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Mobile-Agent Routing Protocol Based on DYMO for MANET

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Dedication

To Allah, My Lord and my Creator,

To Prophet Mohammed (May Allah bless and grant him), My Teacher and Messenger,

To my Palestine, Moreover, all martyrs, prisoners and injured the icon of sacrifice,

To my Parents, Ismail and Najah, who raised me to be the person I am today.

To my Mother in law, Samiha, who prayed Allah for me to be the best.

To my Love, Alaa, who has been a continual source of support, help and encouragement over the graduate.

To my brothers and sister.

To my friends and colleagues.

To All people in my life, who touch my heart, encourage and support me.

Omar Ismail Salem Salah

Declaration

I certify that this thesis submitted for the degree of Master, is the result of my own research, except where otherwise acknowledged, and that this is study (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed.. عمر صلاح

Omar Ismail Salem Salah

Date: 1 /8/2018

Acknowledgments

All Praise to ALLAH, the Almighty (swt), the greatest of all, on whom ultimately we depend for sustenance and guidance. I would like to thank. Almighty Allah for giving me opportunity, determination and strength to do my research.

Peace and blessing of Allah be upon the best of humankind, the Messenger of Allah, Prophet Muhammad (pbuh).

Praise, appreciation and gratitude to the great Muslim scientist Muhammad ibn Musa al-Khwarizmi, whom we use the word “Algorithm” that is derived from his name.

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Abstract

The mobile Ad-hoc network (MANET) is a set of mobile nodes that are grouped together to form a network topology, without relying on a preconfigured communications infrastructure. Such networks can operate in very difficult places, such as conflict zones, places where people can not directly access them and transport networks. If one of the mobile nodes must interact with another node within the same transmission range, they can interact directly with each other; on the other hand, if they are in different transmission ranges, the nodes between them must forward the packet to them. Thus, mobile nodes can be started as routers.

The nodes have the MANET mobility function, and all known routing protocols use a unique sequence number and number of hops to select the correct routing, so that the routing features have the least number of hops and the latest sequence number, the main common routing protocols that use this algorithm to select the shortest path of routing are AODV, DYMO and others. This method of routing choice has nothing to do with the remaining energy inside the nodes. Therefore, most routing protocols do not know about node energy.

Due to the inability of the DYMO protocol to realize node energy when detecting paths between the source node and the destination node, therefore, four suggested approaches are proposed based on the remaining energy levels at the intermediate nodes. In this sense, the proposed approaches select routing paths

with the highest energy level and take into account the number of transitions and the sequence number.

The results of the simulation are shown after the use of performance metrics, where all proposed approaches have played a role in improving the effectiveness of MANET activities.

بروتوكول توجيه الوكيل المحمول بناءً على DYMO لـ MANET

إعداد الطالب: عمر اسماعيل سالم صلاح

إشراف: د. رشدي حمامرة

الملخص

تُعد شبكة Ad-hoc المتنقلة (MANET) مجموعة من العقد المتنقلة التي يتم تجميعها معًا لتشكيل طوبولوجيا شبكة ، دون الاعتماد على بنية تحتية للاتصالات سابقة التهيئة. يمكن أن تعمل مثل هذه الشبكات في أماكن صعبة للغاية ، مثل مناطق النزاع ، والأماكن التي لا يمكن للأشخاص الوصول إليها مباشرة وشبكات النقل. إذا كانت أحدى العقد المتنقلة تريد أن تتفاعل مع عقدة أخرى في نفس نطاق الإرسال ، فيمكنه التفاعل مباشرة ؛ من ناحية أخرى ، إذا كانتا في نطاقات إرسال مختلفة ، فإن العقد الوسيطة بينهما تقومبإحالة الحزمة إليها. وبالتالي ،و لذلفك يمكن اعتبار العقد على انهن موجهات.

تمتلك العقد فيMANET حرية التنقل ، وتستخدم جميع بروتوكولات التوجيه المعروفة رقم تسلسل فريد وعدد القفزات لتحديد التوجيه الصحيح ، و هذا يكون اذا كان التوجيه عنده أقل عدد من القفزات وأحدث رقم تسلسل.

AODV و DYMO وغيرها منبروتوكولات التوجيه الرئيسية تستخدم هذه الخوارزمية لتحديد أقصر مسار للتوجيه.حيث ان هذه الطريقة في اختيار التوجيه لا علاقة لها بالطاقة المتبقية عند العقد. لذلك ، لا تعرف معظم بروتوكولات التوجيه عن طاقة العقدة.

نظرًا لعدم قدرة بروتوكول DYMO على تحقيق طاقة العقدة عند اكتشاف المسارات بين عقدة المصدر وعقدة الوجهة ، فإنه تم اقتراح أربع اقتراحات استنادًا إلى مستويات الطاقة المتبقية في العقد الوسيطة. بحيثتحدد النهج المقترحة مسارات التوجيه بالاعتماد على أعلى مستوى للطاقة وتراعي عدد القفزات ورقم التسلسل.

وتظهر نتائج المحاكاة بعد استخدام مؤشرات الأداء ، أن جميع النهج المقترحة قدمت دورا كبيراً في تحسين فعالية أنشطة MANET.

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Chapter One

Introduction

1.1 Background

This chapter discusses an introduction about the Wireless Network, Wireless Ad-Hoc Network, and MANETs with its characteristics

Wireless Network is a collection of terminal nodes which connected with each other to share resources and information using data links that are established over cable media such as wires or optic cables, or wireless media such as Wi-Fi. There are two types of networks: Wired Networks and Wireless Networks. In Wired Networks the nodes or devices are using wires for transmitting data from one node to another one where the wires go about as a mode of correspondence. With regard to Wireless Networks, the nodes or devices communicate between each other using the radio signal. If one of the devices need to communicate with another device, the source device must be presented with the radio signal of the receiver device and on the same channel; wireless connectivity among mobile users has become more popular than ever before, despite fears that in the past there was no confidentiality and protection of information [1].Increasingly, most places of work even houses need to be covered by the network. With the diversity of types of devices that need communication and the increasing number within the same network show the need for the network to be wireless type. Wireless Networks enable many devices to share files and other resources with freedom of movement within network range while maintaining contact with the network. There are some drawbacks to wireless networks such as slow speed and lack of security compared to Wired Networks, following table1.1 mentions comparison between Wired Network and Wireless Network types is mentioned.

In the 21st century, Wireless Networks have obtained a great value for researchers around the world by assessing many theoretical, practical and operational challenges [3]. This is due to recent technological developments in laptops, mobile phones and wireless data communication devices, such as wireless modems and wireless LANs; this has led to wireless networks becoming available for everyone with Low prices and high data rates.

1.2 Types of Wireless Network

There are two distinct categories that wireless networks are split on their base to enable wireless communication between hosts [4]. The first category is Infrastructure based and the second category is an ad-hoc network.

Table1.1: Comparison between Wired Network and Wireless Network types [2].

Specifications	Wired network	Wireless network
Speed of operation	Higher	lower compare to wired networks, But advanced wireless technologies such as LTE, LTE-A and WLAN-11ad will make it possible to achieve speed par equivalent to wired network
System Bandwidth	High	Low, as Frequency Spectrum is very scarce resource
Cost	Less as cables are not expensive	More as wireless subscriber stations, wireless routers, wireless access points and adapters are expensive
Installation	Wired network installation is cumbersome and it requires more time	Wireless network installation is easy and it requires less time
Mobility	Limited, as it operates in the area covered by connected systems with the wired network	Not limited, as it operates in the entire wireless network coverage
Transmission medium	copper wires, optical fiber cables, Ethernet	EM waves or radio waves or infrared
Network coverage extension	requires hubs and switches for network coverage limit extension	More area is covered by wireless base stations which are connected to one another

Channel Interference and signal power loss	Interference is less as one wired network will not affect the other	Interference is higher due to obstacles between wireless transmitter and receiver e.g. weather conditions, reflection from walls, etc.
Applications	LAN (Ethernet), MAN	WLAN, WPAN(Zigbee, Bluetooth), Infrared, Cellular(GSM,CDMA, LTE)
QoS (Quality of Service)	Better	Poor due to high value of jitter and delay in connection setup
Reliability	High compare to wireless counterpart, as manufactured cables have higher performance due to existence of wired technology since years.	Reasonably high, This is due to failure of router will affect the entire network.

a) Infrastructure Networks

In infrastructure networks, all devices on a wireless network communicate with each other through an access point like a router or base station. Cellular networks and WLAN are examples of this type of wireless networks. Infrastructure networks are suitable for sites where access points can be set up. Figure 1.1 part a) shows how devices are connected using access points.

b) Ad-hoc networks

The mobile nodes form an ad-hoc network where the nodes communicate with each other through radio signals with no need for any infrastructure like access points. Figure (1.1 part b) shows how the devices connected using ad-hoc mode. The nodes on the ends of the transmitter ranges are not connected directly to each other and depend on the intermediate nodes to be connected between these nodes, the intermediate nodes go like routers and all nodes are using ad-hoc networks to communicate. Ad-hoc networks do not depend on any existing infrastructure and therefore they can be deployed in any place. Ad-hoc networks are helpful in disasters recovery situations, rescue operations, military places and war areas where communication network must be deployed rapidly [5]. It can also be used as temporary network for any particular purpose.

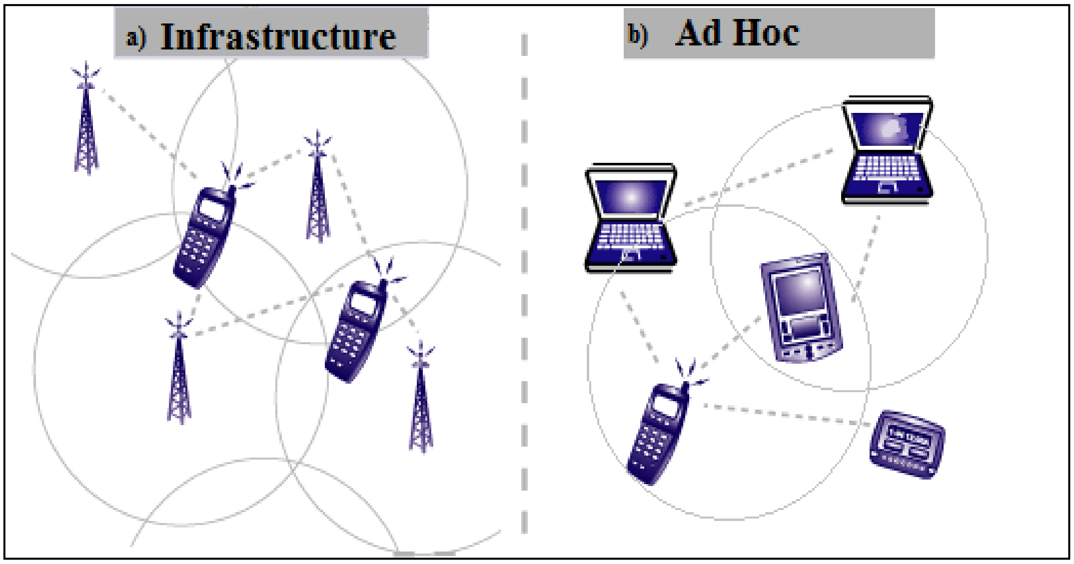


Figure 1.1: a) Infrastructure networks, b) Ad-hoc networks

Wireless Ad-hoc networks are divided into three approaches: Wireless Sensor Network (WSN), Wireless Mesh Network (WMN) and Mobile Ad-hoc Network (MANET). In this Master Thesis the interest and focus will be on in-depth examination of the MANETs.

1.3 Mobile Ad Hoc Networks (MANETs)

Mobile Ad-hoc Network (MANET) is a collections of mobile Nodes that are grouped together to form network topology without relying on a pre-configured communication infrastructure. This kind of networks can be operated in a very difficult places such as conflict zones, places where people can not directly access them and vehicle networks.[6] If one of mobile nodes need to communicate to another node within the same transmission range, they can communicate with each other directly; on the other hand, if they are in a different transmission ranges, the nodes in between of them have to forward the packet for them. Mobile nodes can operate a router. [7]. In MANET, each node or device moves randomly without being affected

by other devices, as it has free movement in all directions and at different speeds, and as a result of these changes, new network topologies are formed [8].Self-organization, decentralized nature and self-management are some of the characteristics of MANETs .
It is normal; however, some devices go out of the transmission range of other devices because of the limited transmission range of each device; which Leading to the fact that routing is one of the most important challenges facing the MANETs [9]. The nodes in MANETs are power constrained because nodes operate with limited energy which affects the duration life time of the nodes. This makes the period which the performance in is acceptable and limited [10]

1.3.1. Characteristics of MANETs:

MANTEs have many characteristics that are described below:

1) Dynamic changes in topology

In MANET, the random movement of the nodes causes the network topology to change naturally. Thus, no one can predict which of the Nodes will be within the network topology and which ones will be off the network topology, and therefore will be disconnect of communication between the nodes and the need to reconnect [11].

2) Decentralized control

Each mobile node acts as a router to keep the path locally by using fractional network information, where the network operations including the discovery of paths and send and receive massages are executed, distributed and controlled by all the nodes [12].

3) Autonomous behavior

All Nodes in MANETs are autonomous nodes, they move on their own as they act according to the state where they located, perhaps as host or routers [11].

4) Infrastructure less

MANET does not require a pre-installed infrastructure; since all the nodes behave independently and all nodes use wireless connectivity to communicate between nodes; therefore, MANET has no fixed routers or central server [11].

5) Multi-hop routing

Intermediate nodes behave like routers or switches when they are part of the path between the source and the destination. When the source and the receiver are outside the transmission range of each other's, the routers will forward packets from source to destination [12].

1.3.2. Constraints of MANETs:

MANET has a lot of difficulties although of the available flexibility through them, these difficulties and limitations are mentioned as follows:

1) Limited bandwidth

All the nodes in MANET operate under a limited bandwidth since MANET are more susceptible to external noise, signal attenuation effects and interferences in presence of time-varying network topology.

2) Energy constraints

The nodes need energy to operate in the working area. This energy is small and has a limited operational average because the available energy sources are small batteries and other sources of non-renewable energy or renewable energy sources operating at certain periods such as solar energy. This means that the life of the nodes is limited and it affects the performance of the network. Therefore, it is necessary to optimize between the routers with each other and the energy available to reach the best efficiency.

3) Resources constraints

The MANET nodes actually have a limited capacity of CPU, memory and other components because the sizes of the nodes are small and can be carried by hand. On the other hand, the energy constraints have a role in influencing the characteristics of the components that made the nodes.

4) Physical security restrictions:

In MANETs is increasingly concerned about the network's vulnerability to physical security threats, such as eavesdropping, denial of service attacks, and spoofing due to network dynamics while allowing routers to enter and exit the ad hoc network. Therefore, these concerns should be taken within the restrictions applied to the MANETs.

1.3.3. Applications of MANETs:

MANET is one of the flexible networks that contain devices with free movement and in all directions. It is easy to add or remove devices to and from the network while maintaining communication between the devices. It can be applied in any place where there is no infrastructure for communication or places that cannot access to them with the inability to apply traditional networks and there are many applications to use MANETs including entertainment, smart farming, wildlife monitoring and sea environment monitoring. Therefore, MANET can be relied upon in most areas and these areas [13].

1) emergency/rescue operations

A mobile Ad hoc network is used to collect data such as search and rescue operations in disaster recovery from infected areas like floods, fires, earthquakes where the most of communication infrastructure is destroyed ,and then these data is transferred to base station which can help many sections such as medical staffs and other independent teams to perform rescue operations since a mobile Ad hoc network could be deployed and implemented very quickly comparing with other networks that may need days or weeks.

2)Personal Area Network:

Personal Area Networks (PANs) are short range MANET such as Bluetooth that formed between personal mobile devices such as a laptops, mobile phone, notepads and wearable devices. PANs can remain an autonomous network at home for example.

3) Sensor Networks

Sensor networks are another application of MANETs which are collected of a huge number of small sensors that can be used to detect temperature, toxins, pressure etc. All sensors forward data to base station that use data to forecast of earthquakes for example.

4) Military regions

Technology and digital communications have become an integral part of battlefields and this technology is used by soldiers in the battlefield to communicate with each other and communicate with the army leadership. In order to execute orders with high accuracy and therefore it is possible to use MANETs in the military to maintain an information network between the soldiers, vehicles and their headquarters.

5) Commercial Applications

There are many areas where MANET can be used, including a smart transport system. If vehicles connect with each other or connect with the infrastructure of the roads, they will prevent collision or traffic congestion. Another example of applications is easy to use it with taxi systems and passengers in order to deliver the nearest vehicles to passengers and also to the presence of MANET in the trade operations include e-banking-commerce and business applications.

6) Collaborative Applications

Some work environments are naturally outside the office or need to be part of their work outside the internal environments. Staffs need to hold external meetings to collaborate and exchange information for a specific project.

1.4 Routing algorithms

The purpose of the route is to choose the paths between the source and the destination in order to deliver the messages to their correct location. It is known that MANET does not need an infrastructure but depends on a set of mobile nodes. Therefore, there is a need to make many hops before messages and packets arrive to destination.

This section focuses on the methods and algorithms that follow to select and find routes [14].

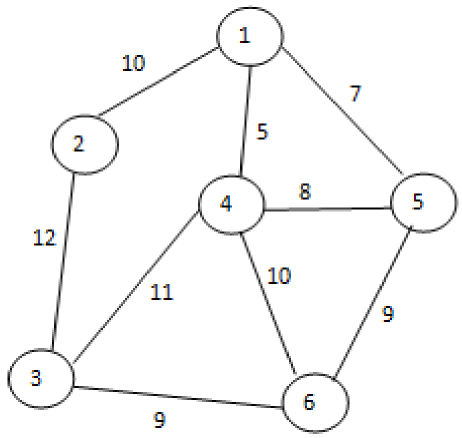
An Ad-hoc network is a very frequently changing topology and ***Conventional protocols*** are designed for a static network topology; therefore, Conventional protocols would have problems to reach a steady state when applied on Ad-hoc networks. If Ad-hoc network will not change its topology very frequently and mobile nodes have low speed, the Conventional protocols such as Link state and distance vector will probably work very fine.

1.4.1. Link State

In link state routing each node give a view of the topology of network with a cost for each link. Therefore, each node will broadcast the costs of its links to other nodes which are in transmission range of each other. When any node receives information about nodes, it updates its picture of the network and selects the next-hop that gives the shortest path for each destination. Figure 1.2 b) shows an example of link state routing.

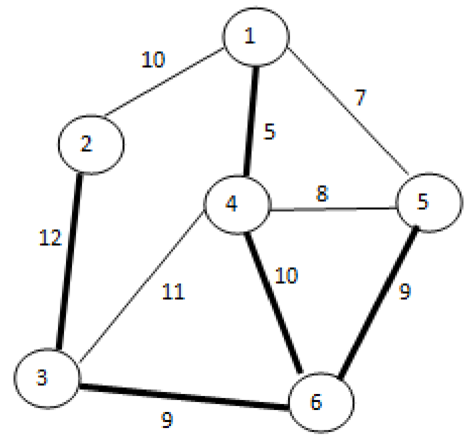
a) Distance Vector routing	b) Link State routing

a) Distance Vector routing



Routing Table of "6"		
destination	Cost	Next Hop
1	15	4
2	21	3
3	9	-
4	10	-
5	9	-
6	0	-

b) Link State routing



Routing Table of "6"		
destination	Cost	Next Hop
1	15	4
2	21	3
3	9	-
4	10	-
5	9	-
6	0	-

Figure 1.2: Network topology: a) Distance Vector routing, b) Link State routing

1.4.2. Distance Vector

In distance vector every node periodically broadcasts to each of its neighbor's data about nodes that it knows how to reach, and each node only listen to cost of its interfaces. When the node gets the information from other nodes, it would then update the routing table after recalculate the data. Each node in distance vector only sends an estimate of distance to rest of nodes in the network to its neighbors. Figure 1.2 a) shows an example of distance vector routing.

The disadvantage of distance vector is its slow convergence when a topology changes. On other hand, it is simple to implement and its computation efficient. However, nodes may update its routing table based on stale data which can cause short-lived or long lived routing loops [15].

1.4.3. Source Routing

In source routing, a source node sends a request packet to create a route to destination by flooding a packet to all nodes in the network. The request packet carry the complete information of the intermediate nodes that in a path. When any node has already learned a route to the destination, it responses the request packet by replay a response packet back to the source. In source routing can avoid routing loops.

1.4.4. Flooding

Many protocols use floods to send control packets to all new nodes. The source sends control packet to the nodes in the transmitter range. The nodes then resend the control packet to the neighbors those around them until the control packet reaches to all nodes within the network.
The node sends the packet just once. To make sure that the same packet is sent once a special number is added to the packet issued by the source.

1.5 Motivation

The nodes have MANET mobility feature and all famous routing protocols use the unique Sequence Number and the number of hops to choose the correct routing so that the routing features have the least number of hops and the latest sequence number. The main common routing protocols that use this algorithm for selecting the shortest routing path are AODV, DYMO and others. This technique of selecting routing has nothing to do with the remaining energy within the nodes. Therefore, most routing protocols are not aware of the energy of the nodes, due to the inability of the DYMO protocol to realize the nodes energy when the paths between the source node and the destination node are discovered. Therefore, four suggested approaches are all proposed based on the remaining energy levels in the intermediate nodes. In this sense, the proposed approaches select the routing paths that have the highest level of energy and taking into account the number of hops and sequence number.

1.6 Problem Statement

The real problem facing MANETs is the routing, because the nodes have freedom of movement. This prevents the stability of the routes between the nodes, because there is disconnect of links and there is a continuous change of the network's topology. These reasons call for proposed approaches that can overcome the problems of routing or reduce the impact of these problems.

1.7 Thesis Contributions:

Routing is one of the most important challenges facing MANETs. There are many researches that try to find protocols that aspire to have the best performance. In this context, four approaches have been proposed and the results of the thesis have proved that there is an improvement in performance according to performance measures.

- We have designed and developed Energy-DYMO, Fuzzy-DYMO, and Neuro-Fuzzy DYMO.
- We have designed and developed Mobile Agent-DYMO.
- We verified the performance of four proposed approaches by simulation and comparing with DYMO.

1.8 Literature Review:

Most current routing protocols for MANET, where the optimal path corresponds to the shortest routing path between the source and the destination with the minimum number of hops and the total remaining power is not seen through this shorter path. This makes it difficult to choose more stable routes between nodes. An energy conservation protocol has been proposed by R. Kumar and M. Gupta, where the route is chosen and the probability of a link fail is reduced due to energy depletion. Simulation results have shown better performance [65].

The authors P. Vyas, M. Tipkari and S. Pathania made a number of changes and then applied these amendments to the Dynamic Source Directive (DSR) Protocol and the Ad-hoc Distance Vector (AODV) Protocol. The results showed that the modified protocols give better results in all network performance metrics [66].

The research by M. N. Torshiz, H. Amintoosi, and A. Movaghar showed an improvement in route selection based on a fuzzy logic system. Fuzzy Energy-based AODV (FE-AODV) is an attempt to extend the life of the nodes in the network and to control the paths and choose the best path based on the lowest number of hops and less bandwidth. [67]

A routing protocol has been proposed by S. H. Yang and K. T. Songwhich takes into account signal strength and battery level, where the protocol uses a fuzzy logic to detect a path with Radio frequency signals. Simulation results show that packet delivery ratio has increased by 10 percent [68].

Researchers P. Kumar, S. Tripathi and P. Pal have controlled congestion control technology through the use of neural network technology for the ability to reliably transmit data via MANET, where the proposed protocol recognizes the mobility behavior of the node. The reason for the weak access of the packets is then determined, and then steps are taken to increase MANET reliability. The simulation results showed that the proposed technology shows an improvement in network performance. [69]

The authors N. H. Saeed, M. F. Abbod and H. S. Al-Raweshidy introduced an intelligent MANET (IMAN) routing protocol system that uses genetic algorithms to select the optimal protocol depending on the state of the network. The researchers used the Neuro-Fuzzy Inference System to construct a system containing three MANET routing protocols (AODV, DSR, and OLSR). The proposed system was then tested by live simulation and results showed an improvement in the values of performance measures [70].

The mobile Agent concept was used in the MANET environment by H. Bakhsh and, M. Abdullah. It has been noted that the mobile agent is remarkably effective and can overcome the obstacles facing most routing protocols. It can increase the performance of MANETs at all levels, where the (ARPM) was proposed according to the research paper [71].

The author Varaprasad focused on developing a routing protocol for mobile networks based on the mobile agent concept. The proposed model tries to find an optimal path, while preserving network properties. The simulation results showed that the proposed protocol succeeded in selecting routing good paths while maintaining high network performance [72].

1.9 Organization of the thesis

The rest of the thesis is organized as follows:

1.9.1. Chapter Two : routing protocols in MANETs are discussed in details

1.9.2. Chapter Three: Artificial Intelligence neural network, fuzzylogic, Neuro-fuzzy, and Mobile Agents are discussed in details.

1.9.3. Chapter Four: The Proposed Protocols are presented.

1.9.4. Chapter Five: speaks about the tools are used in simulation and the results

1.9.5. Chapter Six: provides the conclusion of this thesis and suggests future work in the same field.

This thesis looks at some of these problems and tries to evaluate some of the currently proposed protocols.

Chapter Two: MANET routing protocols

Chapter Two

MANET routing protocols

2.1 Introduction

Wireless networks can be divided into two types depending on the availability of infrastructure. The first type is called cellular networks that have an infrastructure such as access points and base stations that connected to a wired network, so that access points and base stations are the main corner of the network. The second is the ad hoc wireless networks, this type of network does not require an infrastructure such as the access points because each node on the network is considered a router and therefore the transmission of packets between the nodes is done via hops [73].

