**JIMMA UNIVERSITY**

**JIMMA INSTITUTE OF TECHNOLOGY**

**FACULTY OF COMPUTING AND INFORMATICS**

# Improving Multi-path Routing Using Received Signal Strength and Residual Energy in MANETs

**By: Melishew Awoke**

A Thesis Submitted to the School of Graduate Studies of Jimma University, Jimma Institute of Technology, Faculty of Computing and Informatics in Partial Fulfillment for the Degree of Master of Science in Computer Networking.

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# Declaration

I, the undersigned, declare that this thesis entitled: Improving multi-path routing using received signal strength and residual energy in MANETs is my original work and has not been presented for a degree in this or any other universities, and all sources of references used for the thesis work have been appropriately acknowledged.

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# Dedication

*Dedicated to my family Awoke Shumet and Yeshi Shumet.*

## Acknowledgment

First, I would like to say thank you to my Lord who has given me the strength to bear all the difficulties and challenges of life. Secondly, I would like to thank my principal adviser Dr. Girum ketema and co-adviser Mr. Worku Berihane(MSc) for their endless patience and giving me insightful ideas and the constant motivation and support during my work. Finally, my gratitude goes to my family and all my friends for their love, support and encouragement during all my studies.

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## List of Acronyms

AODV - Ad-hoc On-demand Distance Vector

AODVM - On-demand Distance Vector Multipath

AOMDV - Ad-hoc on demand Multipath Distance Vector

DSDV - Destination Sequence Distance Vector

DSR - Dynamic Source Routing

FSR - Fisheye State Routing

IMANET - Internet Based Mobile Ad hoc Networks

LRR - Link Reversal Routing

MDAOMDV - Modified Ad-hoc On-demand Multipath Distance Vector

MDSR - Multipath Dynamic Source Routing

MP-DSR - Multipath Dynamic Source Routing

MSR - Multipath Source Routing

ODMRP - On-demand Multicast Routing Protocol

OLSR - Optimized Link State Routing Protocol

RSSI - Received Signal Strength Indicator

TORA - Temporally Ordered Routing Algorithm

VANETs - Vehicular Ad hoc Networks

WRP - Wireless Routing Protocol

SHARP - Sharp Hybrid Adaptive Routing Protocol

ZHLS - Zone Based Hierarchical Link State Routing Protocol

ZRP - Zone Routing Protocol

# Abstract

*Mobile Ad-hoc Networks (MANETs) are characterized by autonomous, self-organized and dynamic wireless networks with no fixed infrastructure. Nodes are distributed in decentralized and random way in MANET. MANETs are greatly applicable in different areas like remote area, for military battlefield, and in disaster relief, where infrastructure-based network is difficult to deploy. MANET provides many advantages, however it fails to provide longer connectivity due to different factors: such as Nodes in MANET are free to move anywhere in the topology which causes link failure. In addition to node mobility, nodes are equipped with limited battery power and the battery will die because of transmitting, receiving data packets and listening the transmission channel. Link failure and the availability of low energy causes performance degradation in MANET. Frequent disconnection in the network causes packets to be dropped, decreases packet delivery ratio and throughput. In order to maximize network performance, we have modified AOMDV route selection algorithm to select the best path using received signal strength and energy parameter. This metrics improves the network performance by minimizing packet loss rate, enhancing packet delivery ratio and throughput. During route selection, source node selects the best route from the available multiple paths if it has enough signal strength and energy for transmitting and receiving data packet. Ns2.35 network simulator is used to evaluate the network performance. The simulation outcome demonstrates that the proposed solution can effectively improves the network performance such as packet delivery ratio, packet loss ratio and network throughput compared with AOMDV. .*


**Keywords: MANET, Routing**

# Chapter 1

# Introduction

## 1.1 Background of the Study

Wireless networks are being gradually used in the communication among devices of the most diverse types and sizes. Personal computers, telephones, appliances, industrial machines, sensors, and others are being used in numerous environments, for instance in residences, buildings, forests, and battlefields. Diverse wireless network standards and technologies have appeared in the last years to allow easy deployment of applications. It is difficult to deploy wireless networks where there is no infrastructure or the local infrastructure is unreliable. Ad-hoc networks are expected to address the mentioned problems.

A wireless ad-hoc network are combinations of wireless nodes. Wireless nodes can dynamically self-established into random and temporary topology to form a network without any pre-existing infrastructure. Nodes in MANETs communicate directly with one another on wireless networks. If the node is not directly connected, the node can communicate by sending its traffic through intermediate nodes [1].

Wireless networks have been a main part of residential, industrial, and military computing applications in recent years. Recent advances in ad-hoc wireless networking have dismissed fixed infrastructure standards for communication between network users and broadened the horizon of wireless networking. These networks are stated as Mobile Ad-hoc Networks (MANETs), a series of independent terminals that connect to each other via the establishment of a multi-hop radio network. MANETs retain connectivity in decentralized manner [2].

MANETs is a network without infrastructure. It is dynamic in nature in terms of movement of mobile nodes. Each mobile node acts as a router and keeps a table to guarantee route traffic orderly. MANETs are self-governing system of mobile nodes interconnected by wireless links. It is characterized by a complex and dynamic distributed system that contains mobile nodes that can dynamically self-controlled into an ad-hoc network topology. Devices in MANETs may have limited communication range, so a node needs multiple hops to send data to another node [3]. As stated in [4], [6–8] mobile ad-hoc networks have the following characteristics.

- **Dynamic topology:** The network topology in mobile ad-hoc network keeps on changing frequently and unpredictably because nodes are mobile and they can move randomly anywhere in the network.

- **Bandwidth-limited and fluctuating capacity links:** Nodes in the network rely upon batteries which limits their capabilities i.e. services and applications provided by a node.

- **Decentralized network control:** In MANET, the decentralized nature of network control helps to increase robustness against a single point of failure found in a centralized approach.

- **Constrained physical security:** Mobile wireless networks are more likely to be vulnerable to physical security threats than fixed cable networks.

- **Packet loss because of transmission errors:** Ad-hoc wireless networks experiences a much higher packet loss because of factors such as increased collisions due to the existence of hidden terminals, presence of intervention, unidirectional paths, and frequent route breaks due to mobility of nodes.

- **Frequent disconnections/partitions:** The network topology in the ad-hoc wireless network is highly dynamic due to node movements. As a result, the on-going session experiences frequent route breaks. This also leads to frequent changes in the path.

- **Short battery lifetime:** Devices used in these networks have restrictions on the power source in order to preserve portability, size and weight of the device.

Routing is the method of selecting a paths in the network; and the message is routed through the network. Routing in MANETs is difficult due to node mobility and this mobility induces regular changes in topology. MANETs require a robust and flexible mechanism to find and maintain routes. When a node wants to transmit data packets, it will check if there is a route to destination in its routing table. If there is a route it will send the data packets along that path. Otherwise it will broadcast route request packets to the entire network for the existence of the route to the destination. Intermediate nodes or the destination node will send reverse path to the source for available path. The route can be multi-path or uni-path based on the nature of the routing protocol.

Multiple paths are favored as compared to single path due to the availability of multiple routes to the destination. It is important to have multiple paths because if the primary route to the destination fails, there is no need to broadcast route request packet. We can use from the routes stored as a backup. However, still multi-path routing protocols faces performance degradation due to node movement, link failure, hidden terminal problem and nodes having low residual energy along the path.

As nodes move and change the original location, the defined route may be broken and the routing protocol must dynamically check for the available optimal path [9]. Nodes in MANETs can dynamically change their location in the network, resulting in dynamic changes in the topology. Random motion and change in topology can lead to a link failure. Link failure occurs when the node loses its connection to its neighbors and thus causes the path to the destinations to be disrupted. This breakage can occur due to mobility between nodes and failure of the node. The mobile node can fail due to the availability of low remaining energy and causes link between nodes to fail.

Link failure can reduce the transmission rate and increase the data packet latency, thus affecting the performance of MANETs. Link failure should therefore be resolved in order to increase the efficiency of the network and deliver the packet to the intended destination. To solve this problem, several techniques have been implemented, but our proposed technique introduces a new approach to minimize link failure in MANETs by combining different techniques.

## 1.2 Statement of the Problem

Most of the time routing protocols in MANETs uses paths with minimum hop count to forward packets from source to destination. Nodes on a minimum hop path, will deplete their battery power at a higher rate, (as the traffic will follow the minimum hop path) leading to network partition. If the intermediate nodes exhausted all its energy values before it reaches the destination, then it fails to forward the packet to destination. Also, mobile ad-hoc networks are well known by their mobility characteristics. Nodes in MANET are free to move and change their topology. This topology change causes link failure problem.

MANETs provide many advantages. However, due to link failure issues, it can not provide longer connectivity. This link failure problems may lead to the degradation of MANET performance like packet delivery ratio, high overhead and packet transmission delay and also it causes packet loss [2]. Different papers proposed a different approach to solve this problem however, link failure in MANET still needs further study. By combining different approach, we can improve route failure and the network performance. Therefore, this paper is proposed aiming to reduce link failure in MANETs. This approach combines received signal strength and residual energy to minimize link failure and maximizes packet delivery ratio. Hence, this study attempts to answer the following research questions:

1. How to combine different parameters to minimize link failure in MANETs?
2. How to forbid links having insufficient energy and minimum received signal strength from participating in packet transmission?
3. How to select routes having sufficient received signal strength and remaining energy for forwarding data packets?

## 1.3 Objectives

### 1.3.1 General Objective

The general objective of this thesis is improving multi-path routing using signal strength and residual energy.

### 1.3.2 Specific Objectives

In order to achieve the general objective, the following specific objectives are set:

- Study various factors that leads to a frequent link failure.
- Study the weakness and strength of already existing solution to reduce link failure.
- Proposing new algorithm by considering signal strength and residual energy.
- Writing and implement an algorithm for the proposed model.
- Testing and evaluating the proposed work with the previous works using performance metrics.
- Maximizing packet delivery ratio.
- Minimizing packet drops.

## 1.4 Methodology

In order to achieve the objectives of the study, the following methods have been employed.

### 1.4.1 Literature Review

This stage is one of the main stages and involves an in-depth understanding in order to achieve the purpose of this thesis by considering various tools. Various materials, such as books, research papers, journals, proceedings and other documents, are reviewed. The literature review allows one to understand clearly the existing approaches and techniques used to solve the problem.

### 1.4.2 Design and Implementation

The algorithm specified in the objective has been developed during the design process. The designed algorithm takes into account the Received Signal Strength (RSS) and the residual energy of the nodes. Based on the value of the signal intensity and the remaining energy of the node, we can predict which Link will fail and which will not.

### 1.4.3 Evaluation of the Proposed Work

We used the Network Simulator (NS-2) to test the proposed work. NS-2 is an event-driven, open source and portable simulation platform used to study the complex existence of communication networks. NS-2 consists of two main languages, one C++ and the other Object-oriented Tool Command Language (OTCL). In ns-2, C++ defines the internal framework (backend) of the simulation objects, and OTCL defines the external simulation environment (i.e. the front end) for assembling and configuring the objects.

After simulation, ns-2 gives simulation outputs either in form of text-based or animation-based. Since ns-2 simulation tool is the easiest tool and the existing routing protocol is implemented with this tool, we use it for implementing our newly proposed protocol. We have tasted the proposed work in order to examine whether the objectives have been met. The comparative analysis with the current protocol using different performance metrics has been done. The following evaluation criteria have been used to evaluate the efficiency of the proposed system.

- **Average Packet delivery ratio:** The average packet transfer rate is the ratio of the number of packets successfully transferred to the destination to the total number of packets sent by the source.
- **Average Throughput:** The amount of data packets received by the destination per unit time. This is always a key parameter, which determine the performance of routing protocol.
- **Packet dropping ratio:** Packet Loss is the difference between the number of data packets sent and the number of data packets received.

## 1.5 Scope and Limitation

The scope of this thesis is limited to the design and implementation of multi-path routing algorithms in MANET. This work aims to reduce packet loss and improve the packet transmission rate and network throughput in MANET.

The proposed work does not consider any solutions to security issues and node mobility .

## 1.6 Application of The Study

MANETs routing protocols are used in different fields. MANETs [11] is the only option for mobility support where there is no infrastructure or where it is too costly. Some application areas using MANET are given below:

- **Instant infrastructure :** Unplanned meetings, spontaneous interpersonal communication, etc. cannot depend on any infrastructure. So, ad-hoc connectivity must also be set up.

- **Disaster relief :** Infrastructure for disaster breaks and emergency teams have to rely on the infrastructure they set up themselves. Self-organizing networks could, therefore, be a solution.

- **Military Activities:** Many military activities are classified, and for security reasons, it is best to use temporary connections for communication.

- **Remote areas :** In sparsely populated and hilly areas, it is too expensive to set up an infrastructure. Depending on the communication pattern, ad-hoc networks can be a solution.

## 1.7 Organization of The Study

This thesis is divided into 6 chapters. The next chapter covers a literature review on MANETs. This chapter briefly explained the history of ad-hoc networks, their features, application area and challenges. Additionally, different classifications of MANET routing protocols are described in this chapter. In Chapter 3, we talked about different related research works, which are conducted on different routing protocols in MANET.

Chapter 4 is all about the proposed work. It described design considerations for the new proposed protocol, system design issues, and proposed methods and algorithms. Chapter 5 introduced the experimental setup, simulation results and performance evaluation. Finally, Chapter 6 draws conclusions from the results and recommends tasks to be done in the future.

# Chapter 2

# Literature Review

## 2.1 History of Ad-hoc Network

A wireless ad-hoc network is a collection of wireless nodes that can dynamically and automatically established as a random and temporary topology to form a network without using any predefined infrastructure. Each node in ad-hoc network can directly communicate to each other. If there is no direct communication between nodes, they can communicate by sending traffics through intermediate nodes. Every ad-hoc node act as a router [1].

MANET is a wireless ad-hoc network which, is characterized by allowing device to move independently and freely in any direction. MANET is self-organizing and infrastructure-less networks designed to support devices mobility. Each device periodically changes its path to other devices resulting, highly dynamic and autonomous topology. Each device plays the role of a member as well as the router of the network [11].

### 2.1.1 HISTORY OF MANET

The life cycle of ad-hoc could be grouped into first, second and third generation. Currently ad-hoc networks are at the stage of third generation. The first stage of ad-hoc network can be drew back to 1970's. This networks are termed as Packet Radio Network (PRNET). Then the Defense Advanced Research Project Agency (DARPA) announced research of using packet switched radio communication to offer dependable communication between computers and urbanized PRNET.

In the 1980s the ad-hoc networks were more improved and applied as a major aspect of Survivable Adaptive Radio Networks (SURAN) program. This provided a packet switched network to the mobile battlefield in an infrastructure-less environment. It is then termed as the second generation.

Once the idea of commercial ad-hoc network emerged with note book computers and other executable communication equipment [6], third generation ad-hoc networks were came out in the 1990s. Concurrently, the assembly of mobile node was presented. The mobile ad-hoc network working group was emerged and struggle to make standards to routing protocols for ad-hoc networks in the Internet Engineering Task Force(IETF) [2], [4].

