AN EFFICIENT TECHNIQUE FOR ROUTE MAINTENANCE AND NODE MOBILITY MANAGEMENT IN SPARSELY DEPLOYED MOBILE ADHOC NETWORKS

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Dehradun

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Declaration

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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Date:- 19.2.16

Place:- Dehradun

CERTIFICATE

This is to certify that the thesis entitled ***"AN EFFICIENT TECHNIQUE FOR ROUTE MAINTENANCE AND NODE MOBILITY MANAGEMENT IN SPARSELY DEPLOYED MOBILE ADHOC NETWORKS"*** submitted by **MONIT KAPOOR** to **University of Petroleum & Energy Studies** for the award of the degree of Doctor of Philosophy is a bona fide record of the research work carried out by him under our supervision and guidance. The content of the thesis, in full or parts have not been submitted to any other Institute or University for the award of any other degree or diploma.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Mobile Ad Hoc Networks(MANET) are a collection of self-configuring mobile nodes which combine in any random topology so that basic functions of a network like packet forwarding and routing are carried out and network is functional for the duration of time for which it was initially established. MANETs are characterized by random mobility of nodes, frequent disruption in connectivity and limitation of resources such as buffer, battery back-up etc. and most importantly lack of infrastructure or backbone. Ad-hoc networks are named so because they are deployed on the go without any prior planning for dealing with emergency situations mostly, like war scenario, disaster sites like accidents, earthquake etc. These networks are operative for only as long as they are needed. In emergency situations like mentioned the network partitions can last long because thick deployment of nodes shall not be done and hence the main challenges shall be efficient data delivery in sparse deployment, optimal usage of resources of nodes.

The various issues in a MANET are like lack of resources like buffer capacity at a node, limited Battery back up at a node, medium access mechanisms, self-organization capacity and mobility characteristics of nodes apart from maintenance of route entries and overcoming disruptions and rediscovery.

The various applications of MANETs are like Emergency Services, Military Services, Hospital Networks and VANETS. Responding to emergency situations such as disaster recovery is a naturally fitting application in the ad hoc network domain. Ad Hoc network can be of particular use in military for surveillance purposes where the nodes can be sent into hostile enemy areas to

gather information and send it back for own purpose. In a hospital the information flow between medical personnel and devices collecting data from patients is sometimes needed in real time and we can deploy ad hoc networks for the same purpose. It is one of the emerging areas that aim to look at the working of ad hoc network to communicate between vehicles so that traffic management can be done apart from location functionalities and enormous message carrying capacity of all nodes.

There are certain features of ad hoc networks which act as motivation for pursuing this research. Adhoc networks inspite of conceptualized since early 1990’s have been put to limited commercial use. In this work it is aimed to develop a Protocol to use mobility of nodes to advantage and to provide a solution with minimized computational overhead on top of participating nodes. This can be done by adopting an approach which would use limited resources of nodes in an efficient manner. To achieve this in this work the infrastructure within the participating nodes has been created without actually having infrastructure backbone and the drawbacks of relying upon ferry nodes for the purpose of network management was improved upon and mobility of nodes is used to an advantage. This is done with the help of using the longtime gaps between two successive transfers to manage the mobility of nodes in a manner that data delivery efficiency is enhanced.

On observing the applications of MANET, a MANET with thick deployment is highly improbable and if node density is high, it is a suitable candidate to be treated as infrastructure wireless network. Ad hoc network is typical case of infrastructureless network so solutions suited to infrastructure mode cannot be found suitable for infrastructureless networks.

Delay Tolerant Networks popularly referred to as DTNs are the networks where frequent link disruption is witnessed. These networks are characterized by long time network partitions and absence of end to end communication path between all the nodes. In the DTNs, routing gets affected by frequent breakdown of links. If the network is sparsely populated then the phenomena of link disruption is handled by using store and carry nodes. In store and carry nodes, data packets are lying on the node while the nodes are mobile and data is transmitted to neighbouring node when it reaches in proximity of data carrying node. In some works authors have assumed the DTN nodes to be Low Earth Orbiting satellites or PDA's which are rich on resources like computational power, battery backup and buffer.

A significant correlation was established by Ott et al. (2006) between MANET and DTNs where routing and packet forwarding issues of MANETs with sparse deployment were resolved by adopting asynchronous traffic management schemes over AODV protocol. In this work authors used a hybrid approach where protocol used for route maintenance is AODV and packet bundling is done over the communicating nodes using DTNRG specifications as specified in their article by Scott and Burleigh (2005). A bundle is a protocol data unit of the DTN bundle protocol. Each bundle comprises a sequence of two or more than two blocks of protocol data, which are utilized for various purposes. Multiple instances of the one bundle might exist concurrently in different parts of a network. MANET nodes are constrained in terms of buffer availability, processing power and battery capacity. Bundling of packets and buffering over the nodes is quiet promising as deployed in previous work, but a continuous bundling approach can lead to performance degradation due to scarcity of resources over the mobile ad hoc network nodes. But this approach if deployed in a discrete manner, it can bring in positive results as this would reduce the workload on nodes for resolution of bundled packets. Bundled information is needed to restore the network topology, update route table entries and doing other controlling functions as needed on an ad hoc node, but in a sparse deployment same can be done in an efficient manner using this approach on need basis. If this approach is to be adopted then the times at which this activity would be carried out has to be neatly predefined so that there is no confusion amongst nodes with regard to the time slices at which this needs to be done.

In this work intercontact delay or the time elapsed between two successive data transfers has been used to provide this bundled information to the sparse deployment of nodes and nodes at other times carry on with their normal business. Two approaches- Proactive and Reactive have been developed and nodes have been assigned behavior very similar to ferry nodes, albeit that all nodes are now acting ferries.

The network has been set for varying network population of 5 and 8 nodes and trials are carried out using NS2 Simulator which is open source and free to use. The network sizes have been kept 500x500 and 800x800.The Mobility management scheme has been proposed in which the node can not go too far or too near to the node with which it has formed association for the time period for which the data transfer is taking place between two nodes. Once this is over nodes are free to form fresh associations as during intercontact delay the nodes again broadcast their one hop neighbor list which is handled by router function algorithm named as duplication removal algorithm in this work. This behavior was provided to all the nodes and this helps to maintain the uniform network image to all the nodes.

Two protocols have been proposed hence-DSDVMM and AODVMM. DSDVMM is compared with generic DSDV protocol and AODVMM is compared with AODV protocol. It is found mobility management scheme shows its effect in both the protocols as network witnesses higher throughput and lower end to end delay when the node deployment is sparse. As soon as the node population is enhanced the parameters of throughput and End to End delay show very little gains. These two protocols are tested under degraded conditions of low buffer on nodes and reduced transmission range and both the protocols show very encouraging results under these conditions in different set of scenarios. The results are validated at minimum 95% confidence interval using R-Software to perform statistical tests where data is tested for normality and then one – way analysis of variance is carried out and comparative graphs have been plotted using R-GUI.

Later on in the last section, the two proposed protocols are compared amongst each other on the basis of trials that have been carried out and results are verified using two way analysis of variance and it is found that depending on parameters of interest both the approaches weigh out each other. Under combined degraded conditions of low buffer and reduced transmission range both the proposed protocols do not show any difference from each other.

Chapter 1 in this work is about detailed introduction to the Mobile Ad hoc networks and their issues in which its rea of applications, issues and motivation for research is provided. Further in this chapter research objectives are mentioned that arise out of the problem in this rea.

Chapter 2 is about literature survey that was carried out during this research work. Various technical research papers were read and multiple approached were studied to crystallize the problem areas. Certain issues were found are given in this chapter. This chapter also talks about the correlation between sparsely deployed mobile adhoc networks and delay tolerant networks.

Chapter 3 explains the framework designed in this research work for node mobility management and also explains the duplicate link removal algorithm. This framework provides for a certain behavior that the nodes are assigned while performing simulation subsequently. This behavior in incorporated into simulation environment and is tested under different circumstances.

Chapter 4 is about the simulation parameters and the results that are received for the two protocols that are proposed. The two protocols that are proposed are AODVMM and DSDVMM. These protocols are based on the framework and algorithm based on previous chapter, with AODVMM being reactive and DSDVMM being proactive in nature. These protocols are tried under various conditions of low transmission range and low buffer availability and then comparisons are carried out which are reported in this chapter.

Chapter 5 is about the conclusions that we make from the simulations and results which were carried out.

References list is provided at the end followed by Appendices.

List of Abbreviations

Abbreviation	Meaning
ALARM	Adaptive Location Aided Routing Protocol – Mines
AODV	Advanced on Demand Vector
AOMDV	Ad-Hoc On-demand Multi-path Distance Vector Routing
AODVMM	AODV Mobility Managed
AP	Access Points
ASBIT	Adaptive spraying based on intercontact time
ATR	Augmented Tree Routing
BGR	Blind Geographic Routing
BSS	Basic Service Set
BVGF	Bounded Voronoi Greedy Forwarding
CBR	Constant Bit Rate
CBRP	Cluster Based Routing Protocol
CEDAR	Core Extraction Distributed Ad-Hoc Routing
DAG	Directed Acyclic Graph
DART	Dynamic Address Routing
DS	Distributed Set
DDR	Distributed Dynamic Routing Algorithm
DREAM	Distance Routing Effect Algorithm for Mobility
DSDV	Dynamic Destination-Sequenced Distance Vector
DSDVMM	DSDV Mobility Managed
DSR	Dynamic Source Routing

DSRPA	DSR Power Aware
DTN	Delay Tolerant Network
DYMO	Dynamic MANET On-demand Routing
ECGGRID	Energy Conserving GRID
EED	End to End Delay
FAP	Ferry Access Points
FSR	Fisheye State Routing
GAF	Geographical Adaptive Fidelity
GEDIR	Geographic Distance Routing
GeoGRID	Geographical Grid
GeoTORA	Geographical TORA
GF	Greedy Forwarding
GLS	Geographic Location Service
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
GSR	Global State Routing protocol
HSR	Hierarchical State Routing
IARP	Intra-Zone routing protocol
I-DSDV	Improvement of DSDV
IEEE	Institute of Electrical and Electronics Engineers
IERP	Inter-Zone routing protocol
ISIAH	Infra-Structure AODV for Infrastructure Ad-Hoc networks
LAR	Location-Aided Routing
LB	Low Buffer

LBM	Location Based Multi-cast
LANMAR	Landmark Routing
MAC	Medium Access Control
MANET	Mobile Ad Hoc Networks
MDR	Multi-path on-Demand Routing
MM	Mobility Managed
MOBICAST	Mobile Just-in-time Multicasting
MP-DSR	Multi-Path Dynamic Source Routing
OLSR	Optimized Link State Routing
OMR	On-demand Multi-path Routing
OPWP	Optimized Way Points
PAMAS	Power-Aware Multi-Access Protocol with Signaling
PARO	Power-Aware Routing Optimization
PDR	Packet Delivery Ratio
ROAM	Routing On-demand Acyclic Multi-path
RR	Reduced Transmission Range
SiFT	Simple Forwarding over Trajectory
SLURP	Scalable Location Update-Based Routing Protocol
SMR	Split Multi-path Routing
STA	Stations
TCP	Transmission Control Protocol
TORA	Temporary Ordered Routing Algorithm
VANET	Vehicular Ad Hoc network
VBR	Variable Bit Rate

ZHLS	Zone-based Hierarchical Link State routing
ZRP	Zone Routing Protocol

LIST OF FIGURES

List of Tables

Chapter 1
Introduction

1.1 Introduction to Ad Hoc Networks

Mobile Ad Hoc Networks (MANET) is a group of nodes which are capable of self-configuration and these nodes can connect in any arbitrary topology. The nodes shall perform basic functions of the network and network remains on for the time duration for which it was set up. Nodes in a MANETs demonstrate random mobility characteristics, repetitive disruptive connectivity and paucity of resources like memory buffer, battery back-up etc. MANET nodes are infrastructureless and do not have network backbone as defined by Murthy and Manoj (2008). These nodes can perform function of packet forwarding and every participating node can be acknowledged to be a router. The nodes belonging to the MANET shall communicate with each other via a wireless interface on 802.11 MAC Layer (IEEE 802.11 Standards).The participating nodes also act as clients to use the network service of communication within the network, while performing routing functions to enable flow of traffic within network. The nodes cooperate with other neighboring nodes for transmission of their own as well as network's traffic. The network is represented as mobile stations (STAs) and a collection of STAs is called Basic Service Set (BSS).A BSS is a building block of network and in case of a wireless infrastructure network the collection of BSS communicate within and outside BSS via a Distribution system (DS), which is a wireless link for pure wireless networks and it can be guided media link for some BSSs in case of hybrid network, to form an extended network.

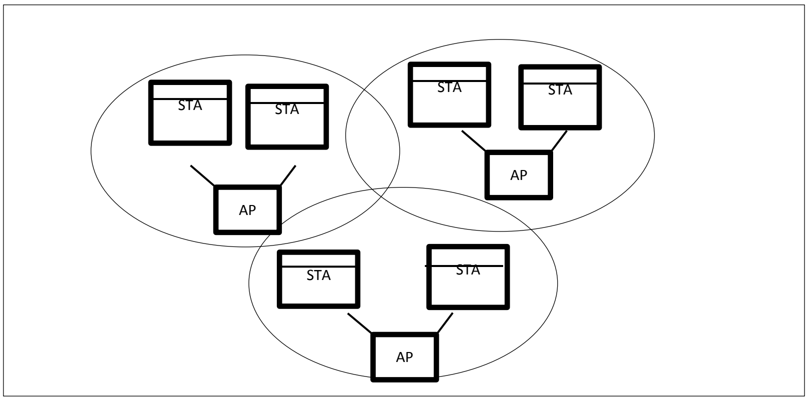

Figure 1.1 Wireless Infrastructure Network Logical Diagram

As it is evident above the mobile stations within BSS connect to each other via their APs (access points) and if the STA from one BSS has to communicate to STA in some other BSS, then it does so via its local AP to other BSS's AP and then to individual STA. But ad-hoc network is a case of infrastructure less mode in which STAs do not communicate via APs. The logical diagram of Mobile Ad Hoc Network reduces to as shown below (Fig 1.2).

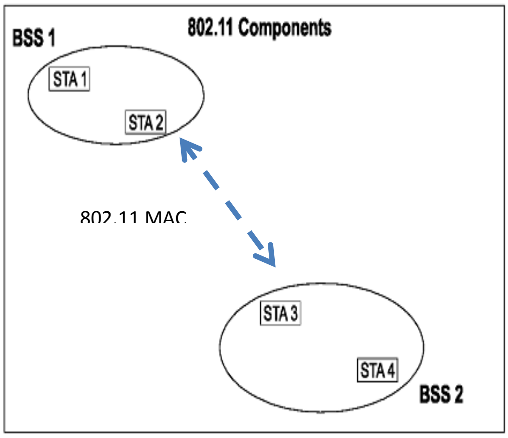

Figure 1.2 An Independent BSS as Mobile Ad hoc network (IEEE Std 802.11™-2007-(Revision of IEEE Std 802.11-1999))

Ad-hoc networks are named so because they are deployed on the fly without any pre planning. These networks are designed to deal with exigency situations which can be war scenario, accidents sites and calamities like earthquake etc. The mobile adhoc networks stay operative for only that time duration for which those shall be needed. In these emergency situations mentioned long lasting network partitions shall occur due to sparse deployment of nodes. The main challenges faced in adhoc network shall be efficiency in data delivery to destination in a sparse deployment and optimal utilization of node's resources.

Over the years multiple researches have been reported that deal with a dense node deployment scenarios. Protocols such as DSR by Johnson and Maltz (1996), DSDV by Perkins and Royers (1994) and AODV by Perkins and Bhagwat (2003) have been proposed for those scenarios. Those proposed protocols aim to tackle issues in connected networks where node deployment is large; or in other words the network is connected. When deployed for ad hoc networks these protocols could lead to problems like huge flooding area, greedy forwarding of messages, higher power consumption, frequency interference problems and flat addressing.

Gollakota et al. (2006) and Oliviera and Braun (2002) have proposed TCP traffic in a MANET which does not confirm to IEEE 802.11 standards document as TCP traffic would lead to network layer operations whereas in Ad Hoc network communication is via 802.11 MAC layer. Hence, any network layer protocol being used for Ad hoc network looks more suited for wireless infrastructure network.

1.2 Issues in a MANET

The various issues in a MANET are:

1. Lack of resources like buffer capacity at a node.
2. Limited Battery back up at a node.
3. Medium Access Mechanisms.
4. Self-Organization capacity and Mobility Characteristics.
5. Maintenance of Route Entries.
6. Overcoming disruptions and rediscovery.

1. Lack of resources like buffer capacity at a node: Mobile nodes are not having infinite buffer capacity and capacity to handle buffer. Hence, efficient buffer handling is expected from each node as with limited processing power at each node. If the node is designed to have extra buffer or processing capacity the node would lose out on portability features. Similarly, excess of processing overhead would result in depletion of battery power.

2. Limited Battery back up at a node: Finite battery backup limits the processing power of the node as the node gets old in the network. If the node is busy in sending more control information via data packets, then the extra processing needs would constrain the precious battery resources. If battery capacity is enhanced, then the node gains in size and payload, thereby affecting its overall mobility.

3. Medium Access Mechanisms: In Ad Hoc Networks, the communication is via wireless links which is an error prone medium. Though in a MANET congestion is not something that shall frequently happen, but still routing protocol has to keep a tab on collision of data packets so as no information is lost. Usage of acknowledgement based schemes would lead to resending of packets which in turn would constitute an unnecessary overhead and would result in consumption of battery resources. A suitable tradeoff has to be arrived upon regarding the acknowledgement and repetition of messages in case of loss of messages due to mobility. Ideally repetition of message has to be minimal.

4. Self-Organization and Mobility Characteristics: Network is essentially self-organizing and in order to self-organize the nodes have to pass their location parameters at regular intervals so that information about the topology is shared among participating nodes as frequently as possible. But with all the nodes being mobile this is highly unlikely scenario.

5. Maintenance of Route Entries: All nodes in a mobile ad hoc network have to maintain route entries and it forms a substantial part of their workload. Route entries have to be updated at specific intervals during network life time and hence all nodes should broadcast their availability to its neighbors so that topology of network is available to each node and in addition to this the topology at all nodes should be uniform so that there is no discrepancy in identifying routes in an ad hoc network.

6. Overcoming disruptions and Rediscovery: Disruptions in message flow from source to destination nodes is one the drawbacks to be overcome. For this nodes have to store the message till a suitable node is found to propagate the message further to the destination node. In event of no node immediately available node with message has to store message till a new node is found over appropriate path. The nodes have to be rediscovered inside network operational area .All the nodes in a mobile ad hoc network has nodes need to have functionality of rediscovery just in case a node is found to be being lying alone.

1.3 Applications of MANETs

1. Emergency Services: Responding to emergency situations such as disaster recovery is a naturally fitting application in the ad hoc network domain. During the time of emergencies, several mobile users (policeman, firefighters, first response personnel) with different types of wireless devices need to not only communicate but also maintain the connectivity for long period of time.

2. Military Services: Ad Hoc network can be of particular use in military for surveillance purposes where the nodes can be sent into hostile enemy areas to gather information and send it back for own purpose.

3. Hospital Networks: In a hospital the information flow between medical personnel and devices collecting data from patients is sometimes needed in real time and ad hoc networks can be deployed for the same purpose.

4. VANET: It is one of the emerging areas that aim to look at the working of ad hoc network to communicate between vehicles so that traffic management can be done apart from location functionalities and enormous message carrying capacity of all nodes.

1.4 Motivation for Research

The following facts about Ad Hoc networks provide us motivation for research.

- Ad Hoc networks inspite of conceptualized since early 1990's have been put to limited commercial use.
- To develop a Protocol to use mobility of nodes to advantage.
- To develop a solution with minimal computational overhead on top of participating nodes.
- Adoption of an approach which would use limited resources of nodes in an efficient manner.
- Ad hoc networks can be deployed for emergency scenarios like war scene, disaster site and can provide services to emergency response systems like flood relief etc.
- Can be very effectively used in Environment monitoring

1.5 Objectives

As suggested in previous sections in this report MANETs are characterized by infrastructurelessness, disruptions, low resources in terms of battery and computational power and high degree of mobility of nodes. In order to overcome the problems as indicated, the aim is to develop a protocol for managing efficient data delivery in a sparsely deployed Mobile Ad-Hoc Network by modifying its mobility vector. This shall be accomplished by achieving the following sub objectives:

a. Create the infrastructure within the participating nodes without actually having infrastructure backbone.
b. Minimize the Computational Overhead incurred on nodes to maintain network operations.
c. Overcome the drawbacks of relying upon Ferry Nodes for the purpose of network management and use mobility of nodes to advantage.
d. Using the longtime gaps between two successive transfers to manage the mobility of nodes in a manner that Data Delivery Efficiency is enhanced.

In this chapter introduction to MANET was provided and research objectives and motivation was listed out. In the chapter 2 the Literature review has been discussed along with the research gaps.

Chapter 2
Review of Literature

2.1 Literature Review

The various issues in previous sections are of particular interest when node deployment is sparse in a MANET. As it is very obvious looking at applications of MANET, a MANET with thick deployment is highly improbable and if node density is high, it is a suitable candidate to be treated as infrastructure wireless network. Ad hoc network is typical case of infrastructure-less network so solutions suited to infrastructure mode cannot be found suitable for infrastructure-less networks.

Sparse nodes problem has been treated by deploying ferrying techniques for data delivery in which network partitions are assumed to last long durations. Message ferrying approach deploys set of special nodes called message ferries that exploits mobility to decrease delays. Message ferrying is a mobility assisted approach where mobility of message ferries is for the purpose of collecting information from network area of operation. The degree of random movement of the nodes is reduced and is made predictable. Ferries are mobile nodes with unlimited resources at its disposal and they move within the network to receive data from nodes within the network. This approach is a proactive approach for data delivery in a sparse network. Ferry nodes are the nodes which facilitate the regular nodes in the network as proposed by Zhao et al. (2004). In this work authors explore this scheme in two ways- Node initiated message ferry scheme and Ferry initiated message ferry scheme. In both these schemes the authors deploy a node trajectory control routine to strike a balance between node's performance and disturbances caused due to restricted movement. They have evaluated their approach under varying buffer sizes, time allowed for ferry movements and varying transmission range for each node.

In another work Li and Rus (2000) authors have also proposed a proactive scheme in which mobile nodes actively modify their trajectories so that messages are transmitted as soon as possible. This paper describes how the node trajectory change can be used to transmit messages in disconnected ad-hoc networks. Authors propose two algorithms. The first algorithm goes on to use full knowledge of the motion pattern of the mobile hosts at times with permitted limited errors. In the second method, Location update is employed because the full knowledge of node's current position is unknown. These algorithms do not use the wait and retry method, as it is not desirable in some emergency cases. This approach to communication is found to be useful for the following two types of distributed applications. First one is when most of the network is connected e.g. in a well-maintained framework for a sensor field, while some hosts are dispersed away from the framework , this does not have too many trajectory modifications to relay messages. In the second approach if the distance between two nodes is slightly larger than the transmission range, nodes need to move small distances to relay messages. This algorithm does not support multiple message transmissions simultaneously, leading to limitation on all the nodes to be a part of a single communication.

Chen et al. (2001) used the moving vehicles on highways for relaying the messages where the messages were stored on moving vehicles and waited for correct opportunity for message to be forwarded further towards destination. The authors found mobility of the vehicles was advantageous for forwarding the messages and enhanced end to end delivery. They found improvement in message delivery where higher relative movement between vehicles was observed.

Ferry based approach is used by Bin Tariq et al. (2006) where the authors design a route for ferry in view of constant random movement of nodes within a network. Ferries rather than being mobile all the time are made to wait at OPWP (optimized waypoints) and these have shown a remarkable improvement in terms of end to end delay. Optimized waypoints are identified with probabilistic methods as those coordinates within the network area around which nodes are highly probable to be found. This is established by careful analysis of mobility patterns of nodes. The authors suggest that the nodes do no need any live connection between each other to ascertain each other’s position. This is an improvement over approach taken by Zhao et al. (2004) where node movement is directed by neighbor’s movement. Ferry route is designed on the basis of established waypoints where the ferry will arrive and wait for the nodes to arrive. Ferry route design is based on the mobility model adopted by nodes in the network and ferries use the same

OPWP till the traffic demands do not change. Nodes are still classified into regular nodes and ferry nodes.

Another technique is provided by Shah et al. (2003) which is very similar to as provided by Zhao et al. and Bin Tariq et al as cited previously. This approach is involving nodes called as data mules which are sent to facilitate traffic in a wireless sensor network field. Nodes in sensor nodes are sparsely deployed and are also fixed at one location and data mules act as carriers of information available at sensor nodes which are stationary. Data mules are same as ferries and since sensor framework is well specified mules travels through those areas only where sensor nodes are found .The main advantages given by the authors in this approach are that Sensors do not have any overhead associated with routing packets from other sensors. For large ad hoc networks, the routing overhead can lead to a substantial increase in energy consumption at a node. Since sensors only rely on Mules and as they are interchangeable, the failure of any number of mules does not mean connectivity failure. The failure definitely increases the latency and decreases the overall efficiency.

Yasmeeny at al. (2012) in their work have further tried to improve the performance of Ferry assisted networks. They have proposed Ferry Access Points (FAPS) and sticky transfers to improve communication in DTN-Disruption Tolerant Network. FAPs are the special nodes deployed in the network area which are stationary and would be present in the path of ferry. Further in this approach sticky transfers are suggested which mean that node to ferry contact as and when it happens will lead to creation of a long lasting contact till the desired interchange of data has been completed. Natural Node movement is compromised during this sticky contact. Disruption tolerant network is paradigm very similar to sparsely deployed ad hoc network for which there is an open research group at www.dtnrg.org. This community works on variety of categories of DTNs and Ferry Assisted DTNs is one of them.

Zhao et al.(2006) in another approach suggested throwboxes in mobile DTNs so that larger contact opportunities are created and these throwboxes are present at fixed location, i.e., they are stationary but placed strategically to provide routing and buffering. Throwboxes are small devices which are equipped with wireless interfaces and storage and are stationary. When two nodes pass around these throwboxes at different times it relays the messages received from the node which came first to the node which came later. Hence in this contact opportunity for contact is created even when there was none valuable between these two nodes.

Zhang (2006) in his work classifies DTN routing schemes as deterministic, enforced and opportunistic. Deterministic routing schemes are used when a priori information about traffic demand and contact is known. Enforced Routing schemes deploy special purpose nodes to provide connectivity as already discussed in previous paragraphs. The usage of ferry based approach confirms to the enforced routing schemes. In some ways even enforced routing techniques also need a priori information about design of routes or locations for placing access points or throwboxes.

Opportunistic routing schemes use techniques of replication where multiple copies per message are flooded in the network as provided in epidemic routing proposed by Becker, 2000. In this messages are flooded into network till an acknowledgement is received. The goals of Epidemic Routing are to efficiently distribute messages through partially connected ad hoc networks in a probabilistic fashion, minimize the amount of resources consumed in delivering any single message, and maximize the percentage of messages that are eventually delivered to their destination. This the authors achieved by proposing the protocol that relies upon the transitive distribution of messages through ad hoc networks. Each node maintains a buffer to keep all the messages and resolves the next hop with the help of a hash function. The authors claim to deliver 100% of the messages which means that the buffer capacity and power consumption on the nodes have been stretched.

This disadvantage of transmission of messages is overcome by using immunity based routing scheme proposed by Mundur et al.(2008) , in which they aim to better epidemic routing in terms of multiple copies being sent to next hops as it limits them for better resource utilization. The number of copies per message are limited so that infinite flooding is not done on the network .This limiting of messages is done with the help of exchanging immunity list between nodes, so that further forwarding of those messages is not done. As a second part of this approach the message is only exchanged with a subset of nodes that satisfy some criteria like number of visits to the destination is the previous instances. The authors claim to reduce delay and increase throughput with over all better resource utilization. The approach is tried by reducing buffer capacity on the nodes and better throughput is reported along with better network efficiency.

Another technique is proposed in spray and wait by Spyroupoulos et al, (2005), in which replication of messages is present in network but the issue that how many messages stay replicated is again a concern and it is further stated by authors that source can't decide how many copies of message can stay in network. Spray and Wait combines the speed of epidemic routing with the simplicity and thriftiness of direct transmission. During spray phase the nodes go on spreading message copies in a manner similar to epidemic routing. Once sufficient copies have been spread to guarantee the fact that at least one of the copy of the message will find the destination with high probability, node stops and lets each node carrying a copy perform direct transmission. Spray and Wait approach can be viewed as a tradeoff between single and multi-copy schemes.

ASBIT i.e. Adaptive spraying based on intercontact time technique is a recent technique proposed by Luo et al.(2012) that identifies the significance of time intervals between two exchanges and it utilizes the same interval to predict the number of inter node contacts within the estimated delivery and delay therein. A contact is a communication opportunity in which mobile nodes comes into communication range with other nodes in DTNs. A node with higher degree of centrality is in a position to maintain more contacts with other nodes in the networks where centrality is a measure of importance of a person in a social network and is measured as degree of centrality. A replication value is assigned to each message when it is generated and any node having copies of a message are infected nodes. Nodes in this approach have to perform this additional task of identifying duplicate messages in their buffers. The approach has three components- calculation of number of copies disseminated, the next hop selection and division of replicated number.

Various categories of Routing Protocols have been suggested for MANETs which are as follows – Proactive, Reactive and Hybrid by Abolhasan et al. (2004).In Proactive routing protocols, the routes to all the destination or component(s) of network are determined at the time of network setup, and periodically maintained by using a route update process.

In proactive routing protocols, each node maintains routing information to every other node (or nodes located in a specific part) in the network. The routing information is usually kept in a number of different tables. These tables are periodically updated and/or if the network topology changes. Mobility Management scheme explained in next sections uses intercontact time as reported by Luo et al.(2012) for this periodic update by establishing associations.

The difference between various Proactive protocols exists in the way the routing information is updated, detected and the type of information kept at each routing table. Each routing protocol shall maintain different numbers of tables as suggested by Mehran et al. The various Proactive Protocols for MANETs which have been proposed from time to time are like DSDV by Perkins and Royers (1994) , FSR by Gerla (2001), GSR by Chen and Gerla(1998).

The second category of routing protocols is Reactive protocol where routes are determined as and when there is a demand and the source wants to run a route establishment process. Hybrid routing protocols combines the principles of Reactive and Proactive Protocols. Each protocol group has different available strategies to perform routing, but would broadly be flat or hierarchical in nature.

In Reactive or On-Demand protocols the route tables are maintained on each node inside the network. The AODV routing protocol proposed by Perkins et al. (2003) is based on DSDV and DSR algorithm. It uses the periodic beaconing and sequence numbering procedure of DSDV and a similar route discovery procedure as in DSR. However, there are two major differences between DSR and AODV. The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address.

This means that AODV has potentially less routing overheads than DSR. The other difference is that the route replies in DSR carry the address of every node along the route, whereas in AODV the route replies only carry the destination IP address and the sequence number. The advantage of AODV is that it is adaptable to highly dynamic networks reported by Mehran Abolhasan et al.(2004). However, node may experience large delays during route construction, and link failure may initiate another route discovery, which introduces extra delays and consumes more bandwidth as the size of the network increases. The various reactive protocols that have been proposed from time to time are like TORA by Park and Corson (1997), ARA by Geunes et al (2002).

Recently in another work by Niewiadomska et al.2013, authors presented mobility model which provides a tradeoff between accuracy of the mobility modeling and computational burden. Authors say in this work that it is difficult at times to model motion of nodes of a real-life ad hoc network. However they iterate that mobility modeling is a critical element that exhibits great influence on the performance characteristics of a cooperative ad hoc network. In this article the authors investigate how to make the nodes cooperative and fulfill a connected network design strategy. They suggest an algorithm for efficient calculating of mobility paths of wireless devices. Their approach adopts two techniques- the concept of an imaginary potential field and the principles of a particle-based mobility. The utility and efficiency of the proposed approach has been justified through simulation experiments. The presented case studies show that the COHERENT NET algorithm can be successfully applied to design self-configuring, cooperative and coherent real life networks. It has thoroughly established by Broc et al. (1998) and Das et al.(2000) that the network efficiency is closely related to adapt the changes that occur in network topology and current link status. Further, in another work by He and Yin, (2008) a canonical mobility measure for MANETs is proposed and this model provides a unified means for measuring degree of mobility in a MANET. These works provide for significance of mobility management schemes that has been established over period of time.

Zamam (2008) in his work, compared the performance of DSDV, AODV and DSR routing protocols for ad hoc networks using NS-2 simulators. In this paper, author observed that various reactive routing protocols, AODV and

DSR, both show better performance than the other in terms of certain metrics. It is still inconclusive to determine which amongst these protocols has overall better performance in MANET. Garousi (2011), performed analysis of network traffic in ad-hoc networks based on the DSDV protocol with laying focus on mobility patterns and communication sequence of the nodes. In this work, author observed via simulations measured the ability of DSDV routing protocol to react to multi-hop ad-hoc network topology changes in terms of network size, network node movement, number of connections among network nodes, and also the amount of data each mobile node transmitted. Perkins & Bhagwat (1998) proposed an efficient DSDV (Eff-DSDV) protocol for ad hoc networks. Eff-DSDV overcomes the problem of non- promising and unused route entries, to improve the performance of DSDV. The proposed protocol has been implemented in simulator and performance comparison has been made with DSDV and DSR protocols. The performance metrics observed are packet-delivery ratios, end-end delay, packets dropped, routing overhead, Length of the route in terms of hops. It has been found after analysis that the performance of Eff-DSDV is superior to regular DSDV and sometimes better than DSR in certain cases. Das et al (2000) also compared the performance of DSDV, AODV and DSR routing protocols for ad hoc networks using NS-2 simulations. In this work, it is observed and established that DSDV uses the proactive table driven routing strategy while both AODV and DSR use the reactive on-demand routing strategy. Both AODV and DSR perform better under high mobility simulations than DSDV. High mobility results in frequent link failures and the overhead involved in updating all the nodes with the new routing information as in DSDV is much more than that involved AODV and DSR, where the routes are created as and when required.

Chao et al (2003) in their work made a performance comparison based on packet delivery fraction and normalized routing load. The issue of energy conservation is critical in a limited energy resource MANET. This study proposes a novel energy-aware routing protocol, ECGRID, for mobile ad hoc networks. ECGRID extends the GRID protocol to account for energy constraints. One is elected as a gateway in each grid to handle route discovery and packet delivery. Energy is conserved by turning the non-gateway hosts' transceivers off when the hosts are idle. A gateway host can awaken sleeping hosts through Radio Frequency tags technology. Accordingly, sleeping hosts need not wake up periodically. A load balance of the mobile host's battery energy scheme is applied to prolong the lifetime of all mobile hosts. Also, ECGRID eliminates the limitation that destination hosts must always be active (as is assumed for earlier protocols, such as GAF). Simulation results demonstrate that ECGRID can not only prolong the lifetime of the entire network but also maintain good packet delivery ratio. A host runs EC-GRID consumes less energy than a host runs GRID does. Additionally, the lifetime is extended in proportion to the host density in the whole network

Rahman et al (2009) have reported that Packet drop rate for DSR is very less than DSDV and AODV indicating that DSR has got higher performance in terms of PDR. Both AODV and DSR perform better under high mobility than DSDV. High mobility has been identified by authors as a phenomenon that occurs due to frequent link failures and the computational overhead involved for updating all the nodes with the new routing information is found to be higher in DSDV than the overhead involved in AODV and DSR protocols.

Lesiuk (1998) in their article have provided with overview of ad hoc routing principles and thereby demonstrating how these differ from conventional routing. Three proposed ad hoc routing protocols, DSDV, TORA, and DSR were commented on.

Mahmoud et al. (2007) analyzed three protocols AODV, DSDV and I-DSDV where they simulated these protocols using NS-2 simulator. These protocols were compared in terms of varying number of nodes, speed and pause time, packet delivery ratio, end to end delay and routing overhead in different environment. Simulation results show that I-DSDV when compared with DSDV, it reduces the Packet drop ratio with little increased overhead at higher rate of node mobility but still I-DSDV can’t compete with AODV in higher node speed and number of node. Vetrivelan and Reddy (2008) analyzed the performance differentials using varying network size and simulation times. They performed two simulation experiments for 10 & 25 nodes for simulation time up to 100 sec. In their experiment, three MANET routing protocols were evaluated with varying MANET Size and Simulation times for mobile ad hoc networks using NS-2 simulation. The general observation from the simulations are the application oriented performance metrics such as Packet Delivery Fraction, Routing Load ,Average End to End delay, and varying number of nodes and Simulation times were analyzed. AODV was found to be exhibiting a better behavior in terms of the Average End to End Delay. The authors explain better performance by a soft-state updating mechanism employed in

AODV to determine the freshness of the routes. In less stressful situation, the Packet Delivery Fraction, the TORA outperforms DSDV and AODV. In stressful situation DSDV outperforms AODV and TORA. In Normalized Routing Load in stressful situation DSDV demonstrate lower routing load in lower Simulation time. In Stressful situation TORA has lower routing load. Stressful situation parameters as reported are not provided for, clearly.

Gowrishanker et al. (2007) compared performance of AODV and OLSR in NS-2 simulator, the simulation period for each scenario was 900 seconds and the simulated mobility network area was 800 m x 500 m rectangle. In each simulation scenario, the nodes were initially located at the centre of the simulation region. The nodes start moving after the first 10 seconds of simulated time. The application used to generate is CBR traffic and IP is used as Network layer protocol. In this approach authors have purposely not started network activity for some time at the start. Arunkumar et al. (2008) in their paper have presented their observations regarding the performance comparison of the routing protocols for variable bit rate (VBR) in mobile ad hoc networks (MANETs). They perform extensive simulations and their studies have shown that reactive protocols perform better than proactive protocols.

Setty et.al. (2010) have done evaluation of the performance of existing wireless routing protocol with AODV in various nodes placement models like Grid, Random and Uniform using QualNet 5.0 simulator.

Khan et al. (2008) studied and compared the performance of routing protocols by using NCTUns 4.0 network simulator. In this paper, performance of routing protocols was evaluated by varying number of nodes in multiples of 5 in the ad hoc network. The simulations were carried out for 70 seconds of the simulation time. The packet size was fixed to 1400 bytes.

