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Behaviour of Routing Protocols in MANETs Investigated for Emergency and Rescue Situation in Sudan

A Research Submitted in Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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الاستهلال

قال تعالى:

﴿ قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ ﴾

البقرة ﴿٣٢﴾

صدق الله العظيم

Dedication:.

From the depths of our hearts we dedicate this thesis to:

Our parents who are paved and still paving the way for us and treating us as winners. Thanks for being so supportive.

All friends who we are so lucky to have, thanks for being the shoulders that we always depend on.

All teachers who are shaping humanity's future, we are so grateful to have had such awesome humans like you. Thank you for all wisdom you shared.

All colleagues who are collaborated in this trip and make it wonderful moments.

To the place that accommodate us, the place where we lose our fears, to Sudan University of Science and Technology, keep shining up, keep progressing up.

To the court that always sentences to help its students not to punish them, To the School of Electronics Engineering.

To all those workers, simple people but doing cruel jobs, we shan't say thank to them because thank isn't enough for them.

ACKNOWLEDGEMENT

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ABSTRACT

Disaster Area Network (DAN) is very crucial in case of natural or man-made disasters. During state of emergency, a rapidly deployable network is the highest priority to conduct search and rescue operations. This research aims at investigating network architecture and routing models for disaster area networks. The main objective and goal of DAN is to ensure reliable, energy efficient communication which is susceptible to mobility and topology changes in the disaster area. The purpose is to improve delay, reduce overhead, minimize energy used, sustain movement and increase bandwidth for multimedia applications. Mobile Ad hoc network (MANET) addresses issues related to rapid and temporary setup and terminal probability and mobility in a disaster area until conventional infrastructure communication is established. We study the behavior of two common reactive routing protocols (AODV and DYMO) in disaster area in different scenarios using OMNET++ simulator to define the suitable protocol in the studied area, in order to insure reliable communication. At the end of the research we obtained that, DYMO is more reliable and stable than AODV, so we recommend to use it in our study case DAN (Marabee Al- shareef).

المستخلص

تعد شبكة منطقة الكوارث أمراً بالغ الأهمية في حالة الكوارث الطبيعية أو التي من صنع الإنسان. أثناء حالة الطوارئ، تكون الشبكة سريعة الانتشار هي الأولوية القصوى لإجراء عمليات البحث والإنقاذ. يهدف هذا البحث إلى التحقق من هيكلة الشبكات ونماذج التوجيه لشبكات مناطق الكوارث. يتمثل الهدف الرئيسي لشبكة منطقة الكوارث في ضمان موثوق وموفر للقدرة وقابل للتغيرات الحركية والطوبولوجية في منطقة الكارثة؛ والغرض من ذلك هو تحسين تأخير الإرسال، تقليل التكاليف غير المباشرة، تقليل القدرة المستخدمة، الحفاظ على الحركة وزيادة عرض النطاق الترددي لتطبيقات الوسائط المتعددة. تعالج الشبكة المخصصة للأجهزة المحمولة (مانيت) القضايا المتعلقة بإنشاء شبكة مؤقتة لتمكن من التنقل والاتصال في منطقة الكارثة حتى يتم إنشاء اتصالات البنية التحتية التقليدية. في هذا البحث قمنا بدراسة سلوك بروتوكولين شائعين في منطقة الكوارث في سيناريوهات مختلفة باستخدام محاكي أومنيت لتحديد البروتوكول المناسب في المنطقة المدروسة؛ من أجل ضمان اتصال موثوق. بنهاية البحث، تمكننا من معرفة أن بروتوكول الشبكة المخصصة الديناميكية حسب الطلب أكثر موثوقية واستقراراً من بروتوكول متجه المسافة حسب الطلب ؛ ولذلك قمنا بالتوصية للعمل به كبروتوكول في شبكة منطقة الكارثة التي قمنا بدراستها (مرابيع الشريف).

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LIST OF ABBREVIATIONS

ABR	Adaptive Bitrate Streaming
AODV	Ad Hoc On-Demand Distance Vector
BSS	Basic Service Set
CBRP	Cluster Based Routing Protocol
DAN	Disaster Area Network
DSDV	Destination-Sequenced Distance Vector
DSR	Dynamic Source Routing
DYMO	Dynamic Manet On-Demand
GUI	Graphical User Interface
IDE	Integrated Development Environment
MANET	Mobile Ad-hoc network
IP	Internet Protocol
IT	Information Technology
NED	NEtwork Description
OLSR	Optimized Link State Routing
OMNET++	Objective Modular Network Testbed in C++

PDR	Packet Delivery Ratio
QoS	Quality of Services
RERR	Route Error
RM	Routing Messages
RREP	Route Reply
RREQ	Route Request
TORA	Temporally Ordered Routing Algorithm
UDP	User Datagram Protocol
WRP	Wireless Routing Protocol
ZRP	Zone Routing Protocol

CHAPTER ONE
INTRODUCTION

1.1 Preface

Mobile Ad-hoc network (MANET) [1] , also known as wireless ad hoc network or ad hoc wireless network is a continuously self-configuring, infrastructure-less network of mobile devices connected wirelessly. It is a type of wireless network that has many free or autonomous nodes such as mobile devices and other mobile pieces. It is also called a network without any central administration or fixed infrastructure. It consists of a number of mobile nodes that use to send data packets through a wireless medium. Each device in a MANET is free to move independently in any direction, and will, therefore, change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. MANET can be defined with two main criteria; Firstly, MANETs are infrastructure-less. All the nodes in the MANET environment connect wirelessly; which means the node/mobile nodes will operate themselves. It does not require any specialized hardware to make a connection between nodes. Secondly, the MANET environment distributed and change their position continuously without any central source. MANET is a dynamic network topology, which all nodes may traverse multiple links to reach their destination. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger internet. They may contain one or multiple and different transceivers between nodes. This results in a highly dynamic, autonomous topology. Besides, MANET is a dynamic network topology, which means the topology will change rapidly and uncertainty. This kind of networks may be function and connected in a larger network, and because of the minimal configuration and a rapid implementation make of an ad-hoc network, therefore this network is applicable to be used in crisis situations such as natural or disaster area, in military clash, emergency situation and other situation that needs for employment of ad-hoc networks. [2]

There is always a need for a good routing protocol in order to establish the connection between mobile nodes since they have the property of dynamic changing topology. A central challenge in the design of ad hoc networks is the development of dynamic routing protocols that can efficiently find routes between two communicating nodes. The routing protocols must be able to cope up with the high degree of node mobility that often changes the network topology drastically and unpredictably. Hence, in order to find out the most adaptive and efficient routing protocol for the highly dynamic topology in ad hoc networks, the routing protocols behavior has to be analyzed using varying node mobility speed and network load.

1.2 Problem Statement

In disaster areas where disaster is frequently happens a proper MANET network should be designed using a random mobility model. The most challenging task in MANET construction is the selection of the best routing protocol that matches the characteristics of the target area, since every disaster area may have different requirements for MANET design parameters.

1.3 Objectives

The main three objectives of this research are as follows:

1. To study the routing issues in MANET.
2. To simulate MANET with two common routing protocols (AODV & DYMO) according to varies values of the parameters.
3. To evaluate the performance of routing protocols in MANET to adapt with the requirements of the disaster area.

The outcomes of the above mentioned objectives are to study the behaviour of AODV and DYMO routing protocols and to identify the suitable and reliable routing protocol – from AODV and DYMO - in the disaster area.

1.4 Proposed Solution

Our proposed solution is to compare between two common routing protocols (AODV & DYMO) and accordingly choose the suitable routing protocol which achieve better performance than the other in different network scenarios with respect to the disaster situation (Marabee Al-shareef as case study).

1.5 Thesis Layout

The rest of thesis includes the following; chapter 2 includes the theoretical background and the related work, chapter 3 explains in detail the methodology, chapter 4 is about the results and analysis, and finally chapter 5 gives conclusion and shows the future directions.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

In Chapter 1, the motivations for necessity of selecting the suitable routing protocol in MANET were highlighted. A primary objective of this thesis is to compare between two common reactive routing protocols in order to choose the suitable protocol in disaster area for different scenarios. To achieve this objective, a general understanding of MANET and routing protocol is necessary. Therefore, this chapter aims to introduce MANET concepts, routing protocol, and simulation tools.

In Section 2.2, the concepts of MANET are described, including the architecture of a typical MANET and infrastructure network, applications, challenges, routing and simulation tools. Section2.3 describes the literature review, finally section 2.4 summaries this chapter.

2.2 Background

In this part a theoretical background of MANET will be explored such as definition of MANET, it's characteristics, applications, challenges, and routing issues.

2.2.1 Mobile Ad Hoc Networks (MANET)

The expansion of wireless technology has brought data transmission via radio waves. Nodes in the network can communicate with each other without a fixed station access point. The structure can form and reform in a network without relying on any network system. An ad hoc network is the latest generation of wireless communication system which is currently developed by many researchers. The Latin term “ad-hoc” justifies the distinguishable characteristics of such a network stating that is designed and dedicated to a specific purpose and cause. MANET has self-configurable nature and its arbitrary topology fulfills the requirements of such systems where they require a real-time data exchange and processing without being concerned with the geographical changes in the topology. MANET is very suitable for the communication in military operation or rescue mission in the disaster area. MANET has been gaining popularity since the production of smart computing devices and the development of wireless communications. The transmission of information from a source to a destination across an inter-network is called routing. To forward data packets from a source to a destination, the neighbor’s node (also known as a router, because it performs data packet forwarding) will send the data packet through multi-hop nodes until the data packet arrives at the destination. The topology of a MANET is unpredictable and can change rapidly. [3]. Figure 2.1 shows the Basic Service Set (BSS).

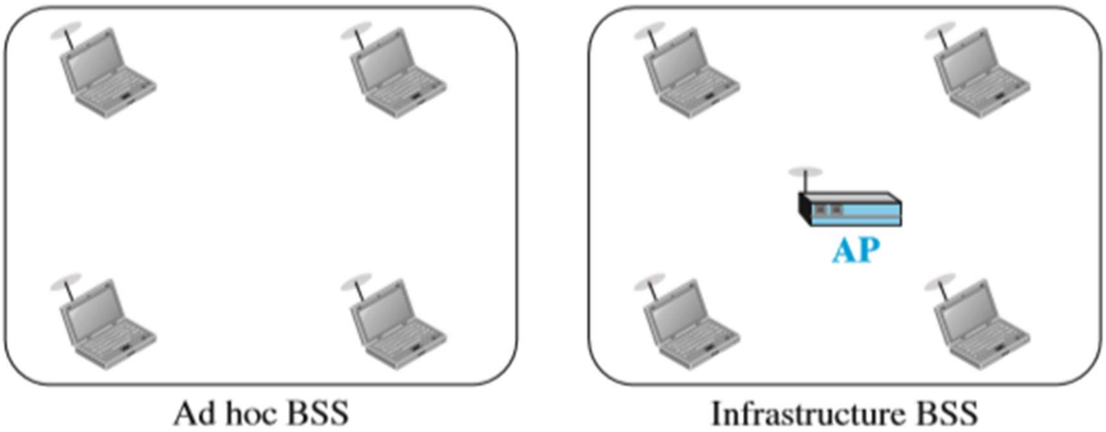


Figure 2.1 Basic Service Set (BSS)

2.2.2 Characteristics of MANET

Some of Characteristics of MANET network are as follows:

i. Distributed Operation

The control of the network is distributed among the nodes, as there is no background network for the central control unit of the operation. Therefore, the node that gets involved in MANET should associate with each other and communicate among them. Besides, when there is a need to implement specific functions such as routing and security, the node in the network must act as a relay to each other. [4]

ii. Multi-hop Routing

When a node had requested to send information to other nodes, which is out of its communication range, the packet needs to be forwarded via one or more intermediate nodes.

iii. Dynamic Topology

The node in MANET is free to move arbitrarily with different speeds. Therefore, the network topology in MANET may change randomly at an unpredictable time. When there is a request to forward the message to the destination, the nodes in MANET will dynamically establish routing among themselves.

2.2.3 Applications of MANET

With the increase of progress in wireless communication, Mobile Ad Hoc Networking is gaining more importance with the large number of widespread applications. Due to dynamic nature of the MANET it has main advantage of decentralization. MANETs has wide range of applications in several domains. Table 2.1 lists MANET applications and corresponding scenarios. [5, 6]

Table 2.1 : Applications of MANET

Application Area	Scenario and Potential services
Military Communication and Operations	• Keep the communication networks of soldiers, vehicles and military always in a good condition and ensure stay connected
Disaster Scenario	• Emergency rescue operation takes over the communication when existing communication infrastructure has damaged or cut off for a safety reason. Generally, it's usually be used in rescue operations to support medic teams such as earthquake, flood, disaster relief etc
Commercial Sectors	• Shopping malls • Airports • Sport stadiums • E-commerce • Vehicular Ad Hoc Network
Home Networking	• Indoor and Outdoor Internet Access • Personal Area Networks

Enterprise Networking	• Indoor and Outdoor Internet Access • Conferences • Meeting Rooms
Education	• Virtual Classrooms • Ad Hoc Communication through meeting or lectures
Sensor Networks	• Smart home applications: smart sensors for home appliances • Geo-location tracking device for humans or animals • Multi-user games • Robotic Pets

2.2.3.1 MANET in Disaster Area

Disastrous events are one of the most challenging applications of multi-hop ad hoc networks due to possible damages of existing telecommunication infrastructure. The deployed cellular communication infrastructure might be partially or completely destroyed after a natural disaster. Multi-hop ad hoc communication is an interesting alternative to deal with the lack of communications in disaster scenarios.

Communication in that situation require a special requirement; such as high speed, reliable communication, an ease connection to the desirable destination. All this requirement and more can be achieved if we carefully select the suitable protocol in each network scenario.

2.2.4 MANET Challenges

Regardless of the attractive applications and different characteristics of MANET, we can introduce several challenges and issues that must be studied carefully. The most important challenges of MANET are mentioned bellow:

i. Routing

Since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive. Multi cast routing is another challenge because the multi cast tree is no longer static due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which is more complex than the single hop communication.

ii. Security and Reliability

In addition to the common vulnerabilities of wireless connection, an ad hoc network has its particular security problems due to e.g. nasty neighbour relaying packets. The feature of distributed operation requires different schemes of authentication and key management. Further, wireless link characteristics introduce also reliability problems, because of the limited wireless transmission range, the broadcast nature of the wireless medium (e.g. hidden terminal problem), mobility-induced packet losses, and data transmission errors.

iii. Quality of Service

Providing different quality of service levels in a constantly changing environment will be a challenge. The inherent stochastic feature of communications quality in a MANET makes it difficult to offer fixed guarantees on the services offered to a device. An adaptive QoS must be implemented over the traditional resource reservation to support the multimedia services.

iv. Inter-networking

In addition to the communication within an ad hoc network, inter-networking between MANET and fixed networks (mainly IP based) is often expected in many cases. The coexistence of routing protocols in such a mobile device is a challenge for the harmonious mobility management.

v. Power Consumption

For most of the light-weight mobile terminals, the communication-related functions should be optimized for lean power consumption. Conservation of power and power-aware routing must be taken into consideration.

vi. Multicast

Multi-cast is desirable to support multiparty wireless communications. Since the multicast tree is no longer static, the multicast routing protocol must be able to cope with mobility including multicast membership dynamics (leave and join).

vii. Location-aided Routing

Location-aided routing uses positioning information to define associated regions so that the routing is spatially oriented and limited.

This is analogous to associatively-oriented and restricted broadcast in ABR. [7]

2.2.5 Routing in MANET

All the type of communication system performs the communication process using mechanism called routing. Routing is a set of rules or algorithm to process and move data from one to other devices in network. This rule determines the appropriate path over which data is transmitted. MANET also uses specific routing protocol to maintain and establish the communication process. A routing protocol in MANET uses routing algorithms to determine optimal network data transfer and communication paths between network nodes. At the same time a routing protocols is responsible to maintain and repair any path if needed. Routing protocol in MANET can be classified based on routing philosophy and based on routing architecture. [8-11]

2.2.5.1 Routing Protocol Based on Routing Philosophy

Routing philosophy divides the protocol based on the underlying routing information update mechanism employed, and how the routing schemes. Based on this criterion, there are three type of routing protocol i.e. reactive protocol (on demand), proactive protocol (table driven) and hybrid protocol. [8-11]

i. Proactive Routing

A proactive protocol is a table-driven protocol mostly focuses on the maintenance and refreshment of information through tables that manages the traffic and the correctness in path direction. Each node will keep network routing information and change routing information periodically. Routing information is maintained mostly on different tables depending on the particular protocol algorithm. The main difference between the various proactive protocols is in the update scheme of these tables. This mechanism can flood the network with active request information to keep the information of table routing always updated. Proactive routing introduced and employed an initial good approach for routing but on the other side, it is surely a scheme that does not fulfill the Quality of Services (QoS) requirements defined by the MANET infrastructure and characteristics. Protocols in the proactive group facilitate a large amount of overhead in their update transmission messages. In large networks with numerous nodes results the latency and in some cases failure in routing. Complementary on the above, their update processes implementations consume a large amount of network bandwidth.

Some examples of proactive routing protocols are Destination-Sequenced Distance Vector (DSDV) [12] , Wireless Routing Protocol (WRP) [13] and Optimized Link State Routing (OLSR). [14]

ii. Reactive Routing

Reactive protocol is on demands protocols that discover the route once needed [11] and finds the route by flooding the network with route request packets [15]. When a route is needed, the source node initiates a route discovery process to the destination. Once established, the route must be maintained until it is no longer needed, or the destination node becomes inaccessible. Reactive protocols trade the routing update delay for less system overhead and less power consumption, which is critical to battery life in the MANET environment [10]. The reactive group is divided in to two main categories, both of them following the same principle of "on-demand" routing but with minor differences on the route discovery area. A protocol that belongs in the source routing category enables the transferred data packets to carry the complete source to the destination and each intermediate node forwards them according to the information contained on the header of each packet [9]. This helps the local storage problem on each intermediate node and reduces the overhead in the update process mechanism.