As stated in [5], MANET routing protocols are sub-categorized in to Vehicular Ad-hoc Networks (VANETs), Intelligent Vehicular Ad-hoc Networks (InVANETs) and Internet based Mobile Ad-hoc Networks (IMANET). The application of MANET can range from small fixed networks with limited power to large scale mobile, extremely dynamic networks. Other than the application, a MANETs wants well-organized scattered algorithm to control network organization, link scheduling, and routing. Conventional routing will not work in this distributed environment because this network topology can change at any point of time.

As pointed out in [7], nodes are equipped with wireless transmitter and receivers through antennas. These antennas can be bidirectional, highly directional, steerable, or some combination of them. At a given interval, counting on the node's positions, and their transmitter and receiver coverage forms, transmission power and co-channel interference levels, a wireless connectivity in the kind of random, multi-hop graph network exist between the nodes. Nodes in ad-hoc modify their transmission and reception power, resulting topology changes in time.

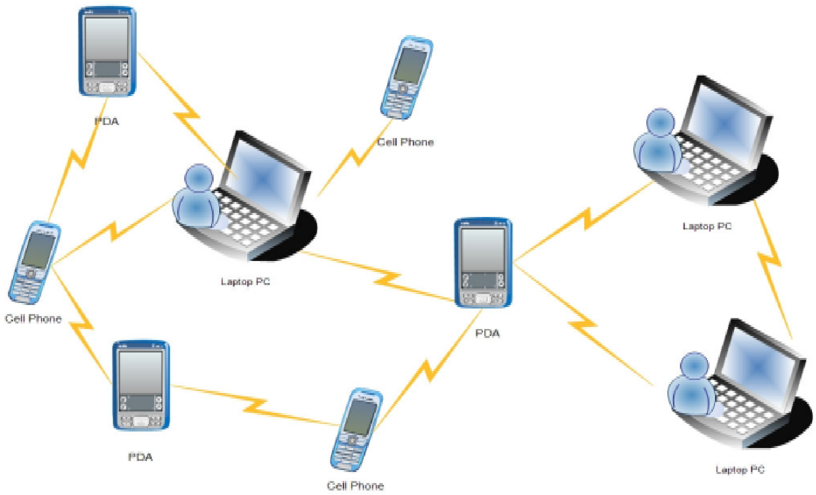


Figure 2.1: Wireless Ad-hoc networks [5]

## 2.2 Application and Challenges of MANET

### 2.2.1 Applications of MANET

MANETS has lots of applications in different areas [5]. The followings are some examples in application areas.

- **Military battlefield :** Military equipment is currently equipped with computer equipment. Ad-hoc networking helps the military with the commonplace network technology to maintain information network between military personnel's, vehicles, and military information head-quarters. The basic technology of ad-hoc network originated in this field.

- **Commercial sector :** Ad-hoc networks can be useful in emergency or rescue operation. Used for disaster relief work, such as fire, flood or earthquake. Emergency rescue operations will go to places where communications are forbidden.

- **Personal Area Network (PAN) :** Short-distance MANET can simplify the inter-communication between mobile devices such as Personal Digital Assistant(PDA), portable computers and mobile phones. The wired cable can be easily changed via wireless connection. PAN is an upcoming application field of MANET in the field of computing technology in the future.

### 2.2.2 Challenges in MANET

Even so, MANET provides many advantages. Due to constant changes in the topology, routing data packets between any pair of nodes has become a difficult task. Some of the challenges are discussed below [8].

- **Limited bandwidth :** Wireless link remains to have considerably lower capacity than infrastructure networks. Additionally, the appreciated throughput of wireless communication after accounting for the effect of multiple access, fading, noise, and interference conditions, etc is often much less than a radio's maximum transmission rate.
- **Dynamic topology :** The connection between nodes may interrupt the trust relationship between nodes. The trust may similarly be disturbed if some nodes are detected as misbehaving.
- **Routing Overhead:** Nodes often change their position in the network in wireless ad-hoc networks. Therefore, outdated paths will generated in the routing table which will result in meaningless routing overhead routing overhead.
- **Hidden terminal problem :** Refers to the collision of packets at a receiving node caused by simultaneous transmission of those nodes that are not within the direct transmission range of the sender, but are within the transmission range of the receiver.
- **Packet losses due to transmission errors:** Ad-hoc wireless networks have a much higher packet loss due to the presence of hidden terminals, the presence of interference, uni-directional links, and frequent route breaks due to the mobility of nodes.
- **Battery constraints:** Devices used in wireless ad-hoc networks have restrictions on the source in order to maintain portability, weight and size.
- **Security threats :** Self-organization feature of MANET brings new security challenges to network design. Since wireless media is vulnerable to eavesdropping and the ad-hoc network function is established through the node cooperation, mobile ad-hoc networks are inherently subject to many security attacks.

## 2.3 Routing Protocol in Mobile Ad-hoc Network (MANETs)

Routing defines a set of instructions, which govern the trip of data packets from source to destination in a network [2]. Routing is the process of searching and keeping routes between the source node and the destination node in the network. A routing protocol is desired whenever a packet needs to be diffused via a number of intermediate nodes [12]. The goal of routing is to find route from source to destination and deliver the packet to the destination. The studies on many functionality of steering protocols have been an active area of research for many years [13]. Routing protocols in MANETs are classified according to different considerations. The classification can be shown in the figure 2.2 below.

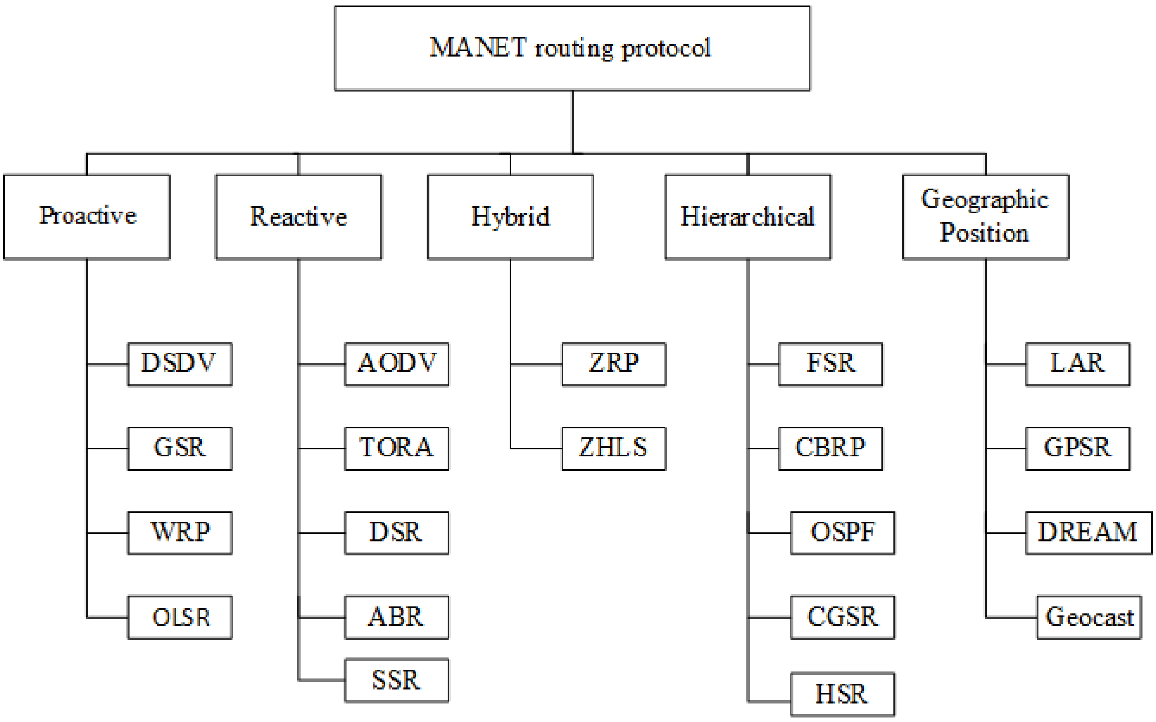


Figure 2.2: Classification of routing protocols in MANETs [3]

### 2.3.1 Table Driven or Proactive Routing Protocol

In this routing protocol, each node preserves routing tables which contains the complete routing information of each nodes in the network. Every node in the network keeps updating their routing table to contain up-to-date view of the entire network [4]. Routing tables are used to store routing information and the routing information is periodically updated when the network faces topology change [10]. In proactive steering, all nodes need to keep up a steady perspective on the system topology. When there is a topology change in the system, comparing refreshes must be engendered through the whole system to tell that there is a change.

Most proactive routing protocols proposed for MANET inherit the properties of algorithms used in wired networks. In order to adjust to the dynamic nature of MANETs, important modifications are made to the wired network routing protocol. Applying table driven routing algorithms, mobile nodes proactively update network state and maintain a route no matter whether data traffic exists or not, the overhead to maintain up-to-date network topology and information is high [3], [15]. DSDV, GSR, Optimized Link State Routing(OLSR), and WRP are some examples among proactive protocols.

- **Destination-Sequenced Distance Vector Routing Protocol(DSDV)**

According to [4], DSDV is an improvement of the classical Bellman Ford routing algorithm. The basic idea is that each node preserves a routing table that contains entire available destinations with corresponding number of hops to reach that destination, and a unique sequence number assigned by the destination node. The sequence number is used to differentiate old routes from new ones and is used to avoid the formation of loops. Hence, routing table information update is both time and even-driven. The routing table may be updated either by a full dump or by an incremental update. A full dump update sends the whole routing table to the neighbors and causes many packets to be spanned. Whereas in incremental updates only the entries that have parameter modification later the last update is broadcasted.

- **Global State Routing (GSR)**

GSR depends on the link state vectors, and the nodes retains global information about the system topology and expands its routing locally. Even if it is similar to DSDV, it improves DSDV by avoiding flooding of routing message [10]. In GSR, each node keeps a neighbor list including the running time of its neighbors, topology table including link state table and next node table containing the next hop to which the bundle is set and the distance table containing the shortest path to each target node [3].

- **Optimized Link State Routing Protocol (OLSR)**

This is an adjustment of link state routing, where each node tries to keep routing information about the network topology. Every node decides the path cost to each of the neighbors by broadcasting hello message sometimes. If the path cost changes, the node will broadcast the information to all other nodes in the network. Whereas in classical link-state algorithms, each node floods the whole network with the modified packets containing updated path cost.

OLSR improves the link-state protocol in two ways. To begin with, it minimizes the size of the update packets sent during the broadcasts by including only a subset of links to its neighbors. This are the links to a select set of neighbors named Multi-Point Relays (MPR). The set of MPRs of a node comprised of the least set of one hop neighbors of that node, so that the node can reach all of its two hop neighbors by utilizing these nodes as relay points. Each node calculates its MPR set based on the neighbor information. Following, rather than broadcasting update information by every neighbor node, only the MPR nodes contribute in broadcasting of these packets in OLSR. This reduces the traffic of control packets during flooding [15].

- **Wireless Routing Protocol (WRP)**

As described in [10], WRP is characterizes as a set of distributed shortest path algorithm that use information about the length of the shortest path to each destination and the next-to-last hop to calculate the path. This protocol minimizes the amount of cases in which a impermanent routing loop can happen. Nodes in this routing protocol preserves four tables known as distance table, routing table, link-cost table and Message Re-transmission List (MRL). In WRP every time the reliability of routing information is checked by every node, this helps to remove routing loop and tries to determine the best solution for routing in the network.

### 2.3.2 On Demand or Reactive Protocols

In this routing protocol, each node keeps one or more tables, with routing information to every other node. All nodes keep on modifying their routing table to keep the recent interpretation of the network [4]. Once a node needs a path to destination, it initiates a route discovery process in the network [10]. If the route to destination found, or no route to destination, route request packet will be dismiss. Active path can fail due to the movement of nodes to new destination. Thus, route preservation is a vital operation of reactive routing protocols [14]. Some examples of reactive routing protocol are DSR, (AODV), TORA and Lightweight Adaptive Multi-cast Algorithm (LAM) [3].

- **Dynamic Source Routing (DSR)**

As described in [16], DSR is one of the reactive routing protocols that use source routing algorithms. In source routing, each data packets consist full routing information to reach its destination. Instead of table-based routing it uses source-based routing. This routing protocol comprises two essential parts named route discovery and maintenance. Every node keeps a cache to store newly discovered paths. If a node needs to transfer a packet to another node, it will check whether there is an entry in its cache. If it is kept in the cache, then it uses that route to transfer the packet. If the entry does not exist in the cache, or expired, at that time the sender broadcasts RREQ to all neighbors requesting for a path to the destination [4].

- **Ad Hoc On-Demand Distance Vector Routing (AODV)**

AODV is one of the on-demand routing protocols. It is largely a modification of DSDV and is designed to support many mobile nodes [3]. In this routing protocol when a source node has data to be forwarded to destination and does not have path to the destination, AODV floods RREQ packet through the network. Many RREQ packet will travel on different paths and will reach the destination. Then the destination node replies RREP packet to the first RREQ packet and discards successive RREQ packets with the same sequence number and broadcast id. The request packet that reached the destination at the earliest is likely crossed a path with minimum delay or hop count [10].

It maintains sequence numbers to administer the freshness of routing information and avoid routing loops. All routing data packets carry these sequence numbers. An important characterization of AODV is that it keeps a timer-based state in every node, for using of individual routing table entries. If it is not used recently, information in a routing table will expire. A set of predecessor nodes is kept for every routing table entry, representing the set of neighboring nodes which use that entry to route data packets to destination. Neighboring nodes are notified with route error packet when the next-hop link fails. Every antecedent node, in line, transmits the RERR to its own arrangement of antecedent, in this manner adequately eradicating all courses utilizing the messed up connect [4].

- **Temporally Ordered Routing Algorithm (TORA)**

As described in [15], TORA is a link reversal routing algorithm and proposed by Park and Corson in 1993. It evolved from LMR and associates the feature Gafni-Bertzekas in a unique single-pass strategy. “ single pass ” means that by processing a single event, all route maintenance tasks can be combined. It is a distributed protocol intended to be extremely adaptive, so it can function in a dynamic network. For a given destination, TORA utilizes arbitrary “ height ” parameter to control the direction of association between any two nodes.

For a node to start a route, it broadcasts a Query to its neighbors. This is rebroadcast through the network till it arrives at the destination, or a node that has a route to the destination. This node replies with an update that contains its height with regard to the destination, which is spread back to the sender.

Each node that receives the update sets its height to be one greater than the height of the neighbor that sent the update. This forms a serious of direct association from the sender to destination, arranged in descending order of height. When a node realizes link failure, it sets its own height higher than that of its neighbors, and issues an update to that effect inverting the direction of the link between them. If it finds that it has no downstream neighbors, the destination is assumed lost, and it issues a clear packet to eliminate the invalid associations from the remaining network.