Jorg (2003) studied the behavior of different routing protocols on network topology changes resulting from link breaks, node movement, etc. In his article he evaluated the performance of routing protocols by varying number of nodes in the repeated network. But he did not investigate the performance of protocols under heavy loads where high mobility of nodes was observed coupled with large number of traffic sources and larger number of nodes in the network, which may lead to congestion situations. Large numbers of nodes are also improbable according to this author. Broch et al. (1998) performed experiments for performance comparison of both proactive and reactive routing protocols. In their Ns-2 simulation, a network size of 50 nodes with varying pause times and various movement patterns were chosen.

While Proactive and Reactive is the classical categorization of Ad hoc network Routing protocols, Alotaibi and Mukherjee (2012) have categorized the ad hoc network protocols into some more categories which are – Geographical routing algorithms, Geo-Cast Routing algorithms, hierarchical routing algorithm, multipath routing algorithm, power aware routing algorithm and hybrid routing algorithm.

A major evolution in communication technology has been the introduction of the Global Positioning System (GPS) which provides the location information and universal timing of a node. The idea central to geographical routing is based on the fact that a sender shall use the destination's geographic location to deliver a message. The location information of the destination can be used instead of the network address in the routing process. Therefore, sender, in Geographical routing, need not be fully aware of the topology of the network. Geographical routing also works on this assumption that every node would know its own location and each source node is aware of the location of its destination at all times. In fact, this idea of using position information for routing was first suggested in the 1980s, when the geographic information was proposed for packet radio networks by Takagi and Kleinrock (1984).

In Geographical routing, there are three techniques: single-path, multi-path, and flooding. In single-path, a single copy of the message travels through the network over a single dedicated route from the source node to the destination node. This approach shall lead to low resource utilization. In flooding nodes broadcasts the message which leads to creation of a huge number of copies of the original message traveling through the network, thereby challenging network resources with redundancy of messages. Since single-path and flooding are the two strategies exactly opposite to each other, multi-path is a middle path technique in which a limited copies of the original message are created and the further transmitted through multiple routes from that are available from the source node to the destination node. Most single-path Geographical Routing Algorithms are further based on two approaches: Greedy Forwarding (GF) proposed by Wan et al. (2006) and Face routing proposed by Bose et al. (1999) .The routing algorithms that rely on flooding develop enhanced techniques to overcome the limitations of flooding. The enhancement techniques for flooding have been reported from time to time to overcome the disadvantages of flooding like packet overhead and inefficient utilization of bandwidth. In a wireless network, the Geographical location information can improve routing performance. Using localization algorithms, the network overhead is reduced. The algorithm proposed for these enhancements are like DREAM by Basagni et al.(1998) ,LAR proposed by Ko and Vaidya (1998). LBM is an improvement over LAR which is proposed by Ko and Vaidya (1999) a little later. Location based multicasting performs geocasting by deploying two schemes of deploying a Forwarding zone where forwarding zone is the measure of whether packet can be forwarded to the next node available in the route and second scheme is where no explicit forwarding zone is deployed and packet is forwarded looking at relative distance between tow nodes. In LAR there is only one destination where as in LBM multicast of packets was possible.

GEDIR is a greedy forwarding technique in which source in order to send the data to the destination in a multihop network simply forwards the packet to the node which is the closest directional neighbor. This process is repeated at each intermediate node till the destination is found. This approach was suggested by Stojmenovic and Lin (2001). Further delivery rate in GEDIR can be enhanced if each node is aware of its two hop neighbor. However this is limited by the fact that if closest neighbor has no route to the destination then message is simply lost.

GeoTORA protocol proposed by Ko and Vaidya (2000) is a geo cast routing algorithm which is a variation of adaptive and hybrid algorithm TORA, temporally ordered routing algorithm. In TORA, proposed by Park and Corson (1997) routing from a source node to a destination node requires a sequence of directed links starting at the source and ending at the destination. Each intermediate node maintains a parameter called "height" which is measured on the basis of number of hops separating the intermediate node from the destination node. A Directed Acyclic Graph (DAG) rooted at the destination node is used to allocate the height for each intermediate node. Every node in the ad hoc network maintains a logical direction vector for its links using value of this height. In this protocol logical links are directed from a node with greater height value to a node with lower height value. In GeoTORA the nodes broadcast message to a group of destinations where source node is anycasting to any member within the ad hoc network using the TORA protocol.

GeoGRID proposed by Liao et al. (2000) is a geo-cast routing algorithm that enhances the greedy forwarding idea of LAR in the geographical routing protocols by reducing the network overhead. Geo-GRID logically reduces the flooding area of the broadcasting messages by deploying the process of partitioning the geographical area of the network into smaller areas, called grids. These grids are logical partitions of the network space and are similar in size. In every grid, one node, which is the closest to the grid center, is elected as a gateway to forward the geo-cast packets among the neighboring grids. Hence, message overhead decreases because, in each grid, non-gateway nodes do not broadcast the grid packets. In Geo-GRID, designing and identifying the grid size is important to achieve network connectivity through the assigned gateways.

Moreover, most Geographical RAs are scalable and fault tolerant as proposed in GLS by Li et al. (2000). However, instantaneous location information may not be accurate at the time the information is needed. In addition, the assumption of all nodes knowing their location in a GEO based protocol may not be realistic. Therefore, the network efficiency depends on the tradeoff between balancing the geographic distribution of the nodes and the occurrence of bottlenecks in network traffic. Most Geographical Routing algorithms start with the Greedy Forwarding technique to find the route for a packet from its source to its desired destination. The main problem with the Greedy Forward technique is that there could be a certain point where a node has no surrounding neighboring nodes within its transmission distance closer to the destination node more than node. Because of this problem, most Geographical RAs include a recovery method to handle the routing process when such cases occur. Flooding in LAR planarity and face in GPSR by Karp and H. Kung (2000), hull tree in GDSTR by Leong et al.(2006), grid in GLS by Li et al.,2000, partitioning to sub-graphs in BVGF proposed by Xing et al.(2004), and heuristics in GEDIR are alternative recovery methods to accomplish the routing.

Another category of routing algorithms is Geo-cast routing algorithms. As explained by Jiang and Camp (2002) in their survey paper and Maihofer et al. (2005) in their article, Geo-cast is the process of sending a message in a wireless network from a source node to a group of destinations by using destination modes' geographical location only. In this approach each node that performs routing is named as geo-router, which are nodes that maintain their route table entries by exchange of service area information with the other neighbors. Service area is the overall information about the zones to which the current geo-router node is attached. Destination node's locations are modelled as various shapes like point, circle or a polygon. Other Geo based protocols are OLSR by Jacquet et al. (2003), BGR by Witt and Turan (2005), ZHLS by Jao-Ng and Lu (1999), SiFT by Capone et al. (2005), SLURP by C.M et al.(2001), ALARM by Boleng and Camp (2004) and MOBICAST by Huang et al.(2003).

Hierarchical routing is a solution for ad hoc networks with large node population where nodes would be grouped that are called zones or clusters. Each cluster would have a cluster head that would act as a gateway for the entire cluster and is also responsible for entire communication within the nodes inside a cluster. Nodes in a clustering schemes are either directly connected to the cluster head or cluster head is available to these nodes within few hops. Routing schemes have to be used for addressing two aspects- Inter cluster routing, i.e. routing between clusters and intra cluster routing, i.e. routing within the nodes inside a cluster. If there is a failure of the cluster head inside one cluster then routing is affected inside that cluster only and for other cluster this failure does not affect too much. The various works cited in the survey paper by Akyldiz et al. (2005) and Akyldiz and Wang (2005) ,Hong et al.(2002) and Liu and Kaiser (2005) in their articles also report that hierarchical schemes do not solve the scalability issues in an adhoc network. Also while designing the structure of hierarchy the cluster heads need to be selected with diligence so that they do not witness congestion and their power consumption remains low. If congestion occurs at Cluster head then overall network performance is decayed. ZRP, Zone routing protocol is one such very famous protocol which was proposed by Haas and Perlman (2002). This protocol puts to use two separate protocols IARP, Intra-Zone routing protocol and IERP, Inter Zone Routing protocol both proposed by Haas et al. (2002) in two different drafts. ZRP protocol has both proactive and reactive components as contributors to the complete solution. In this protocol overlapped zones are created based on the separation distances between the mobile nodes. IARP is a proactive approach that is responsible for routing packets within each zone and IERP is a reactive approach which is responsible for routing packets between two different zones. ZRP also limits the flooding area within wireless network as only nodes which are in the periphery are allowed to broadcast the control messages to the nodes outside the zone of peripheral nodes. Various other protocols which fall in the category of hierarchical protocols are CBRP by Jiang et al.(1999),DDR by Nikaein et al.(2000),CEDAR by Sinha et al.(1999),FSR by Gerla et al.(2001),GSR by Chen and Gerla(1998),HSR by Iwata et al.(1999) and LANMAR by Gerla et al. (2000).

Multipath routing is another category of routing algorithms for mobile ad hoc networks. As the name suggests this protocol works on the theory that multiple paths can be used to route data from a source to destination node. Route or path discovery is done with the help of a predefined criteria like path disjointedness where a metric is introduced to evaluate the diversity of the path, or keeping a measure of traffic distribution and maintaining the paths when status of available paths changes because of change in topology. Multi path routing techniques have been found to be Fault tolerant due to multiplicity of paths, load balancing as and when congestion occurs on central node traffic can be diverted. So as and when failure occurs in a network Multipath Routing Algorithms can use predefined routes which are stable currently instead of rediscovering new routes. Hence these categories of algorithms are found to be better suited to serve the delay parameter of wireless networks as written by Tsai and Moors (2008). ATR i.e. Augmented tree based routing scheme is one example of Multipath routing scheme which is based on structured address space. ATR proposed by Caleffi et al. (2007) is based on DART another hierarchical routing algorithm which was proposed by Erikkson et al. (2004). DART protocol implements a dynamic addressing mechanism that assures scalability in large wireless networks. DART includes two pieces of information in a node's address- a static but a unique identifier which is equivalent to current IP address and dynamic routing address which is derivative of current position of node in network topology. DART also supports heterogeneous networks. ATR enhances DART by adding multipath feature to DART. ATR uses an augmented tree which exploits DHT system over an ordered tree as was provided by DART. Various multipath routing protocols that have been proposed from time to time are MPR-E by Saha et al. (2003), AOMDV by Marina and Das (2003), SMR by Lee and Gerla (2001), MDR by Duluman et al.(2003), DYMO by Chakeres et al.(2005), ROAM by Raju and Aceves (1999), MP-DSR by Leung et al.(2001) and OMR by Nasipuri and Das (1999).

Power aware routing protocols are thoroughly surveyed in their article by Vassileva and Barcelo –Arroyo (2007) in their article. In wireless networks due to high node mobility power issue is a critical issue for all the nodes. For a mobile node battery lifetime is the time allowed for amount of mobility any node can have in an mobile ad hoc network. Longer mobility times mean lesser battery consumption and efficient battery consumption. To reduce power consumption various protocols have been proposed like ISIAH by Lindgren and Schelen (2002), PAMAS by Singh and Raghavendra (1998) ,Dynamic Source Routing Power aware(DSRPA) by Djenouri and Badache (2006) and PARO by Gomez et al. (2003).ISIAH is very similar to AODV in packet forwarding approach. ISIAH differs from AODV in selection of routes that pass only through power base station nodes instead of mobile nodes. So this means infrastructure nodes are provided in this protocols. ISIAH allows node to enters into a power saving mode for short periods thereby reducing power consumption compared to AODV. Power Aware Muti Access Protocol (PAMAS) controls the battery usage of the node based on the frequency of the node's activities. It turns off the power of the nodes which are not participating in the process of transmitting or receiving data. The authors have demonstrated that powering of nodes does not affect the network performance. DSRPA trades-off between network connectivity and power consumption by defining a new routing metric. In DSRPA, the battery freshness is considered in routing to achieve connectivity for longest period of time. Nodes with most fresh battery are selected over other nodes to forward the packets. PARO is the routing algorithm that aims to increase the length of the path to reduce the total transmission power. In PARO a new set of nodes is introduced called "redirectors" which are added to the routing path to reduce the power of the intermediate nodes which are acting as successive hops on the established paths. PARO reduces the individual hop's distance so that power consumption at each hop is minimized. Traditionally, data is transmitted in wireless networks by using maximum power so that no of hops are decreased and shorter path length is achieved like in TORA, DSR and AODV. But PARO sacrifices path lengths to low power successive hop transmission. EADSR is another power aware protocol proposed by Brown et al. (2003).

2.2 Issues found in Literature Review

1. Protocols like DSR by Johnson and Maltz (1996), DSDV by Perkins and Bhagwat (1994), AODV by Perkins and Royer (1999) are designed for connected networks and are more suited for infrastructure networks. These protocols work on assumption that end to end path is available and these protocols work on creating route table entries using proactive or reactive approach.

2. TCP traffic is suggested in MANET environment by Murthy et al. (2006) and Olivera and Braun (2002). TCP is a transport layer protocol and deploys IP packet format to conduct data exchanges. Large amount of control information is passed with each exchange and hence node is unnecessarily burdened with computation of this control information, while it is already established that MANET nodes are having scarce resources at its disposal. This is the drawback it is aimed to be addressed in this research work.

3. Special nodes called as ferry nodes are made to travel in network and in event of failure of ferry node or data mule in their works by Zhao et al.(2004) and Shah et al. (2003), the network operation would fail and entire network would be down. Moreover in their article Shah et al. (2003), the technique suggested is for specific case for wireless sensor networks. However, the concept given by the authors in these works that few nodes in the ad sparse network has to act as ferry i.e. a facilitating node for traffic on network is imperative and is desirable in a sparse population.

4. Ferries stop at OPWP- optimized waypoints and wait for buisiness nodes to come in its proximity at some point, in network run time to offload nodes' buffer. This waiting for nodes contributes to delay and has to be dealt with. The nodes which have to come in proximity to ferry nodes have to plan their routes around waypoints, and any change in the overall movement might lead to a round trip of ferry node useless, if no such contact opportunity is provided with the ferry nodes. This would lead to burden on scarce resources on the nodes and contribute to the overall delay in the system.

5. Mobility of nodes is governed by movement of ferries only during contact time between ferry node and network node as suggested by Yasmeeny et al., (2012), in their article. This is a scenario which is aimed to be replicated during entire duration of network but without ferry nodes, but only for duration of node to node to transfer.

6. It is identified at Delay tolerant network research group, the DTNRG, that DTN is envisaged as a possible representation of a sparsely deployed Ad Hoc network. DTN based routing protocols offer a possible solution to the problem but all the protocols can't be used in scenario of ad hoc network as DTN is envisaged in scenario of Underwater Acoustic Networks , high powered PDA's or Low Earth orbiting Satellites (LEO) etc.

7.Zhao et al.(2006), in their article have talked about throwboxes which are stationary ferries that occur to contact with the nodes in the network within the travel of a node , hence the node that facilitates traffic is stationary and offloads data on nodes by assuming that node is travelling in direction of destination specific traffic acquired by throwbox. Hence, throwbox technique is again waiting for favorable node to arrive. Under adverse mobility patterns the wait for the mobile node's to arrive at designated geographical locations of throwboxes can downgrade node's data collection capabilities by straining its buffering capacity.

8. Approaches provided in Epidemic Routing by Becker (2000) and Mundur et al. (2008), work on concept of multiple sends of the same message in the ad hoc network. In a sparse node deployment this flooding of messages or controlled flooding is highly taxing on resources of mobile nodes and seems improbable too. In a sparse deployment when nodes are constrained to find subsequent nodes for data transmission flooding would be actually not possible. Also, nodes with limited resources would be performing processing the multiple copies of same message without any discount for the resources at disposal of these nodes. This shall definitely lead to inefficient use of the resources at the disposal.

9. In their work Luo et al.(2012), they overcomes the disadvantages of Spyroupoulos et al.(2005), by utilizing the inter contact delay time slice and it is aimed to use this significant inter-contact time for network restoration and use approach similar to Becker (2000) for passing minimal control information for route maintenance only.

10. Niewiadomska et al. (2013), Broc et al.(1998), Das et al.(2000) and He and Yin (2008) in their works have amply tried to demonstrate that mobility management schemes result in better network performance and lifetime. This gives us the confidence that a light weight mobility management scheme

would make the existing protocols suited for ad hoc networks, work better under sparse deployment conditions.

11. Power aware routing protocols work on varying principles of choosing the freshest nodes in terms of battery power or selecting next hop on the basis of a predefined route via power base stations etc. The power availability on each node has to be conveyed to other nodes in a network which shall be an overhead. If infrastructure nodes like power base stations are provided then basic definition of ad hoc networks provided by IEEE is violated. An approach which inherently results in higher throughput and lower end to end delay will automatically improve the battery power on the network nodes thereby resulting in better network lifetime.

12. Multi path routing looks very promising as multiplicity of paths is exploited by various approaches and issues like congestion or failure of nodes is handled very objectively. Multiple paths would occur in networks with relatively large network population and hence multipath approaches are not particularly suited for networks with sparse deployment. In a sparse deployment it's in fact the contact opportunity between nodes which is at a premium and if this can be ensured then the resources on nodes are less challenged and higher efficiency from the network nodes shall be achieved.

13. Geographical routing schemes were initially proposed with greedy forwarding schemes with multiple sending of messages in a wireless network. These techniques were further improved by proposing Geo-casting and hierarchical routing techniques. Geo casting would comprise of sending location parameters of a node and network organizes itself based on location

of all the nodes. Location knowledge is very helpful while deciding next hop of the packet but the cost of sending this entails a huge burden. Also a backbone of GPS or GIS is needed to fetch the location parameters of nodes which is highly taxing on battery power of ad hoc network nodes and infrastructure less ness of adhoc network does not sync in with the presence of these infrastructure. Ad hoc network is a case of infrastructure less wireless network is thoroughly defined by IEEE. Hence these approaches inspite of quiet promising are not suited for ad hoc networks and more so for sparse deployment in an ad hoc network.

14. In variety of works the various authors have used NS2 as a simulation tool of choice where they have created multiple scenarios with varying network sizes and different node population and time duration of simulation. They simulated for various parameters of interest largely centered around the metrics like throughput, end to end delay, battery consumption, packet hit ratio, packet drop ratio etc. In this work Average end to end delay, throughput and packet drop ratio are choosen as parameters of interest. Since no definite node population is classified as sparse deployment so it is aimed to emulate by the node population as simulated in previous works. In this theses work one node has been kept for 100 m^2 area and has been called as a sparse deployment. Any node population greater than this is not qualified as sparse deployment when basic transmission range is 100 meter for any of the node in the ad hoc network.

2.3 DTN and Sparsely Deployed MANETs –Correlation

Delay Tolerant Networks popularly referred to as DTNs are the networks where frequent link disruption is witnessed. These networks are characterized by long time network partitions and absence of end to end communication path between all the nodes, Jain et al. (2003). In the DTNs, routing gets affected by frequent breakdown of links. If the network is sparsely populated then the phenomena of link disruption is handled by using store and carry nodes. In store and carry nodes, data packets are lying on the node while the nodes are mobile and data is transmitted to neighbouring node when it reaches in proximity of data carrying node. Jain et al in their work have assumed the DTN nodes to be Low Earth Orbiting satellites or PDA's which are rich on resources like computational power, battery backup and buffer.

A significant correlation was established by Ott et al. (2006) between MANET and DTNs where routing and packet forwarding issues of MANETs with sparse deployment were resolved by adopting asynchronous traffic management schemes over AODV protocol. Ott et al. (2006) used a hybrid approach where protocol used for route maintenance is AODV and packet bundling is done over the communicating nodes using DTNRG specifications as given in their article by Scott and Burleigh (2005). A bundle is a protocol data unit of the DTN bundle protocol. Each bundle comprises a sequence of two or more "blocks" of protocol data, which serve various purposes. Multiple instances of the same bundle (the same unit of DTN protocol data) might exist concurrently in different parts of a network -- possibly in different representations - in the memory local to one or more bundle nodes and/or in transit between nodes.

MANET nodes are constrained in terms of buffer availability, processing power and battery capacity. Bundling of packets and buffering over the nodes is quiet promising as deployed by Ott et al. (2006), but a continuous bundling approach can lead to performance degradation due to scarcity of resources over the mobile ad hoc network nodes. But this approach if deployed in an intermittent manner or discrete manner can bring in positive results as this would reduce the workload on nodes for resolution of bundled packets. Bundled information is needed to restore the network topology update route table entries and doing other controlling functions as needed on an ad hoc node, but in a sparse deployment same can be done in a discrete manner or using this approach on need basis. If this approach is to be adopted then the times at which this activity would be carried out has to be neatly predefined so that there is no confusion amongst nodes with regard to the time slices at which this needs to be done.

Intercontact delay is the time elapsed between two successive data transfer requests between two nodes. This intercontact delay between two consecutive communications was significantly used by Luo et al. (2012) for overcoming the disadvantages in controlled flooding proposed by Mundur et al. (2008). It is aimed to use this significant intercontact delay in ad hoc networks which are sparsely deployed for route restoration and network connectivity maintenance. However, in this approach next hop selection is based upon degree of centrality of each node. Luo et al. proposed that all the nodes have to be aware of next hop's buffer availability before forwarding the packet. In this thesis hence the motivation is to device a lightweight approach to identify next hop selection, maintain the network by publishing the topology of the network periodically and mitigate the resource challenging phenomena of replication of messages.

In sparse deployment topologies it is very important to device mechanisms where end to end connectivity between nodes is maintained by using controlled mobility similar to ferry assisted DTNs. The nodes can be made to move within certain degree of proximity to each other thereby the nodes need not rely on ferry nodes to facilitate traffic in the network. This forms as basis for *Mobility Management Scheme* proposed in further sections.

In this chapter the literature review was carried out. The various works and their gaps were reported after thorough reviewing. Further, based upon the literature review and research gaps the algorithm and the framework is designed which is being discussed in the chapter 3.

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Chapter 3
Mobility Management Model Description
Framework and Algorithm

3.1 MM Scheme for Node Binding

A node can be considered a transceiver with a range around it in a circular area with node acting as radial point. The radius of the circle is equal to the range of transmission for a node. This imaginary circle moves along with node's random movement. Since Ad hoc network will have node to node communication it means that receiver node has to be inside the circle of sending node for the duration of transfer.

A remote node would be one that is outside the range of the broadcasting node and a node at relatively larger distance would be more remote to another node that is relatively nearer but still outside the range of the node.

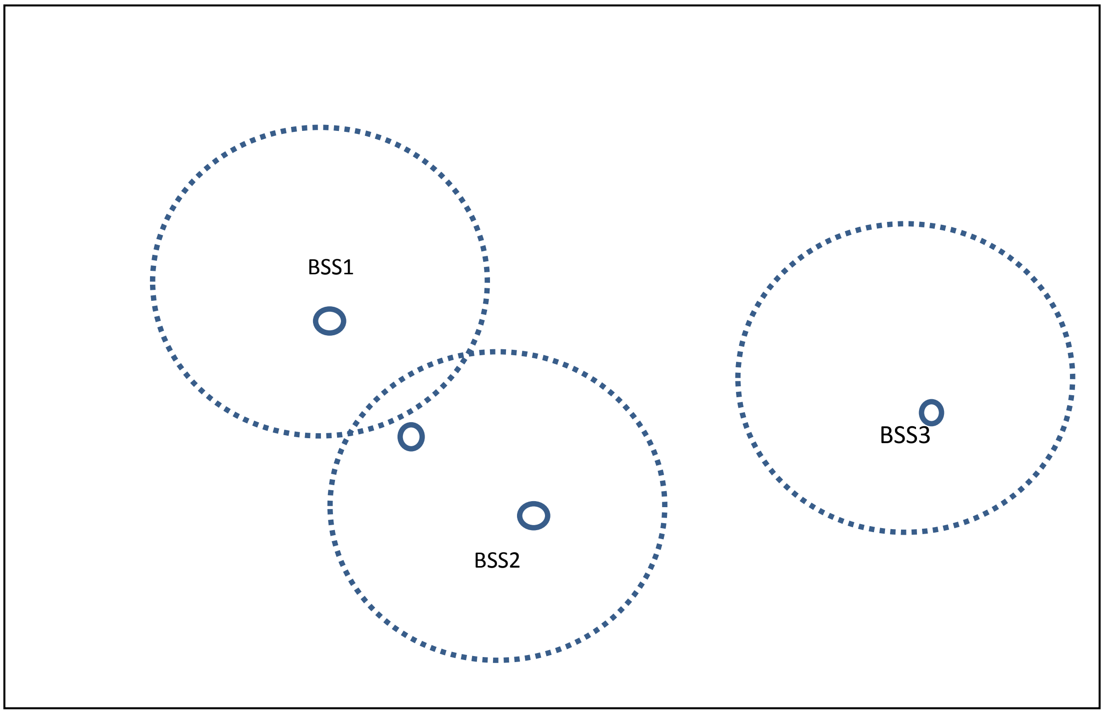

Fig 3.1 Scenario depicting Remote nodes and Nodes within the Transmission range

Here BSS1 has one node in it and the node in BSS3 is remote node for BSS1.For BSS2 the node on outside boundary is to be stopped and node has to be brought in after it reaches the boundary perimeter. The following illustration will explain this concept of node mobility management.

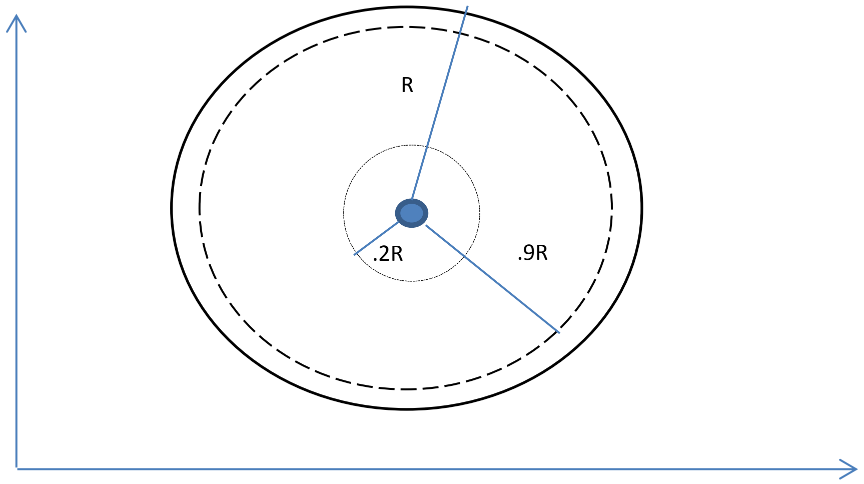

Fig 3.2: Node at center with Threshold radials

Let R be the radius of circle of Transmission range and there be defined a threshold distance D_{th1} which is equal to R, i.e. D_{th1}=R

Now $\exists$ Y ε Y_k s.t. $|Y_k - Y_0| = Y_{dis}$ and $\exists$ X ε X_k s.t. $|X_k - X_0| = X_{dis}$

Therefore,$\sqrt{(Y_{dis})^2 + (X_{dis})^2} = R = D_{th1}$ ---- (3.1)

Let us maximum displacement threshold for any node at any location within the range is 90% of R and minimum displacement threshold for node be 20% of R. This can be put in inequalities 3.2 and 3.3 as below.

$$\sqrt{(Y_{dis})^2 + (X_{dis})^2} <= 0.9R \qquad \text{--- (3.2)}$$

$$\sqrt{(Y_{dis})^2 + (X_{dis})^2} >= 0.2R \qquad \text{--- (3.3)}$$

This has been termed as snoop location test that each node will do for its master node to get its coordinates as given by inequality 3.4.This shall be the basis of formation of node associativity in *Mobility Management Scheme*.

$$0.2R <= \sqrt{(Y_{dis})^2 + (X_{dis})^2} <= 0.9R \qquad \text{--- (3.4)}$$

If the condition is violated, the node shall reset its path to align with the master node and shall keep on doing so, till the next agreed time interval when One Hop Packets are broadcast and network topology is available afresh.

3.2 Probability of the receiving node availability

Transmission Range is R.

Area of Transmission for Omnidirectional Antenna, A_T

$A_T = \pi R^2$ -- (3.5)

Let $.X_1R$ be the Outer Boundary and $.X_2R$ be the Inner Boundary.

Area of Circle for Outer Boundary, A_{out}

$A_{out} = \pi(.X_1R)^2 = (.X_1)^2 \pi R^2$ --(3.6)

Area of Inner Circle, $A_{inn} = \pi(.X_2R)^2 = (.X_2)^2 \pi R^2$ --(3.7)

Area left outside the outer boundary, $A_{left} = A_T - A_{out}$

Total Area not allowed for node movement, A_{not}

$A_{not} = A_{left} + A_{inn}$ --(3.8)

Hence, $A_{not} = [\ .X_2^2 + (1 - .X_1^2)^2]\ \pi R^2$ --(3.9)

Let P_b be the Probability of not finding neighbor node in the space created for neighbor node movement.

$P_b = A_{not} / A_T = [\ .X_2^2 + (1 - .X_1^2)^2]\ \pi R^2 / \pi R^2$

$= .X_2^2 + (1 - .X_1^2)^2$ --(3.10)

In this proposed model $X_1 = 0.9$ and $.X_2 = 0.2$

Hence, $P_b = .04 + (1-.81) = .04 + .19 = 0.23$

Therefore, P_a the probability of finding the node within the customized range due to mobility management scheme is 0.77 when node movement is restricted according to Equation 3.4. The experimental setup and results drawn in this work are according to the above expressions and assumptions.

3.3 Protocol for establishing node associativity and duplicate link removal

In this section, the workflow of the algorithm is described on the basis of the following assumptions.

a. Network is sparsely deployed and here network has been modelled for 4 nodes only.

b. It is assumed that all nodes are aware of maximum network size which is 4 in this case.

c. Nodes broadcast to other nodes there one hop neighbor information after fixed interval of time and network activity is suspended during this time interval.

d. All nodes enter the network simultaneously and if any node is entering after some time the network has started functioning it will not straight way look to connect to some neighbor, though it will be listening to its neighbors if any. It will have to wait for time interval when one hop neighbor is being broadcast by its neighbor.

Algorithm: Since the network size is 4 and node are enumerated in given set N_i= (n1, n2, n3, n4,}.Each node shall maintain a 3×4 Stack of Booleans 1-D matrix for route maintenance, which is to be maintained at each node. Each row of stack matrix shall signify as n^{th} hop entries where each column represents node Ɛ N_i.

Table 3.1 and Table 3.2 are route maintenance matrices for nodes,n1 and n2,where column are indicative of n1,n2,n3,n4 and rows are indicative of 1 hop neighbor,2 hop neighbor and 3 hop neighbor. If any entry in table is 1 it means that corresponding node is a neighbor and row no will tell if it is 1-hop, 2-hop or 3-hop neighbor. This representation is for scenario A in figure 3.

The entries in shaded part of table 3.1 represent the presence of neighbor at a particular hop distance. From here onwards, only shaded portion of table 1 is reproduced under different scenarios and significance of row and columns remains same.

Table 3.1 Route Maintenance Entries in routing table for node n1

Hop no	Node1	Node 2	Node 3	Node 4
1-hop	0	1	0	0
2-hop	0	0	1	0
3-hop	0	0	0	1

Table 3.2 Route Maintenance Entries in routing table for node n2

1	0	1	0
0	0	0	1
0	0	0	0

One hop packet for node n1 in scenario A in figure 3.3 would look like this.

0	1	0	0	(for node n1)

Where first cell represents node n1 and second cell represents node n2 and so on. A presence of 1 in this cell indicates that the node to which that cell belongs is one-hop neighbor of the node for which it is being listed as one hop packet. Similarly, looking at scenario A one hop packets for node n2 and n3 would look like this.

1	0	1	0	(for node n2)

0	1	0	1	(for node n3)

If these one hop packets are stacked one upon another, the matrix of stacked one – hop packets would look like as provided next.

n1	n2	n3	n4	
0	1	0	0	for n1
1	0	1	0	for n2
0	1	0	1	for n3

So on having a look at this matrix it is seen that inconclusive information is available when it is needed to construct network topology image for node n1. Hence if this stack with inconclusive information is to be converted into array as shown in table 3.1 then it shall be needed to apply the algorithm, as proposed subsequently in this section. In the proposed algorithm two transformations are performed on one matrix i.e. Reset column entries for the node inside it's one hop information stack matrix, to zero as a node cannot be neighbor of self. As it can be seen that, for node n1 entry in second row and first column is 1, so this needs to be handled with as well. Another operation is to remove duplicate entries in same column as same node can't be neighbor for multiple hops of the node for which one hop information stack matrix is being evaluated and also is not desired that messages to loopback to the node for whose the column entries are listed as 1 more than once. As it can be seen that node n2 for n1 is one hop neighbor so the occurrence of 1 in third row ,second column suggests that it is 3-hop neighbor as well, but this needs to be addressed as well in the algorithm. Also if the topology changes due to movement of nodes then due care has to be taken for duplicate route entries as can be seen in Scenario B.

The image of network for node n1 is in Figure 3.3, and it is assumed that nodes moves in direction of arrow. Let below be called Scenario A

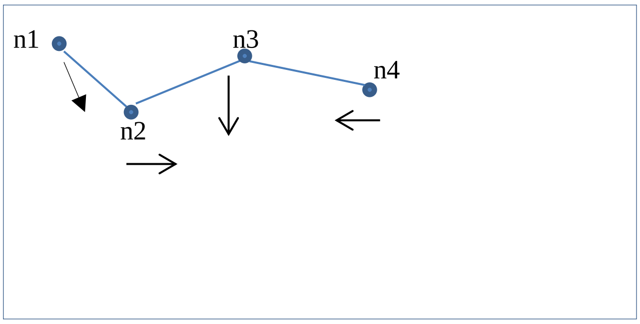

Figure 3.3 Scenario A

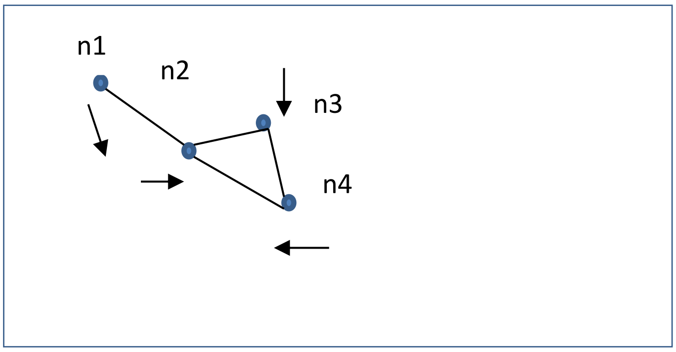

Figure 3.4 Scenario B

Now the matrix for node n1 and n2 for Scenario B is in table 3 and table 4 respectively.

Table 3.3: Route Maintenance Entries in routing table for node n1

0	1	0	0
0	0	1	1
0	0	1	1

Table 3.4: Route Maintenance Entries in routing table for node n2

1	0	1	1
0	0	1	1
0	0	0	0

Here it can be seen that n2, n3 and n4 are connected in a looping topology. There is occurrence of duplicate routes from n1 to n4 e.g., <n1,n2,n3,n4> and <n1,n2,n4> are two possible routes from n1 to n4. Hence which route to be followed is not clear if say data is to be sent from n1 to n4. This situation has a probability of occurrence as node binding scheme has been proposed in previous sections and nodes would move within the network in close proximity to each other sweeping maximum area collectively.

So, the following algorithm is proposed.

Table 3.5 Notations used in algorithm

Notation used	Description
RH(n)	nth hop Information Bits framed in size 4 bit
NS(n)	nth Node's RH(n)s Stack Array of size(n-1×n) for complete route information
AN(n)	Stack for node n for scenario A
BN(n)	Stack for node n for scenario B
RST,NR	Resetted operation, Not Resetted operation

Step1.Node n Ɛ N $_i$ transmits one hop packet containing 4-bit RH(n) frame along with Control information to each one hop neighbor during the interval already known to all nodes .All nodes n broadcast one hop information received from all sources to all their one hop neighbors except the node from which it came. The source and destination information is available in one hop packet in form of control bits.

Step2.Each neighbor node n accepts one hop information, removes control information and pushes RH(n) on NS(n) in modulo 4 order, s.t.,rows RH(n) of NS (n) are in order (n+k)%4 for k=0,1,2,3 where n is the node number.

Order is representative of the node number.

2 (a). If (n+k) %4 equals ZERO, then set order n of RH(n) being pushed onto stack NS(n) as n =4.

Step 3.In NS (n) for node (n) set the n^{th} column bit to ZERO to avoid loopback condition.

Step 4.Start reading 4×4 NS (n) in row major order and preserve 1's as they are encountered. For every node n Ɛ N_i don't read the bit in nth column, and entry is NR whenever 1 is encountered.

4 (a). Preserve 1's only if 1 is not encountered in previous row traversals, i.e., RST if already done a NR for 1 in same column.

5. Drop last row of matrix i.e. the 4^{th} row in this case, NS (n) for network of size 4 is ready.

Output of Algorithm:

This algorithm was tested on a self-prepared computer program and found the algorithm working for a network of size 4 where duplicity of links was handled by passing only one hop information between nodes .In this way same network image is available to all nodes as in this case AN(n) and BN (n) are created for all 4 nodes .

After, step2 the following tables are created on nodes n1 and n2.As it can be seen these tables have four rows whereas the actual table that has route entries has three rows. One extra row has been created due to iterations in step 2 of algorithm.

Table 3.6: Route Maintenance Entries in routing table for node n1

0	1	0	0
1	0	1	1
0	1	0	1
0	1	1	0

Table 3.7 Route Maintenance Entries in routing table for node n2

1	0	1	1
0	1	0	1
0	1	0	0
0	1	0	0

The table 3.8 and table 3.9 are received after the Step 4 and 5 of Algorithm is played. Table 3.8 and Table 3.9 are representative of same network image for both node n1 and n2.The same network image results in zero duplication of messages in the network, when network will be put in operation.

Table 3.8 Route Maintenance Entries in routing table for node n1

0	1	0	0
0	0	1	1
0	0	0	0

Table 3.9 Route Maintenance Entries in routing table for node n2

1	0	1	1
0	0	0	0
0	0	0	0

The network image emerging out of table 8 and table 9 is given in Figure 3.5 below.