In addition, it also allows these nodes not to keep current updates for routes in their tables and neighbours information as well. In the hop by hop or point-to-point subgroup of reactive protocols, a data packet includes only the destination and the next hop address. Under this principle, each intermediate node is forced to keep updating its neighbouring nodes and its routing information related to the desired destination. An intermediate node forwards these packets according to the information they contain. This principle sets a robust architecture to confront the unpredictable topology in MANET and it improves adaptability in routing [9]. Some of routing protocols under this concept are DSR [16], TORA [8] and AODV. [15]

iii. Hybrid Routing

A hybrid protocol is referred to as the protocol that is able to allow combination between proactive and reactive elements no matter their base root protocol. For example, a node communicates with its neighbours using a proactive routing protocol, and uses a reactive protocol to communicate with nodes farther away. In other words, the nodes will choose the best way when communicate with each other. Hybrid protocols are designed in a form to improve scalability and they enable the close nodes to work with each other and maintain proactively close (i.e. from their closest node) routes to the destination and in parallel determine routes to the far away nodes with the use of a route discovery strategy. [17]. Figure below shows routing schemes in MANETs.

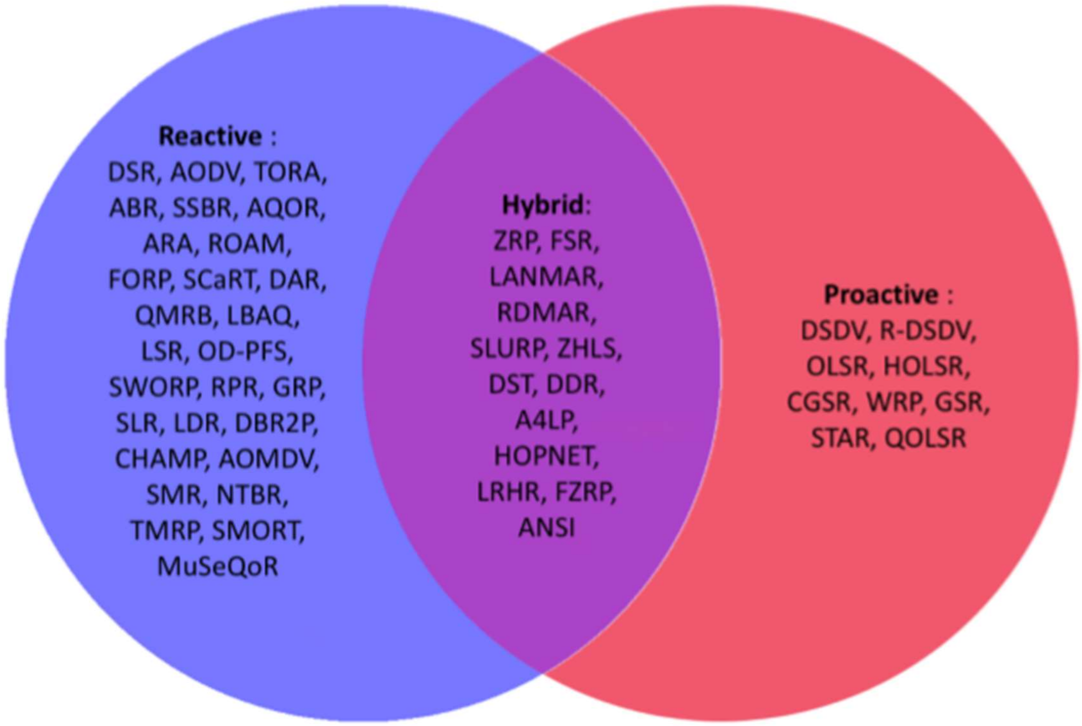


Figure 2.2 Routing schemes in MANETs

2.2.5.2 Routing Classification Based on Architecture

Routing algorithm also classified under two categories based on the topology i.e. clustered routing and flat routing. [10]

i. Clustered Routing

In clustered algorithms, all routing decisions are made by a central controller. Most clustered routings have a form of node hierarchical structure where nodes are clustered in groups. Each group acts as a centralized structure. A central controller or a node leader maintains the connectivity of the group and frequently disseminate routing information to its member nodes.

Clustered approaches may pose many disadvantages [10]. A considerable quantity of information must be communicated from the network to the node leaders, necessitating the sending of data from all nodes in the group to the node leader. The delays are necessary to gather information about the network status and to broadcast the routing decisions that make them unfeasible. In terms of mobility, the rapid movement of nodes may cause additional complexity to the network algorithm. Nodes may frequently join or leave the group resulting in high overhead to maintain or form such centralized structure. In the case where all nodes need to be updated when there are any changes in the network, the problem of synchronization can lead to network instability. Moreover, providing a single point of control also provides for a single point of failure, a highly undesirable characteristic in any system. Examples of clustered routing are Zone Routing Protocol (ZRP) [18] and Cluster Based Routing Protocol (CBRP). [19]

ii. Flat Routing

In flat routing, all nodes carry the same responsibility and there are no distinctions between the individual nodes, and all nodes are equivalent. As for flat routing algorithms, the computation of routes is shared among the network nodes. The nodes are not grouped into clusters or any hierarchical structure. It is a distributed structure where all nodes have the same functionalities and behaviors. Nodes can make their own decision based on local information without the need of being directed by any central controller. This reduces overhead and delay, hence, increasing the network performance. In addition, a decentralized control mechanism has no central point of failure. A broken or failure node will not be affected to the overall network [10]. Examples of flat routing algorithm are the

Destination-Sequence Distance Vector (DSDV), Ad Hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR).

2.2.6 Ad-Hoc On-Demand Distance Vector (AODV) Routing Protocol

The Ad Hoc On-Demand Distance Vector [20, 21] (AODV) routing protocol is a reactive protocol. AODV minimizes the number of required broadcasts by creating routes in an on-demand manner. When a source node desires to send data to other destination nodes, it needs to initiate a path discovery process to locate the other node.

A source node broadcasts a route request (RREQ) packet to its neighbors, which then forwards the request to their neighbors, and so on, until the destination is located. Once the RREQ reaches the destination, the destination node responds a route reply (RREP) packet back to the source node. Hence, all the nodes participating at the route discovery process will have the ability to update their routing tables accordingly.

2.2.6.1 Route Discovery

When a node S wishes to communicate with a node T it initiates RREQ message including the last known sequence number for T and a unique RREQ id that each node maintains and increments upon the sending of an RREQ. The message is flooded throughout the network in a controlled manner. Each node forwarding the RREQ creates a reverse route for itself back to S using the address of the previous hop as the next hop entry for the node originating the RREQ. When the RREQ reaches a node with a route to T a RREP, containing the number of hops to T and the sequence number for that route, is sent back along the reverse path. An intermediate node must only reply if it has a fresh route, i.e., the sequence number for T is greater than or equal to the destination sequence number of the RREQ. Since replies are sent on the reverse path. Route discovery is illustrated in figure 2.3.

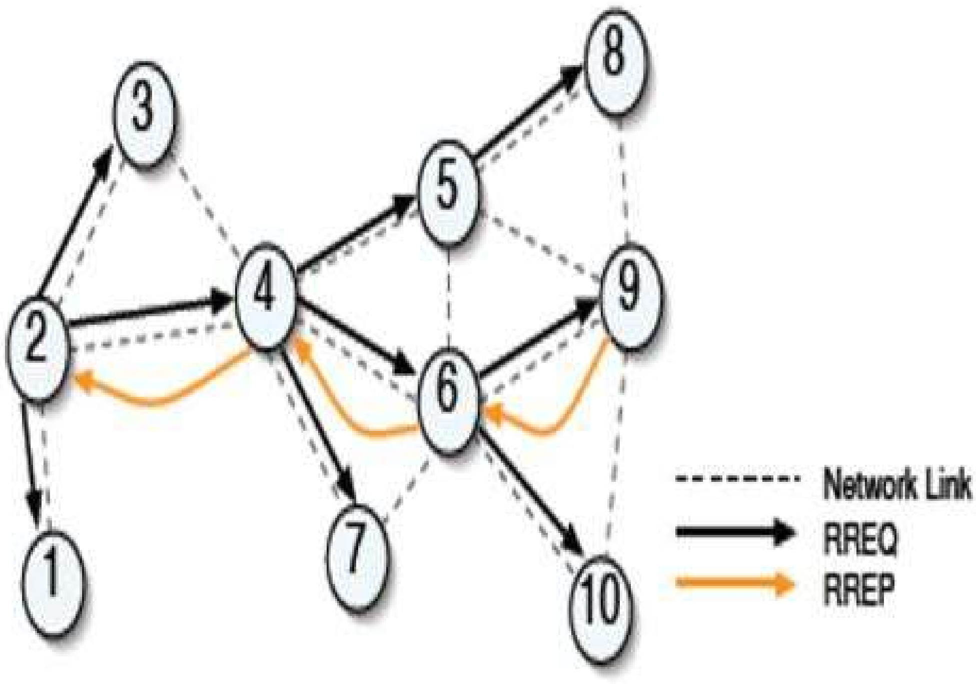


Figure 2.3 Route discovery in AODV

Node 2 wants to communicate with node 9. Each node forwarding the RREQ creates a reverse route to node 2 used when sending back the RREP. If an intermediate node has a route to a requested destination and sends back an RREP, it must discard the RREQ. Furthermore, it may send a gratuitous RREP to the destination node containing address and sequence number for the node originating the RREQ. Gratuitous RREPs are sent to alleviate any route discovery initiated by the destination node.

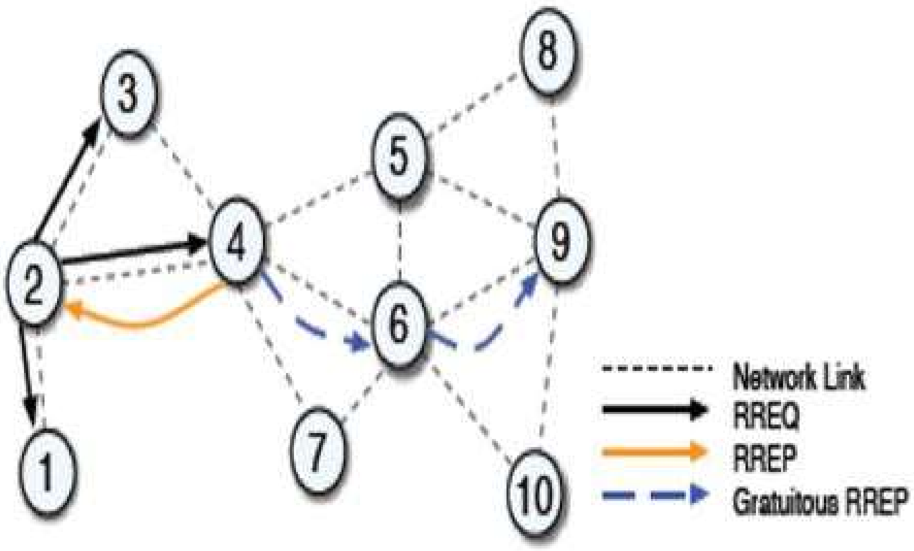


Figure 2.4 Generation of an RREP by an intermediate node

Node 4 has a route to node 9 and sends an RREP to node 2 and a gratuitous RREP to node 9.

2.2.6.2 Route Maintenance

It is the process of responding to changes in topology. To maintain paths, nodes continuously try to detect link failures. Nodes listen to RREQ and RREP messages to do this. Furthermore, each node promises to send a message every n seconds. If no RREQ or RREP is sent during that period, a Hello message is sent to indicate that the node is still present. Alternately, a link layer mechanism can be used to detect link failures. When a node detects a link break, or it receives a data packet it does not have a route for, it creates and sends a Route Error (RERR) packet to inform other nodes about the error. The RERR contains a list of the unreachable destinations. If a link break occurs, the node adds the unreachable neighbour to the list. If a node receives a packet it does not have a route for, the node adds the unreachable destination to the list. In both cases, all entries in the routing table that make use of the route through the unreachable destination, are added to the list. The list is pruned, as destinations with empty precursor lists, i.e., destinations that no neighbours currently make use of, are removed. The RERR message is either unicasted (in case of a single recipient) or broadcasted to all neighbours having a route to the destinations in the generated list. This specific set of neighbours is obtained from the precursor lists of the routing table entries for the included destinations in the RERR list. When a node receives an RERR, it compares the destinations found in the RERR with the local routing table and any entries that have the transmitter of the RERR as the next hop, remains in the list of unreachable nodes. The RERR is then either broadcasted or unicasted as described above. The intention is to inform all nodes using a link when a failure occurs. For example, in figure 2.5, a link between node 6 and node 9 has broken and node 6 receives a data packet for node 9. Node 6 generates a RERR message, which is propagated backwards toward node 2.

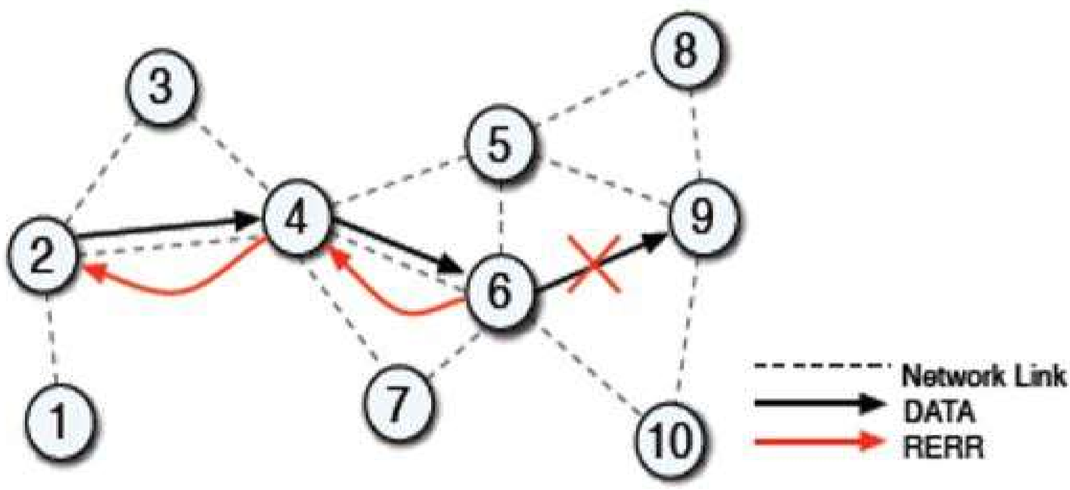


Figure 2.5 Generation of RERR messages. The link between node 6 and node 9 has broken, and node 6 generates an RERR

To find a new route, the source node can initiate a route discovery for the unreachable destination, or the node upstream of the break may locally try to repair the route, in either cases by sending an RREQ with the sequence number for the destination increased by one.

2.2.7 Dynamic MANET On-Demand (DYMO) Routing Protocol

The Dynamic MANET On-demand DYMO routing protocol is a newly proposed protocol currently defined in an IETF Internet-Draft [22] in its sixth revision and is still work in progress. DYMO is a successor of the AODV routing protocol [20]. It operates similarly to AODV. DYMO does not add extra features or extend the AODV protocol, but rather simplifies it, while retaining the basic mode of operation. As is the case with all reactive ad hoc routing protocols, DYMO consists of two protocol operations: route discovery and route maintenance. Routes are discovered on-demand when a node needs to send a packet to a destination currently not in its routing table. A route request message is flooded in the network using broadcast and if the packet reaches its destination, a reply message is sent back containing the discovered, accumulated path. Each entry in the routing table consists of the following fields: Destination Address, Sequence Number, Hop Count, Next Hop Address, Next Hop Interface, Is Gateway, Prefix, Valid Timeout, and Delete Timeout.

2.2.7.1 Route Discovery

When a node S wishes to communicate with a node T, it initiates a RREQ message. The RREQ message and the RREP message, which is known as Routing Messages (RM). The sequence number maintained by the node is incremented before it is added to the RREQ. We illustrate the route discovery process using figure 2.6 as an example. In figure 2.6, node 2 wants to communicate with node 9 and thus, node 2 is S, the source, and node 9 is T, the target destination. In the RREQ message, the node 2 includes its own address and its sequence number, which is incremented before it is added to the RREQ. Finally, a hop count for the originator is added with the value 1. Then information about the target destination 9 is added.

