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# Mobility-aware dynamic broadcasting algorithm to enhance the performance of routing protocol in mobile ad hoc networks

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# MOBILITY-AWARE DYNAMIC BROADCASTING ALGORITHM TO ENHANCE THE PERFORMANCE OF ROUTING PROTOCOL IN MOBILE AD HOC NETWORKS


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By

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A thesis submitted to the school of Research and Graduate Studies of Bahir Dar Institute of Technology, BDU in partial fulfillment of the requirements for the degree of Master of Science in the Information Technology in the faculty of Computing.

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I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can evoke penal action from the sources, which have not been properly cited or acknowledged.

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***To my family***

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# ABSTRACT

Mobile Ad-Hoc Network (MANET) is a group of wireless mobile hosts that creates a temporary network without the help of any central administration or standard support services. In a MANET, every node can communicate with each other as well as they can move randomly in any direction in the network. Mobility is the main factor, which determines the overall performance of the network. High mobility of nodes can cause frequent changes in network topology, leading to frequent link breakages, and increasing the reinitiating of the route discovery process, resulting in more control packets overhead. In addition, broadcasting diffuses information from the source node to all other nodes of the network and commonly used for the route discovery process. However, the result of broadcasting causes broadcast storm problems, which are high redundant rebroadcast, packet collisions and leads to the problem of channel contention. The main objective of this thesis is to design and develop Mobility-Aware Dynamic Broadcasting Algorithm (MADBA) in order to solve the above problems. MADBA considered node speed, direction, and node residual energy in the route request and route reply phase to reduce the chance of link breakage and broadcast storm problems. The performance of proposed algorithm has been tested and evaluated based on the performance metrics: packet delivery ratio, the average end-to-end delay, throughput, routing overhead, and packets lost using. We have used network simulator NS2 V-2.35 to simulate the proposed scheme. The simulation results showed that MADBA reduces mobility and broadcast storm problems compared to the traditional AODV and recent proposed MAD routing protocol in MANETs.



***Keywords***: *MANETs, MADBA, AODV Routing Protocol, Flooding.*

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AODV | Ad hoc on-demand Distance Vector |
| AWK | Aho, Weinberger, Kernighams |
| CBR | Constant Bit Rate |
| DSR | Dynamic Source Routing |
| DSDV | Destination-Sequenced Distance-Vector Routing |
| FP-AODV | Fixed Probability- Ad-Hoc on Demand Distance Vector |
| GSM | Global System for Mobile Communication |
| IEEE | Institute of Electrical and Electronics Engineers |
| LAN | Local Area Network |
| MANET | Mobile Ad hoc Network |
| NAM | Network Animator |

NCPR Neighbor Coverage-based Probabilistic Rebroadcast protocol

Ns2.35 Network simulator version 2.35

OTcl Object Tool command language

OLSR Optimized Link State Protocol

PDR Packet Delivery Ratio

RREQ Route Request

RREP Route Reply

RWP Random Waypoint Mobility Model

Tcl Tool command script language

TTL Time To Live

UDP User Datagram Protocol

WRP Wireless Routing Protocol

WLANs Wireless Local Area Networks

ZRP Zone Routing Protocol

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# CHAPTER ONE

# 1. Introduction

## 1.1. Background

In the past few decades, wireless communication and mobile computing have experienced tremendous growth due to the increase of inexpensive and widely available devices. The communication devices wirelessly connect to the internet to communicate and share data with each other. The main purpose of wireless ad hoc technology is to eliminate the tradition of being attached to the wire as they allow anywhere and anytime connectivity. Mobile ad hoc Networks (MANETs) are one of the types of wireless ad hoc networks.

A MANET is an autonomous system of mobile nodes with routing capabilities connected by wireless links, the union of which forms a communication network (Sarkar, Basavaraju, & Puttamadappa, 2013). Every mobile node can act as a router and it can communicate directly with another node in its physical neighborhood. MANET is a collection of mobile nodes that can dynamically change locations to form a network to exchange information. The main features of MANETs are automatic self-configuring, self-maintenance, inexpensive deployment, and the lack of the need for fixed network infrastructures or centralized administration (Ram & Murthy, 2004). Due to the flexible nature of MANETs, this technology is applicable for different scenarios for example, battlefield communications, disaster relief, emergency operation, and educational, commercial, rescue and search operations (Basagni, Conti, Giordano, & Stojmenovic, 2013). The communication process in MANET has done by routing protocols. However, due to the mobility and constant topology change of MANETs, for these reasons, one of the basic challenges in MANET is the designing of dynamic routing protocols that can be mobility aware and efficiently, to determine the routes between the communicating nodes and with better performance and less overhead(Sarkar et al., 2013). Any MANET routing protocol should be able to keep up with the highest degree of node mobility as node mobility frequently changes the MANET topology randomly and drastically(Basagni et al., 2013; Sarkar et al., 2013).

The routing protocols used in MANET are categorized into three based on how routing information is acquired and maintained by mobile nodes(Bhushan, Gupta, & Nagpal, 2013) (Sarkar et al., 2013) (Stojmenović, 2002). First**.** Proactive **(**table-driven**)** routing protocols: these routing protocol the mobile nodes in the network calculate routes to all reachable nodes a priori and to maintain consistent and up-to-date routing information by using a periodic route update process (Sarkar et al., 2013). Examples of Proactive routing protocols are Destination-Sequenced Distance-Vector Routing (DSDV), and OLSR. Second. Reactive (on-demand) routing protocols: these protocols, when any node wants to communicate to the other node, it applies on-demand route discovery mechanism for creating connections. An example of reactive routing protocols is Dynamic Source Routing (DSR) and Ad-Hoc on Demand Distance Vector (AODV). Third**.** Hybrid routing protocols: These routing is the best practice to combine both proactive and reactive routing protocols. An example of hybrid routing protocols is Zone Routing Protocol (ZRP).

### 1.2. Motivation

Nowadays, wireless networks play an essential role in information technology. One of decentralized type of wireless networks is ad-hoc network. MANETs is a type of ad-hoc network. MANETs is group mobile node that can connect to each other over multi-hop wireless links on an ad-hoc basis. Due to restricted transmission range, the node may not communicate with a distant node directly. However, in MANET every node acts as a relay node. This means any mobile node can communicate with distant node through multi-hop link.

Reactive routing protocols like AODV (Das SR, Belding-Royer EM, 2003) have been designed for MANETs, many of operating efficiently under low network mobility conditions, however do not adapt well in high mobility environments. They select the shortest path between source and destination to transfer the data. The shortest path may not at all times be reliable or active path for data transfer because due to the mobility of the mobile nodes the network topology dynamically changes. The frequent breakage of established path degrades the significant performance of the network (Singh, Saini, Rishi, & Rohil, 2016). When an active route between the source node and the destination node breaks, the routing protocol executes route maintenance procedure which consumes network resources and eventually influences negatively on the performance of the network (Singh et al., 2016). Therefore, to reduce this problem protocol in MANETs should consider the mobility of the mobile node should have been performed efficiently and accurately.

It reduces the number of route rediscovery procedures that eventually enhance network performance.

Broadcasting in MANET is an information distribution process of sending a packet from a source node to other nodes that available in the network (Basagni et al., 2013). Several routing protocols need to flood a route request to seek out a multi-hop route to the destination. For example, ad hoc on-demand routing protocols such as AODV (Das SR, Belding-Royer EM, 2003) typically use broadcasting in their route discovery process. In a MANET in particular, because of node mobility, broadcasting operations are expected to more frequently, such as finding a route to a specific host, paging a specific host, and other network operations in MANETs (Tseng & Chen, 2002).

Broadcasting through flooding could cause serious contention when many adjacent nodes decide to broadcast concurrently and also cause collisions and redundant broadcasts (Basagni et al., 2013). Additionally, node mobility creates a continuously changing network topology, in which routing paths break and new one form dynamically, which causes the performance degradation of network communication of nodes in MANETs. Therefore, broadcasting is one of challenging problems in MANETs. Several approaches have been proposed to solve these issues as we discussed in the literature. However, there is no fitting solution, particularly in dynamic mobility aware when the network topology changing frequently and they did not combine multiple parameter metrics simultaneously with decision methods such as speed, direction and residual energy of mobile nodes.

In this study, in order to solve that problem effectively, we design and develop new MobilityAware Broadcasting Algorithm (MADBA) to allow nodes to adapt dynamic changes of the network topology. This proposed protocol has considered both the node mobility and broadcasting decision mechanism to reduce the chance of link breakage and broadcast storm problems respectively. It means, we have considered node speed, node direction (distance between the nodes in terms of mobility), and residual energy of nodes factor in the proposed algorithm. This proposed algorithm enhances performance of existing protocols in MANETs in terms of different performance metrics.

### 1.3. Statement of the Problem

One of the main features in MANETs is Mobility. Mobility of nodes in a MANETs causes frequent nodes to move in and out of range from one to another, which means the mobile nodes making the network topology to vary dynamically with time. This has led to link breakages, which may lead to frequent path failures, route discoveries and retransmission of data. In addition, it might increase the overhead of routing protocols and end-to-end delay.

In addition, in MANETs, the fundamental data diffusion mechanisms is broadcasting for various network services such as route discovery. However, broadcasting causes routing overhead due to the dynamic network topology nature of MANTEs. The result of rebroadcasting is consuming too much network resources. Besides, it causes many problems such as redundant rebroadcasting, collision, and contention in MANETs. Hence, controlling the redundant rebroadcast for better network performance is a challenging task.

Therefore, the routing discovery needs effective mobility aware dynamic broadcasting method to solve the mobility and rebroadcasting problem.

To this end, the current study will attempt to explore and answer the following research questions:

1. How to develop mobility aware dynamic broadcasting algorithm to enhance performance of routing protocol in MANETs?
2. To what extent can we improve the performance of the routing protocol in MANETs?
3. How the effect of node speed, traffic load, and network density affect the performance of broadcast based routing protocols?

## 1.4. Objective of the Study

### 1.4.1. General Objective

The general objective of this study is to design and develop a mobility-aware dynamic broadcasting algorithm for Mobile Ad Hoc Networks (MANETs).

#### 1.4.2. Specific Objectives

In order to achieve the above-mentioned general objective, this study attempted to deal with the following specific objectives.

- ✓ To study the performance behavior of broadcasting techniques in MANETs.
- ✓ To examine the performance effect of important parameters in MANETs, including the effect of node mobility, traffic load, and network density.
- ✓ To develop mobility aware dynamic broadcasting algorithm.
- ✓ To evaluate the performance of the proposed algorithm and compare it with the existing protocol in MANETs.

### 1.5. Methodology of the study

#### 1.5.1. Research design

In this study, we followed the design science process that recommended in (Gengler, Rossi, Hui, & Bragge, 2006) in order to achieve the objective.

#### 1.5.2. Design and development

In this section, we designed and developed the proposed solution. This activity includes determining the artifact's desired functionality and creating an algorithm. In order to achieve the purpose of this study, we used the simulation software Network Simulator-2 (NS-2) V-2.35. This software is an object-oriented simulator, which is implemented using a combination of C++, and OTcl (an object-oriented extension of Tcl) interpreter. While C++ describes the internal mechanism of the simulation objects(Fall & Varadhan, 2011). Hence, it is suitable for running a large simulation. On the other hand, the OTcl sets up simulation by assembling and configuring the objects as well as scheduling discrete events. (Fall & Varadhan, 2011) NS-2 is working on different platforms like Linux and Windows (using Cygwin). We select a Linux platform for this study, i.e. Ubuntu 18.04.2 LTS, it supports a number of programming tools that can be used make the simulation process.

#### 1.5.3. Testing and Evaluation

In order to evaluate the performance of the proposed algorithm the network simulator NS2 used to conduct the simulation experiments. The three mobility scenarios have been designed and applied by varying node mobility, the density of node and traffic load for simulation experiments. Based on the created scenario proposed algorithm is tested and evaluated the performance in terms of different performance metrics. The metrics such as the packet delivery ratio, the average end-to-m delay, throughput, routing overhead, and packets lost. Then, based on that the performance of the proposed algorithm has compared with the existing routing protocols in MANETs.

### 1.6. Scope of the Study

The focus of this study is to design and develop a Mobility-Aware Dynamic Broadcasting Algorithm for routing in MANETs, which is the extension AODV protocols. To the purpose of reducing the possibility of frequent link breakage, which is caused by node mobility and to enhancing the packet delivery by including the mobility parameters like mobile node speed, direction, and residual energy. The proposed algorithm should been expected to reduce the retransmission of the packet by choosing the specific nodes to rebroadcast the packet to solve the broadcast storm problem. In addition, the proposed algorithm that designed, to enhance performance of routing protocol in MANETs in terms of different performance metrics.

### 1.7. Significance of the Study

The effectiveness of broadcasting is critical for the performance of MANET because the wireless channel in MANETs are with the neighboring nodes. However, an inefficient broadcast approach may generate many redundant rebroadcast packets and its result in extremely low available bandwidth for data traffic. Therefore, the proposed algorithm capable to solve problems that we mentioned. This proposed algorithm expects to reduce the number of rebroadcasting effectively. Therefore, reduce the chance of the number of collisions among the neighboring nodes and reduce the contention problem. In addition to this, our algorithm would work based on set of rules to aware of the dynamic topology of the network behavior, mainly in the route discovery process and route reply process. Therefore, this proposed algorithm reduces effectively the frequent path failure, which means, the packet delivery ratio is high and reduces the time required of data packets to transmit from the source node to desired destination nodes. Moreover, which can achieve higher throughput and lower energy consumption without any sacrificing the reachability or having any significant degradation of the networks.

### 1.8. Organization of the Study

The rest of this paper has organized as follows: Chapter two, deals with literature about MANETs and related works, which has conducted for routing data on MANETs. Chapter Three, the detail of the proposed solution to design and implementation has presented. Chapter Four, provided an extensive simulation study, evaluation of the proposed algorithms, and compared with selected routing protocols. Finally, the conclusion, contribution, and recommendations together with the possible outlooks for future work have presented in chapter five.

# CHAPTER TWO

# 2. Literature Review

## 2.1. Introduction

The primary uses of wireless networks created in the 1970s and their development have continued ever since. Over the last decade, research interest in the area has tremendous growth due to the wide availability and fast deployment of wireless transceivers in different computing devices such as laptop computer, Personal Digital Assistant, and smartphone (K Toh, 2001; Stojmenović, 2002). Initially, the deployment of these wireless technological advances came up with an extension to the fixed LAN infrastructure model, as detailed in the 802.11 standards (Brian P. Crow, Widjaja, Kim, & Sakai, 1997).

The (Stojmenović, 2002) WLAN is a flexible data communication system that can either replace or extend a wired Local Area Network (LAN) to provide location-independent network access between communication devices using waves rather than a cable infrastructure. Wireless communication has become one of the most developed areas of technology renew. The cellular wireless networks have experienced dramatic global growth for the past decade. Currently, the WLAN hot spots rapidly deployed in industrial, commercial and home networks. Moreover, to allow the user with portable computers to surf the internet from any feasible locations like airports, railway stations, hotels, and school or college campus. The main important reasons for their growing popularity is that wireless networks, to some extent, enable people to exchange information on the move anytime and anywhere in the world. As wireless devices become more inexpensive and widely available, communication networks will become more stable and farreaching in daily life (Stojmenović, 2002).

Therefore, this entire kind network typically wireless network requires the fixed infrastructure and central administration for their operation. Due to this, to consume a lot of time and money to set up and maintain. However, the new concept of a wireless network in mobile users is self-creating the network, self-organizing the network and self-administration of the network, this type of network are termed as MANETs.