### 2.3.3 Hybrid Routing Protocol

Hybrid routing protocols are formed by combining proactive and reactive protocols. This routing protocols are designed to overcome the limitation of proactive and reactive routing protocol by combining metrics from both protocols. It is suitable for large-scale networks, where large amount of nodes exists. The large-scale network is divided into zones. Routing in side zone is done using proactive method and outside the zone using reactive method [17]. Some examples of hybrid routing protocols are listed in [3], such as ZRP, ZHLS and Sharp Hybrid Adaptive Routing Protocol(SHARP).

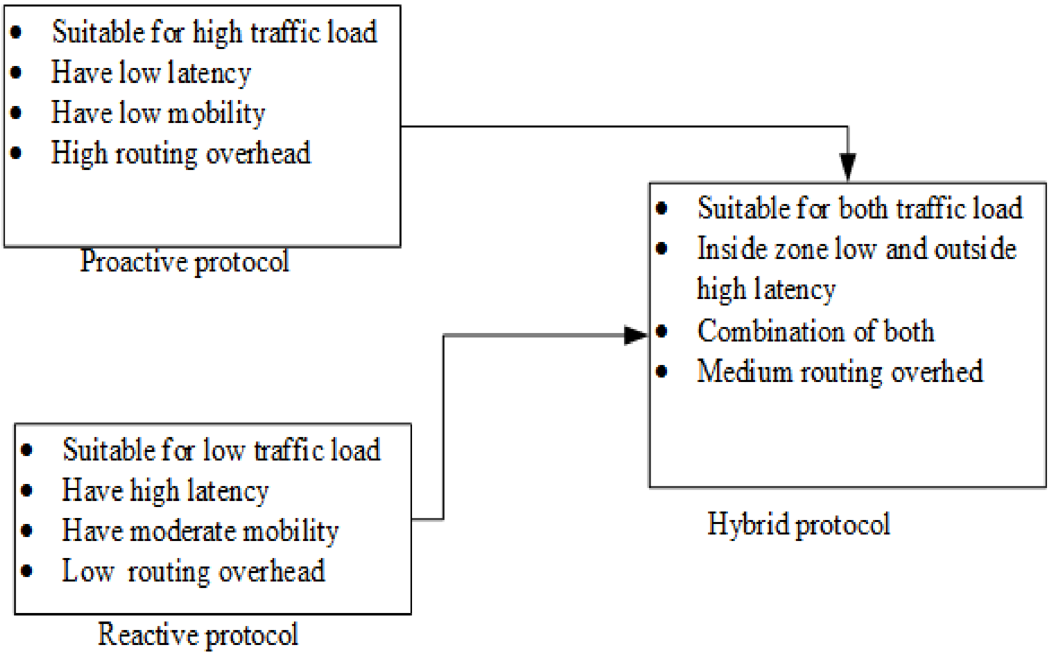


Figure 2.3: Combination feature of proactive and reactive routing protocol [3]

- **Zone Routing Protocol (ZRP)**

ZRP is one of the hybrid routing protocol that divides the network into regions. It offers a hierarchical architecture where every node has to preserve additional topological information requiring extra memory [8]. As described in [11], each node has a predefined zone on its own, including other nodes whose distance is within the predefined relationships of hops. Every node has to preserve the latest view of routing information only for nodes in its zone that reduces the network overhead by the proactive routing protocol. Route discovery is done to communicate with nodes that do not exist in the zone of a node by forwarding query message selectively only to the nodes in its zone rather than all the nodes in the network.

- **Zone Based Hierarchical Link State Routing (ZHLS)**

As pointed out in [18], [19], ZHLS is a hybrid routing protocol. In ZHLS, mobile node knows its location with the help of positioning system such as the Global Positioning System(GPS). The network in ZHLS is divided into non-meeting zones based on geographic information. Every node is aware of the node connectivity in its own zone and the zone connectivity information of the whole network. Link state routing uses two levels; node and global zone level. Unlike other hierarchical routing protocols, ZHLS does not have any cluster head. Meanwhile only zone and node ID of a destination are required for routing, the route from a source to a destination is adjustable to changing topology.

- **Sharp Hybrid Adaptive Routing Protocol (SHARP)**

As described in [11], [17], [18], SHARP adopts proactive and reactive routing by vigorously changing the number of routing information proactively shared . It defines the proactive zones around some nodes. All nodes in the zone radius of a specific node become the participant of that specific proactive zone for that node. If for a given target, there is no node in the specific proactive zone of the node, a reactive routing method is used to create a route to the destination. The nodes in the proactive zone only preserve routes relative to the central node. If some destination are often addressed or required in the network, SHARP proactive zones are created automatically.

### 2.3.4 Hierarchical Routing Protocols

Hierarchical routing is a multilevel clustering of mobile nodes [3]. This routing protocol organizes the network into a tree of cluster, where the roles and functions of the nodes are different at multiple levels of the hierarchy. Hierarchical routing protocols are divided into three sub-categories, which are zone-based, cluster-based and core node [19].

- **Zone Based Hierarchical Routing Protocols**

In zone-based routing algorithms, different routing approaches are used inside and outside the zone. Due to this flexibility, a more efficient overall routing performance can be achieved. Rather than maintaining routing information for the entire network, mobile nodes in the same zone knows how to reach each other with small cost. In some of zone-based routing protocols, specific nodes act as entryway nodes and perform inter-zone communication. Therefore, the network will contain partitions or a number of zones [19].

Some examples of zone-based hierarchical routing protocols are ZHLS, MZRP, ZBMRP, Grid Service(GLS), Hybrid Ad-hoc Routing Protocol(HARP) [20]. As concluded in [14], all zone-based routing protocols uses a different zone construction approach, and this method have a critical impact on the performance each routing protocol. Some zone constructing algorithms uses geographic information. Some zone constructing methods result overlapping zones, and some don't.

- **Cluster Based Hierarchical Routing Protocols**

As pointed out in [18], [19], cluster-based routing is the most common hierarchical routing approach. This routing approach divides the network into interconnected fundamentals called clusters. It uses specific clustering algorithms for cluster head selection. Mobile nodes are grouped into clusters, and cluster heads take the responsibility of membership management and routing functions. Here are some examples of cluster based hierarchical routing protocols; CBRP, Cluster Gateway Switch Routing protocol(CGSR) and Hierarchical State Routing(HSR).

Different clustering algorithms have been presented to group mobile nodes and select cluster-heads. For instance, in HSR, hierarchical addressing is used. Moreover, a location management mechanism is used in HSR to map the logical address to the physical address. Where as, CGSR is based on DSDV routing protocol and each node keeps routing information for other nodes in both cluster member table and the routing table. In CBRP routing protocol each node keeps information about its neighbors, cluster-head keeps information about its members and its neighboring cluster-heads [14].

- **Core Node Based Hierarchical Routing Protocols**

In core node based routing, key nodes are dynamically selected to form the backbone of the network. The construction of the routing path and the control/dissemination of data packets using backbone nodes. In core-node routing protocol, core-node extraction is an important duty. Amongst core-node routing protocols, Core-Extraction Distributed Ad-hoc Routing (CEDAR), OLSR and Landmark Ad-hoc Routing (LANMAR) enforce different methods for core-node extraction [14], [19].

### 2.3.5 Geographic Position (Information Assisted)

As described in [14], the availability of GPS or similar positioning systems allows mobile nodes to easily access geographic information. Geographic routing is also named as position-based routing approach that counts on geographic position information. These routing protocols are topological independent, developed for large and distributed network operations. Geographic position routing protocols are divided into greedy forwarding, flooding based and hierarchical approach [19].

- **Greedy Forwarding (Single-path)**

Shortest path is an instance of single path strategy, where one copy of the message is in the network at any time. Several single path strategies depend on greedy forwarding and face routing. In greedy forwarding, message is forwarded to the destination based on only the local information. In these routing strategies, each node sends the message to its neighbor using the most appropriate local information.

A suitable neighbor is the neighbor with the shortest distance to the destination at each stage. The selection was made according to the optimization principles of the algorithm, but it does not guarantee the packet reach the destination. Metrics can be hop count, geographic distance, progress to destination, direction, power, cost, delay, a combination of these, etc. As discussed in [19], a recovery process is essential to make forwarding hybrid if the message destined a node having no closer neighbor to the destination. Instances of such routing protocols are GPRS and GLS.

- **Flooding-based (Multi-path)**

Messages are flooded across the whole network region or section of the region by flood-based approaches. In order to prevent loops and constant flooding, a node transmits a received packet to all neighbors if this packet has not already been received before. A node delivers a packet if the location is within the specified destination region included in each geo-cast packet is its own location. ALARM and DREAM are examples of flooding-based routing [19].

- **Hierarchical Approaches**

As pointed in [19], hierarchical approach is the third geographic information forwarding strategy. It forms a hierarchy in order to scale a large number of mobile nodes. By using zone-based routing, several techniques combine the position of the nodes and hierarchical network structures. Packets will be routed based on a constructive distance vector if the destination is close to the sender. Location Aided Routing (LAR) is an instance of hierarchical geographic information forwarding.

## 2.4 Multi-path Routing Protocols in MANET

As discussed in [12], routing protocol classification can be done in terms of the number of paths that a protocol provides per source destination pair. In MANET, depending on the number of routes, routing protocols can be divided into single-path and multi-path routing protocols. If the data is forwarded from source node to destination using a single path, then the protocol is single-path. Single-path routing protocols need to repair routes each time the route is broken. Some instances of uni-path routing protocols include DSR and AODV.

Path between source and destination is unstable in MANETs because nodes are distinguished by limited battery capacity, processing, and high degree of mobility. To minimize instability of the path, multiple routes are created between source and destination nodes. From the available multiple routes an alternative route can be used to forward the data from source to destination if the primary route fails [21].

A routing a technique that uses several alternate routes to destination is known as multi-path routing. Whenever a connection failure on a primary route is detected, the source node selects a stable route from the multiple routes available. Multi-path routing minimizes limitations of single-path routing protocols [12].

### 2.4.1 Challenges in Designing Multi-path Routing Protocols

As stated in[12], the following three major challenges were discussed when developing a multi-path routing protocol.

- **How to discover multiple paths ?**

Basically, route discovery process in on-demand routing protocol attempts to discover several routes from source to destination. The process of route discovery mechanism is modified in order to discover multiple paths. Due to the independence of the routes, disjoint routes are preferred in many multi-path routing protocols. Two types of disjoint paths are generally known node-disjoint and link-disjoint. Node-disjoint paths do not have any nodes in common, apart from the destination and source. Whereas, link-disjoint paths do not have any link in common. Therefore, the route discovery process of the existing routing protocols needs to be altered to discover a maximum number of nodes- disjoint or link-disjoint paths.

- **How to select a path ?**

The routing protocol should determine how to choose a route among the discovered paths after discovering all the paths from the source to the destination using the route request message. If a number of routes are discovered, it is required to know how many of these routes should be used (some or all of them). The performance of routing protocol will be similar with single path routing if small number of paths are used from the available multiple paths. On the other hand, if all these paths are used, there is a chance of selecting an excessively long path, which may have adverse effect on the performance of a multi-path routing protocol.

- **How to distribute the load ?**

In multi-path routing, we have multiple paths to the destination, and we need to determine how to use these multi-paths for data transmission. When selecting from multiple paths, another problem arises, that is, how the source node sends the data packet to the destination. The routing protocol can use different paths to send duplicate copies of the data packet, or it can subdivide the entire data packet into multiple segments and then use different paths to send it to the destinations.

Multi-path routing protocols are proposed to address the limitation of uni-path routing, and to increase the efficiency of packet delivery ratio and tolerance for faults. Multi-path routing allows many routes to be chosen from the source to the destination. The following figure shows classification of MANETs for uni-path and multi-path routing protocols. Almost all multi-path routing protocols are based on DSR and AODV [12].

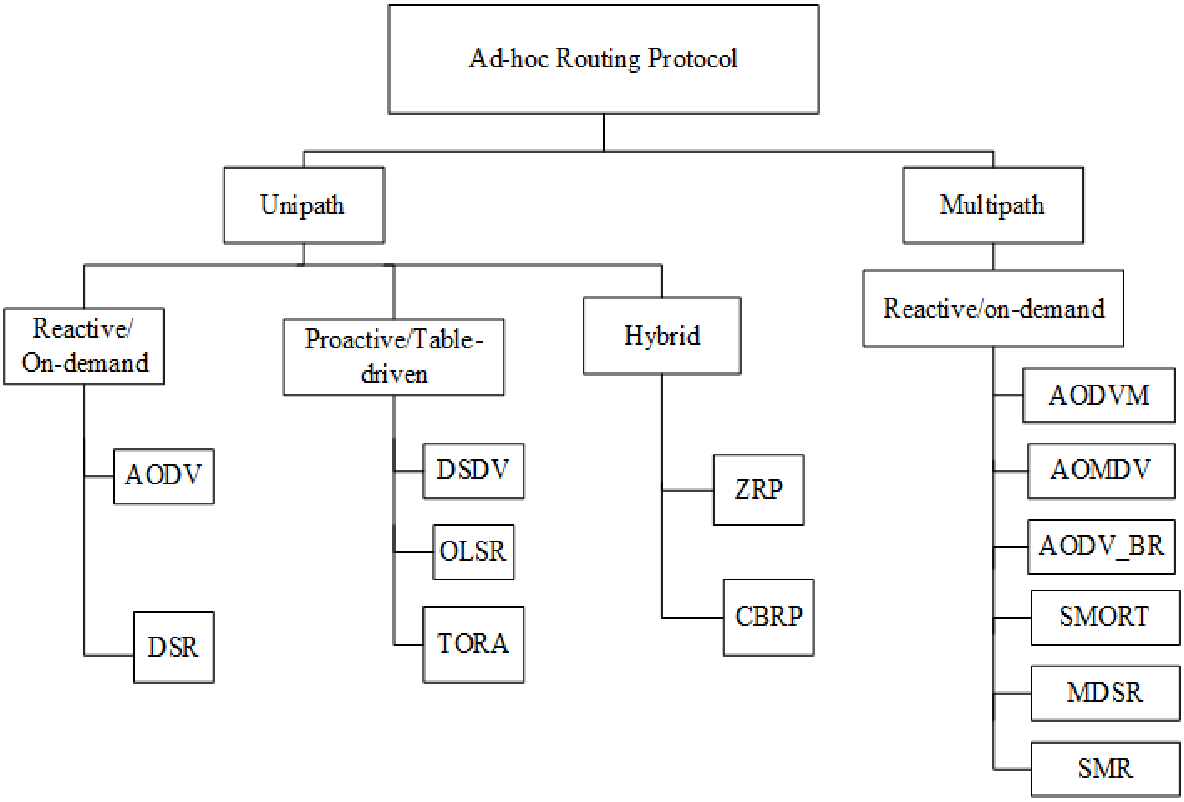


Figure 2.4: Classification of ad-hoc routing protocols based on path [22]

### 2.4.2 Multi-path extension of DSR

- **Multi-Path Dynamic Source Routing (MP-DSR)**

MP-DSR is a QoS-aware multi-path protocol based on DSR. The routing protocol creates and selects routes based on a newly defined QoS metric, end-to-end reliability. The routing protocol selects a set of routes that meet the minimum requirements for end-to-end reliability [22].