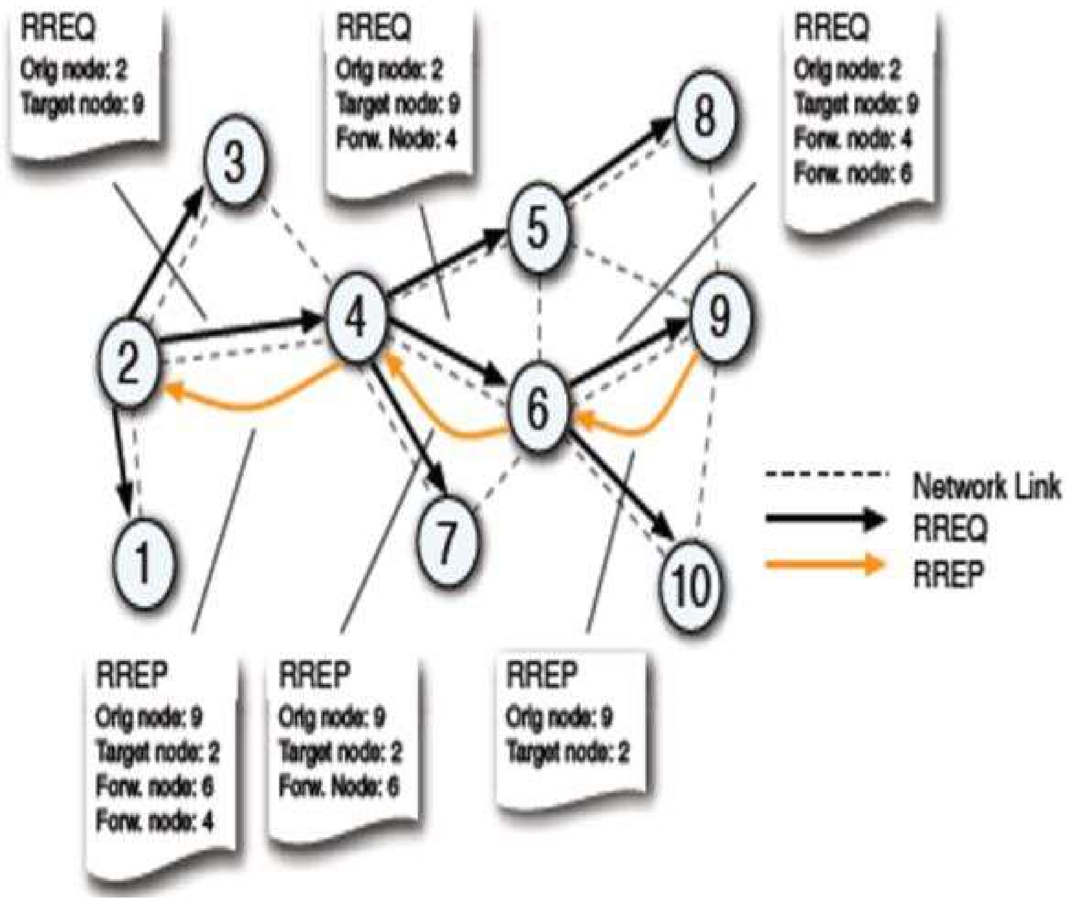


Figure 2.6 The DYMO route discovery process

The figure above illustrates Node 2 wants to communicate with node 9. Each node forwarding the RREQ creates a reverse route to 2 used when sending back the RREP. When sending back the RREP, nodes on the reverse route create routes to node 9.

The most important part is the address of the target. If the originating node knows a sequence number and hop count for the target, these values are also included. The message is flooded using broadcast, in a controlled manner, throughout the network, i.e., a node only forwards an RREQ if it has not done so before. The sequence number is used to detect this. Each node forwarding an RREQ may append its own address, sequence number, prefix, and gateway information to the RREQ, similar to the originator node. Upon sending the RREQ, the originating node will await the reception of an RREP message from the target. If no RREP is received within RREQ WAIT TIME, the node may again try to discover a route by issuing another RREQ. RREQ WAIT TIME is a constant defined in the DYMO specification and the default value is 1000 milliseconds. In figure-8, the nodes 4 and 6 append information to the RREQ when they propagate the RREQ from node 2. When a node receives an RREQ, it processes the addresses and associated information found in the message. An RREP message is then created as a response to the RREQ, containing information about node 9, i.e., address, sequence number, prefix, and gateway information, and the RREP message is sent back along the reverse path using unicast. Since replies are sent on the reverse path, DYMO does not support asymmetric links. The packet processing done by nodes forwarding the RREP is identical to the processing that nodes forwarding an RREQ perform, i.e., the information found in the RREP can be used to create forward routes to nodes that have added their address block to the RREP.

We shortly summarize the route discovery process depicted in figure 2.6. Node 2 wants to communicate with node 9 and floods an RREQ message in the network. As can be seen in the figure, when node 2 begins route discovery, the RREQ initially contains the address of the originator and target destination. When node 4 receives the RREQ, it installs a route to node 2. After node 4 has forwarded the RREQ, it has added its own address to the RREQ, which means it now contains three addresses. Identical processing occurs at node 6 and it installs a route to node 2 with a hop count of 2 and node 4 as the next hop node. When node 9 receives the RREQ, it contains four addresses and has travelled three hops. Node 9 processes the RREQ and install routes using the accumulated information and as it is the target of the RREQ, it furthermore creates an RREP as a response. The RREP is sent back along the reverse route. Similar to the RREQ dissemination, every node forwarding the RREP adds its own address to the RREP and installs routes to node 9.

2.2.7.2 Route Maintenance

Route maintenance is the process of responding to changes in topology that happens after a route has initially been created. To maintain paths, nodes continuously monitor the active links and update the Valid Timeout field of entries in its routing table when receiving and sending data packets. If a node receives a data packet for a destination it does not have a valid route for, it must respond with a Route Error (RERR) message. When creating the RERR message, the node makes a list containing the address and sequence number of the unreachable node. In addition, the node adds all entries in the routing table that is dependent on the unreachable destination as next hop entry. The purpose is to notify about additional routes that are no longer available. The node sends the list in the RERR packet. The RERR message is broadcasted. The dissemination process is illustrated in figure 2.7. A link between node 6 and node 9 breaks and node 6 receives a data packet for node 9. When we say a link is broken, it could just be that the time stamp in the route table entry for a node timed out and the entry has become invalid. Node 6 generates an RERR message, which is propagated backwards towards node 2.

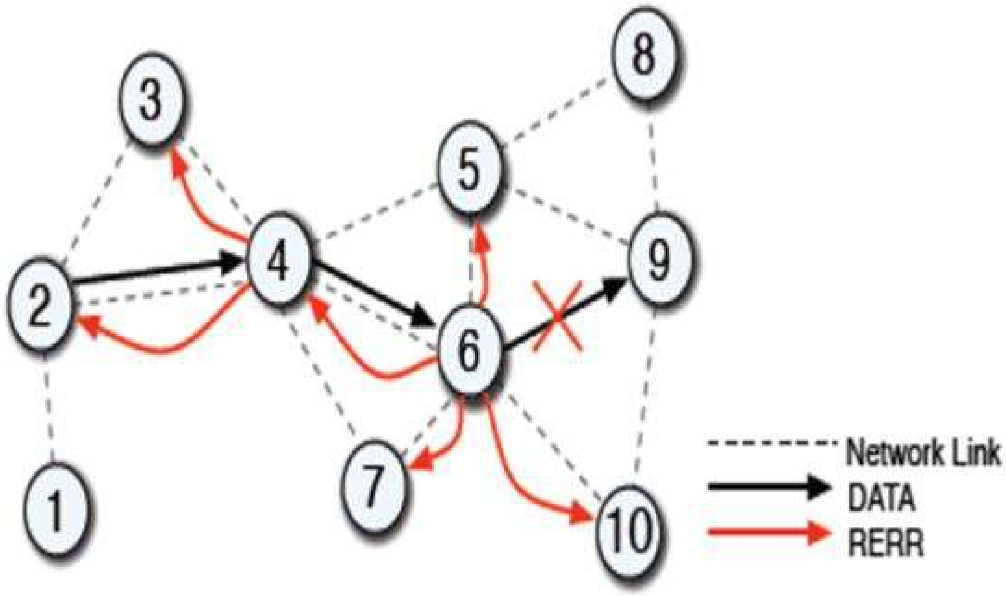


Figure 2.7 Generation and dissemination of RERR messages

The link between nodes 6 and 9 breaks, and node 6 generates an RERR. Only nodes having a route table entry for node 9 propagate the RERR message further. When a node receives an RERR, it compares the list of nodes contained in the RERR to the corresponding entries in its routing table. If a route table entry for a node from the RERR exists, it is invalidated if the next hop node is the same as the node the RERR was received from and the sequence number of the entry is greater than or equal to the sequence number found in the RERR. If a route table entry is not invalidated, the corresponding entry in the list of unreachable nodes from the RERR must be removed. If no entries remain, the node does not propagate this RERR further. Otherwise, the RERR is broadcasted further. The sequence number check mentioned is performed to only invalidate fresh routes and to prevent propagating old information. The intention of the RERR distribution is to inform all nodes that may be using a link, when a failure occurs. RERR propagation is guaranteed to terminate as a node only forwards an RERR message once. In figure 2.7, when the RERR is broadcasted, additional nodes beside node 4 and 2 will receive the message, for example, the nodes 5, 7, and 10. As none of these use nodes 6 as a next hop towards node 9, they all drop the RERR after processing the message. In addition to acting upon receiving a packet to a destination without a valid route table entry, nodes must continuously try to detect link failures to maintain active links.

2.2.8 Performance Study Simulation Tools

In a multi-hop wireless network, the evaluation of network performance can be done through analytical modeling, experimentation networks (testbeds) or software-based simulators. Analytical modeling involves certain simplifications and predictions of performance. Oversimplification and the wrong prediction will lead to false results. Testbeds are generally used to set up real application scenarios on real hardware. Since the experiment uses actual equipment, the results obtained are practically accurate. However, since all the actual equipment can be expensive, usually only small-scale applications with a smaller number of nodes are involved. For economical experiments, a simulation is the best option because it can be carried out without the real hardware. Moreover, simulation is more flexible in simulating MANET with a large queue size, large bandwidth and a large number of nodes.

In addition, simulation results are easier to analyze because information at critical points can be easily logged to diagnose network protocols.

Table 2.2 lists commonly used simulation tools (both open and commercial) for simulation tasks. [23, 24]

Table 2.2 : MANET Simulation Tools Comparison

Simulation Tools	**Type**	**Mobility**	**Simulation Technique**	**Interface**
NS-2	Open source	Support	Discrete Event Simulation	C++ / OTCL
NS-3	Open source	Support	Discrete Event Simulation	C++ / Python
OPNET	Commercial/Academic	Support	Discrete Event Simulation	C
OMNET++	Open source	Support	Discrete Event Simulation	C++
GLOMOSIM	Open source	Support	Discrete Event Simulation	Parsec (C -based)
QUALNET	Commercial	Support	Discrete Event Simulation	Parsec (C -based)

2.2.9 Selecting the Best Simulation Tool

The OMNET++ (Objective Modular Network Testbed in C++) was selected for network modeling and simulation tasks because of its availability and credibility. This simulation tool is a well-designed simulation package written in C++. It is open source and has extensive GUI support to make the tracing and debugging process easier compared to other simulation tools [25] Further, OMNET++ allows the user to design and develop a scenario of network simulation graphically. These features give a precise picture of the simulation at the state of execution. Scenario topologies can be generated as NED files.

In addition, OMNET++ supports hierarchical modeling. This feature allows zooming into the component level and displaying the state of each component during the simulation to observe the data flow and node communications.

The basic entity in OMNET++ is a module. Each module has an actual behavior and can be formed as a sub module. The modules can communicate with each other by sending and receiving messages via connections. OMNET++ can simulate a complex IT system, for example, queuing networks and hardware architecture. In addition, it has an INET extension framework to support wireless and mobile network simulations.

Many network researchers have used OMNET++ for simulation and performance evaluation of MANETs. [23, 24, 26]

2.3 Related Work

Traditional routing algorithms cannot satisfy requirements of a MANET, because of the topology dynamics and limited bandwidth characterizing these networks. Consequently, there is a lot of research related to existing routing algorithms, some of this researches are mention below:

In August 2021 R.K. Upadhyay,S. KumarandJ. Wasim evaluated the performance of AODV, DSR, DYMO, OLSR, Bellman Ford and ZRP routing protocols in term of different performance metrics; namely Average Throughput (bits/s), Average End to End Delay (s) and Average Jitter (s). the selected simulation tool was QualNet simulator. Group mobility model has been selected to show the realistic environment of the movement of mobile nodes under the varying mobility speed of nodes and CBR traffic pattern. The results of the study were that mobility speed has impacted on the performance of routing protocols with increasing mobility speed. DSR and Bellman Ford routing protocols performed good with varying mobility speed in term of Average Throughput. OLSR has outperformed other routing protocols in case of Average End to End Delay. Bellman Ford and OLSR routing protocols performed well in term of Average Jitter with varying mobility speed in comparison to other routing protocols under the group mobility. [27]

In 2019 Yasmin Jahir and others presented a survey on routing protocols in disaster area networks mostly in terms of the network layer. Most of the studied protocols involve either pure Mobile Ad hoc Networks (MANETs) or a hybrid combination of MANETs with other types of networks (Cellular, Infrastructure etc.). The discussed protocols have been evaluated to show improvements in terms of delay, overhead, energy efficiency, throughput, topology and mobility models to help researchers determine what has been investigated, which protocol to use and what are the trade-offs. [28]

In 2016 Varun G.Menon and others analyzed the importance of reliable and continuous communication in disaster recovery and reconstruction works. The data obtained from the questionnaires and personal interviews confirmed that reliable and continuous communication was very important in disaster management services. They also discussed a number of methods given by various researchers for communication in disaster environments. Most of these methods could not guarantee reliable data delivery at the destination device. Using the broadcast property of the wireless medium the proposed Reliable Routing Technique was used for data delivery between two mobile devices in highly mobile ad hoc Mobile Information Systems [29]

In February 2016 S.Sivagurunathan and K.Prathapchandran discussed which of the routing protocols; such as reactive or proactive has better performance in disaster scenario. In order to implement the test bed, they selected a real area in Uttarakhand state, India where the disaster occurred recently hence so many civilizations had vanished due to lack of communication and failure in recovery. The simulation study evaluated the performance of both AODV and DSDV. Based the observation; authors made AODV is suitable for such scenario because packet delay is relatively low compared to DSDV. Though number of nodes is increased, it does not reflect any change in delay. In packet delivery ratio, AODV achieved better result compared to DSDV and throughput also high for AODV compared to DSDV. According to their results; they recommended the use of AODV protocol for such emergency and rescue scenario due to its performance in terms of throughput, Packet Delivery Ratio and End to End Delay. [30]

In 2015 DG Reina and others presented a survey on multihop ad hoc network paradigms for disaster scenarios. They highlighted their applicability to important tasks in disaster relief operations. Their paper reviewed the main work found in the literature, which employed ad hoc networks in disaster scenarios. In addition, they discussed the open challenges and the future research directions for each different ad hoc paradigm. [31]

In 2014 LE Quispe and LM Galan discussed which of the routing strategies for mobile MANETs: proactive, reactive or hierarchical, has a better performance in such scenarios. By selecting a real urban area for the emergency and rescue scenario, the authors calculated the density of nodes and the mobility model needed for the validation study of AODV, DSDV and CBRP in the routing model. The NS2 simulator has been used for their study. They also show that the hierarchical routing strategies are better suited for this type of scenarios. [32]

2.4 Summary

In this chapter, the fundamentals and essential background of MANET were provided and Details of MANET characteristic, applications, challenges and routing protocols are discussed. In addition, a review of the related work was presented.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter discusses the methods and alternatives that have been used from the Beginning until the end of the project. In methodology's chapter also will discuss the Simulation that is used in this project. The simulation tool used is OMNet++ Simulator. Other than that, this chapter also will review the methodology of research and flowchart of the project that can help a better understanding of visualization in the Project implementation.

As mentioned before, MANET in disaster area require special requirements because of random movement nature of people and vehicles during such case, which cause random mobility in network, also number of nodes is not fixed, because rescue team members may frequently join or leave the area. For these reasons, MANET routing protocol need to be selected carefully in our studied disaster case.

3.2 Proposed Scenario: Case Study

The motivation for the work is formed after the flooding which occurred in a suburb in the city of Khartoum in SUDAN called Marabee Al-shareef.

Marabee Al-shareef is a small rural area reside in the Khartoum state along the Nile river and belong to the east-Nile region, latitude of 15° and longitude of 32°. Figure 3.1 illustrate Marabee Al-shareef Map.

Figure 3.1 Marabee Al-shareef Map.

This area has been hit by a hazardous flood in 2013, the water was 1 meter above the ground, there was 4,000 houses were destroyed, and tens of people have been killed. Figure 3.2 illustrate satellite image and topography of Marabee Al-shareef.

Figure 3.2 Satellite image and topography of Marabee Al-shareef

In order to design a MANET in this area under the study, we determined a squire area that covers and exceeds the required area; in order to facilitate the calculation and simulation, and to cover the extension of the area expected to occur in the future. Figure 3.3 shows the area on which the network is designed.

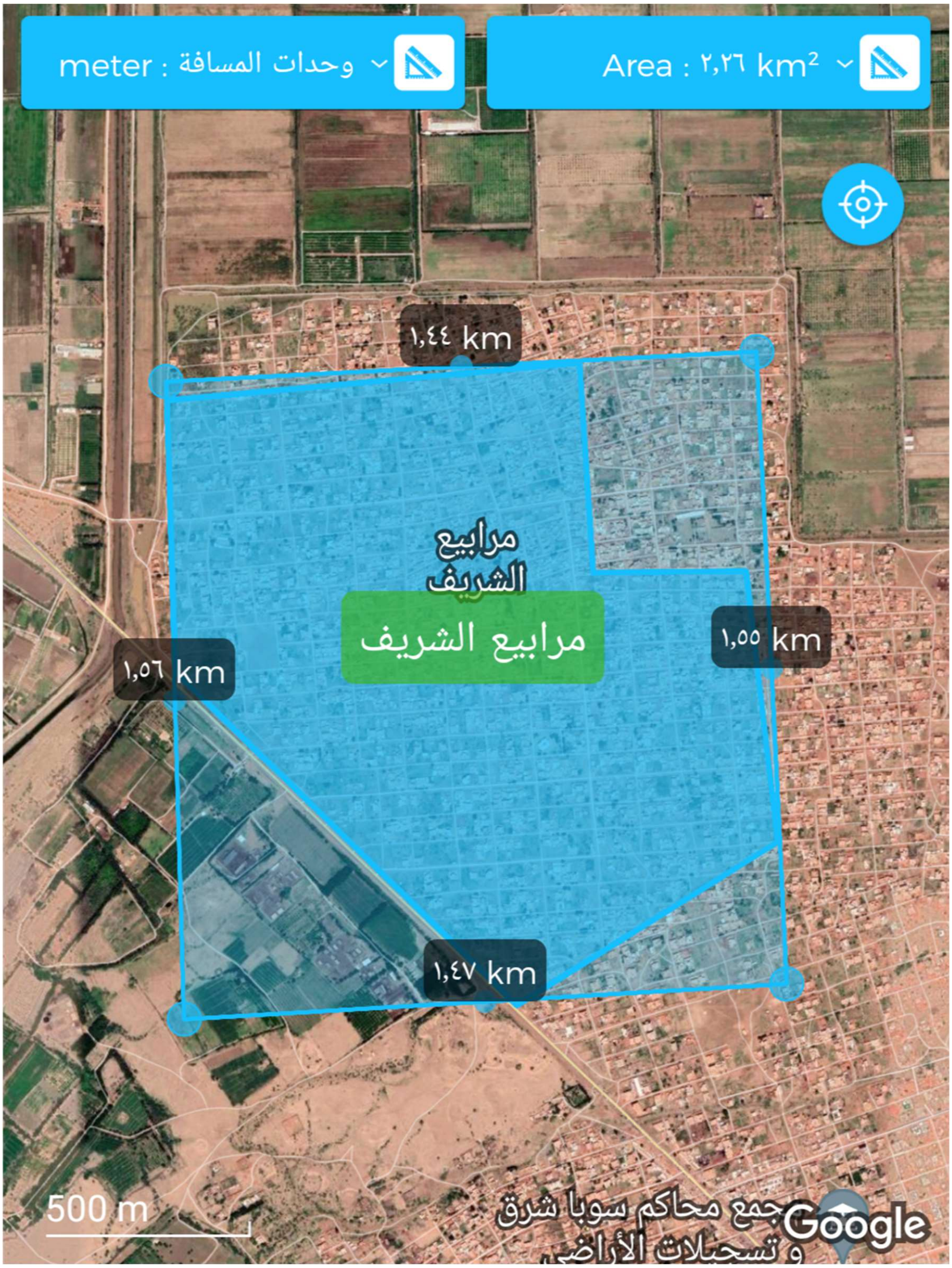


Figure 3.3 Area on which the network is designed.