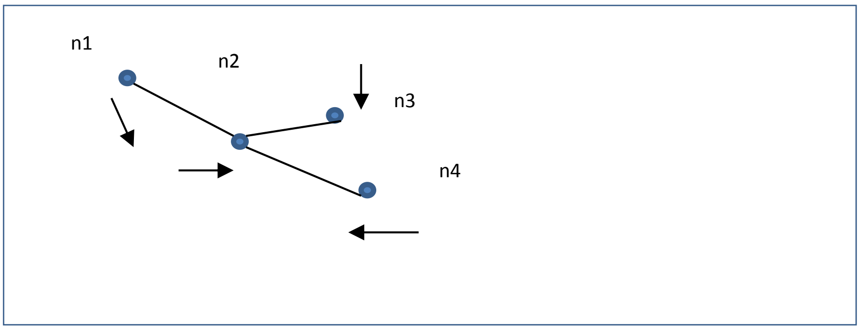

Fig 3.5 Network image after removal of duplicate links

In this chapter the framework within which the experiment shall be carried out is outlined in theoretical format. The mathematical model for mobility management is proposed which shall be incorporated in the simulation experiment design. The next chapter is about simulation was carried out and under what circumstances the mobility management scheme is tested. Results are also discussed and graphs are plotted for comparative study.

Chapter 4
Simulation Environment and Results

Simulation was carried out using NS 2.34 simulator for testing two protocols which are proposed in this work. NS 2.34 simulator can be found freely to be used and is available at http://www.isi.edu/nsnam/ns . It is also pertinent to mention the Vint Project which is available at http://www.isi.edu.nsnam/vint and tutorials by Marc Greis found at http://www.isi.edu/nsnam/ns/tutorial for completion of this work.

The effects of mobility management were studied on two protocols and the protocols proposed are

- AODVMM(Advance on Demand Vector Mobility Managed)
- DSDVMM(Destination sequence Distance Vector Mobility Managed)

Two separate test environments were set for both these protocols. The test environment is set with creation of multiple simulation scripts, similar to as provided in Appendix – I, for different scenarios of network sizes and node population. The initial block of code on the script is to set up the scenario which is elaborated in Tables 4.2 and 4.8. The various fields which are set in the script are listed in these tables. The script deploys a random function to set the destinations for each of the node by generating random destinations coordinates. The nodes are repeatedly assigned random destinations and all this while the mobility management scheme proposed in previous sections is put to use to guide the movement as given in the mobility management expression in the sample simulation script. Each of these scenarios is tried for repeated trials and each trial generates a Trace file and Nam file which is stored in a chronological order for further analysis. Each source node is assigned constant bit rate traffic behavior with a packet size and the time instant at which node generates packets in each of the trials is fixed, even though the nodes are assigned destinations in a random fashion using the random function as provided in the script. Once the nodes start moving mobility management scheme is put to use to guide the movement of the nodes.

For each trial under different scenarios as explained in Table 4.1 and 4.7 the Trace file name and Nam file name was stored for further analysis to be done by Nam animator. Further an AWK script was written as provided in Appendix-II which was executed on each of the trace file that was generated after execution of simulation scripts for each of the scenario that was created. The trace file has the entire trace of the simulation run and each record in the trace file is of same format. So AWK script as given in Appendix- II is run on each trace file to calculate the Throughput and End to End delay for individual trial run. These computed values are then entered into CSV files for Analysis by R-scripts.

The different R-scripts were written to check if the experimental data is normal or not and if the data recorded is found to be normal then the data is validated using standard parametric test functions provided in R programming language (As provided in Appendix-III). Conversely, if the data is not found to be normal then the data is subjected to non-parametric testing functions found in R programming language. In the pairwise comparisons for AODVMM and DSDVMM respectively, individual comparisons have been done using One

Way Analysis of variance tests to validate the test results which are reported in section 4.1 and 4.2 (As provided in Appendix – IV). Finally in section 4.3 AODVMM and DSDVMM has been compared amongst each other using two way Analysis of variance tests and thereby validating the results (As provided in Appendix –V).

After this R-scripts were written using graphics plot libraries to plot the graph between pairwise comparisons of different scenarios. These scripts were written for every individual plot that has been done in this work and a sample script is provided in Appendix –VI.

4.1 Simulation of AODVMM and its comparison with AODV

Nodes were assigned behaviour as discussed in Mobility Management (MM) scheme in the previous sections. Nodes update their locations periodically as provided in MM scheme. Each node has been assigned functionalities which are very similar to ferries. The receiving node after establishing association according to MM scheme does not move out of the outer threshold radius while it is receiving and also can't come too close due to limitations on its movements due to inner threshold radius. Hence, Node movement is constantly controlled by the inner and outer boundaries of imaginary circle whose radius is same as that of transmission range. The associations between communicating nodes are lasting for fixed time duration and once one time interval elapses, the node is free to form fresh associations. R-GUI software was used for the purpose of statistical validation of the results thus achieved and ggplot2 library of R-GUI was used to plot the comparative data graphs, after validating the data.

Some notations have been used in this work which are indicative of the parameters under which the simulation environment was set. These notations indicate about the parameter of interest for particular set up. Sufficient numbers of trials were carried out to establish the validity of the results which were received.

The parameters which have been observed in the trials are Average End to End Delay, Packet Drop Ratio and Throughput. The experimental observational data was evaluated for Normality by conducting normality tests and were validated using parametric tests using the R-studio software. If experimental data was not confirming to normal tests the data has been verified by conducting non parametric tests using R-studio. All the validation has been done with minimum of 95% confidence interval. Table 4.1 contains notations used for the indication of simulation parameters and Table 4.2 has the simulation parameters.

Table 4.1 Notations used in comparative analysis

Notation	Significance
AODV	Advanced On-Demand Vector, when MM scheme is not Deployed
AODVMM	AODV with Mobility Management Scheme
AODVMMRR	AODV with Mobility Management Scheme under Reduced Transmission Range
AODVMMLB	AODV with Mobility Management Scheme under Reduced Buffer Space
AODVRRLB	AODV under Reduced Transmission Range and Reduced Buffer Space
AODVMMRRLB	AODV with Mobility Management Scheme under Reduced Transmission Range and Reduced Buffer Space
PDR	Packet Drop Ratio
EED	Average End to End Delay
THROUGHPUT	Total Throughput observed for all the nodes in the network. Recorded as Percentage.

Table 4.2 Simulation Parameters

Parameter	Value
Network Area	500mX500m,800mX800m
No of nodes	5,8
Data Traffic	CBR, Constant Bit Rate
Packet Size	512Kb
Speed of nodes	20 m/s , for all nodes
Transmission Range	100m/70m (Normal/RR)
Buffer Size	10/7,20/14 (Normal/LB)(5nodes,8nodes)

4.1.1 Comparison of AODVMM with AODV under various conditions for throughput parameter

The trial was carried out for varying number of nodes for a network size of 500X500 meters by deploying 5 and 8 nodes in separate trials. It was witnessed that in case of 5 nodes deployed in network, gains are observed in case of deployment of MM scheme on AODV for the parameter of throughput and better network efficiency is observed. The gains which are observed are significant as confidence interval up to 99.5% is achieved while making comparative analysis of Analysis of variance for similar scenarios.

But, as node population increases from 5 to 8 within same network boundaries the improvement observed in parameters under study is insignificant and does not qualify statistically. When numbers of nodes are increased then the nodes are relatively closer and deployment is less sparse. Due to proximity of nodes the gains made due to MM scheme are not significant. Further, as increase the area of operation is done, i.e., the network size is increased to 800X800 meters for a node population of 8 the improved performance with respect to parameters of interest can be witnessed again.

The MM scheme exhibits significant gains for throughput of the network. The graph plots substantiate the same. In Figure 4.1, 4.2, 4.3 all trials show gain when MM scheme is deployed but the gains in case of AODVMM with 8 nodes in 500X500 the gains in throughput are not significant statistically. Table 4.3 elaborates on this.

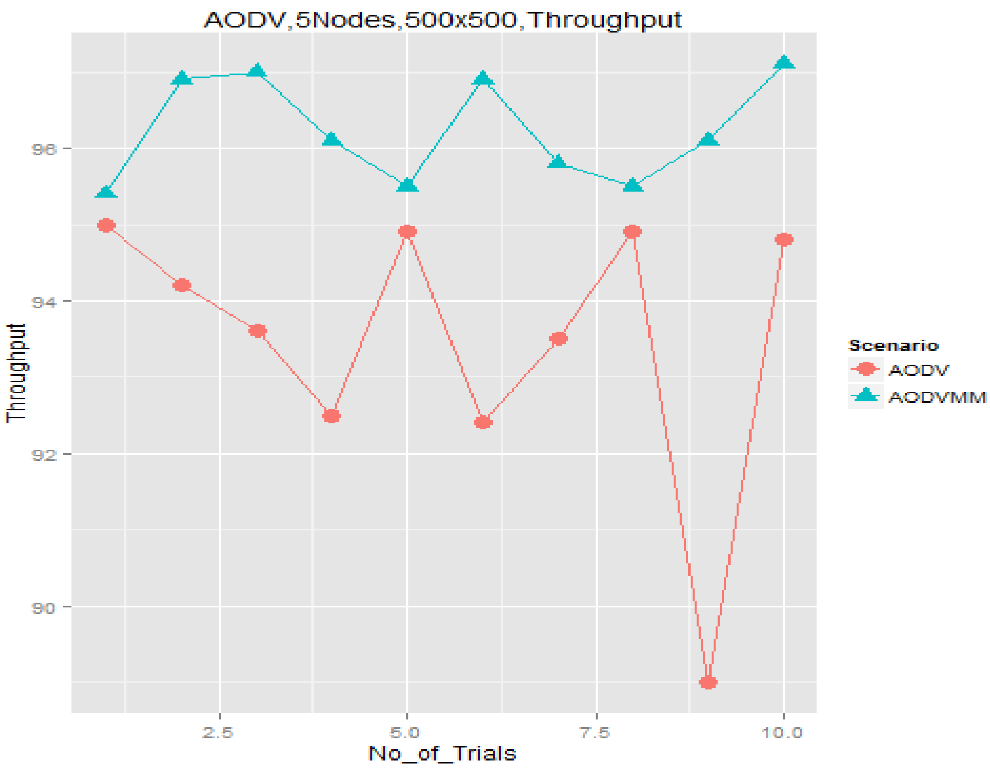

Figure 4.1 Throughput, 5 Nodes , 500x500, AODV v/s AODVMM)

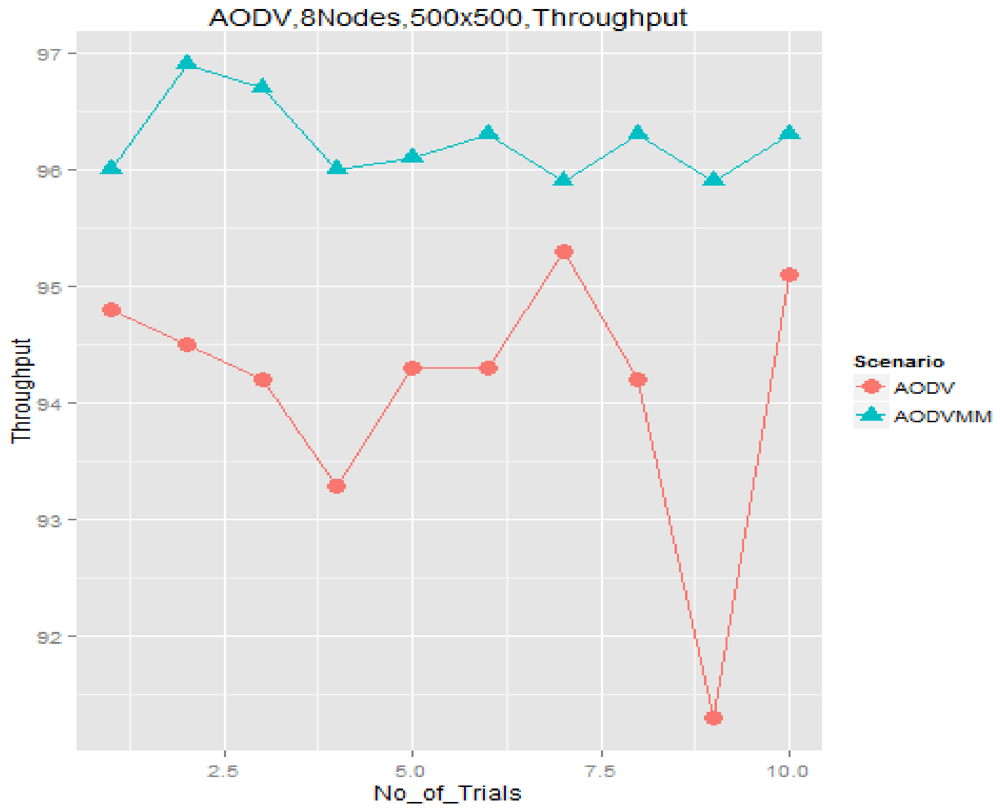

Figure 4.2 Throughput, 8 Nodes, 500x500, AODV v/s AODVMM

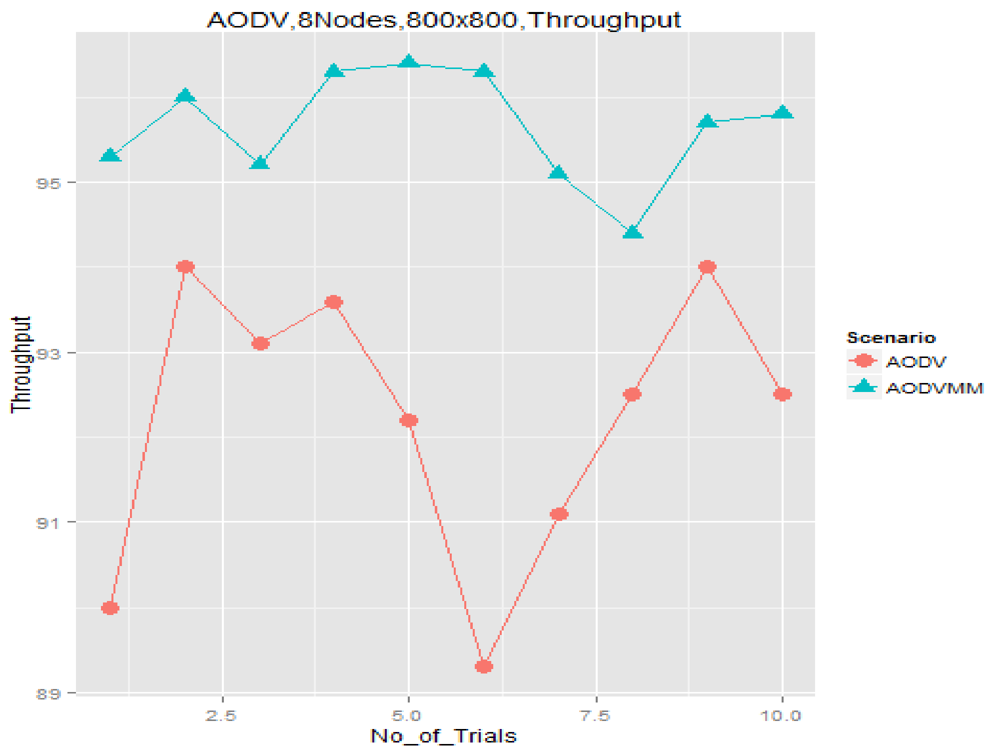

Figure 4.3 Throughput, 8 Nodes, 800x800, AODV v/s AODVMM

Table 4.3 Simulation parameters and Statistical Results for Throughput under Normal Conditions

Comparison	Significance value	Confidence Interval	Conclusion w.r.t to Network Size and no of nodes deployed.
AODVMM-AODV (5 Nodes, 500X500)	0.0003	Valid for CI of 95, 97.5,99.5	AODVMM is better in 5 nodes,500X500 with Throughput as a parameter of interest.
AODVMM-AODV (8 Nodes, 500X500)	0.0408	Valid for CI of 95 only-lesser	AODVMM is better in 8 nodes, 500X500 with Throughput as a parameter of interest.
AODVMM-AODV (8 Nodes, 800X800)	0.0000	Valid for CI of 95 ,97.5,99.5	AODVMM is better in 8 nodes, 800X800 with Throughput as a parameter of interest

As it can be seen from the table 4.3 AODVMM performs much better than AODV under normal conditions for scenario of 500x500 with 5 nodes and 800x800 for 8 nodes. The value of Confidence interval is up to 99.5% which is highly significant.

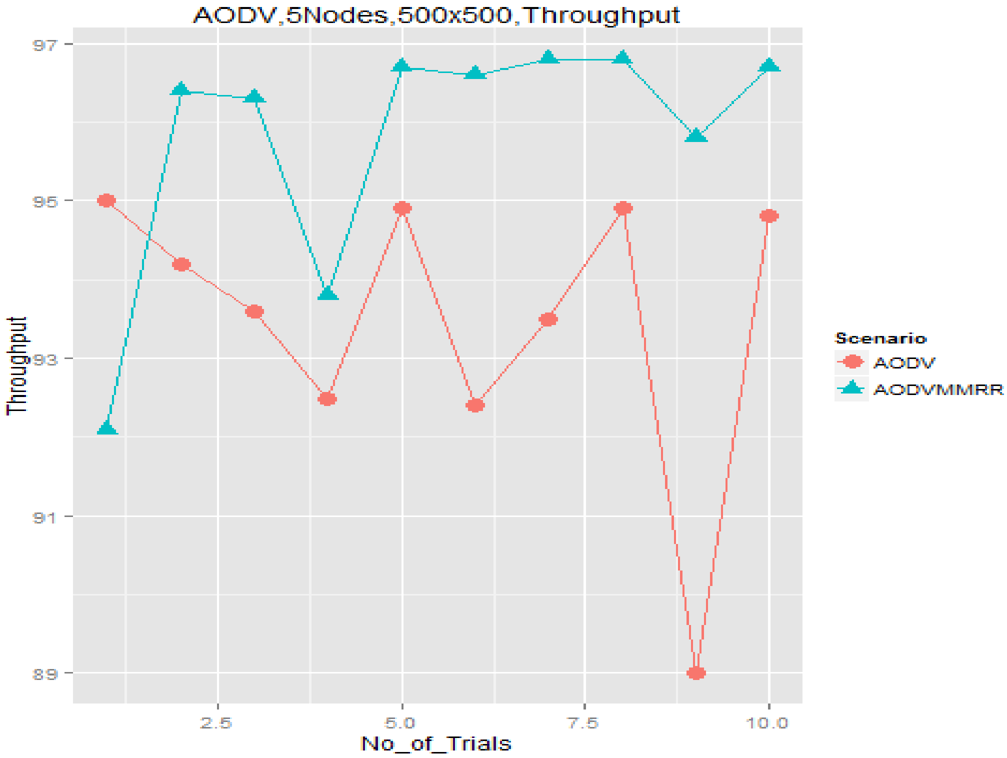

Figure 4.4 Throughput, 5 Nodes, 500x500, AODV v/s AODVMMRR

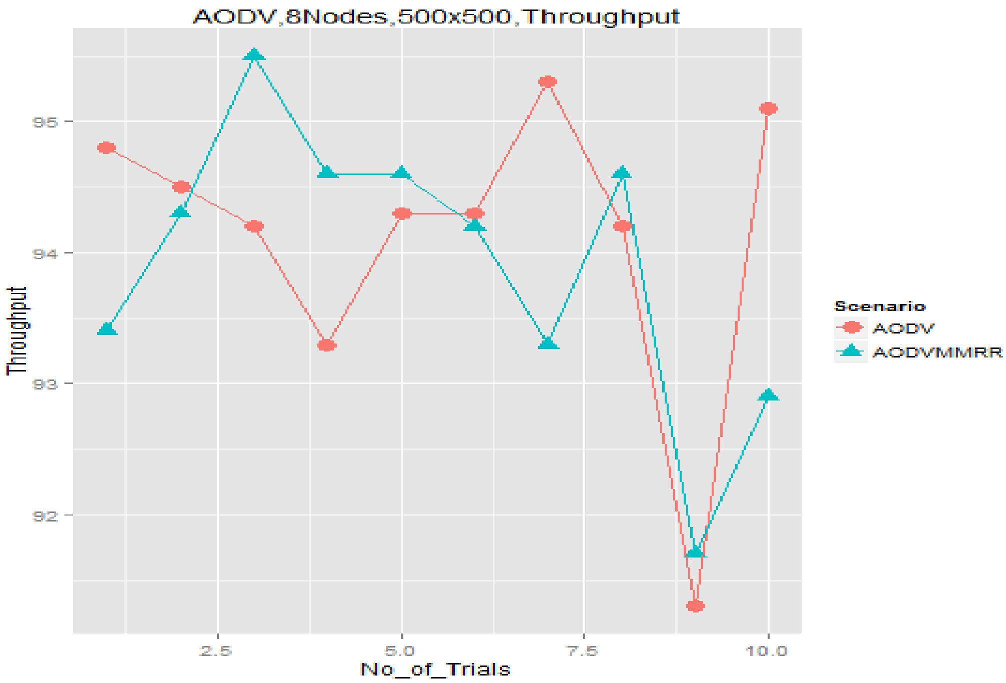

Figure 4.5 Throughput, 8 Nodes, 500x500, AODV v/s AODVMMRR

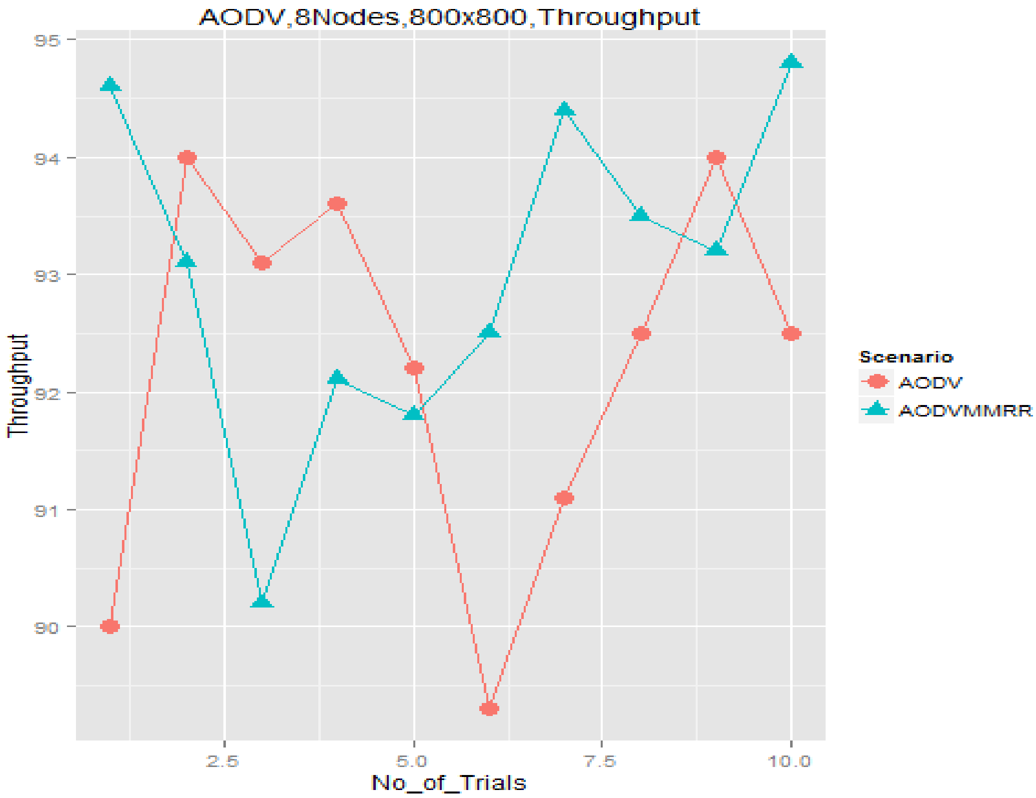

Figure 4.6 Throughput, 8 Nodes, 800x800, AODV v/s AODVMMRR

In figure 4.4, 4.5 and 4.6 Mobility Management Scheme is put to test along with Reduced Transmission Range conditions. When transmission range is reduced the node has to be mobile in lesser area while receiving data and nodes will be in proximity with each other. Hence gains are there to be seen. However, when more nodes populate the same area then the data has to move more hops to reach destination. Due to this phenomenon the packets would be lost due to overloading at buffers hence lesser gains are seen when more nodes are deployed in same area. The gains are witnessed again when network area is enhanced for higher node number. Table 4.4 elaborates the results statistically.

Table 4.4 Simulation parameters and Statistical Results for Throughput under Reduced Range Conditions.

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
AODVMMRR-AODV (5 Nodes, 500X500)	0.0031	Valid for CI of 95, 97.5	AODVMMRR is better in 5 nodes, 500X500 with Throughput as a parameter of interest.
AODVMMRR-AODV (8 Nodes, 500X500)	0.9981	No significant	AODV is better, AODVMM loses gains
AODVMMRR-AODV (8 Nodes, 800X800)	0.0502	Valid for CI of 95	AODVMMRR is better in 8 nodes, 800X800 with Throughput as a parameter of interest

Figure 4.7, 4.8, 4.9 are plots when nodes are communicating under depleted conditions of Reduced Transmission Range and Reduced Buffer at their disposal. It can be seen very clearly that when Mobility Management scheme is deployed along with the Reduced Transmission and Reduced Buffer conditions, the network performance improves significantly for network size of 500x500 with 5 nodes as node population. When the numbers of nodes are increased to 8 for network size of 500x500, then the gains are not so significant whereas the same network performance shows significant enhanced throughput when for 8 nodes and network size of 800x800.Table 4.5 carries the values of pairwise comparisons and their inferences, statistically.

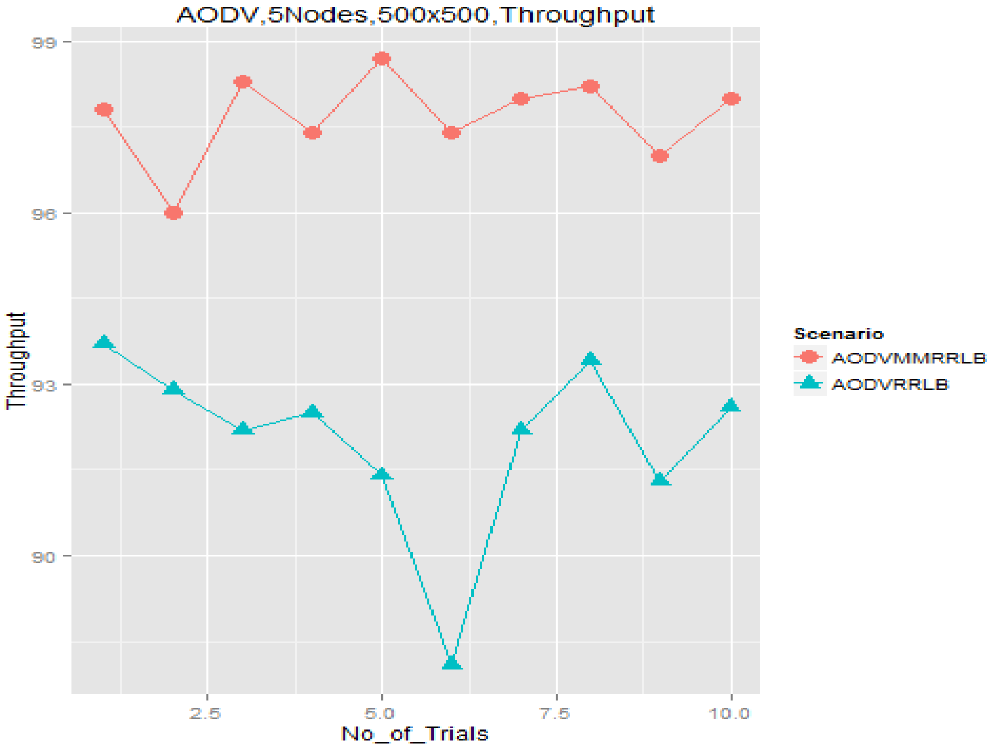

Figure 4.7 Throughput, 5 Nodes, 500x500, AODVMMRRLB v/s AODVRRLB

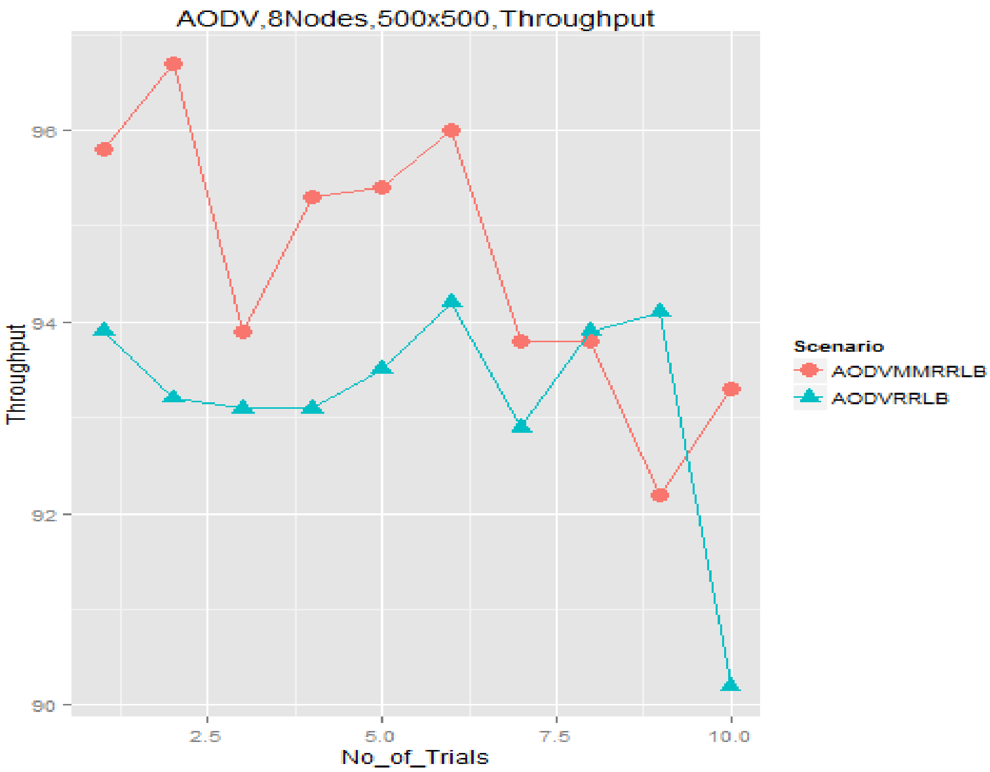

Figure 4.8 Throughput, 8 Nodes , 500x500, AODVMMRRLB v/s AODVRRLB

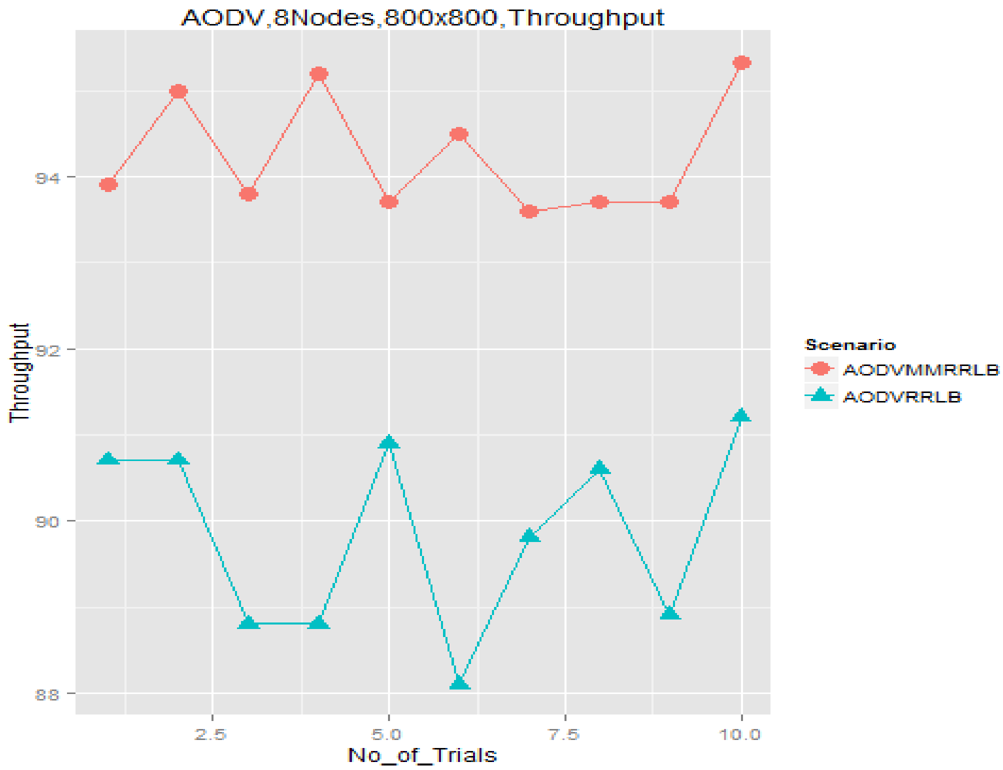

Figure 4.9 Throughput, 8 Nodes, 800x800, AODVMMRRLB v/s AODVRRLB

Table 4.5 Simulation Parameters and Statistical Results for Throughput under Reduced Range and Low Buffer Conditions.

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
AODVMMRRLB-AODVMMRR(5 Nodes, 500X500)	0.0000	Valid for CI of 95, 97.5,99.5	AODVMMRRLB is better in 5 nodes, 500X500
AODVMMRRLB-AODVMMRR(8 Nodes, 500X500	.0824	No significant	Gains are lost
AODVMMRRLB-AODVMMRR (8 Nodes, 800X800)	.0016	Valid for CI of 95,97.5	AODVMMRRLB is better in 8 nodes, 800X800

4.1.2 Comparison of AODVMM with AODV under various conditions for End to End Delay Parameter

The Mobility Management scheme when combined with reduced buffer (refer figure 4.10) i.e. AODVMMLB or reduced transmission range AODVMMLB (refer figure 4.11), clearly has higher end to end delay for network deployment without any modifications, in network parameters for a network size of 500x500 with node population of 5 nodes. However, as shown in figure 4.12 and figure 4.13 the end to end delay observed in network is on higher side for mobility managed scheme with reduced transmission range and low buffer as than without mobility management scheme under reduced range and reduced buffer as shown in figure 4.14 and figure 4.15. The Table 4.6 has statistical parameters for these scenarios.