2.2 Classifications of MANETs Routing Protocols.

With no prior infrastructure, no central authority that controls the ad hoc network, and the permanently changing nature of the MANET, therefore researchers need to proposed a custom routing protocols for the MANETs capable of building the route from sender to receiver correctly that have low consumption of network resources such as battery power, with keep low bandwidth and to get high throughput [16], so that packets and control commands are delivered in a timely manner. The nodes in nature are mobile. New nodes will usually enter the MANET. Some nodes can also be out the MANET. Therefore, the nodes must listen and notify the neighbors of their presence. Each will identify the nodes in its transmission range and announce about the nodes through which it can be accessed. There are a lot of routing protocols that are designed to be used with MANET, which can be divided into two main classifications[17][18][19] based on how routing information is obtained and maintained by mobile nodes which can be either Table driven or On-Demand driven as shown in Figure 2.1.

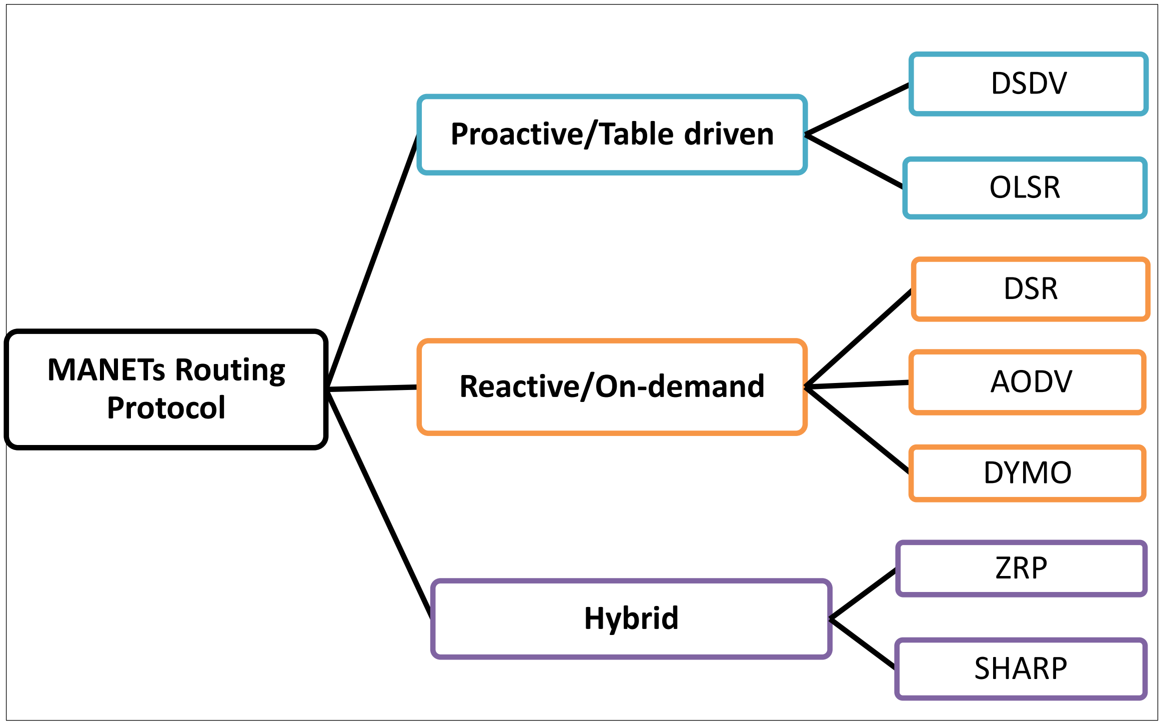


Figure 2.1: Classification of the routing protocols in MANETs

2.2.1. Table driven / Proactive routing protocols:

The routing protocols of MANET depend mostly on the principles of distance vector or link-state. Proactive protocols, also called table-driven protocols these protocols, may be suitable for small networks, but they are not suitable for large networks because of the exchange of control messages continuously because each node tries to maintain routing information for all other nodes within the network and this leads to increase the load in the routing tables and exhaustion of Bandwidth. On the other hand, there is a slight delay in specifying a new routing path when there is information about the receiving node, but the delay is significant if there is no information about the new routing path because a new route will be created. The destination-sequenced distance-vector protocol (DSDV) is an example of distance vector routing protocol where the cost to the destination is the hop counts from source to destination, while Global state routing(GSR) is an example of link-state there are also OLSR,WRP [20][21].

2.2.2. On-demand / Reactive routing protocols:

Rather than maintaining all routes at all times as proactive routing protocols do, on-demand routing protocols only maintain information about active routes and this reduces network traffic with a large number of control messages. When there is a need to establish a connection between a source node and a receiver node, a routing is initiated. First, the protocol begins with the process of exploring the route where the request packet is flooded using the flooding principle in all parts of the ad-hoc network until the request packet reaches the destination or to a node that defines the route to the destination. Second, the response packet is created by destination or intermediate node and sent to the source. Thirdly, when the response "replay" packet arrives at the source node, the routing is maintained as long as the connection is active and deleted when the connection loss. One of the disadvantages of Reactive routing protocols is that the time needed to explore the route from source to destination is long for the first time, so there is a significant delay. DSR, AODV, and DYMO are examples of on-demand protocols [22].

2.2.3. Hybrid Routing Protocols:

Hybrid routing protocols combined the characteristics and advantages of both proactive and reactive routing protocols to overcome the disadvantages of both protocol types. Hybrid routing protocols were proposed to increase scalability by allowing close nodes to work between each other to reduce overhead. The network is divided into smaller networks called zones. The proactive routing feature is used between the nodes within the same zone, while reactive routing is used to discover distant nodes that are outside the zone. By using hybrid routing protocols, the bandwidth is increased because the load resulting from the control messages is limited within the zone only and the initial delay resulting from the discovery of the route is reduced because it is used only between zones, so the efficiency increases [23]. Examples of hybrid routing protocols are Adaptive Distance Vector Routing (ADV), Sharp Hybrid Adaptive Routing Protocol (SHARP) and Zone Routing Protocol (ZRP).

2.2.4. Hierarchical Routing Protocols:

Hierarchical Routing Protocols are a multi-level assembly of mobile nodes where all nodes are divided into clusters of each cluster consisting of a cluster head and several nodes .Where the communication between each cluster and other clusters through the gateways. These gateways are nodes that are involved in more than one cluster at the same time. They are concerned with proactive protocols and reactive protocols at various hierarchical levels. This will reduce overhead and divide the allocated network into a network that is divided into clusters that are easy to handle. Examples of hybrid routing protocols for mobile ad hoc networks are Zone-based Hierarchical Link State routing (ZHLS), Zone Routing Protocol (ZRP) and Hybrid Ad hoc Routing Protocol (HARP).

2.2.5. Geographical Routing Protocols:

In MANET when the nodes mobility is high, there is a very high probability of link failure which is one of the most important challenges facing MANET. For this reason, geographic routing protocols have attracted considerable attention in the topics of routing protocols because they are efficient and scalable when the nodes move at High speed. Depending on the geographic routing protocols there is no need to keep the routing tables up to date and there is no problem if the network topology has changed because these protocols depend on the location information of the destination and the location information of all neighbors. It is not necessary to discover the route or maintenance of the route. Therefore, the overhead is significantly reduced. There are geographic routing protocols like as Distance Routing Effect Algorithm for Mobility (DREAM),Location-aided Routing (LAR) and Energy Aware Geographic Routing (EGR) [24][25][26].

2.3 Desirable attributes in routing protocols:

2.3.1. Loop free: in order to avoid loss of bandwidth or CPU consumption, routing protocols must ensure that the provided routes do not contain loops.

2.3.2. Distributed operation: the protocols must be distributed, and the centralized control node is absent. Thus, any node on the ad hoc network can easily enter and leave.

2.3.3. Energy saving: Ad Hoc network devices have limited battery power and therefore some kind of standby mode is needed.

2.3.4. Security: To ensure security, some preventative security measures, such as authentication and encryption, can be used for MANET.

2.3.5. Multiple routes: Routing protocols should provide alternative routes when the route becomes useless. MANETs are constantly changing topology or there may be a considerable of congestion. Therefore, different routes are used to reduce the reaction.

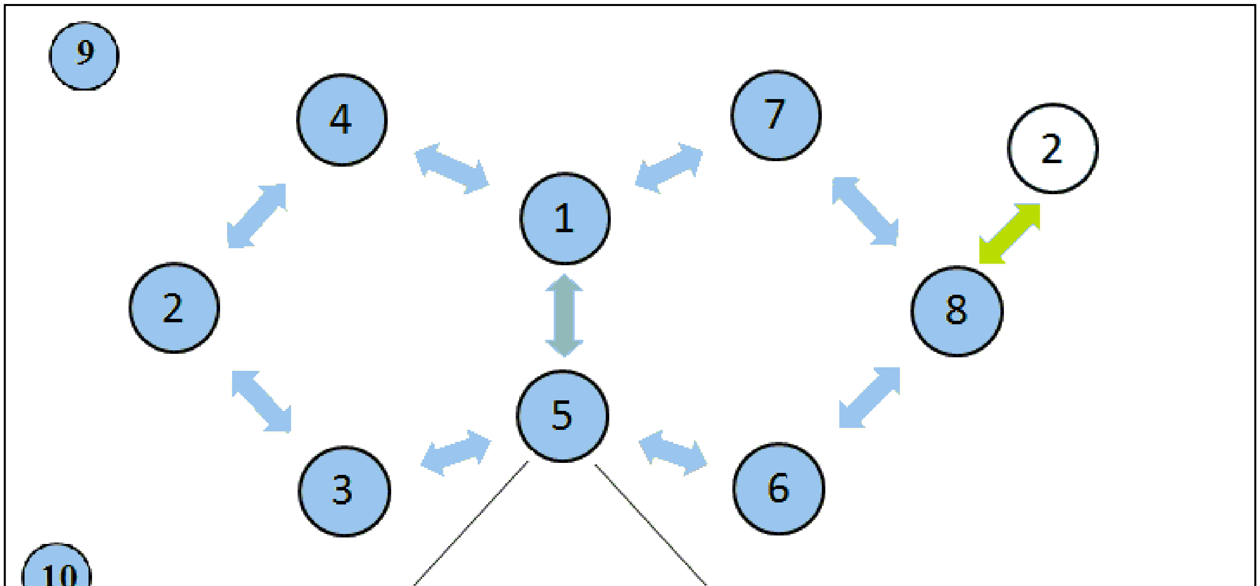
2.4 Main Routing Protocols in MANETs:

In this section, the main common routing protocols used in the MANETs will be discussed as follows: Destination-Sequenced Distance-Vector Routing (DSDV), Optimized Link State Routing Protocol (OLSR), Ad Hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Dynamic MANET On demand (DYMO).

2.4.1. Destination-Sequenced Distance-Vector (DSDV) Routing protocol:

The Destination Sequenced Distance Vector (DSDV) Routing protocol is a table driven algorithm that is established on the concept of the Distance Vector Routing Algorithm with some improvements to guarantee loop free paths at all instants. Because the "distance vector" algorithm in the Ad-Hoc network has the ability to form routing loops and counting that is infinity problem .Depending on DSDV, the routing table for each node has three entries, the destination address, the number of hops required to reach the destination and the **Sequence Number** is used to highlight outdated routes from fresh ones. As with the distance vector, the destination sequence routing protocol nodes broadcast their information periodically. The node schedules the new information that it received and then broadcasts it to its neighbors. Each node updates the information about the other nodes when new information is received if the **Sequence Number** is newer, and then increases the number of hops for the new information by adding one hop. The nodes periodically receive new information. The nodes receive new information with the new **Sequence Number** with the highest value when the network topology changes, and the new information is progressively updated for all nodes until each node is determined in the next hop that will reach the destination.

Take into account the example shown in Figure 2.2. In order to prove that node “2” is alive, it broadcasts a **Hello Message** with a unique **Sequence Number** to which the adjacent nodes are listening and the routing tables of the neighboring nodes are updating the information for node “2”. The adjacent nodes receive the **Hello Message**. If the routing tables are free from the address of node “2”, the “2” address is added directly to the routing tables. If the routing tables contain a previous address for node “2”, a comparison between the Sequence Numbers received from **Hello Message** and **Sequence Number** “Seq_No” in routing tables. If the value of the new **Sequence Number** is higher than the old value or if the value of the **Sequence Number** is equal to the value stored in the routing tables, but the number of hops is less than the store, this indicates a change in the network topology and that the received information is new. Figure2.2 shows the routing table for “2” before change and after change in DSDV. Updates are broadcast to the nodes around the neighboring nodes and within a short time all nodes become aware of new updates [27].Despite the fact that the advantages that ensure the absence of loops are guaranteed, many packets are discarded before the correct route are discovered, and periodic broadcasts significantly increase network overhead.



Before node 2 move			
Destination	Next Hop	Distance	Sequence Number
1	1	1	41
2	3	2	80
3	3	1	102
4	1	2	166
5	5	0	205
6	6	1	220
7	1	2	280
8	6	2	300
9	∞	∞	315
10	∞	∞	330

After node 2 move			
Destination	Next Hop	Distance	Sequence Number
1	1	1	82
2	6	3	161
3	3	1	110
4	1	2	270
5	5	0	215
6	6	1	425
7	1	2	480
8	6	2	350
9	∞	∞	415
10	∞	∞	430

Figure2.2 Routing in DSDV and change of routing tables

2.4.2. Optimized Link State Routing Protocol (OLSR):

Optimized Link Protocol is a table-driven routing protocol that is a modification to the Open Shortest Path First (OSPF) protocol to suit mobile ad-hoc networks. It uses the link state packet mechanism, which specifies a certain number of network nodes to be a *Multipoint Relay*(MPRs); these nodes (MPRs) alone have the right to flood and forward messages in the network [28]. The mechanism is executed when each node on the network sends a **Hello Message** periodically to the neighboring nodes and the neighboring nodes must do not resend the message to another nodes and then the node selects a set of adjacent nodes to become a *Multipoint Relay*(MPRs). Periodically a (MPRs) flood the network with control Topology (TC) messages in order to identify each network node and it's (MPR), this mechanism depends on the selection of set of nodes from the first hop that can cover all the nodes in the second hop. Figure 2.3 illustrates the procedure of the algorithm on node 2.

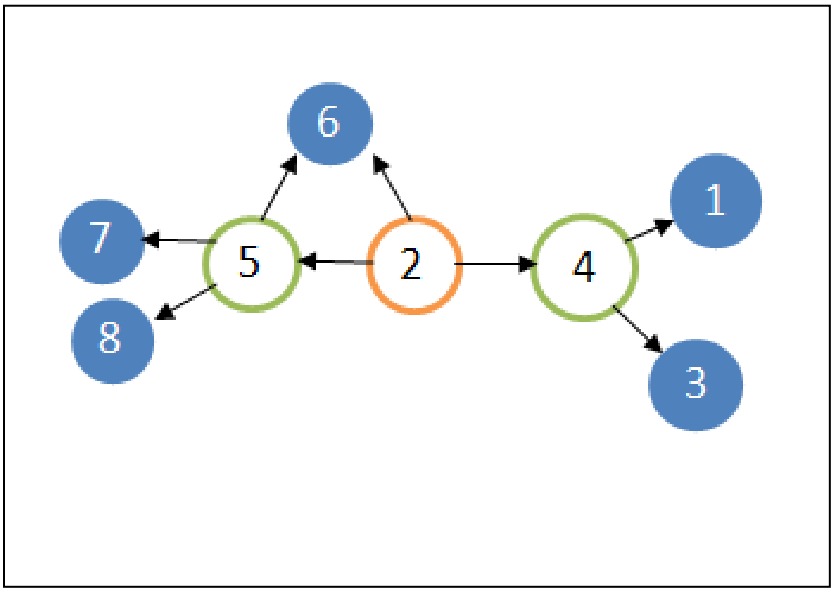


Figure 2.3: node 2 has selected its MPR set

On node 2, the MPR set is defined as node 2, can only reach nodes 7 and 8 by node 5 and therefore node 5 is added to the MPR set and in the same way node 4 is added to the MPR set for the same reason, so node 2 reaches all the nodes through the MPR set, using the MPR set network traffic was reduced from eight transmissions using flooding for forwarding because each node broadcasting data to three transmissions using the MPR set, because nodes 4 and 5, are the only ones responsible for transmitting data for node 2.

In comparison to the traditional link state routing protocol, two additional improvements were achieved, instead of each node broadcasting messages, which indicate the state of each link, only the MPR nodes broadcast their link state. Thus, the first improvement is in reducing the amount of overhead since the number of control packets is small.

The second improvement is that the size of the control packets has been reduced.

Thus, nodes in MANET have information that qualifies them to calculate the shortest path for all the nodes in the network.

2.4.2.1.The Features of OLSR

1) It is also known about the advantages of proactive protocols. Paths are always available when needed, unlike on-demand protocols, and OLSR is a proactive protocol that has the advantages of proactive protocols.
2) OLSR is suitable for high density networks because it does not need all nodes to flood control messages because it has a set of MPR.
3) The information is periodically transmitted to identify any changes in network topology.
4) OLSR needs time to create a new route or rediscover a broken route.
5) Because the nodes of the type MPR periodically broadcast packets, this means overhead on the network.

2.4.3. Dynamic Source Routing (DSR):

The dynamic source routing protocol is classified as an "on-demand" reactive protocol that uses one of the traditional routing protocol algorithms called source routing, which allows any source node to detect the path to any destination node to the network immediately upon request only, as the packet header keeps a list of all the intermediate nodesuntil the packet reaches the destination node, these intermediate nodes are arranged by their distance from the source node. The path information is stored on the source node and the intermediate nodes take advantage of the information in the path. The dynamic source routing protocol does not need periodically exchange of **Hello Message**s because it depends on the MAC layer to detect link failure, thus conserving battery power and reducing network overhead[29].

The Dynamic Source Routing Protocol (DSR) uses two procedures in particular to activate this protocol. The first is to discover the route and the second is to maintain the route.

2.4.3.1. Route Discovery:

The discovery of the route is a procedure that occurs when a source node determines to send a packet to a destination node. The source node begins by searching its cache for a route to the destination node, if no route is found, the source node begins to broadcast a route request packet to all neighboring nodes, which receive the packet and search their own caches on a route to the destination node. If no such route is found, each node adds its own address to the routing request packet and each adjacent node re-broadcasts the routing request packet to all neighboring nodes until the packet is flooded in all Around the network until it reach the destination node or to a node that has a route to the destination node and when the packet arrives to the destination node that creates the reply packet sent to the source node. It is shown in Figure 2.4. During the path discovery process, the source node adds itself to the request packet and the neighboring node adds itself to the list and so on until all hops that have been accessed are added.

On the other hand, the protocol adds a unique number to each routing request packet and the unique number is incremented whenever the same source node sends a new routing request packet, thus identifying any routing request (RREQ) packet based on the source node and the unique number. When The RREQ arrives at destination node by means of different routes then destination node returns a Route Reply (RREP) packet to source node 2, as shown in Figure 2.5, by using symmetric links or asymmetric links, then source node 2 receives (RREP) it saves the route to destination node in its route cache.

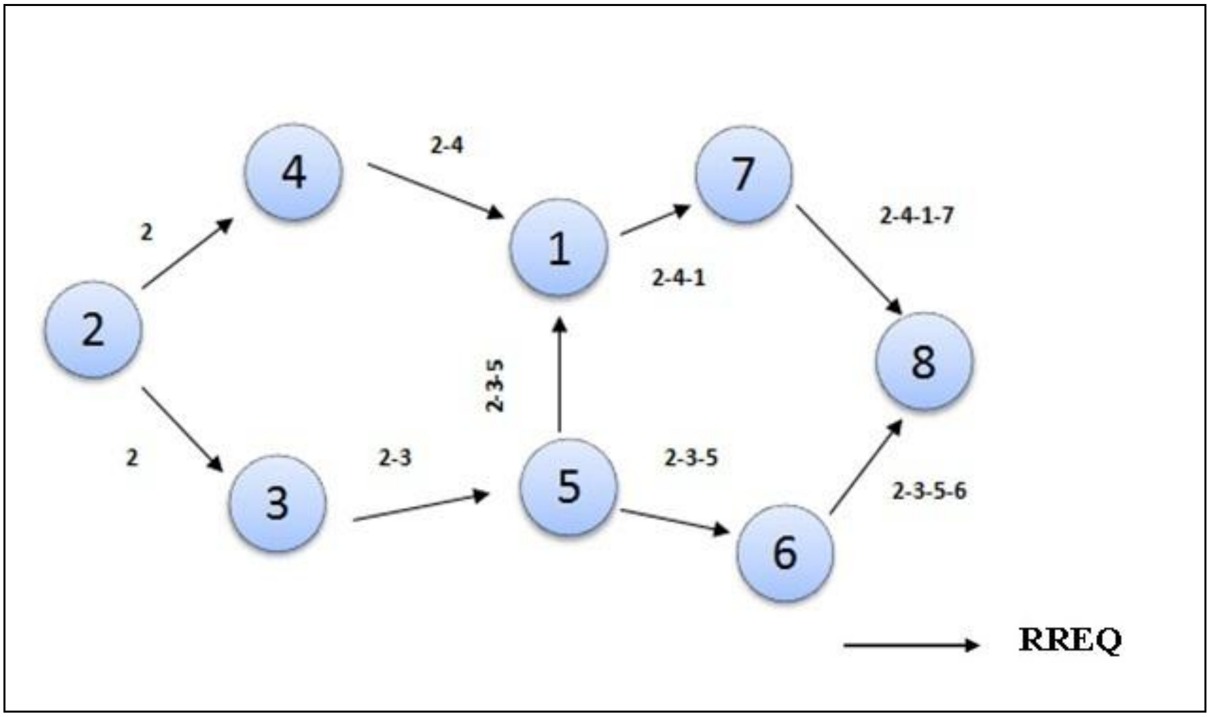


Figure 2.4 Route Request in DSR

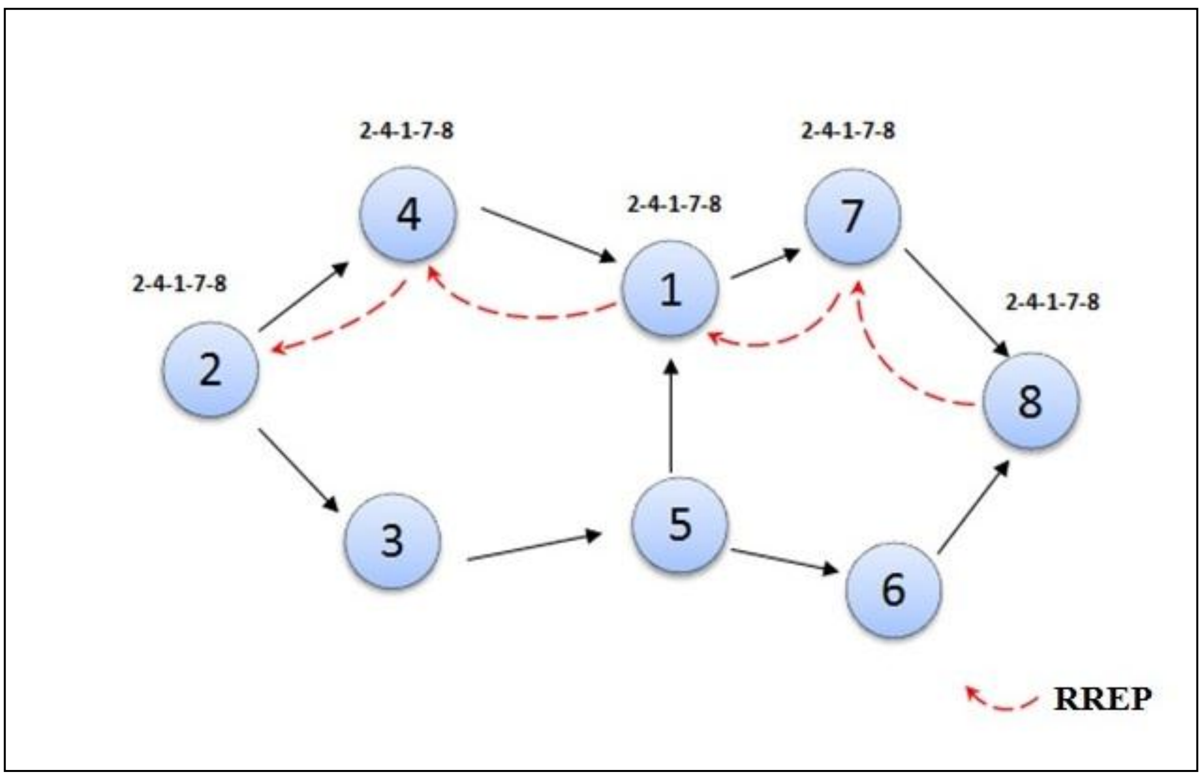


Figure 2.5 Route Reply in DSR

2.4.3.2. Route Maintenance:

When a connection between the nodes is created with each other, it becomes important to make sure that the connections between all the nodes are ready. Therefore, each node must be responsible for each packet sent to another node. It can be heard in more than one way by listening to the MAC layer and the link layer Data, acknowledgment from hop to hop or through passive listening is intended to listen negatively that the node hears the node above which one hop sends packets to a node higher than it. For example in figure 2.6 (4) , (1) and (7) are Three nodes are located in a straight line but at different levels, (4) at level 1 , (1) at level 2 and (7) at level three, when node (4) is at the first hop, (4) can listen to (1) that is sending a packet to (7) which is the third hop and this confirms that (7) is connected to now and can (4) contact with it.

If the error is at the level of the data link layer, the layer determines the error early and the packet is sent a routing error packet (RRER) to the node who create of the packet, and the (RRER) contains the node address that detected the error and the nodes that the packet was not reached. When routing error packet arrives at the source node, the hop where the failure occurred is removed from the routing cache It is possible to rediscover the route again if requested.

On the other hand, if the transmission between two nodes is sporadic and bad, it is impossible to know the node where the failure occurred. Therefore, (RRER)sent back to the source node so that the route is immediately deleted from the routing cache and then rediscover for a newer route.

Is shown in Figure 2.6, if the destination node is moved out of the range of the network's transmission, it was associated with the intermediate node 7 before exiting the network. After a few failed attempts, the intermediate node initiates a (RRER) packet and send it to another node to until reach the source node, which deletes the route from its routing cache unit and is likely to discover and use another Route from source to destination.