## 2.2. Overview of Mobile Ad-Hoc Networks

A MANET is consisting of wireless mobile nodes that dynamically self-organize in temporary network topologies, to allowing the people and devices can thus be seamlessly internetwork in areas without having any infrastructure or central administration (Basagni et al., 2013; Ram & Murthy, 2004). In MANETs, every node makes its own decision independently. MANET is a selfgoverning system of independent mobile nodes randomly connected with each other and forming arbitrary topology (Basagni et al., 2013; Sarkar et al., 2013). In a MANET (K Toh, 2001; Stojmenović, 2002) is self-organized and self-configured network properties due to this flexible nature, it's more appropriate for multiple applications, from military operations and rescues to virtual classrooms. The communication of this application is sharing information among mobile devices. Additionally, MANETs could be useful in areas such as disaster sites, battlefields and temporary local-area networks. Because in these environments, there is often little or no communication infrastructure is not suitable for use, the wireless mobile user could communicate through the quick formation of a MANET (Stojmenović, 2002).

The dynamic network topology is the basic characteristics of MANET. Which means, the network topology changing frequently over time. It lead to frequently valid route failure, due to this increase the chance for reinitiating route discovery. As a result, is increases the chances of an end-to-end delay and reduce network throughput.

Figure 2.1 shows the random movement of nodes in different directions. Despite the challenge of message routing, MANETs are very easy to establish quickly with low cost as compared to infrastructure-based networks.

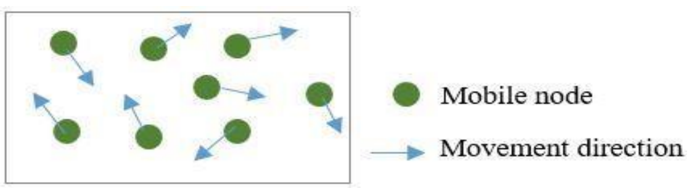



**Figure 2. 1 Random Movement of Mobile nodes**

### 2.2.1. The features of MANETs

A MANET shares many properties in common with wired and infrastructure wireless networks. However, the certain unique features which arise from the characteristics of the wireless channel, the mobility of the nodes and the routing mechanisms used to establish and maintain communication paths (K Toh, 2001), (Eldein & Ahmed, 2017). These features add more complexity and constraints that render the design or analysis of this type of network a challenge(K Toh, 2001). Some features of the MANETs has discussed below:

#### *2.2.1.1. Distributed Operation*

The MANETs need to operate in environments where no centralized coordination is possible. In a MANET, the mobile node communicate among themselves and each mobile nodes acts as a relay as needed to implement specific functions like routing and security(K Toh, 2001).

#### *2.2.1.2. Multi-hop Routing*

When the mobile node in MANET wants to send data to another node that is not present in its transmission range, then the data are traveling through the different intermediated nodes, this process are referred as multi-hop communication. As we know the fact that, every node in MANET can also perform the function of a router to direct the data packet, which helps to achieve multihop communication.

#### *2.2.1.3. Dynamic Topology*

The mobility is very important feature of MANETs, which allows mobile nodes can free to move randomly to different direction without interrupting active communications while the nodes are within the communication range. As a result, network topology it causes the path disconnection between the data sending and data receiving nodes (K Toh, 2001).

#### *2.2.1.4. Autonomous terminal*

Every mobile node in a MANET is independent, which means in a MANET each node act as both host and router.

#### *2.2.1.5. Light-weight terminals*

In MANET, the nodes are mobile with less CPU capability, low power storage and small memory size. It need the optimized algorithms and mechanisms in order to implement the computing and communicating functions.

#### *2.2.1.6. Shared Physical Medium*

The wireless communication medium is accessible to any entity with the suitable equipment and adequate resources. For that reason, access to the channel cannot be restricted (K. Sandeep and K. Suresh, 2015).

### 2.2.2. Applications of MANETs

Due to the flexible nature of MANETs and increased number of lightweight devices and evolution in wireless communication, the MANETs technology is gaining effort with the increasing a number of possible applications for different scenarios for example, educational, commercial, battlefield, rescue, and search operations. The place where a little or no communication infrastructure a MANETs can be applied. If the reader want to read additional information about the application of MANETs can refer to (K Toh, 2001; Stojmenović, 2002). Below are some of the typical application examples such as emergency and military domains has discussed below:

#### *2.2.2.1. Military battlefield*

Ad hoc wireless networks (Stojmenović, 2002) to allow the military to take gain of network technology to communicate among the soldiers, vehicles, and military information head quarter. Making a fixed infrastructure for communication among a group of soldiers in enemy territories may not be possible. In this environments, MANETs provides the required communication mechanism quickly.

#### *2.2.2.2. Collaborative and Distributed Computing*

Other application in MANET is collaborative computing. The requirement of a temporary communication infrastructure for quick communication with minimal configuration among a group of people in a conference or gathering requires the formation of a MANETs (Stojmenović, 2002).

#### *2.2.2.3. Emergency Operations*

The environments where infrastructure-based communication services have destroyed due to natural disasters like earthquakes, fire, and flood, due to rapid deployment of MANETs would be a good solution for coordinating rescue activities. Furthermore, to such operations, MANETs are self-configuration of the system with minimal overhead, without any fixed infrastructure.

### 2.2.3. Merits and demerits of MANETs

Several reasons had better use MANETs than infrastructure-based. The biggest MANETs strength is due to self-configuring networks, the MANETs are independent from any infrastructure or central administration. Therefore, it is possible to apply a MANETs in different environments.

The following are the merits of MANETs (K. Sandeep and K. Suresh, 2015):

- ☞ **No infrastructure and lower cost:**

There are a number of situations, with which a user of a communication system cannot rely on an infrastructure network. Using a service from an infrastructure can be costly for specific applications. The situation with very low density, like desert, mountain, or isolated area, to establish an infrastructure. It is maybe too expensive; because the user may use infrastructurebased service in this situation, they required the cost of installation, maintenance, and repair. Also the same problem with military network. It is clearly useless to build an infrastructure in a battlefield. An independent from infrastructure network has needed in both cases.

- ☞ **Mobility:**

In the wireless communication systems, there need for the rapid deployment of independent mobile users. Some of the most important examples include military networks, emergency or rescue operations, and disaster effort. In these scenarios, we cannot rely on centralized connectivity. MANETs support node mobility; therefore, we can apply it in this type of scenarios.

- ☞ **Decentralized and robust:**

The other importance of MANETs is that they are inherently very robust. For example, may be the access point is not working due to some reason. In this case, all users of that access point loss connectivity to the other networks. However, in case of MANETs the user can solve such problem.

If one mobile node leaves the network, the user can still have connectivity to other nodes and may be the user can use these nodes to multi-hop its message to the destination nodes, providing there is at least one way to required node.

- ☞ **Easy to build and spontaneous infrastructure:**

The malfunction of a network infrastructure is sometimes not avoidable. It is difficult to repair or replace the malfunction infrastructure in short time, while the network's existence must maintained all time. However, to establish an ad hoc is a good deal in such situation.

In another way, there are a number of demerits in MANETs. Some of the examples has listed below:

- ✓ **Routing:** the communication process in MANET has done by routing protocols. However, due to the mobility and constant topology change of MANETs, the issue of routing packets between any pair of nodes becomes a challenging task (K. Sandeep and K. Suresh, 2015). Multicast routing(K Toh, 2001) is another challenge because the multicast tree is no longer static due to the random movement of nodes within the network. The route between nodes may potentially have multiple hops that is more complex than the single hop communication.
- ✓ **Security and Reliability:** the security in MANETs is very important, especially in military applications. Because of a lack of central coordination or administration and shared wireless medium makes them more vulnerable to attacks than wired networks. In additional, the wireless link features announce also reliability problems. Due to the limited wireless transmission range the broadcast nature of the wireless medium. For example hidden terminal problem, mobility-induced packet losses, and data transmission errors.
- ✓ **Dynamic topology and scalability:** Because ad hoc networks do not allow the same kinds of aggregation techniques that are available to standard internet routing protocols, they are vulnerable to the scalability problem.

### 2.3. Routing in MANETs

The main tasks of a routing protocol in MANETs (K Toh, 2001) are finding a feasible path from source to destination and to exchanging the route information. Based on different criteria such as hop length, minimum power required, and lifetime of the wireless link, gathering information about the path breaks and so on. Providing efficient routing protocols are one of the most significant challenges in MANETs and critical to the basic operations of the network (Stojmenović, 2002).

The distinctive characteristics of MANETs, such as node mobility, wireless channel and bandwidth make routing in MANETs a challenging task (K Toh, 2001). Initially, the mobility of nodes results in a highly dynamic network with rapid topological changes. It causing frequent route failures, packet collisions, transient loops, stale routing information, and difficulty in resource reservation. A good MANETs routing protocol should be capably solve all the above issues. Next, the wireless channel working as a shared medium provides a much lower and more variable bandwidth to communicating nodes than in wired networks. As a result, an effective routing protocol for a MANET environment is dynamically adapted to changing network topology and should be designed to be bandwidth efficient by reducing the routing control overhead.

The routing protocols used in MANET are categorized into three based on how the mobile node maintained routing information (Sarkar et al., 2013; Stojmenović, 2002), (Ahmed & Singh, 2016). They are Proactive Routing, Reactive Routing, and Hybrid Routing, as shown in Figure 2.2.

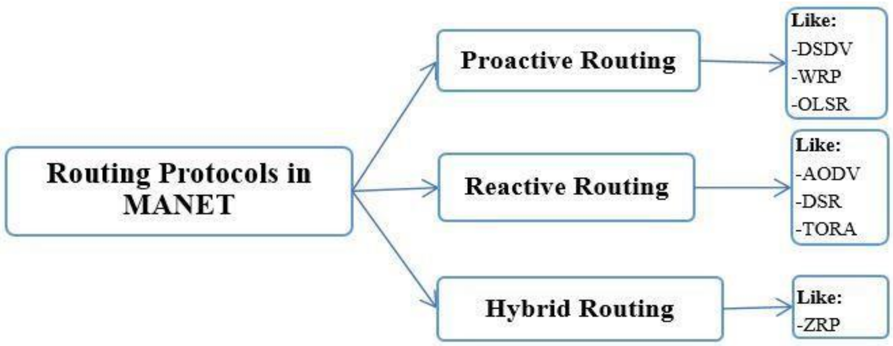



**Figure 2. 2 Routing protocols in MANETs**

### 2.3.1. Proactive (table-driven) routing protocols

These routing protocols maintain the global topology information in the form of tables at every node even before it is needed (K Toh, 2001; Ram & Murthy, 2004; Stojmenović, 2002). These tables are updated frequently, in order to maintain consistent and accurate network state information (Ram & Murthy, 2004). Proactive routing protocol (Ram & Murthy, 2004) have the advantage that routes are available the moment they are needed and delay is less due to already defined routes in the table. Which means each node consistently maintains an up-to-date route to every other node in the network, a source can simply check its routing table when it has data packets to send to some destination and initiate packet transmission. However, the main weakness of these protocols is that the control overhead can be significant in large networks or in networks with rapidly moving nodes due to maintaining up-to-date information. Examples of Proactive routing protocols are DSDV, Wireless Routing Protocol (WRP), Cluster Gateway Switch Routing Protocol (CGSR) and OLSR.

### 2.3.2. Reactive (on-demand) routing protocols

The reactive routing protocols (Ram & Murthy, 2004; Stojmenović, 2002) is not continuously maintaining a route between all pairs of network nodes. Instead, routes are only discovered when they are actually needed [3]. When a source node wants to send data packets to some destination, it checks its route table to determine whether it has a route. If no route exists, it applies on-demand route discovery mechanism for finding a path to the destination. If two nodes never need to communicate to each other, then they do not need to utilize their resources maintaining a path between each other. The route discovery typically consists of the network-wide flooding of a request message (Basagni et al., 2013). The advantage of these routing protocols is that signaling overhead is likely reduce compared to proactive approaches. However, the main shortcoming to reactive routing protocols is the introduction of a route acquisition latency, which means the source nodes may suffer from long delays for route searching before they can forward data packets. An example of reactive routing protocols is AODV, DSR, and Temporally Ordered Routing Algorithm (TORA).

### 2.3.3. Hybrid routing protocols

These routing protocols is the best practice to integrate the characteristics both proactive and reactive routing protocols. It is a better compromise of the first two approaches. Hybrid routing protocols (Basagni et al., 2013) may exhibit proactive behavior given a certain set of circumstances, while exhibiting reactive behavior given a different set of circumstances. It allows for flexibility based on the characteristics of the network. One of the main contribution of these routing protocols is to reduce high overhead of proactive routing protocols as well as reduce the routing discovery latency in reactive routing (Sarkar et al., 2013). The most common drawback of hybrid routing protocols is that the nodes that have high level topological information maintains more routing information, which leads to more memory and power consumption. Example of hybrid routing protocols is ZRP.

## 2.4. Ad-hoc On-Demand Distance Vector (AODV) Protocol

AODV is a distance vector routing protocol that is reactive (Das SR, Belding-Royer EM, 2003; K Toh, 2001; Sarkar et al., 2013) that is responsible for routing data onto a specified pair of nodes in a MANET. The reactive routing protocol implies that sets up a route to a destination only when desire by the source node and does not require maintaining routes to destinations to which it is not communicating.  AODV guarantees loop-free routes by using sequence numbers that indicate how new, or fresh, a route is (Sarkar et al., 2013). AODV (Das SR, Belding-Royer EM, 2003) requires each node to maintain a routing table containing one route entry for each destination that the node is communicating with. AODV, like many other existing routing protocols in MANETs, uses simple blind flooding to establish routes between a known pair of nodes. It creates routes on demand in order to minimize the traffic generated due to broadcasting RREQ packets. When any mobile node wants to communicate with the other node and does not have any route to that node in its route table, it initiates a process. This process is termed as a Route Discovery process. AODV has also route maintenance mechanism. The packets used in this routing protocol are RREQ, RREP, and RERR.

### 2.4.1. Route Discovery Process for AODV

Whenever, any source node in the network attempt to send a packet to a destination node in the network. Source node initially checks whether it has a route to desired destination node in its routing table or not. If an active route available towards the destination, it simply forwards the data packet to the next hop towards the destination. If not, it initiates a route discovery process. A RREQ packet has initiated, if a valid route is not present for a desired destination. It first places the its own IP address, its own current sequence number, Destination IP address, Last known Destination Sequence Number and broadcast ID into a RREQ message. The combination of broadcast ID and the Source IP address used for uniquely identify the particular RREQ packet. Every time when source node initiates a RREQ packet, broadcast ID of this particular node is increment by one, also the hop count field is set to zero. In this way, the source node broadcast the RREQ packet of its neighbor nodes.

When a node receives the RREQ, it first to determine whether it has received a RREQ with the same Originator IP Address and broadcast ID within the specified time. If the node receives the RREQ packet again from its neighbors, the node discards the newly received RREQ (Das SR, Belding-Royer EM, 2003). Otherwise, it creates a reverse route entry into the source node in its route table. It then checks whether it has a fresh enough route to the destination node. In order to respond to the RREQ, the node must either be the destination itself, or an intermediate node with an unexpired route to the destination whose corresponding sequence number is at least as great as that contained in the RREQ (Das SR, Belding-Royer EM, 2003). If these conditions are not satisfied, the node rebroadcasts the RREQ to its respective neighbors by incrementing the hop count value in the RREQ by one, to account for the new hop through the intermediate node. After broadcasting a RREQ, a node waits for a RREP. If a reply has not received within NET_TRAVERSAL_TIME milliseconds, the node may try again to discover a route by broadcasting another RREQ, up to a maximum of RREQ_RETRIES times at the maximum Time to Live (TTL) value. Each new attempt must increment and update the broadcast ID.