3.3 Methodology of The Research

Our methodology to achieve the desired objective will follow the below steps:

Step 1: Setup OMNET++4.6 and INET 3.3.0 frame work.

Step 2: Implement the two protocols in the simulator in our study area (which has the area of 1500 * 1500 m).

Step 3: Execute the simulation in different scenarios (different number of nodes and different speeds).

Step 4: Get the result from the result file and draw them with Excel.

Step 5: Compare the results of the two protocols in different cases and determine which of each has a better performance in disaster situation.

3.4 Project Flowchart

The next figure illustrates the Flowchart of Routing Selection Scheme.

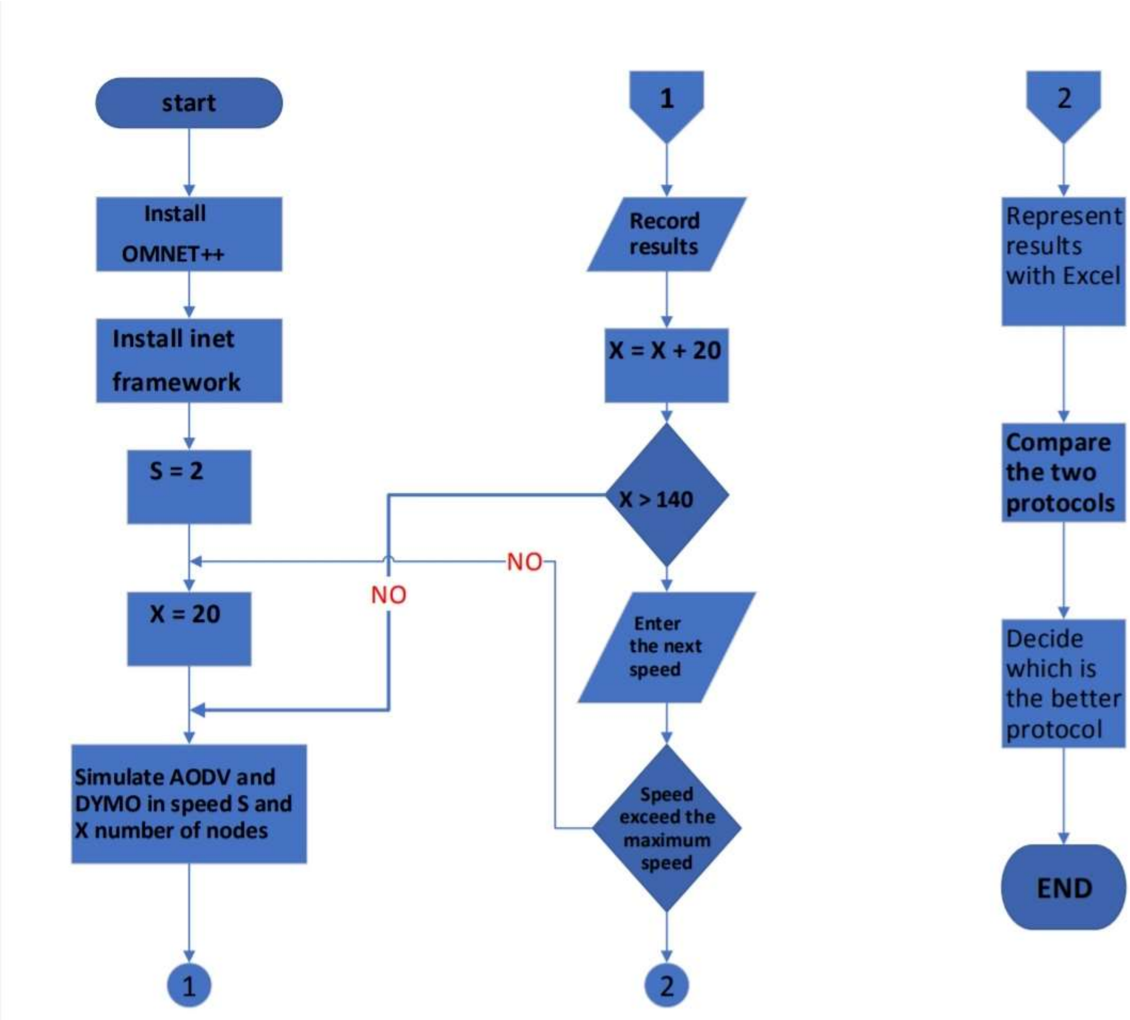


Figure 3.4 Flowchart of Routing Selection Scheme.

The variables S and X in the above flowchart represent the speed of nodes and number of nodes respectively. The maximum speed of nodes in our research is set to 20 m/s.

3.5 Project Framework

Figure 3.5 shows an overview of the project framework.

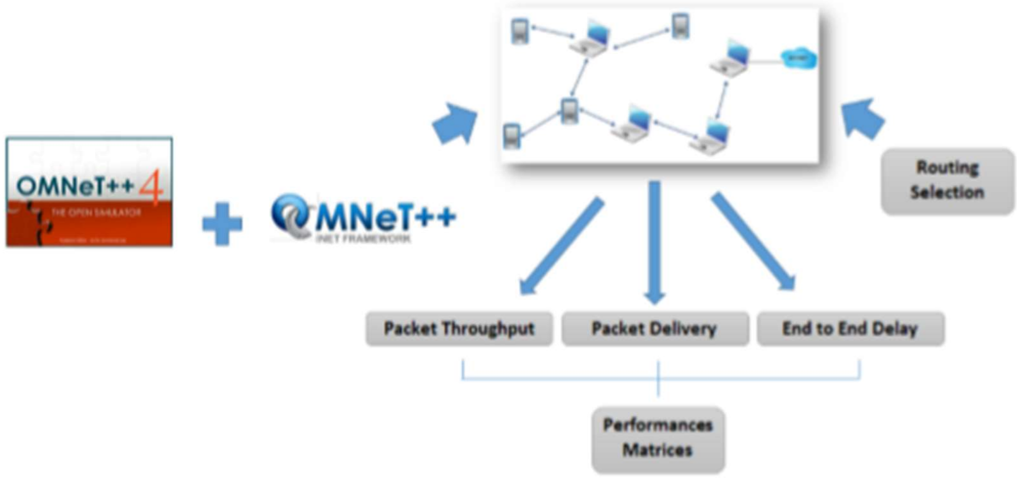


Figure 3.5 Performance Analysis of MANET Routing Protocol

3.6 Simulation

OMNeT++ (Objective Modular Network Test bed in C++) can be defined as a modular component-based C++ simulation library and framework, primarily for building network simulators. Besides, OMNeT++ has extensive GUI support and due to its modular architecture, the simulation kernel and model can be embedded easily into the user application. OMNeT++ is composed of (a) Graphical network editor. A graphical network editor (GNED) to allow graphical topology build, creating files in the Network Description (NED) language (b) Kernel library. A simulation kernel library contains definitions of objects used for the topology creation (c) Command line interface; Includes a Graphical and command line interface for simulation execution (d) A model documentation tool for documentation [33]. The reason to use OMNeT++

version 4.6 for this project because OMNeT++ is an open-source tool that can directly install on Windows 7. Besides, this simulation tool provides to small scale network, which is very suitable to make implementation on the MANET environment.

After the installation of OMNeT++ version 4.6, INET framework imported to OMNeT++ simulation. The purpose of INET framework is to make the implementation and configuration of MANET easier because INET framework is required for the MANET environment in OMNeT++. The file of INET is contains all related files that are needed for the simulation, for instance, AODV, DYMO files with the need to some algorithm. This file is important as the Performance Analysis of MANET Routing Protocols. Therefore, the implementation of OMNeT++ and INET will help to make this project become successfully onwards.

Figure 3.6 OMNeT++ 4.6 Simulation Icon

Figure 3.7 INET Framework Icon

3.7 Summary

This chapter brings about the concept of research methodology that was used in this project, the framework of the project and the flowchart of the algorithm used in the routing selection scheme technique. All of this discussion will help to get more understanding about the project itself.

CHAPTER FOUR

IMPLEMENTATION AND RESULTS

4.1 Introduction

This chapter discussed configuration on the network simulator that is employed in this project which is OMNET++ version 4.6 and implementation of Performance Analysis of MANET Routing Protocol by Varying Speed and Network Load. This phase is important to ensure that the objective of this project is achieved. The evaluation and results of the performance metric are also shown in this chapter.

4.2 Specifications of Simulation Hardware

The below table shows the specification of the hardware which we use it to run the simulation.

Table 4.1 : The Hardware/Software Setup

Operating System	Windows 7
Processor	Intel Core i5 M460 – 2.53 GHz
Memory	6 GM RAM
Compiler	Dev ++
Simulation Environment	OMNeT++ 4.6

4.3 Installation of OMNeT++ Version 4.6

A platform that used to install OMNeT++ version 4.6 is windows7. The steps below show the installation of OMNeT++ version 4.6. All the steps below must be followed one by one to get a successful installation.

Step 1: Download the OMNeT++ 4.6 windows 64 bits version from the link https://omnetpp.org/download/old

Step 2: Extract the download file into C:\

Step 3: After the extracting process completed, select mingwenv file in omnetpp 4.6 and run the file.

Step 4: Next, type 3 commands in mingwenv to install omnetpp into the system.

i. . setenv

ii. ./configure

iii. Make

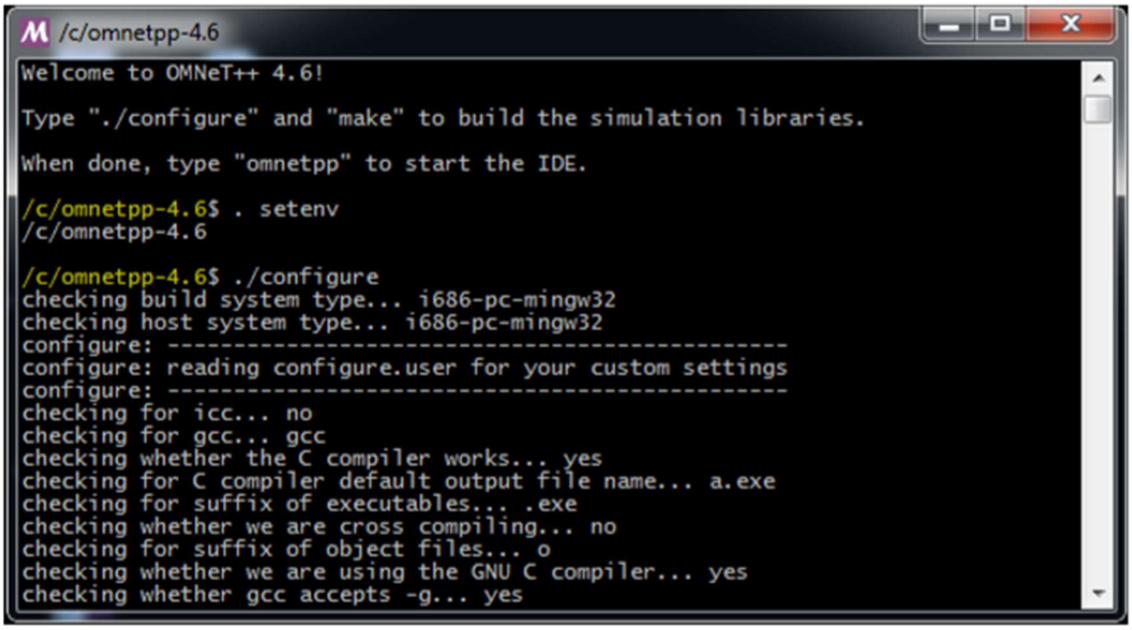


Figure 4.1 Commands which are used in installation OMNeT ++ 4.6

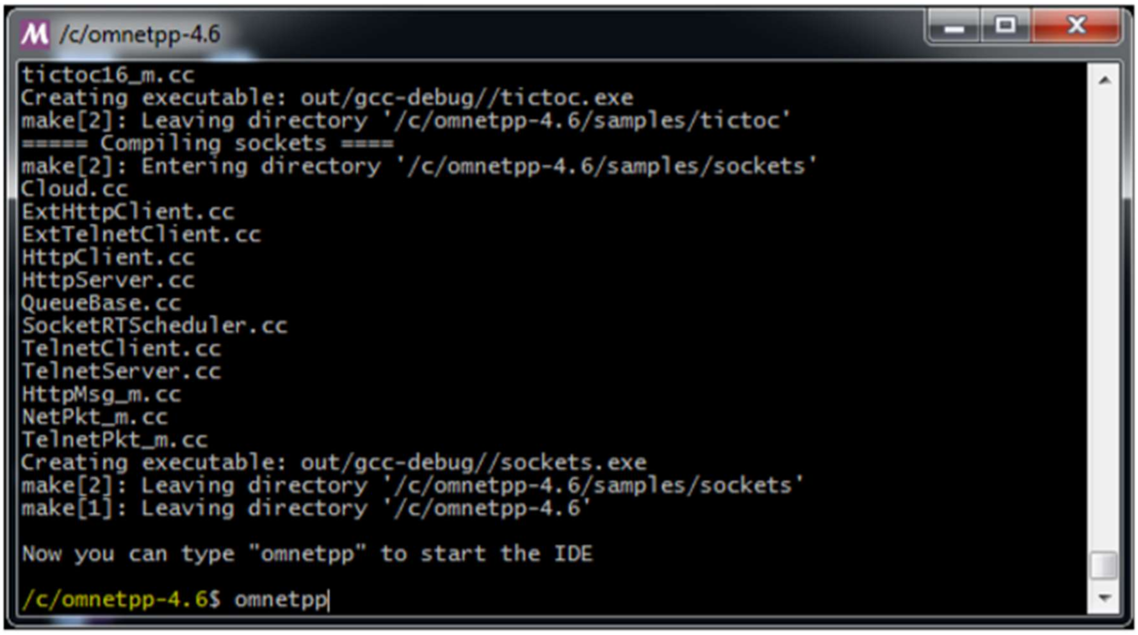


Figure 4.2 OMNeT++ 4.6 Successfully installed

Installation is completed with command omnetpp, then the IDE of OMNeT++ 4.6 is started. After all, the installation OMNeT++ version 4.6 is a success, the INET framework is imported. This is because this framework consists of all files of MANET requirements and components. This project used INET 3.3.0. This framework is imported in OMNeT++ version 4.6.

4.4 Installation of INET 3.3.0 Framework

To successful installation of INET framework, all the steps below must be followed one by one.

Step 1: Download the INET sources from https://inet.omnetpp.org/

Step 2: Unpack it into the directory of your choice.

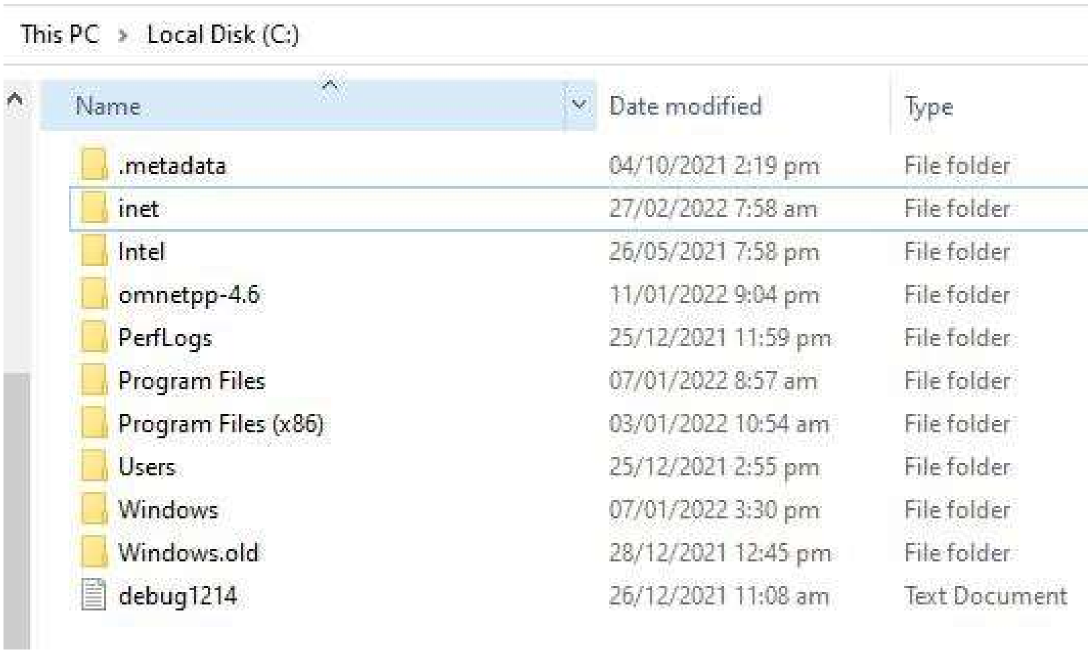


Figure 4.3 INET file after download

Step 3: Start the OMNeT++ IDE and import the project via File -> Import -> Existing Projects to the Workspace. A project named INET should appear.