2.4.3.3. DSR Features

This protocol has the ability to learn the paths by studying all the received packets and storing this information in the routing cache, especially if it is in the promiscuous mode, which is a case where all traffic is heard on the network, without taking into account the addresses of the link layer. Despite the advantage of accessing information, there is a problem with information security because any attacker can listen to information and therefore there must be applications that encrypt the information before sending it.

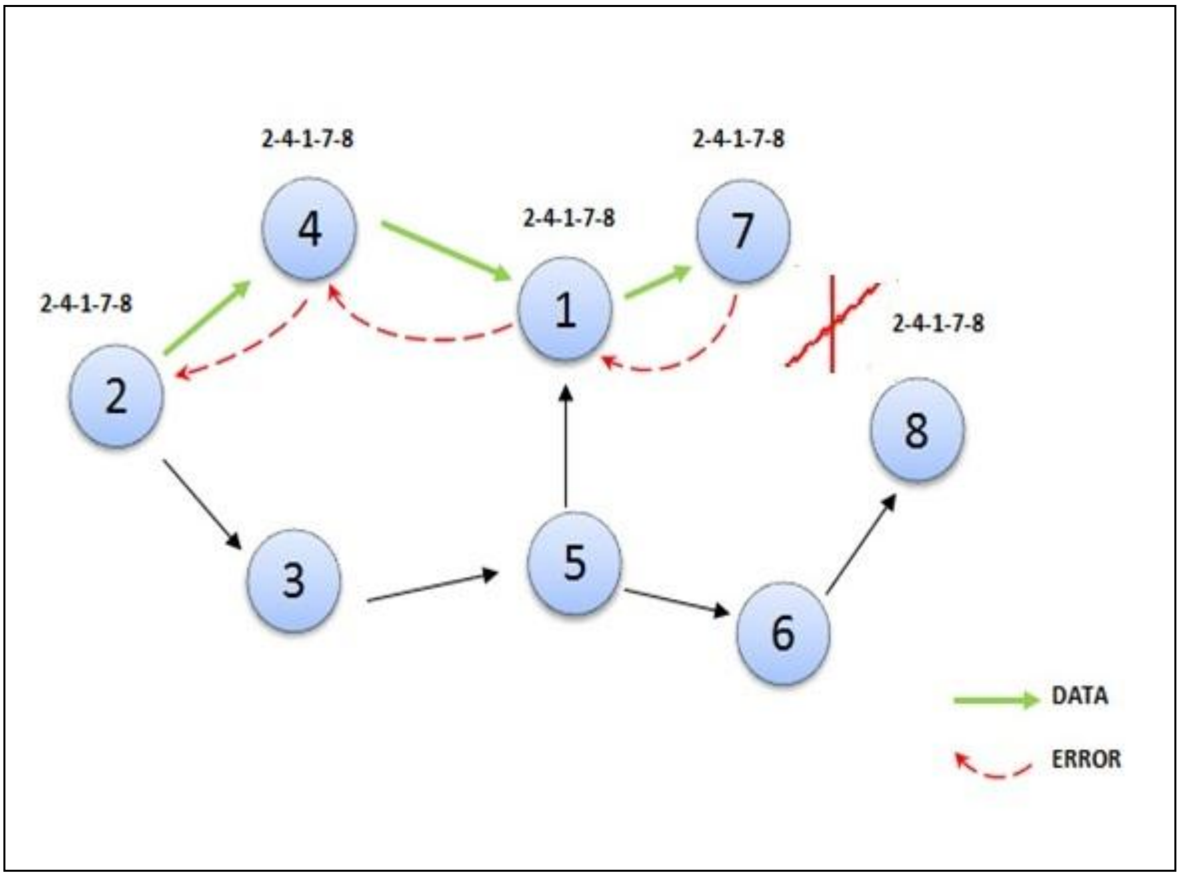


Figure 2.6: Route maintenance in DSR

Nodes have the features of the source routing such as no need to **Hello Message**s periodically, this reduces the overhead and improve the bandwidth, especially when the movements of the nodes are slow or when the increase in the density of packets and therefore the intermediate nodes are routing the packets forward without need to recent information for route. These features help the nodes to conserve battery power.

The following example demonstrates these features and also illustrates some of the faults that may have risen.

If there are three nodes X, Y and Z, where the path from X to Z via Y, this leads to X that learns the route to Z as X learns the route to Y, and on the other hand Y learns the route to X and the route Z, and also Z learn route to X and Y. This method is excellent to learn network topology and reduces overhead in the network, but the disadvantage of this method is that the size of the route request packet increases as the hopping through the intermediate nodes to access the destination node.

Routing protocols generally need to encrypt information because they are easily compromised by phishing attacks.

2.4.4. Ad Hoc On-Demand Distance Vector (AODV):

Ad hoc On-Demand Distance Vector (AODV) is a reactive routing protocol designed on the principle of the distance vector algorithm. This protocol is unlike the proactive protocols since the protocol (AODV) requests the route when needed. For example if there are data packets with the source node and need to be sent to the destination node, and the source nodes do not have any path to the destination node, the request is immediately initiated by source node to discover a path to the destination node [30]. This means that (AODV) does not require the nodes to maintain routes to inactive or unused nodes in communications. In the case of a link break in communications, alerts are sent immediately to the nodes that have been affected only. The protocol also ensures loop free because it uses a unique destination sequence numbers for each packet, and it is optimized to eliminate the problems associated with the distance vector such as “counting to infinitely”. It has the ability to adapt to scarce network resources such as low processing and low memory capacity.

The principle of operation of the protocol is divided into two processes. The purpose of the first process is to discover the route and the second process to manage the route to maintain it. Thus, the protocol uses different types of messages, as the route request (RREQ) message and the route reply (RREP) message are in the first process. The second process uses two types of messages, one is called the route error (RRER) message and the second is called a **Hello Message** (HELLO) [31].

- **Route discovery:**

The discovery of the first process path depends on the protocol (AODV) in order to know the paths to the various safes and maintain them in the routing tables where each route to the destination consists of fields where the fields are the destination address, the destination sequence number, the next hop, hops count. The validity time of routing, the list of active neighbors, and a buffer list for all requests. If the route to the destination is not in the routing table, or if the routing has expired and the node needs to be routed to the destination, the node begins its process by creating a routing request (RREQ) message and this message is transmitted to the network until the destination is reached. The source node must wait a specified time before re-broadcasting the (RREQ) message. During the waiting time, the routing reply (RREP) message must arrive at the source node or the source node will consider that the destination node is not present.

The (RREQ) message consists of the following fields: source address, source sequence number, broadcast ID, destination address, destination sequence number, and hop count, where the destination **Sequence Number** and broadcast ID to block loops and the source **Sequence Number** is Unique number used in order to create a new (RREQ) message, The hop count is a counter that increments by one each time a new intermediate node re-broadcasts the request message forward.

When the (RREQ) message arrives at the intermediate node, it forwards the message if it is not the destination node or does not have a path to the destination node. During this process, the number of hops is incremented by adding one hop to the number of previous hops, and the node creates a reverse path to the source node, where the next hop is the node that sent the routing request (RREQ) message to this node. This part of the process continues until the routing request message reaches the destination node or to an intermediate node that owns the path to the destination node. The (RREP) message is immediately created and unicast it back to the node that requesting it, and during the forward of (RREP) message, the route path is created from the Source node to the destination node, add the path to the routing table, and add the destination node to the list of active neighbors at each intermediate node.

Important notes related to the intermediate node it drops every route request (RREQ) message if it received more than once in the sense that the intermediate node drops all copies, and the same happens with the route reply (RREP) message as the intermediate node examines the message if it is old or fresh.

Figure 2.7 illustrates the route discovery process ,where node 2 needs to communicate with the node 8 in order to send the data, so node 2 creates a message (RREQ) and floods the message over the network until the (RREQ) message reaches node 8. The node 8 for its part creates a reply message (RREP) up to node 2, and within the creation of a request message (RREQ) and the creation of a reply message (RREP), the intermediate nodes learn the paths for both node 2 and node 8

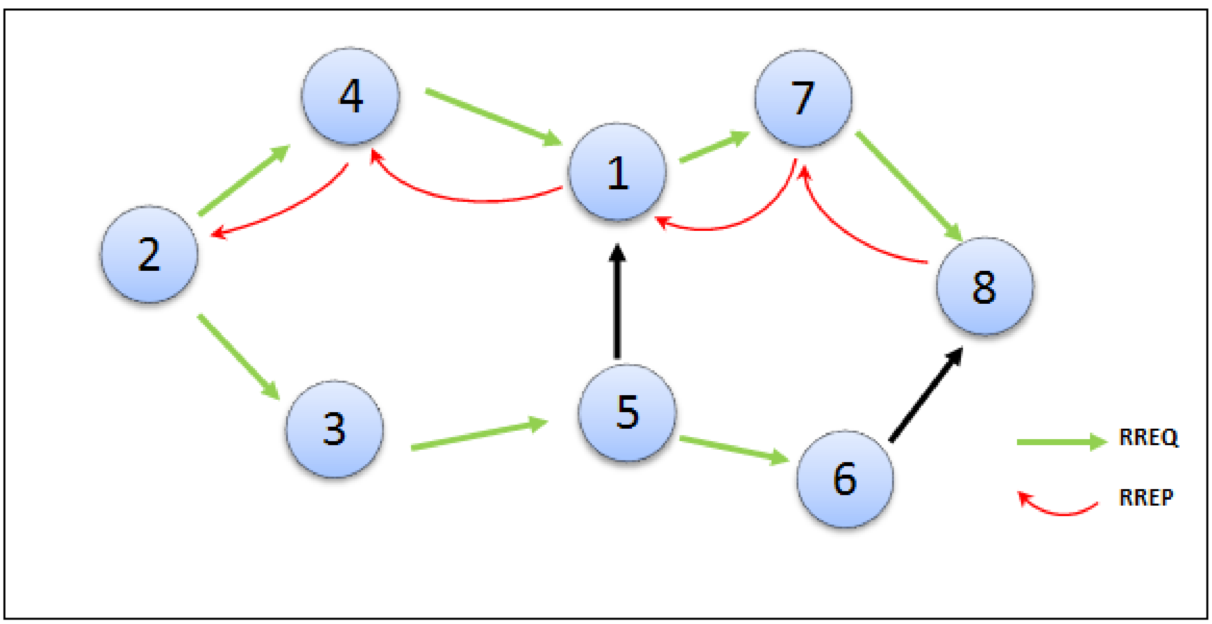


Figure 2.7: Route discovery in AODV.

- **Route maintenance**

The role of the second process, that is called maintenance of the route, is to preserve the routes when the network topology is changed. The nodes periodically send a **Hello Message** to the neighbors' nodes in order to discover the links between each other and verify the correct paths. On the assumption that the node moved or one of the neighbors out of the range of transmission, it means the interruption of links and the **Hello Message** not reach to the neighbors, another assumption that there is information reached to the intermediate node and this node does not maintain the path to the destination node, the node believes that the route has been broken and there is a failure of the link and therefore the node sends notice of failure of the link to the affected nodes.

The node generates and sends a route error (RERR) message to the affected nodes stating all destinations nodes are inaccessible, where the message contains all non-accessible destinations, when (RERR) message arrives at the affected node. The node compares its routing table with the destinations in the route error (RERR) message, then clears the broken paths from the routing table and continues the procedure until the (RERR) message arrives to all affected nodes. After the destinations are cleared from the tables, the source node creates a (RREQ) message to discover a new path or the node that sent the link failure performs discover.

For example, in Figure 2.8, node 2 sends data to the node 8 but when the data is arrived to the node 7 which detect that there is a link broken between node 7 and node 8. Therefore, node 7 creates a message (RERR) that is propagated through the network until it reaches node 2.

2.4.4.1. AODV Features

- AODV reduces the number of control messages. Since discover routes only on demand.
- There is delay time when a new route is required.
- AODV is capable of working efficiently with dynamic networks.
- AODV uses **Hello Message**s periodically that increase the number of packets, but the purpose of messages is to identify neighbors.
- AODV avoids the problem of counting to infinity and because of sequencing the network is protected from loops.
- One RERR is sent to active neighbors, contains a list of all the nodes that were affected by the link failure.

- When the same link failure is reported, the neighbor node may receive multiple RRER messages for different destinations, so the neighbor node may descend, since most of the network traffic is routed to it.

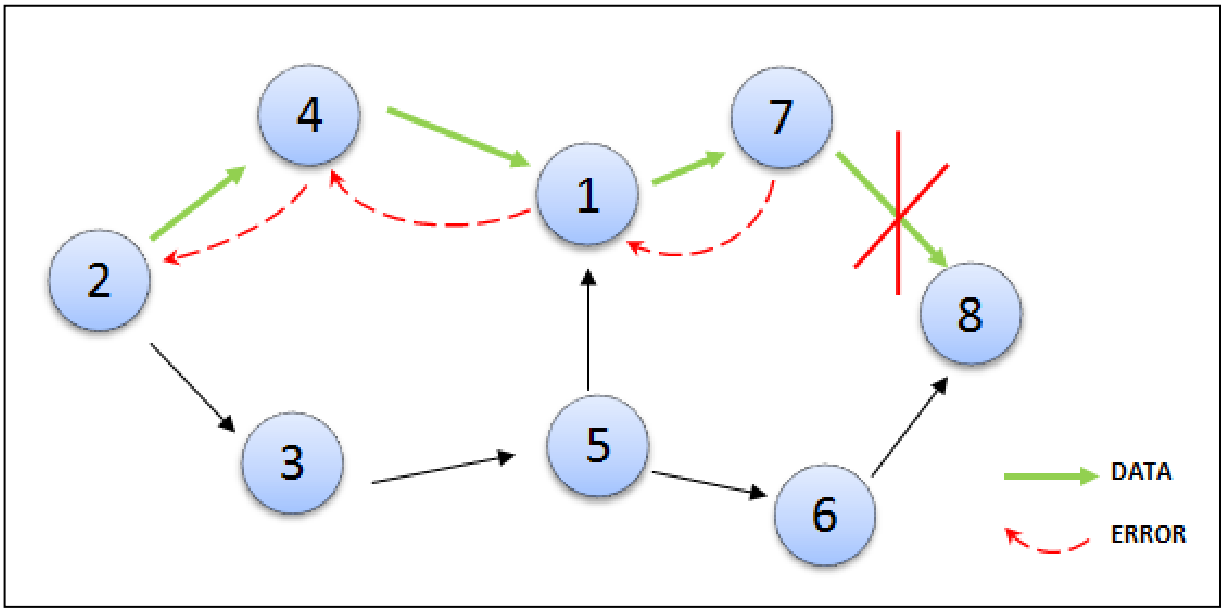


Figure 2.8: Generation of error messages.

2.4.5. Dynamic MANET On-demand (DYMO):

(DYMO) is a Dynamic MANET based on the demand, generated by the use of the characteristics of (DSR) protocol and attributes of (AODV) protocol as well, and therefore is a protocol of type by on demand(reactive), this protocol benefited from the advantage of accumulation of route, which a feature of the (DSR) protocol ,and the (AODV) protocol have eliminated the additions that can be undone without changing the principle of the (AODV) protocol, which is depends on its procedures to applying route discovery and maintain the paths, Such as **Hello Message**s, and precursor lists [32]. So, (DYMO) protocol was working to provide an effective and simple protocol. As in the case of (AODV), loops are dropped along paths using sequence numbers that provide an orderly and correct delivery of incoming information and identify duplicate packets. Like all other reactive routing protocols, two processes need to be used to find out paths and preservation of routing, which are route discovery and route maintenance. These processes need three types of messages: a Routing

Request (RREQ) message, a Routing Reply (RREP) message, and a Routing Error (RERR) message; which the (RREQ) Message and the (RREP) message are used during the route discovery process and a (RERR) is used during the route maintenance process. [33]

- **Route discovery:**

The DYMO nodes routing tables contain the destination address, the **Sequence Number** for the target node, and the next hop (the node address for the neighbor that is part of the path), the number of hops to reach the target node (hop count). Therefore, if the source node needs to send information to a target node the source node searches for a path to the target node of its routing table and if there is no routing to the target node, a routing request message is generated and broadcast across the network. If the request message reaches an intermediate node, the node adds its own address to the message and increases the number of hops by one. When the routing request message reaches the target node, a routing reply message is generated and sent to the node that sent the routing request message. Figure 2.9 illustrates the routing discovery process.

In Figure 2.9 node 2 wants to communicate with node 8 so node 2 creates a message (RREQ) containing the node 2 address and a new **Sequence Number** for the node 2 and then adding one value to the number of hops, and then add the node 8 address and the number of hops to the node 8 And its sequence number. Thus, the RREQ message has information about the node 8. The message is then forwarded using the network broadcasting method, so that each node sends a RREQ message only once depending on the sequence number. Each node that forwards the message (RREQ) adds itself to the message such as node address, sequence number, and gateway. At this time the message is spreading through the network, node 2 is considering receiving a reply message (RREP) from the node 8. This time is called wait time. If the waiting time is over, node 2 resumes creating a new message (RREQ) and returns the operation again. During the broadcast, nodes 4, 1 and 7 are added to a message (RREQ). These nodes process the entries in the message to update their private data as follows. If node 2 is not present in the routing table for each node, the address of node 2 is added so that the next hop Is the node from which the message arrived. And if there is information about node 2, the values in the message (RREQ) are compared to the values in the routing table. If the information in the message (RREQ) is new, the data is updated. The information of the nodes added to the message (RREQ) is also updated in the same way. Before the intermediate node transmits the message (RREQ), it increases the hop count by one and then creates a reverse path to node 2. When the message reaches node 8, the node processes the packet and updates its routing table.

After the arrival of a message (RREQ) to the node 8 and updating the routing table information, a message (RREP) containing information about the node 8 and information about node 2, such as the two node addresses, sequence numbers, and gateway , and then are sent. The process is used to send a reply message (RREP) in the same way as the request message (RREQ), where the intermediate nodes are added to (RREQ) and the data for their routing table is updated up arrival of a message (RREQ) to the node 2 as shown in Figure 2.9.

- **Route maintenance:**

After the process of creating paths and starting the process of transmission and reception there is a need to monitor the changes that get the topology of the network in order to keep the paths available, or discover for new paths. Maintenance of the route is therefore important in maintaining communication between the nodes within the same network. For this purpose, the nodes constantly monitor all the links associated with these nodes and then update the validity date of each active path.

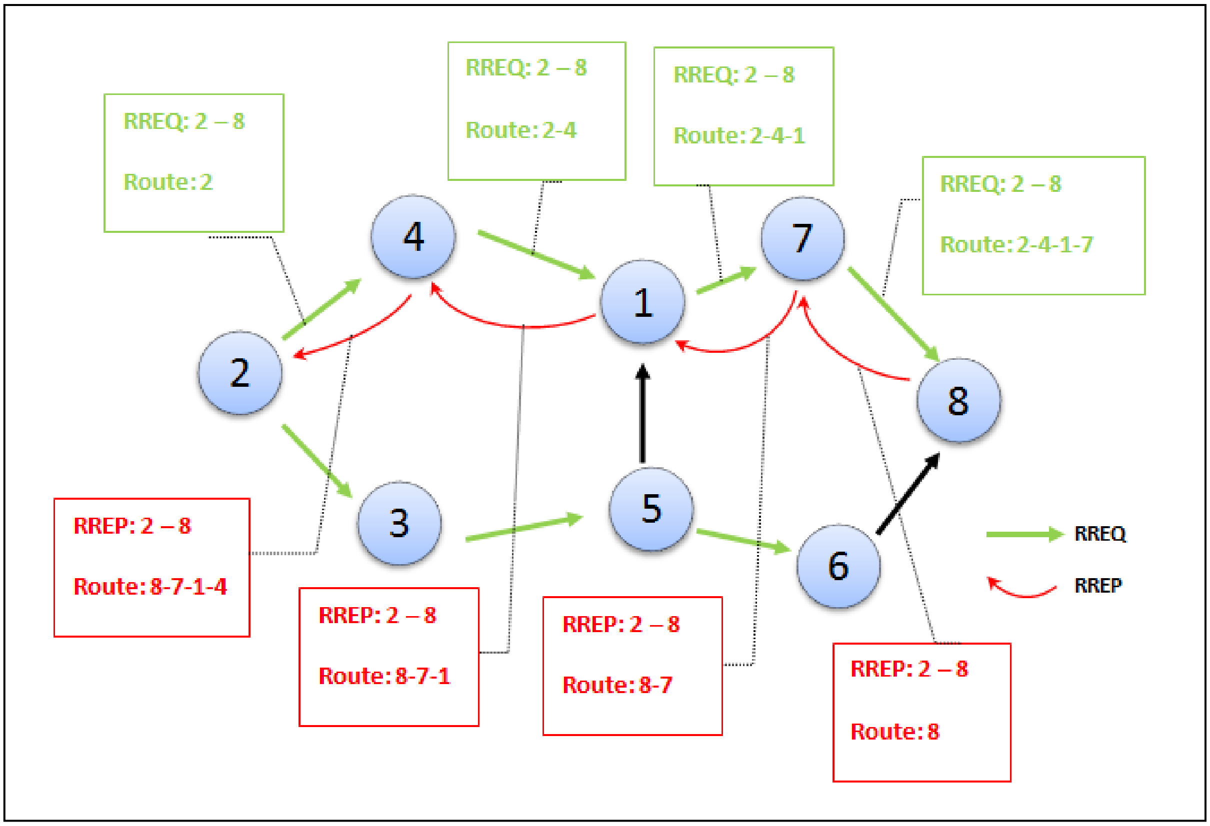


Figure 2.9: Route discovery process for DYMO.

This information is added to a special field on the routing table. If the node has data for an inactive path, the node must create a (RERR) message. When the node generates a path error message, it checks the routing table for each destination based on the infected node (unconnected node which is the next hop). The affected destinations are added to a special list to notify all affected nodes that the paths are no longer available, and then the address and **Sequence Number** of the infected node and the list are added to the (RERR). When the node generates a route error message, it checks the routing table for each destination based on the infected node (unconnected node which is the next hop). The affected destinations are added to a special list to notify all affected nodes that the paths are no longer available, and then the address and **Sequence Number** of the infected node and the list are added to the route error message (RERR),then The node broadcasts an route error message (RERR) to the neighbors, that receive this message and then compares the list that is in the route error message with their routing table where each destination node on the list is compared with the same destination node in the routing tables, If there is a similarity to the destinations so that the affected node is the next hop and the **Sequence Number** of the node in the route error message list is greater than or equal to the **Sequence Number** in the routing tables, the destination entries are deleted. The nodes then re-broadcast the routing error message if some entries remain in the routing table. If the routing table becomes empty, a path error message is dropped and the route error message is dropped if it reaches the nodes that do not need the broken paths. The reasons for breaking the link is when the neighbor node moves out of the range of the transmitter node or if the node moved itself or any other reasons to prevent the connection and it is possible to create a path error message if there is no update of the time field which leads to the path is expired, on other hand the purpose of having the **Sequence Number** of the node within the route error message is to make sure that the data is up to date and that no old data is being transmitted, so the route error message is broadcast only once. The transmission of a routing error message continues until it reaches its destination, and In order to rediscover the path. If there is a need to send data, the node creates a route request message for the destination and then broadcast the message to discover the Path again. Figure 2.10 details the route maintenance process.

Data to node 8 came by node 7, but the link between the two nodes was broken or the validity time of the path ended. The node 7 created an error message (RERR) which is spread back towards node 2. When the intermediate node receives the error message(RERR), it transmits it to the nodes next to it such as node 5 which is not concerned with the information in the error message(RERR), so node 5 drops the error message (RERR).

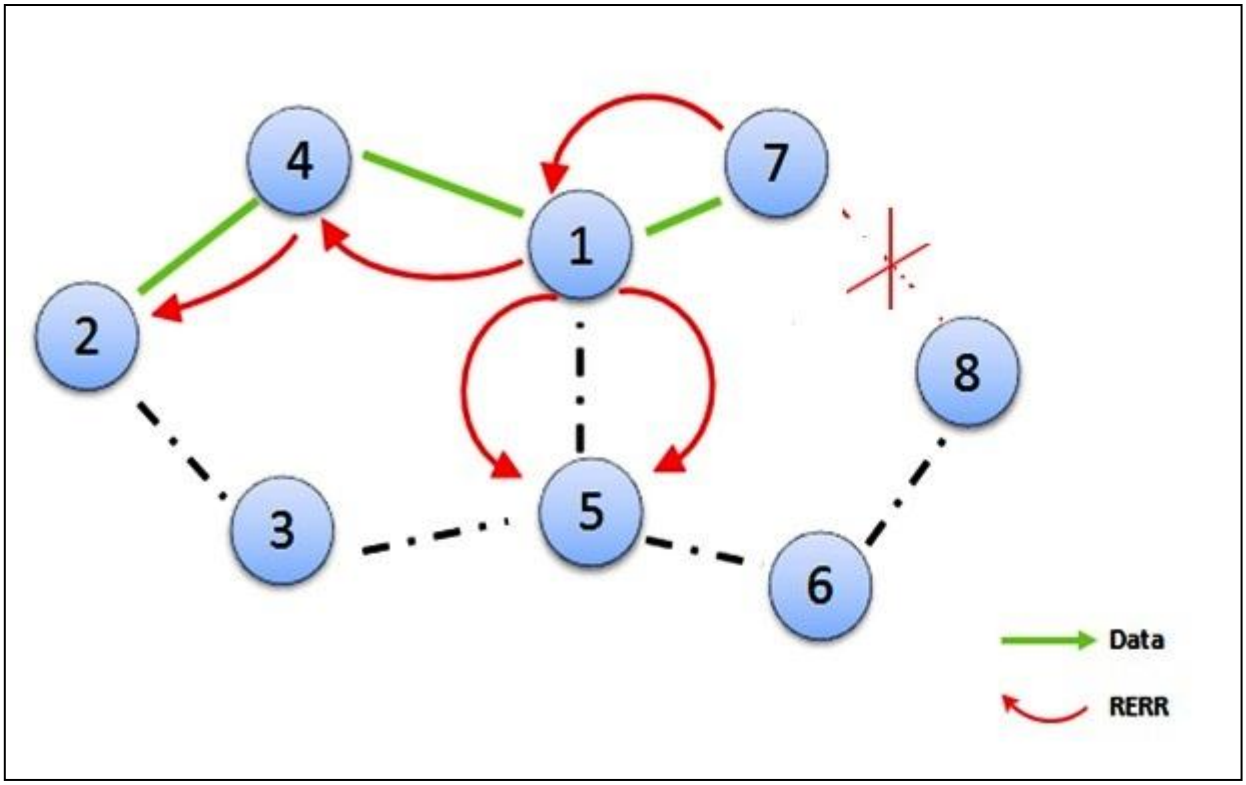


Figure 2.10: Route maintenance process for DYMO

One of the features of DYMO is energy efficiency. If the node has little energy, it cannot participate in the route discovery process. In this case, the node does not redirect any of the incoming RREQ messages. However, it will resolve incoming RREP messages and update its routing tables for future use. In addition, the DYMO routing table is relatively less memory wasted than AODV, even with the "Accumulate the path" feature. In addition, the overhead for the protocol decreases with the increase in network size and high mobility. Performance evaluation shows that DYMO exceeds AODV as the MANET routing protocol [34].