If the destination itself or an intermediate node with a fresh enough route will respond to the RREQ packet using a Route Reply (RREP) packet. Once created, the RREP is unicast to the next hop toward the originator of the RREQ as indicated by the route table entry for that originator (Das SR, Belding-Royer EM, 2003). As the RREP has forwarded back towards the node, which originated the RREQ packet, the hop count field is increment by one at each hop. Thus, when the RREP reaches the originator, the hop counts to represent the distance between hops of the destination from the originator. When an intermediate node receives the RREP, it creates a forward route entry for the destination node in its route table, and then forwards the RREP to the source node. If the current node is not the node indicated by the Originator IP Address in the RREP packet, and a forward route has been created or updated. The node consults its route table entry for the originating node to determine the next hop for the RREP packet, and then forwards the RREP towards the originator using the information in that route table entry. When the source node receives the RREP packet, it can begin using the route to transmit data packets to the destination. If it later receives a RREP with a greater destination sequence number or equivalent sequence number and the smaller hop count, it updates its route table entry and begins using the new route.

If no RREQ packet has sent within, by default, one second, each node broadcast a Hello packet of its neighbors in order to keep connectivity up to date. These packets contain the node's IP address and its current sequence number. The Hello packets have a TTL value.

In figure 2.3 shown that the route discovery process on AODV routing protocol. The reverse and forward routes set up. When the node **1** needs to send data to a destination node **8** and it does not have a valid route to **8**, it initiates RREQ messages (Blue color lines) by flooding into its neighbor nodes (**2**, **3**, and **4**). The neighbor or intermediate nodes cache the received message, broadcast the request into their neighbor, when they have not fresh enough route to node **8**. In addition, when the intermediate nodes received the requests immediately save the route back to the originator that will be used to forward reply (Green color lines). When the broadcasted RREQ reaches the required destination node **8**, the node **8** prepares a RREP (Black color lines) and this reply is unicasted to the originator using the partial route established during the broadcasting of RREQ messages. When source node **1** received the RREP requests, it immediately forward packet to node **8** using the selected route (Red color lines).

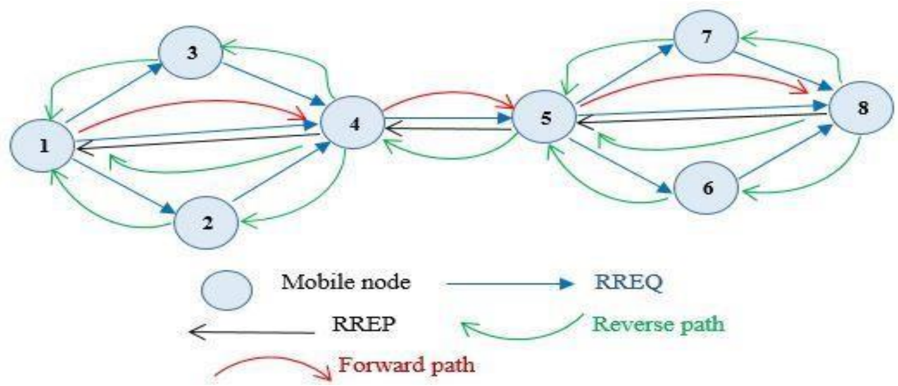



**Figure 2. 3 Route discovery process in AODV**

### 2.4.2. Route Maintenance Process for AODV

In AODV, the route maintenance process is employed addition to the route discovery process. This protocol is responsible for maintaining active routes in the network. Routes has only kept for as long as they are in use. After a timeout period, stale routes would remove from a node's routing table. In addition, it concerned with identifying route breakages. Each node in the network monitors its connectivity to neighbors that has used as next hops for active routes. It can use link layer in notification methods to detect route breakages.

Whenever, a link to a route break, the node upstream of the broken links to invalidate all its routes that use the broken link. Then, the node broadcasts a RERR message to its neighbors. The RERR(Das SR, Belding-Royer EM, 2003) message contains the IP address of each destination, which has become unreachable due to the link break and contains the sequence number of each such destination, increment by one. When the node received a RERR message, a node searches its routing table to see if it has any routes to the unreachable destination, which is the originator of the RERR as the next hop. If the is routes exist, they are invalidated and the node broadcasts a new RERR message to its neighbors. In this way, this process is continuing until the source or the originator node receives a RERR message. The source invalidates the listed routes as previously described and reinitiates the route discovery process by flooding if desires the route.

### 2.4.3. Advantages of AODV Routing Protocol

Several research works had shown that, using AODV in MANET routing has a lot of advantages over the other routing protocols (Eldein & Ahmed, 2017), (Gorantala, 2006). One of objectives of this study is that investigating the Mobility-Aware Dynamic Broadcasting Algorithm (MADBA) of the well-known MANETs routing protocols, which is AODV routing, protocol. Because AODV is necessary for MANETs. It has the following advantages:

- ✓ **Minimal space complexity**: The algorithm makes sure that the nodes that are not in the active path does not maintain route information.
- ✓ **Maximum utilization of the bandwidth**: As the protocol does not require periodic global advertisements, the demand on the available bandwidth is less.
- ✓ **Simple**: It is simple with each node behaving as a router, maintaining the simple routing table.
- ✓ **Coping up with dynamic topology and broken links**: Because of its reactive nature, AODV can handle the highly dynamic behavior of MANTEs. Additionally, when the nodes in the network move from their places and the topology are changed or the links with the active path are broken, the intermediate node that discovers this link breakage propagates a RERR packet. In addition, the source node re-initializes the path discovery if it still desires the route. This ensures quick response to broken links. This quality of AODV is worth considering when one has to study mobility impacts.
- ✓ **Loop-free routes:** The protocol maintains loop free routes by using the simple logic of nodes discarding non-better packets of same broadcast-id.

## 2.5. Broadcasting in MANETs

Broadcasting is the process of sending a message from one mobile node to all other mobile nodes in an ad hoc network. It is an essential operation for communication in ad hoc networks (Tseng & Chen, 2002) as it allows for the update of network information, route discovery and other operations as well. The flooding was one of the primary broadcasting mechanism on in wired and wireless networks (Ram & Murthy, 2004; Tseng & Chen, 2002). When the source node receiving the message for the first time broadcasting messages to all the nodes in the network, the main objective behind broadcasting is to distribute messages from source nodes to all other nodes in the network  (Tseng & Chen, 2002). There are two basic models, which used in broadcasting with respect to the physical layer, namely, one-to-all models, and one-to-one model. In case of the oneto-all model, the messages broadcasted by source node reach all the nodes that are in transmission range of it. In addition, in case of one-to-one model is each source-transmitted packet would give to a specific neighbor only. As a matter of fact, flooding is mainly associated with one-to-all models (Ram & Murthy, 2004).

Subsequently, flooding is simple and easy to implement, provides transparency in topology and having localized nature. However, there is a limitation that when the network size grows flooding can affect the significant performance of the network and may lead to a serious problem which are termed as broadcast storm (Bakhouya, 2013; Basagni et al., 2013; J. Sharma, Bhatia, & Kaur, 2018; V. Sharma & Vij, 2017; Tseng & Chen, 2002; Williams & Camp, 2002). Which means there are three basic problems are occurring in MANETs. Firstly, because radio propagation is omnidirectional and the transmission ranges of several nodes may cover a physical location, a large number of redundant rebroadcast would been occurred. Second, heavy contention could exist because when there are messages in the buffer, but it is not able to send them because channel is blocked by other messages sent in the network of neighboring nodes (Basagni et al., 2013). Third, collisions may occur when there is a hidden node in the network, because two or more nodes simultaneously rebroadcast the packet into the same destination node (Yu-Chee, Sze-Yao, YuhShyan, & Jang-Ping, 1999).

In general, in MANET the efficiency of broadcasting protocol can dramatically affect the performance of the whole network. The proper use of a broadcasting method can reduce the number of rebroadcasts. Therefore, in this study is proposed algorithm in order to solve a problem that we stated. This proposed algorithm designed; reduce the number of rebroadcasting effectively. As a result, reduce the chance of the number of collisions among the neighboring nodes and reduce the contention problem.

## 2.6. Applications of Broadcasting in MANETs

The broadcasting is basic process in MANETs in which the same packet has transmitted from the sender node to all the remaining nodes that available on the network. The applications, which make use of broadcasting, serves several purposes. For example, paging of a particular node, packet forwarding to the entire mobile network, network management, overhead control, route discovery, and maintenance. In addition, the broadcasting mechanism in MANETs acts as a backbone of several protocols like for purpose of the route discovery process in AODV (Das SR, BeldingRoyer EM, 2003), the route request is transmitted in the network to determine a path to a particular destination mobile node. Each node keeps the broadcasting ID and the name of the mobile node from which the packet has been received. When the route request has reached destination, immediately it replies with a unicast packet, and each intermediate node is able to establish return routes. In a MANETs, any communication protocol should contend with the issue of interference in the wireless medium. When two or more nodes broadcast a packet to its neighbor at the same time, the common node will not receive any of these packets. Which means, the collision has happened at the common nodes.

Due to the limited radio range of mobile nodes, the MANET is multi hop in nature. Hence, the packet which is transmitted from the valid mobile source may be cannot reach the desired node in a single hop.(Shanmugam, Subburathinam, & Palanisamy, 2016) Therefore, at this time the intermediate nodes may need to help the broadcast operation by retransmitting the packet to other mobile nodes in the network. In a MANET(Shanmugam et al., 2016), the process of selecting the intermediate node is the most important factor because these nodes will use the significant resources of the network. Therefore, this should be reduced insignificant redundancy forwarding process in order to reduce the chance of numbers of collision and contention of the channel. In addition, in order to improve the performance of routing protocols in MANETs.

## 2.7. Related Works

For the aim of this study, we reviewed and analyzed several earlier literatures, which has published particularly in the field of routing protocols in MANETs. In order to gives basic research possibilities, and gaps of that particular area. In the earlier, a number of research contributions have addressed to deal with the rebroadcast storm issues and mobility aware routing models to adapt to node movement in MANETs and to reduce frequent link breakages; this occurs continuously node mobility in MANETs, mainly in the case of the route discovery process. According to (Bakhouya, 2013; J. Sharma et al., 2018; V. Sharma & Vij, 2017; Williams & Camp, 2002) the authors have classified the broadcasting method in MANETs, they are: the simple (blind) flooding, Location-based, Distance-based, Neighbor-knowledge-based, Counter-based, and Probabilistic-based methods.

The simple flooding method is one of the straight forward approach to perform broadcasting in MANET (V. Sharma & Vij, 2017; Tseng & Chen, 2002; Yu-Chee et al., 1999). In this method, source node advertises route request packets to its neighboring nodes. After receiving the route request packets these neighboring nodes check if they have received this message earlier if yes, they will drop or discarded the packet, and if not, then the packets advertised to their neighbor's and so on in the network until all the nodes receive the route request packets. Flooding is suitable with the low-density networks. However, as the size grows this method may lead to congestion in the network, which in turn will consume all the battery life of the nodes (Tseng & Chen, 2002). Furthermore, flooding to consume significant network resources and it may result leads to serious redundant transmissions giving rise to broadcast storm which may in turn cause collision and contention in the network (Tseng & Chen, 2002), (Bakhouya, 2013; J. Sharma et al., 2018; V. Sharma & Vij, 2017).

As mentioned in (Tseng & Chen, 2002; Yu-Chee et al., 1999) have been proposed solutions to reduce the numbers of the redundant rebroadcasts and improve the broadcast storm problem is the probabilistic based method. This method is similar to simple flooding, except that nodes only rebroadcast with a predetermined forwarding probability, which means, when a node receives a broadcast packet for the first time, it rebroadcasts the packet with a fixed probability p. And the probabilistic based methods are also simpler and easier to implement as the authors described in (Tseng & Chen, 2002).

However, the researchers in (K. Sandeep and K. Suresh, 2015; K Toh, 2001; Tseng & Chen, 2002; Yu-Chee et al., 1999) have explained that the probabilistic based method does not accomplish a high level of saved rebroadcast packets and these methods have poor reachability in most cases, particularly in a low-density network. Because every node has the same probability of rebroadcasting the packet regardless of its number of neighbors. For example, in dense region, many mobile nodes share the same transmission coverage area. Therefor the randomly selecting nodes do not reduce rebroadcasts without degrade the effectiveness packet delivery reachability. On the other hand, in a sparse region have a less shared coverage area. Therefore, the mobile nodes may not receive the entire broadcast packet with the probabilistic method except the probability parameters are high.

As discussed in (Haas & Halpern, 2006) the authors have proposed a gossiping based approach each node transmits a packet with a gossiping probability. Information distributed by gossiping protocol spreads quickly and reliably with high probability. In addition, the authors found that this approach could reduce routing overhead by 35% as compared to flooding. However, this a gossiping based scheme is limited to high-density networks.

As discussed in (Zhang, Wang, Xia, & Sung, 2013) the authors have explained a neighbor coverage-based probabilistic rebroadcast protocol (NCPR), this protocol combined both neighbor coverage and probabilistic methods. This technique used to reduce overhead, this relates to broadcasting. NCPR uniquely designed for MANET and it takes the comparison across a popular way scheme by stimulation using collision rate, normalized routing overhead, packet delivery ratio, and random packet loss rate. The authors concluded that end-to-end delay reduced by 53.9% in NCPR protocol and decrease the number of retransmissions and improve the routing performance. However, in MANETs leads to periodic link breakage, which in turn leads to periodic failure and route discoveries, hence the overhead has created.

As discussed in (Shanmugam et al., 2016) the authors have proposed a Dynamic probabilistic based routing Scheme. In these scheme packets forwarded to the neighbor node with dynamically computed probability, which is forwarding probability. The probability function is calculated based on the density of the local neighbors and cumulative amount of neighbor mobile nodes (Shanmugam et al., 2016). Hence, it is vital to identify the dense and sparse regions (Shanmugam et al., 2016). As the author has discussed, the proposed approach shows the improved performance compared to the AODV and Fixed Probability AODV (FP-AODV) routing protocols. In generally, the proposed approach(Shanmugam et al., 2016) is outfitted the route to smaller number of mobile nodes, which are contributed in the route request forwarding and the connectivity ratio is high in denser network. However, the throughput of network is very low when the region of the network is spare, the reason behind is the poor connectivity ratio among the mobile nodes in sparse region and the end-to-end delay is high. Due to this, the failure of RREQ packet to reach the destination is high. On the other hand, due to high contention number of unnecessary retransmission of packet.

Adaptive forwarding strategy (Alghamdi, Pooley, & King, 2016) uses the data of 1-hop neighboring radios. In these strategy nodes does not require a positioning system to find their location. The node that receives the message from separate groups taken as gateway nodes. This gateway node helps in forwarding route request packets and unessential rebroadcast removed. As mentioned in (Chekhar, Zine-Dine, Bakhouyi, & Aaroud, 2015) adaptive broadcast protocols have been proposed. In these broadcasting scheme the as the authors evaluated its performance. The obtained results of this scheme has significant save rebroadcasts, higher reachability and little increase in latency compared to simple flooding and fixed probability-based schemes. As the authors in (Darabkh, Judeh, Bany, & Althunibat, 2018) addressed a new reactive routing protocol. The aim of this protocol is establishing more stable data routes over vehicular ad-hoc networks. To bring more strength to proposed protocol, the authors developed a new approach that switches the method between the mobility aware route creations and the classical AODV route buildings based on reaching a proposed retrial threshold. However, this proposed scheme has not considered residual energy when selects the stable route path. The residual energy metric also contributes to reduce in link breakage during the exchange of data.