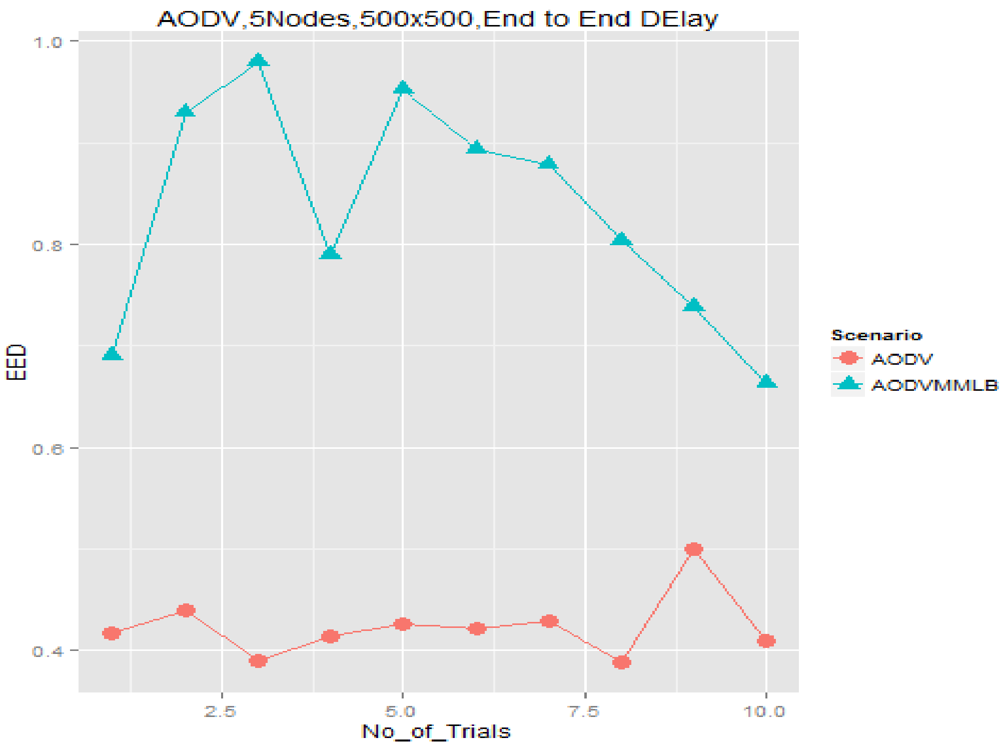

Figure 4.10 End to End Delay, 500x500, 5 Nodes, AODVMMLB v/s AODV

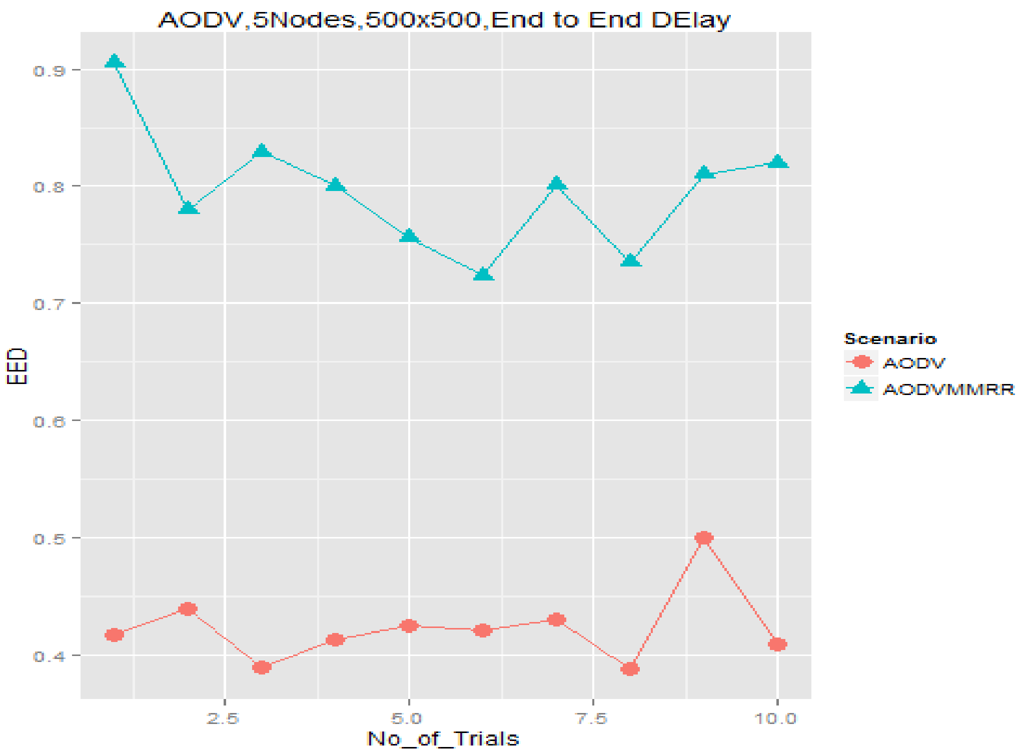

Figure 4.11 End to End Delay, 5 Nodes, 500x500, AODVMMRR v/s AODV

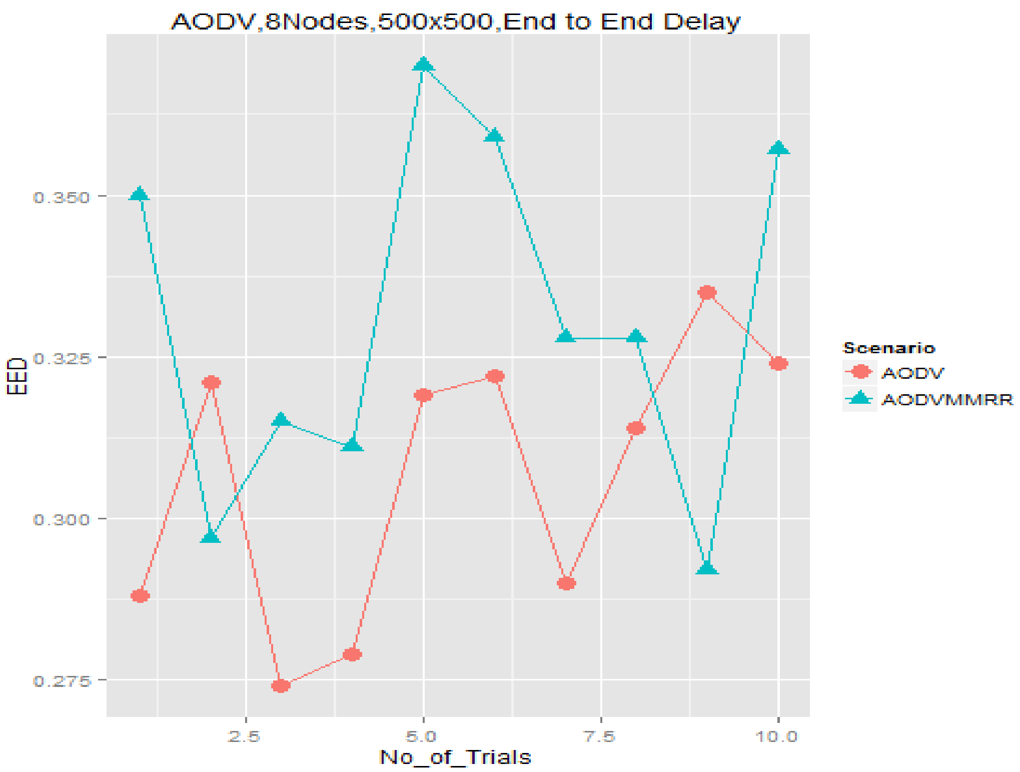

Figure 4.12 End to End Delay, 8 Nodes, 500x500, AODVMMRR v/s AODV

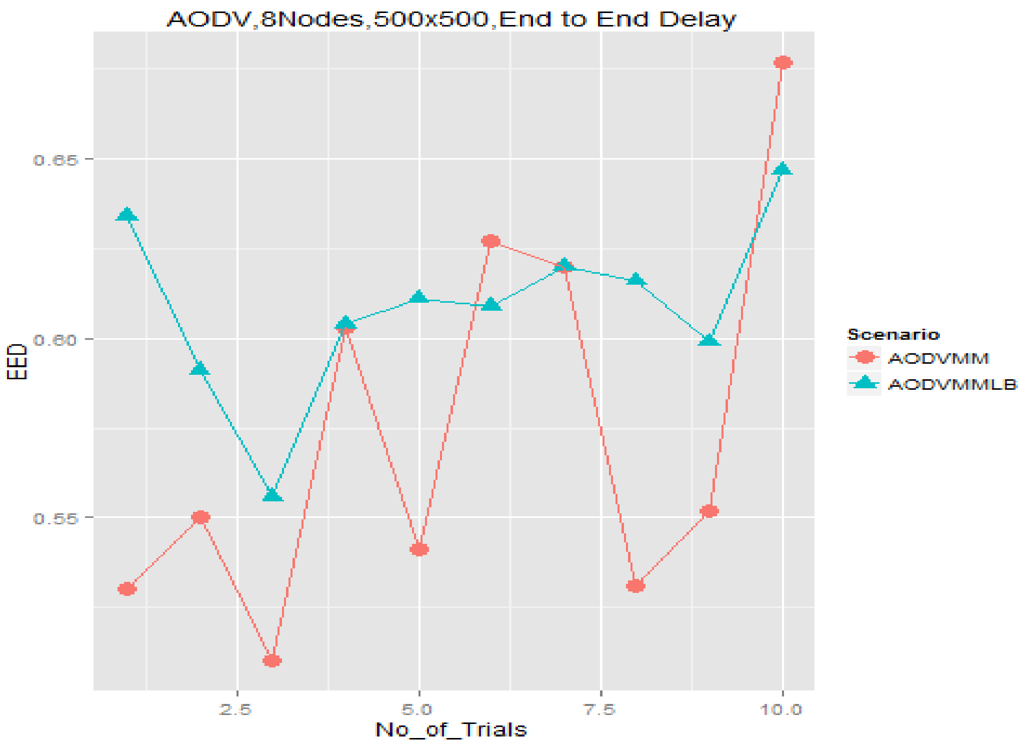

Figure 4.13 End to End Delay, 8 Node, 500x500, AODVMMLB v/s AODV

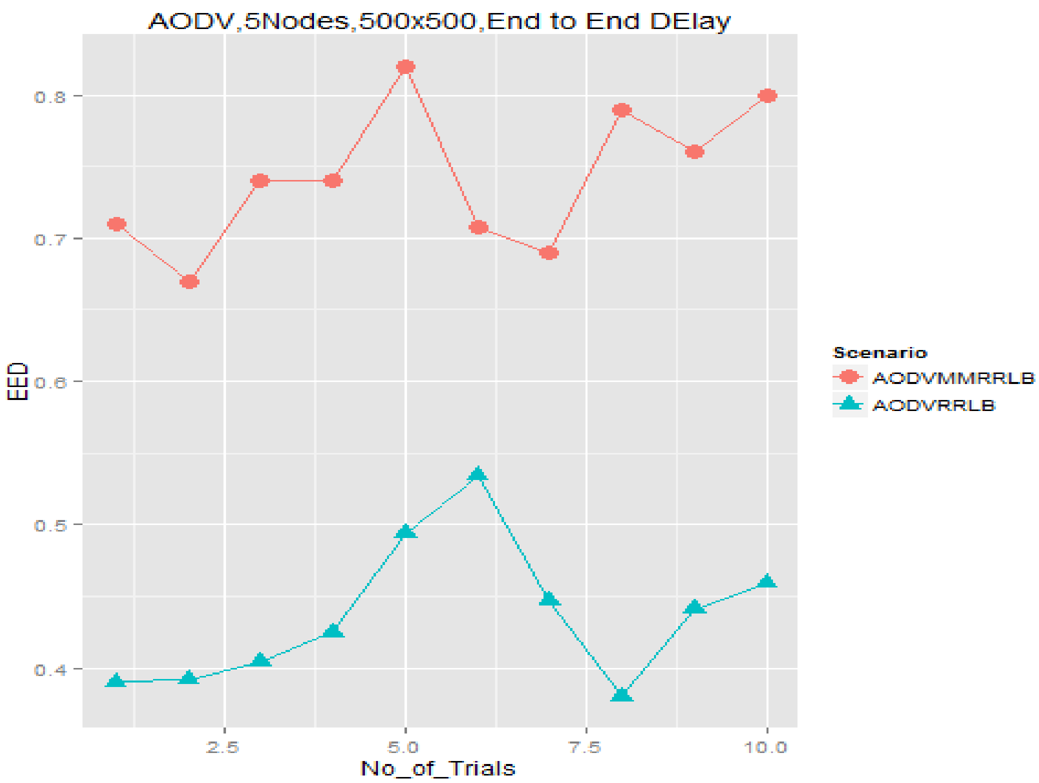

Figure 4.14 End to End Delay, 5 Nodes, 500x500, AODVMMRRLB v/s AODVRRLB

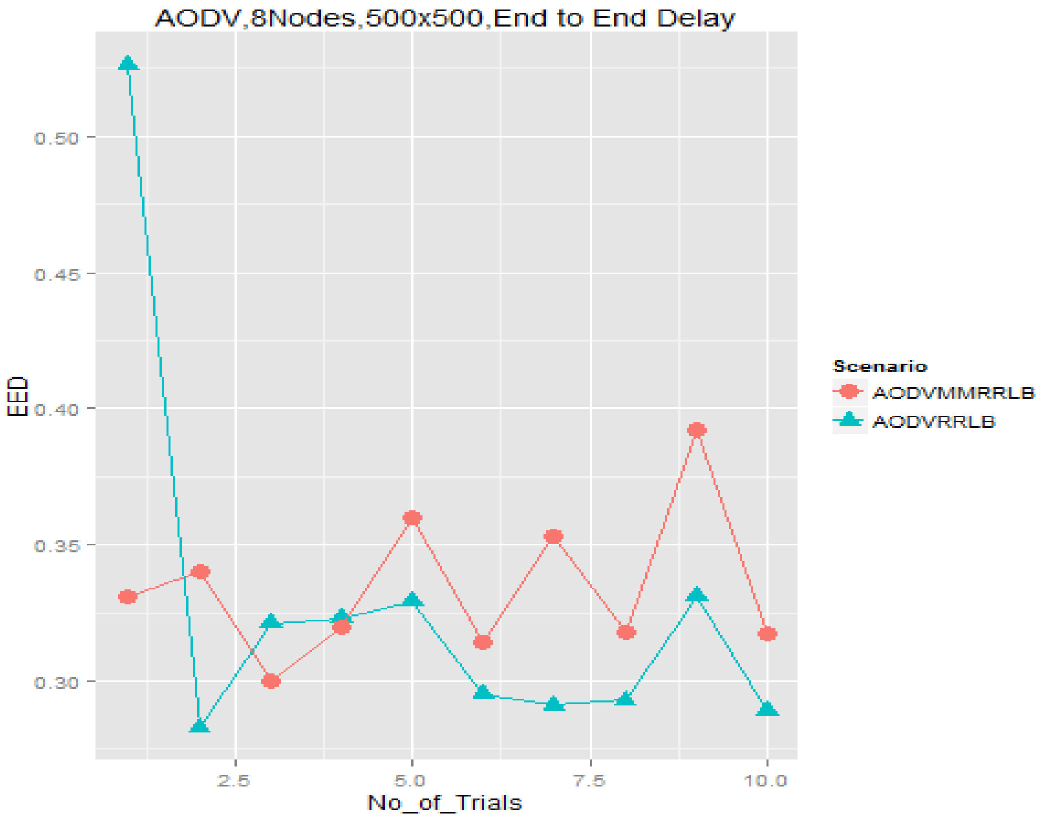

Figure 4.15 End to End Delay, 8 Nodes, 500x500, AODVMMRRLB v/s AODV

As it can be seen in the table 4.6 AODVMMRR and AODVMMLB shows higher end to end delay than AODVMM, and thus the gains if any in throughput are being observed are at the cost of higher end to end delay.

Table 4.6 Simulation parameters and Statistical Results for End to End Delay under all conditions

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
AODVMMRR-AODVMM (5 Nodes, 500X500)	0.0000	Valid for CI of 95, 97.5,99.5	Higher Delay under reduced range
AODVMMLB-AODVMM(8 Nodes, 500X500	.0000	Valid for CI of 95, 97.5,99.5	Higher delay under Low Buffer
	.		

AODVMMRRLB-AODVRRLB (5 Nodes, 500X500)	0000	Valid for CI of 95,97.5,99.5	Higher Delay under MM scheme
AODVMMRR-AODVMM (8 Nodes, 500X500)	.7957	Invlaid	Can’t be relied upon
AODVMMLB-AODVMM(8 Nodes, 500X500	.4531	Invalid	Can’t be relied upon
AODVMMRRLB-AODVRRLB (8 Nodes, 500X500)	.9994	Invalid	Can’t be relied upon

4.2 Simulation of DSDVMM and its comparison with DSDV

NS-2.34 Simulator is used for setting up the trials for testing this mobility management scheme coupled with DSDV protocol. Nodes were assigned the behavior as discussed in MM scheme in previous sections, such that the nodes update their destinations periodically based upon the MM scheme.

Here each node is assigned role very similar to ferry nodes. The node which is receiving does not move out of the outer boundary and also never comes too close as fixed by inner circle boundary. The associations are lasting for fixed time intervals and after one time interval elapses the nodes form fresh associations. The R-GUI was used for statistical validations of results and ggplot2 library in R-GUI was also used to plot the comparative graphs post statistical analysis.

Certain notations have been used which indicate the scenario in which simulation trial was carried out. These notations also depict the parameter of interest for a particular trial. Sufficient number of trials was carried out to establish certain level of certainty about the results thus achieved.

The parameter evaluated were Average End to End Delay and Throughput. The test data received after the trial was subjected to Normality test and wherever the data was not Normal, non-parametric test were done to establish validity and in case of Normal data parametric test were carried. All the validation has been done with minimum 95% Confidence Interval.

Table 4.7 carries the details of notations used and Table 4.8 carries the simulation parameters.

Table 4.7 Notations used for comparative analysis in DSDVMM

Notation	Significance
DSDV	Destination Sequence Distance Vector, when MM scheme is not Deployed
DSDVMM	DSDV with Mobility Management Scheme
DSDVMMRR	DSDV with Mobility Management Scheme under Reduced Transmission Range
DSDVMMLB	DSDV with Mobility Management Scheme under Reduced Buffer Space
DSDVRRLB	DSDV under Reduced Transmission Range and Reduced Buffer Space
DSDVMMRRLB	DSDV with Mobility Management Scheme under Reduced Transmission Range and Reduced Buffer Space
PDR	Packet Drop Ratio
EED	Average End to End Delay
THROUGHPUT	Total Throughput observed for all the nodes in the network. Recorded as Percentage.

Table 4.8 Simulation parameters for DSDVMM

Parameter	Value
Network Area	500mX500m,800mX800m
No of nodes	5,8
Data Traffic	CBR, Constant Bit Rate
Packet Size	512Kb
Speed of nodes	20 m/s , for all nodes
Transmission Range	100m/70m (Normal/RR)
Buffer Size	10/7,20/14 (Normal/LB)(5nodes,8nodes)

4.2.1 Comparison between DSDVMM with DSDV with under various conditions for Throughput as parameter

The Trial was carried out for network size of 500X500 by deploying 5 and 8 nodes. It is observed that in case of 5 nodes deployed in the network significant gains are made by deploying DSDVMM scheme over the deployment when MM is not used. The gains are significant up to a confidence interval of *99.5%* in some pairwise comparisons of Analysis of variance.

But as the number of nodes is enhanced to 8 for network size of 500x500 the gains made are lost. This happens because when nodes are in close proximity to each other in relatively less sparse deployment (8 nodes as compared to 5 nodes) the advantages of MM scheme are lost. However when for a deployment of 8 nodes the network area is enhanced to 800X800 most of the gains which are due to MM scheme can be witnessed again.

The MM scheme exhibits significant gains in terms of Throughput of the network. The following graphs exhibit the same. While the throughput is exhibited as improved in 5 nodes deployed in 500X500 and 8 nodes in 800X800 but throughput shows little gains when 8 nodes are deployed in 500X500 area. This happens primarily because nodes are already too close to each other and data packets make more hops to reach destination and get dropped in between due to overflow of buffers in the intermediary nodes . Though it is amply demonstrated that DSDVMM scheme outperforms DSDV protocol for a sparsely deployed MANET in terms of gains made in for throughput parameter.

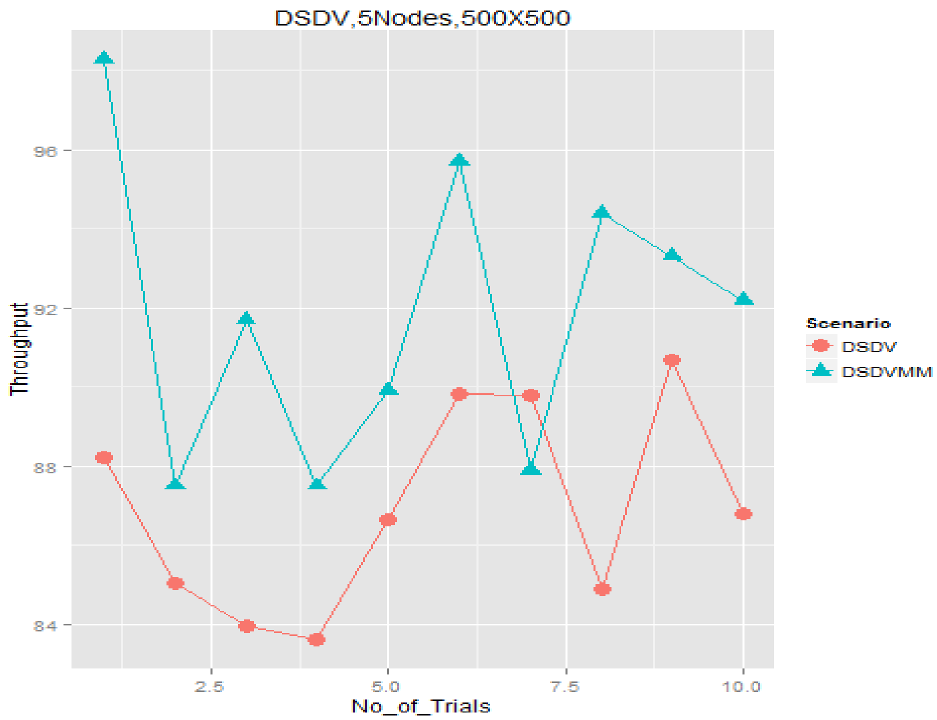

Figure 4.16 Throughput, 5 Nodes, 500X500, DSDV v/s DSDVMM

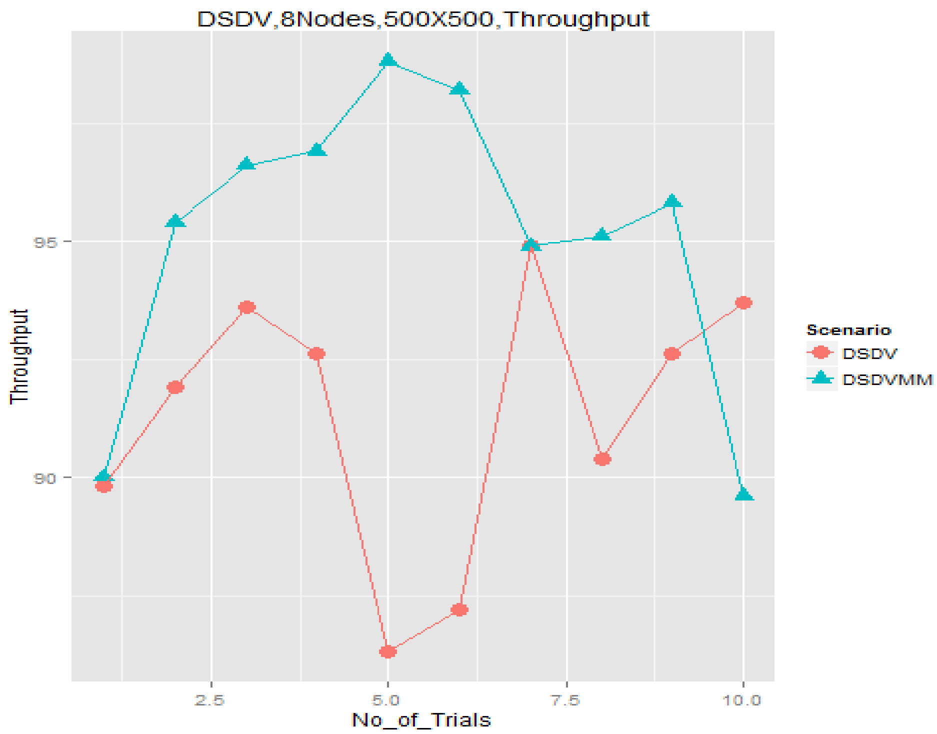

Figure 4.17 Throughput, 8 Nodes, 500X500, DSDV v/s DSDVMM

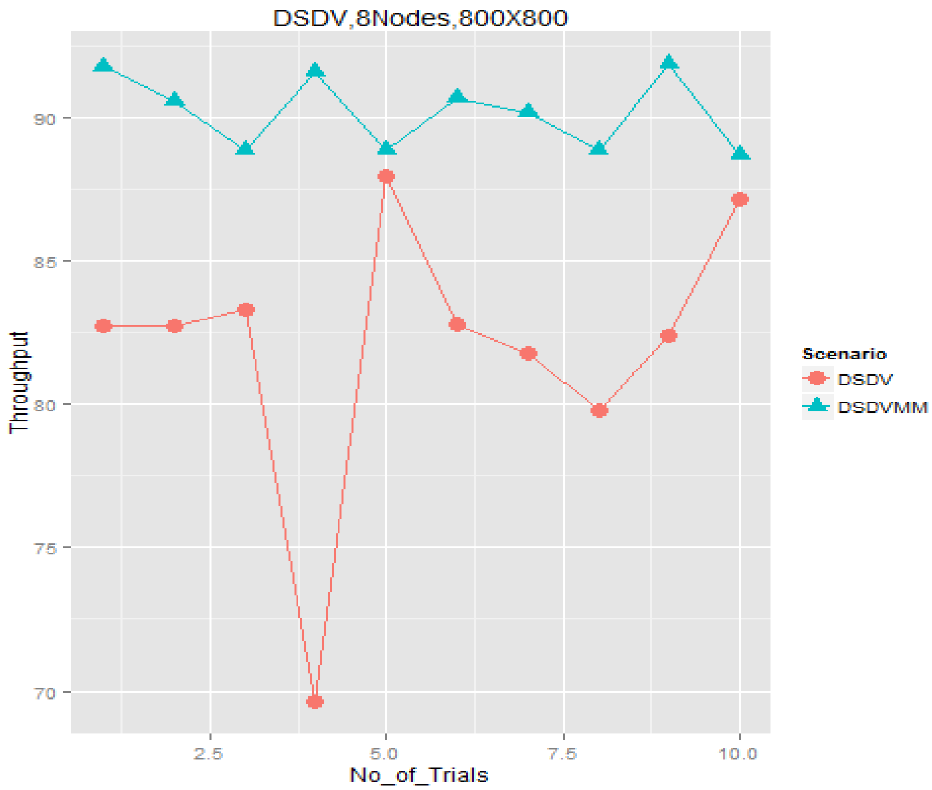

Figure 4.18 Throughput, 8Nodes, 800X800, DSDV v/s DSDVMM

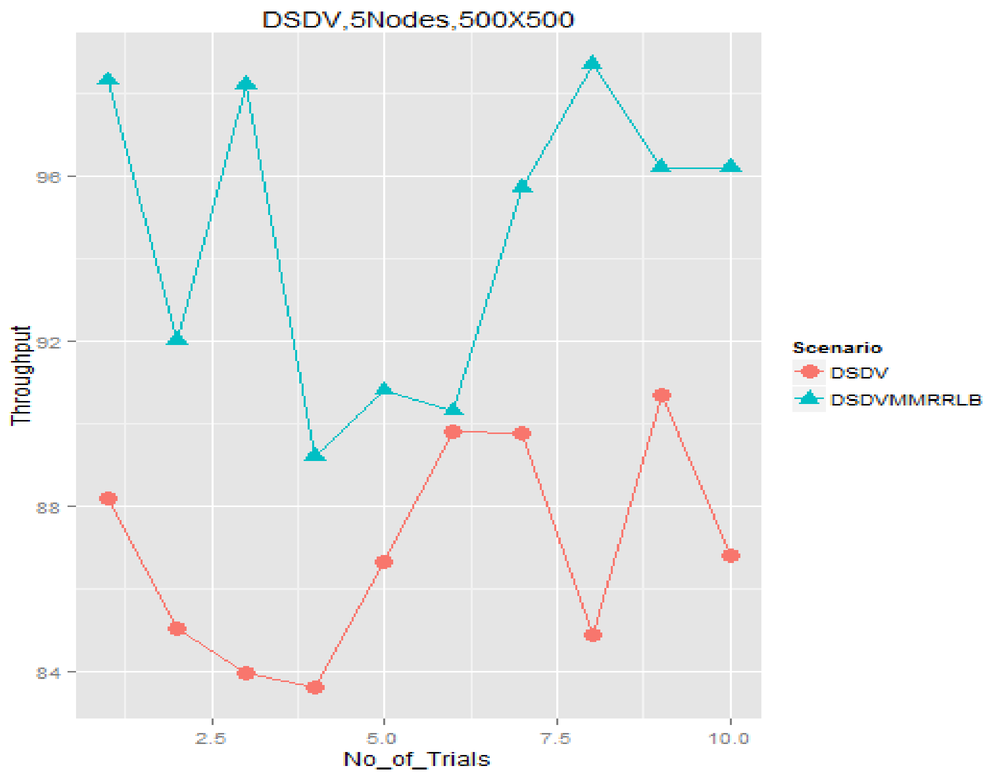

Figure 4.19 Throughput, 5 Nodes, 500X500, DSDV v/s DSDVMMRRLB

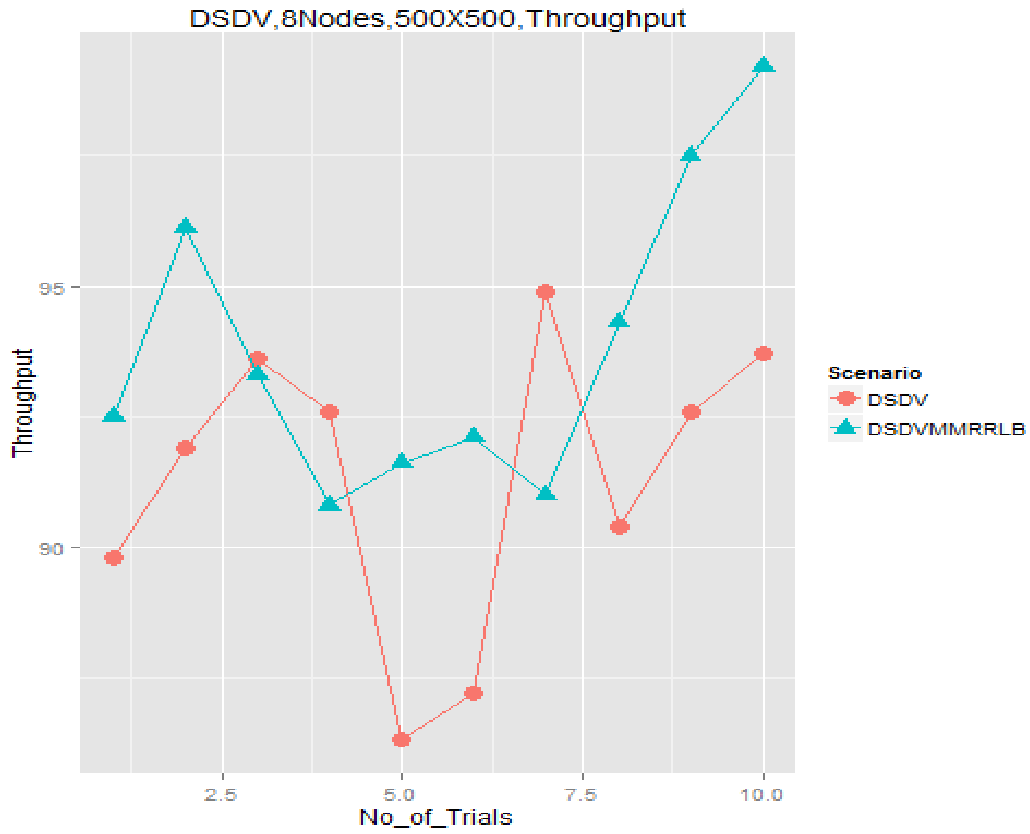

Figure 4.20 Throughput, 8 Nodes, 500X500, DSDV v/s DSDVMMRRLB

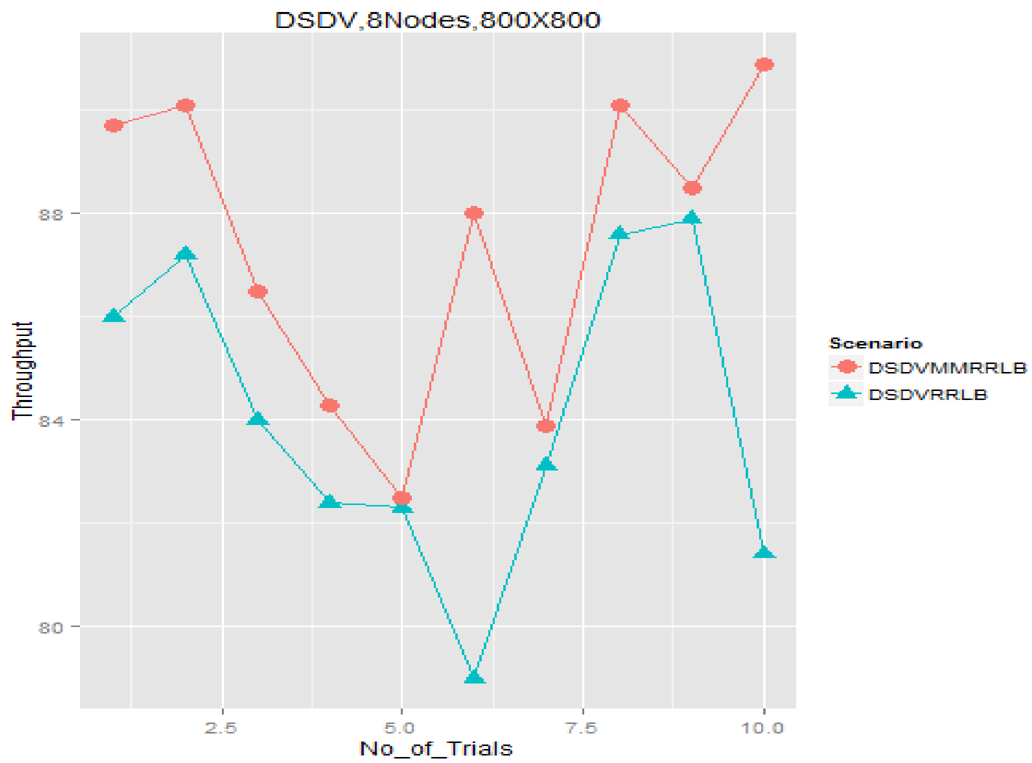

Figure 4.21 Throughput, 8 Nodes, 800X800, DSDVMMRRLB v/s DSDVRRLB

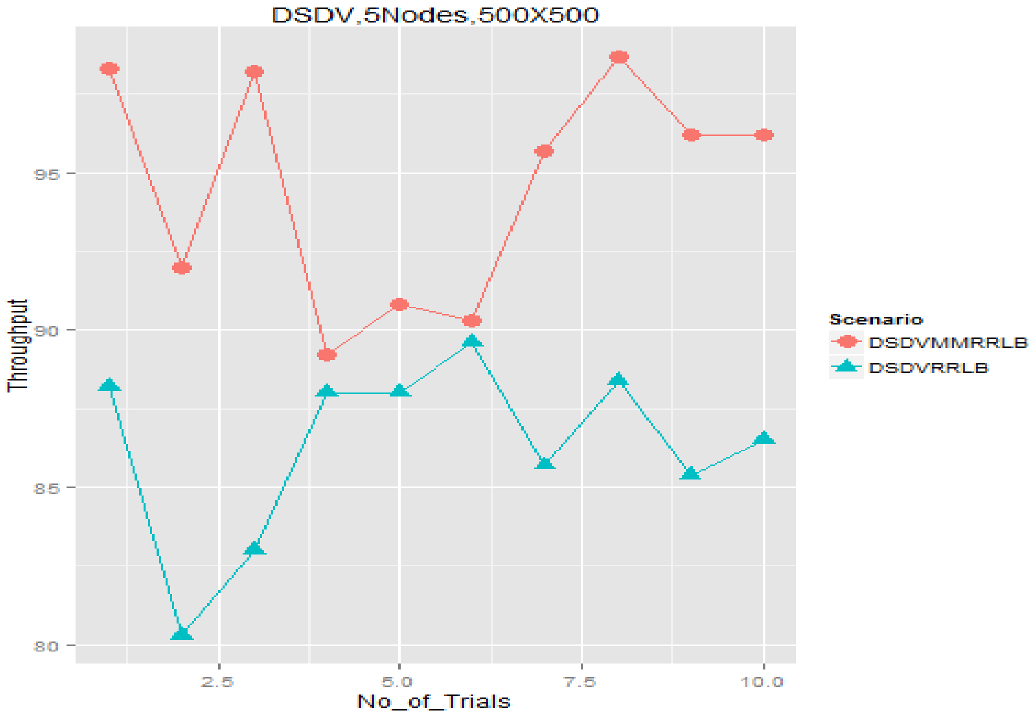

Figure 4.22 Throughput, 5 Nodes, 500X500, DSDVMMRRLB v/s DSDVRRLB

Table 4.9 Simulation parameters and Statistical Results for Throughput in 500X500 area for 5Nodes

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
DSDVMM-DSDV	0.0224	Valid for CI of 95, 97.5.	DSDVMM is better in 5 nodes,500X500 with Throughput as a parameter of interest.
DSDVMMRRLB-DSDV	0.0001	Valid for CI of 95, ,97.5,99.5.	DSDVMMRRLB is better in 5 nodes, 500X500 with Throughput as a parameter of interest.
DSDVMMRRLB-DSDVLBRR	0.0000	for CI of 95 ,97.5,99.5	DSDVMMRRLB is better in 5 nodes, 500X500 with Throughput as a parameter of interest

As it can be seen (Refer Figure 4.17 and 4.20) the plots for 500X500, 8 nodes indicate that the gain that is made in throughput using MM in the 500X500, 5 nodes deployment is lost. Figure 4.16 and 4.18 clearly indicate that throughput is enhanced on deploying Mobility Management Scheme along with DSDV i.e. DSDVMM.. Results shown in Figure 4.19 are extremely significant when the network conditions are degraded in terms of reduced transmission range (RR) and lowered buffer (LB) MM scheme under these conditions both for network sizes of 500x500 and 800x800 (Refer Figure 4.21 and Figure 4.22).

The MM scheme looks to perform well under degraded conditions of RR and LB. Under RR the area allowed for movement by the Node as indicated by Equation 3.4 in previous section is lessened. This results in lower mobility as there is every likelihood of node reaching the destination before the time interval for next update of neighbors arrives. Due to this nodes remain under close proximity to each other in this scheme, hence LB conditions drawbacks are minimized to a great extent because of this kind of managed mobility environment. The experimental data for throughput was not Normal for 800X800, 8 node deployment; hence non parametric test was used for validating the test results. Table 4.10 elaborates about the test data for those scenarios.

Table 4.10 Simulation parameters and Statistical Results for Throughput in 800X800 for 8 nodes

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
DSDVMM-DSDV	0.0227	Valid for CI of 95,	DSDVMM is better in 8 nodes,800X800 with Throughput as a parameter of interest.
DSDVRRLB-DSDVMM	0..0227	Valid for CI of 95.	DSDVMM is better in 8 nodes, 800X800 with Throughput as a parameter of interest.

4.2.2 Comparison between DSDVMM with DSDV under various conditions for End to End Delay as parameter

Refer Figure 4.23 and Figure 4.24, the End to end delay shows lower values for MM schemes under various conditions. Figure 4.23 and Figure 4.24 clearly indicate lower end to End Delay for MM schemes as compared to Figure 4.25 and Figure 4.26 where when 8 nodes are deployed in 500x500 the gains are lost. When more nodes are present in the same area then MM scheme does not show similar gains as it is showing in lesser node deployed. This can be attributed to the reason that when nodes are more in same area then packets exchange more hops before reaching final destination and hence higher End to End Delay.

When 8 nodes are deployed in bigger area then the phenomena of lower end to End delay recorded for MM schemes is restored as shown in figure 4.27 and 4.28.