- **Features of DYMO protocol:**

DYMO is energy efficient when the network is large and demonstrates high mobility and the DYMO routing table is relatively less consumed than AODV, even with the path accumulation function, so the overhead for the protocol decreases with the increase in network size and high mobility. On the other hand, DYMO does not work well with low mobility; that the overhead of the control message is high enough and not needed. DYMO shows performance degradation at very low traffic, and the overhead of routing outstrips actual traffic. Despite the fact that DYMO works well when traffic is routed from one part of the network to another.

2.4.6. Performance Comparison of Routing Protocols in MANETs

There are several studies that provide a comparison between routing protocols in terms of performance indicators. The simulation results of many research studies show that reactive routing protocols outperform proactive routing protocols according to[35][36][37].
Simulation results [37] the packet delivery fraction compared to the number of nodes. Obviously, the performance of the AODV routing protocol is better than DSDV and DSR as the number of nodes increases. And that AODV provides the throughput better than DSDV and that it exceeds DSR [37].

Simulation results of [38]. Three routing protocols were discussed on demand. AODV, DSR and DYMO, and performance were compared to evaluate the performance of each protocol in different network environments. All three protocols work well when the density of nodes is low, the movement of nodes is slow and a small number of connections. However, the increased density of nodes and the rapid movement of nodes or more communications, AODV and DYMO begin to exceed the performance of DSR.

Simulation results of [74] show the packet delivery fraction compared to the Node Mobility m/s, where DYMO and AODV are close to each other, and in Figure 2.14 shows the End to end delay compared to the Node Mobility m/s, where DYMO is better than AODV [74].These two figures compare between AODV and DYMO protocols using performance metrics where the simulation environment contains different nodes speeds and different levels of maliciousness, where the End to End delay and Packet delivery ratio are shown in the two figures when the maliciousness ratio is 0%.

2.5 Summary

Technology has become more sophisticated over time and the means of communication became available in hands, especially wireless devices such as phones, laptops and tablets. With the increasing use of these devices emerged the need to establish networks for these kind of devices, and there is a need to develop protocols with high performance and efficiency and protected from risks. These protocols are different from traditional protocols. In this chapter, the categories of router protocols related to MANETs were discussed, such as reactive protocols, proactive protocols, hybrid protocols, hierarchical protocols, and geographic protocols.

Proactive and reactive protocols were discussed extensively with the characteristics and features of each protocol. With comparison of the famous protocols in each classification, it appeared that the DYMO protocol had better simulated results than other protocols.

Chapter Three: Artificial Intelligence

Chapter Three

Artificial Intelligence

3.1 Introduction

Artificial Intelligence (AI) has a major impact on the improvement and evolution of MANET performance. A number of artificial intelligence techniques are used to improve and solve MANET routing problems, the following are examples of this

3.2 Fuzzy Approach

Since 1965 researchers have been busy applying the invention presented by Professor Lotfi Zada [39] at the University of California, where he introduced the fuzzy logic, which is an extension of the binary logic. Instead of one and zero or true and wrong, the fuzzy logic adopted all values to infinity between zero and one. The idea of the invention of fuzzy logic was to try to imitate man's way of thinking and logic, so that loose language phrases such as "long", "short", "hot" and "cold" were used instead of precision of using values such as "180 centimeters" and " 30 ° C "[40]. For example, without using fuzzy logic, if it was said that" 175 centimeters "means a tall man, so the 174 cm tall man is short, but when using the fuzzy logic, the tall and short values range from completely short to completely tall. Because 174 is found in the fuzzy area between tall and short, has tall and short features Therefore, fuzzy logic is used with uncertainty and inaccuracy.

Fuzzy logic is flexible and able to deal with inaccurate data, this makes it available to model a large number of problems in the world where used in engineering, medicine, science, economics, management, factory control systems, error detection systems, control of cars and control of trains, aircraft , communication networks ,telephone networks, robotics and artificial intelligence development [41]. Work is still under way to develop and introduce fuzzy logic in other aspects of technology to help break down obstacles.

The structure of the fuzzy logic system consists of four phases as shown in Figure 3.1. And these stages are the fuzziffication, the inference engine, the rule base, and defuzziffication.

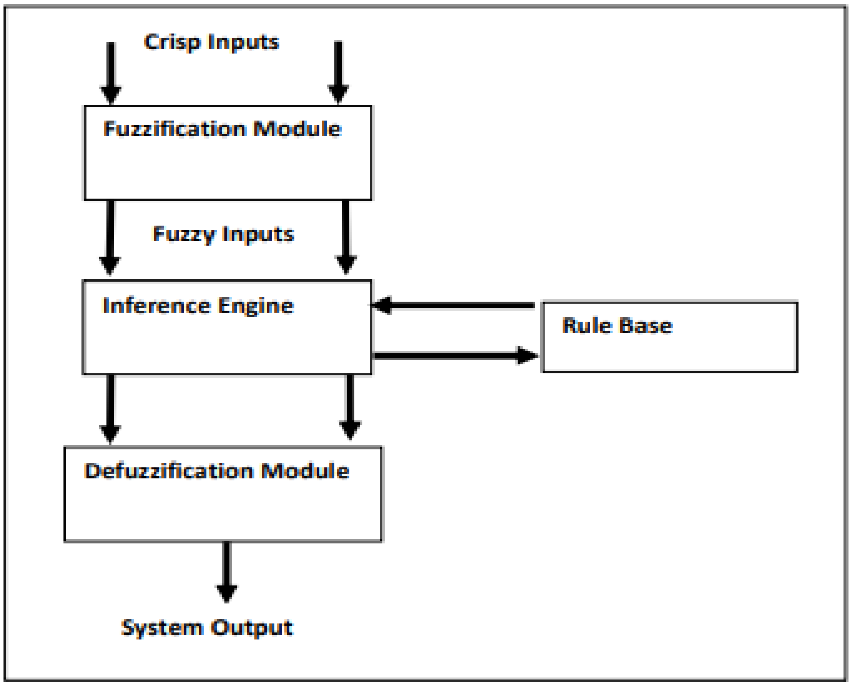


Figure.3.1: Block Diagram of fuzzy logic controller

3.2.1. Fuzziffication

In Fuzzier phase which is the first stage in the fuzzy logic system that takes the crisp values of input parameters and then outputs the fuzzy set corresponding to the input based on the specific membership function of each input, where any fuzzy set can be defined as a conjugal set as shown in equation (3.1).

$$A = \{(x, \mu_A(x)) | x \epsilon X, \mu_A(x): X \rightarrow [0,1]\} (3.1)$$

Where A is fuzzy set, $\mu_A(x)$its membership function,x member of the crisp set and X is called in fuzzy logic the universe of discourse and defines all the possible values that x can take.

3.2.2. Inference Engine

The inference engine does the mapping of each fuzzy input value with the output fuzzy value depending on the output membership function, so that it is mapped based on the results that appear at Rule base.

3.2.3. Rule Base

This module contains rules of IF-THEN linguistic rules, fuzzy sets of input and fuzzy set of output. The general form of these rules is according to the following equation (3.2). If the fuzzy logic system has a number of inputs and one output, the rule form is:

$$R^j: IF n_1 is A_1 \; AND\backslash OR n_2 is A_2 \; AND\backslash OR \dots . n_p is A_P THEN b is O^j \quad (3.2)$$

Where $\boldsymbol{R}$ *is rule* $\boldsymbol{j}$ *is number of rule,* $\boldsymbol{n_1}$..$\boldsymbol{n_p}$,$\boldsymbol{p}$ *total numbers of linguistic variables and* ***n, b*** *are linguistic variables,*$\boldsymbol{A_{1\dots p}}$*are input fuzzy sets , and* ***O*** *is the output fuzzy sets.*

Each rule produces one output fuzzy value and with the large number of rules on which tests are performed, there must be some way to assemble these fuzzy outputs and produce one fuzzy output value representing all rules for the same fuzzy output. This operation is done after passing the rule base and before entering the final stage of fuzzy logic system that it called aggregation.

3.2.4. Defuzziffication

All electronic systems deal with crisp values, so the purpose of the defuzzification process is to reverse the first phase called fuzzification. After aggregation the fuzzy values and obtaining a single fuzzy value, the final phase converts this fuzzy value to a numerical value. Centroid and mean of maximum [42][43] can be used as a defuzzification method or one of these methods[44][45][46].

3.3 Neural Network Approach

Neural networks are networks based on anatomy of the nervous system of living organisms. The neural network consists of a group of neural cells that are interconnected and functioning at the same time as each neuronal cell with a weight and each interconnection between each nerve cell has a weight. A connection has a different weight than another connection. Neurons are trained to perform specific and complex tasks. This training is based on the use of a large number of inputs and then the identification and classification of these inputs [47].For learning and training there are three types that are used on neural networks, namely, supervised learning, reinforcement learning and non-supervised learning.

The most common method of learning is supervised learning where learning is done by training neurons by giving the neurons a set of data that contains input and output. With frequent training, the desired results are produced so that the weights of the neurons and the connections between them can be re-established, In order for the results to be close to the actual outputs. Supervised learning methods consist of at least three layers: an input layer, an output layer and at least a hidden layer, such as sandwiches between the two layers.

Layer interconnecting by connecting the input layer outputs, with hidden layer inputs, and hidden layer outputs is connected to the output layer inputs. Where the data is spread from layer to layer and the weights are reset to reach the desired output. This method is called the Back-propagation network [48]. Figure 3.2 shows three–layer neural network architecture where the i1, i2 are neurons of the input layer, and j1, j2 neurons are a hidden layer. On the other hand, neurons o1, o2 are the output layer, from the beginning there are inputs and there are desired outputs and the neural network system will try to reach the desired outputs, so that the training process is as follows: First, the input of each neuron in the hidden layer will be calculated according to Equation (3.3).Such that:

$$j1 = w_1 * i_1 + w_2 * i_2$$

Second, the result of equation 3.3 is used as part of Equation (3.4), called the activation function, and the activation function is often a logistic function. Thirdly, the same method of calculation is applied to all neurons in the hidden layer.

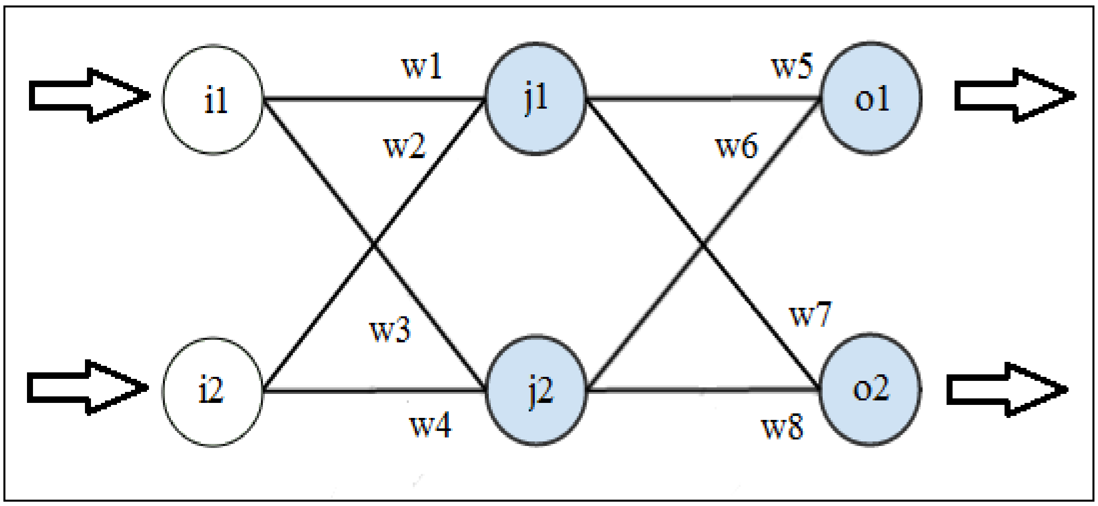


Figure 3.2: Three–layer neural network architecture

Finally the same stages are applied to the neurons in the output layer so that the results of the neurons in the hidden layer are the inputs of neurons in the output layer.

$$ji = \sum_{p=1}^{n} i_p w_p \qquad (3.3)$$

$$where p = 1 \ldots\ldots n$$

$$jo = f(ji) \qquad (3.4)$$

$$where f(ji) = \frac{1}{1 + e^{-ji}}$$

After the results for all the neurons in the output layer are shown, the total error is calculated using equation (3.5).
If there is a desire to reduce the error, the system needs Equation (3.6) in order to update the value of the weights where the output layer weights are first updated, then the hidden layer weights and so on. Then the steps are taken back from the beginning.

$$E_{total} = \sum \frac{1}{2}(d - o)^2 \quad (3.5)$$

$$\text{where: d} = \text{desired output}, \text{and o} = \text{neuron output}$$

$$w_{new} = w_{old} - \alpha \frac{\partial E_{total}}{\partial w_{old}} \quad (3.6)$$

$$where \alpha is \text{learning rate.}$$

The other two methods are used to create networks that do not need learning and training before they are created [49] [50].
Neural networks have been used in many fields such as robotics, engineering, industries, medicine, surveillance, voice recognition, face recognition, image processing, wireless networks, AD HOC networks and other fields.

3.4 Neuro-Fuzzy Approach

Neural Fuzzy is a collection of the desirable characteristics of neural networks in addition to the desirable characteristics of the system of fuzzy logic where a flexible new system takes advantage of empirical data in terms of training and learning and then presented as linguistic bases. So that it is able to predict that the results of the system are desirable and translate the state of the system.
In the first neural fuzzy stages, data is collected, which a sample is representing the principle and method of operation of the system to be designed. The sample is then purified from any abnormal data, and the advantages that the proposed system will be determined so that

learning is easier, after obtaining the data sample, the learning phase is initiated. It is the stage of searching for the best standards and values in order to find the desired outputs. It is normal to apply the neural fuzzy systems in the same areas as the application of fuzzy logic systems or areas where the application of neural networks such as monitoring, data analysis and control in the areas of wireless networks and infrastructure of cities and transport.

The nuero-fuzzy system is divided into three classifications according to the way in which neural networks and fuzzy logic are combined:

a. Cooperative Neuro-Fuzzy System

In this approach, the data set generated by the neural networks is used to create fuzzy sets and to create fuzzy rules. After that, the role of neural networks ends and Fuzzy logic remains the real engine of the system.

b. Concurrent Neuro-Fuzzy System

In this approach, the role of neural networks is limited to giving data as input to the fuzzy logic or the neural networks are located on the other end of the fuzzy logic to change the output of the fuzzy logic without the training of the fuzzy logic elements.

c. Hybrid Neuro-Fuzzy System

The fuzzy system uses neural networks to modify the elements of fuzzy logic, for example an adaptive neuro-fuzzy inference system (ANFIS).

In some cases, it is difficult for the fuzzy control unit to measure the inputs in a desired way. Therefore, the neural network helps the fuzzy system to effectively increase the performance level. Figure 3.3 shows the Architecture of Neural-Fuzzy Network ,there are several neuro-fuzzy architectures one of them is Adaptive Network based Fuzzy Inference System (ANFIS) [51][52] which contains five layers where the first is responsible for assigning the input variable relative to all membership functions. The second layer calculates the precedents of the rules. The third layer settles the strengths, the fourth layer determines the results of the rules and the last layer calculates the summation of all the signals that arrive to this layer to create system output.

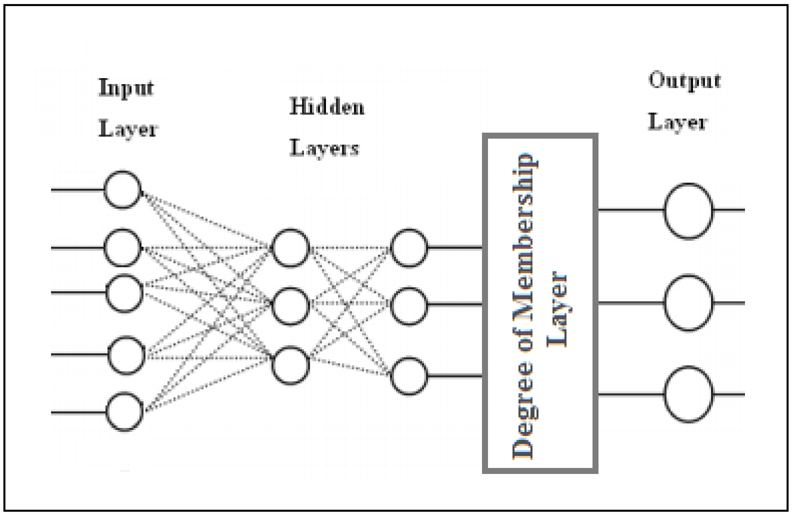


Figure 3.3: Architecture of Neural-Fuzzy Network

3.5 Mobile agents

Routing is a challenge that is strongly present in the MANET environment because MANET relies on the nodes for routing between any two nodes and therefore there are limits in the use of MANET environment resources. Despite the development of nodes technology, the challenge of routing is still in place, so there has been researches in the use of new technologies such as The mobile agent, who tries to provide a solution to the problem of routing or reduce it and researches have shown that there is a perfect performance and high for a mobile agent when working in a MANET environment [53][54].

3.5.1. Introduction of Mobile agent

The initial definition of a mobile agent is a program that executes a specific task and moves from node to node where it has autonomy and has an interactive environment, this definition shows the basic characteristics that must be available with each mobile agent and are the following [55]:

a) Mobility

The agent must be able to navigate within the network environment so that it can move from node to node with the ability to do his task in the host node.

b) Autonomous

Agents must be programmed to be independent in making decisions and have artificial intelligence to perform tasks.

c) Interactive

With the characteristics of movement and independence, the agents must interact with the environment and other agents and there is a well thought-out reaction to the changes occurring within the environment.

Figure 3.4 shows the structure of the agent where it receives a new state and compares it with the old internal state in order to create an updated new internal state. Internal state is information of routing tables in network topology.

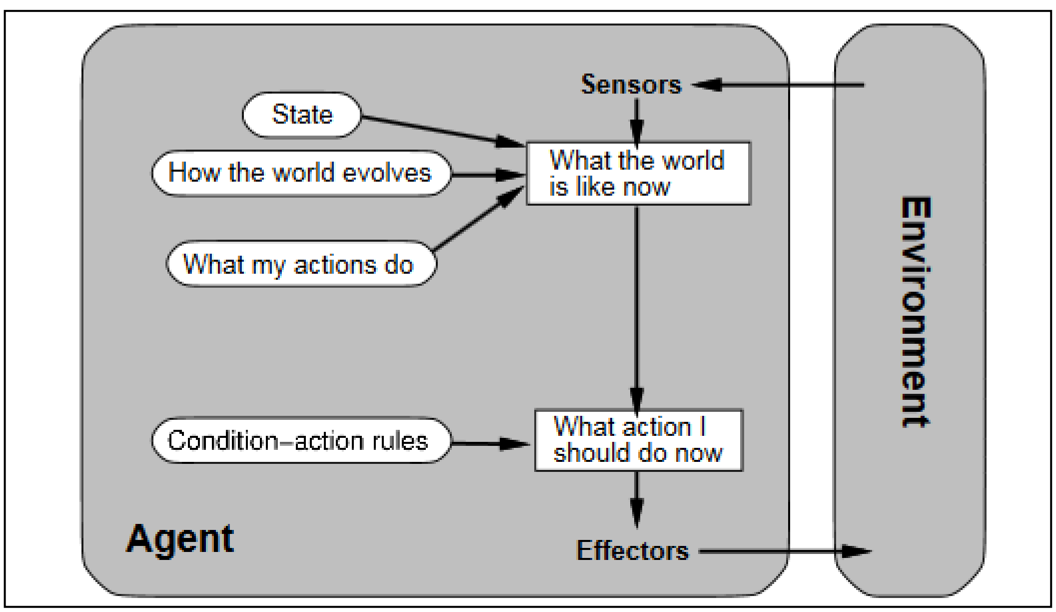


Figure 3.4 mobile agent structures [81].

In spite of the many benefits offered by agents such as reducing overhead on the network and agents work on the MANET networks of the relatively large, where the transaction of information is large, but there is the problem of security and the way to protect the network from attacks and periodic update agents and broadcast periodically to The network consumes bandwidth, so it is necessary to perform appropriate procedures to allow the use of mobile agents in MANET, In addition to the general characteristics that must be available at the agents there are additional advantages when using agents on the mobile Ad Hoc networks ,Streamline consumption is minimized and delays are minimized. Figure 3.5 shows the existence of agents within MANETs.

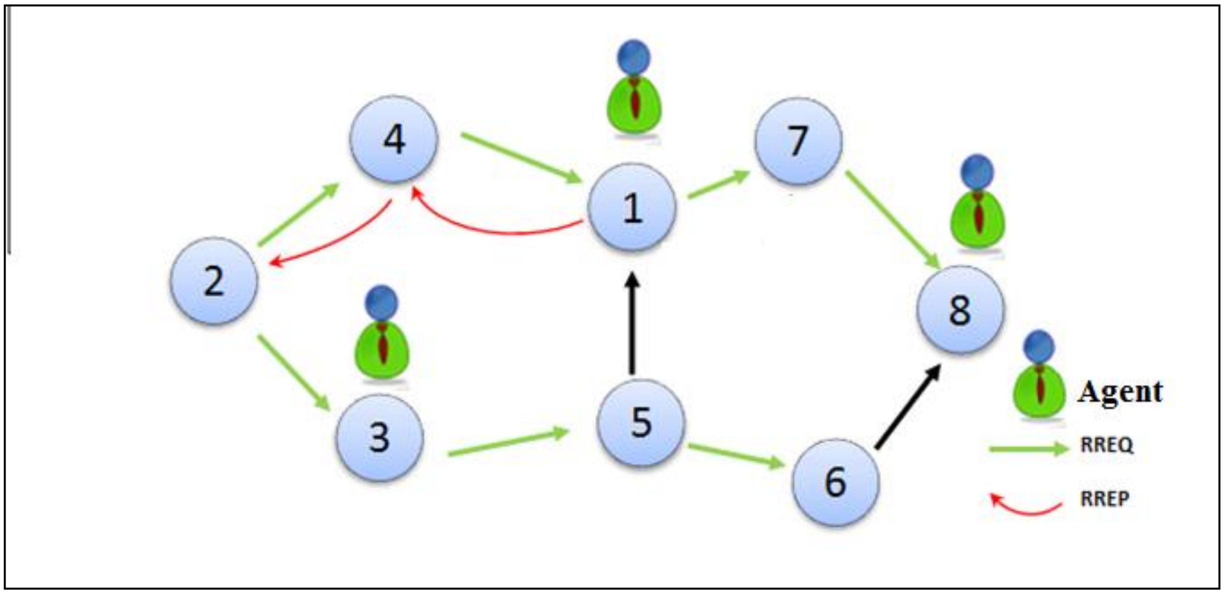


Figure 3.5 mobile agents within MANETs

3.5.2. Mobile Agents Advantages

a) Reduces bandwidth consumption, Depending on the method of communication adopted by Mobile Agent, the bandwidth is used when the transfer of mobile Agent from node to another only.

b) Increased fault tolerance, particularly in distributed systems.

c) Eligibility, because it does not cause pressure on the overhead of the network.

d) Expansion and Works with heterogeneous networks, the mobile client system is developed on the basis of independent platform (Like Java).

3.6 Summary

In this chapter we talk about artificial intelligence and the most important methods which are used and which can be used to improve the performance of MANETs. The most important features were mentioned in all approaches and areas of use of each approach. The use of artificial intelligence with routing protocols has not been discussed and left to be discussed in the coming chapters.

Chapter Four: The Proposed Protocols

4.1 Introduction

4.2 First Approach: EDYMO (ENERGY-DYMO) .

4.3 Second Approach: FDYMO (FUZZY - DYMO) .

4.4 Third Approach: NFDYMO (NEURO -FDYMO) .

4.5 Fourth Approach: Mobile Agent –DYMO (MADY).

Chapter Four

The Proposed Protocols

7.1 Introduction

MANETs are a collections of mobile Nodes that are grouped together to form network topology Without relying on a pre-configured communication infrastructure, this kind of networks can be operate in very difficult places such as disaster areas, conflict zones, war and places where people can not directly access them[5].The mobile ad-hoc networks nodes are limited by the battery power due to the fact that the nodes operate with limited energy. This affects the longevity of the nodes [10]. In order to communicate between the source node and the target node, the nodes need to use multiple hops routing, if the two nodes are not in the same range of transmission for each. Of the nature of the nodes in MANET have the possibility of mobility and access to the network and exit freely from it and with nature of mobility obviously there will be a break links between the nodes and there will be a loss of routes and change in the topology of the network. These changes cause the protocols to re-discover new paths, which ultimately affect network performance.

In this chapter, intelligent routing protocols for mobile ad-hoc networks (MANET) will be proposed. Depending on the concepts of fuzzy, neural networks and mobile agents. The goal is to get good quality service by finding the most convenient data transfer paths. Therefore a Fuzzy-based, Neural-Fuzzy based, mobile agents based and Energy aware are four approaches have been proposed to enhance Dynamic Manet On-demand (DYMO). Figure 4.1 The flowchart of the basic operations of the DYMO protocol where the route discovery is explained, where the process begins to search for a path to the destination node on the same source node, if the path is not found a request message is sent to the neighboring nodes in order to search for the destination node or path to the destination node, and the re-transmission of the request message continues until the destination node is reached, Information is added about each intermediate node that has broadcast the message. The source node is then told about the route by using a reply message and save the route to target node in its routing table and also the intermediate node save the route.