As stated in (Khamayseh, Obiedat, & Yassin, 2011) the authors proposed a mobility and load aware routing scheme (MLR), which has built a stable route and load balancing among the several routes in a high mobility and a high traffic load situation. This scheme makes the use of the speed and traffic load intermediate nodes to determine the reliable route during the route discovery phase each node. The authors used Markovian Decision Process tool to decide whether to rebroadcast or discard when each node received a request packet. The obtained result is reducing the effects of the broadcast storm problem, increase the throughput, and reduce routing overheads on the network compared to AODV protocol. However, the authors did not consider the residual energy and direction of the node. Because selecting a reliable route may have a low power of the mobile node, and the node because of mobility may the neighbor's node run out of range, it leads to increase the chance of link breakage and increase re-initiating route discovery process. In addition, the limitation of this scheme is the authors only modify the route discovery phase of the original reactive protocols. However, not consider in route replay phase, when it considered, it could be a better performance. Because after RREQ packets sent to destination the topology is changing due to mobile node mobility.

As discussed in (P.Kamalakkannan, Salem, & Kumar, 2012) the authors have proposed the RAODV algorithm that deals with link breakage during the exchange of data in MANETs. This algorithm, the dealing with mobility prediction of nodes the selection of routing path based on delay and bandwidth metrics helps to improve the Quality of Service. However, the weakness of this algorithm is that only consider mobility prediction of the Received Signal Strength value. However, not taken as metric like the residual energy and speed of mobile nodes.

In (Murshedi & Wang, 2015) the authors have designed and implemented a Mobility Adaptive Ad-hoc On Demand Distance Vector routing protocol, which extends the AODV routing protocol using hello message. This protocol is capable of predicting the mobility of the nodes, when compared with the traditional AODV protocol. Because, it repairs the link breakage in the local link and establishes the other link instead of initiating route discovery phase. However, the overhead is increased due to the maintenance of active neighbor list of next hop to provide an alternative link during node mobility and it has broadcast storm problem like AODV, because route discovery phase it broadcast route request packet by blind flooding in to neighbor nodes.

In (Rashid, Waqar, & Kiani, 2017) the authors has proposed a link stability algorithm for MANETs based on relative mobility and residual energy of nodes. However, this algorithm not considered distance between the movements of neighbor nodes. This scheme the remaining energy and relative mobility only considered in route replay phase, but not in the route discovery process. In addition, the scheme has broadcast storm problem, because the node without any consideration broadcast RREQ packet into its neighbor.

As mentioned in (Swidan, H. B. Abdelghany, & Saifan, 2016) the authors have proposed MDA routing protocol. This protocol proposed improved AODV protocol to build more stable routes and reduce the chance for link breakages use the node speed and direction with respect to the source and destination nodes. This proposed scheme improved the performance when compared with AODV in terms of delivery ratio, end-to-end delay, routing overhead, and energy consumption. However**,** when the authors proposed this scheme did not consider the number of the redundant rebroadcasting packets generated by nodes in the network, which may cause increasing the chances of the contentions and collision problems in the network. The selected most reliable path may have contained the low power of a mobile node; it leads to increases link breakage problem. Because each mobile node uses a battery power. This proposed scheme only considered the speed of nodes' movements in the RREQ broadcasting process. However, not taken into account the direction of the node in the RREQ process. Because, if the direction of node is measured in the RREQ process, it could be improved the performance routing protocol in MANETs. In addition, the scheme in RREP process, when the node that broadcast back the RREP packet to the previous hop, only consider the speed of that previous hop in order to whether the RREP packet forward or not. However, do not consider the direction of node of a previous hop. Because, it might lead to increase unnecessary rebroadcast packets.

# CHAPTER THREE

# 3. Proposed Routing Algorithm

## 3.1. Design of the Proposed Algorithm

In this study, we proposed a Mobility-Aware Dynamic Broadcasting Algorithm (MADBA) for routing in MANETs. In a MANET, no restrictions on node mobility, which means the nodes change position quite frequently. Therefore, the node's mobility should consider when designing a routing protocol for MANETs. Therefore, our proposed algorithm is capable to quickly adapt-frequently changing of network topology and we considered the node's mobility, because the node mobility causes many problems in MANET, as we mentioned above. The knowledge of position is significant for successful routing of packets in MANETs. To achieve objective of this study, we considered node mobility, assume each node that is available in the network to enable Global Position System (GPS) and the nodes connect to each other using omnidirectional antenna and range of each antenna is equal. Each node periodically sends hello message to the other nodes to get their position in the current time. Based on these coordinates information each mobile node can compute its speed and distance between its neighbor nodes easily. Hence, every node capable to know the current location of neighboring or intermediate node information. Therefore, each node in the network is aware of their current location based on geographical coordinate information of nodes.

In this study, we used the well-known AODV protocol (Das SR, Belding-Royer EM, 2003) to develop the proposed algorithm. Because AODV has shown better performance in mobility condition relative to other protocols in MANETs. To achieve the main objective of the proposed algorithm, the modification has been done on the traditional reactive protocol in AODV. The required modifications in the structure of the AODV routing protocol is: First, we modified the structure RREQ control packets. Next, we modified the structure of routing tables and modified the RREP control packets. Finally, the route discovery and route reply initiation and forwarding decision have explained. The detail description of the modification part has discussed below.

### 3.1.1. Distance Calculation between Communicating Mobile Nodes

The following description detailed how we calculate the distance between the mobile nodes after a certain time interval. Suppose there are two mobile nodes $n_1$ and $n_2$, having the transmission ranges r of each other. Let $(X_{n1},Y_{n1})$ and $(X_{n2},Y_{n2})$ are the X and Y coordinates of nodes $n_1$ and $n_2$ respectively. As shown below in Figure 3.1, the nodes $n_1$ and $n_2$ move at the speed of $V_{n1}$ and $V_{n2}$ respectively.

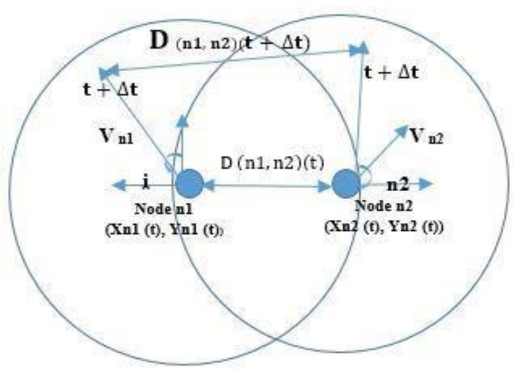



**Figure 3. 1 Position estimation for mobile nodes**

When the movement of the mobile node in MANET changes over time, its speed and direction change. We compute the Euclidean distance between two neighbor nodes (node $n_1$ and it's neighbor node $n_2$) at the time (t). Based on location values of the node $n_1$ at a time (t) and the received location of the node $n_2$ from its RREQ message at a time (t), which then refers to $D_{(n1,n2)}$ (t). After a certain time interval, the same distance calculations occur later in time (t+Δt); Δt means the estimated future time position of a node, which refereed to $D_{(n1,n2)}$ (t+Δt).

Example: let at (t) time position coordinate of the node $n_1$ ($X_{n1(t)}$,$Y_{n1(t)}$) and position coordinate of node $n_2$ is and ($X_{n2(t)}$,$Y_{n2(t)}$). Therefore, the distance between the node $n_1$ and node $n_2$ at a time **(t)** defined as:

$$\mathbf{D}_{(n1,\,n2)}(\mathbf{t}) = \sqrt{(X_{n2(t)} - X_{n1(t)})2 + (Y_{n2(t)} - Y_{n1(t)})2} \text{ --------------------- } \mathbf{(1)}$$

After some time **(t+Δt),** the position of the node n1 is ($X_{n1(t+\Delta t)}$,$Y_{n1(t+\Delta t)}$) and the position of node n2 is ($X_{n2(t+\Delta t)}$,$Y_{n2(t+\Delta t)}$). Therefore, the distance between the node $n_1$ and $n_2$ at a time **(t+Δt)** defined as:

$$\mathbf{D}_{(n1,\,n2)}(\mathbf{t}+\Delta\mathbf{t}) = \sqrt{(X_{n2(t+\Delta t)} - X_{n1\,(t+\Delta t)})^2 + (Y_{n2(t+\Delta t)} - Y_{n1\,(t+\Delta t)})^2} \text{----------- } \mathbf{(2)}$$

In the end, if $D_{(n1,\,n2)}(t) > \mathbf{D}_{(n1,\,n2)}(\mathbf{t}+\Delta\mathbf{t})$ then the node $n_1$ and $n_2$ have come to each other at a time interval ($\mathbf{t}$ and $\mathbf{t}+\Delta\mathbf{t}$). So two nodes are joining each other for that time instant. In addition, if $D_{(n1,\,n2)}(t) < \mathbf{D}_{(n1,\,n2)}(\mathbf{t}+\Delta\mathbf{t})$ The nodes are moving away from each other, at this time nodes have high probabilities to disconnected. By using this mechanism each node gets the information, whether the node joining or separating from its neighbors.

### 3.1.2. Route Request (RREQ) Message Format

The Hello message technique in MANETs, protocol plays an essential role to determine the connectivity between the neighboring nodes. Every broadcast message similarly used as a hello message, indicating the existence of neighbor nodes. When a node receives a Hello message that sent from its neighbor, it creates the routing table entry to the neighbor to maintain connectivity. If a node has not sent any broadcast control message within a specified interval, a hello message is locally broadcast(Singh et al., 2016). When a neighbor node receives failure of any hello message for several time intervals it shows that a neighbor is no longer inside the transmission range, and the result is connectivity has been lost(Das SR, Belding-Royer EM, 2003).

In this study, we modified the RREQ message, which broadcasted by each node among its neighbors to maintaining its routing table. Because of the route discovery process of proposed algorithm is work based on speed, the distance between the movement of nodes, and the remaining energy of the node. Therefore, the entries of the RREQ message of the AODV protocol needed to extend by adding three new fields to its structure. The newly added fields are:

- **Xposition**: it contain the X coordinate the position of the mobile node.
- **Yposition**: it contain the Y coordinate the position of the mobile node.
- **Speed**: it contains the current speed of the mobile node.

| … | $X_{position}$ | $Y_{position}$ | Speed (m/s) |
|---|---|---|---|

**Table 3. 1 Modified RREQ/Hello Message Format**

When the node broadcasts the message into its neighbors, neighbors will receive the RREQ message and each neighbor node get required parameters used to store in neighbor fields in its routing table. Each node of the network will follow the process. By this method, every node is getting the information about the location of neighbors at a certain interval of time.

### 3.1.3. Routing Table Format

A routing table is a set of rules and contains the information necessary to forward a packet about its origin and along the best path toward its destination. It stores the information in the form of a table. Based on the above equation, the routing tables of our proposed algorithm adds two new fields. They are:

- **Speed** of the neighbor node
- **Direction**: it is contain the set values of node movement based on the difference of distance between communicating mobile nodes

| … | Speed (m/s) | Direction values |
|---|---|---|

**Table 3. 2 Modified Routing Table Format**

The direction in the routing table used to set whether a neighbor is joining or separating. In order to set the direction value using a comparison of the distance between the mobile node that the equation (1) and (2). If the nodes are joining from each other and if the distance between the two nodes is constant the direction is set to one. Otherwise, if the node is separate from each other, the direction is set to zero. Each mobile node maintains its routing table based on this way.

### 3.1.4. Residual Energy (RE) of Mobile Nodes

To improve the performance of the network in MANETs, we should consider the residual energy of nodes. Because the mobile nodes run by using a battery in the MANETs, so its energy is restricted. A mobile node loses a certain amount of energy when it transmitted and received a packet. In this study, we considered the residual energy to the forwarding decision in a proposed algorithm of by the node when received RREQ packets. Because it could reduce, the broadcast operations in the route discovery process and decreased the chance of a link failure. The residual energy is the remaining energy at every node, which is the energy left after completion of the entire routing process of the networks.

In this study, the proposed algorithm used a generic radio energy model (Nguyen, Khan, & Ngo, 2018) to estimate the energy consumed by the node like Initial Energy (IE), Residual Energy (RE), Consumption Energy (CE) and Energy Operation (EO) at a time (t). The following equation used to compute the residual energy of the nodes.

$$\mathbf{RE=IE-EC_{(t)}} \text{ ------------------------------ } \mathbf{(3)}$$

Whereas RE is the residual energy of a node, IE is the initial energy of a node and $EC_{(t)}$ is the energy consumed by a node after time (t). To estimate energy consumed for transmitting N number packets, we used the following equation:

$$\mathbf{TE_{(t)} = N \times PT_{(t)}} \text{ ------------------------------ } \mathbf{(4)}$$

Whereas $TE_{(t)}$ refers to the transmission energy of a node at a certain time. $PT_{(t)}$ refers to the power spent through the transmission of N number of data packets and at a certain period of time the neighbor nodes exchanging routing information. In the same way, the estimated energy consumption in a receiving time of the node for transmitting **N** numbers of packets, we used the following equation:

$$\mathbf{RE_{(t)} = N \times PR_{(t)}} \text{ ------------------------------ } \mathbf{(5)}$$

Whereas $RE_{(t)}$ refers to receiving the energy of a node at a certain time. $PR_{(t)}$ refers to the power spent through receiving N number of data packets and at certain period of time the neighbor nodes exchanging routing information. In MANETs, the node consumes energy at a certain period; particularly it has performed internal process like connecting, updating the routing table, and catching. Therefore, to compute the total energy consumption of node at the time t in all transmission, reception and internal operation are used the following equation:

$$\mathbf{EC_{(t)} = TE_{(t)} + RE_{(t)}) + EO_{(t)}} \text{ ------------------------------ } \mathbf{(6)}$$

Hence, by using this method we can calculate the residual energy of nodes at certain periods by using the above equation (3). Based on this, our proposed algorithm considered the residual energy in the broadcasting decision in order to reduce the chance of a broadcast storm problem.

### 3.1.5. Route Discovery Process of Proposed Algorithm

The proposed algorithm is an On-Demand Routing Protocol. When the source node wants to transmit data to the destination node and it has no routing entry for the particular destination than the route discovery process of the proposed protocol initiated. The initiation of a route discovery process done by broadcasting new RREQ packets to all neighbor nodes. This new RREQ packet is an extension of the AODV RREQ packet that has shown in Table 3.1. When an RREQ packet received by a neighbor node, it checks whether the RREQ packet is duplicate or not. If it is duplicate, immediately discard or drop the RREQ packet. If not, it searches for the reverse route towards the source node in its routing table. If there is already a route present in the table, then it updates the existing route otherwise create a reverse route towards the source node.

If the receiving neighbor node is not the destination node and there is no valid route that exists towards the destination in its routing table, then it before broadcasting the RREQ to check whether its speed is below a predefined threshold speed. This means this neighbor or intermediate node is not running out of the transmission range from its neighbor node it has received this RREQ packet before. In addition, the neighbor or intermediate node checks whether the two nodes' direction value is one. Because the nodes moving with high speed, it increase the chances for an unsuccessful route creating process, which led to a link breakage problem. In addition, check whether the neighbor node residual energy value is greater than the threshold value of energy. Finally, if it satisfied the condition its update route to the originator, increments the hop count by one and broadcast the RREQ packet to its neighbor nodes. If the condition is not satisfied, it discards this particular RREQ packet and does not re-broadcast this RREQ packet any further. Each node of the network until the RREQ packet reaches the destination or an intermediate node that has a valid route to the destination will follow this process. As a result, the route expected to be composed of more stable wireless links with longer lifetimes. When we select the value of threshold speed, the maximum speed on the network has to be taken into account. This means if the nodes speed is high in the broadcasting process the chosen value of speed threshold is relatively to be too high and if the speed of nodes low, that participate in the forwarding process, the chosen value of speed threshold is relatively to be too low. The main objective of this value of threshold speed is to build more reliable or stable routes under both high mobility and low mobility of mobile nodes.