- **Multi-path Source Routing Protocol (MSR)**

MSR is another extension of DSR and aims to improve throughput and packet delivery ratio of TCP and UDP. This routing protocol reduces end-to-end delay and the queue size. But it adds an extra overhead. Hence, MSR reduces network congestion. The route discovery process is the same with that of DSR except multiple disjoint routes are discovered. However, the MSR protocol needs more routing table space and more processing complexity due to the maintenance of link failure. It needs to handle the route error messages for the extra routes per destination [12]

- **Multi-path Dynamic Source Routing (MDSR)**

MDSR is a multi-path extension of DSR protocol which was proposed by Nasipuri and Das. In DSR the destination node replies to every received request packet. MDSR solves the flooding problem by replying only to a selected set of queries. After receiving all requests, the destination replies back only to those route requests that are link-disjoint from the primary source route [12]. A source keeps all the routes in the cache. If the shortest route is broken it uses an alternate route which is the shortest among the remaining routes in the cache. If that route is also broken then nodes looks for other alternate route and this process goes on till all the routes in the cache are used [21].

### 2.4.3 Multi-path extension of AODV

- **On-demand Distance Vector Multi-path (AODVM)**

The first adapted version of AODV protocol is the AODVM. It is intended to determine multiple node disjoint paths between the source and destination. The RREQ and RREP process are altered for this protocol while the route recovery and maintenance are the same as that of AODV. In AODVM, the intermediate nodes are not allowed to forward the route reply directly to the source. It is more reliable and achieves better overall performance compared to AODV. In AODVM, the duplicate RREQ packets are not systematically discarded as in AODV [21].

As stated in [12], AODVM's main goal is primarily to build a multi-path routing framework to provide improved robustness to node failures. In order to provide the reliability of paths and security, AODVM introduces reliable path segments, which is formed by reliable nodes. Nodes that connect two segments have to be reliable.

- **Ad-hoc On-demand Multi-path Distance Vector (AOMDV)**

AOMDV is an extension of AODV routing protocol which discovers multiple routes between source and destination node. Whereas in AODV a single path will be selected to forward packet from source to destination node [21]. The major difference between AODV and AOMDV lies in two categories. The hop count in AODV is replaced with the advertised hop count in AOMDV and the next hop is replaced by the route list. Route list contain a list of the next-hops along with the corresponding hop counts. All the next hops have the same sequence number. For each destination, a node maintains the advertised hop count, which has a maximum hop count for all the paths [24].

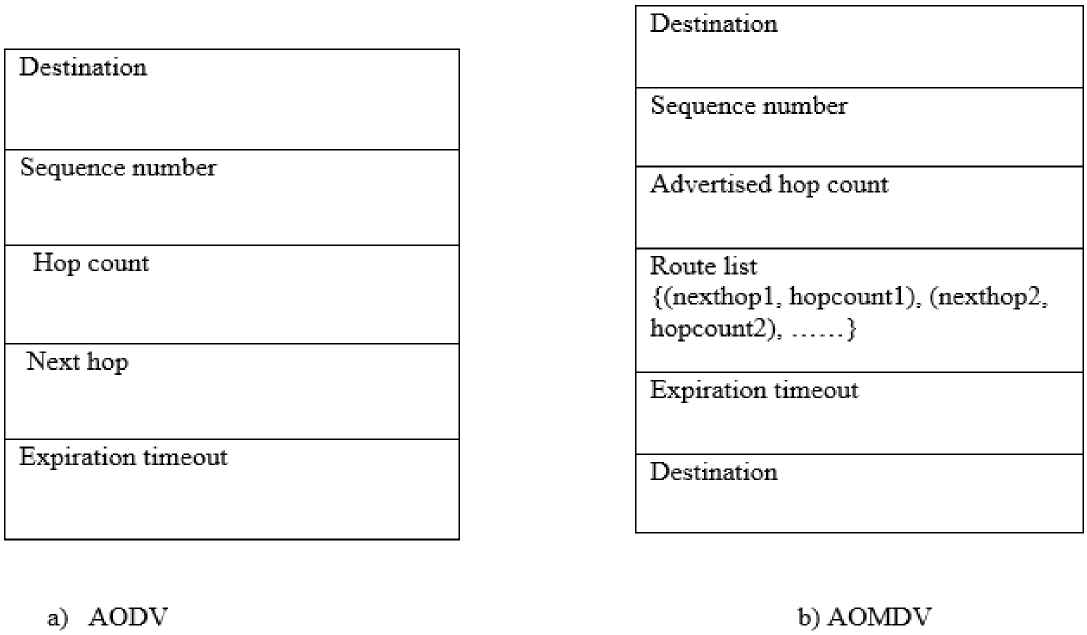


Figure 2.5: Routing table comparison between AODV and AOMDV [21]

When the source wants to forward a data packet and the route to the destination is unknown, AOMDV performs route discovery process on-demand. The route discovery packet is abbreviated as RREQ and broadcasted by every mobile node in the network. For each RREQ packet encountered, the destination forwards a route reply packet back to the source. An intermediate node is a node between source and destination, that forwards a received RREP to the neighbor nodes that are along the way to the source [23]. Each path arriving at a node during route discovery possibly defines an alternative route to the source or the destination. In order to eradicate any likely loops, AOMDV uses new metric termed as advertised hop count. AOMDV algorithm works as follows.

**if** $(seqnum_i^d < seqnum_j^d)$ **then** (1)

$seqnum_i^d := seqnum_j^d;$ (2)
**if** $(i \neq d)$ **then** (3)
$advertised\_hopcount_i^d := \infty;$ (4)
$route\_list_i^d$ = NULL; (5)
**insert** $(j, advertised\_hopcount_j^d + 1)$ **into** $route\_list_i^d;$ (6)

**else** (7)
$advertised\_hopcount_i^d := 0;$ (8)
**endif**
**elseif** $(seqnum_i^d = seqnum_j^d)$ **and** (9)
$((advertised\_hopcount_i^d, i) > (advertised\_hopcount_j^d, j))$ **then**

**insert** $(j, advertised\_hopcount_j^d + 1)$ **into** $route\_list_i^d;$ (10)

**endif**

Figure 2.6: Route update rule of AOMDV [25]

## 2.5 Transmission Power Model and Energy Conservation

The transmission range of a node is an important aspect, which has a greater impact on the network connection. If a node has an adequate higher transmission range, it can maintain connectivity even at higher mobility. In a multi-hop communication situation, link failures may be common because of a fast change in network topology due to node mobility. If we increase the power transmission range to raise the one-hop distance of a node, it will definitely avoid link failure.

As mentioned in [26], radio propagation models are implemented in a network simulator. They are used to estimate received signal power of each packet. For each node, a predefined receiving threshold exists. Packets are identified as an error and are dropped by the MAC layer if its signal power is lower than the receiving threshold. Three kinds of propagation models are implemented in ns-2, which are free space model, two-ray ground reflection model and shadowing model.

- **Free Space Model**

Only one clear line of sight view is assumed between transmitter and receiver in free space model. An equation is given below by H.T.Fries, to measure the obtained signal power in free space at distance d.

$$Pr(d) = \frac{Pt \times Gt \times Gr \times \lambda^2}{(4\pi)^2 d^2 L} \tag{2.1}$$

Where $Pt$ transmitted signal power, $Gt$ and $Gr$ are the antenna gains of the transmitter and the receiver respectively. $L$ is system loss, and $\lambda$ is the wavelength. The free space model basically represents the communication range as a circle around the transmitter. If a receiver is within the circle, it receives all packets.

- **Two-ray Ground Reflection Model**

Two-ray ground reflection model considers both the direct path and a ground reflection path. It model gives more accurate prediction at a long distance than the free space model. The received power at distance $d$ is predicted by the formula.

$$\mathrm{Pr}(d) = \frac{Pt \times Gt \times Gr \times ht^2 \times hr^2}{d^4 L} \tag{2.2}$$

Where $Pt$ transmitted signal power, $Gt$ and $Gr$ are the antenna gains of the transmitter and the receiver respectively. $ht$ and $hr$ are height of the transmitter and receiver antenna, whereas $d$ is the distance and $L$ is system loss. The equation shows a faster power decrease with an increase in distance. Two-ray ground model is used for longer distances. Usually, if $d$ is smaller than the cross-over distance uses free space model.

$$dc = \frac{4\pi \times ht \times hr}{\lambda} \tag{2.3}$$

- **Shadowing Model**

As described in [27], the free space and two-ray ground propagation models estimate the received power as a fixed function of length. They both characterize the dialogue as a perfect circle. Due to the multi-path transmission impact known as vanishing effects, the received power at a certain distance d is an arbitrary variable. The shadowing model consists of two parts. The primary one is called the path loss model, that estimates the mean power received at a distance d denoted by $\Pr(d_0)$.

$$\left[\frac{\Pr(d)}{\Pr(d_0)}\right] = -10\beta \log\left(\frac{d}{d_0}\right)^{\beta} \tag{2.4}$$

Where, Beta is a called the path loss index and is usually found through field measurements based on experience. The second part reflects the difference of determined power at certain distance. It is a log-normal arbitrary variable that is, it is of Gaussian distribution if measured in $dB$. The complete shadowing model is denoted by the following formula.

$$\left[\frac{\Pr(d)}{\Pr(d_0)}\right] = -10\beta \log\left(\frac{d}{d_0}\right) + XdB \tag{2.5}$$

Where$XdB$ is a Gaussian arbitrary variable with nil mean and standard deviation's? shadowing model encompasses the perfect circle model to a comfortable statistic model. Nodes can exclusively probably communicate when near the boundary of the communication layout.

# Chapter 3

# Related Work

## 3.1 Introduction

In this chapter different papers related to link failure and stable route selection are reviewed. Different papers proposed different solution to minimize link failure and maximize network performance in mobile ad-hoc networks. The methodology and the parameters used to solve link failure and performance enhancement are analyzed and criticized below.

Most proposed energy efficient routing algorithms used routes with higher energy value repeatedly. Using this route with higher energy value all the time causes energy of the node to degrade and the route will fail. If routes fail, we need to discovery process. Generating route discovery process frequently will reduce energy of the nodes. According to [28] to overcome selecting the same routes every time, this paper proposed an energy efficient route selection mechanism.
This approach selects alternative routes based on energy level of all routes. For available multiple routes the proposed approach will select a route based on energy threshold value. If the energy level of the route is above 30%, then this path will be selected to transmit data packets. Once the other routes reached to the threshold level, then we can forward hello message to the nodes along available routes for improving their battery by applying power backup or using wirelessly charging. While developing the proposed approach energy level parameter is added in AOMDV. The energy level information is collected at the time of route discovery process.

According to [29], an on-demand multicast routing protocol is proposed, which can quickly select the best path during link failure to minimize the data transmission delay in MANET. The algorithm is based on selecting a path with minimum number of neighboring nodes and delay (cost). If the number of neighboring node and cost is the same for multiple routes, AASOP selects the path that is crated first(uses FIFO method). The algorithm selects the optimal path from multiple paths and it attempts to transfer the data quickly. The simulation result shows that AASOP approach outperform the existing ODMRP. However, the paper only consider total neighbor nodes and cost of the path. This can lead the path with minimum neighbor node and path cost to fail due to energy loss of the node.

In [30], this article proposes a method to reduce the path discovery delay and find the shortest best path (SOP). The algorithm calculates the delay and available bandwidth of each node, and selects a path with the smallest delay and the largest available bandwidth as the best path from the source to the destination. The source node on receiving the reply from the destination node transfers the packets. Transmission is preceded in the usual way. When there is a link failure in the route to destination, SaP protocol finds the optimized path to transfer data to the destination "D" from Source S. When a node's link is about to fail, the sending node senses this problem and starts to save the packets in its buffer. If there is link a breakage then the node fails to transfer the packets, then the sending node finds an alternate node to the failed node. It just seeks help from the alternate node to transmit it to the next node.

According to [31], the objective is to decrease connection failure in MANETs by using the signal strength obtained from each node. The algorithm determines the signal intensity of each node when transmitting the RREQ packet and sends the RREQ to the neighbors' node if the signal strength of the node is medium or high. Otherwise the RREQ packet will be dropped. However, the problem here is that the paper only considers the signal strength. Assuming only signal intensity decreases the performance of routing protocol due to the fact that received signal strength suggests that the node is nearest to the transmitter. It does not grantee the node having high signal strength remains connected because of node movement and power failure.

Authors in [32], proposed an algorithm that aims to avoid route breaks in Mobile Ad-hoc Network (MANET) during routing the data packets by using Received Signal Strength (RSS) based AODV. The route break is predicted by using the parameter RSS and node density. The proposed scheme predicts the route failure in the MANET by evaluating the RSS value periodically. If the RSS value is less than the defined threshold value in the sense the link failure is expected in between the nodes. Then the responsible intermediate node locally repairs the route to reach the destination. It is often considered that the transmission delay in the network is minimized by node density.

According to [33], proposed a routing protocol which provides multi-path discovery, efficient utilization of bandwidth and controlled traffic load route recovery at the time of failure. The proposed work is simulated using NS2 and the proposed protocol is efficient in overcoming the problem of stale routes in multi-path routing protocols. The results also show that the rate of packet transmission is greatly increased and the end-to-end delay is reduced.

AODV has been improved to minimize the rate of packet loss, as described in [34]. The node that detects the link failure will send ICMP messages and request the energy and number of resources to minimize link failure in the network. Due to decentralized network characteristics, nodes may change their location and results link failure. To reduce link failure in the network, the node which detects the link failure will send ICMP message and ask for the energy and number of resources. The node will revert back with the energy and number of resources. The node with maximum energy and maximum resources will be selected as best path recovery node from source to destination.

Routing overhead consumes parts of network capacity and restricts the supported traffic in the network. For on-demand protocols, routing overhead depends on the possibility of link failure. The paper in [35], analyzes the collision possibility induced by hidden node problem and the effect of failure possibility. A mathematical examination of the overhead theoretical routing grounded on the probability of link failure is given. OPNET 14.5 framework is used to simulate the specified scenarios and the outcome indicates that the theoretical analysis fits with the simulation result.

In order to reduce link failure, the paper in [36] considered three assumptions. The first assumption selects the path that has the highest signal strength, the second assumption selects the path having minimum hop count as the final path, and the third assumption selects the path having fresh sequence number as a final path. Simulation results show that the proposed technology reduces delay, overhead, packet loss and improves throughput.