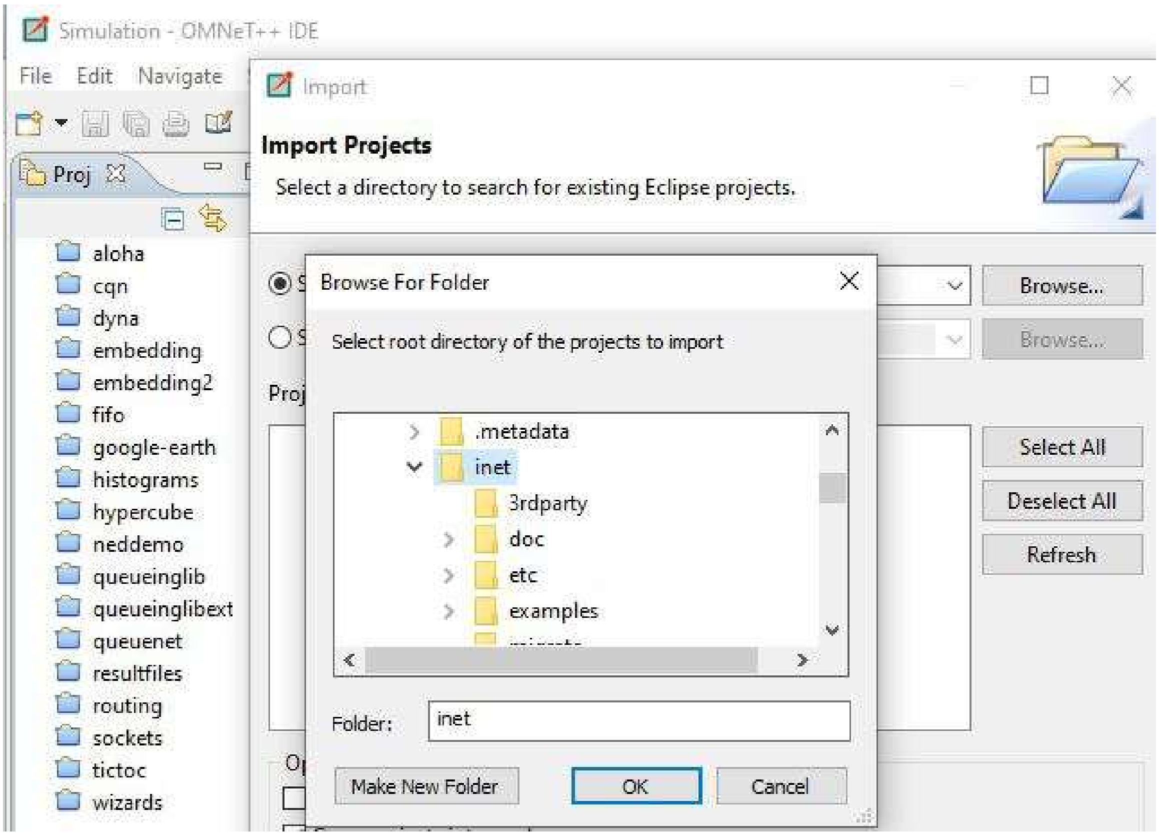


Figure 4.4 Import of INET framework in OMNET++

Step 4: Build with Project -> Build, or hit Ctrl+B.

4.5 Simulation Environment

One of the ways we can evaluate the two routing protocols is to compare quantitative performance metrics measured while conducting experimental evaluations. These metrics must measure the suitability and performance of the routing protocol. IETF Mobile Ad Hoc Working Group has proposed several metric. In this study is used OMNeT++ as a simulation tool to compare these two on-demand routing protocols. In this comparison the same parameters are utilized for each simulation scenario; these parameters are summarized in table 4.2.

Table 4.2 : Simulation Parameter

System Parameters	**Reflection in Real Scenario**	**Values Utilized**
Number of nodes	Rescuers involved in rescue operation	20,40,60, 80, 100, 120, 140
Mobility Model	Rescuers can move along a zigzag line from one rescue point to another by the way rescue points are uniformly distributed over the given affected area	Random Waypoint Mobility Model
Simulation Time	Denoting the overall time of rescue operation	400 Sec
Simulation Size	Denoting the covering area for rescue operation	1500m x 1500m
Protocols	Used for exchange emergency related information	AODV, DYMO
Data Rate	Denoting amount of digital data moved from one evacuation point to another	2Mbps
Message Size	Denoting the unit of data that is originated from one evacuation point to another	512 bytes

Wi-Fi ad hoc	Rescuer's nodes are in ad hoc mode so that easy deploy at anywhere and need of centralized structure	802.11b
Traffic	Type of data that is transmitted during the rescue operation.	UDP
Node Speed	Denoting the moving object speed	2 m/s, 5 m/s, 12 m/s, 20m/s
Transmission Range	Denoting the actual amount of transmit power of radio frequency produced by the rescuer's node	250 m

Table 4.2 shows the setup of the simulation environment. In this simulation, nodes are divided into four types (Human, vehicle, drone and helicopter) and each type node has a different speed. These four types of heterogeneous nodes move randomly on 1500(m) x 1500(m) fields. The reason for using an area of 1500(m) x 1500(m) is because the area simulating the actual size in the real MANET environment for our studied area. For the simulations, the Random Waypoint Mobility Model [34] is used. It is a popular model for simulations, because of its wider availability and simplicity and suitable for disaster nature. Message type is set to UDP; because real time communication is needed in disaster situation. Massage size is set to 512 bytes. Lastly, in disaster recovery, troops can be reinforced on battlefield, and victims can also increase suddenly which cause increase number of the node on the network. So, to figure out the effect of this change, simulations are executed on 20 nodes up to 140

nodes with the same environment parameter. Simulation run in 400 s in order to be enough to obtain results.

4.6 Configuration of MANET Routing Protocols in OMNet++

4.6.1 Omnetpp.ini File

This file indicates the main function of the simulations that consists of simulation time limit, declaration number of nodes, transmission range, speed of mobility, and set the area of the simulation area.

Algorithm: Simulation Environment

Simulation time = 400 (s) // Simulation time is fixed

Number of host = X // Based on user

Area of simulation = 1500 (m) x 1500 (m) // Area is fixed

Transmission range = 250 (m) // Transmission is fixed

Speed of mobility = S (m/s) // Based on moving object

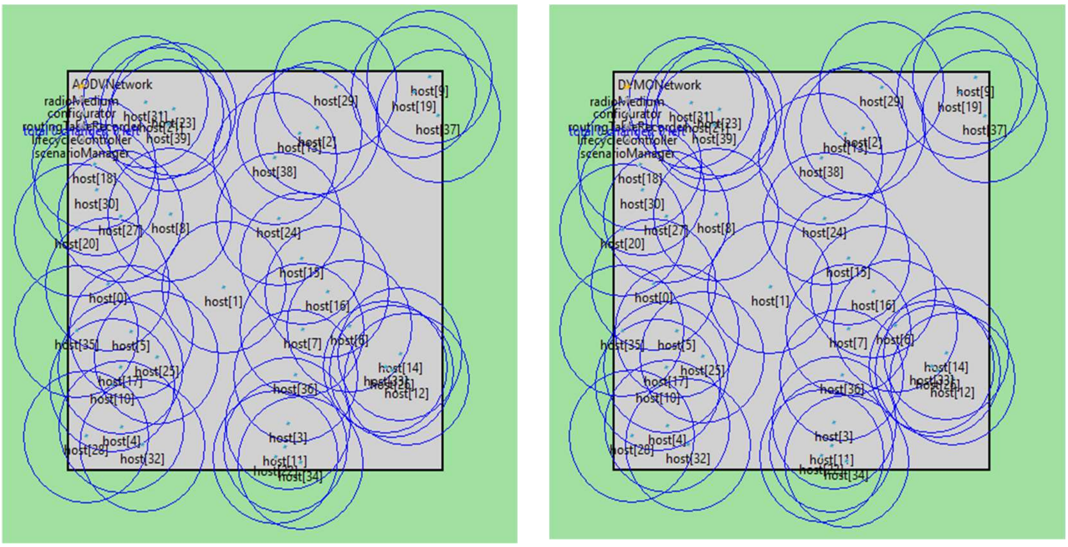
The declaration can change. For example, the declaration number of the host (X) can be changed from 20 up to 140, speed (S) varying from 2 m/s, 5 m/s, 12 m/s and 20 m/s as explained in the simulation parameter before. Simulation time and area of the simulation are fixed during the whole simulation.

4.6.2 Simulation of AODV and DYMO Routing Protocols

Figure 4.5 up to figure 4.11 show Simulation of 20 up to 140 Node in the area of 1500m x 1500m using AODV and DYMO protocols.

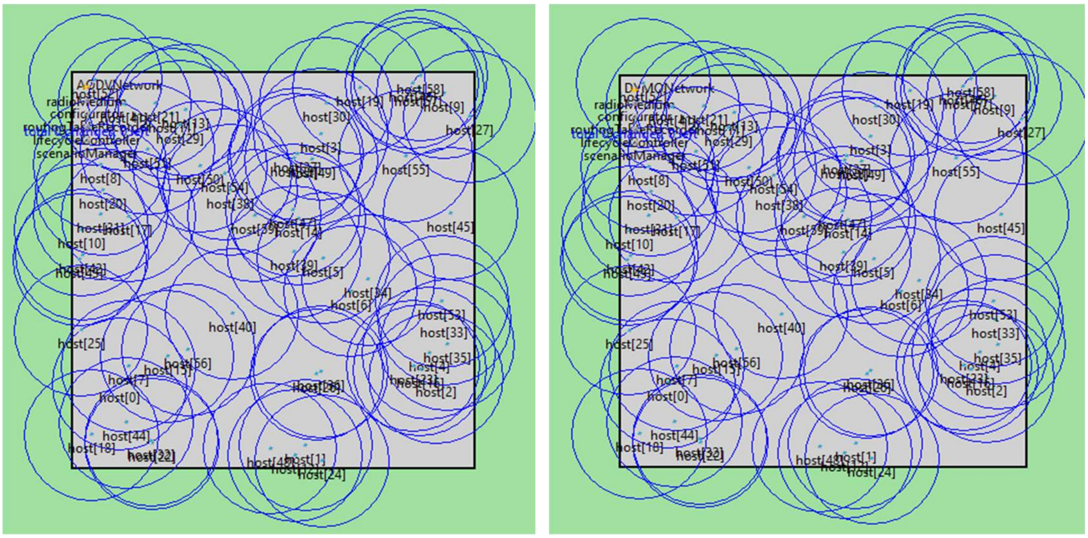
a **b**

Figure 4.5 Simulation of 20 Number of Nodes (a: AODV, b: DYMO)



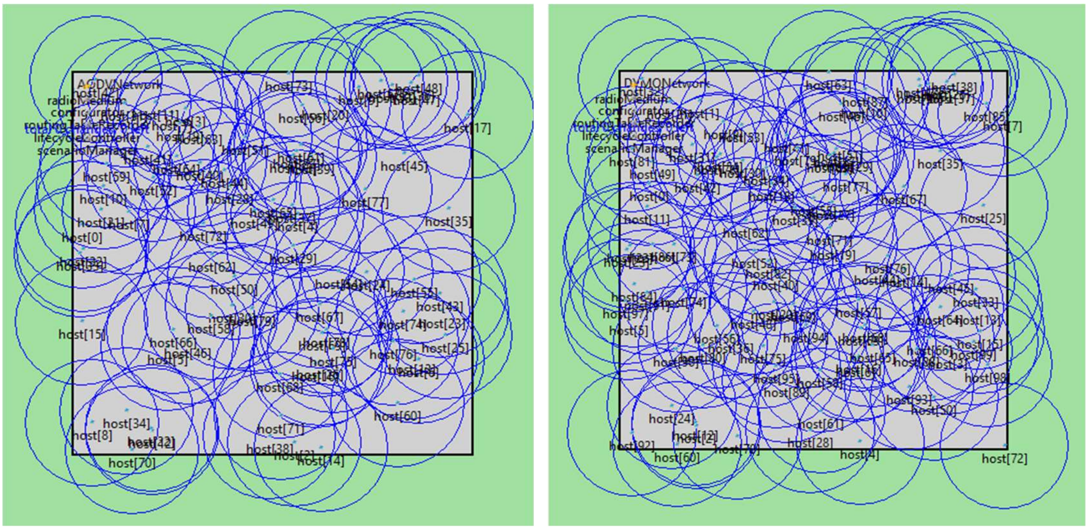
a **b**

Figure 4.6 Simulation of 40 Number of Nodes (a: AODV, b: DYMO)



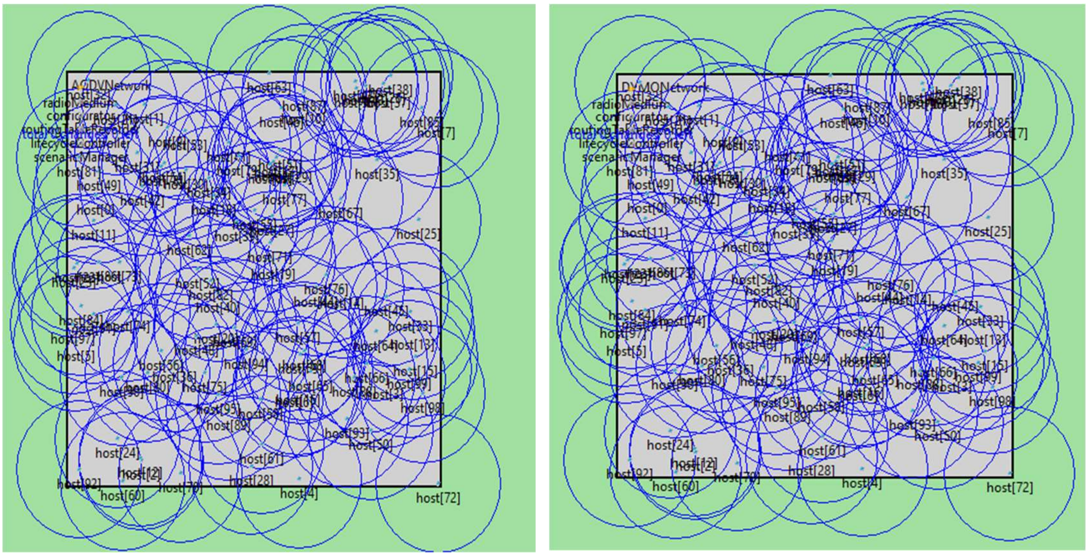
a b

Figure 4.7 Simulation of 60 Number of Nodes (a: AODV, b: DYMO)



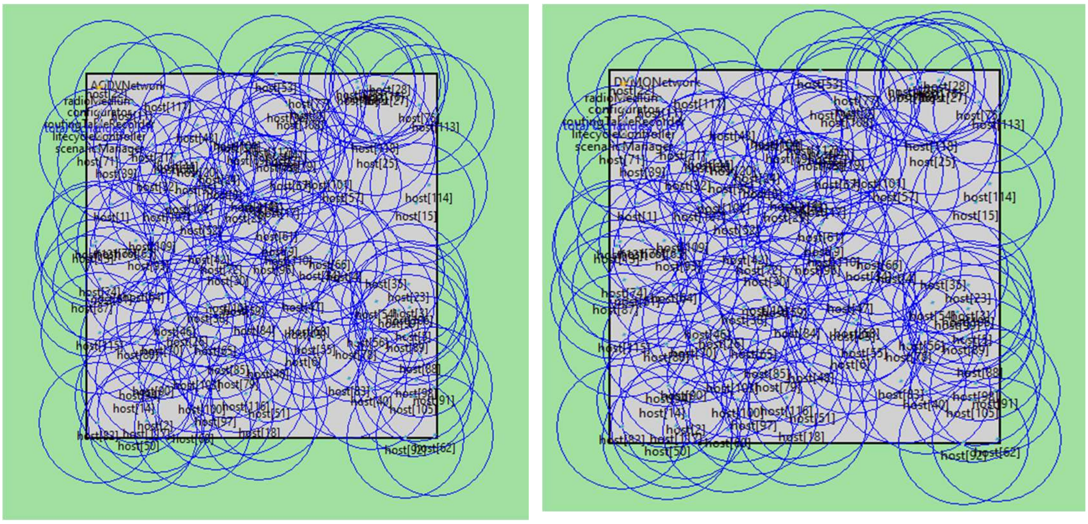
a b

Figure 4.8 Simulation of 80 Number of Nodes (a: AODV, b: DYMO)



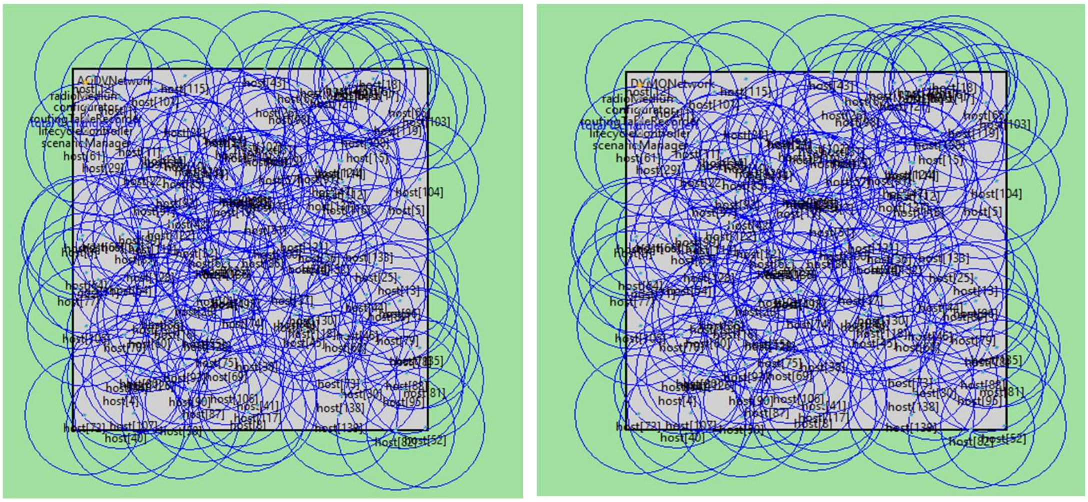
a b

Figure 4.9 Simulation of 100 Number of Nodes (a: AODV, b: DYMO)



a b

Figure 4.10 Simulation of 120 Number of Nodes (a: AODV, b: DYMO)



a b

Figure 4.11 Simulation of 140 Number of Nodes (a: AODV, b: DYMO)

4.7 Results

The suitability of the MANET routing protocol is decided on the basis of the performance parameters. In this project, three parameters are used for analyzing the performance of MANET routing protocol; Packet Delivery Ratio, Average End to End Delay and Throughput. For evaluated the results, there is a formula that gives the specific answer.