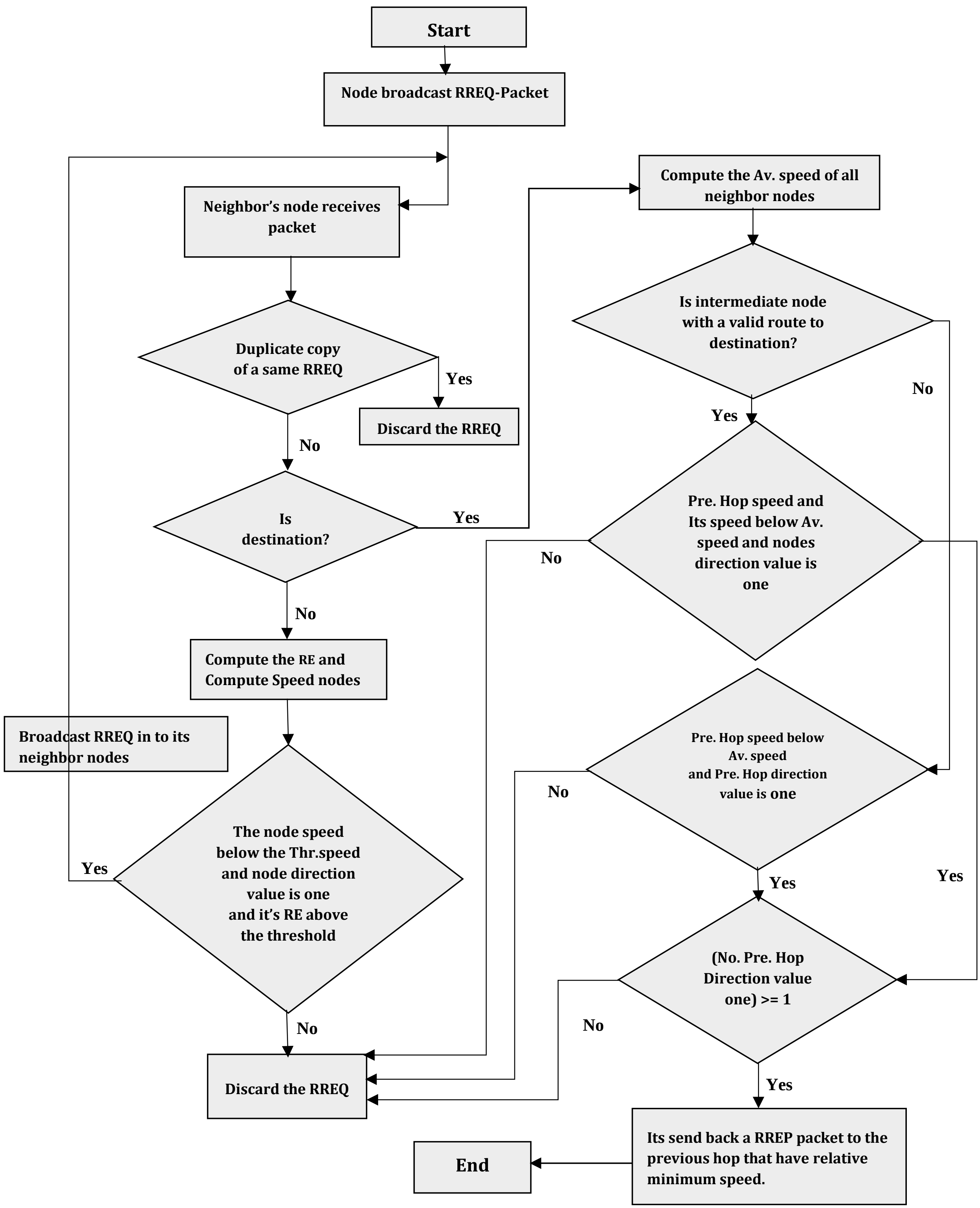
### 3.1.6. Route Reply Process of Proposed Algorithm

When the RREQ packet reaches the destination or an intermediate node that has a valid route to the destination. This destination node is to verify the speed and direction of its neighbor nodes through which the request was received from the node Routing Table. This process has two different conditions based on where this node is the destination itself or an intermediate node that has an active route to the destination.

The first condition, if the node is an intermediate node that has an active route to the destination. Update its route and initiate RREP packet to the previous-hop from which it has received the RREQ packet only the previous hop and its intermediate node is moving with the speed is below average speed all neighbor nodes and also they are not separate from each other. Next condition, if the node is the destination itself, update its route and initiate RREP packet to the previous-hop from which it has received the RREQ packet only the previous hop is moving with the speed is below average speed all neighbor nodes and it is not separated from the destination node, which means the direction value is one. If not discard or drop the RREQ packet. If the number previoushop direction values are greater than equal to one, generate RREPs, select the path which contains nodes with having minimum relative speed values in order to achieve better link stability. If not discard or drop the RREQ packet.

When, every intermediate node received the RREP packet from its neighbor node, immediately updating its routing table in order to build a forward path to the destination then initiates the RREP packet through the reverse path to the next previous hop in the way of the source node. Each intermediate node that received the RREP packet until the RREP packet reaches the original source node will follow this process. The format of the RREP packet in the proposed algorithm extended by adding fields to store needed information like the speed and position values of the nodes.

**Figure 3. 2 Proposed MADBA Operation in Route Discovery and Route Reply Process**


Start
Node broadcast RREQ-Packet
Neighbor's node receives packet
Duplicate copy of a same RREQ
Yes
Discard the RREQ
No
Is destination?
Yes
No
Compute the RE and Compute Speed nodes
Broadcast RREQ in to its neighbor nodes
Yes
The node speed below the Thr.speed and node direction value is one and it's RE above the threshold
No
Discard the RREQ
Compute the Av. speed of all neighbor nodes
Is intermediate node with a valid route to destination?
No
Yes
Pre. Hop speed and Its speed below Av. speed and nodes direction value is one
No
Pre. Hop speed below Av. speed and Pre. Hop direction value is one
No
Yes
Yes
(No. Pre. Hop Direction value one) >= 1
No
Yes
Its send back a RREP packet to the previous hop that have relative minimum speed.
End

***Algorithm 1.*** *<u>Pseudocode of the proposed MADBA routing algorithm</u>*

**Notations:**

**1.** **SA:** Source or initiator address
**2.** **DA:** Destination address
**3.** **IN:** Intermediate node that has a valid route to the desired destination node
**4.** **EDi:** Euclidian distance between the initiator node and a destination node in the initial time
**5.** **EDf:** Euclidian distance between initiator node and destination node of in final time **6.** **RT:** Route Table
**7.** **RRM:** Route request message
**8.** **RREP:** Route request reply
**9.** **Received pair:** Source address and RREQ_ID
**10.** **REn:** Residual energy of node
**11.** **SIn:** Speed of source or initiator nodes.
**12.** **SNn []:** Speed of all neighbor nodes in a recipient routing table
**13.** **SPn:** Previous hop speed
**14.** **PHn:** Number of previous hop
**15.** **SN:** Source node
**16.** **DM:** Direction of movement if **EDi** > **EDf** set to 1 and **Edi** < **EDf** set to 0 in recipient routing table
**17.** **BEGIN**
**18.** SN Broadcast **RRM** into all neighbor nodes, then find match Received pair to do this:
**19.** Boolean found = False
**20.** **For** (a =1 to Rout_Table. Length)
**21.** **If** (Received_pair == RT [a]) then
**22.** found = True;
**23.** **End if**
**24.** **if** (found) then
**25.** Drop **RRM**
**26.** Else
**27.** **If** (**SA!** = **DA**) then
**28.** **If (**REn > Threshold_Energy && SIn < Threshold_Speed && Its DM==1**) then**
**29.** Update **RT**
**30.** Update **RRM**
**31.** Broadcast **RRM** into its neighbor nodes
**32.** **Else**
**33.** Drop **RRM**
**34.** Loop Break
**35.** **End else**
**36.** **End if**
**37.** **Else**

**Switch (**Node category**)**
**Case**: "**IN**" **then**
Count=0
**For** (b = 1 **to** neighbors. Length)
Count = Count + SNn [b]
**End for**

```
Average_Speed = Count / neighbors. Length
If (SPn & SIn < Average_Speed && both DM==1) then
Fun()
Counter=0
For (i =1 to Rout Table. Length)
if (PHn value of DM = 1) then
Counter ++
End if
End for
if (Counter >= 1) then
Update Routing Table
It send back an RREP packet to the previous hop that has minimum speed.
Drop Received RRM
Loop Break
Else
Drop RREP packet
Loop Break
End Fun
End else
End If
End If
End Case
Case: “Final destination” then
Count=0
For (c = 1 to neighbors. Length)
Count = Count + SNn[c]
End for
Average_Speed = Count / neighbors. Length
If (SPn < Average_Speed && DM==1) then
Call to fun()
Update Routing Table
Its send back a RREP packet to the previous hop
Drop Received RRM
Loop Break
Else
Drop Received RRM
Loop Break
End else
End If
End Case
End If
End for
End BEGIN
```

## 3.2. Simulation Environment

In this section, we discussed about Simulation Software, the Simulation Model, Performance Metrics, Simulation Setup and lastly the scenario designs, which is used to achieve the aim of this study.

### 3.2.1. Simulation Software

In order to achieve the purpose of this study, we used the simulation software NS-2 V-2.35. It is a discrete event simulation software for network simulations (Fall & Varadhan, 2011). It has been developed by the University of California at Berkeley and the Virtual Inter-Network Test-bed (VINT) project (Fall & Varadhan, 2011). NS-2 is one of the most popular network simulator tools among networking researchers, which is working on different platforms like Linux and Windows (using Cygwin). We select a Linux platform to do this study i.e. Ubuntu 18.04.2 LTS, it can support a number of programming development tools that can be used the simulation process. This simulation tool has proved useful in studying the dynamic nature of communication networks. It used for simulating wireless networks, including WLANs, MANETs, and Sensor Networks. It is a popular and powerful network simulation tool, and the number of users has increased greatly over the last decade (Fall & Varadhan, 2011). This is because it is freely available, open-source and includes detailed simulations of the important operations of such networks. NS-2 has a visual representation of the simulated network by tracing nodes movements and events and writing them in a network animator (NAM) file.

#### 3.2.1.1. Mobility Model

In a MANET, the mobile nodes are frequently moving from one position into another. However, the ways to find the model these movement patterns are often not obvious. The mobility models can be accurately captured the properties of real-world mobility patterns. It used to describe the movement pattern of nodes. Mobility pattern is the actual set of movements that result from applying the mobility model to one or more nodes (Kim, Kotz, & Kim, 2006).

In order to, carefully evaluate the performance of routing protocols in MANETs the mobility model is necessary to realistically capture the movements of mobile nodes that eventually utilize the given protocol. Currently, two types of mobility models used (Kim et al., 2006) for the evaluations of protocols that developed for MANETs. They are traces (Kim et al., 2006) and synthetic (Kim et al., 2006) models. Traces are mobility patterns observed in real-life systems. This type of mobility model used to provide the correct information, especially when they involve a large number of participants and appropriately long observation periods. However, the new environments like MANETs not easily modeled if traces have not yet been created. In this kind of environment, synthetic models are often used. The synthetic mobility models such as the random waypoint model (A. Sharma, Gurpreet, & Singh, 2013) attempt to represent the behaviors of mobile nodes without the use of traces.

Because of the different types of movement patterns of mobile users, and how their location, velocity, and acceleration change over time, different mobility models should use to emulate the movement pattern of targeted real-life applications. Currently, there are several mobility models available. However, in order to evaluate the performance of our proposed algorithm, we used the Random Waypoint (RWP) mobility model.

#### 3.2.1.2. Random Waypoint Mobility Model (RWP)

RWP mobility model (A. Sharma et al., 2013) is the most popular mobility model used for performance analysis of routing protocol in MANETs. The model describes a collection of nodes that placed randomly within a restricted simulation area. It has two important parameters, they are $V_{max}$ and $T_{pause}$ where $V_{max}$ is the maximum velocity for every mobile station and $T_{pause}$ is a mobile node begins by staying in one place for a specified period of time. Each mobile node independently chooses a random initial point and waits for a certain period called pause time. After $T_{pause}$ expires, the mobile node moves with a velocity chosen normally between [$V_{min}$, $V_{max}$] to a randomly chosen destination. Upon arrival, it pauses for a certain time period and then moves to a new randomly chosen destination with a new chosen velocity. Each node repeats this process until the simulation stops.

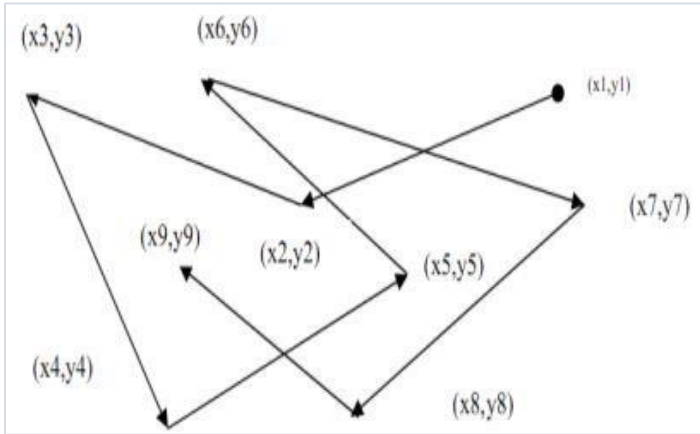



**Figure 3. 3 Random waypoint mobility model** (A. Sharma et al., 2013).

### 3.2.2. Performance Evaluation Metrics

To evaluate the performance analysis of the proposed algorithm in this study, we used usual performance metrics that have been used in the existing performance analysis of routing protocol in MANETs (Bhatia & Sharma, 2016),(Adlakha & Arora, 2015). The performance metrics description followed in this study to calculate the values directly from trace files for the aim of to evaluate the proposed protocol and compare this protocol with well-known AODV existing routing protocol and recently proposed MAD protocol in MANETs are given below.

- **Packet delivery ratio**: is refers to the ratio between the number of packets sent by constant bit rate sources and the number of packets received by the CBR sink at the destination. It is a measure of the reliability of the protocol.
- **Average End-to-End Delay:** it refers to average time data packets spent to reach to the desired destinations. It is included entire delays caused by buffering throughout the route discovery process, processing in intermediate nodes, queuing at the interface queue, and retransmission delays.
- **Throughput**: It defined as the total number of packets received by the destination in a given time period and typically measured in bits per second (bps).
- **Normalized Routing overhead**: It defined as the number of routing packets transmitted per data packet delivered at the destination. When a packet sent over several hops, each transmission of the packet counts as one transmission.

- **Packets lost:** It defined as to determine of the number of packets dropped by the nodes due to several causes. The causes that we have considered for evaluation are collisions rate, duplicate packet, and the link break.