Link failure or node energy depletion causes re-routing and establishing a new route from the source node to destination which consumes extra node energy, reduces connectivity of the network and early partition of the network. Energy-related parameters consideration in routing is vital solution to enhance network lifetime. As pointed out in [37] the paper presents an enhancement in AODV routing protocol and proposed a new Hop count and Node Energy based Routing Protocol (HNERP). HNERP uses hop count and node energy as a combined routing function for energy efficient route selection. In this approach life time of the network is enhanced by avoiding data transmission through nodes with low energy and balance the energy consumption among all nodes in the network. HNERP uses those nodes in route selection which have higher energy levels and ensures that the selected route is the shortest route for data transfer. In HNERP only node which has higher energy levels are selected for routing data packets. Simulation result obtained from NS-2 shows that HNERP reveals better performance in term of network lifetime, packet delivery ratio and throughput while it reduces end-to-end delay as compared to AODV routing protocol

## 3.2 Summary

The literature reviewed in this chapter are related to reducing link failure and increasing performance of routing protocols in MANET. Different approaches and parameters are used to solve the underlined problem. The parameters used in the above literature to solve the problem are bandwidth, received signal strength, path cost(delay), hop count and energy. From the results of the papers we can conclude that link failure and performance degradation still needs further improvement. In order to maximize network performance like packet delivery ratio, network throughput and to minimize the probability of link failure ,we have combined received signal strength and energy parameter. Routes that do not satisfied the threshold value of both parameter are excluded from transmitting the packet because it will increasing the likelihood of link failure resulting overall performance degradation.

# Chapter 4

# Proposed Model and Algorithm

## 4.1 Overview of Adhoc On Demand Multi-Path Distance Vector(AOMDV)

AOMDV is based on distance vector concept and uses hop by hop routing approach. It is an on-demand routing protocol, which discovers route on demand. It is a multi-path extension of AODV. AOMDV offers two main services namely route discovery and maintenance. Using single route discovery process, multiple routes to destination are discovered in multi-path routing approaches. The multiple routes can be used for load balancing and also used as a backup route if the primary route fails. Route update rules are applied locally at every node. Routing table contains routes which are both loop-freedom and disjoint property. The routes should satisfy the link and node disjointedness.

In the proposed work, received signal strength and remaining energy are combined to reduce link failures in multi-path routing protocols (especially AOMDV). More packet's delivery ratio can be achieved by reducing link failure in multi-path routing protocol. Multi-path routing is proposed to find multiple routes between source and destination.

## 4.2 Approach and Algorithm for Modified Protocol

The modified protocol combines residual energy, threshold energy and signal strength parameters. These parameters have significant impact on the improvement of AOMDV routing protocol. AOMDV routing protocol is a multi-path routing protocol. It is an improvement of AODV, which is single path routing. AOMDV uses the shortest path concepts to choose multiple routes to the destination. Due to energy deficiency, nodes may fail to transmit the data packet to the intermediate node or destination. Hence the shortest path is not always efficient and stable.

These problems cause the efficiency of the AOMDV protocol to decline. Performance can be expressed by satisfying conditions such as packet delivery ratio, packet loss rate and network throughput. In this study, we focus on choosing the best and most effective path during path discovery process to improve the execution of the AOMDV routing protocol. Our aim is to design a routing protocol to increase the stability of the network and maintaining the network connectivity using residual energy of the nodes.

### 4.2.1 Flow Chart of The Modified AOMDV Routing Protocol

AOMDV routing protocol is modified to select stable and efficient route for forwarding data packets to destination. Our goal is to maximize route stability in multi-path routing and enhance network performance. The modified algorithm performs threshold calculation for both received signal strength and energy values. AOMDV is a multi-path routing protocol which discovers route on demand.
If a node needs to transfer data to destination, it floods route request packet to the available nodes in the network. Reverse path with route replay packet indicates that there is a route to destination.

In the modified AOMDV routing protocol, from the available multiple paths to the destination node the path that has received signal strength greater than or equals to the defined received signal threshold will be selected as the best path. Furthermore, the best path that has strong received signal strength will be checked if the nodes along that route have enough residual energy to transmit and receive data packets to and from the neighboring nodes. If the nodes have enough residual energy, the best path to destination will be the path having enough signal strength and residual energy. However, if the node has higher signal power but minimum energy value the source node should select an alternative route having sufficient energy.

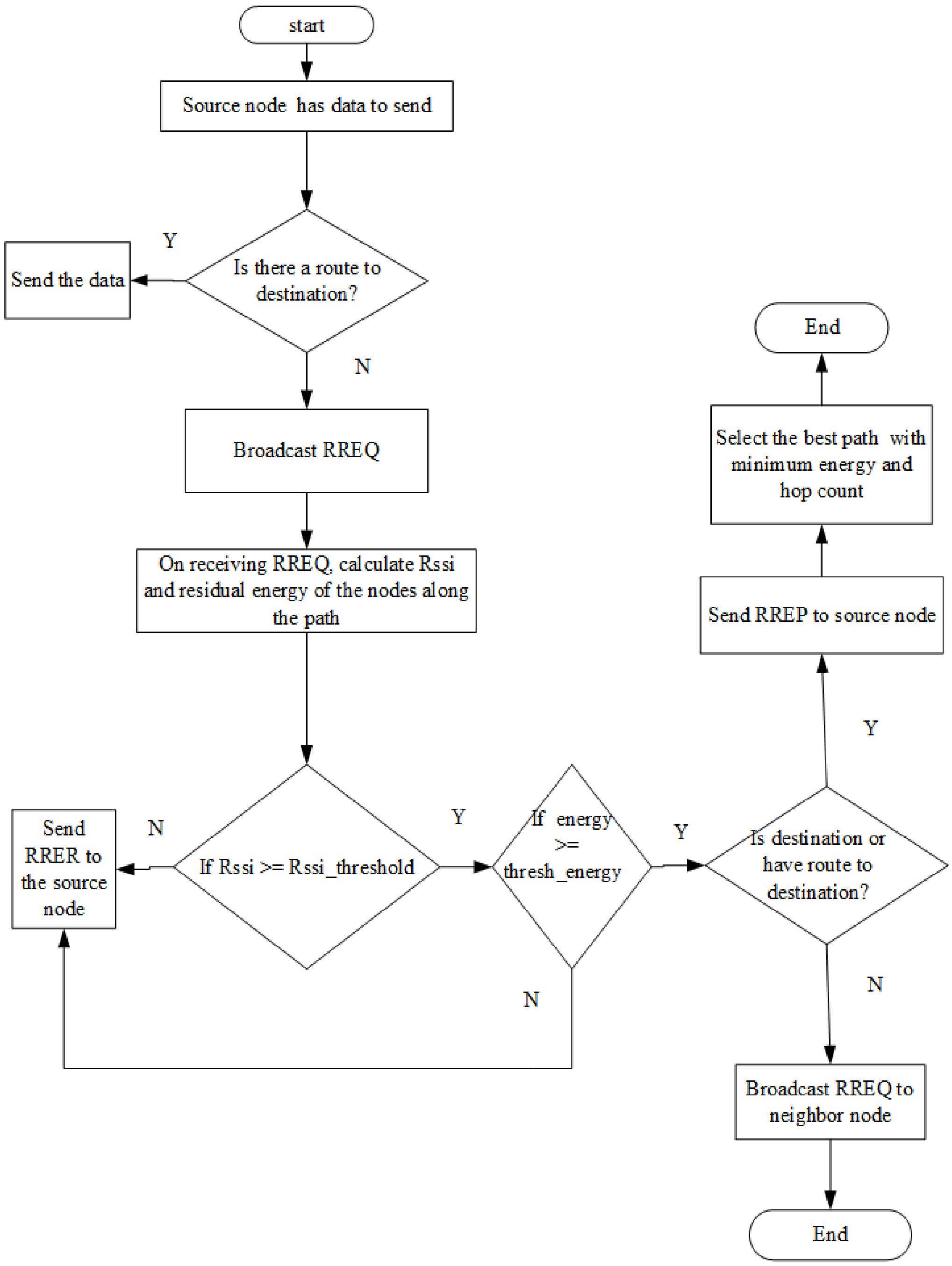


Figure 4.1: Flowchart of the proposed work (MDAOMDV)

### 4.2.2 Route Selection Based on Residual and Threshold Energy

The proposed work combines three parameters residual energy, threshold energy and received signal strength. Threshold_energy parameter is considered to decide whether all nodes in the route from source node to destination have enough energy to transmit or received data. Threshold_Energy will be defined and each node can transmit the data if it has energy greater than the defined threshold value. Nodes that have lesser residual energy than the defined threshold are considered to fail sooner and are not selected to transmit data to the destination.

In this energy efficient model, a threshold energy value is proposed for every node in the network to dynamically check whether the node can participate in the path discovery process or not. The algorithm proposed to select a node k only if residual_energyk is greater than Threshold_energy, where residual_energyk, is the residual energy of the node k and threshold _energy is the threshold energy. The residual energy of the node k can be calculated by the initial energy of the node k minus energy consumed by node k. If the residual energy is larger than energy threshold value, then the transmission data is allowed through that node. Every node depends on the local information of the energy level to decide whether to participate in the route selection process or not.

The main goal of this approach is to isolate an energy hungry node which may not forward packet on behalf of others and minimize packet loss which may be caused due to the energy exhaustion of nodes. Residual energy is an energy which is calculated by subtracting consumed energy from the initial energy of the nodes. Initial energy is an energy which is given for the nodes at the start of simulation. This initial energy will degrade because of transmitting and receiving packets. When the simulation comes to an end, each node will have certain energy or zero energy. The energy left after the end of simulation is known as residual energy or remaining energy and measured by joule.

Each node in MANETs functions on limited battery energy. Power management becomes more challenging problem in MANETs many research goings-on are dedicated in this area to stronger the network life and decrease the energy consumption in network. Packet transmission and reception is the most energy consuming activities in MANET. In the entire process of communication and computation, mobile node exists in four modes sleep, active, idle and overhear.

As pointed out in [38], [39] data packet transmission in MANTS involves the transmission and reception of data packets between nodes. A node will send data packets to its neighbor node during transmission mode. The energy required to transmit data packet from one node to other is called transmission energy. Transmission energy depends on the packet size in bits. Transmission energy can be calculated using the following formula.

$$E_{tx} = \frac{330 \times P_{size}}{2 \times 10^6} \tag{4.1}$$

$$Pt = \frac{E_{tx}}{T_t} \tag{4.2}$$

Where $E_{tx}$ is transmission energy, $P_{size}$ is packet size in bits, $P_t$ is transmission power and $T_t$ is time reserved to spread data packet. In reception mode a node receives the data packet from neighbor node. The energy required to accept data packet is called reception energy and it also depends on the packet size in bits. The reception energy is worked out by using the next formula:

$$E_{rx} = \frac{230 \times P_{size}}{2 \times 10^6} \tag{4.3}$$

$$P_r = \frac{E_{rx}}{T_r} \tag{4.4}$$

Where $E_{rx}$ is reception energy, $P_{size}$ is packet size in bits, $P_r$ is transmission power and $T_r$ is time taken to receive data packet from neighbor nodes . we can conclude that residual energy is an energy left in the node after nodes consume some energy for forwarding and receiving data packets to and from some nodes.

We can calculate residual energy level of a node after transmitting or receiving data packets by subtracting consumed energy from initial energy.

$$\begin{aligned} E_{residual} &= E_{initial} - E_{consumed} \\ E_{residual} &= E_{initial} - (E_{tx} + E_{rx} + Idle) \end{aligned} \tag{4.5}$$

The $threshold\_energy$ is used to decide whether the path have sufficient energy to forward packet to destination node. It is calculated by adding transmission energy, reception energy and idle power.

$$Threshold\_energy = E_{tx} + E_{rx} + Idle \tag{4.6}$$

Where $Threshold\_energy$ is the threshold energy, $E_{tx}$ and $E_{rx}$ are transmission and reception energy respectively and idle power is the energy loss while listening the channel.

We need residual energy parameter to select a path with sufficient remaining energy and isolate routes having low residual energy. If nodes have residual energy which is minimum than the defined threshold energy, nodes will drop the packet instead of forwarding to the intermediate nodes or to the destination. This problem raises packet dropping problem, less packet delivery ratio and minimum throughput. Therefore, in order to reduce packet loss and to increase network throughput, we have to select stable routes which will forward packets to the intermediate nodes.

### 4.2.3 Route Selection Based on Received Signal Strength

Radio propagation models are used to predict the received signal strength power of each packets. Received signal strength is measured in decibels. This parameter decides whether the nodes are in transmission ranges of the other nodes. If the nodes are in the transmission range of the other node, they can communicate to each other. That means nodes in the same transmission range can receive route request broadcasted by other nodes in the same transmission range.

Using two-ray ground propagation model we have calculated the receiving power at a certain distance and this parameter is compared with receiver threshold. If the received power level is greater than the receiver threshold value then the path will be selected to transmit data packet. The receiver threshold (RX Thresh) is the parameter used to specify the communication range of the wireless nodes and the threshold is the minimal power of the packet required for successful reception. If a packet reaches a node with a power level above the receiver threshold, the receiver will be within the transmission range of the sender.

In our case we have used two ray ground model to calculate received signal strength at a certain distance d. The model affords more exact forecast at long distance. The received signal at distance d is anticipated by two-ray ground model in equation 2.2. The distance among two nodes can be calculated using Euclidean distance formula [40]. The distance between any two points(x, y) can be calculated using Euclidean distance formula as follows.

$$d = \left[(X_2 - X_1)^2 + (Y_2 - Y_1)^2\right]^{1/2} \tag{4.7}$$

The distance among nodes are determined based on the position of nodes and stored on each of the node's neighbor information table. Whenever a node accepts the RREQ packet from a neighbor, it extracts the position information from its neighbor table and calculates the distance to its neighbor and then updates the neighbor information table with the information corresponding to that node. The proposed MDAOMDV routing protocol uses information from the neighbor table to calculate remaining energy of a node to reach its neighbor nodes in a network.

### 4.2.4 Algorithm for the Proposed Modified AOMDV

The main objective of proposing this algorithm is aimed at ignoring nodes with less battery power and less signal strength from participating in route establishment and find stable path that can forward data packets to the intended intermediate node or destination. To achieve the proposed goal, we have applied energy threshold and signal strength values for filtering routes.