4.7.1 Packet Delivery Ratio

Packet delivery ratio represents the ratio of the total received packets at the destination to total initiated packets from the source node. It represents both the completeness and correctness of the routing protocol. In this project, the ratio is compared the number of nodes 20 up to 140 with different speeds which are 2 m/s, 5 m/s, 12 m/s and 20 m/s. Figure 4.12, 4.13, 4.14 and 4.15 show the Packet Delivery Ratio with Varied the number of nodes. In the scenario of speed 5m/s, 12m/s and 20m/s respectively.

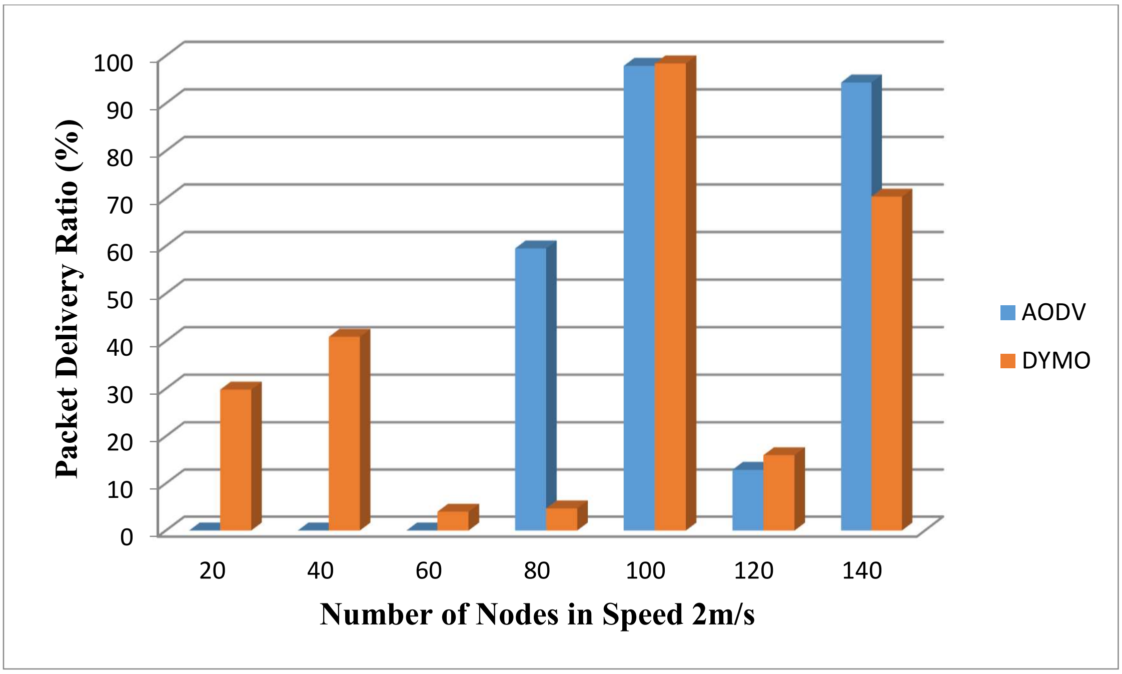


Figure 4.12 Packet Delivery Ratio with Varied Number of Nodes in Speed 2 m/s (Human)

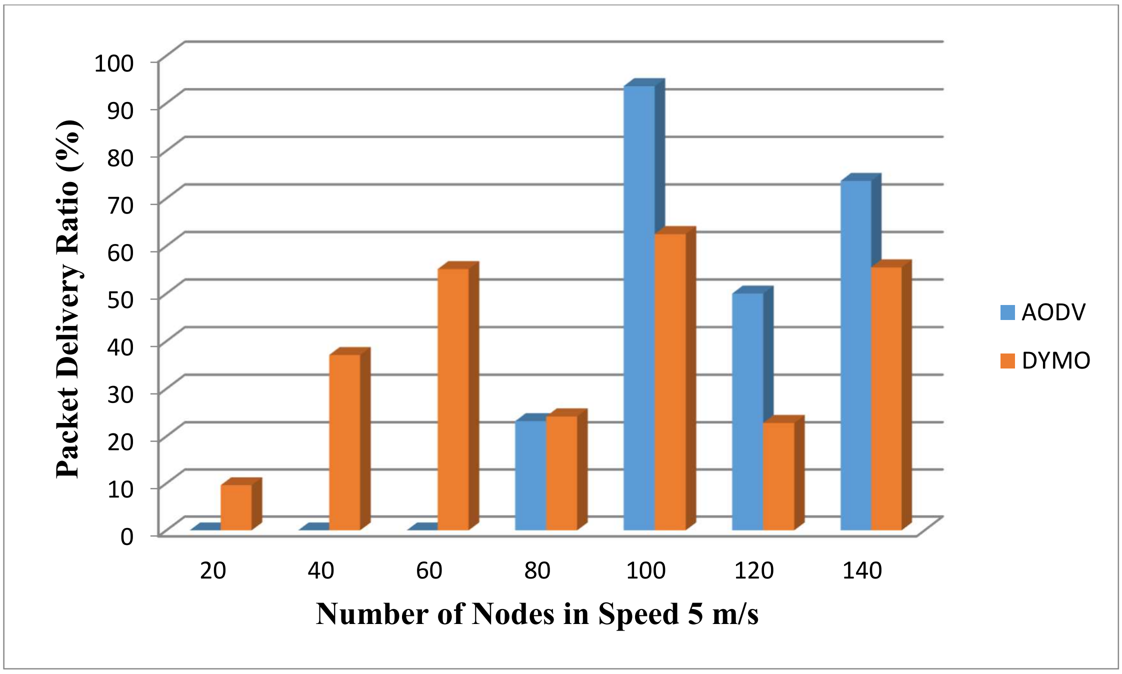


Figure 4.13 Packet Delivery Ratio with Varied Number of Nodes in Speed 5 m/s (Vehicle)

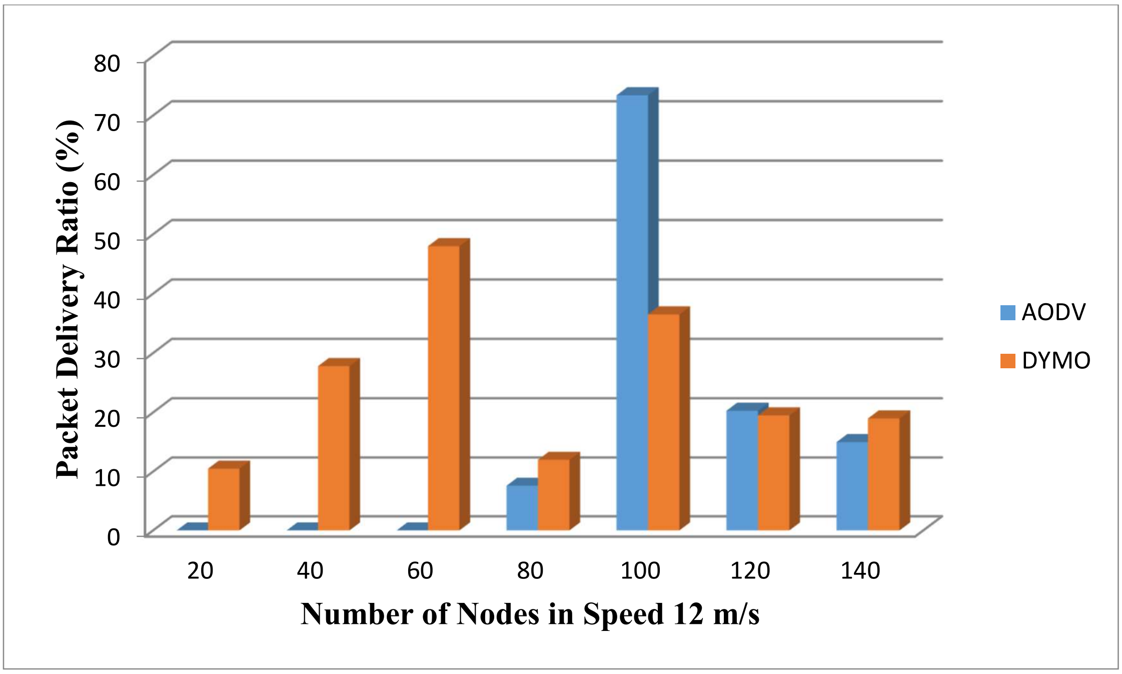


Figure 4.14 Packet Delivery Ratio with Varied Number of Nodes in Speed 12 m/s (drone)

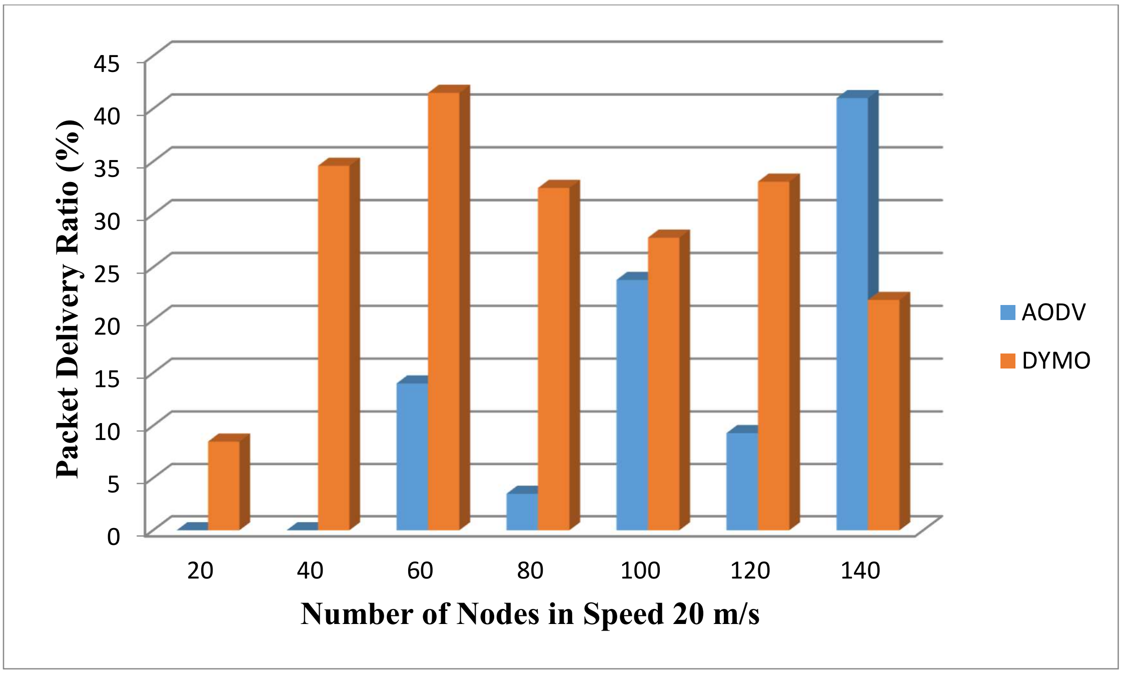


Figure 4.15 Packet Delivery Ratio with Varied Number of Nodes in Speed 20 m/s (helicopter)

As it can be seen from the above figure 4.12 DYMO exceeds AODV in term of PDR when the node density is low, for high node density the opposite is true. In figure 4.13, DYMO achieve higher PDR than AODV when number of nodes is less than 100. In contrast, AODV outperform DYMO when number of nodes is more than 100. Also, in figure 4.14 AODV exceeds DYMO in PDR when the number of nodes is 100 and 120 nodes, otherwise, DYMO exceeds AODV. Finally, in figure 2.15 DYMO PDR – almost- outperform AODV in all cases. We easily can say that DYMO shows better packet delivery ratio than AODV in the majority of the results.

4.7.2 Packet Throughput

It is defined as the total number of packets delivered over the total simulations time. In this project, the throughput is compared the number of nodes 20 up to 140 with different speeds which are 5 m/s, 12 m/s and 20 m/s.

Figure 4.16, 4.17, 4.18 and 4.19 shows a comparison between both routing protocols on the basis of throughput vs. the number of nodes at different speed. Throughput here represents the number of messages delivered per one second, and the combination of receiving data and control packets.

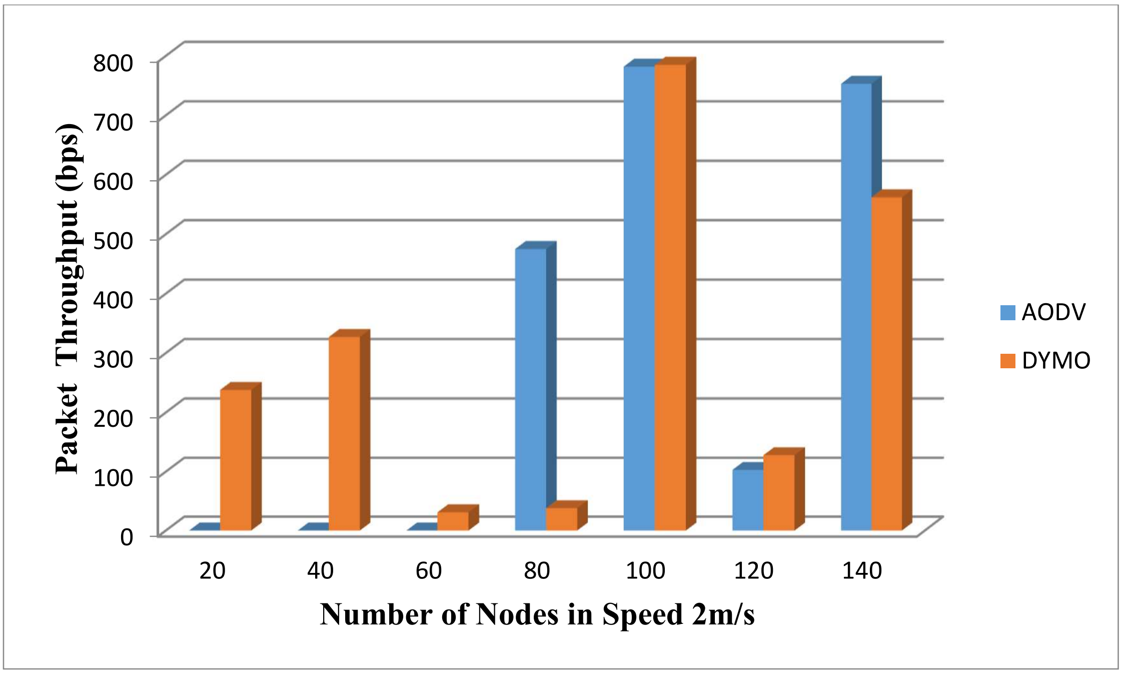


Figure 4.16 Packet Throughput with Varied Number of Nodes in Speed 2 m/s (Human)

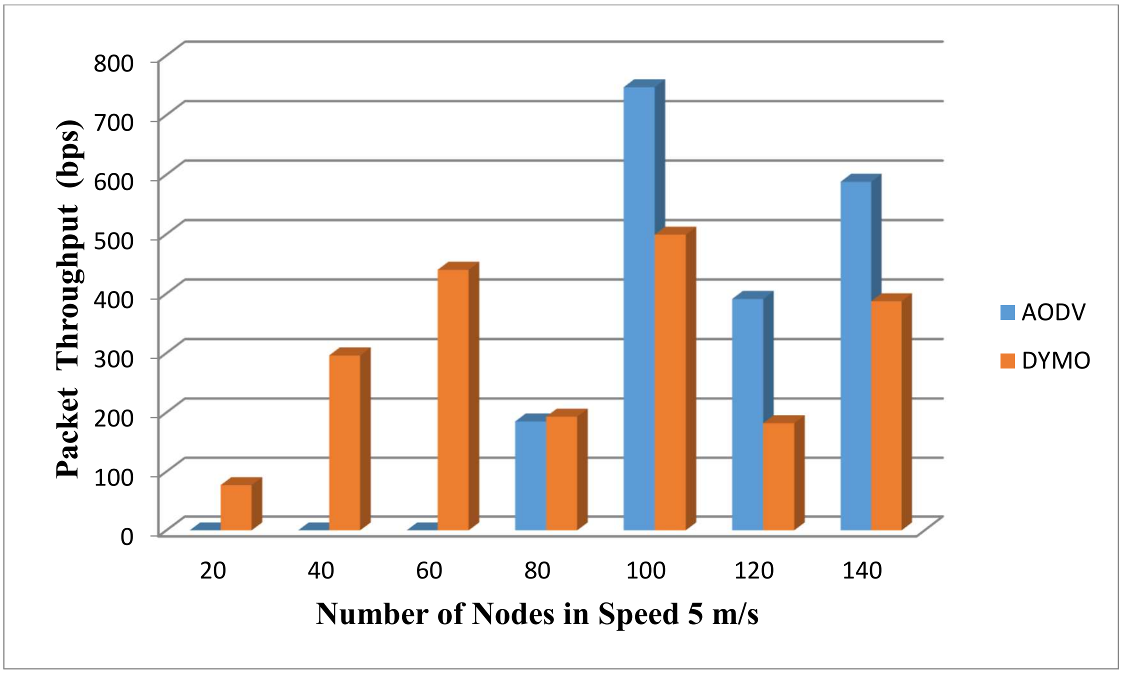


Figure 4.17 Packet Throughput with Varied Number of Nodes in Speed 5 m/s (Vehicle)