### 3.2.3. Simulation Setup

The simulation scenarios designed to investigate the performance of the MADBA in MANETs under the RWP Model. The scenarios are composed of 10, 20, 30, 40, and 50 mobile nodes with a simulation area of 1000m X 1000m. We used the simulation time of 120 seconds, which is enough to evaluate the considered proposed protocol by varying node mobility, the density of node and traffic load. The pause time used is 10 seconds, minimum speed 0 and a maximum speed of 60m/s is used. Each node uses the IEEE 802.11 MAC layer protocol to send and receive messages. Traffic sources are constant bit rate (CBR). The connection between the source and destination node spread randomly over the network. 512-byte data packets used with a rate of 10 packets per second. The network bandwidth is two Mbps. We used Two-Ray Ground model for radio propagation. Each node has a 250-meter radio transmission range.

In our case when we run of the simulator, we used two kinds of inputs; they are movement file and a connection pattern file. A movement file used to describe the movement of each mobile node. In network simulator, the movement file has all the movement of the nodes at different times with different speed. We generated the movement file of the RWP mobility model by using **setdest** command, which is available under ~ns/indep-utils/cmu-scen-gen/setdest directory. When we run **setdest** we used the following command as shown below:

***./setdest [-n num_of_nodes] [-p pausetime] [-s speedtype] [-m minspeed] [-M maxspeed] [-t simtime] [ P puasetype] [-x maxx] [-y maxy] > [out/movement-file]***

A connection pattern file determines the type of traffic connection; which is whether it is TCP or CBR connections between wireless mobile nodes. In our case, the connection pattern file is set up with random traffic generated by the CBR type of traffic connection. It also gives an idea about the number of sources and the total number of connections made by the nodes in that simulation time. We generated this file by using a ***cbrgen*** command; which available under ~ns/indeputils/cmu-scen-gen. The following command line is we used to create the traffic generator script: ***ns cbrgen.tcl [-type cbr|tcp] [-nn nodes] [-seed seed] [-mc connections] [-rate rate] >***

***[out/pattern-file]*** The following figure 3.4 is the NAM that created using the Random waypoint mobility model with 50 mobile nodes moves randomly.

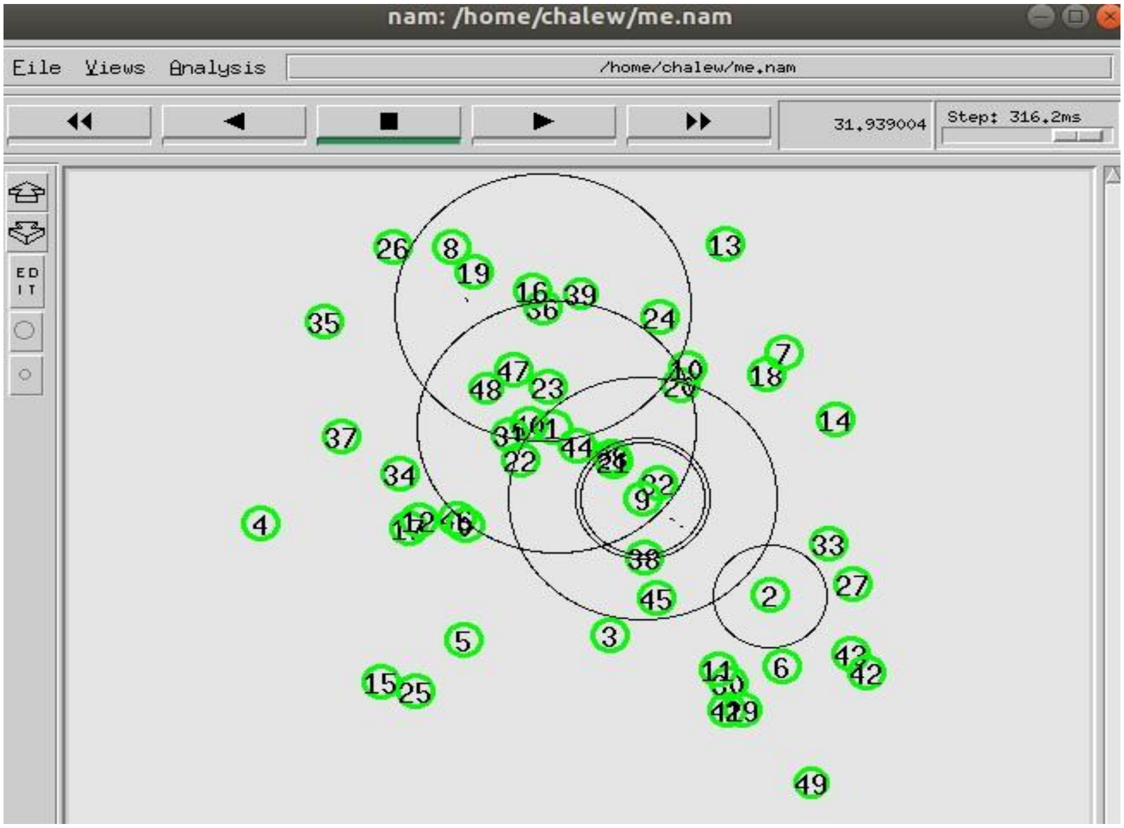



**Figure 3. 4 Screen shot of the simulation on NS2 using RWP model**

### 3.2.4. Scenarios

To accomplish the purpose of this study, three simulation experiments have designed and applied by varying node mobility, the density of node and traffic load in terms of different performance metrics. The simulation scenarios have discussed below:

#### 3.2.4.1. Scenario-One: Impact of Network Density

In order to check the impact of node density of our proposed algorithm in MANETs the network density has been varied by changing the number of nodes deployed over a 1000m x 1000m area of each simulation scenario and keep all other parameters unchanged. Each mobile node in the network moves with a random speed selected between 0 and 20m/Sec. For each simulation experiment five connections or traffic flows, which have randomly chosen a source to destination are used. The simulation parameters of the Scenario-One as stated below.

| Parameters | Value |
|---|---|
| Simulator Network | NS-2 |
| Propagation Model | Two Ray Ground |
| Simulation Area | 1000m X 1000m |
| Number of Nodes | 10, 20, 30, 40, and 50 |
| MAC type | IEEE 802.11 |
| Antenna type | Omnidirectional |
| Interface Type | Phy/WirelessPhy |
| Packet Rate | 10 Packets/Sec |
| Traffic Type | Constant Bit Rate (CBR) |
| Node Speed | Min 0 m/Sec - Max 20 m/Sec |
| Mobility Model | RWP |
| CBR flows | 5 |
| Packet Size | 512 bytes |
| Transmission Range | 250m |
| Queue Length | 50 |
| Pause Time | 10 s |
| Simulation Time | 120 s |

**Table 3. 3 Simulation Parameters of the Scenario-One**

#### 3.2.4.2. Scenario -Two: Impact of Node Mobility

To evaluate the impact of node mobility on the performance analysis of our proposed algorithm in MANETs protocol. The simulations experiments have conducted where the mobility of 50 nodes placed over a 1000m x 1000m area has varied by changing the maximum node speed on the network and keep all other parameters unchanged. The maximum speed on the network has been varied from 0 to 50m/sec. The simulation parameters of the Scenario-Two has specified below.

| Parameters | Value |
|---|---|
| Simulator Network | NS-2 |
| Propagation Model | Two Ray Ground |
| Simulation Area | 1000m X 1000m |
| Number of Nodes | 50 |
| MAC type | IEEE 802.11 |
| Antenna type | Omnidirectional |
| Interface Type | Phy/WirelessPhy |
| Packet Rate | 10 Packets/Sec |
| Traffic Type | Constant Bit Rate (CBR) |
| Min Speed | 0 m/Sec |
| Max Speed | 10, 20, 30, 40, and 50 m/Sec |
| Mobility Model | RWP |

| | |
|---|---|
| CBR flows | 5 |
| Packet Size | 512 bytes |
| Transmission Range | 250m |
| Queue Length | 50 |
| Pause Time | 10 s |
| Simulation Time | 120 s |

**Table 3. 4 Simulation Parameters of the Scenario-Two**

### 3.2.4.3.Scenario -Three: Impact of Offered Load

In scenario to evaluate the impact of offered load on the performance of our proposed algorithm in MANETs, we considered different numbers of the source to destination pairs (CBR flows) over a 50-node network. The offered load has varied over the range 5, 10, 15, 20 and 25 flows and all other parameters are the same in each simulation. The simulation parameters of the Scenario- Three are listed in below.

| **Parameters** | **Value** |
|---|---|
| Simulator Network | NS-2 |
| Propagation Model | Two Ray Ground |
| Simulation Area | 1000m X 1000m |
| Number of Nodes | 50 |
| MAC type | IEEE 802.11 |
| Antenna type | Omnidirectional |
| Interface Type | Phy/WirelessPhy |
| Packet Rate | 10 Packets/Sec |
| Traffic Type | Constant Bit Rate (CBR) |
| Node Speed | Min 0 m/Sec - Max 20 m/Sec |
| Mobility Model | RWP |
| CBR flows | 5, 10, 15, 20, and 25 |
| Packet Size | 512 bytes |
| Transmission Range | 250m |
| Queue Length | 50 |
| Pause Time | 10 s |
| Simulation Time | 120 s |

**Table 3. 5 simulation parameters of the Scenario-Three**

# CHAPTER FOUR

# 4. Results and Discussions

## 4.1. Introduction

In this section, we discussed the acquired simulation result and based on this result to evaluate the performance of the proposed algorithm and it compared with traditional AODV(Das SR, BeldingRoyer EM, 2003) and recently proposed MAD(Swidan et al., 2016) protocols. When we compared our proposed solution with this selected protocol, we used the most important quantitative performance metrics. The metrics are like packet delivery ratio, the average end-to-end delay, average throughput, routing overhead, and packets lost using NS-2 V-2.35 based on different simulation scenarios. Moreover, the critical analysis of acquired results has shown in this section.

### 4.1.1. Results from Scenario - I

In this section discussed the performance impact of network density when the proposed MADBA compared with AODV and MAD protocol over different network density in terms of different selected performance metrics. Deploying 10, 20, 30, 40, and 50 nodes have varied the network density over a specified simulation area of 1000m X 1000m. Each node in the network moves with a maximum speed is 20 m/Sec.


**Figure 4. 1 Packet Delivery Ratio vs. No. nodes**

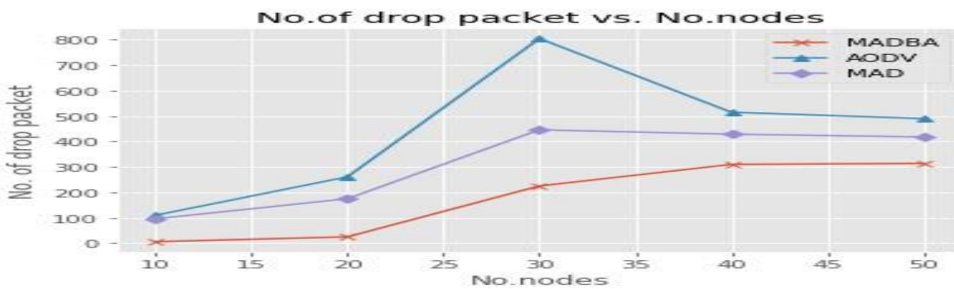



**Figure 4. 2 No. drop packet vs. No. nodes**

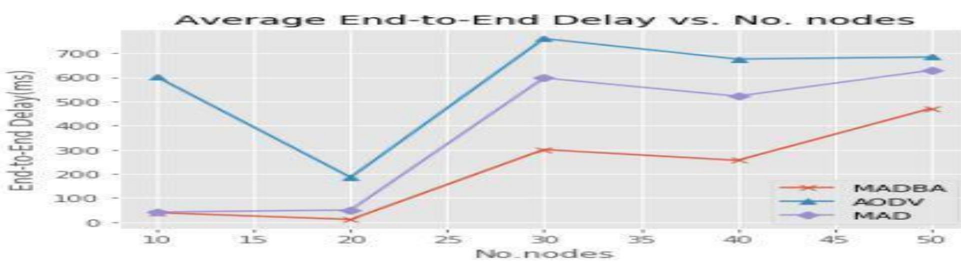



**Figure 4. 3 Average End-to-End Delay vs. No. nodes**

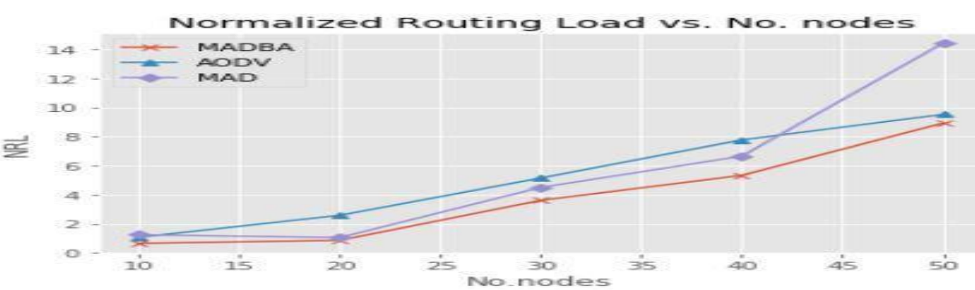



**Figure 4. 4 Normalized Routing Load vs. No. nodes**

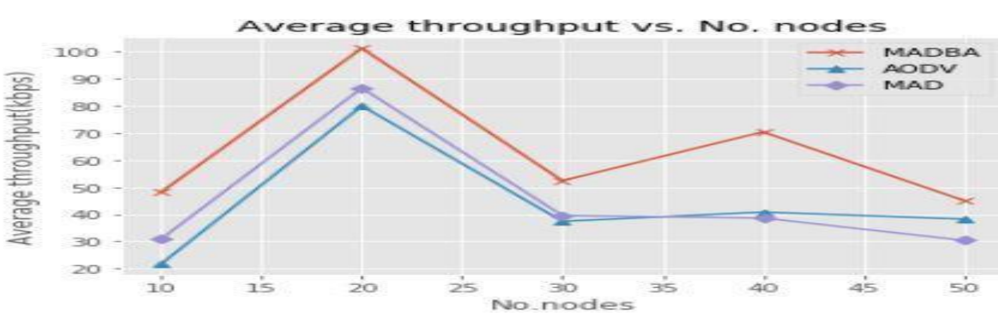



**Figure 4. 5 Average throughput vs. No. nodes**

Figures 4.1, 4.2, 4.3, 4.4, and 4.5 show results. As shown in Figure 4.1, the packet delivery ratio (PDR) of the protocol is decreasing as the number of nodes increases. This is because a higher number of network density causes the link breakage and congestion of packets may occur more frequently and a packet drop increases. However, at every node density, the proposed MADBA generates more PDR compare to AODV and MAD protocols, due to it reduces the chance of several link breakages that increase the amount of data packet loss. It decreases the rebroadcasting packet, which increases the possibility of collisions and contentions. As we considered the high speed, distance between communicating nodes and low energy in both phases of RREQ and RREP of the mobile nodes the established path between the nodes has less chance to break the link. Which makes MADBA to select a reliable route and reduces the chance of data lost. In Figure 4.2 the proposed MADBA shows that; it drops the least number of data packets since the number of link failures and collision are less. When the node's density is increased, the delay has increased as shown in figure 4.3 especially after the number of nodes is 20, because it increases the possibility of packet collision and contention. It lead to frequent rebroadcasting of packets, thus increasing the delay. However, it shows a significant improvement in the case of MADBA. It means the MADBA takes on an average less delay than AODV and MAD protocols when data packets has sent from the source to the destination node. The reason is reducing the possibility of reinitiating RREQ packets hence the total delay is decreased. As shown the Figure 4.4 the number of nodes increased routing load also increased gradually. The simulation result shows the routing load of the MADBA is less than AODV and MAD. Because of the reduction of redundant rebroadcast of the RREQ packet, there is less chance of packet collisions and less link breakage. When the link breakage reduces eventually reduces the re-initiation of route discovery and maintenance process. The simulation result in figure 4.5 shows that the proposed algorithm gives higher throughput than the AODV and MAD. Because in MADBA considered the node mobility to select the best route that has fewer probabilities to break the link for the data transmission.