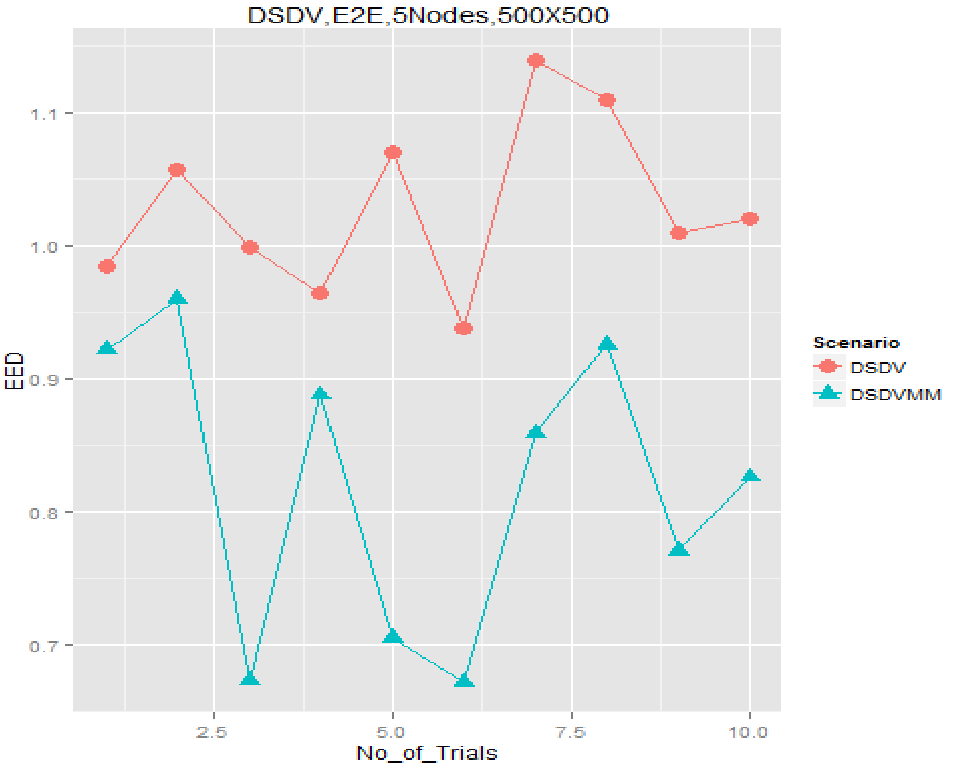

Figure 4.23 End to End Delay, 5 Nodes, 500X500, DSDV v/s DSDVMM

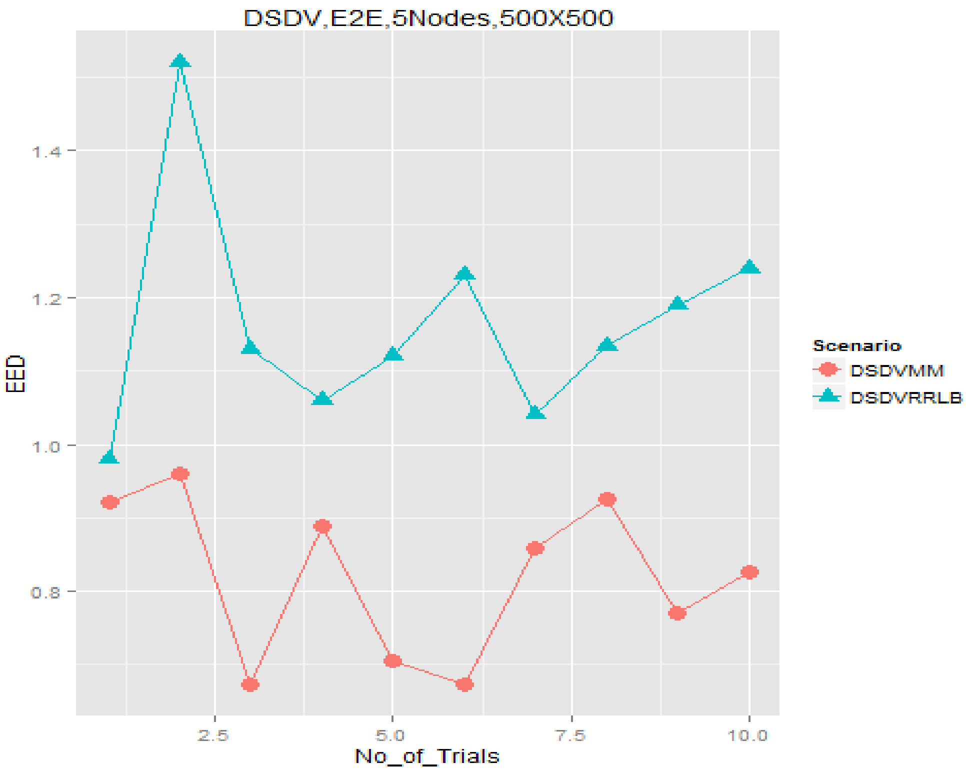

Figure 4.24 End to End Delay, 5 Nodes, 500X500, DSDVMM v/s DSDVRRLB

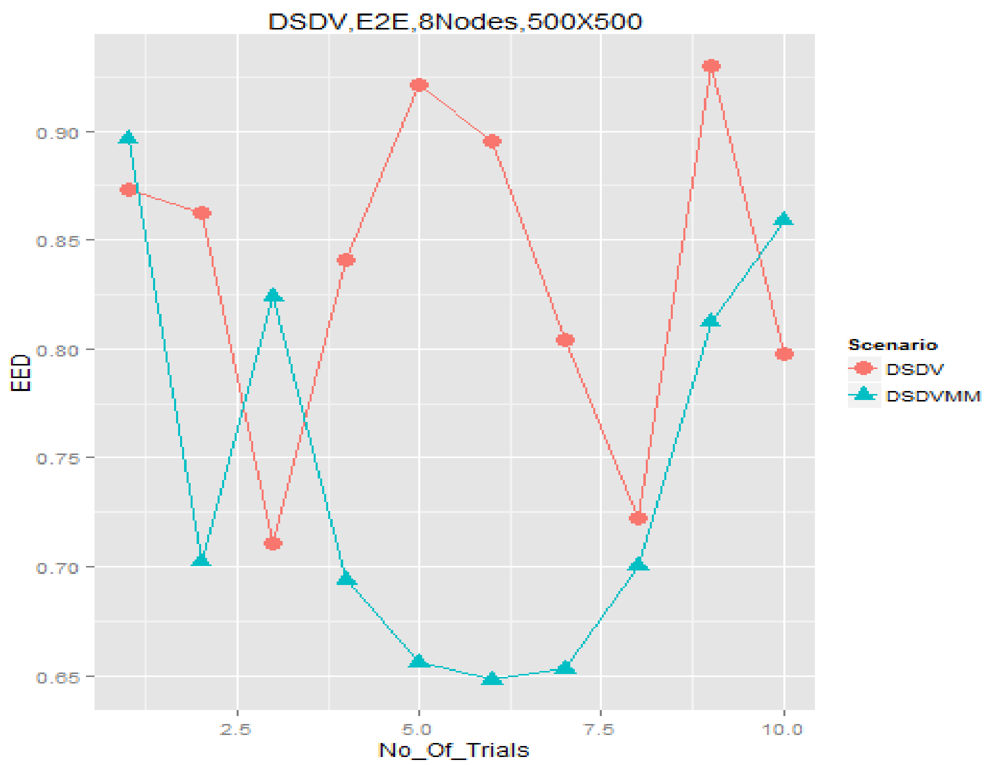

Figure 4.25 End to End Delay , 8 Nodes, 500X500, DSDV v/s DSDVMM

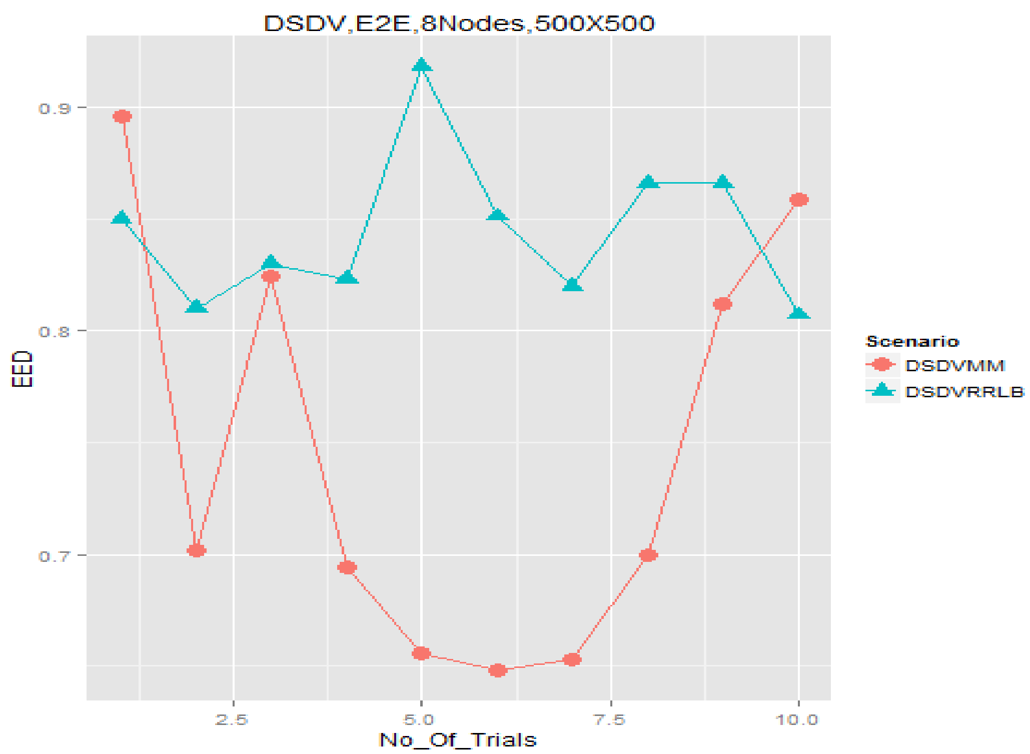

Figure 4.26 End to End Delay, 8 Nodes, 500X500, DSDVMM v/s DSDVRRLB

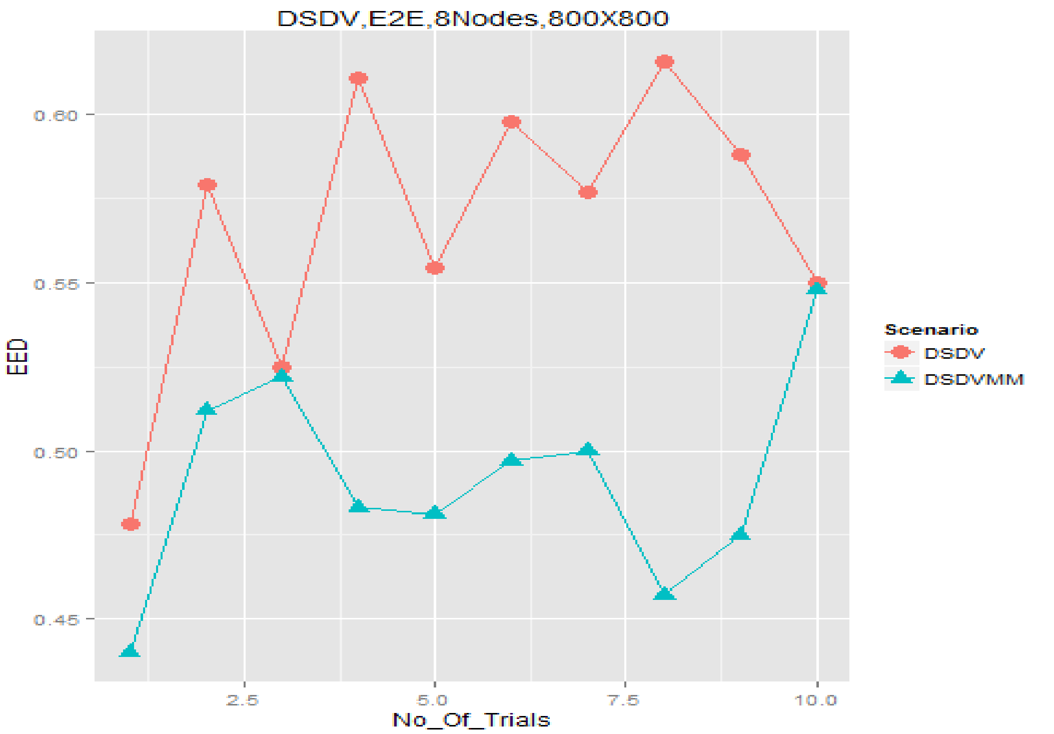

Figure 4.27 End to End Delay, 8 Nodes, 800X800, DSDV v/s DSDVMM

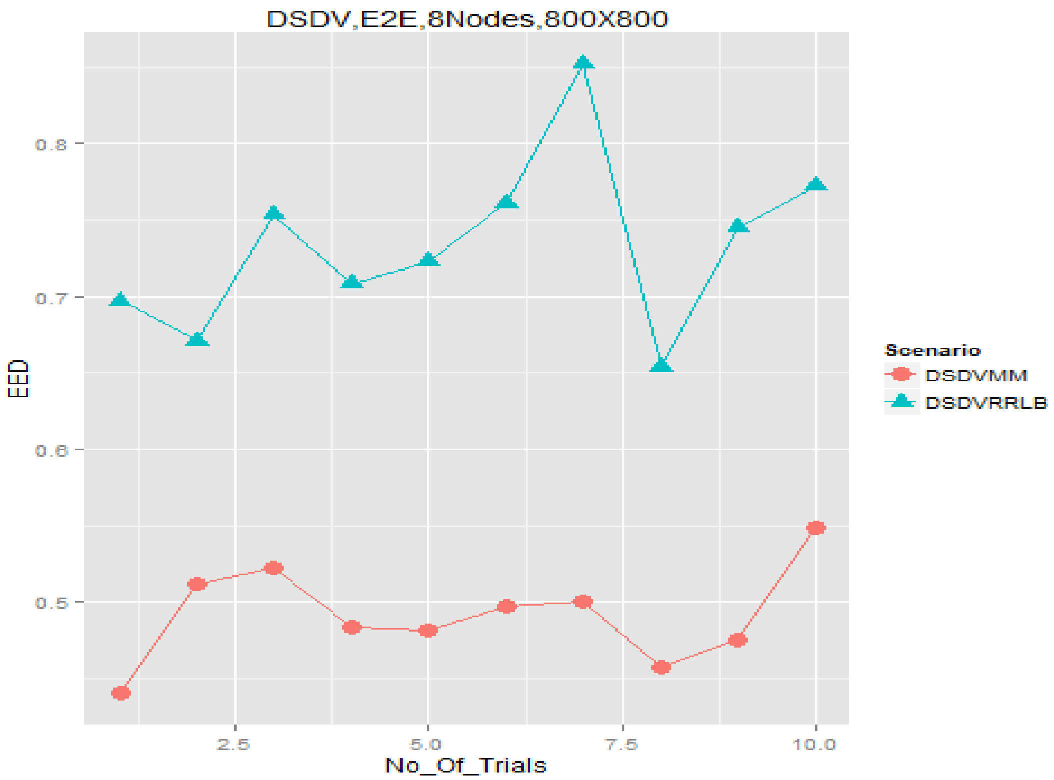

Figure 4.28 End to End Delay, 8 Nodes, 800X800, DSDVMM v/s DSDVRRLB

The same is reported in statistical terms in Table 4.11 and 4.12.

Table 4.11 Simulation parameters and Statistical Results for End to End Delay in 500X500 for 5 Nodes

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
DSDVMM-DSDV	.0028	95,97.5,99.5	DSDVMM shows lower E2ED as compared to DSDV.
DSDVMM-DSDVRRLB	.0016	95,97.5,99.5	DSDVMM shows lower E2ED as compared to DSDVRRLB

Table 4.12 Simulation parameters and Statistical Results for End to End Delay in 800X800 for 8 Nodes

Comparison	Significance value	Confidence Interval	Conclusion w.r.t to Network Size and no of nodes deployed.
DSDVMM-DSDV	.0072	95,97.5	DSDVMM shows lower E2ED as compared to DSDV.
DSDVMM-DSDVRRLB	.0016	95,97.5,99.5	DSDVMM shows lower E2ED as compared to DSDVRRLB

As it can be seen DSDVMM shows much lower End to End delay than DSDV and DSDVRRLB. DSDVMM has already shown higher throughput than DSDV, so this is a very significant result to arrive upon. This is observed in both the network sizes of 500x500 and 800x800 with sparse deployment. As soon the node population is increased it is seen that the end to end delay parameter is also disturbed. The confidence interval achieved is 99.5% in most of the cases which is very significant as these gains are significant along with higher throughput being observed, as explained in previous section.

4.3 Comparison between AODVMM with DSDVMM with Throughput and End to End Delay as Parameter

In this section the two way analysis of results have been done with respect to the two protocols which have been proposed. All the scenarios in which gain has been found while comparing between mobility managed protocol and generic protocol, now the same scenarios have been compared with each other. In the figures below from 4.29 to 4.44 the comparison has been done between mobility managed reactive protocol and mobility managed proactive protocol for all scenarios of reduced range and low buffer for both the network sizes of 500x500 and 800x800.The statistical analysis of these results has been incorporated in Table 4.13 and 4.14.

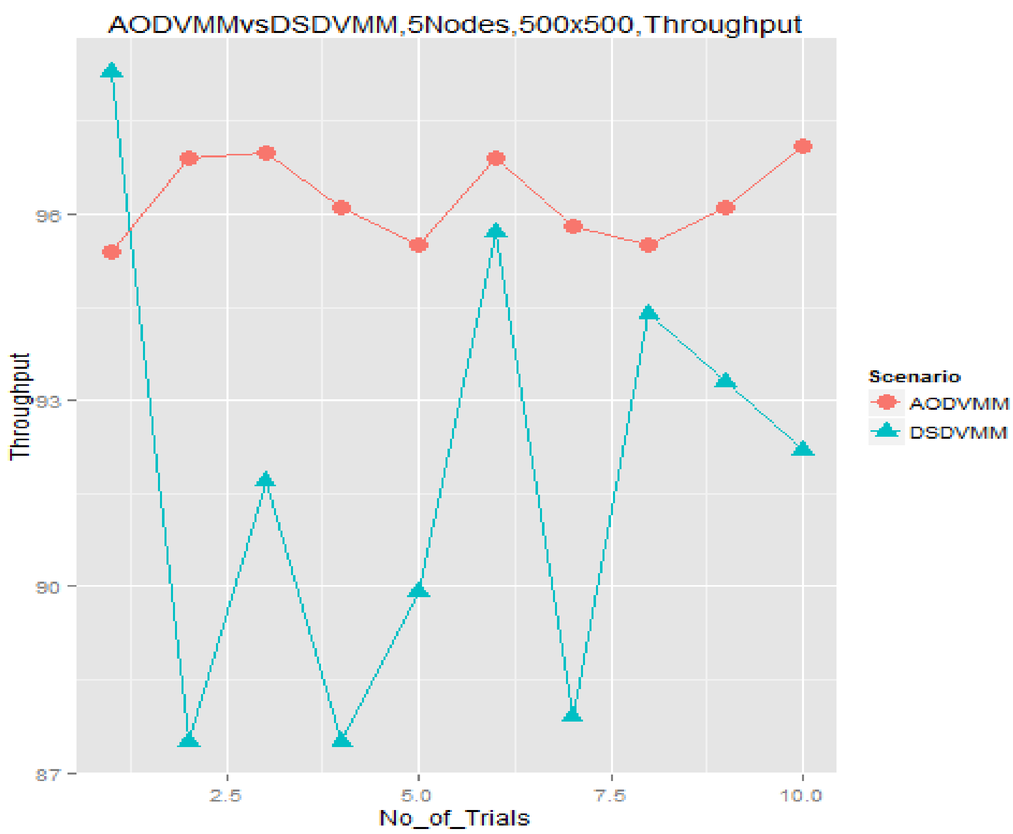

Figure 4.29 Throughput, 5Nodes, 500x500, AODVMM v/s DSDVMM

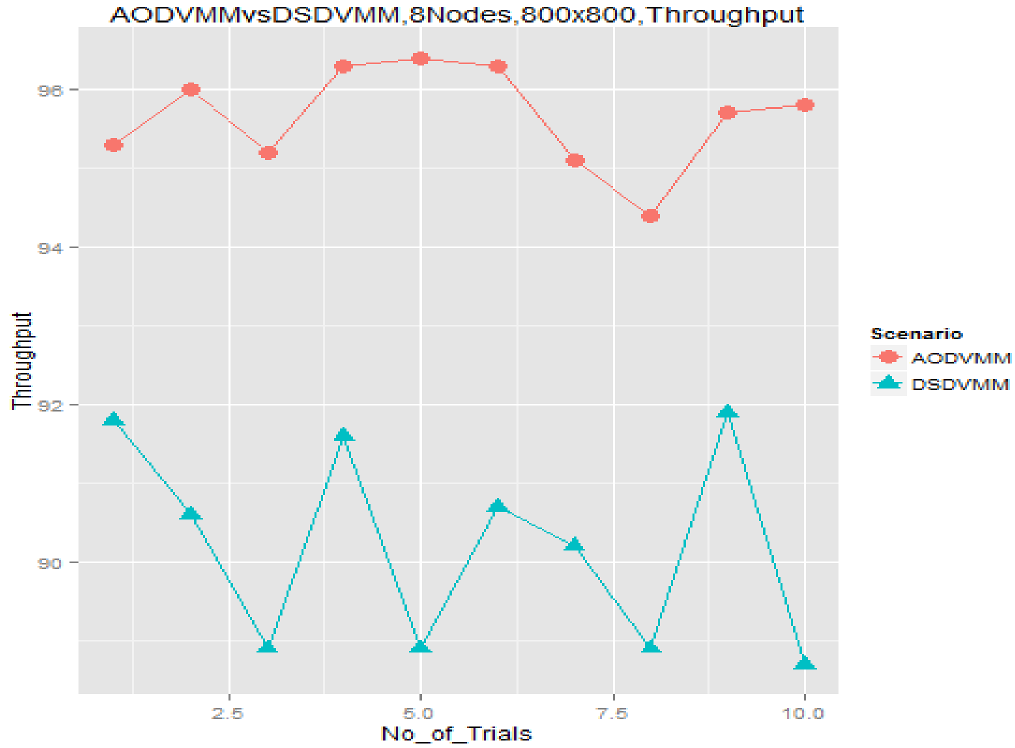

Figure 4.30 Throughput, 8Nodes, 800x800, AODVMM v/s DSDVMM

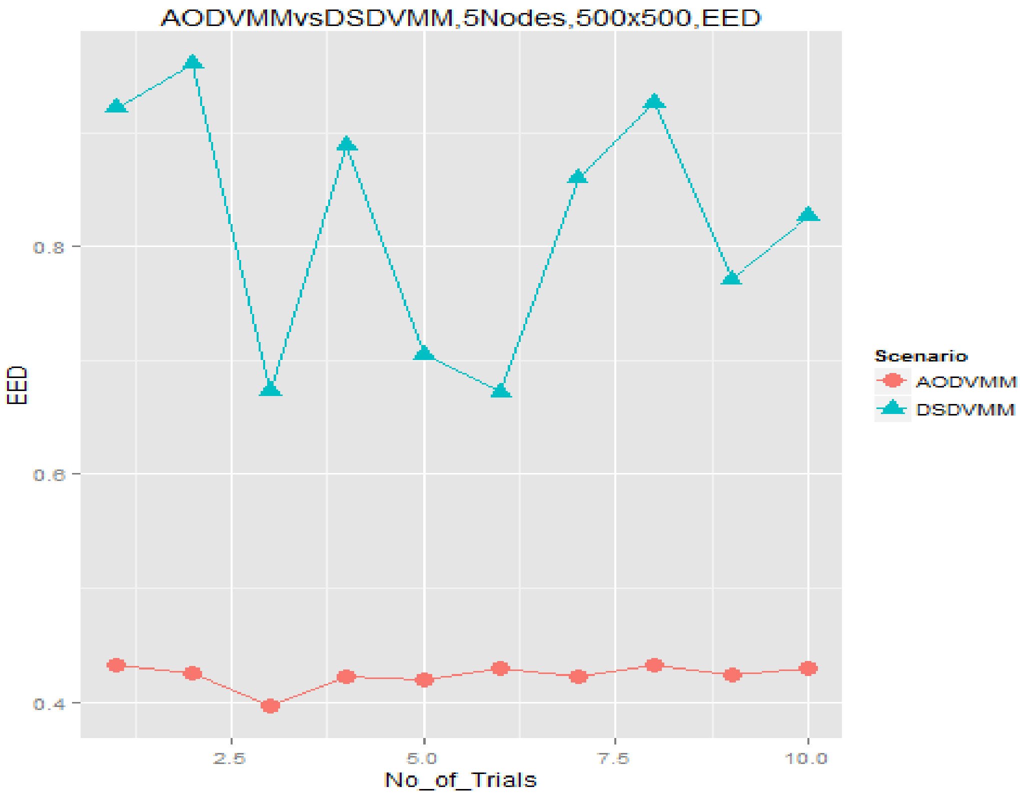

Figure 4.31 End to End Delay, 5Nodes, 500x500, AODVMM v/s DSDVMM

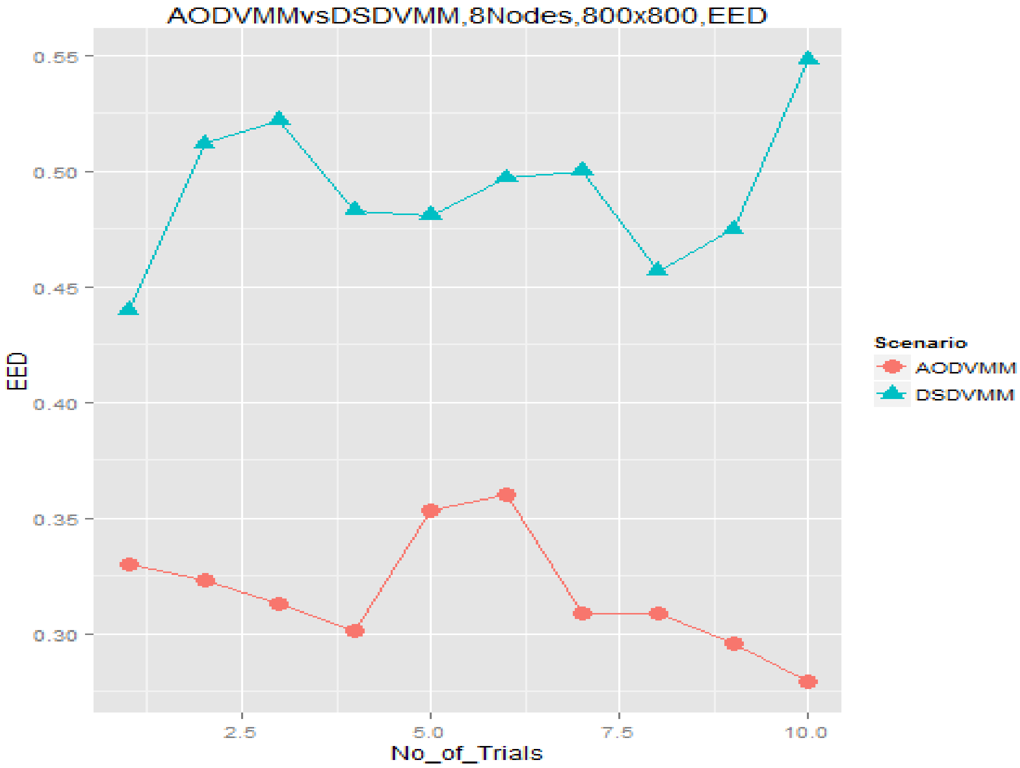

Figure 4.32 End to End Delay, 8Nodes, 800x800, AODVMM v/s DSDVMM

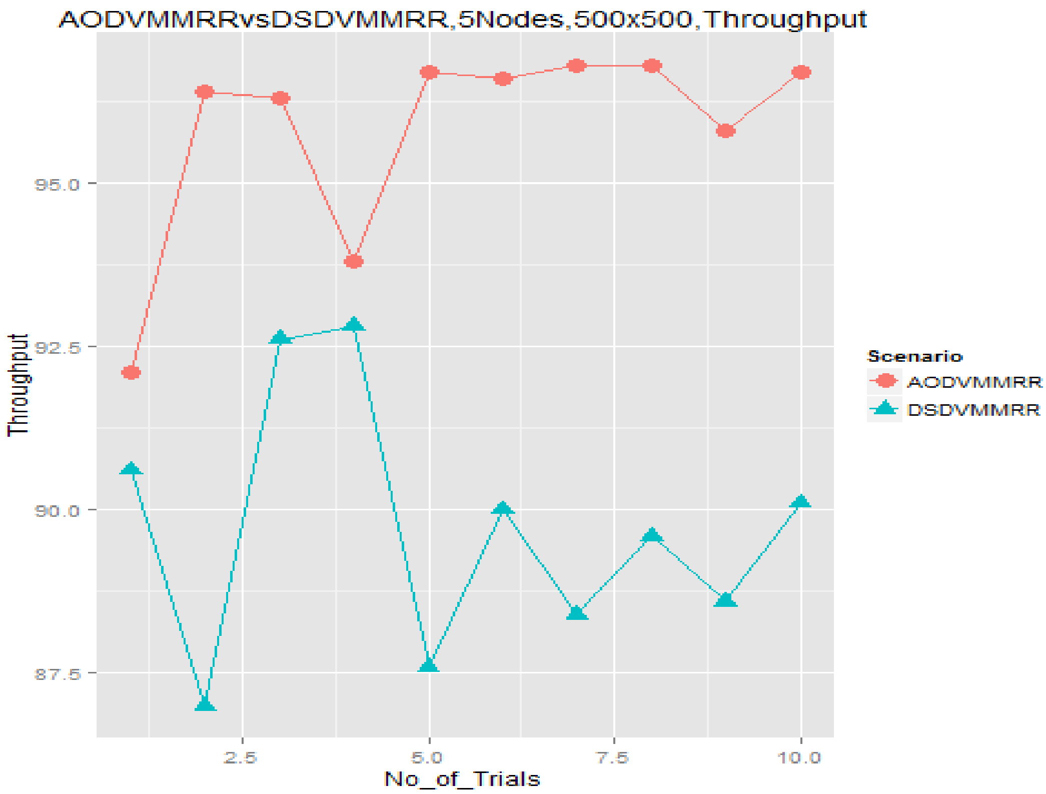

Figure 4.33 Throughput, 5Nodes, 500x500, AODVMMRR v/s DSDVMMRR

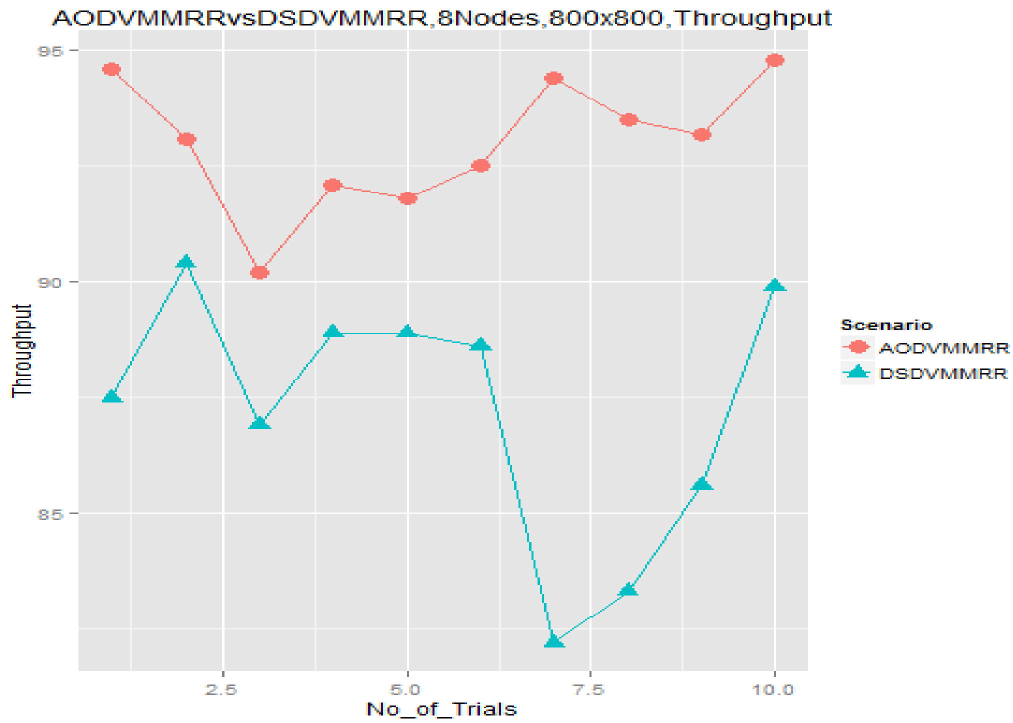

Figure 4.34 Throughput, 8Nodes, 800x800, AODVMMRR v/s DSDVMMRR

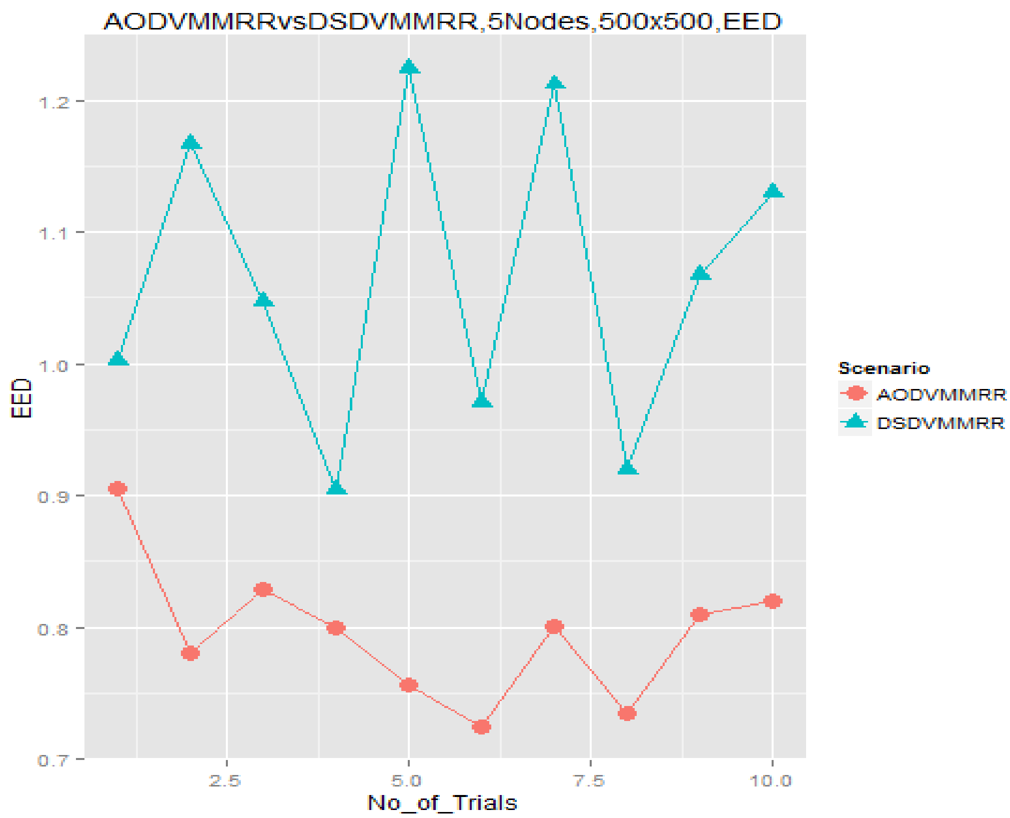

Figure 4.35 End to End Delay, 5Nodes, 500x500, AODVMMRR v/s DSDVMMRR

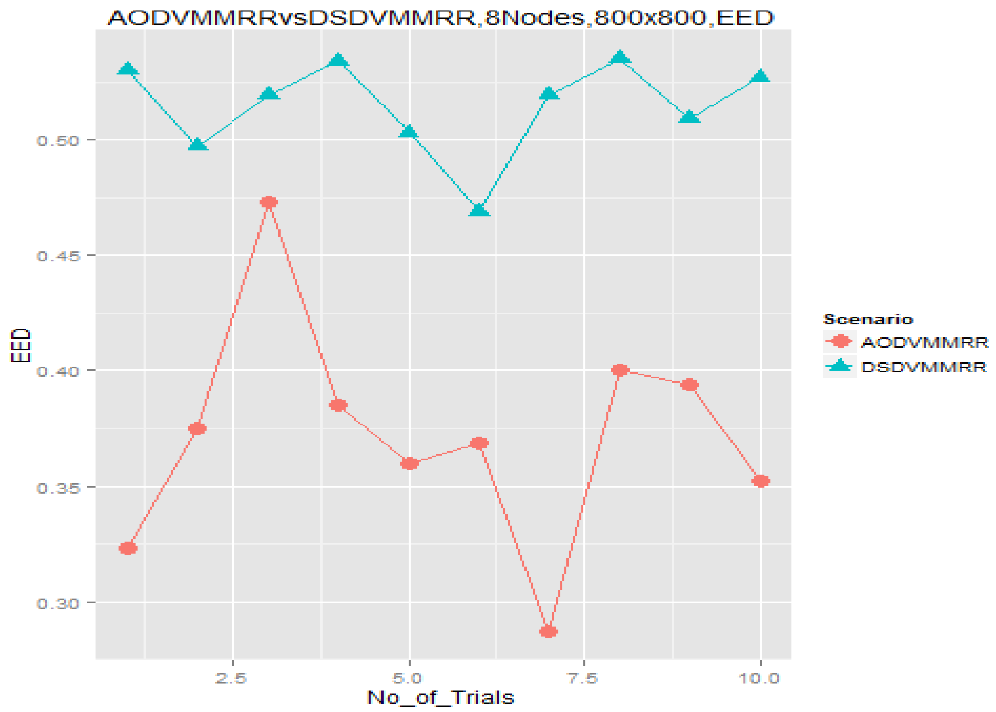

Figure 4.36 End to End Delay, 8Nodes, 800x800, AODVMMRR v/s DSDVMMRR

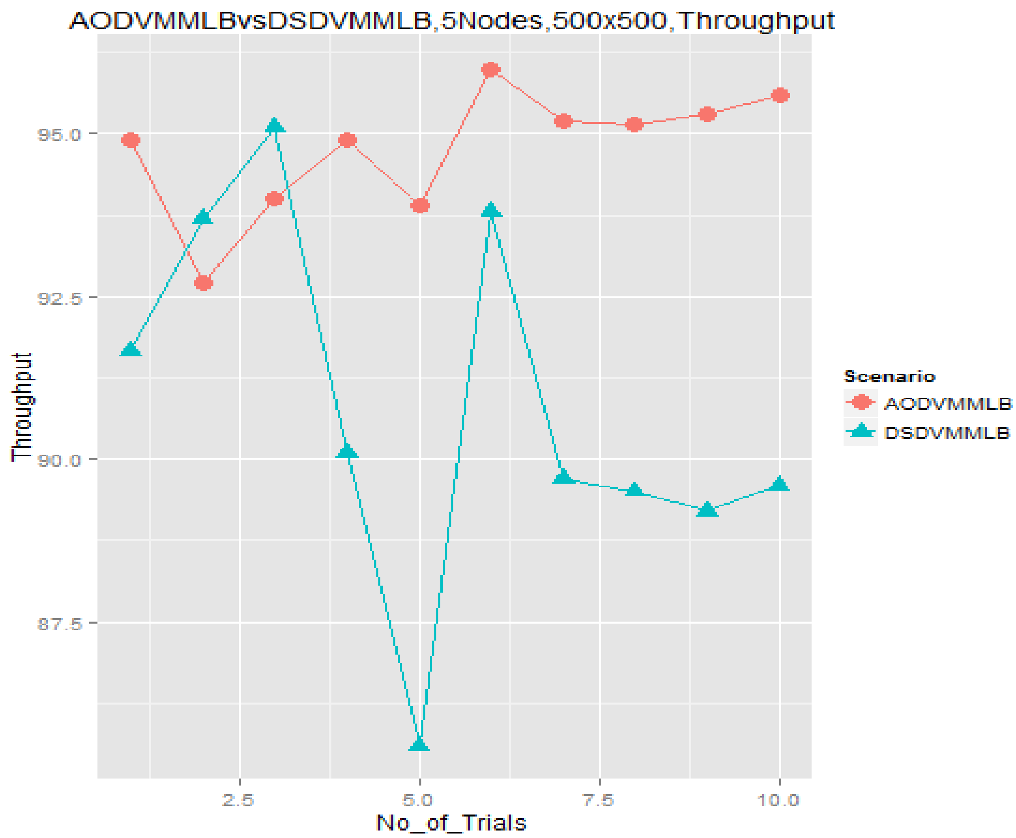

Figure 4.37 Throughput, 5Nodes, 500x500, AODVMMLB v/s DSDVMMLB

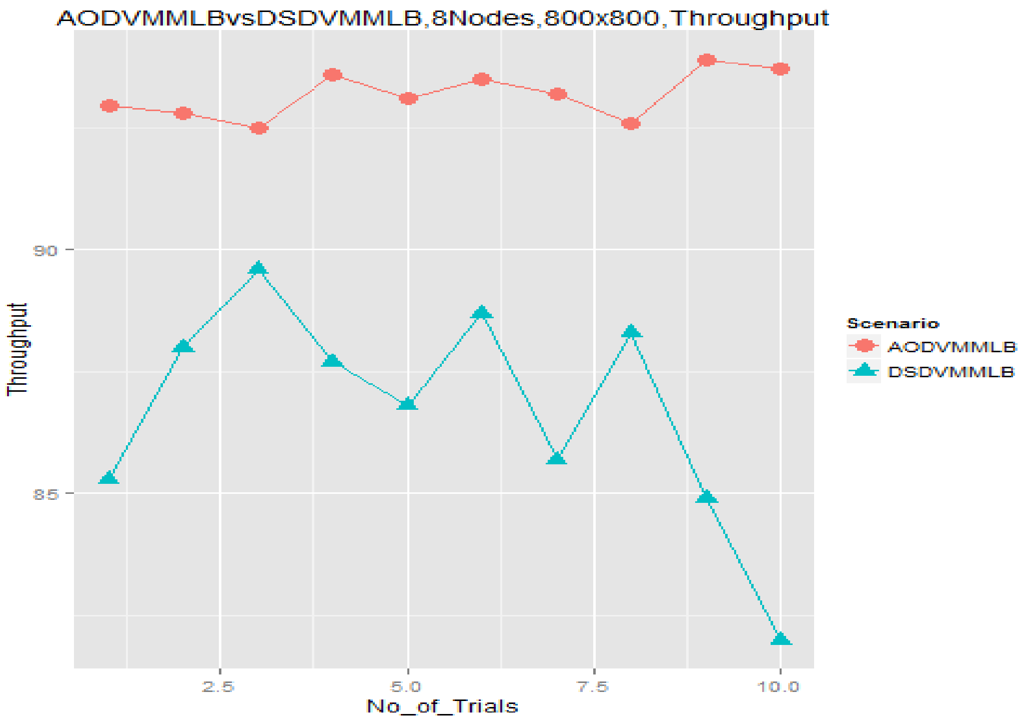

Figure 4.38 Throughput, 8Nodes, 800x800(AODVMMLB v/s DSDVMMLB)