After discovering multiple paths to destination, we have sorted all multiple paths according to the available remaining energy. The available remaining energy in the path is the total remaining energy of the nodes divided by the number of nodes in the route(%). Using the formula below we can calculate the residual energy of each paths. We have sorted the routes according to the available remaining energy. The available multiple paths are sorted with their corresponding hop count and remaining energy. Finally the best path is selected based on minimum remaining energy and hop count.

$$path\_remaining\_energy = \frac{\sum node\_residual\_energy}{numberofnode} \tag{4.8}$$

**Algorithm 1** Algorithm for route selection process in MDAOMDV

**Input:** residual_energy, available paths
**Output:**Stable route with minimum energy and hop count

```
for ( i ← in n) to all available paths do
    Compute remaining_energy of all nodes along multiple paths
    Sort available multiple paths with corresponding lifetime
    if (paths ≥ 2) then
        select the best path with minimum remaining energy and minimum hop count
    else
        send RRER packet back to the source node
    end if
end for
```

Figure 4.2: Route replay algorithm for MDAOMDV

**Scenario of route selection in MDAOMDV**

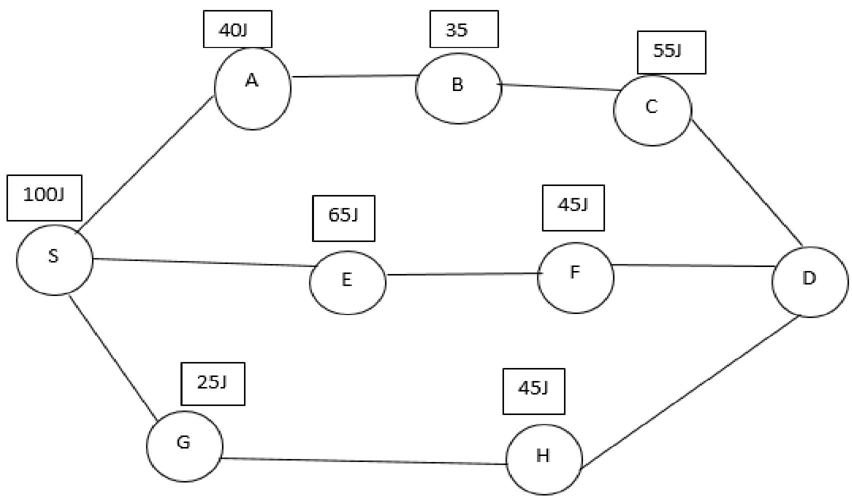


Figure 4.3: Route selection in MDAOMDV

In the proposed work multiple routes to destination are discovered excluding routes with insufficient residual energy and signal strength. The next task is selecting the primary route to transmit the data packet to destination. As we describe in the previous section, the primary route is selected based on having minimum residual energy and hop count. We have excluded routes having insufficient energy and signal strength from participating in route selection. Now our task is selecting the best route to destination from routing table. From the above figure, we have three routes to destination.

| Available routes to destination | | | |
|---|---|---|---|
| Routes | route list | average remaining energy | hop count |
| Route1 | S → A → B → C → D | 43J | 4 |
| Route2 | S → E → F → D | 55J | 3 |
| Route3 | S → G → H → D | 35J | 3 |

From the lists of routes available in the above table, the primary route choice is route 3. This is because the route have minimum remaining energy and hop count. If we select the route which has maximum remaining energy, the other discovered multiple routes are useless. Additionally the route having maximum remaining energy may have the large distance, which causes delay.

# Chapter 5

# Experimental Setup and Performance Evaluation

## 5.1 Experimental Setup

This chapter discourse experimental setup for our proposed model which is discussed in Chapter Four. Meanwhile it is quite a multi-part task to make a comparison between existing and the proposed protocol on a real time network, the simulation environment is used to simulate the new proposed protocol with existing routing protocol. For this thesis we have selected ns-2 as a simulation environment.

As discussed in [41], ns is an event driven network simulator program, established at the University of California Berkley, which contains many network objects such as protocols, applications and traffic source behavior. On the simulation layer NS uses Object oriented Tool Command Language (OTcl) programming language to read user simulation scripts. OTcl language is in fact an object-oriented extension of the Tcl Language. The Tcl language is totally compatible with the C++ programming language.

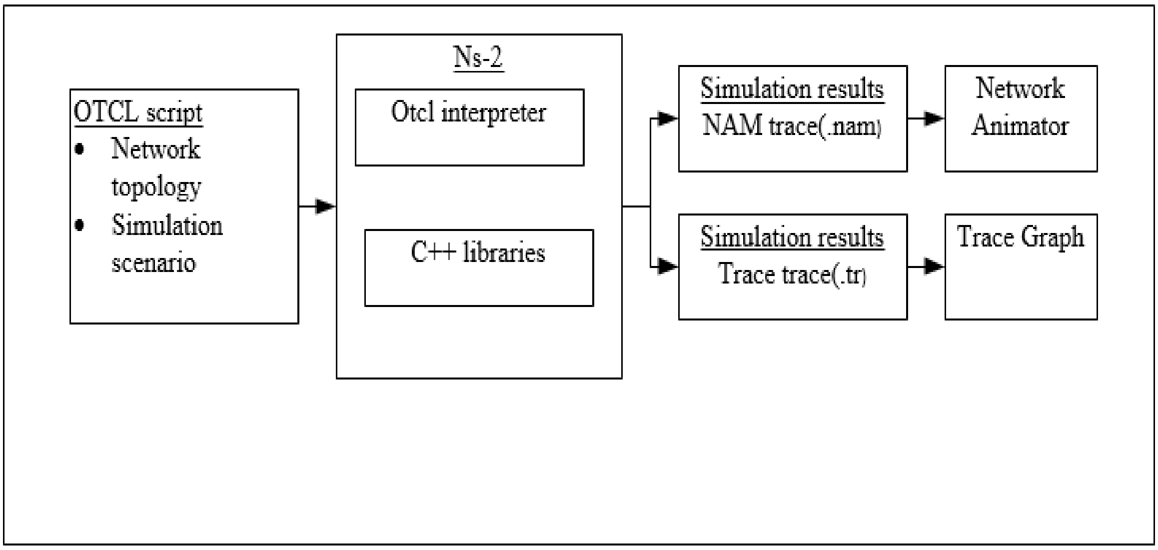


Figure 5.1: ns 2 schema [41]

An OTcl script composed by a user is interpreted by network simulator. As OTcl script is being interpreted, NS creates two main analysis reports simultaneously. Which are known as Network Animator (NAM) object that shows the visual animation of the simulation and trace object that comprises the behavior of all objects in the simulation. Both of them are created as a file by ns. Nam file is used by NAM software that comes along with ns and ".tr" file includes all simulation traces in the text format.

**Network Animator (Nam) trace**: As described in [42] nam is a Tcl/Tk based animation tool that is used to visualize the ns simulations and real-world packet trace data. The first step to use nam is to produce a nam trace file. Topology information like nodes, links, queues, node connectivity should be comprised by nam trace file.

**Trace File**: We can collect output or trace data on simulation using different methods [41]. In general, trace data is displayed during execution of the simulation or put in a file to be post-processed and analyzed. They have .tr extension and which records the events happened in simulation result. We used NS 2.35 for simulation environment, which is all-in-one package and installed in the Linux environment using Ubuntu 16.04.

We have selected NS2 because it is a open source simulator mostly used for academic research in the areas of computer networks. This simulator is widely used in the research area related to MANETs and wireless sensor networks. Complex scenarios can be simply tested using NS2. Since most researchers implemented their work using NS2, it is easy to rectify errors. It also supports routing protocols and platforms.

## 5.2 Performance Evaluation

This section investigates the performance of our proposed approach MDAOMDV with AOMDV. To analyze the performance of proposed MDAOMDV scheme with existing protocol, the network simulator ns-2 is used.

### 5.2.1 Simulation Environment

For performance evaluation, nodes are randomly deployed in 1000 m × 1000 m area. Simulations are supported using network simulator ns-2. Each node is equipped with a transceiver. Different nodes communicate via radio signals having transmission range of 250 m. In our simulation, IEEE 802.11 is used as MAC layer protocol. The mobility of the nodes is determined by random way point mobility model. For Transport control protocol (TCP) data sessions, node pairs are randomly selected and 512 bytes data packet size is used. The performance of modified AOMDV (MDAOMDV) and AOMDV routing protocols are evaluated by using NS 2.35 by illustrating different parameters.

The following table shows simulation parameters. After running C++ objects with Tcl simulation script, the result of simulation generated as trace files and the .awk file is prepared for analyzing the trace files into graphs for various performance metrics.

| List of simulation parameters | |
|---|---|
| Parameter | Values |
| Simulator | Ns-2.35 |
| Number of nodes | 5, 10, 20, 30, 40 |
| Traffic | FTP |
| Simulation time | 30-130 seconds |
| Packet size | 512 bytes |
| Mobility model | Random waypoint |
| Routing protocol | MDAOMDV, AOMDV |
| Radio propagation Model | Two Ray Ground |
| Antenna model | Omni |
| Transmission Range | 250 meters |
| Dimension | 1000*1000 |
| Speed | 20m/s |
| Channel Type | Wireless Channel |
| Initial energy | 100 J |

Table 5.1: Simulation parameters

### 5.2.2 Performance Metrics

The performance of modified protocol MDAOMDV is evaluated using following metrics to compare the result with the existing protocol of AOMDV.

**Packet delivery ratio:** The average packet delivery ratio is the ratio of number of packets that are successfully delivered to a destination to the total number of packets that have been sent by source.

$$PDR = \sum_{\mathrm{i=1}}^{\mathrm{n}} \frac{\text{total received packets}}{\text{total sent packets}} * 100 \tag{5.1}$$

$$\text{packet loss} = \text{number of packets sent} - \text{number of packets received} \tag{5.2}$$

$$\text{packet loss ratio} = \frac{\text{total dropped packets}}{\text{total sent packet}} \tag{5.3}$$

**Throughput:** is a measure of the amount of data transmitted from the source to the destination in a unit period of time (second).

$$\text{throughput of a node} = \frac{\text{total data bits received}}{\text{simulation time}} \tag{5.4}$$

The throughput of the network is finally defined as the average of the throughput of all nodes involved in data transmission.

$$\text{Network Throughput} = \frac{\sum_{i=1}^{n} Throughput\ of\ all\ nodes}{\text{Number of nodes}} \tag{5.5}$$

### 5.2.3 Simulation Result and Discussion

The performance of MDAOMDV is compared with AOMDV for different performance metrics such as packet delivery ratio (PDR), packet loss ratio and network throughput.

| Simulation time vs packet delivery ratio(%) | | |
|---|---|---|
| Simulation time(sec) | AOMDV | MDAOMDV |
| 30 | 94.53 | 95.30 |
| 40 | 95.03 | 95.50 |
| 50 | 95.12 | 95.72 |
| 60 | 95.23 | 95.93 |
| 70 | 95.53 | 96.04 |
| 80 | 95.60 | 96.32 |
| 90 | 95.88 | 96.56 |
| 100 | 96.14 | 96.80 |
| 110 | 96.29 | 97.00 |
| 120 | 96.60 | 97.28 |
| 130 | 96.88 | 97.53 |

Table 5.2: Simulation time vs packet delivery ratio

Table 5.2 represents the packet delivery ratio of the proposed MDAOMDV and AOMDV protocol with respect to simulation time. The packet delivery of both routing protocols increases with simulation time. But the modified AOMDV protocol delivers more packet to the destination. Average packet delivery ratio of the proposed and the existing AOMDV protocol are represented graphically below in figure 5.2.

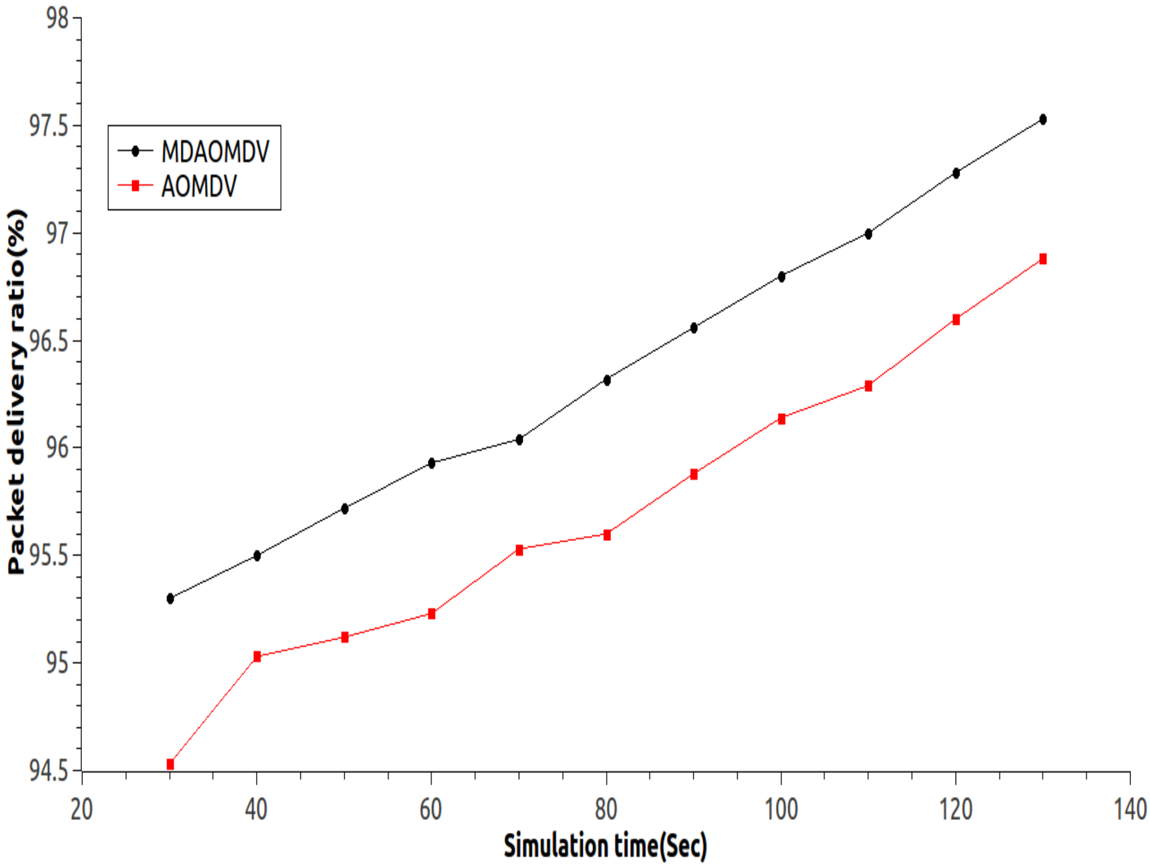


Figure 5.2: Simulation time vs packet delivery ratio

| Number of node vs packet delivery ratio(%) | | |
|---|---|---|
| Number of node(in number) | AOMDV | MDAOMDV |
| 5 | 97.50 | 98.08 |
| 10 | 96.81 | 97.10 |
| 20 | 95.45 | 95.55 |
| 30 | 95.02 | 95.32 |
| 40 | 94.01 | 94.45 |

Table 5.3: Number of node vs packet delivery ratio

The above table comprises MDAOMDV and AOMDV packet delivery ratio with respect to number of nodes. We have set the simulation time constant and the number of node variable. The packet delivery ratio of AOMDV and MDAOMDV protocols decreases with an increase in number of nodes. This result is represented by figure 5.3 below.

