %combine all nodes in traffic low in a matrix
    nodes.all.loc=[nodes.RtoL.loc;nodes.LtoR.loc];
```

```
nodes.all.speed=repmat([nodes.speed;nodes.speed],[size(nodes.all.loc,1)/(2*no
desno),1]);
    % RSU to node distance calculation
    RSU=distance_nodetoRSU(nodes,RSU,RSUrange);
    % node to node distance calculation
    nodes=distance_nodetonode(nodes,OBUrange);

    %% cluster formation
    for jj=1:clusterNo
        % stores the each clustered vehicle index with RSU
        RSU{jj}.LtoR.clusterIndex=find(RSU{jj}.LtoR.inrange);
        RSU{jj}.RtoL.clusterIndex=find(RSU{jj}.RtoL.inrange);
        RSU{jj}.all.clusterIndex=find(RSU{jj}.all.inrange);
        % stores the RSU ID in each cluster with each node
        nodes.LtoR.RSU(RSU{jj}.LtoR.clusterIndex)=jj;
        nodes.RtoL.RSU(RSU{jj}.RtoL.clusterIndex)=jj;
        %% cluster head election
        %2. network connectivity level calculation
        nodes= nwconnectlevel(nodes,LW,RSU,jj);
        %3. average distance level
        nodes= avgDistancelevel(nodes,LW,RSU,jj);
%         %4. average velocity
        nodes = avgVelcoity(nodes,LW,RSU,jj);

        if ~isempty(RSU{jj}.RtoL.clusterIndex)
            nodes.RtoL.IW=[];
            for kk=1:numel(RSU{jj}.RtoL.clusterIndex)

input=[nodes.RtoL.NCLnorm(kk),nodes.RtoL.ADLnorm(kk),nodes.RtoL.AVLnorm(kk),0
.5];
                nodes.RtoL.IW(kk)=evalfis(input,fuzzystr);
            end
            [~,ind]=max(nodes.RtoL.IW);
            CH=RSU{jj}.RtoL.clusterIndex(ind);
            h2=plot(nodes.RtoL.loc(CH,1),nodes.RtoL.loc(CH,2),'<r');
            pause(0.001)
            set(h2,'Visible','off')

        end
        if ~isempty(RSU{jj}.LtoR.clusterIndex)
            nodes.LtoR.IW=[];
            for kk=1:numel(RSU{jj}.LtoR.clusterIndex)

input=[nodes.LtoR.NCLnorm(kk),nodes.LtoR.ADLnorm(kk),nodes.LtoR.AVLnorm(kk),0
.5];
                nodes.LtoR.IW(kk)=evalfis(input,fuzzystr);
            end
            [~,ind]=max(nodes.LtoR.IW);
            CH=RSU{jj}.LtoR.clusterIndex(ind);
            h3=plot(nodes.LtoR.loc(ind,1),nodes.LtoR.loc(ind,2),'>r');
            pause(0.0001)
            set(h3,'Visible','off')
        end
    end
%     %% cluster head election
```

```
%     % 1. lane weight
%     LW=laneWeight(laneNo);
%     %2. network connectivity level calculation
%     nodes= nwconnectlevel(nodes,LW,RSU,jj);
%     %3. average distance level
%     nodes= avgDistancelevel(nodes,LW);
%     %4. average velocity
%     nodes = avgVelcoity(nodes,LW);
    %5. average reward
    % with second part when spectrum sensing is designed

    % read .fis file
%     fuzzystr=readfis('CHsel_fuzzy');
%     LW.LtoRnorm=LW.LtoRnorm.*ones(1,size(nodes.RtoL.loc,1));
%     LW.RtoLnorm=LW.RtoLnorm.*ones(1,size(nodes.RtoL.loc,1));
%     for kk=1:size(nodes.RtoL.loc,1)
%
input=[nodes.RtoL.NCLnorm(kk),nodes.RtoL.ADLnorm(kk),nodes.RtoL.AVLnorm(kk),0
.5];
%         nodes.RtoL.IW(kk)=evalfis(input,fuzzystr);
%     end
    pause(0.000001)
    set(h,'Visible','off')
    set(h1,'Visible','off')

end
%%
```

Network connectivity level

```
function nodes= nwconnectlevel(nodes,LW,RSU,clusterNo)
%%
% this function calculated the network connectivity level
%%
% total nodes in vicinity of each nodes in each flow
```

```
indexLtoR=RSU{clusterNo}.LtoR.clusterIndex;      % nodes in cluster in LtoR
traffic flow
betaLtoR=sum(nodes.LtoR.inrange(indexLtoR,indexLtoR))-1;
betaLtoR(betaLtoR==-1)=0;
indexRtoL=RSU{clusterNo}.RtoL.clusterIndex;      % nodes in cluster in R toL
traffic flow
betaRtoL=sum(nodes.RtoL.inrange(indexRtoL,indexRtoL))-1;
betaRtoL(betaRtoL==-1)=0;

% total nodes in the vicinity in both traffic
alpha=sum(nodes.all.inrange(RSU{clusterNo}.all.clusterIndex,RSU{clusterNo}.al
l.clusterIndex))-1;
alpha(alpha==-1)=0;
% save var alpha LW betaLtoR betaRtoL nodes RSU clusterNo


nodes.RtoL.NCL=alpha(1:numel(indexRtoL))*LW.RtoL+betaRtoL;
nodes.RtoL.NCLnorm=normalize(nodes.RtoL.NCL);

nodes.LtoR.NCL=alpha((numel(indexRtoL)+1):end)*LW.LtoR+betaLtoR;
nodes.LtoR.NCLnorm=normalize(nodes.LtoR.NCL);
```

CH selection FIS