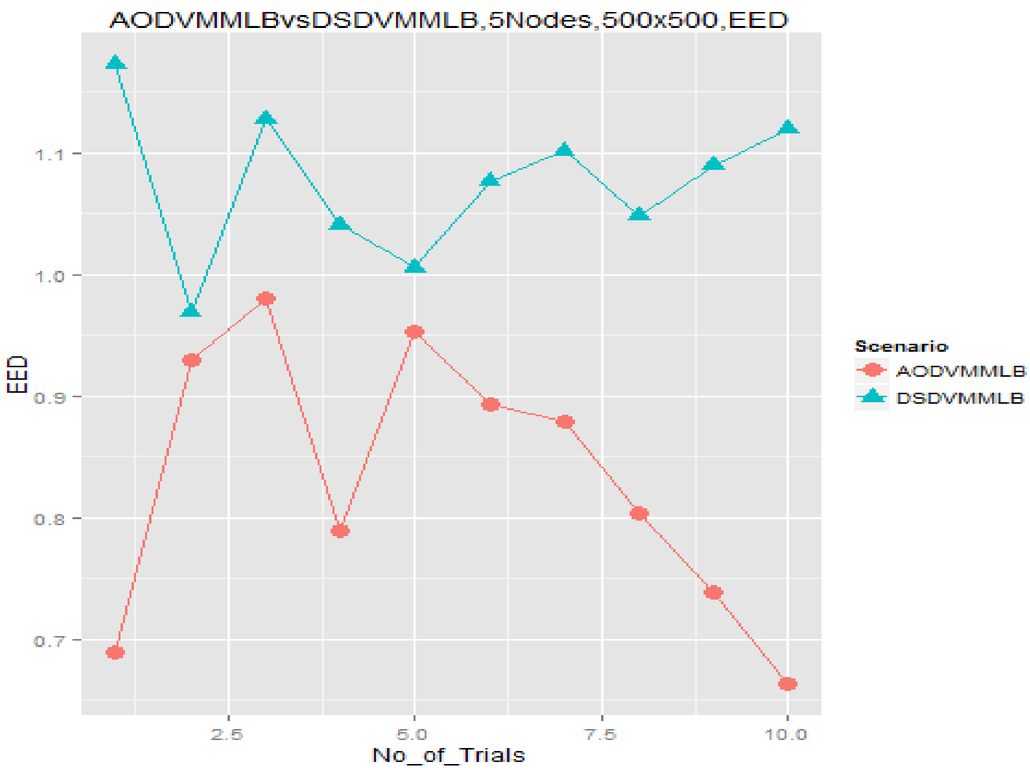

Figure 4.39 End to End Delay, 5Nodes, 500x500(AODVMMLB v/s DSDVMMLB)

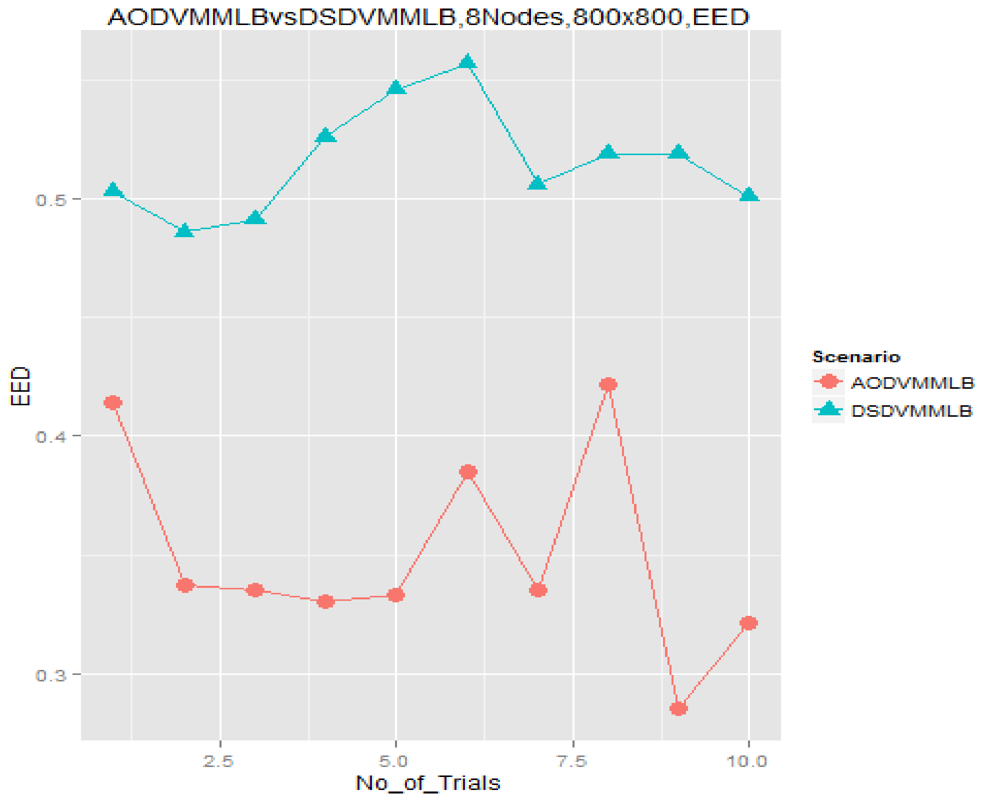

Figure 4.40 End to End Delay, 8Nodes, 800x800(AODVMMLB v/s DSDVMMLB)

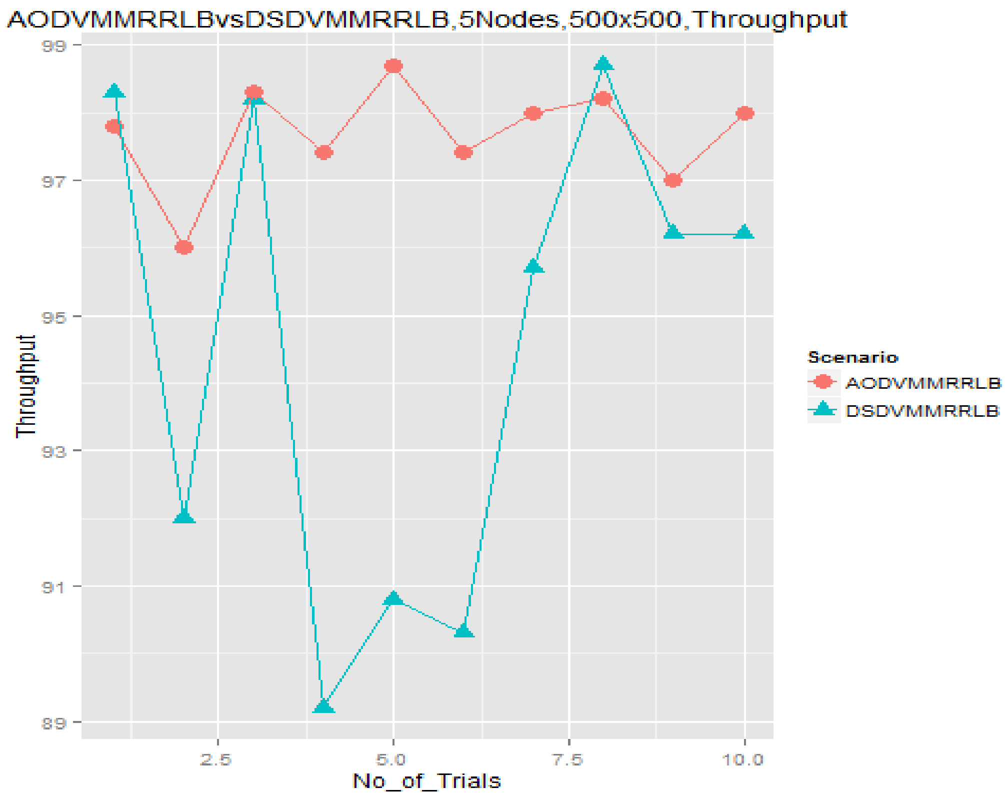

Figure 4.41 Throughput, 5Nodes, 500x500(AODVMMRRLB v/s DSDVMMRRLB)

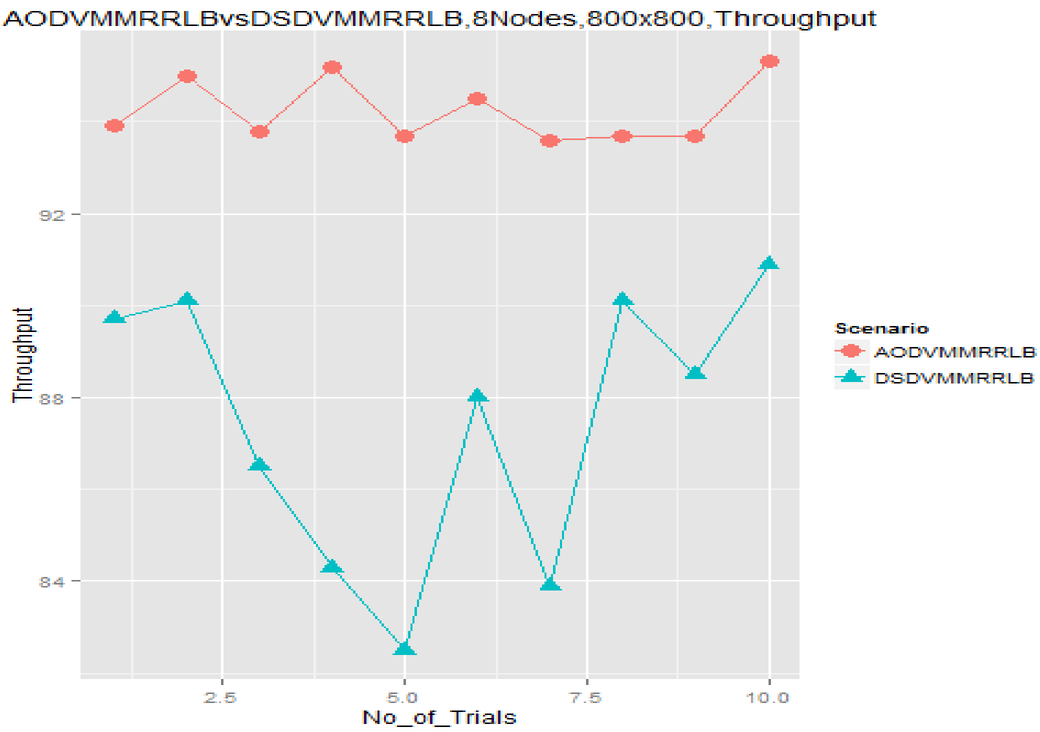

Figure 4.42 Throughput, 8Nodes, 800x800(AODVMMRRLB v/s DSDVMMRRLB)

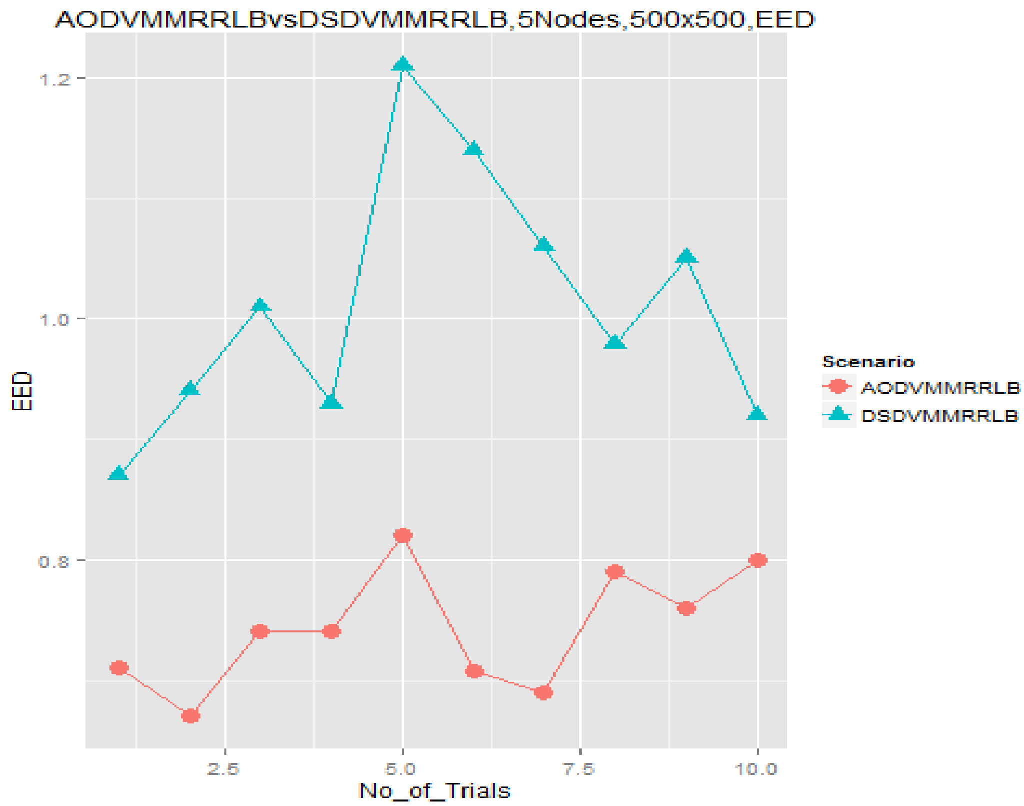

Figure 4.43 End to End Delay, 5Nodes, 500x500(AODVMMRRLB v/s DSDVMMRRLB)

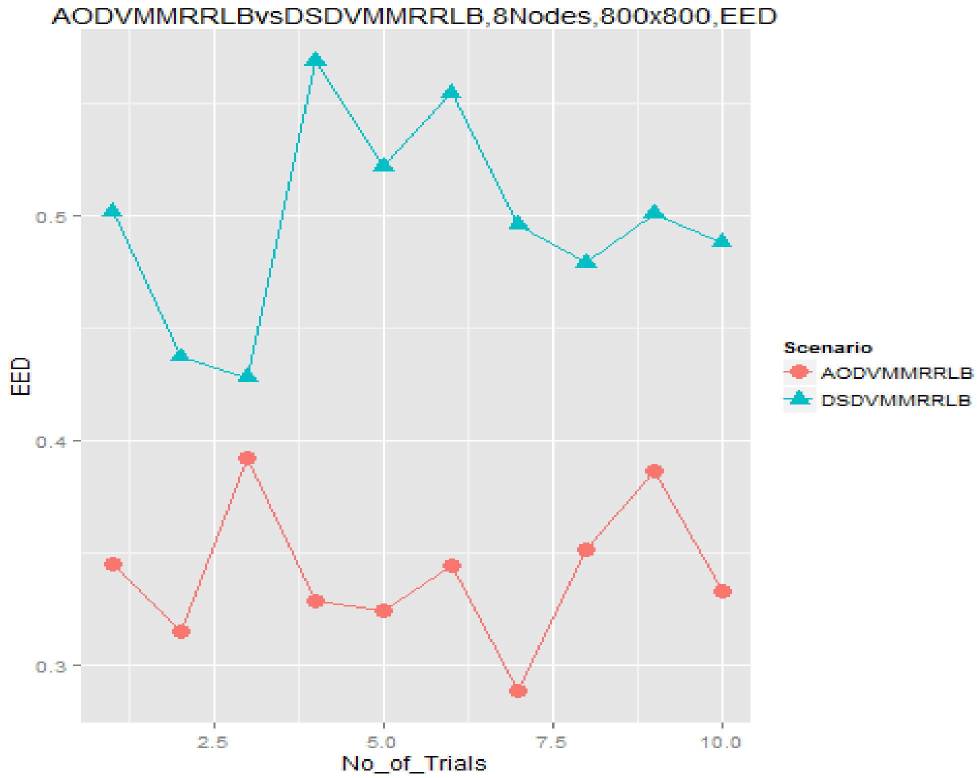

Figure 4.44 End to End Delay, 8Nodes, 800x800(AODVMMRRLB v/s DSDVMMRRLB)

Table 4.13 Simulation Parameters and Statistical Results for 500x500, 5 Nodes, Throughput & EED combined

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
AODVMM-DSDVMM	0.0080	Valid for CI of 95, 97.5	AODVMM is better in 5 nodes,500X 500
AODVMMRR -DSDVMMRR	0.0000	Valid for CI of 95,97.5,99.5	AODVMMRR is better in 5 nodes,500x500
AODVMMLB-DSDVMMLB	0.0000	Valid for CI of 95 ,97.5,99.5	AODVMMLB is better in 5 nodes,500x500
AODVMMRRLB-DSDVMMRRLB	0.1933	Invalid	Not reliable

As it can be seen in table 4.13 pairwise comparison of AODVMM is made with DSDVMM, AODVMMRR v/s DSDVMMRR and AODVMMLB v/s DSDVMMLB AODVMM performs better than DSDVMM. But the comparison between AODVMMRRLB with DSDVMMRRLB is not reliable. Hence, if parameter of interest Throughput and End to End delay is considered together AODVMM is better in RR condition and LB conditions. But under depleted conditions of RRLB the gains being reflected are insignificant and do not hold statistically. So under depleted conditions of reduced range and Low buffer any protocol can be chosen between AODVMM and DSDVMM whereas under conditions of either RR or LB AODVMM scores much better than DSDVMM. The gains are significant in excess of 97.5% confidence intervals. In this comparison it is pertinent to mention AODVMM is better than AODV and DSDVMM is better than DSDV for as it is reported in previous sections.

Similarly, the two way analysis for 800x800 network size of 8 nodes also shows similar results as are reported for 5 nodes, 500x500.Table 4.14 provides these on the next page. The results shown are significant for a Confidence Interval of 95% and above.

Table 4.14 Simulation Parameters and Statistical Results for 800x800, 8 Nodes, Throughput and EED combined

Comparison	Significance value	Confidence Interval	Conclusion wrt to Network Size and no of nodes deployed.
AODVMM-DSDVMM	0.0001	Valid for CI of 95, 97.5,99.5	AODVMM is better in 8 nodes,800X 800
AODVMMRR -DSDVMMRR	0.0000	Valid for CI of 95 only-lesser	AODVMMRR is better in 8 nodes, 800X800
AODVMMLB-DSDVMMLB	0.0000	Valid for CI of 95 ,97.5,99.5	AODVMMLB is better in 8 nodes, 800x800
AODVMMRRLB-DSDVMMRRLB	0.1081	Invalid	Can't be relied upon

In this chapter the simulation setup creation, result generation and result validation is done. In next chapter conclusions on the basis of findings in this chapter and future scope is discussed.

Chapter 5
Conclusions and Future Scope

The two protocols which have been developed and tested are AODVMM and DSDVMM. The significance of results is discussed separately for these two protocols as follows.

5.1 AODVMM

5.1.1 Throughput

It can be seen that throughput parameter shows marked improvement in mobility management scheme. In pairwise comparison of AODVMM to AODV, it can be seen that End to End delay shows insignificant variance so as to be considered and this can be clearly concluded that AODVMM clearly scores when throughput is the parameter of interest without any causal effects on End to delay of the network. Same is not found for pairwise comparison of AODVMMRR with AODV as this leads to higher end to end delay witnessed in the case of MM scheme. Hence this gain in throughput comes with a trade-off of higher end to end delay.

The pairwise comparisons for AODVMMRRLB with AODVRRLB shows significant gains for throughput parameter but again at the cost of higher end to end to delay.

5.1.2 End to End Delay

For all other pairwise comparisons the throughput gains observed under MM schemes like AODVMMLB,AODVMMRR in comparison to AODV the end to end delay does not show any change on higher or lower side. Hence this can be concluded that AODVMM schemes when coupled with RR and LB gives us higher throughput at the cost of longer delays but when MM scheme is coupled with RR(AODVMMRR) and LB(AODVMMLB) and compared against AODV the it shows higher throughput but end to end delay parameter is not disturbed, hence the gains made are not at the cost of higher end to end delay.

Higher end to end delay in MM schemes when coupled both with RR and LB, is being witnessed because nodes when are in close proximity, they work within a small area and due to lower buffers the node transmits more packets to intermediate nodes before the packet is delivered to destination nodes. The nodes being in close proximity to each other facilitate this forwarding function more efficiently when relatively degree of sparseness is higher, and the moment the network population is increased for the same area of operation, the presence of more nodes under guided mobility schemes lead to creation of more network traffic within the same area and the depleted buffers cannot handle as much traffic and it is a kind of flooding phenomenon that will happen within the sparse deployment. Hence, as expected this will lead to more packet loss and hence lower throughput.

5.2 DSDVMM

Two parameters have been considered while reporting results which are Throughput and End to End Delay. The significance of results is discussed below.

5.2.1 Throughput

It is observed that MM schemes exhibit better throughput when degree of sparseness is high ,i.e., when 5 nodes are deployed in 500x500 area and 8 nodes are deployed in 800x800 area. However, when the same MM scheme was used for a lesser sparse deployment, i.e., 8 nodes in 500x500 area the throughput exhibits drop. The Statistical inferences also enlist significance values for pairwise comparisons made as insignificant below a Confidence Interval of 95% and hence the MM scheme under performs in scenario where sparse deployment is not present.

Therefore, it is evident that the DSDVMM scheme is suitable for certain degree of sparseness and hence can be put to use. It is even suitable under lower transmission range and reduced buffer on nodes, which is a very encouraging as lesser transmission range will result in lesser power consumption and lesser buffer on nodes means lesser overhead on the nodes resulting in lower payloads and lower power consumption and better utilization of resources.

5.2.2 End to End Delay

DSDV proactively manages the routing table to ensure End to End to Paths from sending nodes to receiving nodes.MM scheme helps DSDV protocol to choose its immediate neighbors in routing protocol and also fixes destinations of the immediate neighbors according to the transmission range of sending node and its current position. This the network does at fixed time intervals.

End to End delay shows marked improvement for MM schemes in sparse deployment. Lower End to End Delay is observed in DSDVMM because even though deployment is sparse the nodes have at least one neighbor to offload packet as it is in its transmission range due to MM scheme. Due to this binding of movement nodes within transmission range the packets reach the destination with a lower end to end delay. The Gains DSDVMM shows over DSDV are extremely significant as the gains are valid up to confidence interval of 99.5%.The Gains in DSDVMM over DSDVRRLB are understandable as lower buffer would results in packets reaching destination with more number of hops.

As compared to throughput in this parameter DSDVMMRRLB does not show any significant gains over DSDVRRLB.

5.3 AODVMM v/s DSDVMM

While making comparison between the two proposed protocols for varying network sizes, two way analysis of variance was carried out using experimental data of parameters of End to End Delay and Throughput. It is reported in previous section in Table 4.13 and 4.14. It is found that AODVMM performs much better than DSDVMM under RR and LB conditions when both the parameters of End to End Delay and Throughput are considered. Therefore Mobility management scheme performs better in Reactive protocol AODVMM under reduced range(RR) and low buffer(LB).

In the condition when transmission range is reduced and buffer capacity is also lowered the comparison of gains in both AODVMMRRLB and DSDVMMRRLB are inconclusive and any protocol can be chosen as both the protocols show significant improvement over AODVRRLB and DSDVRRLB respectively.

Since, reactive protocol is outperforming proactive protocol it is because proactive protocol searches for routes proactively, though the node associativity is realigned after some time interval repetitively .The proactive nature of the protocol generates more packets for route maintenance apart from traffic data packets. And since network population is sparse it results in higher data packet loss. In contrast in the reactive approach route maintenance is carried out as and when new topology is available. Once nodes associate the route table entries are updated only after a certain time interval is elapsed as per the mobility management scheme. Hence, lesser data packets are generated for route maintenance due to which comparatively higher throughput is achieved in reactive protocol AODVMM.

5.4 Future Scope

In this work the mobility management scheme has been put to use under reduced transmission range and low buffer conditions. The results have been quiet promising under some of the scenarios. It is aimed that in future mobility management schemes shall be designed for nodes moving in space so that mobility management model takes care of three coordinates in 3-D space. Also it is aimed that the present mobility management scheme is tested for Adhoc nodes moving inside sensor fields taking guidance from sensor nodes to manage mobility of mobile nodes.

In this work mobility management model is designed assuming that node is transmitting in all directions and Omni directional antenna parameters are used for simulation. It is also aimed to test this mobility management model for nodes having sectoral antennas and aperture antennas.

Mobility management scheme as described in this work can also be tested for hybrid protocols as in this work proactive and reactive protocols were tested.

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APPENDICES

```
#initial code block to set up the scenario
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)         40                        ;# max packet in ifq
set val(nn)             8                         ;# number of mobilenodes
set val(rp)             AODV                       ;# routing protocol
#set val(rp)             DSR                       ;# routing protocol
set val(x)       800
set val(y)       800
set range        100
#--------------------
# Initialize Global Variables
set ns_          [new Simulator]
set tracefd     [open AODV18_10.tr w]
$ns_ trace-all $tracefd

set namtrace [open AODV18_10.nam w]

$ns_ namtrace-all-wireless $namtrace $val(x) $val(y)

# set up topography object
set topo       [new Topography]

$topo load_flatgrid $val(x) $val(y)

# Create God
create-god $val(nn)

#---------------------
# Create channel #1 and #2
set chan_1_ [new $val(chan)]
set chan_2_ [new $val(chan)]



# configure node, please note the change below.
$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) \
           -topoInstance $topo \
```

```
           -agentTrace ON \
           -routerTrace ON \
           -macTrace ON \
           -movementTrace OFF \
           -channel $chan_1_
#-----------------------------------

#-----------------------------------
proc randvals { maxRangex } {

        set value [expr int([ expr rand() * $maxRangex])]

          #puts "Value obtained from the random $value"

        return $value


          }
proc randvals { maxRangey } {

        set value [expr int([ expr rand() * $maxRangey])]

          #puts "Value obtained from the random $value"

        return $value


          }
#-------------------------

set mxrangex $val(x)
set mxrangey $val(y)
#-------------------------
#Setting the node
for {set i 0} {$i < $val(nn) } {incr i} {
      set node_($i) [$ns_ node]
      $node_($i) random-motion 0        ;# disable random motion
}

#--------------------------Size
#----------- assigning destinations using random function s.t. the
#coordinates are governed by the dimensions of the network
for {set i 0} {$i < $val(nn) } {incr i} {

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangey]

#puts " rand xval =$h1"
#puts " rand yval =$h2"
$node_($i) set X_ $h1
$node_($i) set Y_ $h2
$node_($i) set Z_ 0.0

}
```

```
for {set i 0} {$i < $val(nn)} {incr i} {

      $ns_ initial_node_pos $node_($i) 20
      set flag($i) 0
}



#set varX 10
#set varY 10

for {set i 0} {$i < $val(nn) } {incr i} {

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangey]

set varX($i) $h1
set varY($i) $h2
#puts " rand xval =$h1"
#puts " rand yval =$h2"

$ns_ at 0.000000000000 "$node_($i) setdest $h1 $h2 20.0"
#$ns_ at 10.00000000000 "$node_(1) setdest 258.446979634068
108.386939063715 0.000000000000"
#$ns_ at 10.00000000000 "$node_(2) setdest 258.446979634068
108.386939063715 0.000000000000"

}


for {set i 0} {$i < $val(nn) } {incr i} {

#set X varX($i)
#set Y varY($i)

set now [$ns_ now]
set node_x [$node_($i) set X_]
set node_y [$node_($i) set Y_]
set old_x $varX($i)
set old_y $varY($i)
puts " time=$now node X=$node_x   node Y=$node_y"
set tempx [expr $node_x - $old_x]
set tempy [expr $node_y - $old_y]
puts "X=$tempx  Y =$tempy"
set sqrx [expr $tempx * $tempx]
set sqry [expr $tempy * $tempy]
set sum1 [expr $sqrx  + $sqry]
set dist [expr int(sqrt($sum1))]
puts "$dist"
#Deploying the mobility management expression
set thresh [expr $dist * 0.2]
set max [expr $dist * 0.9]
puts "thresh=$thresh"
if {$dist > $thresh} {
```

```
puts "resetting"
#set node_x [$node_($i) set X_]
#set node_y [$node_($i) set Y_]
#$node_($i) setdest $h1 $h2 5.0
} else {
#$node_($i) setdest $h1+10 $h2+10 5.0
puts "not resetting" }
}
$ns_ at 3.0 "$node_(1) setdest 240.0 240.0 20.0"
for {set i 0} {$i < $val(nn) } {incr i} {
puts "array $varX($i) $varY($i)"
}
#-------------------------------------
#setting agents between 1 and 2
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(1) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(2) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 0.557023746220864 "$cbr_(0) start"
#setting agents between 5 and 7
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(5) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(7) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 0.557023746220864 "$cbr_(0) start"

#desintaions assigned to nodes by random function call
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 0.557023746220864  "$node_(1) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 0.557023746220864  "$node_(2) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 0.557023746220864  "$node_(5) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 0.557023746220864  "$node_(7) setdest $h1 $h2 20.0"
```

```
#---------------------------------------
set now [$ns_ now]
set node_x [$node_($i) set X_]
set node_y [$node_($i) set Y_]
set old_x $varX($i)
set old_y $varY($i)
puts " time=$now node X=$node_x   node Y=$node_y"
set tempx [expr $node_x - $old_x]
set tempy [expr $node_y - $old_y]
puts "X=$tempx  Y =$tempy"
set sqrx [expr $tempx * $tempx]
set sqry [expr $tempy * $tempy]
set sum1 [expr $sqrx  + $sqry]
set dist [expr int(sqrt($sum1))]
puts "$dist"
#Deploying the mobility management expression
set thresh [expr $dist * 0.2]
set max [expr $dist * 0.9]
puts "thresh=$thresh"
if {$dist > $thresh} {
puts "resetting"
#-----------------------------------------------------------
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(1) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(6) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 2.557023746220864 "$cbr_(0) start"
#setting agents
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(3) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(7) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 2.557023746220864 "$cbr_(0) start"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 2.557023746220864  "$node_(1) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 2.557023746220864  "$node_(3) setdest $h1 $h2 20.0"
```

```
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 2.557023746220864  "$node_(6) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 2.557023746220864  "$node_(7) setdest $h1 $h2 20.0"

#----------------------------------------
set now [$ns_ now]
set node_x [$node_($i) set X_]
set node_y [$node_($i) set Y_]
set old_x $varX($i)
set old_y $varY($i)
puts " time=$now node X=$node_x   node Y=$node_y"
set tempx [expr $node_x - $old_x]
set tempy [expr $node_y - $old_y]
puts "X=$tempx  Y =$tempy"
set sqrx [expr $tempx * $tempx]
set sqry [expr $tempy * $tempy]
set sum1 [expr $sqrx  + $sqry]
set dist [expr int(sqrt($sum1))]
puts "$dist"
#Deploying the mobility management expression
set thresh [expr $dist * 0.2]
set max [expr $dist * 0.9]
puts "thresh=$thresh"
if {$dist > $thresh} {
puts "resetting"
#------------------------------------------------------------


set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 2.557023746220864 "$node_(5) setdest $h1 $h2 20.0"
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(7) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(5) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 7.55 "$cbr_(0) start"
#----------------------------------------
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(2) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(4) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
```

```
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 7.55 "$cbr_(0) start"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 7.55  "$node_(7) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 7.55  "$node_(5) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 7.55  "$node_(2) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 7.55  "$node_(4) setdest $h1 $h2 20.0"
#----------------------------------------
set now [$ns_ now]
set node_x [$node_($i) set X_]
set node_y [$node_($i) set Y_]
set old_x $varX($i)
set old_y $varY($i)
puts " time=$now node X=$node_x   node Y=$node_y"
set tempx [expr $node_x - $old_x]
set tempy [expr $node_y - $old_y]
puts "X=$tempx  Y =$tempy"
set sqrx [expr $tempx * $tempx]
set sqry [expr $tempy * $tempy]
set sum1 [expr $sqrx  + $sqry]
set dist [expr int(sqrt($sum1))]
puts "$dist"
#Deploying the mobility management expression
set thresh [expr $dist * 0.2]
set max [expr $dist * 0.9]
puts "thresh=$thresh"
if {$dist > $thresh} {
puts "resetting"
#------------------------------------------------------------


#---------------------------------------
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 10.100000000000 "$node_(0) setdest $h1 $h2 20.0"

#--------------------------------------------------
#setting up agents between
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(0) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(1) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
```

```
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 10.557023746220864 "$cbr_(0) start"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 10.100000000000 "$node_(1) setdest $h1 $h2 20.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 10.100000000000 "$node_(2) setdest $h1 $h2 20.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 10.100000000000 "$node_(3) setdest $h1 $h2 20.0"

set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(2) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(3) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 10.557023746220864 "$cbr_(0) start"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.100000000000 "$node_(0) setdest $h1 $h2 30.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.100000000000 "$node_(1) setdest $h1 $h2 30.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.100000000000 "$node_(2) setdest $h1 $h2 30.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.100000000000 "$node_(3) setdest $h1 $h2 30.0"
#-------------------------------------------------------------

#---------------------------------------
set now [$ns_ now]
set node_x [$node_($i) set X_]
set node_y [$node_($i) set Y_]
```

```
set old_x $varX($i)
set old_y $varY($i)
puts " time=$now node X=$node_x   node Y=$node_y"
set tempx [expr $node_x - $old_x]
set tempy [expr $node_y - $old_y]
puts "X=$tempx  Y =$tempy"
set sqrx [expr $tempx * $tempx]
set sqry [expr $tempy * $tempy]
set sum1 [expr $sqrx  + $sqry]
set dist [expr int(sqrt($sum1))]
puts "$dist"
#Deploying the mobility management expression
set thresh [expr $dist * 0.2]
set max [expr $dist * 0.9]
puts "thresh=$thresh"
if {$dist > $thresh} {
puts "resetting"
#------------------------------------------------------------

set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(1) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(4) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 15.557023746220864 "$cbr_(0) start"
#-------------------------------------------------
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(2) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(6) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 15.55 "$cbr_(0) start"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.55 "$node_(1) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.55 "$node_(2) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.55 "$node_(4) setdest $h1 $h2 20.0"
```

```
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 15.55 "$node_(6) setdest $h1 $h2 20.0"



#----------------------------------------
set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(2) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(4) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 19.557023746220864 "$cbr_(0) start"

set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(0) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(3) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 19.557023746220864 "$cbr_(0) start"

set udp_(0) [new Agent/UDP]
$ns_ attach-agent $node_(1) $udp_(0)
set null_(0) [new Agent/Null]
$ns_ attach-agent $node_(7) $null_(0)
set cbr_(0) [new Application/Traffic/CBR]
$cbr_(0) set packetSize_ 512
$cbr_(0) set interval_ 0.05
$cbr_(0) set random_ 1
$cbr_(0) set maxpkts_ 10000
$cbr_(0) attach-agent $udp_(0)
$ns_ connect $udp_(0) $null_(0)
$ns_ at 19.557023746220864 "$cbr_(0) start"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 19.557023746220864 "$node_(1) setdest $h1 $h2 20.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 19.557023746220864 "$node_(2) setdest $h1 $h2 20.0"
```

```
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 19.557023746220864 "$node_(0) setdest $h1 $h2 20.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 19.557023746220864 "$node_(3) setdest $h1 $h2 20.0"

set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 19.557023746220864 "$node_(4) setdest $h1 $h2 20.0"
set h1 [randvals $mxrangex]
set h2 [randvals $mxrangex]
$ns_ at 19.557023746220864 "$node_(7) setdest $h1 $h2 20.0"
#----------------------------------------
set now [$ns_ now]
set node_x [$node_($i) set X_]
set node_y [$node_($i) set Y_]
set old_x $varX($i)
set old_y $varY($i)
puts " time=$now node X=$node_x   node Y=$node_y"
set tempx [expr $node_x - $old_x]
set tempy [expr $node_y - $old_y]
puts "X=$tempx  Y =$tempy"
set sqrx [expr $tempx * $tempx]
set sqry [expr $tempy * $tempy]
set sum1 [expr $sqrx  + $sqry]
set dist [expr int(sqrt($sum1))]
puts "$dist"
#Deploying the mobility management expression
set thresh [expr $dist * 0.2]
set max [expr $dist * 0.9]
puts "thresh=$thresh"
if {$dist > $thresh} {
puts "resetting"
#-----------------------------------------------------------


#4-------------------------------------

for {set i 0} {$i < $val(nn) } {incr i} {
    $ns_ at 25.0 "$node_($i) reset";
}
$ns_ at 25.0 "stop"
$ns_ at 25.01 "puts \"NS EXITING...\" ; $ns_ halt"
proc stop {} {
    global ns_ tracefd
    $ns_ flush-trace
    close $tracefd
}

puts "Starting Simulation..."
$ns_ run
```