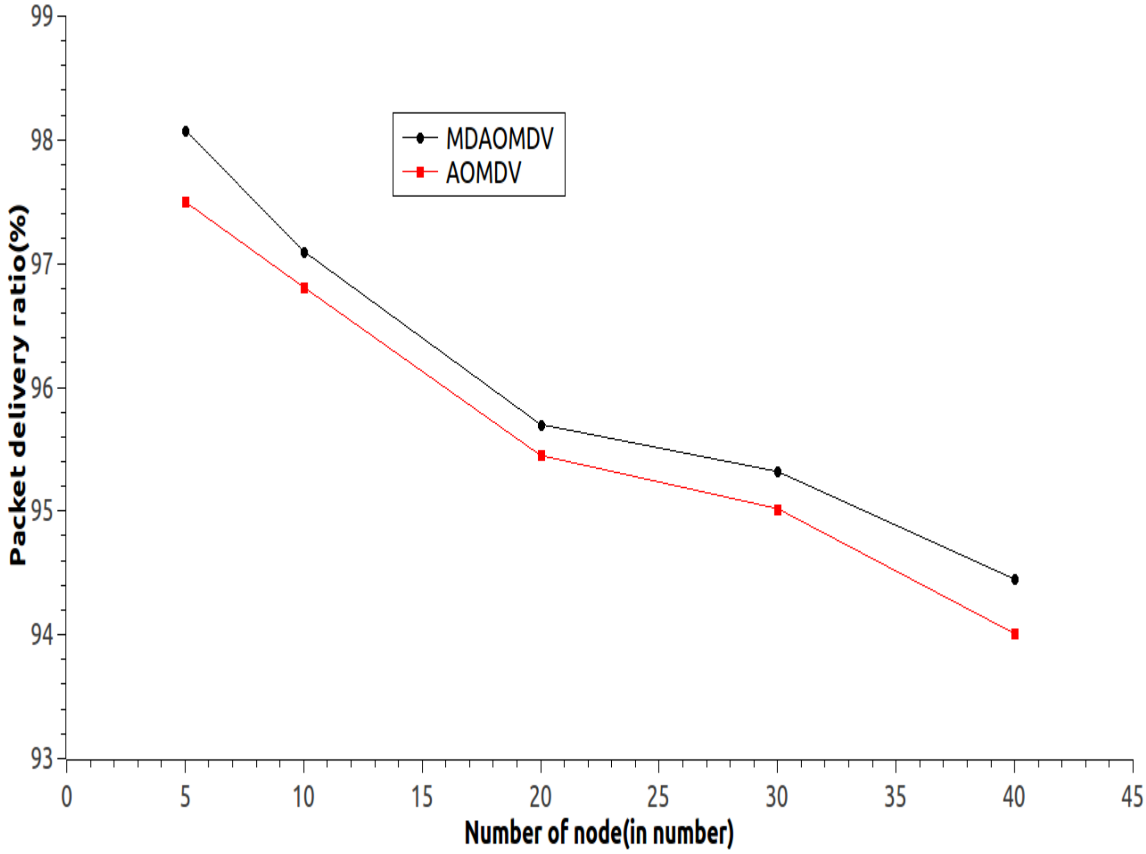

Figure 5.3: Number of nodes vs packet delivery ratio

| Simulation time vs network throughput(kbps) | | |
|---|---|---|
| Simulation time(sec) | AOMDV | MDAOMDV |
| 30 | 3,686.40 | 4,434.98 |
| 40 | 4,029.13 | 4,705.15 |
| 50 | 4,272.55 | 4,877.58 |
| 60 | 4,283.41 | 4,977.68 |
| 70 | 4,458.11 | 5,063.61 |
| 80 | 4,596.33 | 5,122.59 |
| 90 | 4,696.59 | 5,166.02 |
| 100 | 4,778.67 | 5,196.54 |
| 110 | 4,847.56 | 5,230.86 |
| 120 | 4,901.43 | 5,254.26 |
| 130 | 4,951.71 | 5,269.23 |

Table 5.4: Simulation time vs network throughput

Table 5.4 above represents network throughput of MDAOMDV and AOMDV. The throughput of the existing and the modified protocols increases with an increase in simulation time. From the above result we can conclude that the modified routing protocol achieves more throughput than the existing protocols with an increase in simulation time. The comparison is represented graphically in figure 5.4 below.

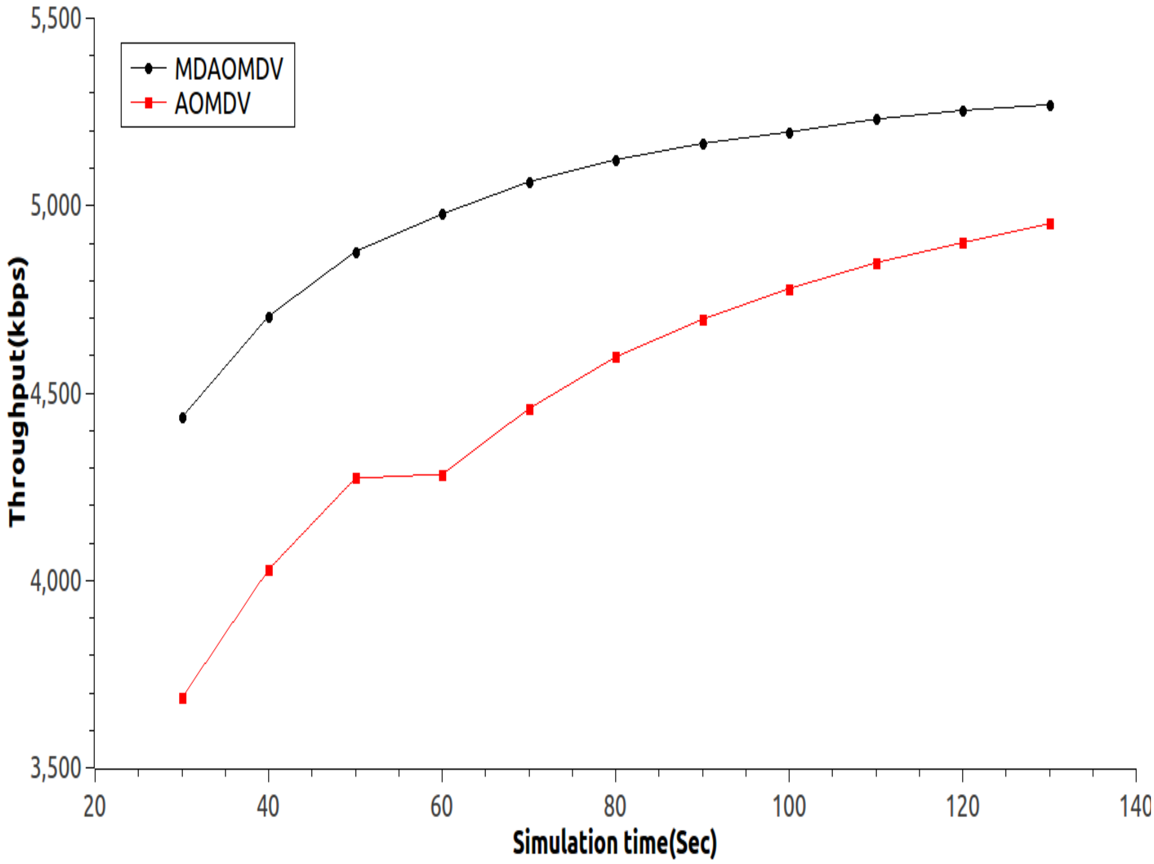


Figure 5.4: Simulation time vs network throughput

| Simulation time vs packet loss ratio(%) | | |
|---|---|---|
| Simulation time(sec) | AOMDV | MDAOMDV |
| 30 | 5.14 | 4.96 |
| 40 | 4.97 | 4.58 |
| 50 | 4.94 | 4.35 |
| 60 | 4.68 | 4.15 |
| 70 | 3.75 | 3.33 |
| 80 | 3.13 | 2.79 |
| 90 | 2.68 | 2.39 |
| 100 | 2.35 | 2.1 |
| 110 | 2.09 | 1.87 |
| 120 | 1.88 | 1.68 |
| 130 | 1.71 | 1.53 |

Table 5.5: Simulation time vs packet loss ratio

Table 5.5 comprises packet loss ratio of both MDAOMDV and AOMDV with respect to simulation time. As we can see from the table for both protocols the packet loss ratio decreases with an increase in simulation time. However, the proposed approach achieves minimum number of dropped packets compared with the AOMDV protocols. The result is represented diagrammatically by figure 5.5 below.

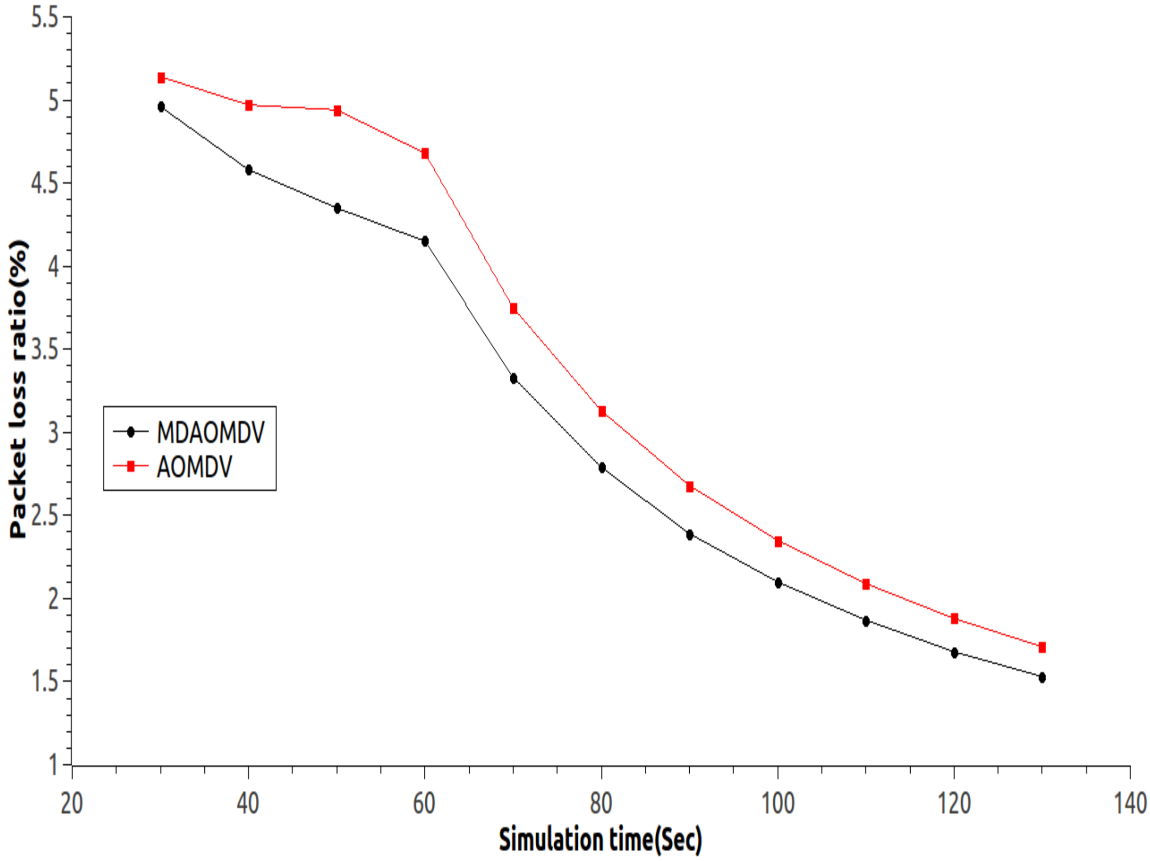


Figure 5.5: Simulation time vs packet loss ratio

# Chapter 6

# Conclusion and Future Work

## 6.1 Conclusion

A Mobile Ad hoc Network is a dynamically formed self-organized network by an independent system of mobile nodes linked by wireless connections. With the advancements of wireless technology, finding the best path for MANET routing protocol is increasing rapidly. One of the most popular routing protocols for mobile ad-hoc network is the Ad hoc On-Demand Multi-path Distance Vector (AOMDV) routing protocol. On-demand is a major characteristic of AOMDV, which means that routes are established only when they are needed by a source node.

The limited battery power and low signal strength in this protocol may lead to node breakdown consequently affecting the packets which are delivered at destination. In order to solve the problem of existing protocol, we have designed a new protocol called Modified Ad hoc On-Demand Multi-path Distance Vector (MDAOMDV). In this paper, MDAOMDV protocol is proposed to select the best and efficient route between source and destination by using residual energy, threshold energy and received signal strength parameter. The threshold energy value used for excluding nodes having energy less than threshold value from participating in route discovery process.

The newly proposed protocol improves the performance of AOMDV protocol by increasing the packet delivery ratio, throughput and by minimizing dropping rate. The proposed algorithm is implemented and simulated using ns-2 simulator. The simulation result demonstrates that the MDAOMDV routing protocol is performs better than AOMDV in terms of packet delivery ratio, network throughput and packet loss rate.

## 6.2 Future Work

In the proposed work we have tried to enhance the performance of multi-path routing by addressing the issues related to link failure. Among several causes of link failure and performance degradation , we have addressed the problem related to energy and link instability. Simulation result shows the modified MDAOMDV protocol performs betters in terms of packet delivery ratio, throughput and packet drop rate. However, for further improvement additional solutions for link failure should be suggested. therefore, we recommend the following direction.

The movement of nodes and topology change is among the major challenges in MANET. It is the also major cause of performance degradation. Further study must be done on predicting link failure from the previous topology history of nodes.

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# Appendix: Sample Screen-shoot of the proposed MDAOMDV

### Appendix A: Network Animator (NAM)and Trace File

The figures below show the NAM screen-shots for the NS-2 simulations at different point of time of the simulations. The below image shows the nodes at the start of the simulation and the green color represents that the nodes have high energy levels. The below screen-shot shows the trace file of proposed work in NS-2.