```
[System]
Name='CHsel_fuzzy'
Type='mamdani'
Version=2.0
NumInputs=4
NumOutputs=1
NumRules=81
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]
Name='NCL'
Range=[0 1]
NumMFs=3
MF1='low':'trapmf',[-0.5 0 0.1 0.3]
MF2='medium':'trimf',[0.1 0.5 0.9]
MF3='high':'trapmf',[0.7 0.9 1 1.5]

[Input2]
Name='ADL'
Range=[0 1]
NumMFs=3
MF1='low':'trapmf',[-0.5 0 0.1 0.3]
MF2='medium':'trimf',[0.1 0.5 0.9]
MF3='high':'trapmf',[0.7 0.9 1 1.5]

[Input3]
```

```
Name='AVL'
Range=[0 1]
NumMFs=3
MF1='low':'trapmf',[-0.5 0 0.1 0.3]
MF2='medium':'trimf',[0.1 0.5 0.9]
MF3='high':'trapmf',[0.7 0.9 1 1.5]

[Input4]
Name='LW'
Range=[0 1]
NumMFs=3
MF1='low':'trapmf',[-0.5 0 0.1 0.3]
MF2='medium':'trimf',[0.1 0.5 0.9]
MF3='high':'trapmf',[0.7 0.9 1 1.5]

[Output1]
Name='IW'
Range=[0 1]
NumMFs=3
MF1='low':'trapmf',[-0.5 0 0.1 0.3]
MF2='medium':'trimf',[0.1 0.5 0.9]
MF3='high':'trapmf',[0.7 0.9 1 1.5]

[Rules]
1 1 1 1, 1 (1) : 1
1 1 1 2, 1 (1) : 1
1 1 1 3, 1 (1) : 1
1 1 2 1, 1 (1) : 1
1 1 2 2, 1 (1) : 1
1 1 2 3, 1 (1) : 1
1 1 3 1, 1 (1) : 1
1 1 3 2, 1 (1) : 1
1 1 3 3, 2 (1) : 1
1 2 1 1, 1 (1) : 1
1 2 1 2, 1 (1) : 1
1 2 1 3, 1 (1) : 1
1 2 2 1, 1 (1) : 1
1 2 2 2, 2 (1) : 1
1 2 2 3, 2 (1) : 1
1 2 3 1, 2 (1) : 1
1 2 3 2, 2 (1) : 1
1 2 3 3, 2 (1) : 1
1 3 1 1, 1 (1) : 1
1 3 1 2, 2 (1) : 1
1 3 1 3, 2 (1) : 1
1 3 2 1, 2 (1) : 1
1 3 2 2, 2 (1) : 1
1 3 2 3, 2 (1) : 1
1 3 3 1, 2 (1) : 1
1 3 3 2, 3 (1) : 1
1 3 3 3, 3 (1) : 1
2 1 1 1, 1 (1) : 1
2 1 1 2, 1 (1) : 1
2 1 1 3, 1 (1) : 1
2 1 2 1, 1 (1) : 1
2 1 2 2, 1 (1) : 1
```

```
2 1 2 3, 2 (1) : 1
2 1 3 1, 2 (1) : 1
2 1 3 2, 2 (1) : 1
2 1 3 3, 3 (1) : 1
2 2 1 1, 1 (1) : 1
2 2 1 2, 1 (1) : 1
2 2 1 3, 2 (1) : 1
2 2 2 1, 2 (1) : 1
2 2 2 2, 2 (1) : 1
2 2 2 3, 3 (1) : 1
2 2 3 1, 3 (1) : 1
2 2 3 2, 3 (1) : 1
2 2 3 3, 3 (1) : 1
2 3 1 1, 2 (1) : 1
2 3 1 2, 2 (1) : 1
2 3 1 3, 2 (1) : 1
2 3 2 1, 2 (1) : 1
2 3 2 2, 3 (1) : 1
2 3 2 3, 3 (1) : 1
2 3 3 1, 2 (1) : 1
2 3 3 2, 3 (1) : 1
2 3 3 3, 3 (1) : 1
3 1 1 1, 1 (1) : 1
3 1 1 2, 1 (1) : 1
3 1 1 3, 1 (1) : 1
3 1 2 1, 1 (1) : 1
3 1 2 2, 1 (1) : 1
3 1 2 3, 2 (1) : 1
3 1 3 1, 1 (1) : 1
3 1 3 2, 2 (1) : 1
3 1 3 3, 2 (1) : 1
3 2 1 1, 1 (1) : 1
3 2 1 2, 1 (1) : 1
3 2 1 3, 2 (1) : 1
3 2 2 1, 2 (1) : 1
3 2 2 2, 3 (1) : 1
3 2 2 3, 3 (1) : 1
3 2 3 1, 3 (1) : 1
3 2 3 2, 3 (1) : 1
3 2 3 3, 3 (1) : 1
3 3 1 1, 2 (1) : 1
3 3 1 2, 2 (1) : 1
3 3 1 3, 3 (1) : 1
3 3 2 1, 2 (1) : 1
3 3 2 2, 3 (1) : 1
3 3 2 3, 3 (1) : 1
3 3 3 1, 3 (1) : 1
3 3 3 2, 3 (1) : 1
3 3 3 3, 3 (1) : 1
```