Appendix - II

```
BEGIN {
   # simple awk script to generate end-to-end
   # in a form suitable for plotting with xgraph

   highest_packet_id = 0;
   pauseTime = 0;
   count =  0;
   ndelay = 0;
   Tcount = 0;
   Dcount = 0;
}

{
   action = $1;
   time = $2;
   node_1 = $3;
   node_2 = $4;
   src = $5;
   flow_id = $8;
   node_1_address = $9;
   node_2_address = $10;
   seq_no = $11;
   packet_id = $12;


   if($4 == "MAC" && $1 == "s") {

          start_time[$6] = $2;

    } else if(($7 == "MAC") && ($1 == "r")) {

        end_time[$6] = $2;

    }
    else if(($1=="D"))
{
    Dcount++;
}
    else if(($1=="D" || "r" || "c"))
{
    Tcount++;
}

      start = start_time[$6];
      end = end_time[$6];
      delay=   start -end;

         ndelay =  ndelay + delay ;
         count ++;
```

```
}

END {
   printf("End to End Delay %f ms\n",(ndelay/count*1000));
   printf("Total packet sent are %f\n",Tcount);
   printf("Average EndtoEnd Delay is %f\n",((ndelay/count*1000)/Tcount));
   printf("Total dropped packet are %f\n",Dcount);
   printf("Packet Dropped Ratio is %f\n",(Dcount/Tcount));

  }
```

Throughput(AODV,no of nodes:8,800X800)

```
setwd("I:/R_Results/AODV")
Data1=read.csv("AODV_8nodes_800x800.csv")
attach(Data1)
shapiro.test(Throughput)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  Throughput
## W = 0.9557, p-value = 0.02919
```

```
bartlett.test(Throughput~Scenario)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Throughput by Scenario
## Bartlett's K-squared = 18.52, df = 5, p-value = 0.002359
```

```
aov.test=aov(Throughput~Scenario)
summary(aov.test)
```

```
##             Df Sum Sq Mean Sq F value  Pr(>F)
## Scenario     5  191.1    38.2    32.5 3.9e-15 ***
## Residuals   54   63.5     1.2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(aov.test)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = Throughput ~ Scenario)
##
## $Scenario
##                          diff     lwr      upr  p adj
## AODVMM-AODV             3.420  1.9868  4.85316 0.0000
## AODVMMLB-AODV           0.954 -0.4792  2.38716 0.3745
## AODVMMRR-AODV           0.791 -0.6422  2.22416 0.5824
## AODVMMRRLB-AODV         2.013  0.5798  3.44616 0.0016
## AODVRRLB-AODV          -2.380 -3.8132 -0.94684 0.0001
## AODVMMLB-AODVMM        -2.466 -3.8992 -1.03284 0.0001
## AODVMMRR-AODVMM        -2.629 -4.0622 -1.19584 0.0000
## AODVMMRRLB-AODVMM      -1.407 -2.8402  0.02616 0.0571
## AODVRRLB-AODVMM        -5.800 -7.2332 -4.36684 0.0000
## AODVMMRR-AODVMMLB      -0.163 -1.5962  1.27016 0.9994
## AODVMMRRLB-AODVMMLB     1.059 -0.3742  2.49216 0.2625
## AODVRRLB-AODVMMLB      -3.334 -4.7672 -1.90084 0.0000
## AODVMMRRLB-AODVMMRR     1.222 -0.2112  2.65516 0.1367
## AODVRRLB-AODVMMRR      -3.171 -4.6042 -1.73784 0.0000
## AODVRRLB-AODVMMRRLB    -4.393 -5.8262 -2.95984 0.0000
```

End to End Delay(AODV,no of nodes:8,500X500)

```
setwd("I:/R_Results/AODV")
Data1=read.csv("AODV_8nodes_500x500_E2ED.csv")
attach(Data1)
shapiro.test(EED)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  EED
## W = 0.7931, p-value = 9.115e-08
```

```
bartlett.test(EED~Scenario)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  EED by Scenario
## Bartlett's K-squared = 22.22, df = 5, p-value = 0.0004762
```

```
aov.test=aov(EED~Scenario)
summary(aov.test)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Scenario     5  0.957  0.1914     108 <2e-16 ***
## Residuals   54  0.096  0.0018
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(aov.test)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = EED ~ Scenario)
##
## $Scenario
##                            diff      lwr      upr  p adj
## AODVMM-AODV              0.2675  0.21177  0.32323 0.0000
## AODVMMLB-AODV            0.3021  0.24637  0.35783 0.0000
## AODVMMRR-AODV            0.0241 -0.03163  0.07983 0.7957
## AODVMMRRLB-AODV          0.0279 -0.02783  0.08363 0.6787
## AODVRRLB-AODV            0.0215 -0.03423  0.07723 0.8625
## AODVMMLB-AODVMM          0.0346 -0.02113  0.09033 0.4531
## AODVMMRR-AODVMM         -0.2434 -0.29913 -0.18767 0.0000
## AODVMMRRLB-AODVMM       -0.2396 -0.29533 -0.18387 0.0000
## AODVRRLB-AODVMM         -0.2460 -0.30173 -0.19027 0.0000
## AODVMMRR-AODVMMLB       -0.2780 -0.33373 -0.22227 0.0000
## AODVMMRRLB-AODVMMLB     -0.2742 -0.32993 -0.21847 0.0000
## AODVRRLB-AODVMMLB       -0.2806 -0.33633 -0.22487 0.0000
## AODVMMRRLB-AODVMMRR      0.0038 -0.05193  0.05953 1.0000
## AODVRRLB-AODVMMRR       -0.0026 -0.05833  0.05313 1.0000
## AODVRRLB-AODVMMRRLB     -0.0064 -0.06213  0.04933 0.9994
```

TwoWAYANNOVA(No of nodes:8,800X800)

```
setwd("I:/R_Results/AODVvsDSDV")
Data1=read.csv("E2ED_Throughput_800x800.csv")
attach(Data1)
shapiro.test(Throughput)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  Throughput
## W = 0.9296, p-value = 9.068e-06
```

```
shapiro.test(EED)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  EED
## W = 0.9348, p-value = 1.952e-05
```

```
bartlett.test(Throughput+EED~Scenario)
```

```
##
##  Bartlett test of homogeneity of variances
##
## data:  Throughput + EED by Scenario
## Bartlett's K-squared = 83.64, df = 11, p-value = 2.906e-13
```

```
aov.test=aov(Throughput+EED~Scenario)
summary(aov.test)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)    
## Scenario     11   1864   169.4      32 <2e-16 ***
## Residuals   108    572     5.3                   
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
TukeyHSD(aov.test)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = Throughput + EED ~ Scenario)
##
## $Scenario
##                            diff       lwr       upr  p adj
## AODVMM-AODV              3.3655  -0.07303  6.80403 0.0610
## AODVMMLB-AODV            0.9319  -2.50663  4.37043 0.9989
## AODVMMRR-AODV            0.7910  -2.64753  4.22953 0.9998
## AODVMMRRLB-AODV          1.9818  -1.45673  5.42033 0.7407
## AODVRRLB-AODV           -2.3430  -5.78153  1.09553 0.4994
## DSDV-AODV               -9.9962 -13.43469 -6.55763 0.0000
## DSDVMM-AODV             -1.8903  -5.32883  1.54823 0.7941
## DSDVMMLB-AODV           -5.3864  -8.82493 -1.94787 0.0001
## DSDVMMRR-AODV           -4.8676  -8.30613 -1.42907 0.0004
## DSDVMMRRLB-AODV         -4.6541  -8.09263 -1.21557 0.0009
## DSDVRRLB-AODV           -7.7782 -11.21673 -4.33967 0.0000
## AODVMMLB-AODVMM         -2.4336  -5.87213  1.00493 0.4389
## AODVMMRR-AODVMM         -2.5745  -6.01303  0.86403 0.3505
## AODVMMRRLB-AODVMM       -1.3837  -4.82223  2.05483 0.9710
## AODVRRLB-AODVMM         -5.7085  -9.14703 -2.26997 0.0000
## DSDV-AODVMM            -13.3617 -16.80019 -9.92313 0.0000
## DSDVMM-AODVMM           -5.2558  -8.69433 -1.81727 0.0001
## DSDVMMLB-AODVMM         -8.7519 -12.19043 -5.31337 0.0000
## DSDVMMRR-AODVMM         -8.2331 -11.67163 -4.79457 0.0000
## DSDVMMRRLB-AODVMM       -8.0196 -11.45813 -4.58107 0.0000
## DSDVRRLB-AODVMM        -11.1437 -14.58223 -7.70517 0.0000
## AODVMMRR-AODVMMLB       -0.1409  -3.57943  3.29763 1.0000
## AODVMMRRLB-AODVMMLB      1.0499  -2.38863  4.48843 0.9969
## AODVRRLB-AODVMMLB       -3.2749  -6.71343  0.16363 0.0774
## DSDV-AODVMMLB          -10.9281 -14.36659 -7.48953 0.0000
## DSDVMM-AODVMMLB         -2.8222  -6.26073  0.61633 0.2207
## DSDVMMLB-AODVMMLB       -6.3183  -9.75683 -2.87977 0.0000
## DSDVMMRR-AODVMMLB       -5.7995  -9.23803 -2.36097 0.0000
## DSDVMMRRLB-AODVMMLB     -5.5860  -9.02453 -2.14747 0.0000
## DSDVRRLB-AODVMMLB       -8.7101 -12.14863 -5.27157 0.0000
## AODVMMRRLB-AODVMMRR      1.1908  -2.24773  4.62933 0.9910
## AODVRRLB-AODVMMRR       -3.1340  -6.57253  0.30453 0.1100
## DSDV-AODVMMRR          -10.7872 -14.22569 -7.34863 0.0000
## DSDVMM-AODVMMRR         -2.6813  -6.11983  0.75723 0.2901
## DSDVMMLB-AODVMMRR       -6.1774  -9.61593 -2.73887 0.0000
## DSDVMMRR-AODVMMRR       -5.6586  -9.09713 -2.22007 0.0000
## DSDVMMRRLB-AODVMMRR     -5.4451  -8.88363 -2.00657 0.0000
## DSDVRRLB-AODVMMRR       -8.5692 -12.00773 -5.13067 0.0000
```

```
## AODVRRLB-AODVMMRRLB     -4.3248  -7.76333 -0.88627 0.0031
## DSDV-AODVMMRRLB        -11.9780 -15.41649 -8.53943 0.0000
## DSDVMM-AODVMMRRLB       -3.8721  -7.31063 -0.43357 0.0138
## DSDVMMLB-AODVMMRRLB     -7.3682 -10.80673 -3.92967 0.0000
## DSDVMMRR-AODVMMRRLB     -6.8494 -10.28793 -3.41087 0.0000
## DSDVMMRRLB-AODVMMRRLB   -6.6359 -10.07443 -3.19737 0.0000
## DSDVRRLB-AODVMMRRLB     -9.7600 -13.19853 -6.32147 0.0000
## DSDV-AODVRRLB           -7.6532 -11.09169 -4.21463 0.0000
## DSDVMM-AODVRRLB          0.4527  -2.98583  3.89123 1.0000
## DSDVMMLB-AODVRRLB       -3.0434  -6.48193  0.39513 0.1364
## DSDVMMRR-AODVRRLB       -2.5246  -5.96313  0.91393 0.3808
## DSDVMMRRLB-AODVRRLB     -2.3111  -5.74963  1.12743 0.5212
## DSDVRRLB-AODVRRLB       -5.4352  -8.87373 -1.99667 0.0000
## DSDVMM-DSDV              8.1059   4.66733 11.54439 0.0000
## DSDVMMLB-DSDV            4.6098   1.17123  8.04829 0.0011
## DSDVMMRR-DSDV            5.1286   1.69003  8.56709 0.0001
## DSDVMMRRLB-DSDV          5.3421   1.90353  8.78059 0.0001
## DSDVRRLB-DSDV            2.2180  -1.22057  5.65649 0.5852
## DSDVMMLB-DSDVMM         -3.4961  -6.93463 -0.05757 0.0426
## DSDVMMRR-DSDVMM         -2.9773  -6.41583  0.46123 0.1585
## DSDVMMRRLB-DSDVMM       -2.7638  -6.20233  0.67473 0.2479
## DSDVRRLB-DSDVMM         -5.8879  -9.32643 -2.44937 0.0000
## DSDVMMRR-DSDVMMLB        0.5188  -2.91973  3.95733 1.0000
## DSDVMMRRLB-DSDVMMLB      0.7323  -2.70623  4.17083 0.9999
## DSDVRRLB-DSDVMMLB       -2.3918  -5.83033  1.04673 0.4665
## DSDVMMRRLB-DSDVMMRR      0.2135  -3.22503  3.65203 1.0000
## DSDVRRLB-DSDVMMRR       -2.9106  -6.34913  0.52793 0.1834
## DSDVRRLB-DSDVMMRRLB     -3.1241  -6.56263  0.31443 0.1127
```

```
```{r}

setwd("I:/R_Results/AODV")

Data1=read.csv("AODV_5nodes_500x500.csv")

attach(Data1)

library(ggplot2)

graphData=read.csv("AODV_5nodes_500x500_graph.csv")

p=ggplot(graphData,aes(x=No_of_Trials,y=Throughput,colour=Scenario,shape=Scenario))+geom_point(s
ize=4)

p+geom_line()+ggtitle("AODV,5Nodes,500x500,Throughput")

```{r}

datanew=subset(graphData,Scenario=="AODV"| Scenario=="AODVMM")

p=ggplot(datanew,aes(x=No_of_Trials,y=Throughput,colour=Scenario,shape=Scenario))+geom_point(siz
e=4)

p+geom_line()+ggtitle("AODV,5Nodes,500x500,Throughput")
```

List of Publications

1. Monit Kapoor, Manish Prateek, A Proposed Architecture for Efficient Data Delivery and Route Maintenance in a Sparsely Deployed Mobile Ad Hoc Network , AISC series of Springer. Volume 258, pp 513-524, March, 2014. DOI: 10.1007/978-81-322-1771-8_45

2. Monit Kapoor, Manish Prateek, Kamal Bansal, Evaluation of mobility managed reactive protocol AODVMM in a sparsely deployed mobile ad hoc network, International Journal of Wireless and Mobile Computing, Inderscience. Volume 9, No 1, 2015. DOI: 10.1504/IJWMC.2015.071680

A Proposed Architecture for Efficient Data Delivery and Route Maintenance in a Sparsely Deployed Mobile Ad Hoc Network .

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Abstract. Mobile ad hoc networks have seen tremendous research being carried out looking into various issues in the area of routing, disruption tolerance and mobility control amongst other issues. MANET has a typical environment and in many works MANET is not treated as a case of infrastructureless network. This work aims to treat Ad Hoc networks differently than a Wireless Infrastructure Network. This work also aims at proposing a framework for route maintenance of a network of any size in case of sparsely deployed topologies and maintain the mobility of all the nodes to the advantage of the participating nodes.

Keywords: Mobile ad hoc networks, Mobility Management, IEEE 802.11 Standards, Sparse Node, Delay Tolerant Networks

1 Introduction

Mobile Ad Hoc Networks(MANET) are a collection of self-configuring mobile nodes which combine arbitrarily in any topology so that basic functions of a network are carried out and network is up for the duration of time for which it was established. MANETs are characterized by random mobility of nodes, frequent disruption in connectivity and limitation of resources such as buffer, battery back-up etc. and most importantly lack of infrastructure or backbone [1]. Each node in a MANET can perform network function of Packet forwarding and thus each node is acting like a Router, hence at each node route maintenance activity has to be carried out.. Participating nodes in a MANET communicate with other nodes in the network through 802.11 MAC Layer [2].They can be found as STA(Stations) which are part of IBSS(Independent Basic Service Set) in IEEE standards. A Collection of interacting IBSSs' is represented as Mobile ad-hoc network where the

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Basic Service set functionality is without any backbone as illustrated in Figure 1 ahead in this article.

Ad-hoc networks have been named like this as they are created on the go mostly without any prior planning and they are deployed for dealing with emergency situations mostly, like battlefields, or natural disaster sites earthquake and other natural calamities etc. These networks are operative for only as long as they are needed. In emergency situations like mentioned the network partitions can last long because thick deployment of nodes shall not be done and hence the main challenges in our view shall be efficient data delivery in sparse deployment, optimal usage of resources of node. However, it has been seen over a period of time that commercially Ad Hoc network have not been in use as much as in above mentioned scenarios.

Many articles [3, 4, 5] have been dealing with a high node density scenario there by proposing protocols such as DSR, DSDV and AODV. These protocols aim to solve problems of typically "connected networks". A connected network would be one in which node density in the network deployment area is relatively high.

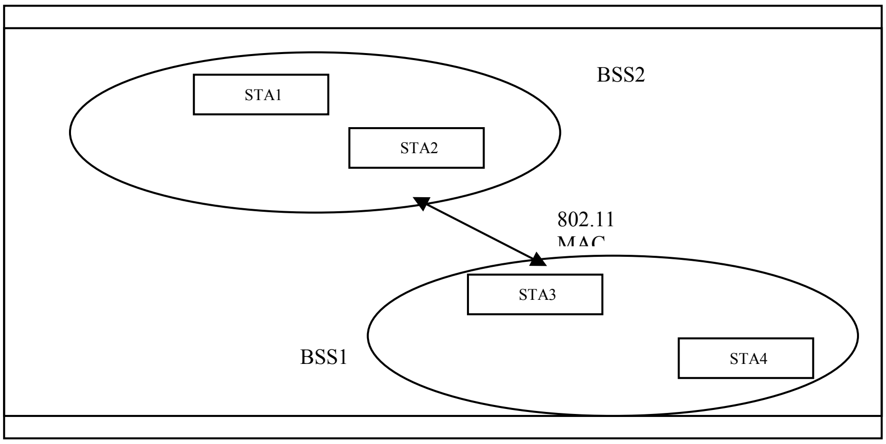

FIG 1: IBSS as Ad Hoc Network (Source :802.11 Standards)

Some of articles go on to indicate TCP traffic [6,7] in a MANET which is in clear opposite to what has been proposed in 802.11 standards where as we can see in figure above Stations are part of basic service set and interacting BSS's combine to form an Ad hoc network. Since there is no portal involved here as is seen in [2] in case of wireless infrastructure network hence it can be safely concluded that Ad Hoc networks are a case of a infrastructureless network and TCP traffic can't be a characteristic of Ad Hoc networks. Hence Ad hoc network looks more suited to conditions mentioned in Delay Tolerant Networks at [8], a separate research group is working on node mobility management, data buffering amongst others.

Rest of the paper is organized as follows. Section II briefly discuss about various issues that concern us in design of routing protocol for Mobile Ad Hoc network. Section III is about related works in the area of MANET and Delay Tolerant Network environment and their co relation. Section IV mentions about existing drawbacks in the related works .Section V contains description about concept of remoteness and mobility management. Section VI provides the protocol design and framework and Section VII is the conclusion section.

2. Design Issues

The identified issues in design of a routing protocol are:

A. Route Entries at a node: MANET nodes are constantly moving in random direction and due to changing topology paths keep on varying and it is needed to maintain the route entries on the move .Lack of infrastructure increases the need of accurate network mapping all the time so that network function is not hampered. But doing so should be with minimum overhead.

B. Mobility: Nodes are mobile and this mobility can be put to use so as the network becomes self-organizing and stable over a period of time. Mobility control again relies on network mapping at each node but is constrained by limited battery power. Inclusion of extra control information in data packets for the purpose of self-organization shall cause faster depletion of battery and has to be optimized.

C. Limited resources availability: Mobile Nodes have finite battery power and limited buffer and processing capacity. Any processing overhead would result in faster consumption of battery and any increase in battery or buffer at node would lead to loss of free mobility as payload of nodes will increase.

3. Related Works

Sparse node problem has been treated by deploying ferrying techniques in [9]. Message ferrying approach deploys set of special nodes called message ferries that exploits mobility to decrease delays. OPWP technique also uses this kind of approach in [10] where ferry nodes rather than being mobile all the time show controlled mobility around, optimized waypoints. Another technique which is very similar to [9],[10] uses data mules which are moved into a sensor field to facilitate traffic in a wireless sensor network[11], in which sensor field has a sparse deployment of nodes. Sensor nodes are pinned at one location and data mules act as carriers of information available at sensor nodes which are stationary. Ferry Access Points (FAPS) propose in [12] sticky transfers as a method to improve communication in DTN. In this node to ferry contact as and when it happens will lead to creation of a long duration contact resulting transfer of complete data. But, natural node movement is controlled during this sticky contact. Another approach is in [13] where throwboxes have been suggested in DTNs having mobile nodes so that larger contact opportunities are created and these throwboxes are present at advantage location provide routing and buffering.

In [14] DTN routing schemes are classified as deterministic, enforced and opportunistic. Deterministic routing schemes are used when a priori information about traffic demand and contact is known. Enforced Routing schemes deploy special purpose nodes to provide connectivity as already discussed in [9, 10, 11, 12, 13]. Enforced routing techniques also require beforehand information about design of routes or locations for placing throwboxes to facilitate traffic. Opportunistic routing schemes use flooding mechanism where multiple copies of each message is flooded in the network as provided in epidemic routing [15].As proposed in [16] the approach aims to better [15] by limiting multiple copies being sent to next hops for better resource utilization. Another technique is proposed in spray and wait [17] in which replication of messages is present in network but the concern that how many messages stay replicated is again a concern and it is stated in [17] that source can't decide how many copies of message can stay in network. ASBIT [18] is a recent technique that identifies the significance of time intervals between two exchanges and it utilizes the same interval to predict the number of inter node contacts within the estimated delivery and delay therein. In [19] the authors provide mechanism to source packets from nodes to a node as compared to node to a base station in DSG routing where traffic is sent from a node to a base station, a sensor node and deploys distributed caching.DSG-N^2 routing identifies social grouping among nodes based on contact patterns between nodes.

4. Observations to related works

These are:

1. Special nodes are made to travel in network and in event of failure of ferry node, data mule in [9], [11] the network operation would fail. Moreover in [11] the technique suggested is for specific case for wireless sensor networks. However, the concept that some node has to act as ferry is supported.

2.In [10] ferries stop at OPWP and wait for buisiness nodes to come at some point in network run time to offload nodes' buffer. This waiting for nodes contributes to delay.

3. In [12] mobility of nodes is governed by movement of ferries only during contact time between ferry node and network node. This is a scenario to be replicated during entire duration of network but without ferry nodes, and only for duration of node to node to data transfer. .

4.In [14] throwboxes are stationary ferries that occur to contact within the travel of a node , hence the node that facilitates traffic is stationary and offloads data on nodes by assuming that node is travelling in direction of destination specific traffic acquired by throwbox. Hence, throwbox technique is again waiting for favorable node to arrive.

5. Approaches provided in [16], [17] work on concept of multiple sends and in a sparse node deployment this flooding or controlled flooding is highly taxing on resources of mobile nodes and seems improbable too.
6. In [18] it overcomes the disadvantages of [17] by utilizing the inter contact delay and it is aimed to use this significant inter-contact time for network restoration.
7. In [19] the network is managed by caching at base stations as well node to node transfers on type of request basis which suggest that it is not a case of sparsely deployed network whereas DTN environment is a typical case of sparsely deployed topology.

5. Concept of Remoteness and Mobility Management

A node can be considered a transceiver with a range around it in a circular area with node acting as radial point. The range of transmission for a node is equal to radius of the circle. This imaginary circle moves along with node's random movement. Since Ad hoc network will have node to node communication it means that receiver node has to be inside the circle of sending node for the duration of transfer. A remote node would be one that is outside the range of the broadcasting node and a node at relatively larger distance would be more remote to another node that is relatively nearer but still outside the range of the node.
Also, there can be scenario where node would be moving into the circle in the direction of center of the circle. In this scenario the node has to stop after coming inside the circle. This effort of controlling the receiver position inside the broadcasting node's transmission range would be called as mobility management.

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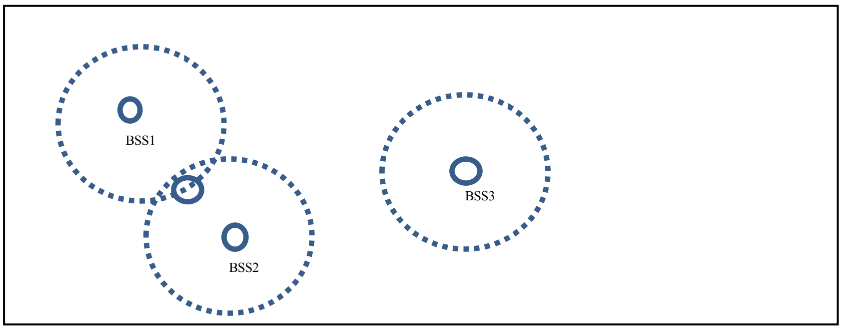

Fig 2: Scenario depicting Remote nodes and Nodes within the Transmission range

Here BSS1 has one node in it and the node in BSS3 is remote node for BSS1.For BSS2 the node on outside boundary is to be stopped and node has to be brought in after it reaches the boundary perimeter.
The following iluustartion will explain this concept of node mobility management.

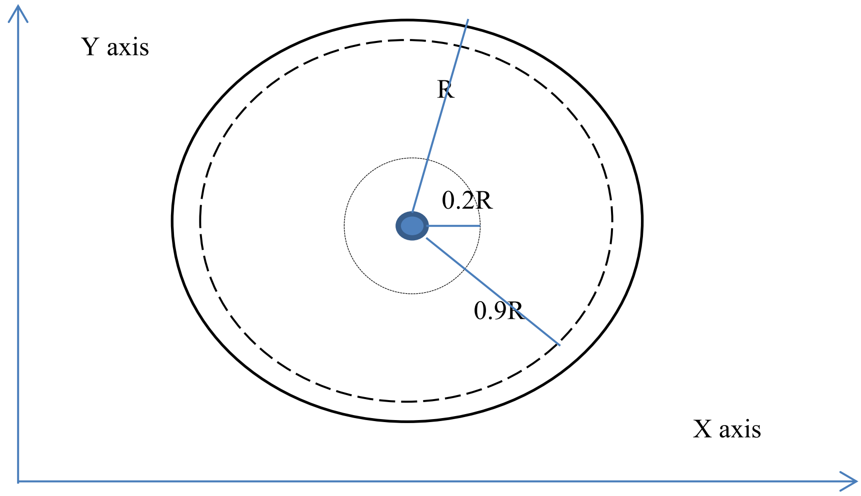

Fig 3: Node at center with Threshold radials

Let R be the radius of circle of Transmission range and there be defined a threshold distance D_{th1} which is equal to R, i.e. D_{th1}=R

Now $\exists$ Y Ɛ Y_k s.t. $|Y_k - Y_0| = Y_{dis}$ and $\exists$ X Ɛ X_k s.t. $|X_k - X_0| = X_{dis}$
Therefore,$\sqrt{(Y_{dis})^2 + (X_{dis})^2} = R = D_{th1}$ ---(1)
Let us maximum displacement threshold for any node at any location within the range is 90% of R and minimum displacement threshold for node be 20% of R.This can be put in inequalities 2 and 3 as below.

$\sqrt{(Y_{dis})^2 + (X_{dis})^2} <= 0.9R$ --- (2)

$\sqrt{(Y_{dis})^2 + (X_{dis})^2} >= 0.2R$ --- (3)

We shall term this as snoop location test that each node will do for its master node to get its coordinates as given by inequality 4 as under.
$0.2R <= \sqrt{(Y_{dis})^2 + (X_{dis})^2} <= 0.9R$ --- (4)

If the condition is violated, the node shall reset its path to align with the master node and shall keep on doing so ,till the next agreed time interval when One Hop Packets are broadcast and network topology is available afresh.

6. Protocol design and framework

In this section, the workflow of the algorithm is described on the basis of the following assumptions.
a. Network is sparsely deployed and here we model network for 4 nodes only.

b. We assume that all nodes are aware of maximum network size which is 4 in this case.
c. Nodes broadcast to other nodes there one hop neighbor information after fixed interval of time and network activity is suspended during this time interval.
d. All nodes enter the network simultaneously and if any node is entering after some time the network has started functioning it will not straight way look to connect to some neighbor, though it will be listening to its neighbors if any. It will have to wait for time interval when one hop neighbor is being broadcast by its neighbor.
In this section, the workflow of the algorithm is described on the basis of the following assumptions derived out of favorable scenarios in previous section.
a. Network is sparsely deployed and here we model network for 4 nodes only.
b. We assume that all nodes are aware of maximum network size which is 4 in this case.
c. Nodes broadcast to other nodes there one hop neighbor information after fixed interval of time and network activity is suspended during this time interval.
d. All nodes enter the network simultaneously and if any node is entering after some time the network has started functioning it will not straight way look to connect to some neighbor, though it will be listening to its neighbors if any. It will have to wait for time interval when one hop neighbor is being broadcast by its neighbor.

Algorithm: Since the network size is 4 and node are enumerated in given set N_i= (n1, n2, n3, n4,}.Each node shall maintain a 3×4 Stack of Booleans 1-D matrix for route maintenance, which is to be maintained at each node. Each row of stack matrix shall signify as n^{th} hop entries where each column represents node Ɛ N_i.
Table 1 and Table 2 are route maintenance matrices for nodes,n1 and n2,where column are indicative of n1,n2,n3,n4 and rows are indicative of 1 hop neighbor,2 hop neighbor and 3 hop neighbor. If any entry in table is 1 it means that corresponding node is a neighbor and row no will tell if it is 1-hop, 2-hop or 3-hop neighbor.
The entries in shaded part of table 1 represent the presence of neighbor at a particular hop distance. From here onwards, only shaded portion of table 1 is reproduced under different scenarios and significance of row and columns remains same.

Table 1: Route Maintenance Entries in routing table for node n1

Hop no	Node1	Node 2	Node 3	Node 4
1-hop	0	1	0	0
2-hop	0	0	1	0
3-hop	0	0	0	1

Table 2: Route Maintenance Entries in routing table for node n2

1	0	1	0
0	0	0	1
0	0	0	0

Then, image of network for node n1 is in Figure 2, and we assume nodes moves in direction of arrow. Let below be called Scenario A

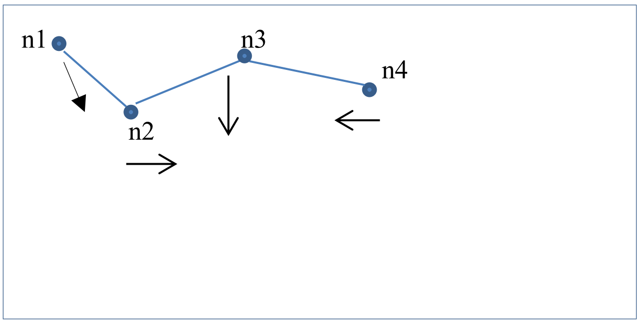

FIGURE 4: Scenario A

Zeros in last row of matrix for n2 signify that there is no three hop neighbor for node 2.Also it can be seen that same network image is available at node n1 and n2. Let the below be called scenario B shown in figure 3 when nodes have moved to enter a new topology.

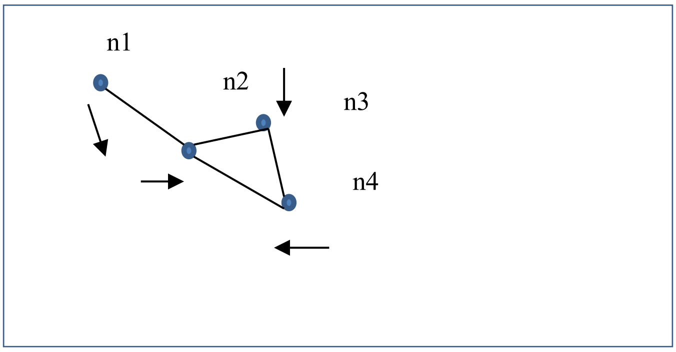

FIGURE 5: Scenario B

Now the matrix for node n1 and n2 for Scenario B is in table 3 and table 4 respectively.

Table 3: Route Maintenance Entries in routing table for node n1

0	1	0	0
0	0	1	1
0	0	1	1

Table 4: Route Maintenance Entries in routing table for node n2

1	0	1	1
0	0	1	1
0	0	0	0

Here it can be seen that n2, n3 and n4 are connected in a looping topology and hence which route to be followed is not clear if say data is to be sent from 1 to 4. So, the following algorithm is proposed.

Table 5: NOTATIONS USED IN ALGORITHM

Notation used	Description
RH(n)	nth hop Information Bits framed in size 4 bit
NS(n)	nth Node's RH(n)s Stack Array of size(n-1×n) for complete route information
AN(n)	Stack for node n for scenario A
BN(n)	Stack for node n for scenario B
RST,NR	Resetted operation, Not Resetted operation

Step1.Node n Ɛ N_i transmits one hop packet containing 4-bit RH(n) frame along with Control information to each one hop neighbor during the interval already known to all nodes .All nodes n broadcast one hop information received from all sources to all their one hop neighbors except the node from which it came. The source and destination information is available in one hop packet in form of control bits.

Step2.Each neighbor node n accepts one hop information, removes control information and pushes RH(n) on NS(n) in modulo 4 order, s.t.,rows RH(n) of NS (n) are in order (n+k)%4 for k=0,1,2,3 where n is the node number.

Order is representative of the node number.

2 (a). If (n+k) %4 equals ZERO, then set order n of RH(n) being pushed onto stack NS(n) as n =4.

Step 3.In NS (n) for node (n) set the n^{th} column bit to ZERO to avoid loopback condition.

Step 4.Start reading 4×4 NS (n) in row major order and preserve 1's as they are encountered. For every node n Ɛ N $_i$ don't read the bit in nth column, and entry is NR whenever 1 is encountered.
4 (a). Preserve 1's only if 1 is not encountered in previous row traversals, i.e., RST if already done a NR for 1 in same column.
5. Drop last row of matrix i.e. the 4th row in this case, NS (n) for network of size 4 is ready.

7. Results and Conclusions

We played this algorithm on a self-prepared computer program and found the algorithm working for a network of size 4 where duplicity of links was handled by passing only one hop information between nodes .In this way same network image is available to all nodes as we created AN(n) and BN (n) for all 4 nodes .
After, step2 the following tables are created on nodes n1 and n2.As it can be seen these tables have four rows whereas the actual table that has route entries has three rows. One extra row has been created due to iterations in step 2 of algorithm.

Table 6: Route Maintenance Entries in routing table for node n1

0	1	0	0
1	0	1	1
0	1	0	1
0	1	1	0

Table 7: Route Maintenance Entries in routing table for node n2

1	0	1	1
0	1	0	1
0	1	0	0
0	1	0	0

The table 8 and table 9 are received after the Step 4 and 5 of Algorithm is played. Table 8 and Table 9 are representative of same network image for both node n1 and n2.The same network image results in zero duplication of messages in the network when network will be put in operation.

Table 8: Route Maintenance Entries in routing table for node n1

0	1	0	0
0	0	1	1
0	0	0	0

Table 9: Route Maintenance Entries in routing table for node n2

1	0	1	1
0	0	0	0
0	0	0	0

The network image emerging out of table 8 and table 9 is given in Figure below.

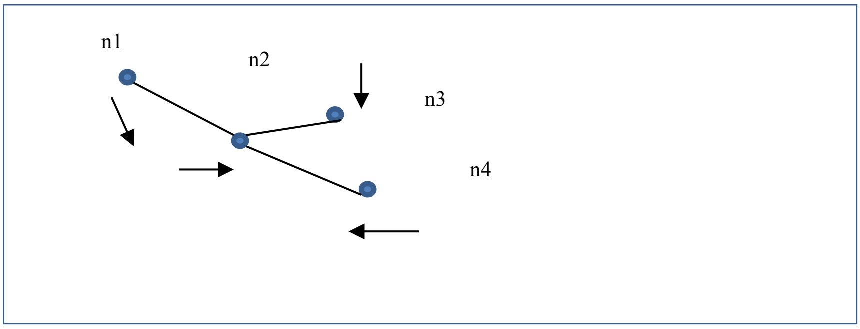

FIGURE 3: Scenario emerging for both n1 and n2

In this Paper we have tried to establish the Parameter of mobility by modeling node as a transmitter which transmits in one circular fashion and then we have tried to propose a routing protocol for the same. It is seen that duplicity of links is handled very well by the routing protocol and any node at any given point in life of network has same image of topology of the network. The controlled mobility feature allows the node to remain in close proximity to each other while data transmission is taking place. In our future work we shall propose packet format for the same and shall model it for varying network sizes.