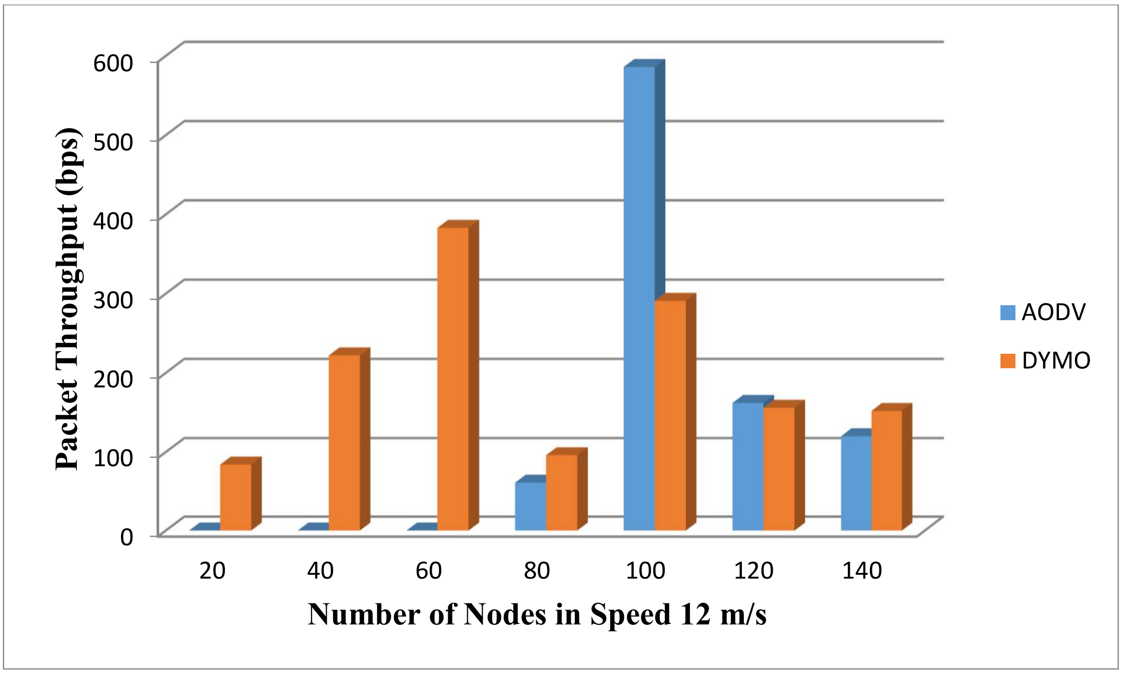


Figure 4.18 Packet Throughput with Varied Number of Nodes in Speed 12 m/s (drone)

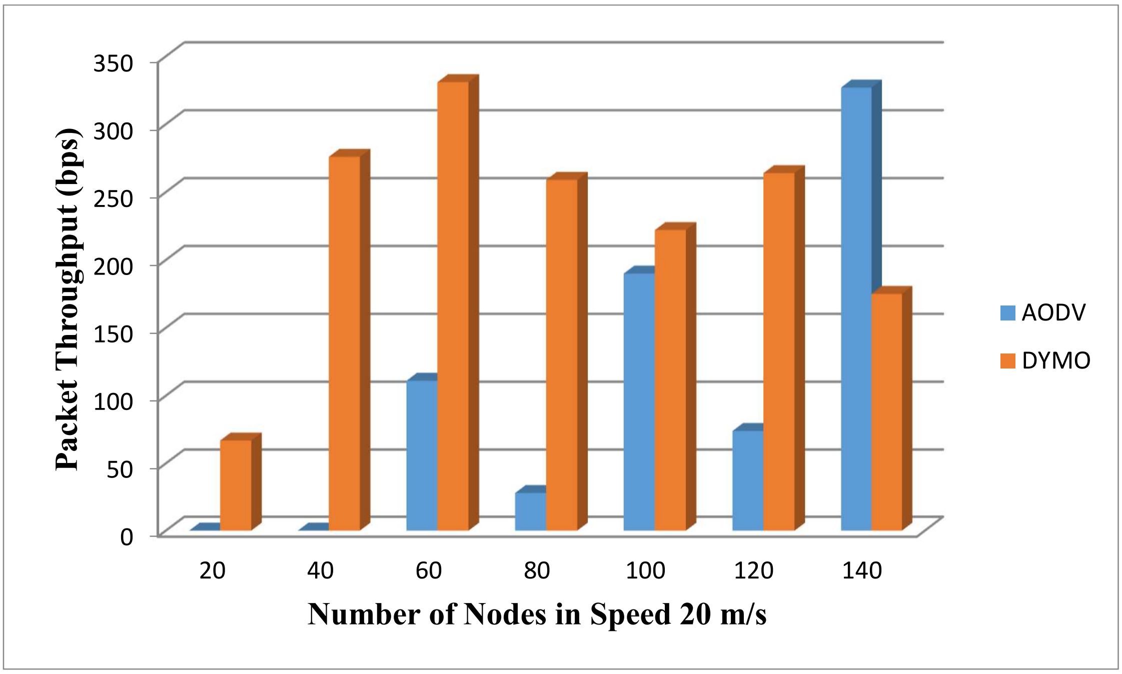


Figure 4.19 Packet Throughput with Varied Number of Nodes in Speed 20 m/s (helicopter)

In speed of 2 m/s DYMO exceeds AODV in term of throughput when the node density is low, for high node density the opposite is true. In speed of 5 m/s DYMO achieve higher PDR than AODV when number of nodes is less than 100. In contrast, AODV outperform DYMO when number of nodes is more than 100.in speed of 12 m/s AODV exceeds DYMO in term of throughput when the number of nodes is 100 and 120 nodes, otherwise, DYMO exceeds AODV. Conclusively, when nodes speed is 20 m/s DYMO Throughput – almost- outperform AODV in all cases.

4.7.3 Average End to End Delay

Average End to End Delay is the average time taken by a data packet to reach from source node to a destination node. It is the ratio of total delay to the number of packets received.

Figure 4.20 up to figure 4.23 shows the end-to-end delay for AODV and DYMO. with figure 4.20 showing delay for the number of nodes in speed 2 m/s, 4.21 showing delay for the number of nodes in speed 5 m/s, figure 4.22 for the number of Nodes in speed 12 m/s and figure 4.23 for the number of nodes in speed 20 m/s.

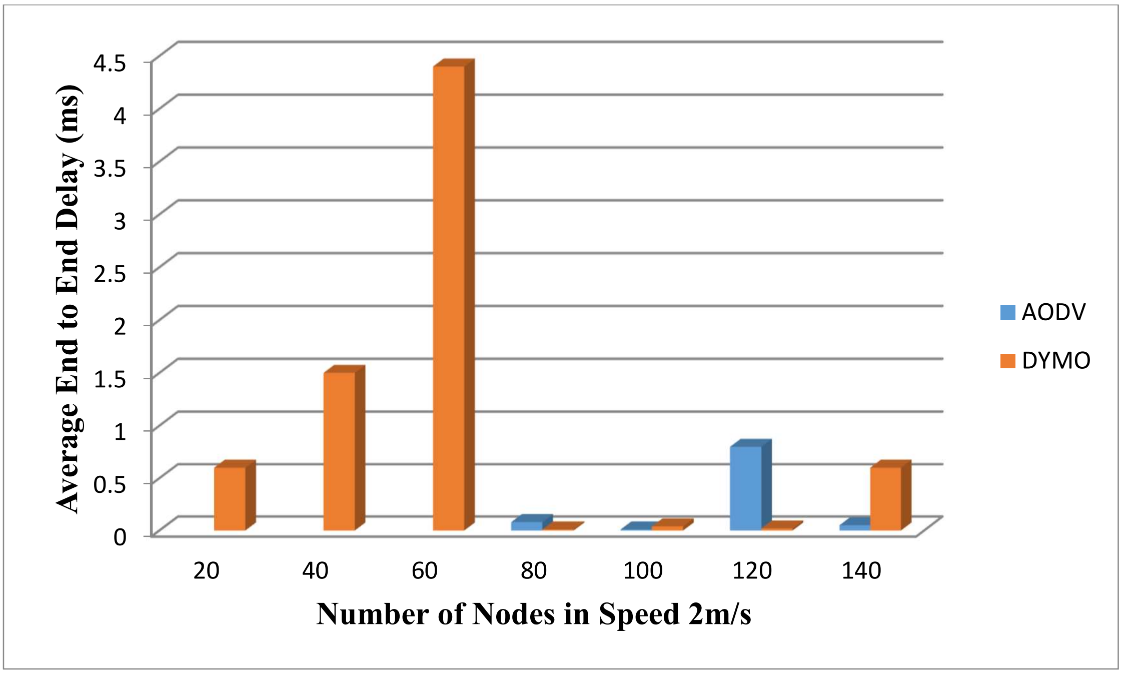


Figure 4.20 Average End to End Delay with Varied Number of Nodes in Speed 2 m/s (Human)

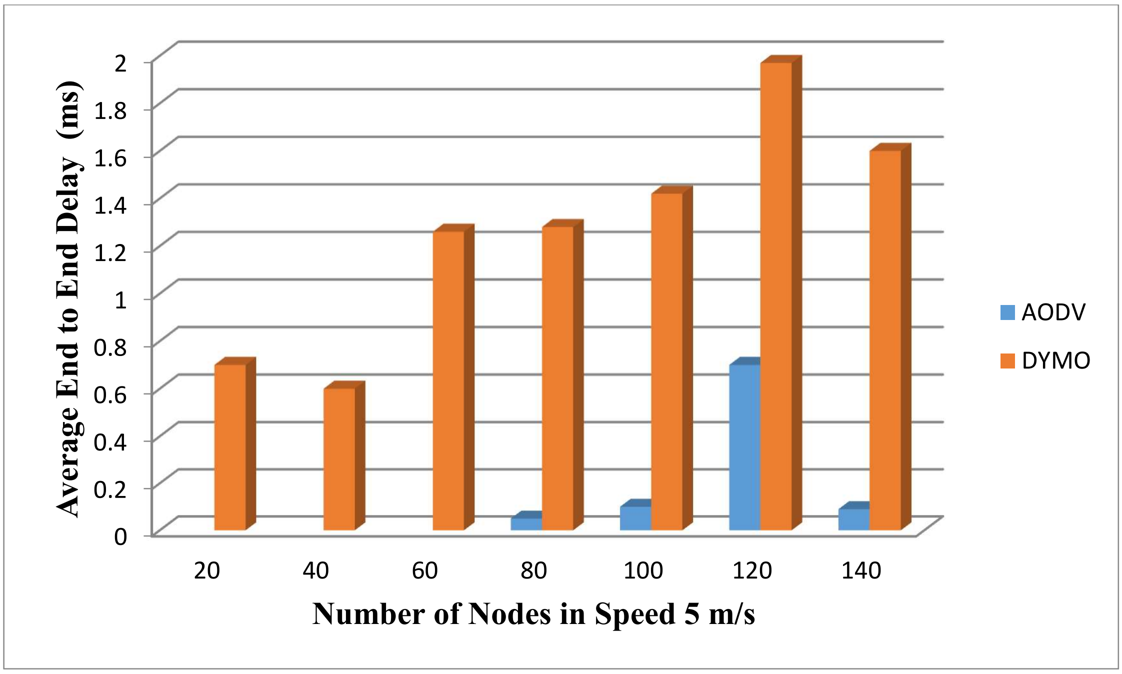


Figure 4.21 Average End to End Delay with Varied Number of Nodes in Speed 5 m/s (Vehicle)

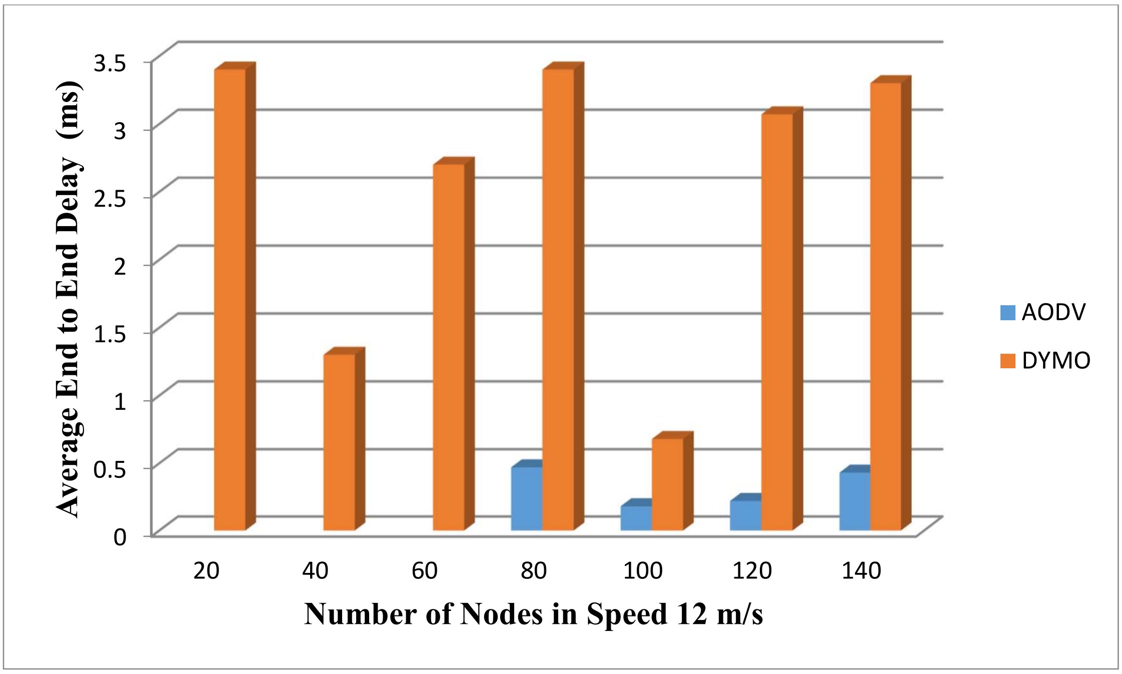


Figure 4.22 Average End to End Delay with Varied Number of Nodes in Speed 12 m/s (drone)

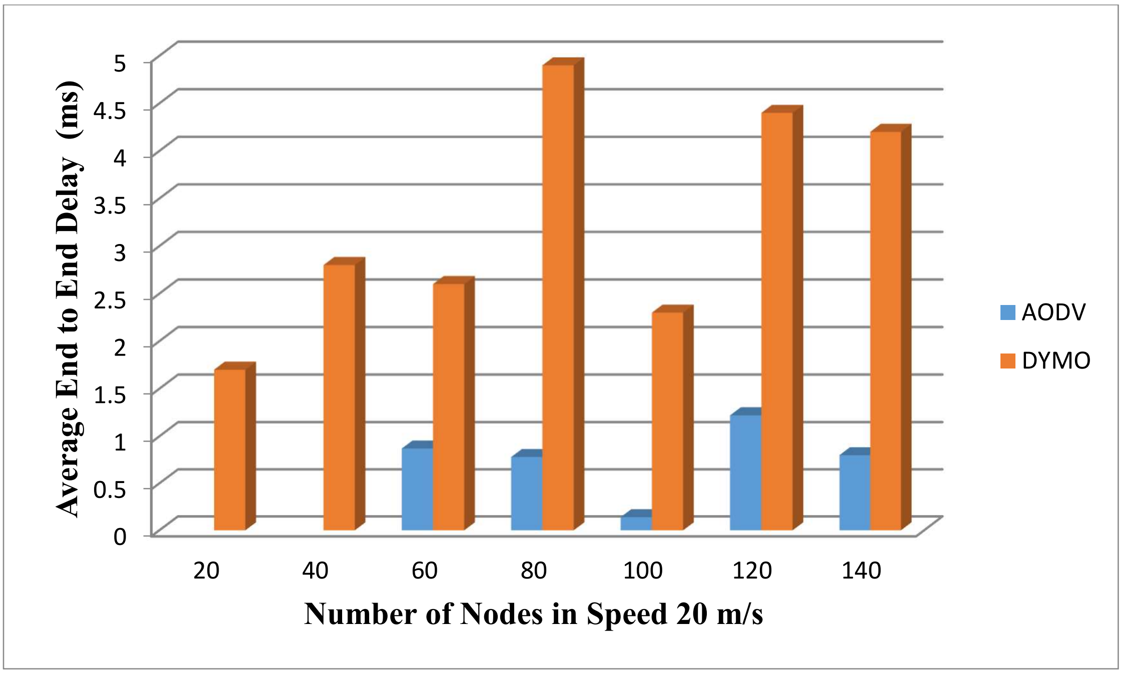


Figure 4.23 Average End to End Delay with Varied Number of Nodes in Speed 20 m/s (helicopter)

Almost in all cases, the delay of DYMO is increasing compared to the AODV. It was observed that delay is increasing with the increased in speed. In the Average Delay perspective, the performance of AODV can be considered better than DYMO.

The impact of node density in the performance metrics is represented in a fluctuation in the values of PDR, throughput and average end-to-end delay in all speeds. That kind of fluctuation occurs because of the random way mobility model which make difficulty in the prediction of the results. Although performance metrics fluctuation affects DYMO as well as AODV; effect in DYMO is not great; so, we can say that DYMO show steady performance when compared to AODV.