However, in existing AODV protocol select the shortest route and do not consider the node's mobility whereas selecting the route that may cause the frequent link breakage that affects the overall throughput of the network. In addition, the fewer rebroadcasts result in less degree of collision and contention, which leads the MADBA to get higher throughput.

### 4.1.2. Result from Scenario - II

In this section discussed the performance impact of node mobility on proposed MADBA, AODV, and MAD over 50-network density in terms of different selected performance metrics. The maximum speed mobile node on the network has varied from 10, 20, 30, 40, 50m/Sec over a specified simulation area of 1000m X 1000m.

As shown the figure 4.6, we have analyzed the impact of node mobility on the PDR. We observed that from this figure the node speed increases the PDR of all protocol decreases. This is because the more valid route begins to break as the speed of node increases that causes to initiate RREQ retransmitting, which leads to consume more bandwidth and increase rebroadcast. However, the proposed MADBA protocol outperform compared to AODV and MAD. This means the PDR in MADBA has improved due to its reduction of the chance of rebroadcasting and reduce the chance of link break. As we considered the high speed, direction and low energy of the mobile nodes the established path between the nodes has less chance to break the link. Therefore, fewer rebroadcast of the routing message causes smaller bandwidth consumption and reduces collisions and contentions, which affected the significance of the network.


**Figure 4. 6 Packet Delivery Ratio vs. Max Speed**

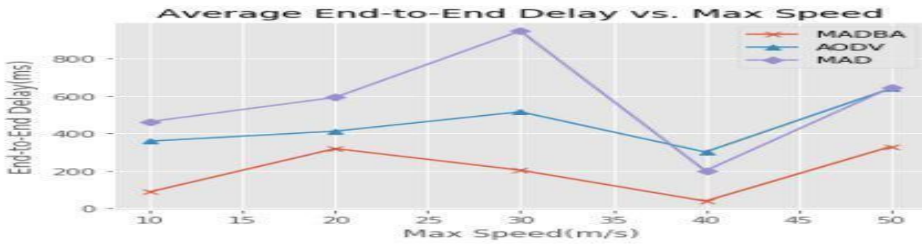



**Figure 4. 7 Average End-to-End Delay vs. Max Speed**

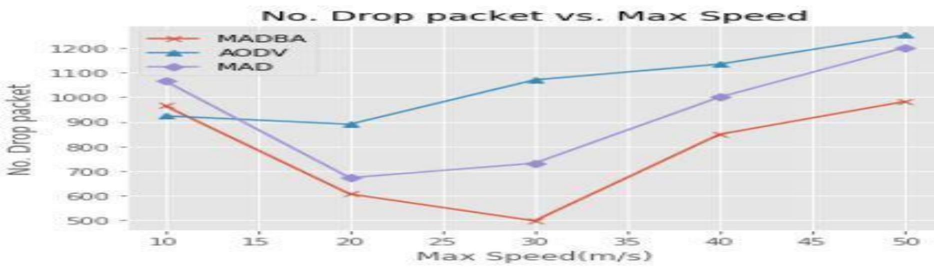



**Figure 4. 8 No. of drop packet vs. Max Speed**


**Figure 4. 9 Normalized Routing Load vs. Max Speed**

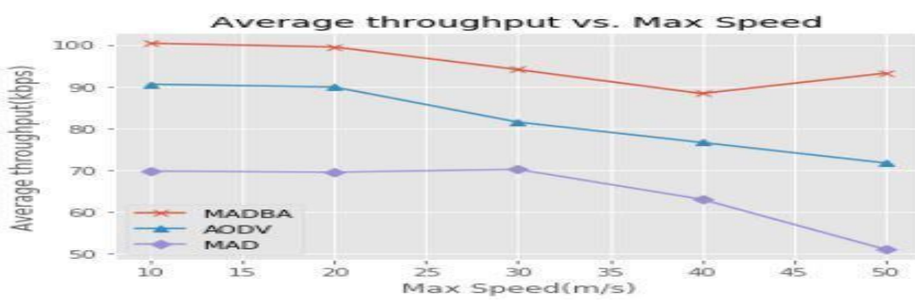



**Figure 4. 10 Average Throughput vs. Max Speed**

In figure 4.7 shows, we have analyzed the impact of node mobility on the performance of MADBA, AODV, and MAD protocol in terms of average end-to-end delay has presented. It shows that in all maximum node speeds the proposed MADBA consume less time than this two protocol. Because of the route discovery process in a proposed algorithm, consume less time as compared to AODV and MAD, due to the reduction of a link breakage problem. In figure 4.8 shows, we have analyzed the impact of node mobility in terms of the number of lost packets. It shows the proposed algorithm is achieving better performance than the existing protocol. Because we considered the maximum speed and low energy of nodes in the phase of route discovery and replay. It increases the chance of link breakage problems due to the mobility of mobile nodes. In figure 4.9 shows the impact of node mobility on the performance of MADBA, AODV, and MAD protocol in terms of Network Routing Load. We observed from a figure the overhead has increased with increased speed of mobile nodes. The reason is the paths between sources and destination node repeatedly breakages and re-establishes due to mobility. Moreover, the RREQ packets not reach the desired destinations. Hence, this kind of problem is lead to reinitiate a route discovery process that eventually increases the network routing load or overhead. However, our proposed MADBA has achieved better performance in terms of routing load. Because it reduces, the unnecessary rebroadcast of the RREQ packet and selects the reliable route at the destination with reducing the redundant rebroadcast of the RREQ packet. In figure 4.10 shows that the speed of the nodes increases, the throughput has decreased. Due to mobility, the valid route between source and destination node breaks, which causes to reinitiate RREQ packet, which leads to more rebroadcast and greater bandwidth consumption. Therefore, the throughput decreased when the node speed is increased. However, the graph shows proposed MADB has better outperformed. The reason is it reduces link breakage and reduce the rebroadcast RREQ packet that gives smaller consumption of bandwidth and reduces the chance of collisions and contentions. Therefore, it gives a higher throughput.

### 4.1.3. Results from Scenario - III

This section presented about to evaluate the impact of offered load on the performance of our proposed algorithm MADBA and it's compared with AODV and MAD over 50 network density in terms of different selected performance metrics. The offered load has varied over the range 5, 10, 15, 20 and 25 flows and all other parameters are the same in each simulation.

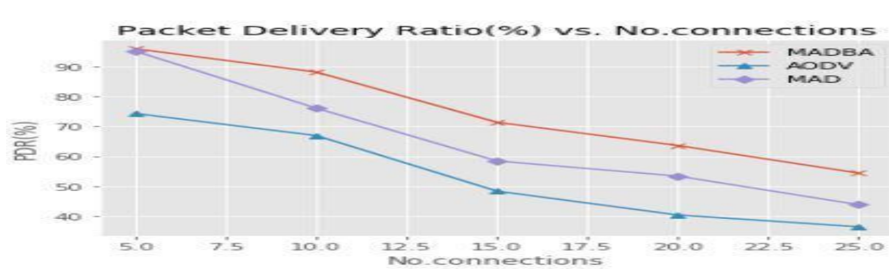



**Figure 4. 11 Packet delivery ratio vs. No. connections**

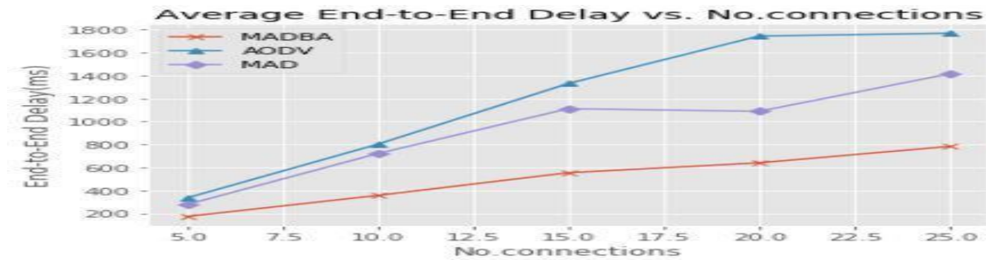



**Figure 4. 12 Average End-to-End vs. No. connections**

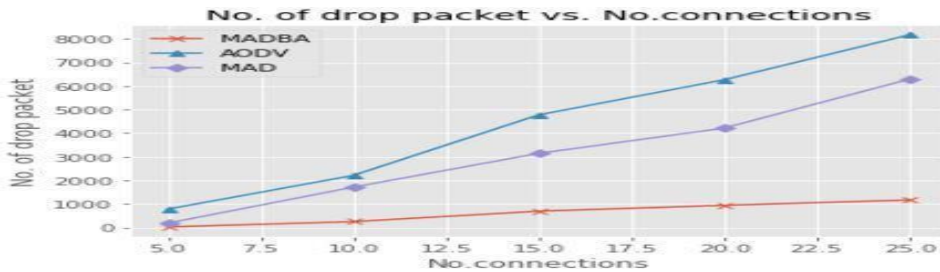



**Figure 4. 13 No. of drop packet vs. No. connections**

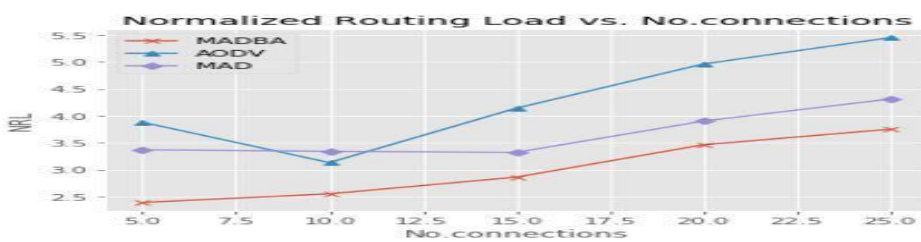



**Figure 4. 14 Normalized routing load vs. No. connections**

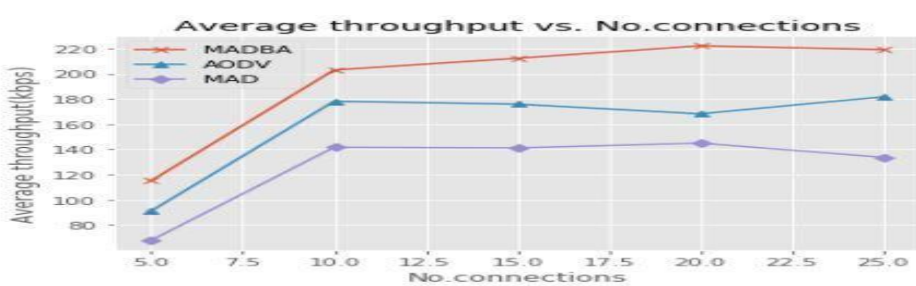



**Figure 4. 15 Average throughput vs. No. connections**

Figure 4.11 explains the benefit of using MADBA in terms of PDR with varying traffic loads. When the traffic load increases, the PDR of AODV and MAD also decreases, because of the increase in the number of routing and data packets due to the high mobility nodes that participate in the routing process, it caused channel contention and packet collision that leads to dropping in packet delivery. As we have shown that from Figure, 4.11 the MADBA outperforms than AODV and MAD at every traffic load. Because of this improvement is the MADBA selects the route with the longest lifetime as well as the reduction of control packets. The less rebroadcast of the routing message causes smaller bandwidth consumption. This has also affected positively on the network and reduces collisions and contentions, and eventually gives the higher packet delivery. Average network delay has shown in figure 4.12, it shows that the MADBA small delay values almost the whole number of CBR sources, which means it performed better to the other protocols. However, from the start until the end, the delay of AODV continuously moved up the number of CBR sources increased. It shows that increasing the number of delay times also increases the routing Load. AODV offered high delay as compared to MADBA and MAD protocols. As we illustrate figure 4.14, it shows that the number of routing packets concerning traffic load. As we observed from this figure, the traffic load increases in the network the routing packets increases for all protocols. Increasing traffic load increases the redundant re-transmission of the routing packets, causing congestion and packet collision in the network, as a result, more RREQ packets and data packets have dropped before reaching the destination. The proposed algorithm MADBA has less routing overhead when compared with AODV and MAD because the proposed algorithm controls the retransmission of the RREQ packets by dropping the redundant broadcast packets and it selects the most reliable path between source and destination node. Because this path reduces the chance of route failure. It results in the reduction of route maintenance procedure and network routing load involved in the route discovery and maintenance process. MADBA shows a significant improvement in terms of network routing load as compared to AODV and MAD. In general, when we evaluated the proposed algorithm MADBA and it has compared with selected protocol, we observed that the MADBA to perform better in terms of all selected quantitative performance metrics.

## 4.2. Summary of the Results

This section presented a summary of the simulation results in the proposed algorithm in the previous section. The simulation in this research has divided into three scenarios. In the first scenario, the performance analysis of MADBA, AODV, and MAD has performed by varying node density, a second scenario by varying node speed, and by varying the offered load in the third scenario.

After this extensive simulation of our proposed MADBA algorithm in MANETs, we observed that the MADBA performs the best when compared to existing selected protocols. It is showing a better performance with high packet delivery ratio and throughput, and minimizing delay and routing load. This is because, in our proposed algorithm, we considered multiple constraints for existing protocols. Even when the nodes are moving at a very high speed, the performance of MADBA is optimum and maintains a very low packet drop number. The reason behind this optimum performance is MADBA considered the highest speed value nodes and its direction values that lead to break the link to increase the chance of packet drop or loss. However, when the increase in the size of the network density, all protocols has significantly decreased the performance seen. This is due to the increase in the number of intermediate mobile nodes resulting in a high possibility of path breakage and loss of data packets and increases updating of topology information. Due to this, the average delay is increased. Therefore, the normalized routing load has increased as we have shown in figure.

# CHAPTER FIVE

# 5. Conclusion and Future Work

## 5.1. Conclusion

In the last few decades, the rapid growth of mobile devices as well as progress in wireless communication in MANETs has gaining importance with the increasing number of widespread applications. However, the mobility of nodes in a MANETs is difficult because the network topology may change constantly and the available state information for routing is indefinite.

Therefore, in this study, we designed and developed a MADBA for MANETs that overcomes the limitation of existing routing protocols. In this algorithm, we combine multiple parameter metrics together with decision-making methods like speed, direction, and residual energy of mobile nodes into route discovery and route reply process. It has shown through extensive simulations that the proposed schemes outperform than AODV and MAD schemes in several operating conditions and scenarios. Unlike the previous works, our strategy based on the node speed, direction and residual energy to select more stable routes, among the intermediate nodes located in the path of the source and destination nodes.

In general, the MADBA algorithm was tested and evaluated, through conducting several simulation scenarios performed by varying node density, varying node speed, and by varying the offered load of the network. Our proposed algorithm is evaluated in terms of widely used performance metrics, which include packet delivery ratio, the average end-to-end delay, throughput, normalized routing overhead, and packets lost. Furthermore, in order to prove the performance of our proposed algorithm, we have done a comparison experiment with AODV and MAD. The simulation result of the proposed algorithm shown that it achieves significant performance gains as compared to the AODV and MAD protocol in MANETs.

## 5.2. Contribution

This study contributes to knowledge by designing and developing MADBA to improve the performance of the routing protocol in MANETs. During the attempt to design the proposed algorithm, the following contributions to knowledge emerged.

- Designed and develop a MADBA routing protocol, which was considered as a major extension of AODV, for the aim of improving the performance of the routing protocol in MANETs.