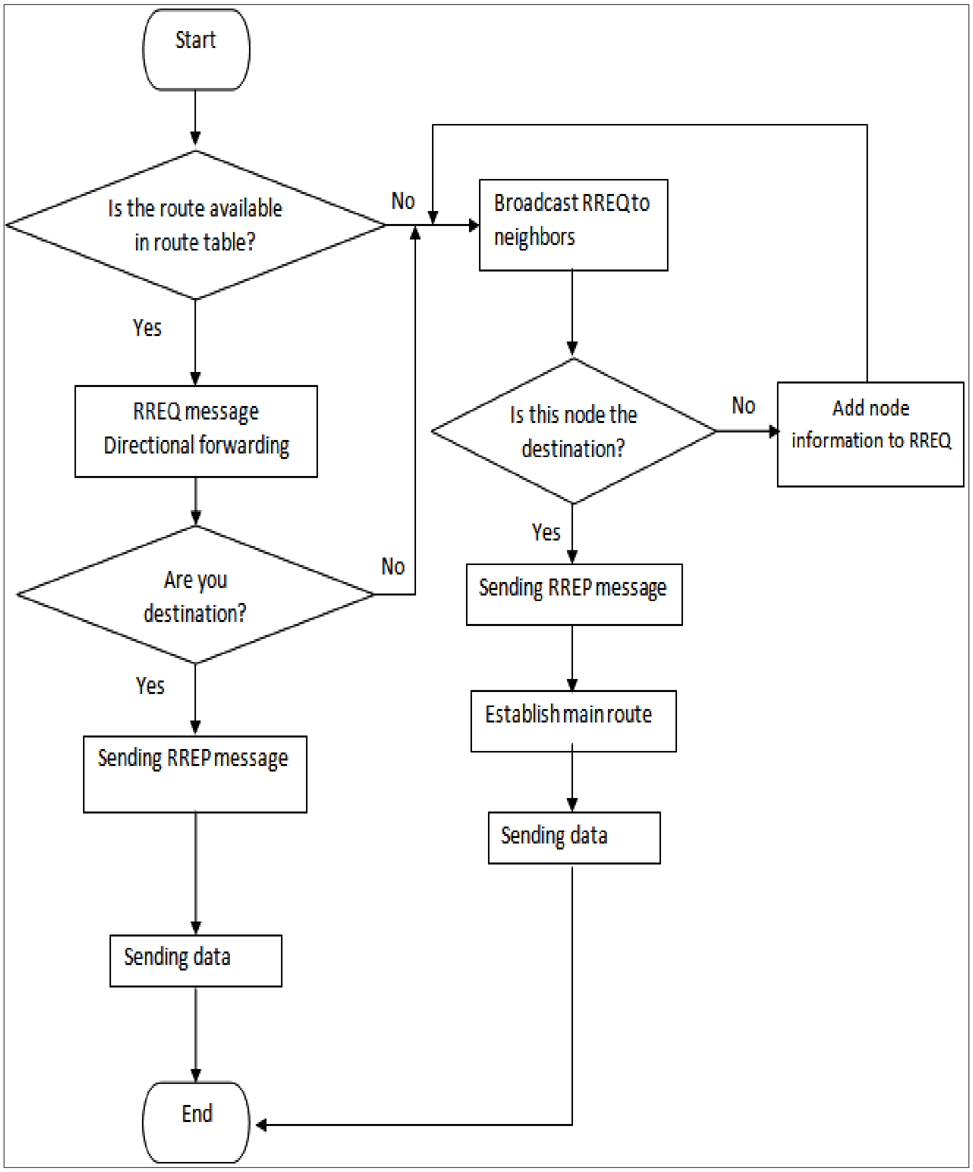


Figure 4.1: flowchart for DYMO protocol

7.2 First Approach: EDYMO (ENERGY-DYMO)

In DYMO protocol there are two processes: discovery path and the process of maintaining the path, the proposed protocol is making adjustments to the process of discovery path to improve the performance of the discovery of the path. Each node in MANET need energy to move and send data and receive information and these measures consume energy and source energy. The power sources for the nodes are batteries that are limited in capacity and difficult to replace or recharging batteries, so attention must be given to the amount of energy consumed.

EDYMO introduces two new fields in DYMO's Route messages: Energy and Total energy fields. The EDYMO routing protocol is introduced, which is modified to make the network life more efficient. In most cases, there is more than one route between the source and the distention. For each route there are a certain number of nodes (N) and each node has different values of energy. The Energy field in the RREQ is the battery energy of node, and Total energy is a summation of total power of all nodes of route as equation (4.1) shows.

$$\text{Total energy}=\sum_{n=1}^{n=N} \text{Energy}_n \qquad (4.1)$$

When the source node needs to send data, a request message is created and the node's available energy value is added to the energy field and the same value is added to the total energy field. The node then sends the request message to the neighbor's nodes that receive the request message and compare the information on the request message with the information on the routing tables for each node. If there is no route to the destination node, the information with the request message is added to the routing table such as the sequence number, the number of hops, the total energy and after the information is entered into the routing table. The intermediate node adds information about itself to the request message. These entries, such as the address of the intermediate node, adding one value to the number of hops, performing the summation of the battery power of the intermediate node with the value of total energy field, and then re-updating the total energy field with the new value. The intermediate node then broadcasts the request message again. The process of receiving the request message continues, adding one value to the number of hops, adding the power values of the intermediate nodes to the total energy values and then broadcasting until the request message reaches the destination node or to an intermediate node that has the path to the destination node. When the request message arrives at the destination, the information is compared with the routing table depending on the sequence number, the number of hops and the total energy. If the **Sequence Number** value in the request message is greater than the value in the routing table, the request message is accepted. If the **Sequence Number** value is the same as the **Sequence Number** value in the routing table, a new test is performed where the number of hops is equal to or less than the number of hops in the routing table, then the total energy that must be greater than or equal to the value in routing table if these tests pass successfully, the destination node creates a reply message and sends it to the source node. So when a destination node receives several (RREQ) s from different routes, it determine the best route depend on who has freshest route, minimum hop count and maximum total energy. Each intermediate node who receives an RREQ adds its own energy to total energy value. Figure 4.2 and Figure 4.3 are show Original Route Request (RREQ) Message Format and Routing Block (RBlock) respectively. Also figure 4.4 shows the modification to the Routing Block by adding Total energy field.

```
    0                   1                   2                   3
   0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |     Type      |          Len          |    TTL    |I|A|  Res  |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  .                         TargetAddress                         .
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |                          TargetSeqNum                         |
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  |  THopCnt  |Res|                                               .
  +-+-+-+-+-+-+-+-+                                               .
  .                                                               .
  .                    Routing Block 1 (RBlock1)                  .
  .                                                               .
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  .                                                               .
  .                    Additional Routing Blocks                  .
  .                                                               .
  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4.2: show Original Route Messages Format [80].

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                    |G|  RBPrefix   |Res| RBHopCnt  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    .                          RBNodeAddress                        .
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          RBNodeSeqNum                         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4.3: Routing Block (RBlock) Format [80].

```
0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                                    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                    |G|  RBPrefix   |Res| RBHopCnt  |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    .                          RBNodeAddress                        .
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          RBNodeSeqNum                         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                      TotalEnergy                              |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4.4: the modification Routing Block (RBlock) Format.

7.3 Second Approach: FDYMO (FUZZY - DYMO)

FDYMO introduces new field in EDYMO's Route messages: Fuzzy filed. The field value is selected by applying the fuzzy logic theory, in order to choose the most suitable path from source to destination. The advantages of using fuzzy logic to model any system are easy to understand using natural language, flexible, can use it to model nonlinear functions, and the experiences of professional experts are main part for build any system[77][78]. The basic units of a fuzzy logic controller have been explained as follows:

Fuzzication Module: convert each crisp input into a fuzzy set, for this purpose membership functions are used, it is proposed here that route metrics that are used to make a decision are total energy available in a path, and hop count. On another hand the output linguistic variable is fuzzy route. Figure 4.5 shows the membership functions of the total energy input. The total energy input consists of three membership functions that describe input values. Figure 4.6 shows the membership functions for entering the hop count.

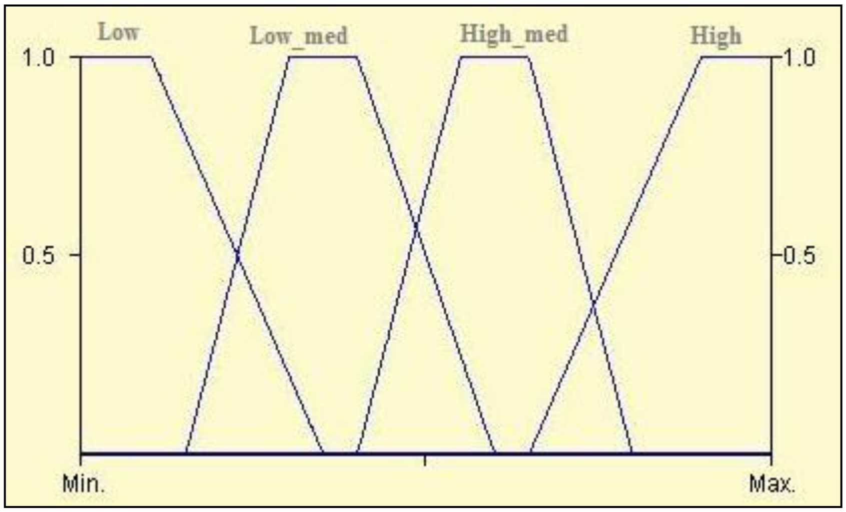


Figure 4.5: The membership functions of the total energy input.

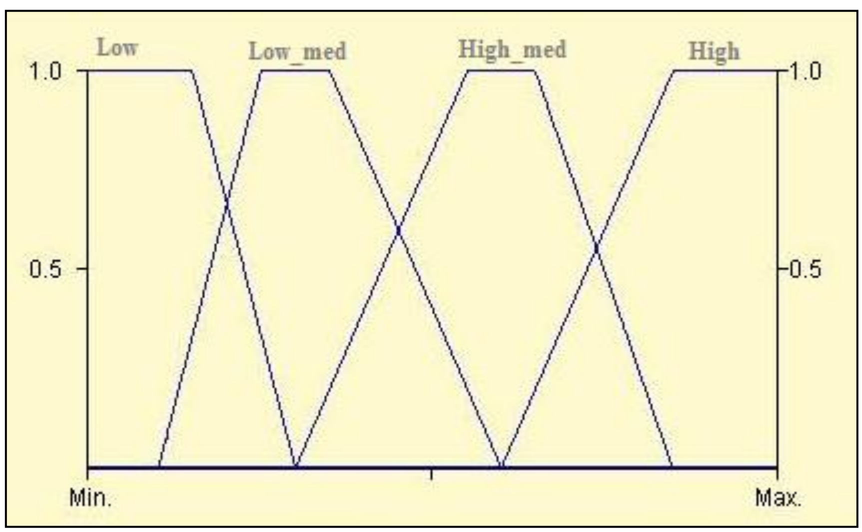


Figure 4.6: The membership functions of the hop count input.

Rule Base: this module contains rules of IF-THEN linguistic rules, Table 4.1 shows the fuzzy linguistic rules used in the FDYMO simulation. The rules were chosen based on many simulated attempts to produce the best possible result.

TABLE 4.1: The Rule Base of FDYMO

Hop Count	Energy	Optimal value
Low	Low	Low
Low	Low-med	Med
Low	High	VeryHigh
Low	High-med	VeryHigh
Low-med	Low	Low
Low-med	Low-med	Low
Low-med	High	VeryHigh
Low-med	High-med	High
High-med	Low	VeryLow
High-med	Low-med	Low
High-med	High	High
High-med	High-med	Med
High	Low	VeryLow
High	Low-med	Low
High	High	High
High	High-med	Low

Defuzzification Module: which is a module, converts fuzzy sets into a crisp set, a crisp value in accordance with its membership function and an operator set, for example, mean of maximum as equation (4.2)shows:

$$\text{MOM} = \frac{\sum_{x` \in T} x`}{T} \quad (4.2)$$

$$T = \{x \mid \mu(x`) = Support\mu(x)$$

Where T is the set of output x that has highest degree [75][76].

Figure 4.7 shows the membership functions of the end result as all the membership functions were compared in order to reach the desired result.

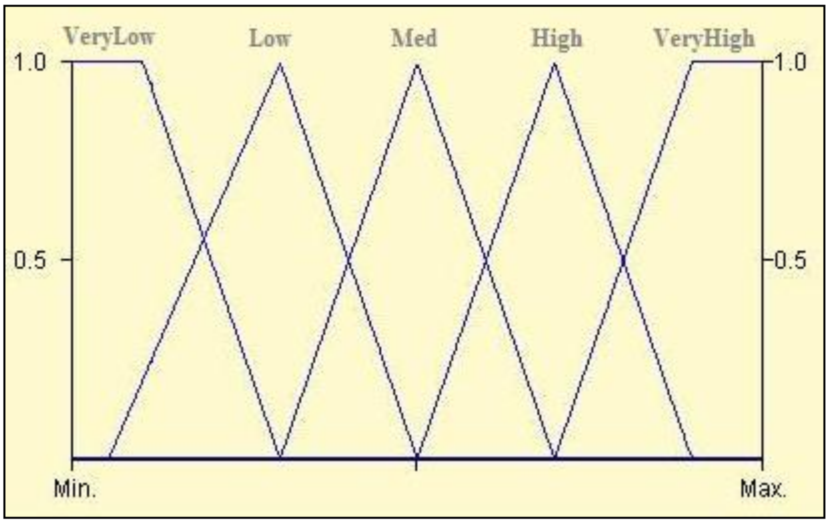


Figure 4.7 shows the membership functions of the optimal value.

7.4 Third Approach: NFDYMO (NEURO -FDYMO)

A fuzzy system with good realization is not an easy task. Since for the development of the system it is necessary to find membership functions, and the corresponding rules are often a boring process of trials. This leads to the conception of using neural networks, where the simplified mathematical model of the brain systems, that serve as a widely distributed computing network, they are not a program to perform a specific task, but they are depending on trained and learning. The utility of the neural network enables its continuous support of the fuzzy system in order to determine the required variables values. In some cases, it is difficult for the fuzzy control unit to measure the inputs in a desired way. Therefore, the neural network helps the fuzzy system to increase the performance level effectively. In this proposed protocol, the system of fuzzy logic was replaced with a system of neural networks and fuzzy logic, relying on the same entries, the number of hops and the total energy of route. In the first neural fuzzy stages, data is collected, which a sample is representing the principle and method of operation of the system to be designed.

These samples are trace routes of the mobility scenarios made by the nodes. The sample is then purified from any abnormal data, and the advantages that the proposed system will be determined so that learning is easier, after obtaining the data sample, the learning phase is initiated. The learning phase is the stage of searching for the best standards and values in order to find the desired outputs. The values of membership functions are adjusted during the learning process. NFDYMO operation can be modeled by the pseudo code in algorithm 4.1.

Algorithm 4.1: operation model to NFDYMO

```
// Method for broadcast of RREQ messages
route_discovery (Destination_node) {
// Get info from routing table (if there exists an entry)
IF (routing_entry) { SETseq_num= rt_seq_num , thopcnt= rt_hopcnt,
Energy=rt_Energy,FUZZY=rt_FUZZY }
ELSE    SET  seq_num= 0,thopcnt= 0, Energy=Local_Energy ,FUZZY=Local_FUZZY
BROADCAST  RREQ  to Neighbors }
//Method for handling RREQ messages
Receive_RREQ (RREQ, Destination_node) {
IF (Destination_node == target_node) {
IF (routing_entry) UPDATE ROUTE,Send_RREP(Source_node)
ELSE  INSERT ROUTE, Send_RREP(Source_node, RREQ) }
IF (Destination_node != target_node ){
IF (seq_num>rt_seq_num) OR ((seq_num= rt_seq_num) AND
(FUZZY>rt_FUZZY) ) UPDATE Route,
FORWARD_PATH_ACCUMULATION_RREQ }}
// Method for broadcast RREP messages
Send_RREP(Source_node, RREQ)
{SET rrep_seq_num= seq_num ,thopcnt=0
BROADCAST RREP}
// Method for handling RREP messages
Receive_RREP (RREQ ,Source_node)
{ IF (Source_node== target_node) UPDATE  Route, SEND Data
```

```
IF (Source_node!=target_node ){
IF (rrep_seq_num>rt_seq_num) OR ((rrep_seq_num= rt_seq_num) AND
(FUZZY>rt_FUZZY) ) UPDATE Route, FORWARD  RREP }}
```

7.5 Fourth Approach: Mobile Agent –DYMO (MADY)

A mobile agent is a simple and small message containing routing information about nodes that move freely between nodes in order to help get new paths available between the nodes [79]. MADY is a mobile-based DYMO routing protocol, where agents communicate indirectly to take advantage of available information. Agents update routing information and see routing information on the nodes that may have been modified by other agents. Therefore, the information can be used in order to know the paths to the nodes without the agent reaching the nodes. Figure 4.8 shows the flow chart of mobile agent process.

In MANETs nodes create a mobile agents that contains a routing information table which have fields including hop count, source node address, destination node address and sequence number, the node broadcasts the mobile agent in the network that moves freely. When an intermediate node receives the mobile agent, the data is updated according to the information that is with the mobile agent. The mobile agent adds the address of the intermediate node to it, adding one value to the number of hops on the previous nodes in the routing table, and the agent moves to a new node that updates the routing information if there is the reason for the change; the mobile agent continues to move until the expiration time expires. If the node receives the same mobile agent again there is no reason to update the information. Mobile agents are contacted indirectly through updates by each mobile agent on the nodes. If an agent reaches a node and after a period of time another agent arrives from another node, the agent knows about the updates made by the former agent.

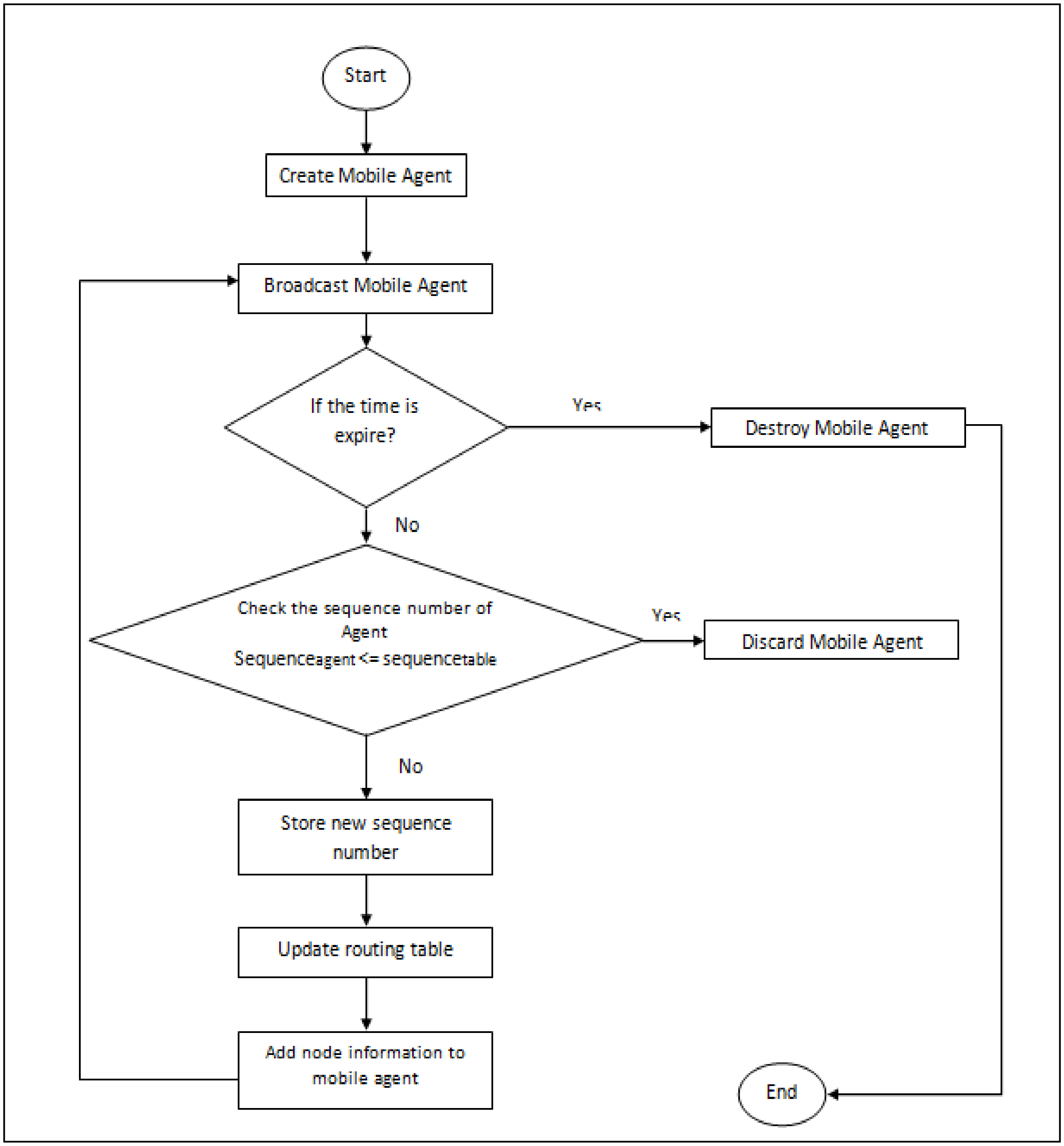


Figure 4.8: flow chart of mobile agent process

Because the size of the agent is small, it does not cause an increase in the overhead of the network and it moves automatically. The main purpose of using agents is to help finding paths between nodes. Agents can reduce the time needed to detect any path after the link is broken because the agents have additions paths for destination in routing tables of intermediate nodes.

The sequence diagram of route discovery of MADY the mobile agent is shown in figure 4.9, and Sequence Diagram of mobile agent process is shown in figure 4.10, by using the proposed approach, the route discovery was improved and the path maintenance phase was followed by the procedures followed on DYMO protocol.

As shown in Figure 4.9, Figure 4.10 the nodes begin by sending agents to the network, but the number of agents will increase the overhead. Therefore, it was suggested that a certain number of nodes responsible for creating and sending the agents according to the MAC address. Therefore the nodes that will create the agents will be chosen depending on the classification of nodes into even nodes and odd nodes during the simulation process. On the other hand, expiration time has been set for each agent, and an interval time has been proposed to re-create and send new agent. Figure 4.9 Node (N_{i+3}) wants to communicate to node (N_i) thus RREQ packet is sent to node (N_i), but the response was after two hops instead of three hops because the agent had updated the routing tables, and Intermediate node (N_{i+1}) return (RREP) packet to Node(N_{i+3}). Therefore, the time required to complete the discovery route phase of the router has become less, allowing the bandwidth to increase and allow the early start of data transmission between the two nodes.