4.7.4 Deep Performance Analysis

For more understanding of the behavior of the two protocols to know which is the best; we analyzed the average of various performance metrics based on number of speeds in different number of nodes. figure 4.24, 4.25 and 4.26 shows number of nodes against average performance metrics based on the number of speeds, the metrics are PDR, throughput and average end to end delay respectively.

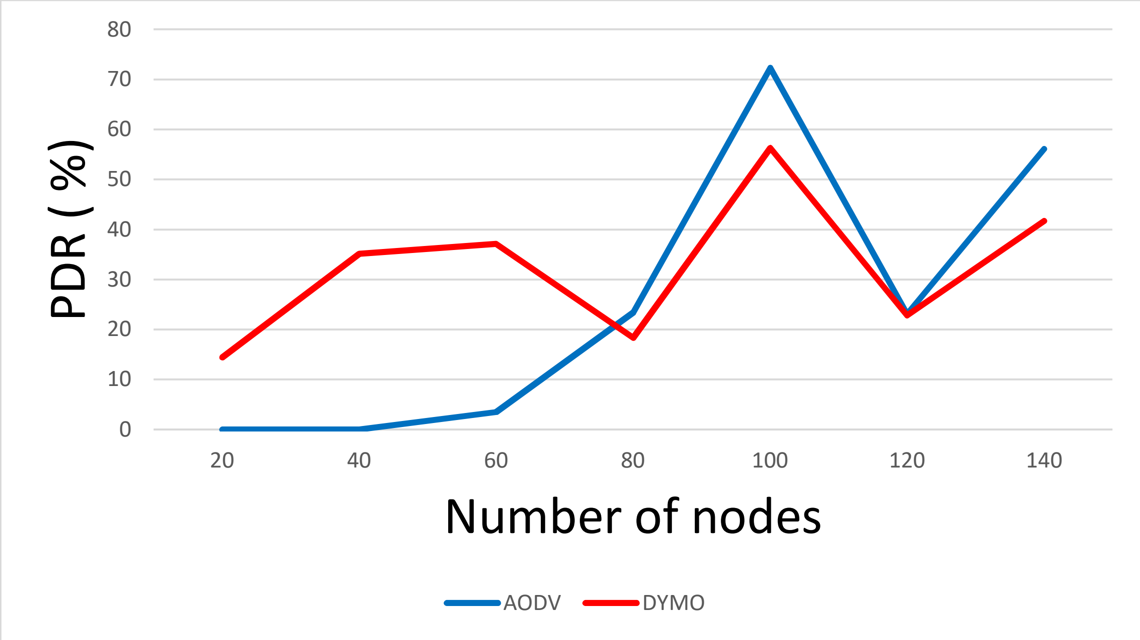


Figure 4.24 The average Packet delivery ratio based on different Speeds with Varied Number of Nodes.

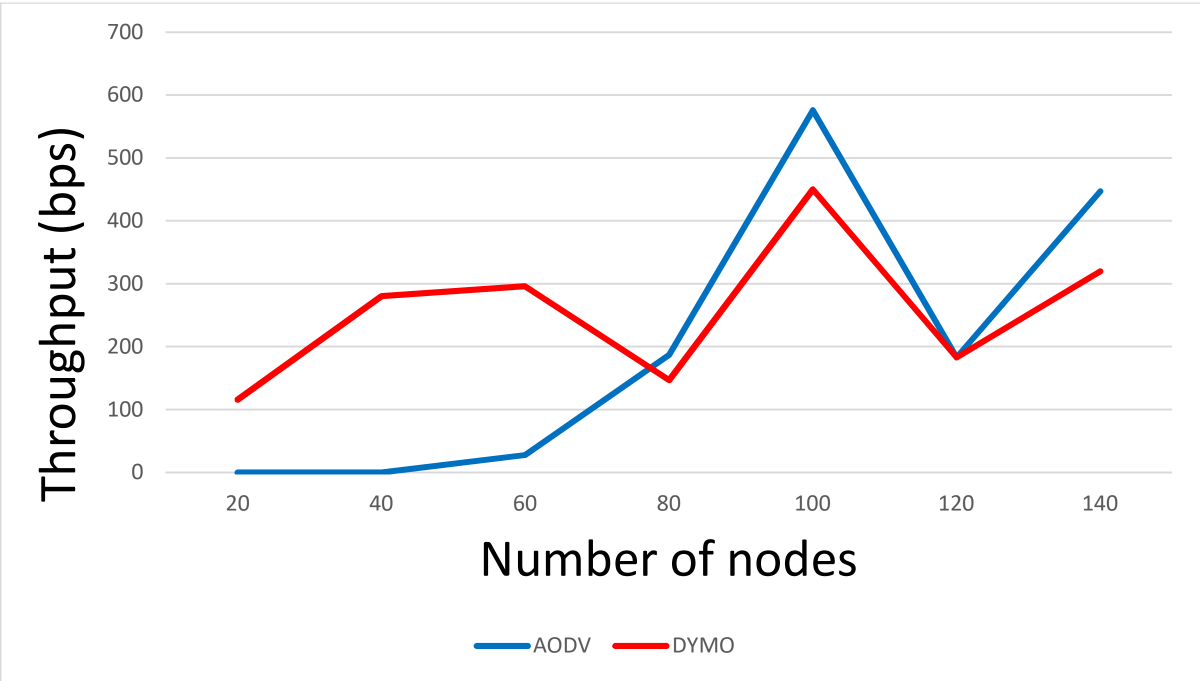


Figure 4.25 The average Throughput based on different Speeds with Varied Number of Nodes.

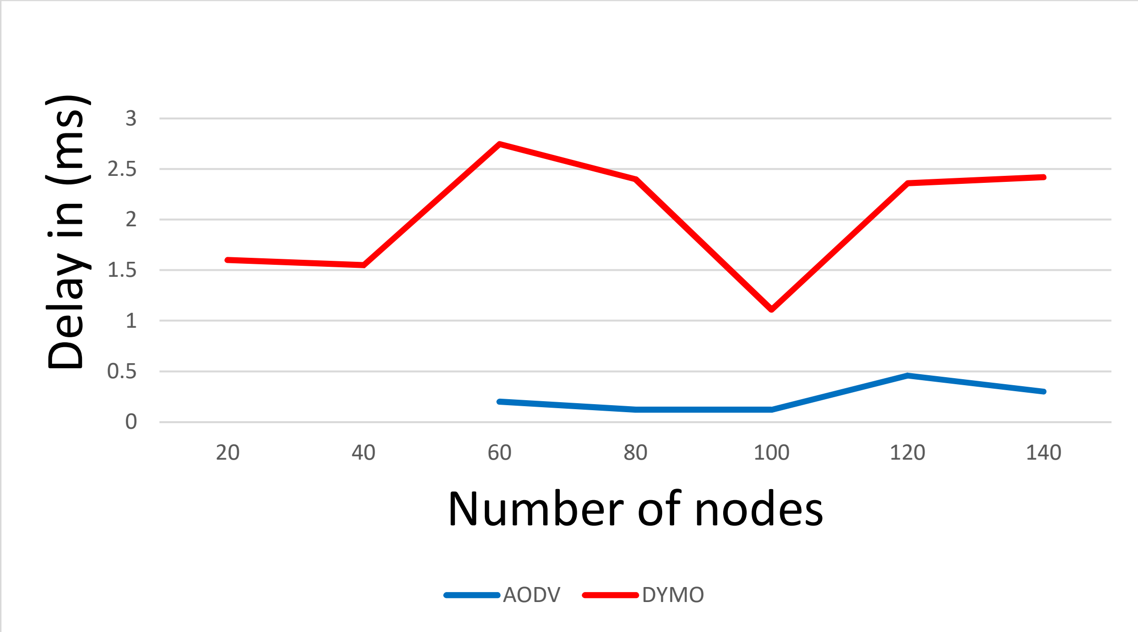


Figure 4.26 The average of average End to End Delay based on different Speeds with Varied Number of Nodes.

As can be clearly seen in figure 4.24 and figure 4.25 AODV achieve very low – approximately 0- amount of average PDR and average throughput when the number of nodes is below 60, while DYMO give acceptable amount of PDR and throughput regardless of the number of nodes. That behavior can influence on the disaster case where few number of connected devices become available – especially in the first moments and last moments of the catastrophic- DYMO will act better than AODV. In figure 4.26 an average of the average end-to-end delay of DYMO is increasing compared to the AODV.

We also analyzed the average of various performance metrics based on different number of nodes in different Speeds. Figure 4.27, 4.28 and 4.29 shows speeds against average performance metrics based on the number of nodes on PDR, throughput and end to end delay respectively.

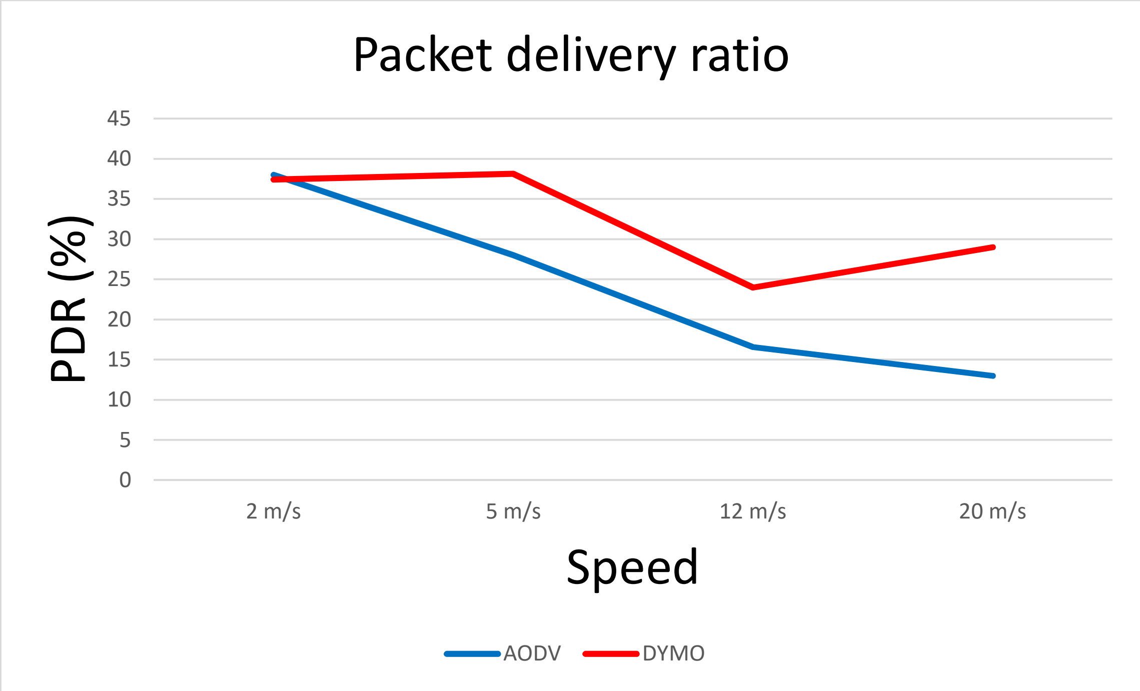


Figure 4.27 The average Packet delivery ratio based on different Number of Nodes with Varied Speeds.

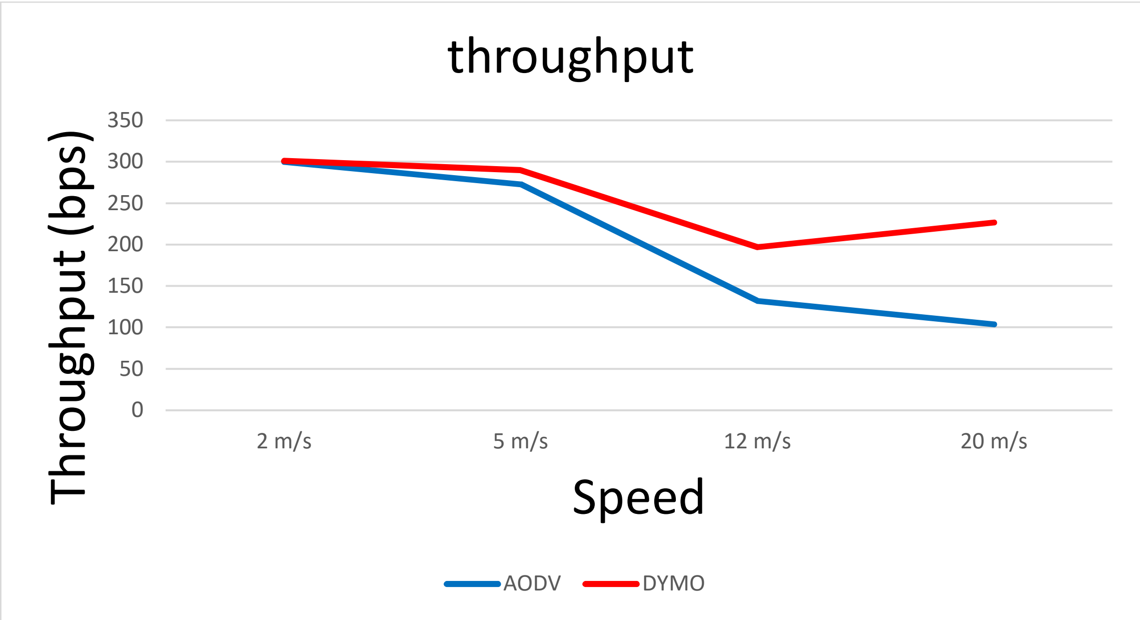


Figure 4.28 The average Throughput ratio based on different Number of Nodes with Varied Speeds.

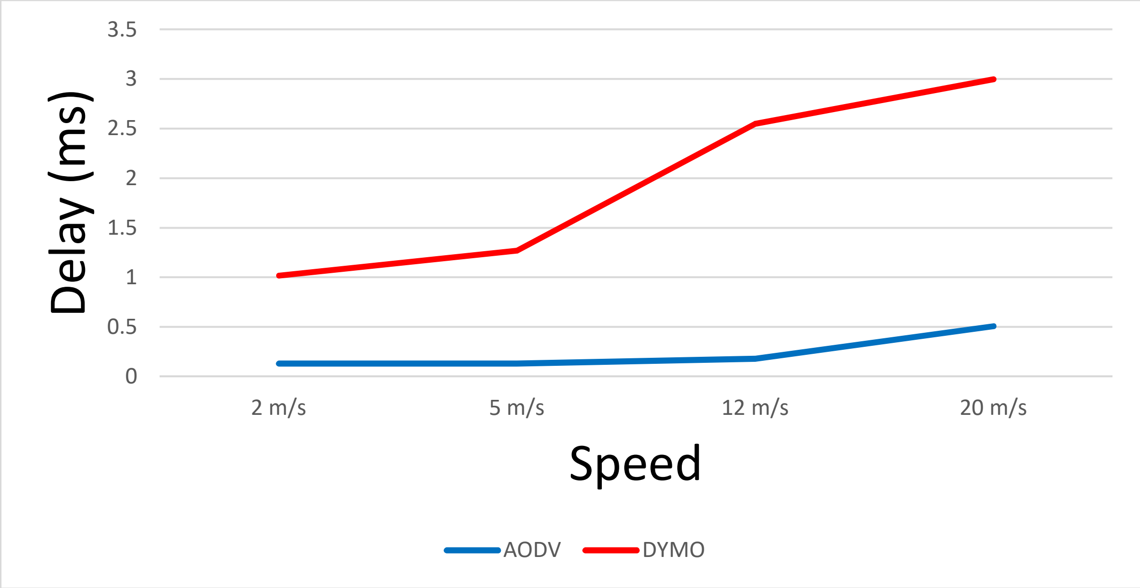


Figure 4.29 The average of average End to End Delay ratio based on different Number of Nodes with Varied Speeds.

As can be clearly seen in figure 4.27 and figure 4.28 average PDR of DYMO and AODV and average throughput based on different number of nodes decrease with the increase of speed, but DYMO outperform AODV. In figure 4.29 average of average end to end delay is directly proportional to speed either for AODV or DYMO, but AODV is better than DYMO in the term of average end to end delay in all speeds.

According to the above results we recommend to use DYMO protocol in our study case; because it achieves stability and good performance especially with low speeds and low number of nodes, which make it cope with the variation of the node density and speed in the disaster area.

4.8 Summary

In the process of selecting the better between the two protocols to be implemented in the disaster situation in Marabee Al-shareef it is clearly shown from the above results in the previous section that DYMO outperform AODV thus DYMO will be the best choice to operate in the mentioned disaster scenario. Despite of that DYMO is worse than AODV in term of average end to end delay but it's still acceptable amount of delay (don't exceeds a few milliseconds).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The simulation of MANET is one of the significant ways in order to spread the knowledge to the people and in order to let people understand about the operation of MANET. In the real world, MANET gives more benefits to users that are residing in a restriction situation, such as, disaster area and military were obtaining the wired network would be very impractical. This also could help to save a person that gets involved in a disaster area. For this purpose, the performance analysis of the MANET routing protocol needs to be done to make sure that it can provide a better quality of service in routing selection. So that devices can communicate effectively. Therefore, based on the discussion the performance analysis technique is proposed to be done in simulation rather in the real world. The results of the simulation are shown in the previous chapter. The results are evaluating the performance of packet throughput, packet delivery ratio and average end to end delay after analysis of MANET routing protocols by varying speed and network load on OMNet++. Implementation in a real-world environment requires time and consumes a high cost to develop. Thus, this simulation is employed to cope with these problems operatively. At the end of the research, we recommend to use DYMO protocol to be operated in the MANET, which deployed in Marabee Al-shareef.

5.2 Recommendations

There are some suggestions that can be made for future work, which can be used to upgrade the efficiency and performance of this project. First of all, hybrid speeds of nodes can be applied in single scenario to make it more realistic. Secondly, this simulation can be used for realistic scenario by incorporate of some factors, which are involved with the real-world environment such as path loss model, population, service type…ETC.

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