- ☞ Creating a stable and reliable route between a source and destination nodes based on node speeds, residual energy, and distance for the neighbor nodes.
- ☞ The combination of factors we considered unlike other protocols in both route discovery and route replay phase.
- ☞ In proposed MADBA avoids unnecessary broadcasting of RREQ information. Because the node does not broadcast the routing request (RREQ) if it does not have sufficient energy (battery lifetime), which means the remaining energy of a node below the threshold values.

In general, the researchers in the literature as discussed have suggested several routing metrics. However, they did not combine multiple parameter metrics with decision-making techniques to exchange information through the network and to minimize routing overhead. To the best of our knowledge, none of these studies addressed node speed, distance calculation, and residual energy of nodes simultaneously within the selection or establishing a stable and reliable route between a source and destination nodes. Therefore, in this study, we have considered node speed, directionvalue, and the remaining energy of a mobile node as a factor in the proposed algorithm.

## 5.3. Future Work

This study focused on the improvement of routing performance. The simulation results of the proposed algorithm have been compared with some of the available alike protocols. The results of these comparisons are encouraging and shown reasonable improvement in the routing performance in the MANETs. During the attempt to design and develop the proposed protocols, several thoughts derived about the possible future work that could be done in order to further improve the routing performance in MANETs. Some of the points can be pointed out as future outlooks:

This study has offered an intensive performance evaluation of the proposed algorithm, which has implemented in the traditional AODV protocol. It would be interesting to look at the impact of these algorithms on other reactive routing protocols in MANETs, such as DSR.

This study in order to get the node mobility parameters for calculating the distance between mobile node use GPS. It would be a favorable research direction to use another option to get the mobility parameters.

In MANETs, network topology is very dynamic as mobility of nodes are very random and rapid. Due to this, the wireless link vulnerable to attacks. Therefore, it need secure solution to the dynamic behavior of the network.

In addition, we recommend for a future in decision-making techniques would be interesting to get better performance. When by considering additional factors like quality of wireless links and routing load.

Finally, in this study, the simulation-based analysis for studying the impact of nodes' mobility, density, and traffic load has evaluated and performed. The performing analysis of the proposed algorithm using all the scenarios, metrics, and it will be an interesting way to explore and develop a testbed to obtain realistic results.

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# APPENDIX

## Appendix 1, TCL Script for Simulation

```
#  By Chalew.Z
#======================================================================
#  Simulation parameters setup
#======================================================================
set val(chan)   Channel/WirelessChannel                    ;# type of channel  set val(prop)
Propagation/TwoRayGround                  ;# radio-propagation model set val(netif)
Phy/WirelessPhy                            ;# network interface type set val(mac)
Mac/802_11                                ;# MAC type set val(ifq)
Queue/DropTail/PriQueue                    ;# interface queue type set val(ll)      LL
;# link layer type
```

```
set val(ifqlen) 50                                        ;# max packet in ifq set
val(ant)    Antenna/OmniAntenna                           ;# antenna model set val(rp)
MADBA                                        ;# routing protocol set val(nn)     50
;# number of mobile nodes set val(x)     1000                                         ;#
X dimension of topography set val(y)     1000                                         ;#
Y dimension of topography set val(cp)     "/home/user/chalew/traffic/c25"
;# connection pattern file set val(sc)     "/home/user/chalew/scenarios/s50n"        ;#
node movement file.
set val(stop)   120.0                                     ;# time of simulation end
#=========================================================================
#       Initialization
#=========================================================================
#Create a ns simulator set ns_
[new Simulator] #Setup
topography object set topo
[new Topography] $topo
load_flatgrid $val(x) $val(y)
# Create God set god_ [create-
god $val(nn)] #Open the NS
trace file set tracefile [open
madba25.tr w]
$ns_ trace-all $tracefile
# Create new trace file
$ns_ use-newtrace #Open
the NAM trace file set
namfile [open me.nam w]
$ns_ namtrace-all $namfile
$ns_ namtrace-all-wireless $namfile $val(x) $val(y)
#Create wireless channel set
chan [new $val(chan)];
#=========================================================================
#     Mobile node parameter setup
#=========================================================================
$ns_ node-config -adhocRouting  $val(rp) \
                              -llType           $val(ll) \
                              -macType        $val(mac) \
                              -ifqType          $val(ifq) \
                              -ifqLen           $val(ifqlen) \
                              -antType         $val(ant) \
                              -propType       $val(prop) \
                              -phyType        $val(netif) \
                              -channel          $chan \
                              -topoInstance    $topo \
                              -agentTrace         ON \
                               -routerTrace        ON \
                               -macTrace            ON \
                               -movementTrace   ON \
                               -energyModel  "EnergyModel" \
```

```
                              -initialEnergy 100.0 \
                              -rxPower 0.7 \
                              -txPower 0.9 \
                              -idlePower 0.6 \
                              -sleepPower 0.1
#====================================
#       Nodes Definition
#====================================
for {set i 0} {$i < $val(nn)} { incr i } {
set node_($i) [$ns_ node]
} for {set i 0} {$i < $val(nn)} {incr i}
{ $node_($i) set X_ [expr
rand()*500]
$node_($i) set Y_ [expr rand()*400]
$node_($i) set Z_ 0
}
#======================================================================
# source connection-pattern and node-movement scripts
#======================================================================
puts "Loading connection pattern..." source $val(cp)
puts "Loading scenario file..." source
$val(sc)
#====================================
#   30 defines the node size in nam
#====================================
for {set i 0} {$i < $val(nn)} { incr i } {
$ns_ initial_node_pos $node_($i) 50
} for {set i 0} {$i < $val(nn) } { incr i }
{
$ns_ at $val(stop) "\$node_($i) reset"
}
$ns_ at $val(stop) "$ns_ nam-end-wireless $val(stop)"
$ns_ at $val(stop) "finish"
$ns_ at $val(stop) "puts \"done\" ; $ns_ halt"

#Define a 'finish' procedure proc
finish {} {
global ns_ tracefile namfile
$ns_ flush-trace
close $tracefile close
$namfile
exec nam me.nam &
exit 0 }
$ns_ run
```

## Appendix 2, AWK Script for Reading Trace Files

This script used to calculate the quantitative performance metrics such as packet delivery ratio, average end-to-end delay, average throughput, normalized routing overhead, and number of packets lost.

```
BEGIN {
printf("********************************************************************************\n");
printf("*                    Quantative performance metrices result                 *\n");
printf("********************************************************************************\n");
n=50; packet_recvd[n] = 0; packet_forwarded[n] = 0; packet_sent[n] = 0; packet_drop[n] = 0; recvdSize
= 0 startTime = 1e6 stopTime = 0
energy_left[n] = 100; # Initial Energy assigned to each node in Joules
                              total_pkt_sent=0; total_pkt_recvd=0;
total_pkt_drop=0; total_pkt_forwarded=0; pkt_delivery_ratio = 0;
overhead = 0; start = 0.000000000; end = 0.000000000;
packet_duration = 0.0000000000; recvnum = 0; i=0;
delay = avg_delay = recvdNum = 0
total_energy_consumed = 0.000000;}{
event              =         $1; time
                   =         $3;
              # For energy consumption
node_num       =         $5;
energy_level   =         $7;
node_id        =         $9;
level          =         $19;
pkt_type       =         $35;
packet_id      =         $41;
no_of_forwards =         $49;
flow_id        =      $39;
pkt_size       =      $37;
flow_type      =      $45;
#======================================================================
# In for loop change values from n to number of nodes that u specify for your simulation
#======================================================================
if((pkt_type == "cbr") && (event == "s") && (level=="AGT")) {
         for(i=0;i<n;i++) {                    if(i == node_id) {
                   packet_sent[i] = packet_sent[i] + 1; }
}}else if((pkt_type == "cbr") && (event == "r") && (level=="AGT")) {
         for(i=0;i<n;i++) {
                   if(i == node_id) {
                   packet_recvd[i] = packet_recvd[i] + 1; }
}
}else if((pkt_type == "cbr") && (event == "d")) {
for(i=0;i<n;i++) {
                   if(i == node_id) {
                   packet_drop[i] = packet_drop[i] + 1; }
```

```
}
}else if((pkt_type == "cbr") && (event == "f")) {
for(i=0;i<n;i++) {
                    if(i == node_id) {
                    packet_forwarded[i] = packet_forwarded[i] + 1; }
}}
#===========================================================================
# Routing Overhead
#===========================================================================
if ((event == "s" || event == "f") && (level == "RTR") && (pkt_type == "message" || pkt_type ==
"AODV"))
{  overhead = overhead + 1; }
#===========================================================================
# Calculating Average End to End Delay
# Store packets send time
#===========================================================================
        if (level == "AGT" && sendTime[packet_id] == 0 && (event == "+" || event == "s")) {
        if (time < startTime) {
                              startTime = time}
                    sendTime[packet_id] = time
                    this_flow = flow_type }
         # Update total received packets' size and store packets arrival time
        if (level == "AGT" && event == "r") {
        if (time > stopTime) {
                              stopTime = time
                    }
                   # Store received packet's size
        recvdSize += pkt_size
                    # Store packet's reception time
                    recvTime[packet_id] = time
         }
#=========================================================================== # to
compute energy consumption
#===========================================================================
if(event == "N") {
         for(i=0;i<n;i++) {
                    if(i == node_num) {
                            energy_left[i] = energy_left[i] - (energy_left[i] - energy_level); } }}} END
{
for(i=0;i<n;i++) {
printf("%d %d \n",i, packet_sent[i]) > "pktsent.txt"; printf("%d
%d \n",i, packet_recvd[i]) > "pktrecvd.txt"; printf("%d %d
\n",i, packet_drop[i]) > "pktdrop.txt"; printf("%d %d \n",i,
packet_forwarded[i]) > "pktfwd.txt"; printf("%d %.6f \n",i,
energy_left[i]) > "energyleft.txt"; total_pkt_sent =
total_pkt_sent + packet_sent[i]; total_pkt_recvd =
total_pkt_recvd + packet_recvd[i]; total_pkt_drop =
total_pkt_drop + packet_drop[i];
```

```
total_pkt_forwarded = total_pkt_forwarded + packet_forwarded[i]; total_energy_consumed
= total_energy_consumed + energy_left[i];
}
#==========================================================================
# Packet delivery ratio
#==========================================================================
pkt_delivery_ratio = (total_pkt_recvd/total_pkt_sent)*100;
#==========================================================================
# Compute average delay
#==========================================================================
        for (i in recvTime) {
                delay += recvTime[i] - sendTime[i]
                recvdNum ++
         }
         if (recvdNum != 0) {
                avg_delay = delay / recvdNum
        } else {
        avg_delay = 0
         }
# Output
         if (recvdNum == 0) {
printf("=================================================================\n" \
      "#  Warning: no packets were received, simulation may be too short  #\n" \
     "=================================================================\n\n")
         }
printf("Start Time                          :%d\n",startTime);
printf("Stop Time                           :%d\n",stopTime);
printf("Total Packets Sent                :%d\n",total_pkt_sent); printf("Total
Packets Received          :%d\n",total_pkt_recvd); printf("Total Packets
Dropped            :%d\n",total_pkt_drop); printf("Total Packets Forwarded
:%d\n", total_pkt_forwarded); printf("Packet Delivery Ratio
:%.2f%\n",pkt_delivery_ratio);
printf("Routing Load                        :%g \n",overhead);
printf("Normalized Routing Load           :%g \n", overhead/total_pkt_recvd);
printf("Average Throughput                :%g kbps\n", (recvdSize/(stopTime-startTime))*(8/1000));
printf("Average End to End Delay           :%g ms\n", avg_delay*1000); printf("Total Energy Consumed
:%g Joules\n", total_energy_consumed); if(((total_pkt_recvd + total_pkt_drop)/total_pkt_sent)==1) {
printf("Statistics Correct !!!");
}}
```

## Appendix 3, Sample Traffic Scenario File

```
#########################################################################
# This is a sample traffic scenario file generated by ns-2 and Bonmotion Tool
#########################################################################
# nodes:   50,     max conn:  25,  send rate:  0.10000000000000001,  seed: 1 #
# 1 connecting to 2 at time 2.5568388786897245
#
```

```
set udp_(0) [new Agent/UDP] $ns_ attach-
agent $node_(1) $udp_(0) set null_(0)
[new Agent/Null] $ns_ attach-agent
$node_(2) $null_(0) set cbr_(0) [new
Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.10000000000000001
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 2.5568388786897245 "$cbr_(0) start"
#
# 4 connecting to 5 at time 56.333118917575632
#
set udp_(1) [new Agent/UDP] $ns_ attach-
agent $node_(4) $udp_(1) set null_(1)
[new Agent/Null] $ns_ attach-agent
$node_(5) $null_(1) set cbr_(1) [new
Application/Traffic/CBR]
$cbr_(1) set packetSize_ 512
$cbr_(1) set interval_ 0.10000000000000001
$cbr_(1) set random_ 1
$cbr_(1) set maxpkts_ 10000
$cbr_(1) attach-agent $udp_(1)
$ns_ connect $udp_(1) $null_(1)
$ns_ at 56.333118917575632 "$cbr_(1) start"
#
# 4 connecting to 6 at time 46.96568928983328
#
set udp_(2) [new Agent/UDP] $ns_ attach-
agent $node_(4) $udp_(2) set null_(2)
[new Agent/Null] $ns_ attach-agent
$node_(6) $null_(2) set cbr_(2) [new
Application/Traffic/CBR]
$cbr_(2) set packetSize_ 512
$cbr_(2) set interval_ 0.10000000000000001
$cbr_(2) set random_ 1
$cbr_(2) set maxpkts_ 10000
$cbr_(2) attach-agent $udp_(2)
$ns_ connect $udp_(2) $null_(2)
$ns_ at 146.96568928983328 "$cbr_(2) start"
#
# 6 connecting to 7 at time 55.634230382570173
#
set udp_(3) [new Agent/UDP] $ns_ attach-
agent $node_(6) $udp_(3) set null_(3)
[new Agent/Null] $ns_ attach-agent
```

```
$node_(7) $null_(3) set cbr_(3) [new
Application/Traffic/CBR] $cbr_(3) set
packetSize_ 512
$cbr_(3) set interval_ 0.10000000000000001
$cbr_(3) set random_ 1
$cbr_(3) set maxpkts_ 10000
$cbr_(3) attach-agent $udp_(3)
$ns_ connect $udp_(3) $null_(3)
$ns_ at 55.634230382570173 "$cbr_(3) start"
#
# 7 connecting to 8 at time 29.546173154165118
#
set udp_(4) [new Agent/UDP] $ns_ attach-
agent $node_(7) $udp_(4) set null_(4)
[new Agent/Null] $ns_ attach-agent
$node_(8) $null_(4) set cbr_(4) [new
Application/Traffic/CBR] $cbr_(4) set
packetSize_ 512
$cbr_(4) set interval_ 0.10000000000000001
$cbr_(4) set random_ 1
$cbr_(4) set maxpkts_ 10000
$cbr_(4) attach-agent $udp_(4)
$ns_ connect $udp_(4) $null_(4)
$ns_ at 29.546173154165118 "$cbr_(4) start"
#
# 7 connecting to 9 at time 7.7030203154790309
#
set udp_(5) [new Agent/UDP] $ns_ attach-
agent $node_(7) $udp_(5) set null_(5)
[new Agent/Null] $ns_ attach-agent
$node_(9) $null_(5) set cbr_(5) [new
Application/Traffic/CBR] $cbr_(5) set
packetSize_ 512
.
.
.
.
.
```