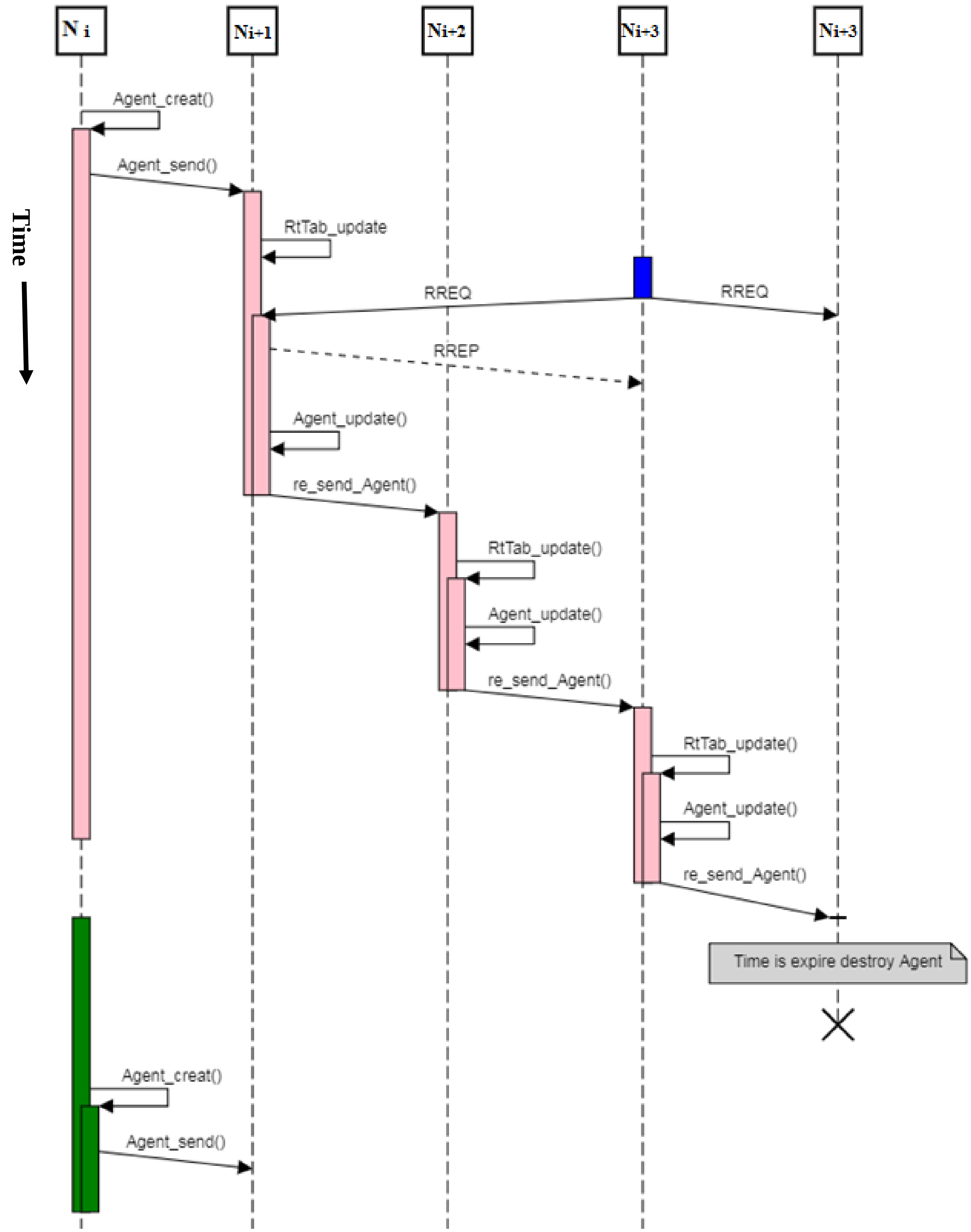


Figure 4.9: Sequence Diagram of Route discovery of MADY

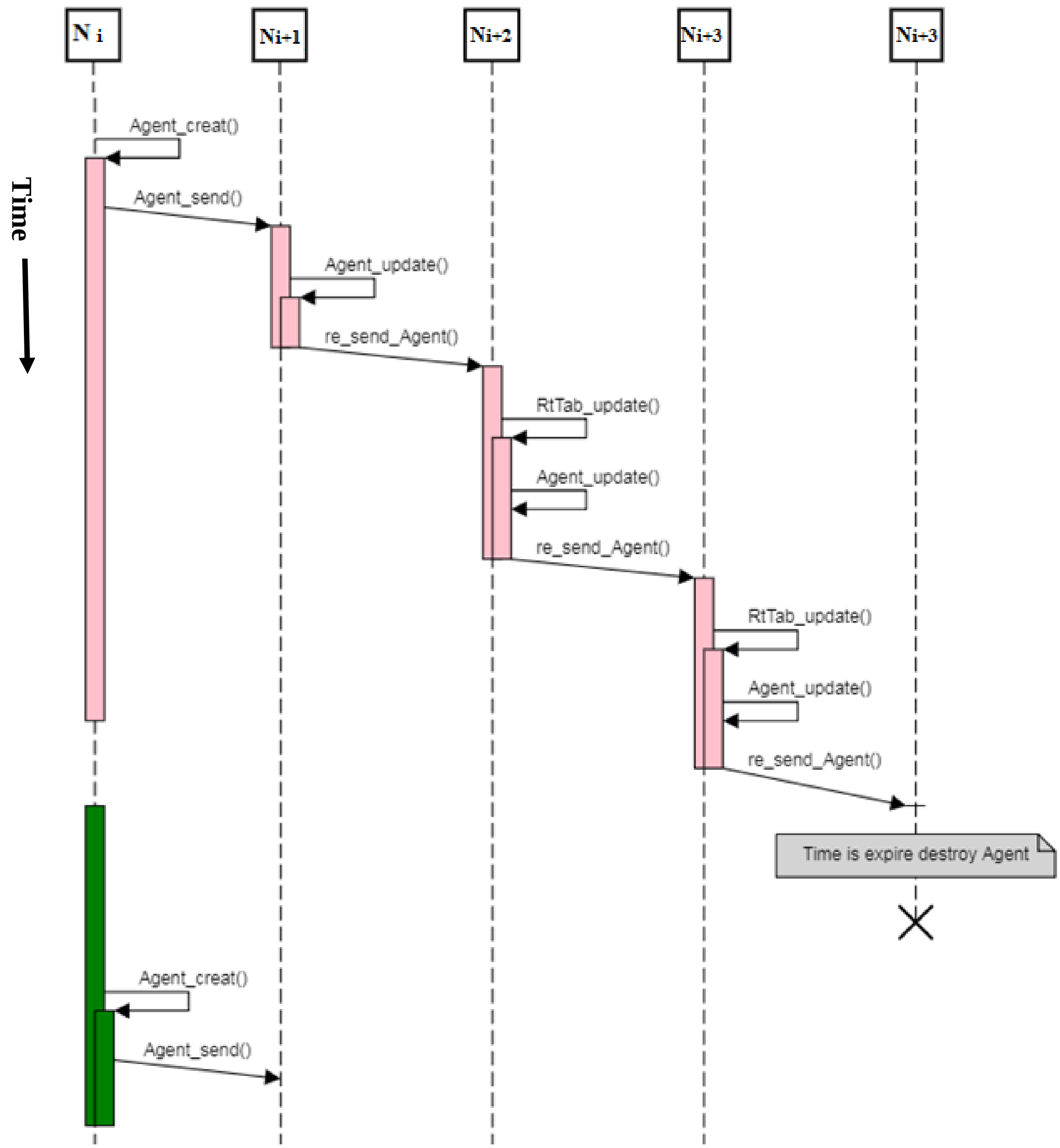


Figure 4.10: Sequence Diagram of Mobile Agent process

Chapter Five: Simulation and Results

Chapter Five

Simulation and Results

5.1 Introduction

This chapter will present simulations conducted to test the proposed approaches, along with a good comparison of the proposed approaches and the DYMO protocol in terms of performance indicators. There are different types of programs that specialize in network simulation such as wired and wireless networks and ad hoc networks. Simulation tools provide the opportunity to test, develop and improve routing protocols. Examples of these platforms are NS-2, NS-3, OPNET++, and Qualnet. There are also software tools for designing mobility scenarios, such as Bonnmotion, where the most important simulation elements in MANETs are the mobility of nodes. There are also software tools for designing a fuzzy logic system such as Matlab fuzzy logic toolbox[57], JfuzzyQT[57], XFuzzy3[58] and others[59][60]

A simplified explanation of each tool used in this thesis will be provided.

5.1.1. Simulation Tool : NS-2

Ns2 is commonly used in simulations of the MANETs. They use two programming languages to apply simulations, one to write code that is in the background where C ++ is used, and the second language is used forward with users, called the object-oriented tool command language tool (OTCL). [61] As the Ns-2 is an open-source discrete event-driven simulator. It was also explained that two languages used in the simulation, one language used for coding, and the other language is used for working with the tool environment. These two languages are associated with the use of TclCL. Figure 5.1 shows the structure used in the NS-2 simulation tool.

As shown in the form from the north to the right, the script is written using OCTL and then the file is saved on extension (.tcl) and the file is run using ns2 shell executable command ns.

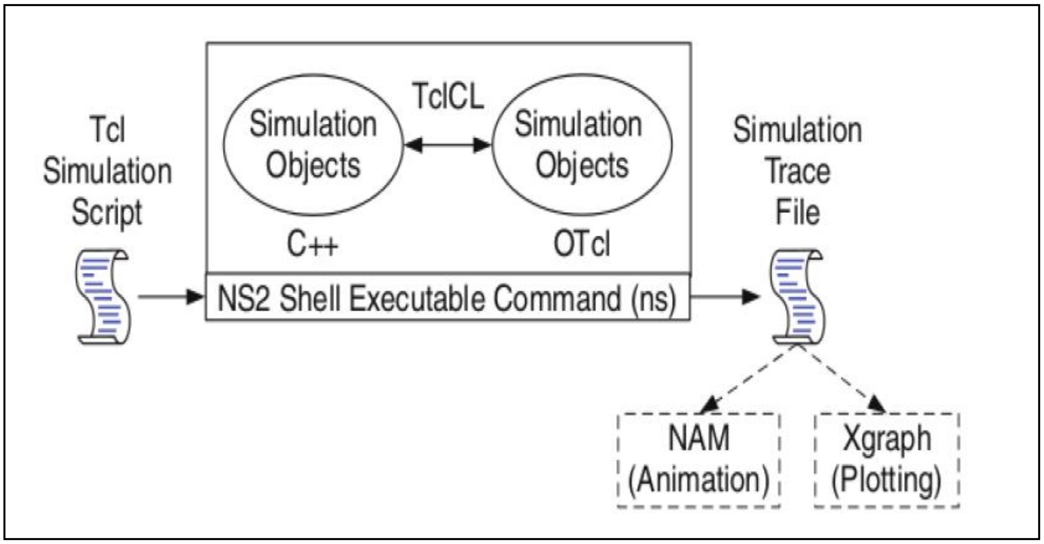


Figure 5.1 shows the structure used in the NS-2[62]

At this stage there is a threading process between the two languages in order to output two files, one of the two files is called trace file and the other file is called network animator. Trace file is rows of information that can be used to know the performance of a network, Perl files, and AWK files are used to extract the appropriate information for each network performance such as stats about the status of packets, delays and other performance aspects and network animator file it is used with a software tool to show an animation for network such as the NAM.

5.1.2. BonnMotion[63]

A software tool has been written on the basis of the Java language is the function of generating scenarios for mobility and analysis of mobility scenarios, where the use of the script file in many simulation tools and there are a lot of institutes and institutions that develop this software and take advantage of the outputs provided by the software has A list of models for mobility as shown below:

- The Random Street model.

- The Random Waypoint model.
- The Random Walk model.
- The Reference Point Group Mobility model.
- The Gauss-Markov model.
- The Manhattan Grid model.
- The Disaster Area model.

5.1.3. Xfuzzy3[64]

Xfuzzy 3.0 is a fully programmable environment based on Java and is therefore available to run on any platform. The program develops systems that use fuzzy logic inference. It is divided into several tools covering all phases of the fuzzy system design from the first description phase until the implementation phase Its primary function is to be able to develop complex systems flexibly and allow users to expand the range of features available.

In the description phase, the user defines the fuzzy system and in the verification phase, the simulation and monitoring are performed in the verification phase, learning algorithms are implemented and there is a synthesis phase in order to convert the system into programming languages in order to be implemented in different systems. The relationship between all these phases is the use of a common specification language, XFL3.

5.2 Simulation and Network Environment

Simulation was performed using the ns-2 simulator under the Ubuntu Linux operating system. The DYMO protocol files have been modified to suit each proposed approach and new files have been added to DYMO as well. All scenarios were applied to an area simulating 5000 mx1000 m based on Table 5.1 where Mobility model is Random way point and simulation time 900s.

One node was selected as a source node and one node as a destination node throughout the simulation period without changing the selected nodes.

The simulation was applied to each proposed approach, relying on maintaining the number of nodes without change and changing the speeds from 10 m/s, 15 m/s, 20 m/s, 25 m/s and 30 m/s, the simulation was performed when the number of nodes was 50, and when the number of nodes was 100.

TABLE 5.1: Simulation Parameters

Parameters	values
Simulation time	900s
Channel type	Wireless channel
Mobility model	Random way point
Type of antenna	Omni directional
Topology area	5000m x 1000m
Number of Nodes	20,30,50,100
Speed	10 to 30 m/s
Routing protocol	DYMO,EDYMO,FDYMO,NFDYMO,MADY
Traffic type	CBR
Initial energy	10J

5.3 Performance metrics

In this simulation, three performance measures were used to test the performance of the proposed approaches by averaging all cases for each scenario where AWK files were used to calculate performance metrics.

a) **Packet Delivery Ratio (PDR):** is the ratio of the number of packets received in the receiver and the number of packets sent from the origin.
b) **End to End Delay**: Is the average time of delivery of data packets to the delivery to the destination, which includes all delays.
c) **Throughput:** Is the average number of bits delivered per second, or the amount of data per unit of time delivered successfully.

5.4 Simulation Results

The simulation results were obtained in accordance with the trace files obtained using 42 scenarios.

The results of the performance metrics are the average performance metrics for all scenarios, so that performance metric is measured for each scenario, and then an average of all performance metrics for all scenarios. Use AWK files to sort and extract results as shown below:

5.4.1. Results of performance metrics at 50 Nodes

Throughput in different speeds are shown in Table5.2, Figure5.3 shows the throughput of DYMO, EDYMO, FDYMO, and NFDYMO where the throughput of NFDYMO is the best at low speed, EDYMO and FDYMO are better than DYMO.

Table5.2: Throughput [Kbps] at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	3.514	3.186s	3.946	3.002	1.994	3.612
EDYMO	3.736	3.25	3.82	2.812	1.852	3.484
FDYMO	3.652	3.202	3.724	2.948	1.682	3.374
NFDYMO	3.742	3.222	3.842	3	1.82	3.5

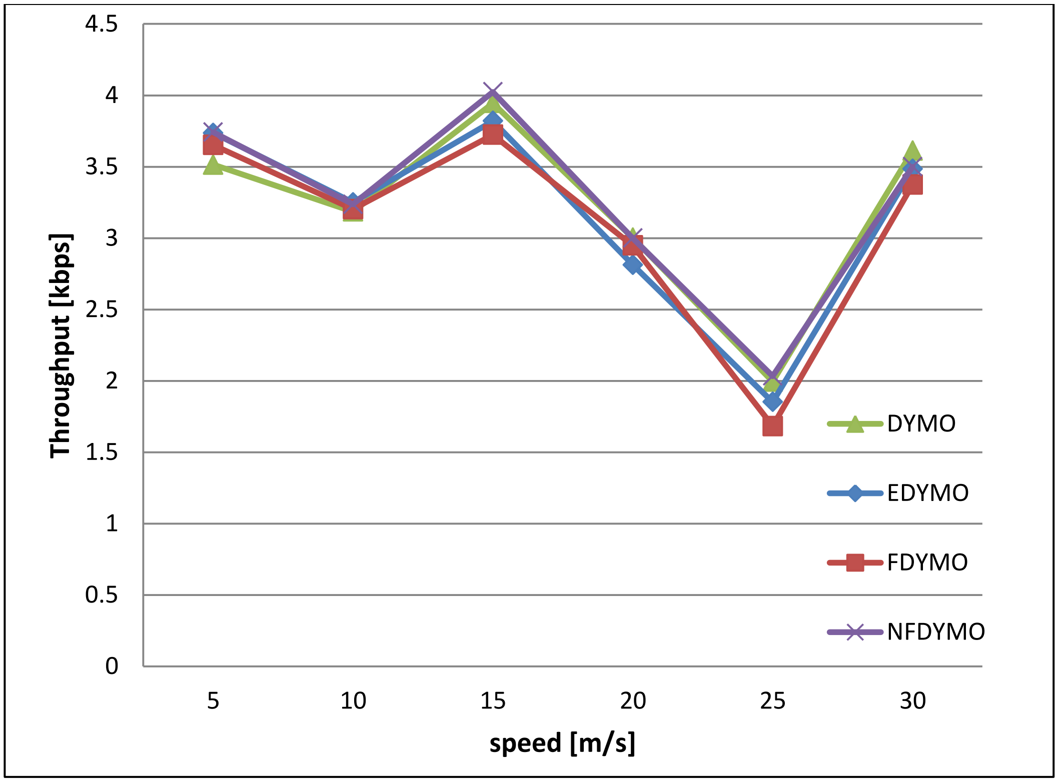


Figure.5.3: Throughput in different speeds

Packet delivery ratios at different speeds are shown in Table5.3. Figure.5.4 shows the Packet delivery ratio of all proposed models where (NFDYMO) is more efficient than conventional routing protocol, at 5, 10, and 15 mps speeds EDYMO and FDYMO are better than DYMO.

Table5.3, Packet Delivery ratio at different speeds

protocol	Speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	16.692	14.606	15.55	13.04	7.658	13.858
EDYMO	16.98	14.64	16.276	13.246	8.326	14.396
FDYMO	16.692	14.606	15.55	13.04	7.658	13.856
NFDYMO	16.98	14.64	16.276	13.246	8.326	14.396

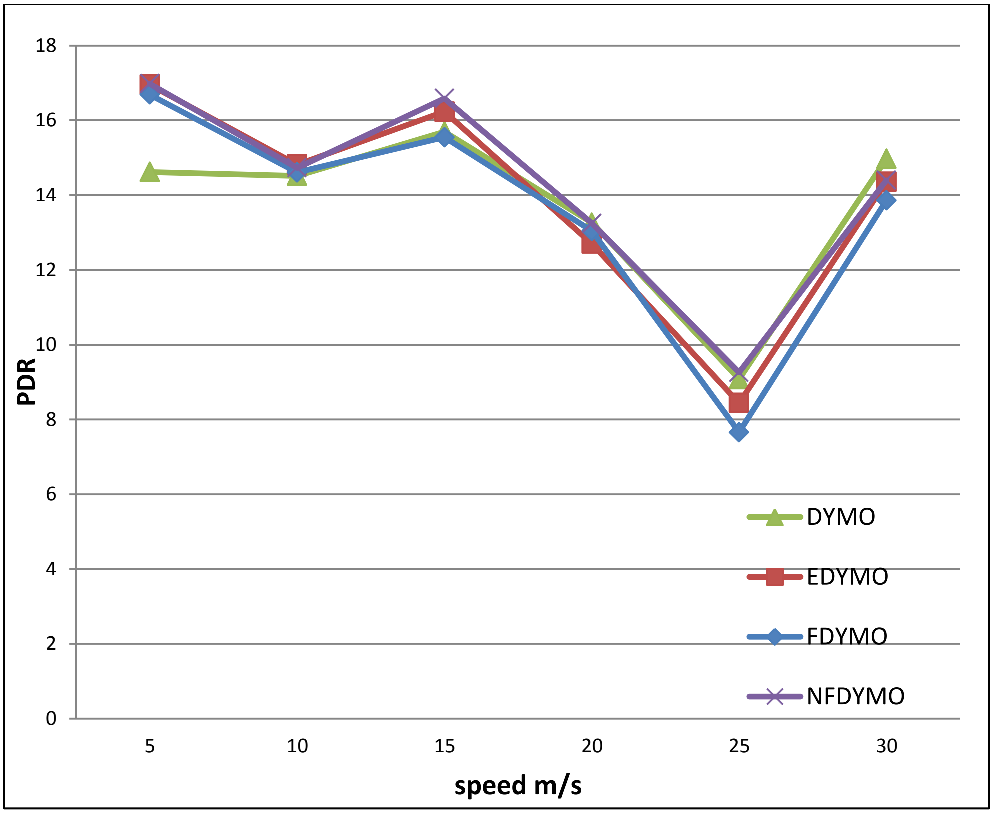


Figure.5.4: Packet Delivery ratio for 50 Nodes at different speeds

End to end delay of DYMO, EDYMO, FDYMO, and NFDYMO at different speeds are shown in Table 5.4, and Figure6.5 at 15, 25 and 30 mps speeds, FDYMO is better than DYMO, EDYMO

Table5.4: End to End Delay [ms] at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	122.1793	282.141	409.27	610.7	721	720.13
EDYMO	227.59	398.05	460.42	683.9	522.5	789
FDYMO	192.75	396.71	363.29	597.83	397.66	692.01
NFDYMO	278.35	304.24	387.411	650.84	610.4	818.03

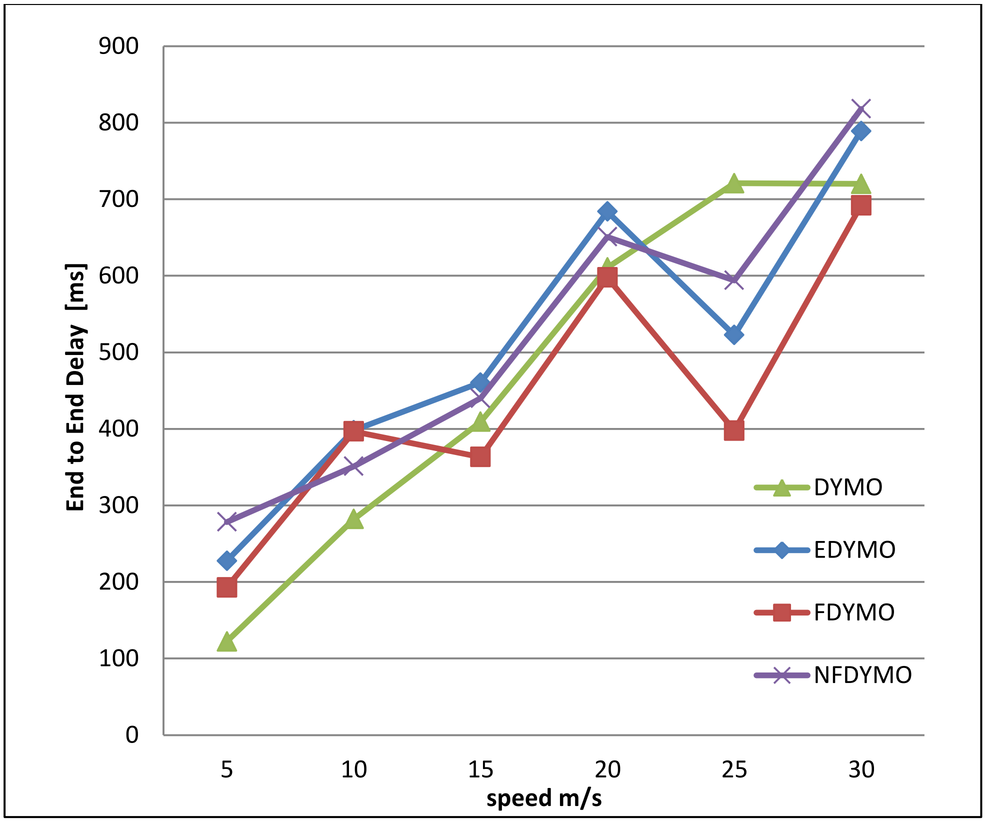


Figure5.5: End to End Delay at different speeds

5.4.2. Results of performance metrics at 100 Nodes

Throughputs at different speeds are shown in Table6.5. Packet delivery ratios at different speeds are shown in Table5.6, and end to end delay in different speeds are shown in Table 5.7. On Figure.6.6 NFDYMO throughput is increased, when number of nodes increased also that happened to all protocols, and NFDYMO has the best throughput, on another hand EDYMO and FDYMO are better than DYMO at 5, 10, and 15mps, Figure.6.7shows the packet delivery ratio of all proposed models where EDYMO is better than DYMO and FDYMO at 15 mps

Table5.5:Throughput[Kbps] at different speeds

protocol	Speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	5.55	9.014	10.096	7.934	4.036	8.206
EDYMO	6.226	9.256	10.77	7.114	3.718	8.64
FDYMO	5.858	8.916	10.206	6.534	3.522	7.14
NFDYMO	5.536	8.706	9.232	6.314	3.692	8.676

Table5.6: Packet Delivery ratio at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	26.682	43.35	48.516	38.174	19.414	39.438
EDYMO	26.99	44.50	51.848	33.852	17.884	40.74
FDYMO	25.728	42.89	45.552	31.418	16.8	34.346
NFDYMO	26.61	41.86	44.352	30.364	17.744	41.548

Figure.5.7 shows the packet delivery ratio of all proposed models where EDYMO and NFDYMO are better than DYMO and FDYMO at 15 mps,

For all proposed approaches their behavior takes the same direction as the speed increases and there is a shortcoming with the proposed approach (FDYMO) with increased speed.

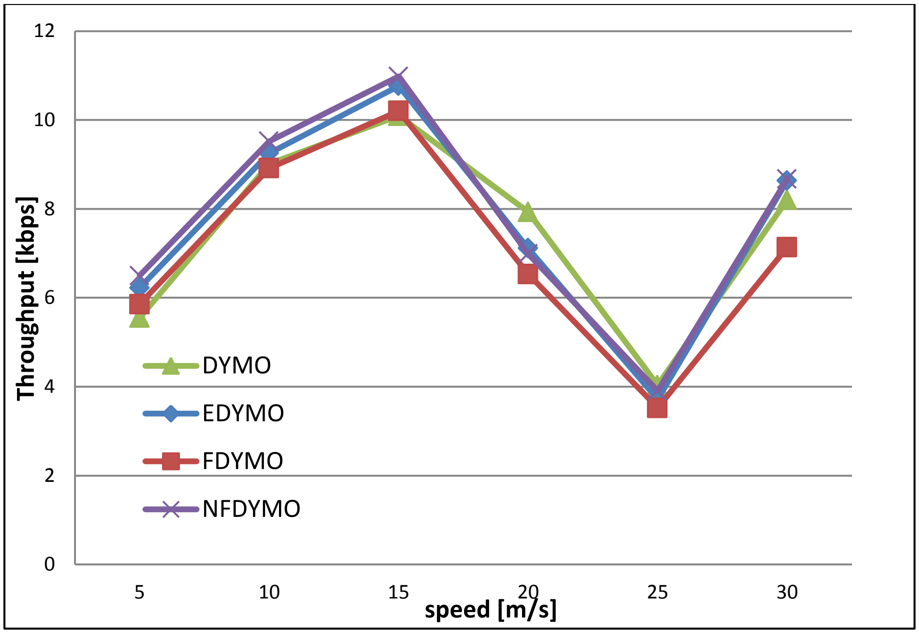


Figure5.6: Throughput at different speeds

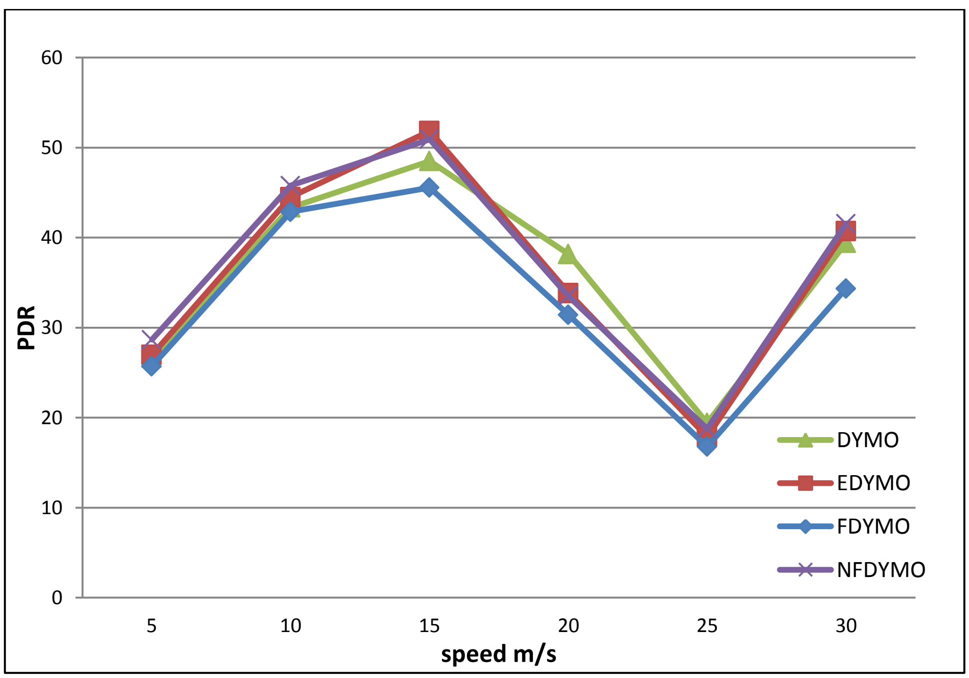


Figure.5.7: Packet Delivery ratio at different speeds

On Figure 5.8 EDYMO and FDYMO is better than DYMO at 5, and 30 mps speeds, on another hand NFDYMO remains almost similar to DYMO effectiveness on both cases.