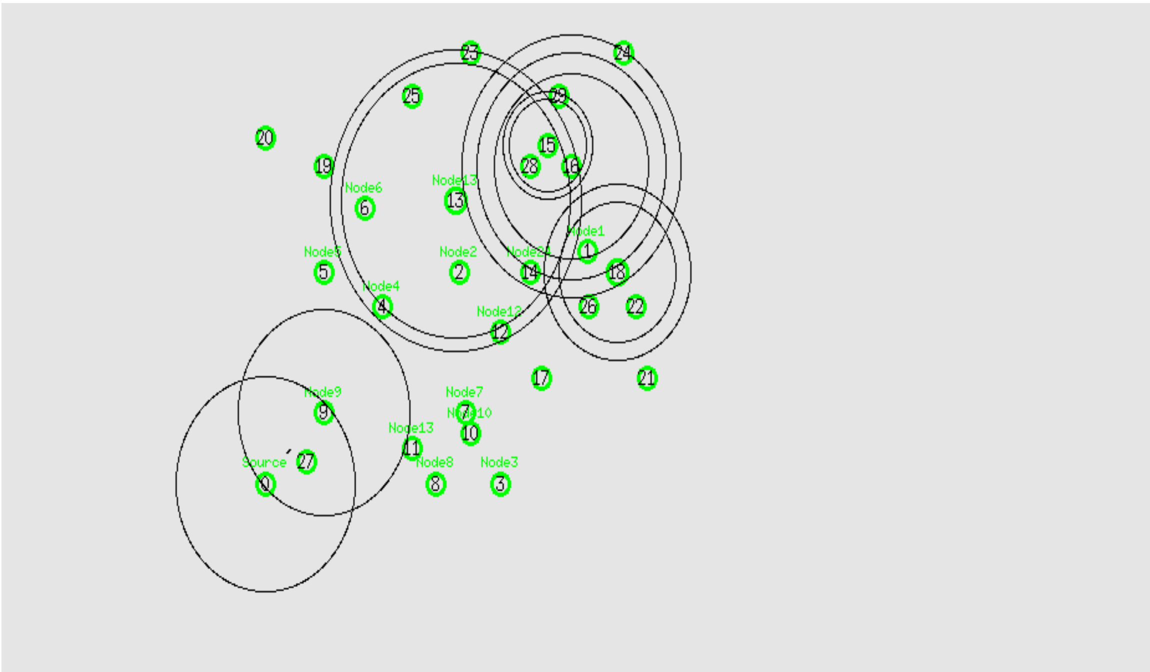


Figure 1: Nodes start transferring data to destination node

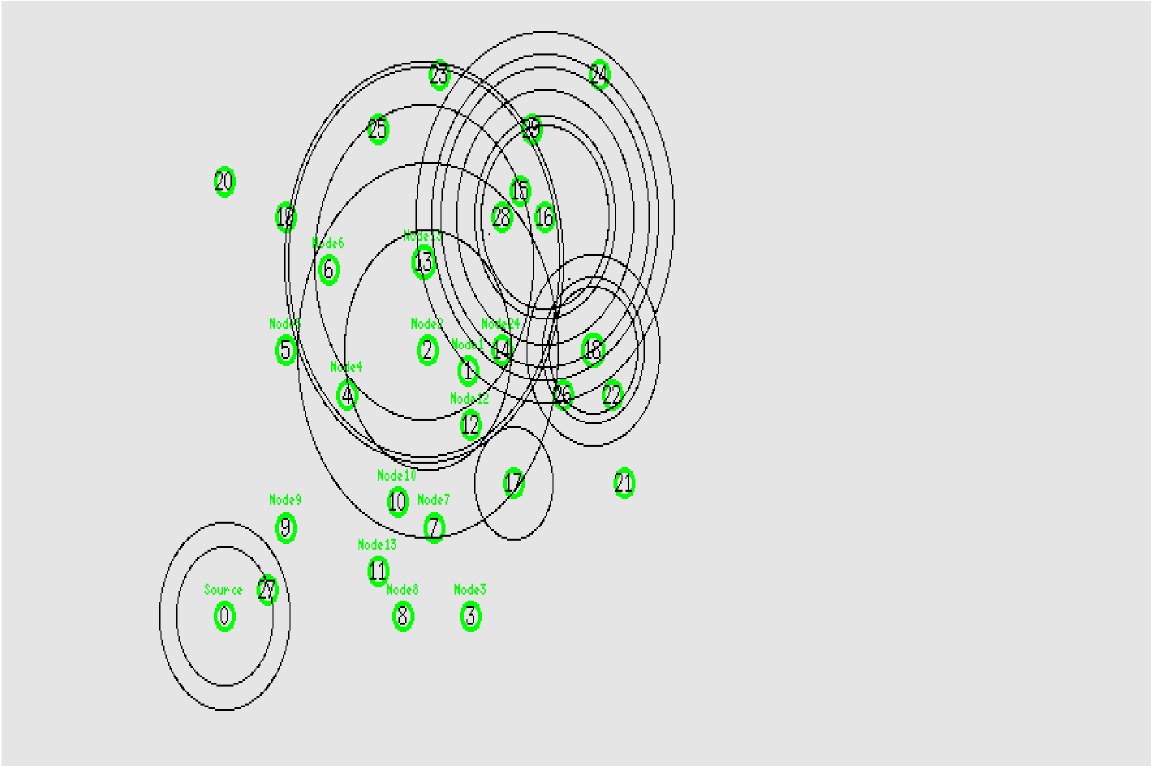


Figure 2: Nodes start transferring data to destination node and starts to change location

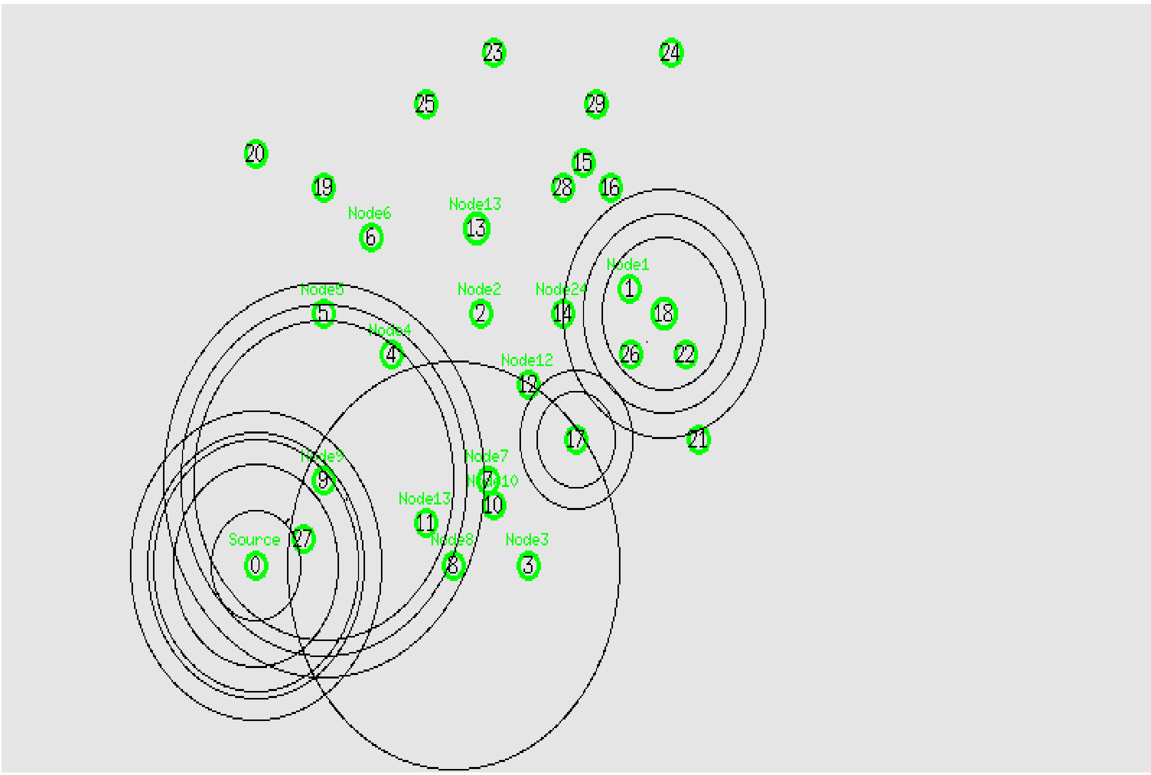


Figure 3: Nodes start transferring data to destination node and starts to change location

The figure below shows trace file of the proposed modified AOMDV file in ns2.

```
r -t 1.004994038 -Hs 9 -Hd -2 -Ni 9 -Nx 150.00 -Ny 150.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.004994173 -Hs 27 -Hd -2 -Ni 27 -Nx 120.00 -Ny 80.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.004994261 -Hs 0 -Hd -2 -Ni 0 -Nx 50.00 -Ny 50.00 -Nz 0.00 -Ne 99.798473 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.004994303 -Hs 5 -Hd -2 -Ni 5 -Nx 150.00 -Ny 350.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.004994366 -Hs 10 -Hd -2 -Ni 10 -Nx 260.00 -Ny 240.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.004994409 -Hs 4 -Hd -2 -Ni 4 -Nx 250.00 -Ny 300.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.004994557 -Hs 11 -Hd -2 -Ni 11 -Nx 300.00 -Ny 100.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019038 -Hs 9 -Hd -2 -Ni 9 -Nx 150.00 -Ny 150.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019173 -Hs 27 -Hd -2 -Ni 27 -Nx 120.00 -Ny 80.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019261 -Hs 0 -Hd -2 -Ni 0 -Nx 50.00 -Ny 50.00 -Nz 0.00 -Ne 99.798473 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019303 -Hs 5 -Hd -2 -Ni 5 -Nx 150.00 -Ny 350.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019366 -Hs 10 -Hd -2 -Ni 10 -Nx 260.00 -Ny 240.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019409 -Hs 4 -Hd -2 -Ni 4 -Nx 250.00 -Ny 300.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
r -t 1.005019557 -Hs 11 -Hd -2 -Ni 11 -Nx 300.00 -Ny 100.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
1.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 29 -P mdaomdv -Pt 0x2 -Ph 1 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
s -t 1.005294878 -Hs 5 -Hd -2 -Ni 5 -Nx 150.00 -Ny 350.00 -Nz 0.00 -Ne 99.798649 -Nl RTR -Nw --- -Ma 0 -Md ffffffff -Ms 1 -Mt 800 -Is
5.255 -Id -1.255 -It MDAOMDV -Il 52 -If 0 -Ii 0 -Iv 28 -P mdaomdv -Pt 0x2 -Ph 2 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
s -t 1.005669878 -Hs 5 -Hd -2 -Ni 5 -Nx 150.00 -Ny 350.00 -Nz 0.00 -Ne 99.798649 -Nl MAC -Nw --- -Ma 0 -Md ffffffff -Ms 5 -Mt 800 -Is
5.255 -Id -1.255 -It MDAOMDV -Il 110 -If 0 -Ii 0 -Iv 28 -P mdaomdv -Pt 0x2 -Ph 2 -Pb 1 -Pd 13 -Pds 0 -Ps 0 -Pss 4 -Pc REQUEST
```

Figure 4: Trace file of MDAOMDV

# Appendix B: TCL script for the proposed MDAOMDV

```
# A tcl script created by melishew to simulate MDAOMDV
set val(chan)                    Channel/WirelessChannel    ;# channel type
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(ant)                     Antenna/OmniAntenna        ;# antenna model
set val(ifqlen)                  50                         ;# max packet in ifq
set val(nn)                      30                         ;# number of mobilenodes
set val(rp)                      MDAOMDV                    ;# routing protocol
set val(energymodel)             EnergyModel                ;# Energy Model
set val(initialenergy)           100.00                     ;#initial energy in jouls
set val(x)                       1000                       ;# X dimension of topography
set val(y)                       1000                       ;# Y dimension of topography
set val(maxSpeed)                20.0                       ;# movement  maximum speed  [m/s]
set val(movementStart)           70.0                       ;# movement start time [s]
set val(stop)                    130                        ;# time of simulation end
# simulator object
set ns              [new Simulator]
set tracefd         [open f30.tr w]
set windowVsTime2 [open win.tr w]
set namtrace        [open f30.nam w]

$ns trace-all $tracefd
$ns use-newtrace
$ns namtrace-all-wireless $namtrace $val(x) $val(y)

# set up topography object
set topo [new Topography]
$topo load_flatgrid $val(x) $val(y)

# general operational descriptor- storing the hop details in the network
create-god $val(nn)

```

```
#********************************** UNITY GAIN, 1.5m HEIGHT OMNI DIRECTIONAL ANTENNA SET UP **************

Antenna/OmniAntenna set X_ 0
Antenna/OmniAntenna set Y_ 0
Antenna/OmniAntenna set Z_ 1.5
Antenna/OmniAntenna set Gt_ 1.0
Antenna/OmniAntenna set Gr_ 1.0
#Transmission range setup
Phy/WirelessPhy set CPThresh_ 10.0
Phy/WirelessPhy set CSThresh_ 1.559e-11    ;#250m
Phy/WirelessPhy set RXThresh_ 3.65262e-10 ;#250m
Phy/WirelessPhy set Rb_ 2*1e6
Phy/WirelessPhy set Pt_ 0.281838
Phy/WirelessPhy set freq_ 914e+6
Phy/WirelessPhy set L_ 1.0
#  Create nn mobilenodes [$val(nn)] and attach them to the channel.
#

# configure the nodes
#$ns node-config -adhocRouting $val(rp)\
$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) \
                         -channelType $val(chan) \
                         -topoInstance $topo \
                         -energyModel $val(energymodel) \
                         -initialEnergy 100 \
```

```
                         -txPower 0.6 \
                         -rxPower 0.4 \
                         -idlePower 0.2 \
                         -sleepPower 0.01 \
                         -agentTrace ON \
                         -routerTrace ON \
                         -macTrace ON \
                         -movementTrace ON \


        for {set i 0} {$i < $val(nn) } { incr i } {
                set n($i) [$ns node]

}

```

```
# Define node initial position in nam
for {set i 0} {$i < $val(nn)} { incr i } {
# 30 defines the node size for nam
$ns initial_node_pos $n($i) 30
}

# Telling nodes when the simulation ends
for {set i 0} {$i < $val(nn) } { incr i } {
    $ns at $val(stop) "$n($i) reset";
}

# ending nam and the simulation
$ns at $val(stop) "$ns nam-end-wireless $val(stop)"
$ns at $val(stop) "stop"
$ns at 130.01 "puts \"end simulation\" ; $ns halt"
proc stop {} {
    global ns tracefd namtrace
    $ns flush-trace
    close $tracefd
    close $namtrace
    exec nam f30.nam &
}
```

# Appendix C: AWK scripts for performance analysis of existing and proposed MDAOMDV

```
# awk file to calculate PDR and droped packets.
BEGIN {
      sendPkt=0
      recvPkt=0
      forwardPkt=0
      lost=0
}

{
packet=$19
event=$1
if(event=="s" && packet=="AGT") {
        sendPkt++;
}
if(event=="r" && packet=="AGT") {
        recvPkt++;
}
if(event=="f" && packet=="RTR") {
        forwardPkt++;
}
lost =sendPkt - recvPkt
}

END {
        printf(" Total number of sent packets %d \n", sendPkt)
        printf("The  Total number of received packets are %d \n", recvPkt)
       # printf("The forwarded packets are %d \n", forwardPkt)
        printf(" Total number of droped Packets  %f \n", lost)
        printf(" The Packet loss ratio  %f \n", (lost/sendPkt)*100)
        printf(" The packet delivery ratio  %f \n", (recvPkt/sendPkt)*100)
}
```

Figure 5: awk script to calculate packet delivery ratio and packet dropping ratio

```
# awk script to calculate throughput for 15 nodes at time 45 sec
BEGIN {
        recvdSize = 0
        startTime = 1
        stopTime = 40
    }

    {
              event = $1
              time = $2
              node_id = $9
              pkt_size = $37
              level = $19

    # Store start time
    if (level == "AGT" && event == "s" && pkt_size >= 512) {
      if (time < startTime) {
              startTime = time
              }
        }

    # Update total received packets' size and store packets arrival time
    if (level == "AGT" && event == "r" && pkt_size >= 512) {
        if (time > stopTime) {
              stopTime = time
              }
        # Rip off the header
        hdr_size = pkt_size % 512
        pkt_size -= hdr_size
        # Store received packet's size
        recvdSize += pkt_size
        }
    }

    END {
        print("recieved size", recvdSize)
        printf("Average Throughput[kbps] = %.2f \n",(recvdSize/(stopTime-startTime))/15)
    }
```

Figure 6: awk script to calculate throughput