Table5.7: End to End Delay [ms] at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	505.837	243.6986	467.8	718.00	751.8	626.43
EDYMO	357.29	437.64	582.93	791.9	779.21	600.73
FDYMO	406.319	437.50	549.411	814.533	813.40	549.64
NFDYMO	380.02	271.04	563.69	694.54	809.20	605.241

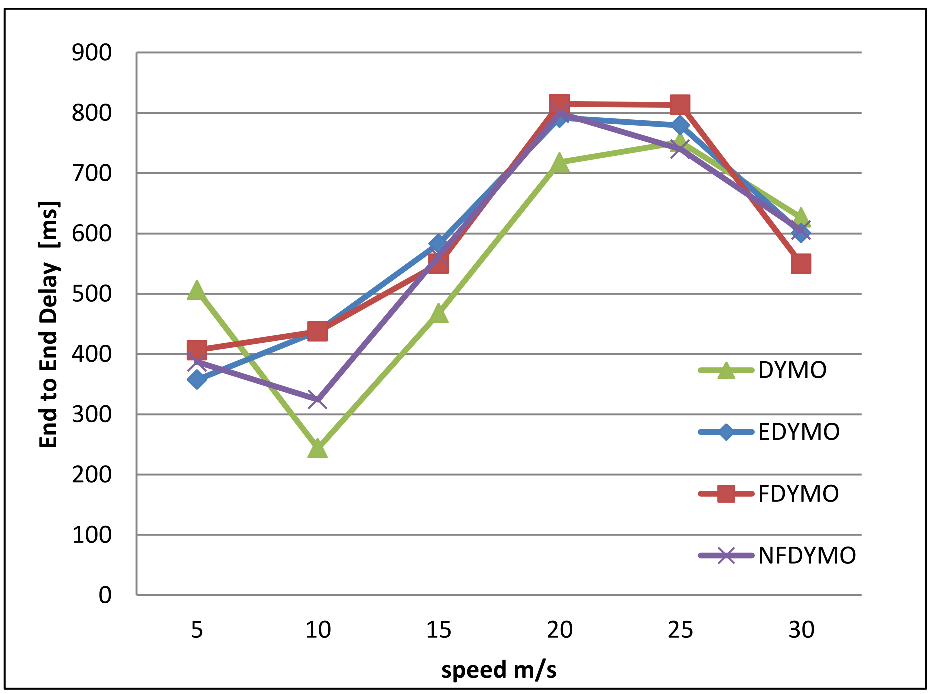


Figure.5.8: End to End Delay at different speeds

5.4.3. Results of performance metrics at 50 Nodes MADY

From a clearer point of view, MADY was compared with DYMO and with EDYMO and NFDYMO the throughput at different speeds are shown in Table5.8. Packet delivery ratios at different speeds are shown in Table5.9. End to end delay in different speeds are shown in Table 5.10.

Figure 5.9 illustrates throughput proposed approaches with a clearly showing that the MADY has outperformed its performance on all approaches and on DYMO.

Table5.8: Throughput [Kbps] at different speeds

protocol	Speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	3.514	3.186s	3.946	3.002	1.994	3.612
EDYMO	3.736	3.25	3.82	2.812	1.852	3.484
NFDYMO	3.742	3.222	3.842	3	1.82	3.5
MADY	3.586	4.124	5.186	3.498	2.3	4.67

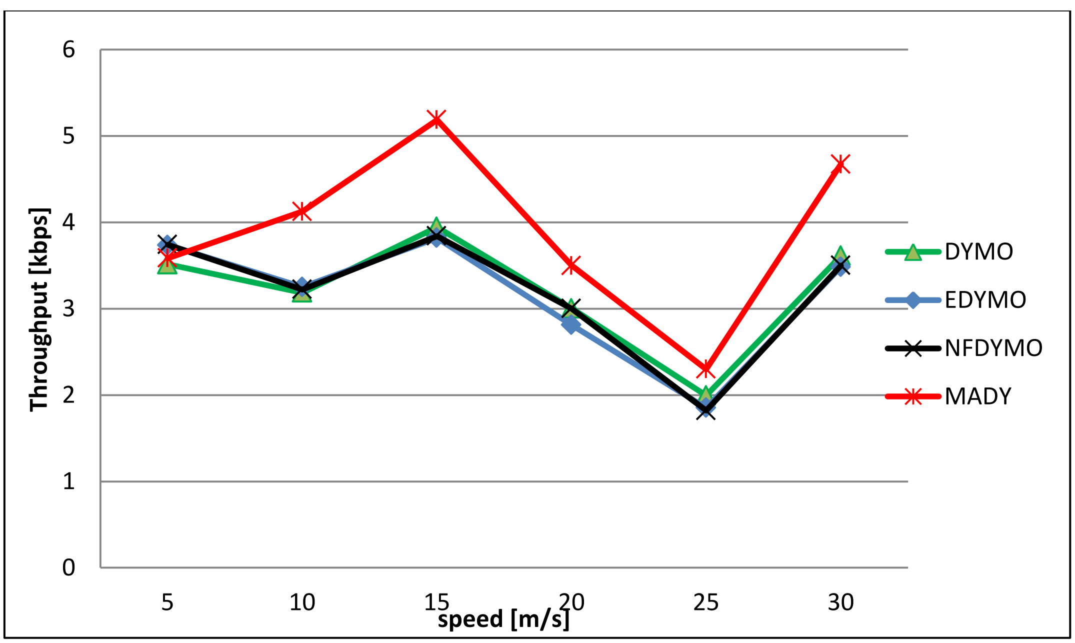


Figure5.9: Throughput at different speeds

The MADY packet delivery ratio in Figure 5.10 appears to be high compared to other suggested approaches with increased speed, especially at 15 and 30 speed.

Table5.9: Packet Delivery ratio at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	16.692	14.606	15.55	13.04	7.658	13.858
EDYMO	16.98	14.64	16.276	13.246	8.326	14.396
NFDYMO	16.98	14.64	16.276	13.246	8.326	14.396
MADY	16.5	19.208	21.088	16.182	10.96	22.49

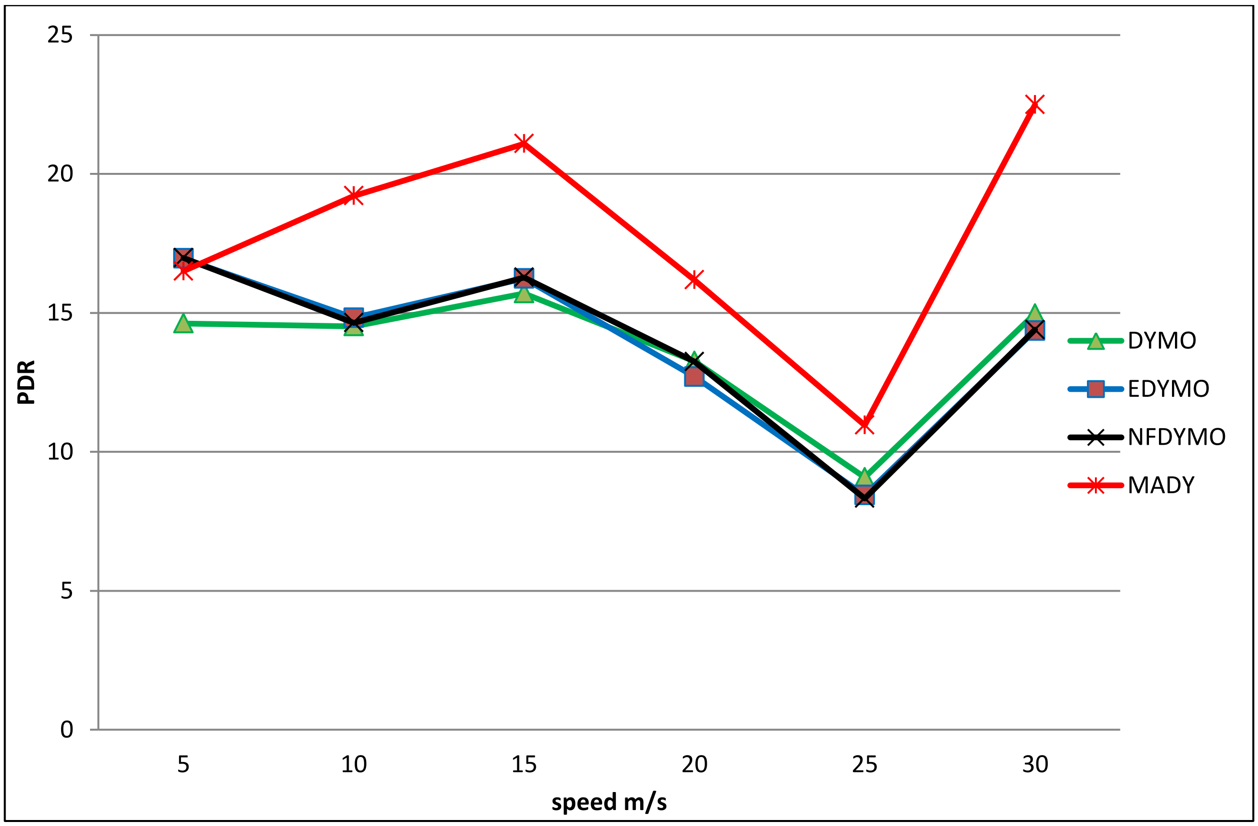


Figure.5.10: Packet Delivery ratio at different speeds

Despite the progress that has appeared with the proposed approach (material) in Figure.5.9 and Figure.5. 10. However, this showed an increase in delays in the network and was the best case when the speed of the nodes was 5 m / s and 15 m / s as shown in Figure 5.11

Table5.10: End to End Delay [ms] at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	122.1793	282.141	409.27	610.7	721	720.13
EDYMO	227.59	398.05	460.42	683.9	522.5	789
NFDYMO	278.35	304.24	387.411	650.84	610.4	818.03
MADY	550.16	1168.63	711.259	1196.477	1201.95	1393.411

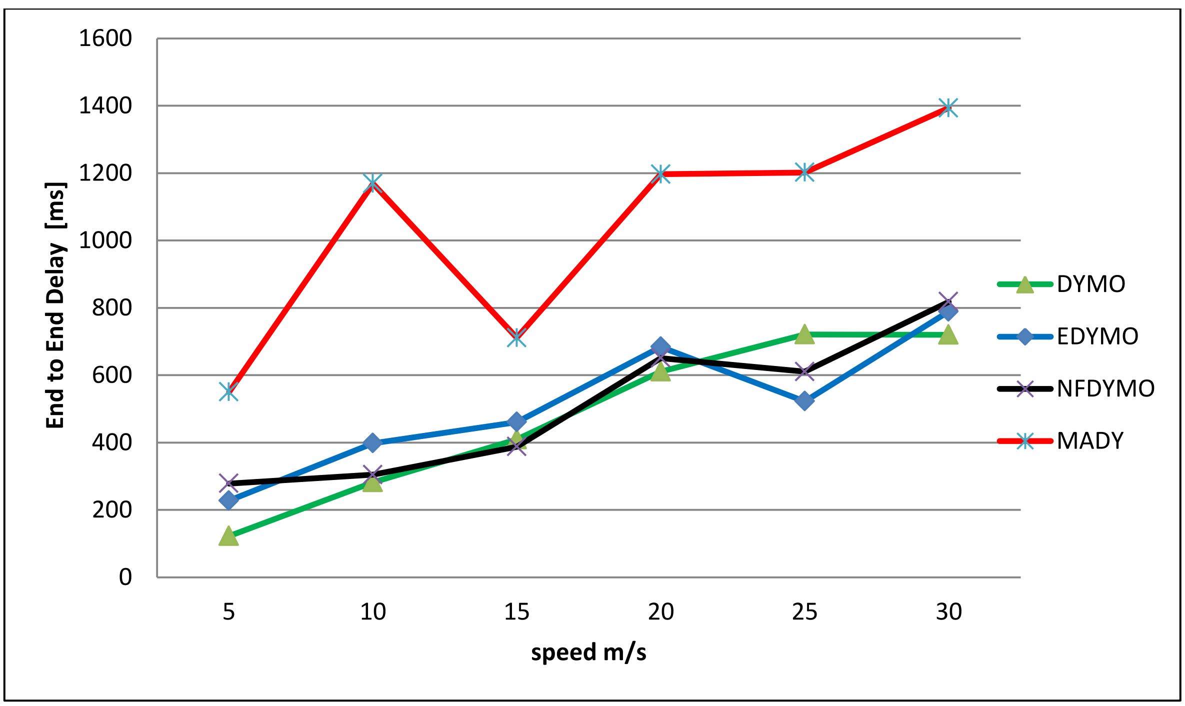


Figure.5.11: End to End Delay at different speeds

5.4.4. Results of performance metrics at 100 Nodes MADY

Throughputs in different speeds are shown in Table5.12. Packet delivery ratios at different speeds are shown in Table5.13. End to end delay in different speeds are shown in Table 5.14.

Table 5.12: Throughput [Kbps] at different speeds

protocol	Speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	**5.55**	**9.014**	**10.096**	**7.934**	**4.036**	**8.206**
EDYMO	**6.226**	**9.256**	**10.77**	**7.114**	**3.718**	**8.64**
FDYMO	**5.858**	**8.916**	**10.206**	**6.534**	**3.522**	**7.14**
NFDYMO	**5.536**	**8.706**	**9.232**	**6.314**	**3.692**	**8.676**
MADY	**7.378**	**12.656**	**10.852**	**7.794**	**5.372**	**11.28**

Figure 5.12 shows that (MADY) succeeded in exceeding the protocols at most speeds and equal (EDYMO) and (DAYMO) at a speed of 15 m / s and 20 m / s, respectively.

Table 5.13: Packet Delivery ratio at different speeds

protocol	speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	26.682	43.35	48.516	38.174	19.414	39.438
EDYMO	26.99	44.50	51.848	33.852	17.884	40.74
NFDYMO	26.61	41.86	44.352	30.364	17.744	41.548
MADY	30.69	52.42	52.174	37.354	19.976	54.198

Figure5.12: Throughput at different speeds

The packet delivery ratio is shown in Figure5. 13. When the number of nodes is large in the case of using MADY, there is a noticeable improvement in network performance.

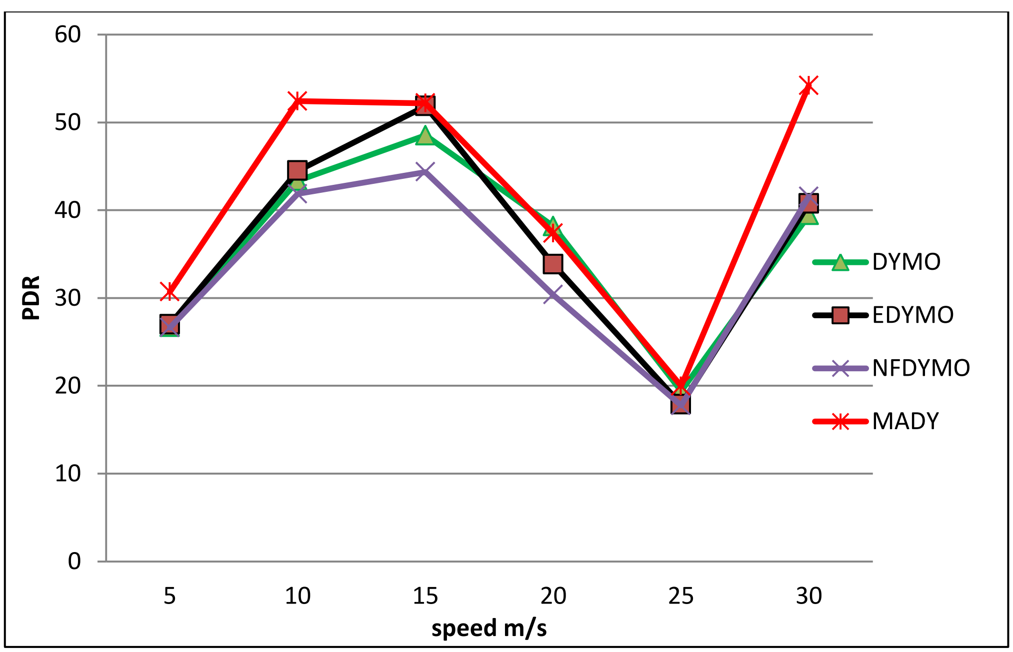


Figure.5.13: Packet Delivery ratio at different speeds

There is a significant improvement in the delay time of the proposed approach (MADY), since the delay is close to the protocol readings (DYMO), in addition to this, there was an improvement in the delay time with increasing speed, as shown at a speed of 20 m / s to 30 m / s, Figure 5.13 illustrates the end to end delay when the number of nodes is 100.

Table5.14: End to End Delay [ms] at different speeds

protocol	Speed					
	5 m/s	**10 m/s**	**15 m/s**	**20 m/s**	**25 m/s**	**30 m/s**
DYMO	505.837	243.6986	467.8	718.00	751.8	626.43
EDYMO	357.29	437.64	582.93	791.9	779.21	600.73
NFDYMO	380.02	271.04	563.69	694.54	809.20	605.241
MADY	702.32	460.15	561.92	841.015	665.76	511.12

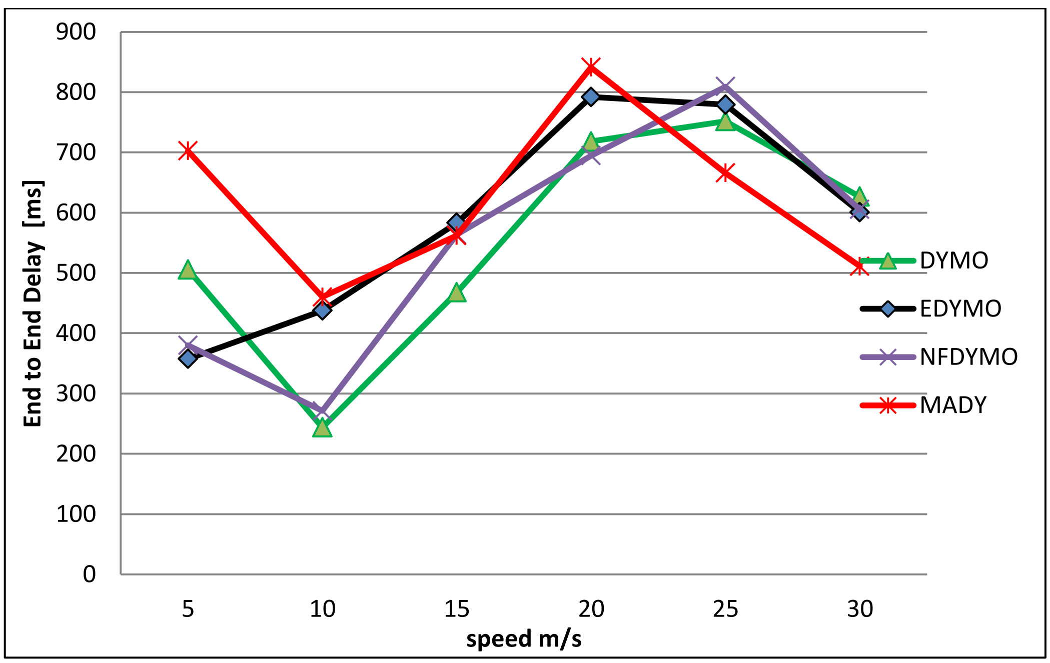


Figure.5.14: End to End Delay at different speeds

5.4.5. Results of performance metrics at 50 Nodes When Topology area is 1000 by 1000.

New scenarios were released on an area of 1000 square meters, which means that there is a new random distribution of nodes that can affect different results if they are compared with previous scenarios. Table 5.15, Table 5.16, and Table 5.17 are showing the values of performance metrics.

Figure 5.15 shows that MADY succeeded in exceeding the protocols at most speeds and all other approaches are very close to each other.

Table 5.15: Throughput [Kbps] at different speeds when area 1000m^2

Speed	Protocol				
	DYMO	EDYMO	FDYMO	NFDYMO	MADY
5 m/s	3.3203125	3.384313	3.336313	3.356313	4.258313
10 m/s	2.44140625	2.315406	2.219406	2.337406	3.681406
15 m/s	1.5625	1.3725	1.5085	1.5605	2.0585
20 m/s	1.513671875	1.371672	1.201672	1.339672	1.819672
25 m/s	1.455078125	1.327078	1.217078	1.343078	2.517078
30 m/s	0.87890625	1.100906	1.016906	1.106906	0.950906

Table 5.16: Packet Delivery ratio at different speeds when area 1000m^2

Speed	Protocol				
	DYMO	EDYMO	FDYMO	NFDYMO	MADY
5 m/s	70	70.3	70.088	70.122	74.69
10 m/s	72	72.536	71.852	72.578	77.39
15 m/s	72.2	71.638	71.976	72.182	75.118
20 m/s	68.2	67.562	66.778	67.446	70.08
25 m/s	65	64.388	63.886	64.426	72.52
30 m/s	58	60.334	60.072	60.36	59.88

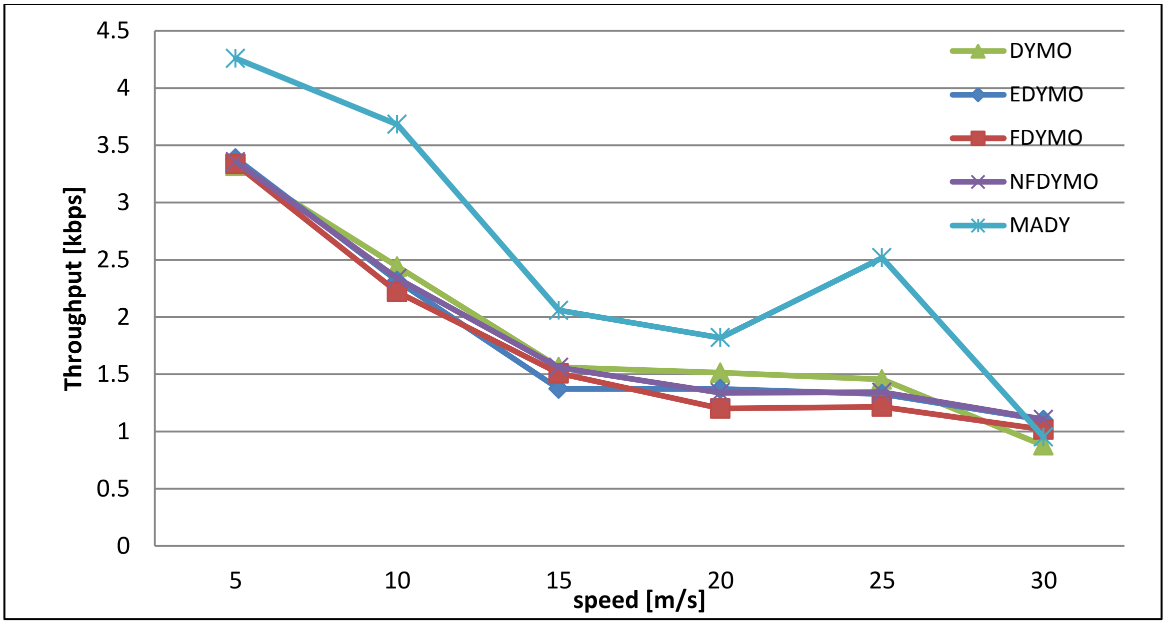


Figure5.15: Throughput at different speeds at area1000m^2

Table5.17: End to End Delay [ms] at different speeds when area 1000m^2

Speed	Protocol				
	DYMO	EDYMO	FDYMO	NFDYMO	MADY
5 m/s	230	345.9145	344.5765	252.1003	1116.491
10 m/s	170	221.1558	124.013	148.139	471.9864
15 m/s	150	223.2044	137.1446	190.1558	735.786
20 m/s	240	41.5022	83.34134	296.0697	887.6319
25 m/s	300	368.8224	271.9346	397.903	973.2782
30 m/s	310	415.4107	380.5731	466.1735	737.9901

The packet delivery ratio is shown in Figure5. 16. When the speeds of nodes are slow in the case of using MADY, there is a noticeable improvement in network performance. On other hand DYMO and other approaches are close to each other.

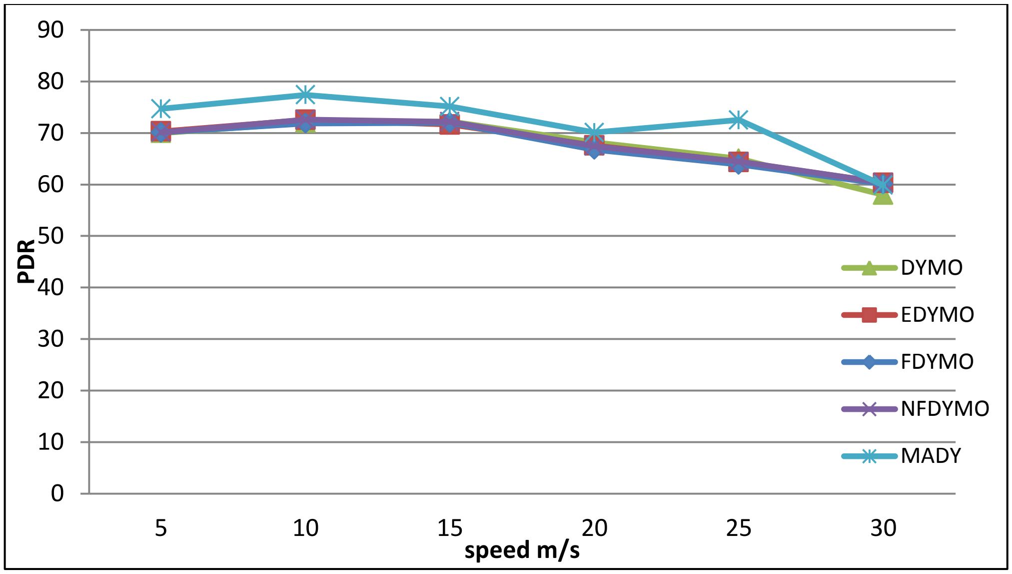


Figure 5.16: Packet Delivery ratio at different speeds at area1000m^2

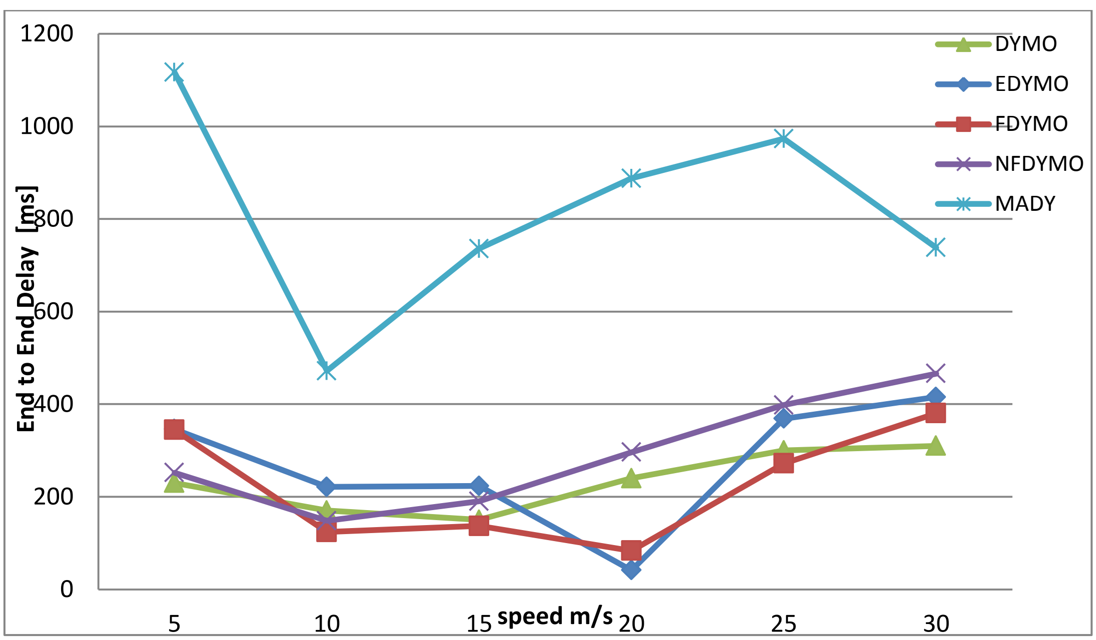


Figure.5.17: End to End Delay [ms] at different speeds at area1000m^2

End to End Delay is shown in Figure5. 17. EDYMO and FDYMO have best delay at 20 m/s, NFDYMO is very close to DYMO, but when the nodes speeds have increased, NFDYMO has become worse, but MADY has the worst behavior since it has a significant delay, but the delay is reduced as nodes speeds increase.

5.5 Summary

In this chapter, four proposed approaches were designed to improve the performance of the DYMO protocol and the performance metrics were applied to ensure that the proposed approaches are improving the performance of MANETs were clearly implemented.

Based on the trace files, it was concluded that the proposed approaches showed an improvement in performance of MANETs where it emerged that the end to end delay became better, especially with the increase in the number of nodes, and throughput increased and the packet delivery ratio improved their performance. And the confidence that the speed of the nodes and their number influenced the simulation results, as shown in all the figures and tables, where the use of figures to illustrate what appeared in the tables.

The performance metrics of four proposed approaches are increased when topology area becomes 5000m, but the end to end delay become worse, because the collisions between nodes decreased when area increased.

Chapter Six: Conclusion and Future Works

Chapter Six

Conclusion and Future Works

6.1 Thesis Conclusion:

In this thesis four different approaches were presented based on the DYMO protocol where a modification was proposed to the phase called route discovery. Depending on the advantage of the battery power value of the chosen routes, this proposed approach was called (EDYMO) and then a second approach was proposed depending on the fuzzy logic system called FDYMO. The third proposed approach is based on the use of neural networks, and fuzzy logic where the proposed approach called NFDYMO. The last proposed approach was to take advantage of mobile agents and this approach was named MADY. The simulation results are shown after the use of performance metrics such as end to end delay, through put and packet delivery ratio. All proposed approaches had a role in improving the performance of MANETs, and the proposed approach (MADY) was clearly distinct and positive in MANETs performance metrics.

6.2 Future Works

In this thesis, four proposed approaches have been applied to improve the performance of the DYMO protocol. The same approaches can be used with other types of MANET protocols.

In this thesis, security considerations relating to mobile Ad hoc networks have not been addressed. These networks pain from many attacks and security breaches such as denial of service, black hole attacks and gray hole attacks. Therefore, proposed approaches can be developed to eliminate these attacks and protect mobile Ad hoc networks of potential risks.

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Appendix A:

Published Paper

An Intelligent Routing Protocol Based on DYMO for MANET

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An Intelligent Routing Protocol Based on DYMO for MANET

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***Abstract*- in this paper, intelligent routing protocols for mobile ad-hoc networks (MANET) will be proposed .Depending on the concepts of fuzzy and neural networks. The goal is to get good quality service by finding the most convenient data transfer paths, therefore a Fuzzy-based, Neural-Fuzzy based and Energy aware are three approaches have been proposed to enhance Dynamic Manet On-demand (DYMO),All approaches were implemented in ns-2 simulator and compared with original protocol in terms of performance metrics, which showed that there was an improvement in route efficiency.**

Keywords: DYMO, MANET, Fuzzy logic, Fuzzy Neural Networks, Intelligent Routing Protocol.

I. INTRODUCTION

MANETs are a collections of mobile Nodes that are grouped together to form network topology Without relying on a pre-configured communication infrastructure this kind of networks can be operate in very difficult places such as Disaster areas, conflict zones, war and places where people can not directly access them.[1] The mobile ad-hoc networks nodes are limited by the battery power due to the fact that the nodes operate with limited energy. This affects the longevity of the nodes [2]. In order to communicate between the source node and the target node, the nodes need to use multiple hops routing, if the two nodes are not in the same range of transmission for each. Protocols are therefore classified into two types. The first type is: Proactive routing protocols, because all paths are known before communication. The second type is referred to as reactive routing protocols, by Using this type, a routing request is sent to the network to learn about a route to the destination

A. Table-Driven :

1. **Destination Sequence Distance Vector (DSDV)** When this protocol is run on nodes, the protocol performs an initial delay, because the nodes need to store all available paths in the routing tables for each node to cover the available nodes. The protocol sends periodic messages to maintain paths for detecting any changes to the network, such as entering a new node or disrupting the node. [3].

2. **Wireless Routing Protocol (WRP)** Although the speed of finding the path to the available node, the protocol needs a primitive delay time and a large space of cache memory which is naturally limited, since the protocol configure a number of tables that help to maintain the paths, that consume the memory and the power of node. And also every node Sends hello messages regularly to neighbor nodes which consume the bandwidth [4].

B. On-Demand Routing:

1. Dynamic Source Routing (DSR) The Protocol is based on two successive procedures. Route discovery occurs when a source node is request to communicate with a target node where a path is created and the route is saved in the routing table. On the other hand, when a communication failure occurs or change of network topology, the routing maintenance procedure is activated. These two procedures contribute to reducing the overhead of the network because the number of messages decreases

2. Ad-hoc On Demand Distance Vector (AODV) creates and maintains routes by using route discovery and route maintenance. (AODV) has taken advantage of (DSR) features and has benefited from the (DSDV) features such as a routing over hops, a unique sequence number for each destination and periodic hello messages. [6].

3. **Temporally Ordered Routing Algorithm (TORA)** There is a range of limitations that limit the effectiveness of the network and (TORA) works effectively with these limitations, it depends on maintaining the route information of the neighbor nodes. One of the protocol features is that it eliminates loops and outdated packets, and creates more of a route to the same destination node. On the other hand of the protocol that performance degrades with increased mobility. [7].

4. **DYMO (Dynamic MANET On-demand Routing)** is Successor of AODV and Reduced overhead in route discovery and route maintenance [8].

The paper is structured as follows: In section two describe in detail the working principle of DYMO protocol, Sections three and four evaluates the performance of the proposed methods

II. DYMO ROUTING PROTOCOL

The DYMO routing protocol uses hop by hop routing mechanism, if A Node (source) need to send data to D Node (destination), (A) will flood the network by broadcast RREQ packet to all the other neighboring nodes in the network, (B) Node (intermediate node) broadcast received RREQ packet after adds itself to RREQ packet, if the node (D) receives the RREQ packet, it passes the RREP packet to the sender node A by unicast RREP packet. as shown in figure1.(a). DYMO is the next generation of AODV and more simply, it also added new features to the routing request message; where each Intermediate node adds its address to routing message [8].

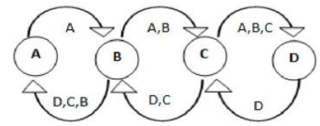

Figure1.(a) : DYMO protocol

DYMO protocol and AODV protocol uses route discovery and route maintenance by following same basic operations. When node wants to send data to destination that is not in its routing table. The originating node create a route request message and broadcast the message, each intermediate node receiving the RREQ, and search in his route table to find destination if not founded With each new hop, the intermediate node adds its address to the routing request packet, therefore the packet size is increasing each time it is forwarded, then adding to its route table a path for the sender node , and finally the RREQ broadcasting again, While RREQ reaches its destination or an intermediate node that has a path to it, the RREP packet is created and sent back to the source. When RREP packet reaches the originator of the routing request packet, the path is recorded to its routing table. Each node has only one routing entry for each destination stored in the routing table, If the node receives more than one route for the same destination, it chooses the freshest sequence number and if the sequence number for all routes does not differ, the node will choose the path with fewer hop counts .On other hand When a source node receive a route error (RERR) packet this mean there is link break. Upon receiving the RERR the source node initiate new RREQ to find path again if the source want to send data to that destination. [9][17], the path accumulation adds some improvement such as: a reduced number of RREQ packets. The flowchart of the basic operations of the DYMO protocol is shown in Figure.1 (b).

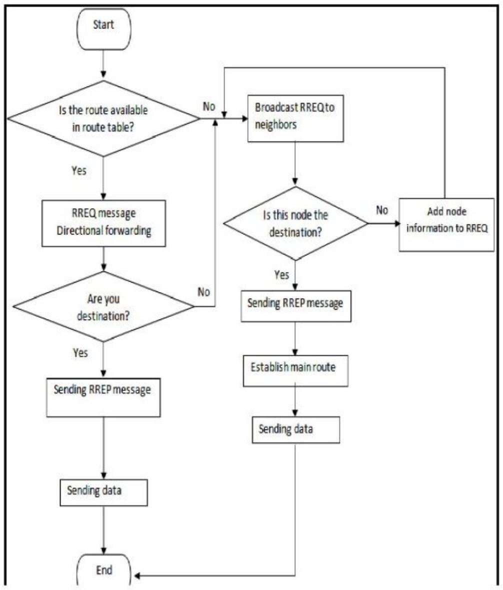

Figure1.(b) : flowchart for DYMO protocol

III. Proposed Model

The following three approaches have been proposed to improve the DYMO routing protocol.

1. EDYMO (Energy-DYMO)

EDYMO introduces two new fields in DYMO's Route messages: Energy and Total energy fields. The EDYMO routing protocol is introduced, which is modified to make the network life more efficient.

The drawback of a model based on energy is that the origin itself can leak; since the calculation of energy is based on the rate of transmission and reception of nodes.

A. Energy and Total Energy Fields

In most cases, there is more than one route between the source and the distention. For each route there is a certain number of nodes (N) and each node has different values of energy. The Energy field in the RREQ is the battery energy of node, and Total energy is a summation of total power of all nodes of route as (1) shows.

$$\text{Total energy}= \sum_{n=1}^{n=N} Energy_{\ n} \qquad (1)$$

B. Route Selection Process

When a destination node receives several (RREQ) s from different routes, it determine the best route depend on who has freshest route ,minimum Hop Count and maximum Total energy .each intermediate node who receives an RREQ adds its own energy to Total energy value .

2. FDYMO (Fuzzy - DYMO)

FDYMO introduces new field in EDYMO's Route messages: Fuzzy filed. The field value is selected by applying the fuzzy logic theory, in order to choose the most suitable path from source to destination. The advantages of using fuzzy logic to model any system are : easy to understand using natural language , flexible, can use it to model nonlinear functions, and the experiences of professional experts are main part for build any system.[10][11] A fuzzy system is a group of "if-then" rules where maps the inputs membership functions to the output variable. The values of ambiguous inputs form curves called membership functions where each value is reflected to a fuzzy value. These actions are controlled by the fuzzy logic controller as illustrated by the figure 2.

The basic units of a fuzzy logic controller have been explained as follows:

A. **Fuzzication Module:** convert each crisp input into a fuzzy set, for this purpose membership functions are used, It is proposed here that Route metrics that are used to make a decision are Total energy available in a path, and hop count. On another hand the output linguistic variable is Fuzzy route.

B. **Rule Base :** this module contains rules of IF-THEN linguistic rules , Table 2 shows the fuzzy linguistic rules used in the FDYMO simulation .

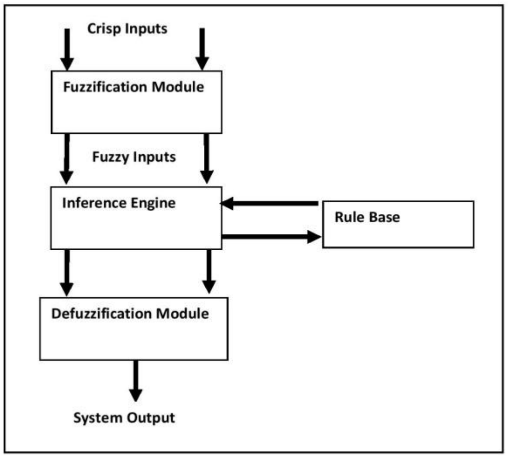

Figure.2. Block Diagram of fuzzy logic controller

C. **Defuzzification Module:** which is a module, converts fuzzy sets into a crisp set, a crisp value in accordance with its membership function and a operator set, for example ,Mean of Maximum as (2) shows.:

$$\text{MOM} = \frac{\sum_{x`\in T} x`}{T} \quad (2)$$

$$T = \{x \,|\mu(x`) = Support\; \mu(x)$$

Where T is the set of output x that has highest degree [12][13].

3. NFDYMO (NEURO -FDYMO)

A fuzzy system with good realization is not an easy task. Since for the development of the system it is necessary to find membership functions, and the corresponding rules are often a boring process of trials. This leads to the conception of using neural networks, where the Simplified mathematical model of the brain systems, that serve as a widely distributed computing network, they are not a program to perform a specific task, But are depend on trained and learning. The utility of the neural network enables its continuous support of the fuzzy system in order to determine the required variables values. In some cases, it is difficult for the fuzzy control unit to measure the inputs in a desired way. Therefore, the neural network helps the fuzzy system to effectively increase the performance level. There are several neuro-fuzzy architectures one of them is Adaptive Network based Fuzzy Inference System (ANFIS) [15][16] which contains five layers where the first is responsible for assigning the input variable relative to all membership functions. The second layer calculates the precedents of the rules. The third layer settles the strengths, the fourth layer determines the results of the rules and the last layer calculates the summation of all the signals that arrive to this layer to create system output.
NFDYMO operation can be modeled by the pseudo code in Algorithm 1

IV. PERFORMANCE EVALUATION

The protocol DYMO was implemented in C++ language using DYMOUM version and simulated using NS2 Table 1 shows the significant parameters selected for the NS2 simulation to perform comparison between DYMO, EDYMO, FDYMO, and NFDYMO.
The proposed studies were compared with DYMO, and were focused on three performance indicators, which are Throughput, End to End Delay, and Packet Delivery ratio.
Various performance metrics analyzed are as follows:

1. **Throughput:** Is the average number of bits delivered per second, or the amount of data per unit of time delivered successfully.

2. **End to End Delay**: Is the average time of delivery of data packets to the delivery to the destination, which includes all delays.

3. **Packet Delivery Ratio:** The ratio of the number of packets received in the receiver and the number of packets sent from the origin.

Algorithm 1: operation model to NFDYMO

```
// Method for  broadcast of RREQ
messages
route_discovery (Destination_node)
{
// Get info from routing table (if
there exists an entry)
IF (routing_entry) { SET  seq_num=
rt_seq_num , thopcnt= rt_hopcnt,
Energy=rt_Energy,FUZZY=rt_FUZZY }
ELSE    SET  seq_num= 0,thopcnt= 0,
Energy=Local_Energy
,FUZZY=Local_FUZZY
BROADCAST  RREQ  to Neighbors }

//Method for handling RREQ messages
Receive_RREQ (RREQ,
Destination_node) {
IF (Destination_node ==
target_node) {
IF (routing_entry) UPDATE
ROUTE,Send_RREP(Source_node)
ELSE  INSERT ROUTE,
Send_RREP(Source_node, RREQ) }
IF (Destination_node != target_node
){
IF (seq_num> rt_seq_num) OR
((seq_num= rt_seq_num) AND
(FUZZY> rt_FUZZY) ) UPDATE Route,
FORWARD_PATH_ACCUMULATION_RREQ }}

 // Method for broadcast RREP
messages
Send_RREP(Source_node, RREQ)
{SET rrep_seq_num= seq_num ,
thopcnt=0
BROADCAST RREP}

// Method for handling RREP
messages
Receive_RREP (RREQ ,Source_node)
{ IF (Source_node== target_node)
UPDATE  Route, SEND Data
IF (Source_node!= target_node ){
IF (rrep_seq_num> rt_seq_num) OR
((rrep_seq_num= rt_seq_num) AND
(FUZZY> rt_FUZZY) ) UPDATE Route,
FORWARD  RREP }}
```

TABLE 1: Simulation Parameters

Parameters	values
Simulation time	900s
Channel type	Wireless channel
Mobility model	Random way point
Type of antenna	Omni directional
Topology area	5000m x 1000m
Number of Nodes	20,30,50,100
Speed	10 to 30 m/s
Routing protocol	DYMO,EDYMO,FDYMO
Traffic type	CBR
Initial energy	10J

TABLE 2: The Rule Base of FDYMO

Hop Count	Energy	Optimal value
Low	Low	Low
Low	Low-med	med
Low	High	VeryHigh
Low	High-med	VeryHigh
Low-med	Low	Low
Low-med	Low-med	Low
Low-med	High	VeryHigh
Low-med	High-med	High
High-med	Low	VeryLow
High-med	Low-med	Low
High-med	High	High
High-med	High-med	med
High	Low	VeryLow
High	Low-med	Low
High	High	High
High	High-med	Low

In Figure.3 (a) and Figure.3 (b) shows the throughput of DYMO, EDYMO, FDYMO, and NFDYMO where in Figure .3(a) the throughput of NFDYMO is the best at low speed, EDYMO and FDYMO are better than DYMO. On Figure.3 (b) NFDYMO throughput is increased, when number of nodes increased also that happened to all protocols, and NFDYMO has the best throughput, on another hand EDYMO and FDYMO are better than DYMO at 5, 10, and 15mps.

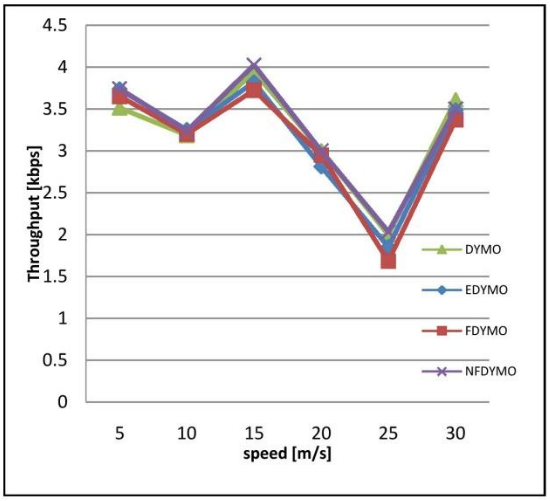

Figure.3 (a) Throughput for 50 nodes in different speeds

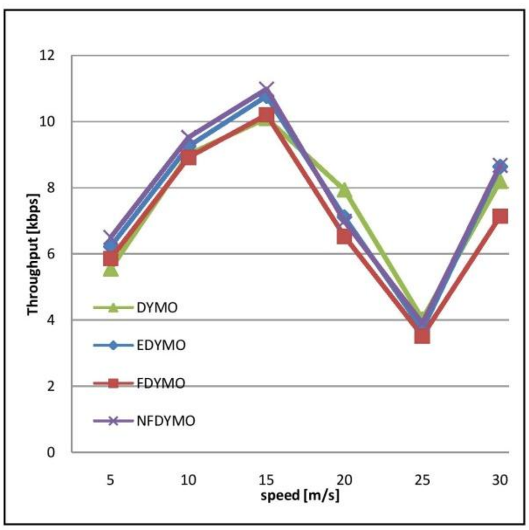

Figure.3 (b) Throughput for 100 nodes in different speeds

After evaluating performance parameters, performance (NFDYMO) is generally more efficient than the traditional routing protocol.

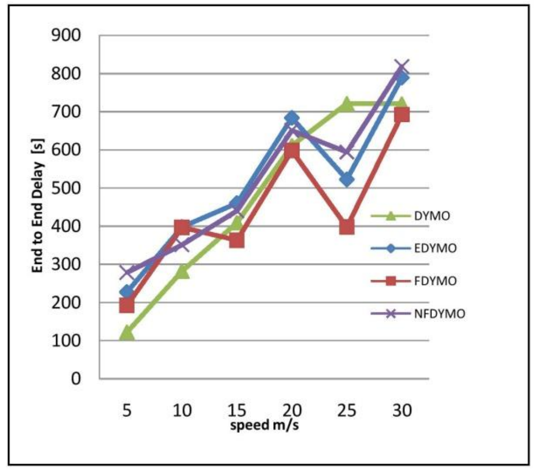

Figure.4 (a) End to End Delay for 50 Nodes in different speeds

The End to End Delay of DYMO, EDYMO, FDYMO, and NFDYMO appears in Figure.4 (a) and Figure.4 (b), where in Figure 4(a) number of nodes is fifty nodes. at 15, 25 and 30 mps speeds, FDYMO is better than DYMO, EDYMO, But on Figure .4 (b) EDYMO and FDYMO are better than DYMO at 5, and 30 mps speeds, on another hand NFDYMO Remains almost similar to DYMO effectiveness on both cases.

Figure.5 (a) and Figure.5 (b) shows the Packet Delivery ratio of all proposed models where (NFDYMO) is more efficient than conventional routing protocol, in Figure. 5(a) at 5, 10, and 15 mps speeds EDYMO and FDYMO are better than DYMO .but on Figure .5 (b) EDYMO is better than DYMO and FDYMO at 15 mps

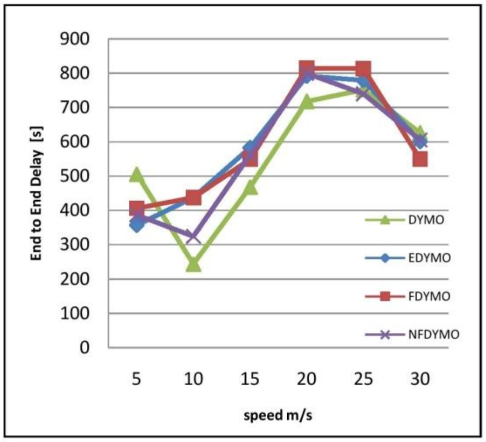

Figure.4 (b) End to End Delay for 100 Nodes in different speeds

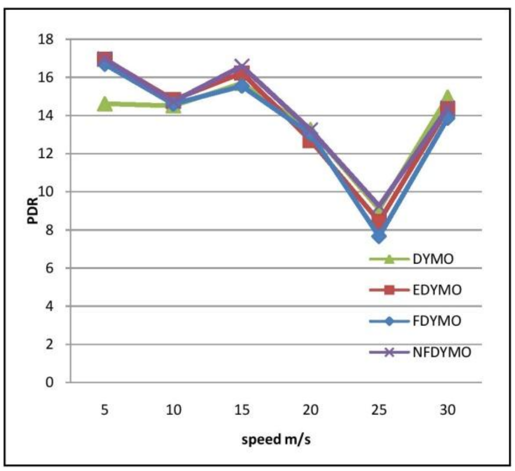

Figure.5 (a) Packet Delivery ratio for 50 Nodes at different speeds

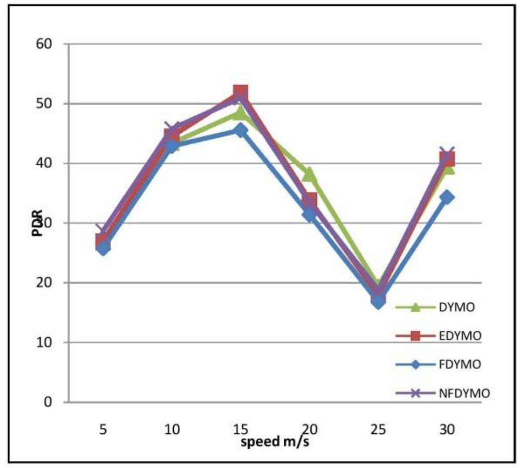

Figure.5 (b) Packet Delivery ratio for 100 Nodes at different speeds

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V. CONCLUSION

This paper shows EDYMO, FDYMO, and NFDYMO as extensions for DYMO, to ensure that the conditions of choice of routes are effective and have a positive impact on the efficiency of the use of battery power. The simulation results show that the NFDYMO, EDYMO and FDYMO have improved the performance of DYMO.

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