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Evaluation of mobility managed reactive protocol AODVMM in a sparsely deployed mobile ad hoc network

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Abstract: Mobile ad hoc networks are characterised by random movement of nodes leading to frequent link disruptions apart from extra overhead to maintain network topology. AODV is a reactive protocol intended to maintain the network topology periodically for a MANET. This work aims to deploy a mobility managed mobile ad hoc network which uses AODV protocol along with the mobility managed (MM) scheme as proposed to enhance throughput by using MM scheme. The AODVMM protocol is also tested under varying buffer availability conditions and reduced transmission range for varying network sizes and different number of nodes.

Keywords: MANET; mobility management; routing protocol; sparse node; AODVMM; delay tolerant networks.

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1 Introduction

Mobile ad hoc networks (MANETs) are characterised by random node movements leading to frequent link disruptions resulting in degraded network performance. Network operations are maintained by nodes in the MANET and nodes serve as routers for some packets while they move around the network doing their own task (Murthy and Manoj, 2008). Delay tolerant networks (DTNs) are the networks in which the nodes communicate under trying conditions of frequent link disruptions, low buffer capacity and low node density in the area of operation. DTN research group exists at dtn.org and the group works on various issues concerning DTNs like mobility management, data buffering and more.

Various categories of routing protocols have been suggested for MANETs which are as follows: Proactive, Reactive and Hybrid (Abolhasan et al., 2004). In proactive routing protocols, the routes to all the destination or component(s) of network are determined at the time of network setup, and periodically maintained by using a route update process. The second category of routing protocols is reactive protocol where routes are determined as and when there is a demand and the source wants to run a route establishment process. Hybrid routing protocols combines the principles of Reactive and Proactive Protocols. Each protocol group has different available strategies to perform routing, but would broadly be flat or hierarchical in nature.

Zhang (2006) classified DTN routing protocols as deterministic, enforced and opportunistic. Deterministic routing is used when a priori information about traffic demand and contact is known. Enforced routing techniques deploy special nodes to maintain network connectivity and data transmission (Zhao et al., 2004; Bin Tariq et al., 2006; Shah et al., 2003; Yasmeeny et al., 2012; Zhao et al., 2006). Enforced routing mechanism shall also require beforehand information about the design of mobility paths and exact locations to be identified beforehand if throw boxes are to be placed in the network area. Flooding of multiple messages is employed where multiple copies of same message are present in the network as suggested in epidemic routing (Vahadat and Becker, 2000; Mundur et al., 2008).

Sparse node scenarios are handled by using message ferries which are special nodes with infinite resources, and they move in network area to take data from other nodes in the network and finally deliver the data to destination nodes (Zhao et al., 2004). Further optimised waypoints were identified (Bin Tariq et al., 2006) where the node goes to these waypoints (OPWP) which are points in the network where there is more probability of finding other nodes who want to offload the data on to ferry node. Ferry node reaches these waypoints and even waits for other nodes to arrive at in the vicinity of waypoints. Here nodes have controlled mobility but the node is stopped at the waypoint rather than it being mobile.

Shah et al. (2003) proposed to have data mules inside the sensor field which are again similar to ferry nodes. FAPs were proposed (Yasmeeny et al., 2012) where node ferry pair form a sticky contact for a longer duration and the node mobility is compromised for the duration of sticky contact. Throwboxes are special purpose nodes placed at different locations in a network where they serve mobile node for buffering their data and also participate in routing operations (Zhao et al., 2006).

In another approach known as epidemic routing multiple copies of the same message were sent over the network to ensure delivery of the message to the target node. Nodes keep on re-transmitting the message till it has reached the destination node (Vahadat and Becker, 2000).

Controlled flooding mechanism was adopted so that no node received the same message twice (Mundur et al., 2008). Further the intercontact delay between two consecutive communications was significantly used for overcoming the disadvantages in controlled flooding (Luo et al., 2012). We also aim to use this significant intercontact delay in ad hoc networks which are sparsely deployed for route restoration and network connectivity maintenance.

Recently Cabanis et al. (2013) have proposed caching at base stations as well as at nodes for ascertaining request categories in a DTN, which does not seem to be suitable for sparsely deployed ad hoc network where nodes are constrained by scarce resources and random mobility patterns.

In Reactive or On-Demand protocols the route tables are maintained on each node inside the network. The AODV (Perkins et al., 2003) routing protocol is based on DSDV (Perkins and Watson, 1994) and DSR algorithm. It uses the periodic beaconing and sequence numbering procedure of DSDV and a similar route discovery procedure as in DSR. However, there are two major differences between DSR and AODV.

The most distinguishing difference is that in DSR each packet carries full routing information, whereas in AODV the packets carry the destination address.

This means that AODV has potentially less routing overheads than DSR. The other difference is that the route replies in DSR carry the address of every node along the route, whereas in AODV the route replies only carry the destination IP address and the sequence number. The advantage of AODV is that it is adaptable to highly dynamic networks (Abolhasan et al., 2004). However, nodes may experience large delays during route construction, and link failure may initiate another route discovery, which introduces extra delays and consumes more bandwidth as the size of the network increases.

The various reactive protocols that have been proposed from time to time are like TORA (Park and Corson, 1997), ARA (Geunes et al., 2002) and some more.

Rest of the paper is organised as follows. Section 2 is about the similarities between MANETs and DTN environment and the relevance of the mobility scheme developed. Section 3 elaborates on the mobility management scheme that has been developed and which shall be embedded in reactive routing protocol. Section 4 explains the simulation parameters and results along with the methodology. Section 5 is about significance of the results and Section 6 contains conclusions and future scope.

2 DTN and sparsely deployed MANETs-motivation

Delay tolerant networks, popularly referred to as DTNs, are networks where frequent link disruption is witnessed. These networks are characterised by long time network partitions and absence of end to end communication path between all the nodes (Jain et al., 2004). In the DTNs, routing gets affected by frequent breakdown of links. If the network is sparsely populated then the phenomenon of link disruption is handled by using store and carry nodes. In store and carry nodes data packets are lying on the node while the nodes are mobile and data is transmitted to neighbouring node when it reaches in proximity of data carrying node. Jain et al. (2004) in their work have assumed the DTN nodes to be Low Earth Orbiting satellites or PDA's which are rich on resources like computational power, battery backup and buffer.

A significant correlation was established by Ott et al. (2006) between MANET and DTNs where routing and packet forwarding issues of MANETs with sparse deployment were resolved by adopting asynchronous traffic management schemes over AODV protocol (Perkins et al., 2003). Ott et al. (2006) used a hybrid approach where protocol used for route maintenance is AODV and packet bundling is done over the communicating nodes using DTNRG specifications (Scott and Burleigh, 2005).

MANET nodes are constrained in terms of buffer availability, processing power and battery capacity. Bundling of packets and buffering over the nodes is quiet promising as deployed by Jorg et al., but this will lead to performance degradation due to scarcity of resources over the mobile ad hoc network nodes.

Intercontact delay is the time elapsed between two successive data transfer requests between two nodes. This intercontact delay between two consecutive communications was significantly used by Guangchun Lao et al. for overcoming the disadvantages in controlled flooding proposed by Mundur et al. (2008). We also aim to use this significant intercontact delay in ad hoc networks which are sparsely deployed for route restoration and network connectivity maintenance. However, in this approach next hop selection is based upon degree of centrality of each node. Also Luo et al. (2013) proposed that all the nodes have to be aware of next hop's buffer availability before forwarding the packet. In this work hence the motivation is to device a lightweight approach to identify next hop selection, maintain the network by publishing the topology of the network periodically and mitigate the resource challenging phenomena of replication of messages.

In sparse deployment topologies it is very important to devise mechanisms where end to end connectivity between nodes is maintained by using controlled mobility similar to ferry assisted DTNs. The nodes can be made to move within certain degree of proximity to each other thereby the nodes need not rely on ferry nodes to facilitate traffic in the network. We form this as the basis for the Mobility Management Scheme proposed in further sections. We use AODV protocol where it updates the route tables for each node reactively and updation of links is done all the while nodes confirm to Mobility Management Schemes. The nodes periodically update the neighbours based upon their random movement and form associativity amongst the nodes for Mobility Management Scheme as proposed.

3 Mobility management scheme

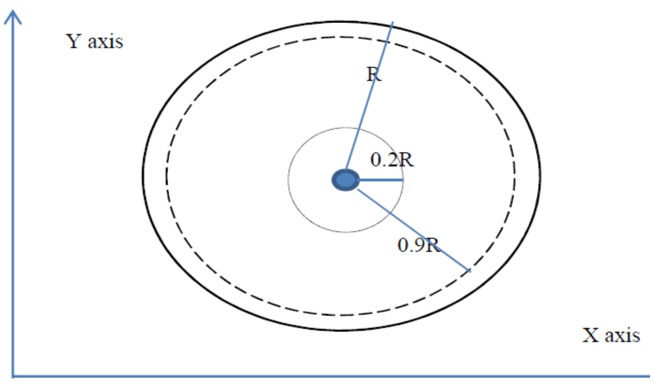
Mobility management scheme is explained with the help of two components: node binding scheme and probability of nodes being available to each other based upon transmission range.

3.1 Node binding scheme

Nodes having Omni Antenna transmit in a circular fashion with node forming the epicentre of an imaginary circle whose radius is the transmission range I of the node. The nodes periodically update their neighbours at specified intervals and send packets to the nodes which are in close proximity with each other. Once a neighbour has been established by a sending node then the neighbour is not allowed to move out of a specified area of location of source node.

Let R be the radius of circle of transmission range and there be defined a threshold distance D_{th1} which is equal to R, i.e. $D_{\text{th1}}=R$ (as shown in Figure 1).

Figure 1 Transmission radius representation (see online version for colours)



Now $\exists\, Y \in Y_k$ s.t. $|Y_k - Y_0| = Y_{\text{dis}}$ and $\exists\, X \in X_k$ s.t. $|X_k - X_0| = X_{\text{dis}}$

$$\text{Therefore, } \sqrt{(Y_{\text{dis}})^2 + (X_{\text{dis}})^2} = R = D_{\text{th1}} \tag{1}$$

Let maximum displacement threshold for any node at any location can be put in inequalities 2 and 3 as below where maximum displacement of paired node from the sending node is .9R and minimum displacement from the sending node is .2R.

$$\sqrt{(Y_{\text{dis}})^2 + (X_{\text{dis}})^2} \le 0.9R \tag{2}$$

$$\sqrt{(Y_{\text{dis}})^2 + (X_{\text{dis}})^2} \ge 0.2R \tag{3}$$

The node performs a location test for other node which is receiving with the help of test condition given below.

$$0.2R \le \sqrt{(Y_{\text{dis}})^2 + (X_{\text{dis}})^2} \le 0.9R \tag{4}$$

If the condition is violated, the node shall reset its path to align with the master node and shall keep on doing so, till the next agreed time interval when One Hop Packets are broadcast and network topology is available afresh.

3.2 Probability of the receiving node lying in the coordinate space created for the node movement

Transmission range is R and area of transmission for omnidirectional antenna is A_T

$$A_T = \pi R^2 \tag{5}$$

Let $.X_1R$ be the outer boundary and $.X_2R$ be the inner boundary, and area of circle for outer boundary, A_{out}

$$A_{\text{out}} = \pi(.X_1R)^2 = (.X_1)^2\, \pi R^2 \tag{6}$$

Area of inner circle, $A_{\text{inn}} = \pi(.X_2R)^2 = (.X_2)^2\, \pi R^2$ (7)

Area left outside the outer boundary, $A_{\text{left}} = A_T - A_{\text{out}}$

Total area not allowed for node movement, A_{not}

$$A_{\text{not}} = A_{\text{left}} + A_{\text{inn}} \tag{8}$$

Hence, $A_{\text{not}} = [.X_2^2 + (1 - .X_1^2)^2]\, \pi R^2$ (9)

Let P_b be the probability of not finding neighbour node in the space created for neighbour node movement.

$$\begin{aligned} P_b = A_{not} / A_T &= \left[.X_2^2 + \left(1 - .X_1^2\right)^2\right] \pi R^2 / \pi R^2 \\ &= .X_2^2 + (1 - .X_1^2)^2 \end{aligned} \tag{10}$$

In our model $X_1 = 0.9$ and $.X_2 = 0.2$

Hence, $P_b = .04 + (1 - .81) = .04 + .19 = 0.23$

Therefore, P_a the probability of finding the node within the customised range due to mobility management scheme is 0.77 when node movement is restricted according to equation (4). The experimental setup and results drawn in this work are according to the above expressions and assumptions.

4 Simulation and results

NS2.34 simulator is used for setting up the trials for testing the AODVMM protocol. NS 2.34 simulator can be found freely to be used and is available at http://www.isi.edu/nsnam/ns. It is also pertinent to mention the Vint Project which is available at http://www.isi.edu.nsnam/vint and Tutorials by Marc Greis found at http://www.isi.edu/nsnam/ns/tutorial for completion of this work.

Nodes were assigned behaviour as discussed in Mobility Management (MM) scheme in the previous sections. Nodes update their locations periodically as provided in MM scheme. Each node has been assigned functionalities which are very similar to ferries. The receiving node after establishing association according to MM scheme does not move out of the outer threshold radius while it is receiving and also can't come too close due to limitations on its movements due to inner threshold radius. Hence, node movement is constantly controlled by the inner and outer boundaries of imaginary circle whose radius is same as that of transmission range. The associations between communicating nodes are lasting for fixed time duration and once one time interval elapses, the node is free to form fresh associations. The results are plotted using Xgraph utility of Linux .R-GUI software was used for the purpose of statistical validation of the results thus achieved and ggplot2 library of R-GUI was used to plot the comparative data graphs, after validating the data.

We have used some notations in this work which are indicative of the parameters under which the simulation environment was set. These notations indicate about the parameter of interest for particular set up. Sufficient numbers of trials were carried out to establish the validity of the results which were received.

The parameters which have been observed in the trials are Average End to End Delay, Packet Drop Ratio and Throughput. The experimental observational data was evaluated for Normality by conducting normality tests and was validate using parametric tests. If data was not confirming to normal tests the data has been verified by non-parametric tests. All the validation has been done with minimum of 95% confidence interval. Table 1 contains notations used for the indication of simulation parameters and Table 2 has the simulation parameters.

Table 1 Notations used

Notation	*Significance*
AODV	Advanced On-Demand Vector, when MM scheme is not Deployed
AODVMM	AODV with Mobility Management Scheme
AODVMMRR	AODV with Mobility Management Scheme under Reduced Transmission Range
AODVMMLB	AODV with Mobility Management Scheme under Reduced Buffer Space
AODVRRLB	AODV under Reduced Transmission Range and Reduced Buffer Space
AODVMMRRLB	AODV with Mobility Management Scheme under Reduced Transmission Range and Reduced Buffer Space
PDR	Packet Drop Ratio
EED	Average End to End Delay
THROUGHPUT	Total Throughput observed for all the nodes in the network. Recorded as Percentage.

Table 2 Simulation parameters

Parameter	*Value*
Network area	500 m × 500 m, 800 m × 800 m
No. of nodes	5, 8
Data traffic	CBR, Constant Bit Rate
Packet size	512 Kb
Speed of nodes	20 m/s, for all nodes
Transmission range	100 m/70 m (Normal/RR)
Buffer size	10/7, 20/14 (Normal/LB) (5 nodes, 8 nodes)

The trial was carried out for varying number of nodes for a network size of 500X500 by deploying five and eight nodes. It was witnessed that in case of five nodes deployed in network, gains are observed in case of deployment of MM scheme on AODV. The gains are significant as confidence interval up to 99.5% is achieved while making some comparative analysis of Analysis of variance for similar scenarios.

But, as we increase the node population from five to eight the improvement observed in parameters under study is insignificant and does not qualify statistically. When numbers of nodes are increased then the nodes are relatively closer and deployment is less sparse. Owing to proximity of nodes the gains made due to MM scheme are not significant. Further, as we increase the area of operation, i.e., the network size to 800X800 for a node population of 8 the improved performance with respect to parameters of interest can be witnessed again.

The MM scheme exhibits significant gains for throughput of the network. The graph plots substantiate the same. Figures 2, 3, 4 all show gain when MM scheme is deployed but the gains in case of AODVMM with eight nodes in 500X500 are not significant statistically. Table 3 elaborates on this.

Figure 2 Throughput, five nodes (AODV vs. AODVMM) (see online version for colours)

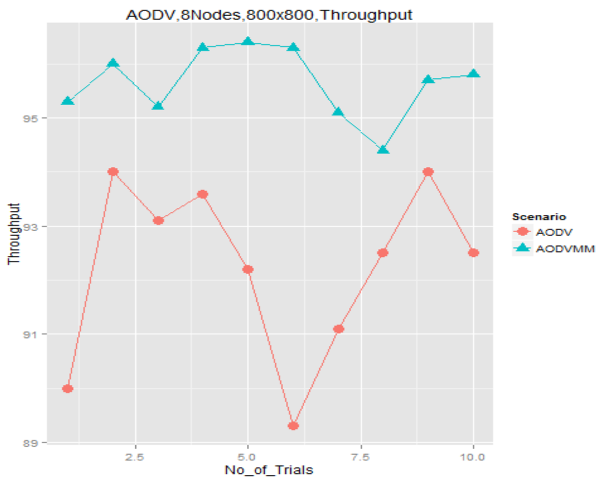


Figure 3 Throughput, eight nodes (AODV vs. AODVMM) (see online version for colours)

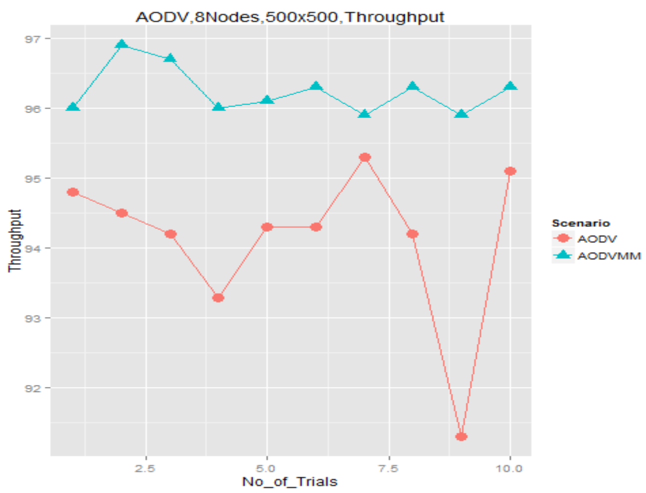


Figure 4 Throughput, eight nodes (AODV vs. AODVMM) (see online version for colours)

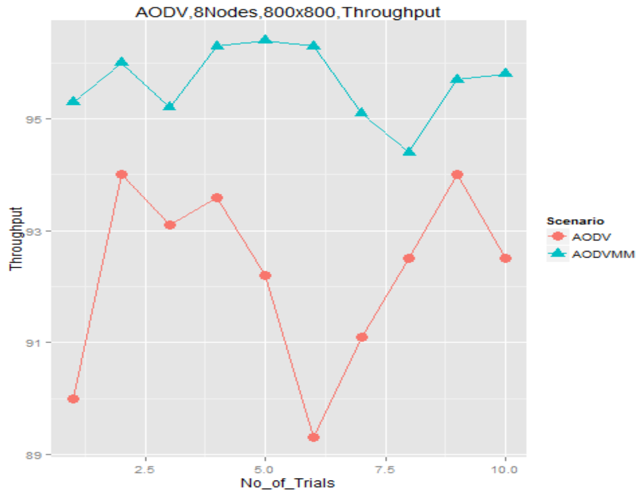
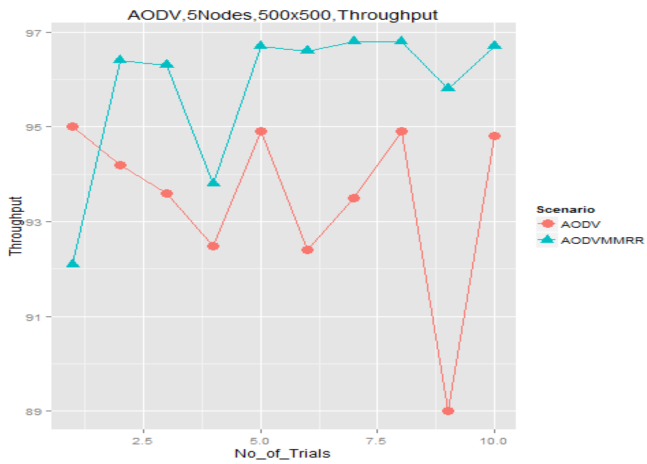


Table 3 Simulation parameters and statistical results for throughput under normal conditions

Comparison	*Significance value*	*Confidence interval*	*Conclusion w.r.t. to network size and no of nodes deployed*
AODVMM-AODV (5 nodes, 500 × 500)	0.0003	Valid for CI of 95, 97.5, 99.5	AODVMM is better in five nodes, 500 × 500 with throughput as a parameter of interest
AODVMM-AODV (eight nodes, 500 × 500)	0.0408	Valid for CI of 95 only-lesser	AODVMM is better in eight nodes, 500 × 500 with throughput as a parameter of interest
AODVMM-AODV (eight nodes, 500 × 500)	0.0000	Valid for CI of 95, 97.5, 99.5	AODVMM is better in eight nodes, 500 × 500 with throughput as a parameter of interest

Figure 5 Throughput, five nodes (AODV vs. AODVMMRR) (see online version for colours)



In Figures 5, 6, 7 Mobility Management Scheme is put to test along with Reduced Transmission Range conditions. When transmission range is reduced the node has to be mobile in lesser area while receiving data and nodes will be in proximity with each other. Hence gains are there to be seen. However, when more nodes populate the same area then the data has to move more hops to reach destination. Owing to this phenomenon the packets would be lost due to overloading at buffers hence lesser gains are seen when more nodes are deployed in same area. The gains are witnessed again when network area is enhanced for higher node number. Table 4 elaborates the results statistically.

Figure 6 Throughput, eight nodes (AODV vs. AODVMMRR) (see online version for colours)

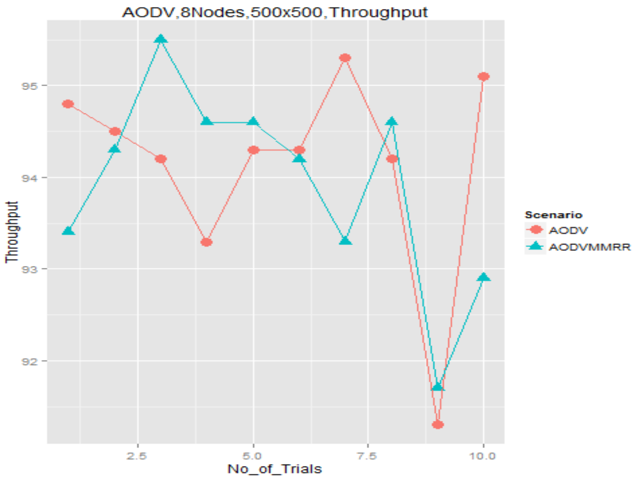
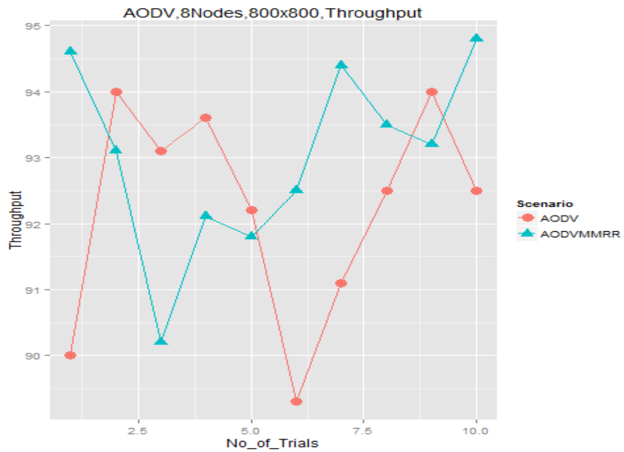


Figure 7 Throughput, eight nodes (AODV vs. AODVMMRR) (see online version for colours)



Figures 8, 9, 10 are plots when nodes are communicating under depleted conditions of Reduced Transmission Range and Reduced Buffer at their disposal. It can be seen very clearly that when Mobility Management scheme is deployed along with the Reduced Transmission and Reduced Buffer conditions, the network performance improves significantly for network size of 500x500 with five nodes as node population. When the numbers of nodes are increased to eight for network size of 500x500, then the gains are not so significant whereas the same network performance shows significant enhanced throughput when for eight nodes and network size of 800x800. Table 5 carries the values of pairwise comparisons and their inferences, statistically. The Mobility Management scheme when combined with reduced transmission range (refer Figure 11) or reduced buffer (refer Figure 12), clearly has higher end to end delay for network deployment without any modifications, in network parameters for a network size of 500x500 with node population of five nodes. However, as shown in Figure 13 and Figure 14 the end to end delay observed in network is on higher side for mobility managed scheme with reduced transmission range and low buffer as than without mobility management scheme under reduced range and reduced buffer as shown in Figure 15 and Figure 16. Table 6 has statistical parameters for these scenarios.

Table 4 Simulation parameters and statistical results for throughput under reduced resource along with low buffer conditions

Comparison	*Significance value*	*Confidence interval*	*Conclusion w.r.t. to network size and no. of nodes deployed*
AODVMMRRLB-AODVMMRR (five nodes, 500 × 500)	0.0000	Valid for CI of 95, 97.5, 99.5	AODVMMRRLB is better in five nodes, 500 × 500
AODVMMRRLB-AODVMMRR (eight nodes, 500 × 500	.0824	Not significant	Gains are lost
AODVMMRRLB-AODVMMRR (eight nodes, 500 × 500)	.0016	Valid for CI of 95, 97.5	AODVMMRRLB is better in eight nodes, 500 × 500

Figure 8 Throughput, five nodes (AODVMMRRLB vs. AODVRRLB) (see online version for colours)

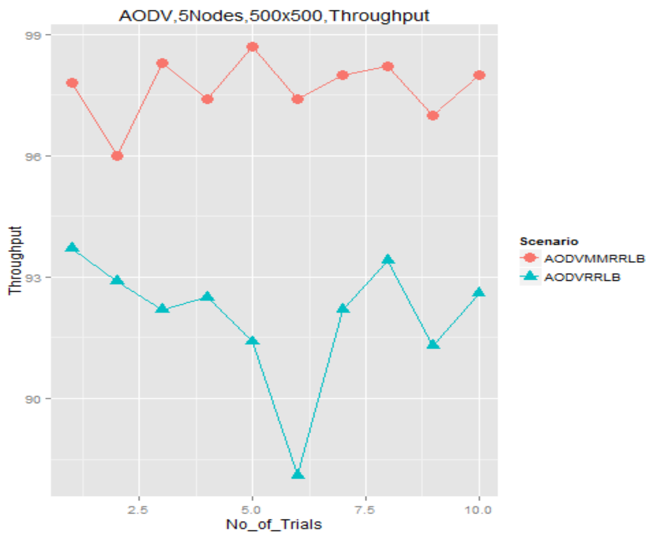


Figure 9 Throughput, eight nodes (AODVMMRRLB vs. AODVRRLB) (see online version for colours)

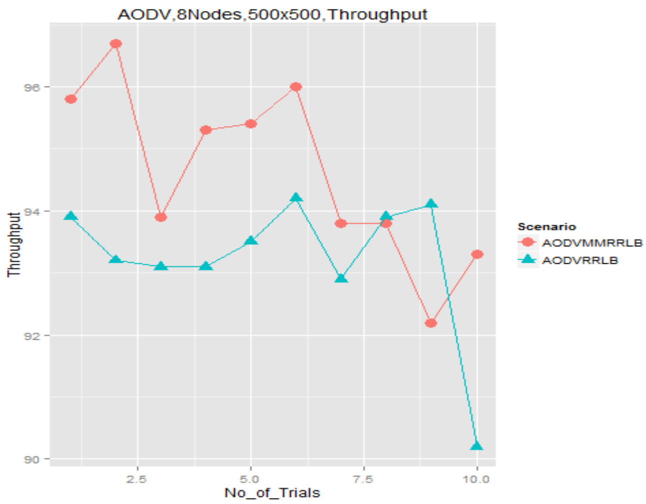


Figure 10 Throughput, eight nodes (AODVMMRRLB vs. AODVRRLB) (see online version for colours)

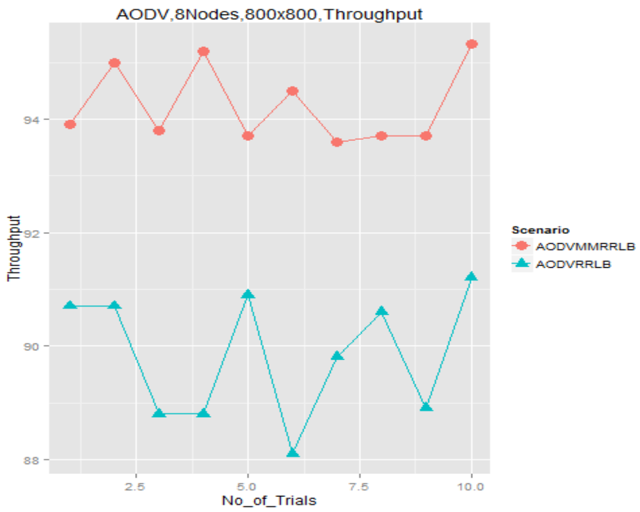


Figure 11 End to end delay, five nodes (AODVMMLB vs. AODV) (see online version for colours)

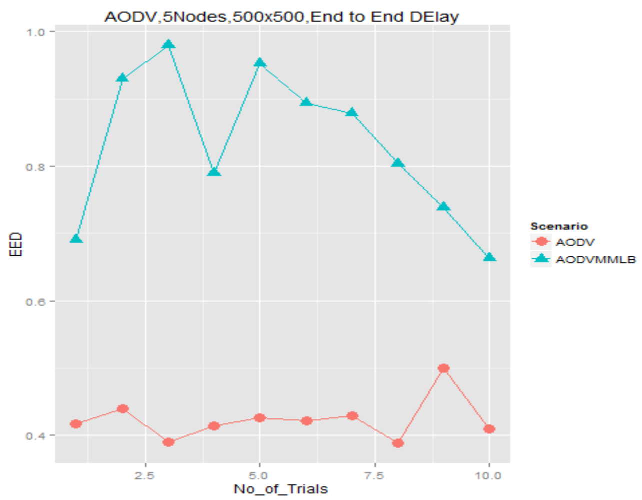


Figure 12 End to end delay, five nodes (AODVMMRR vs. AODV) (see online version for colours)

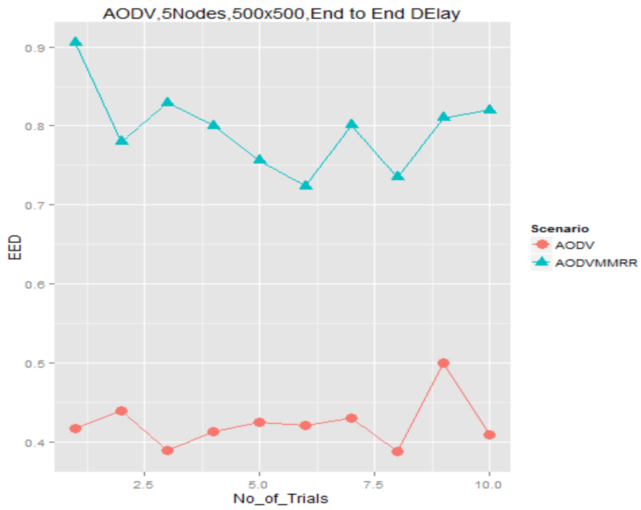


Figure 13 End to end delay, eight nodes (AODVMMRR vs. AODV) (see online version for colours)

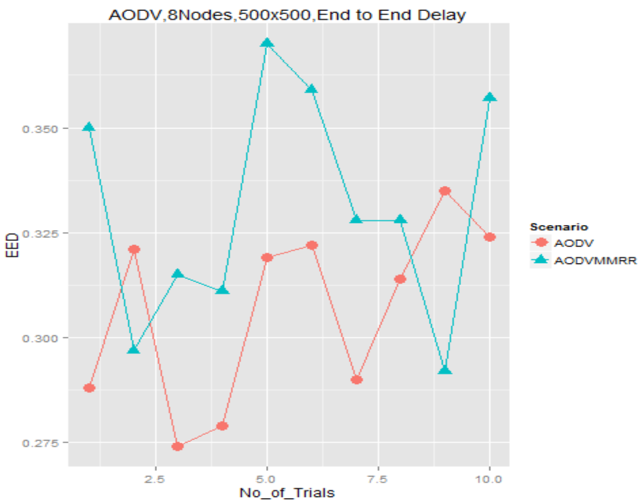


Figure 14 End to end delay, eight nodes (AODVMMLB vs. AODV) (see online version for colours)

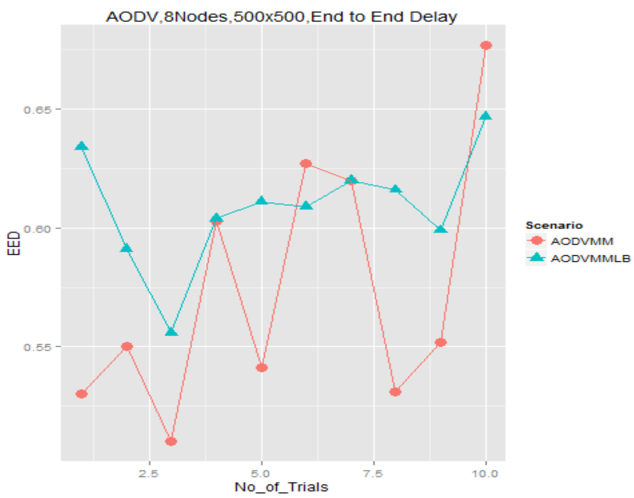


Figure 15 End to end delay, five nodes (AODVMMRRLB vs. AODVRRLB) (see online version for colours)

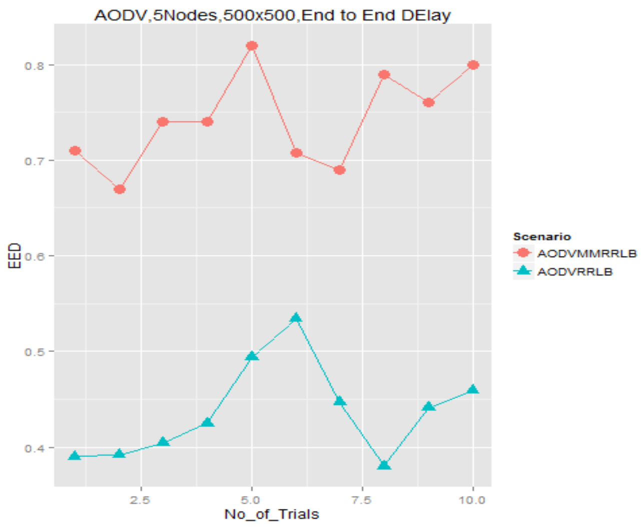


Figure 16 End to end delay, eight nodes (AODVMMRRLB vs. AODV) (see online version for colours)

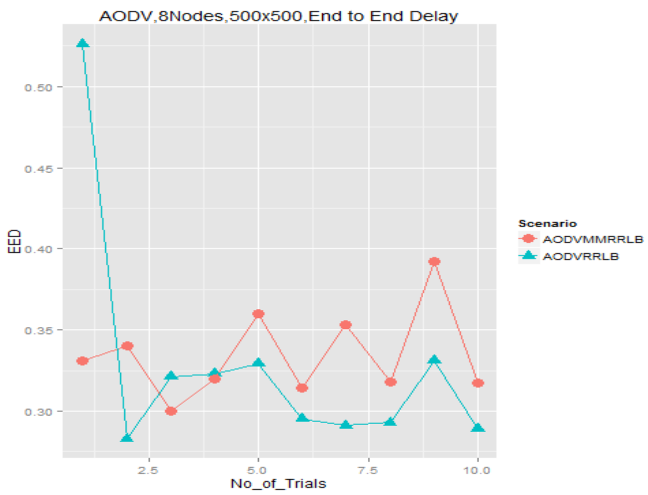


Table 5 Simulation parameters and statistical results for throughput under reduced resource conditions

Comparison	*Significance value*	*Confidenc e interval*	*Conclusion w.r.t. to network size and no. of nodes deployed*
AODVMMRR-AODV (five nodes, 500 × 500)	0.0031	Valid for CI of 95, 97.5	AODVMMRR is better in five nodes, 500 × 500 with throughput as a parameter of interest
AODVMMRR-AODV (eight nodes, 500 × 500)	0.9981	Not significant	AODV is better, AODVMM loses gains
AODVMMRR-AODV (eight nodes, 800 × 800)	0.0502	Valid for CI of 95	AODVMMRR is better in eight nodes, 800 × 800 with throughput as a parameter of interest

Table 6 Simulation parameters and statistical results for end to end delay under all conditions

Comparison	*Significance value*	*Confidence interval*	*Conclusion w.r.t. to network size and no. of nodes deployed*
AODVMMRR-AODVMM (five nodes, 500 × 500)	0.0000	Valid for CI of 95, 97.5, 99.5	Higher delay under reduced range
AODVMMLB-AODVMM (eight nodes, 500 × 500	.0000	Valid for CI of 95, 97.5, 99.5	Higher delay under low buffer
AODVMMRRLB-AODVRRLB (five nodes, 500 × 500)	.0000	Valid for CI of 95, 97.5, 99.5	Higher delay under MM scheme
AODVMMRR-AODVMM (eight nodes, 500 × 500)	.7957	Invalid	Can't be relied upon
AODVMMLB-AODVMM (eight nodes, 500 × 500)	.4531	Invalid	Can't be relied upon
AODVMMRRLB-AODVRRLB (eight nodes, 500 × 500)	.9994	Invalid	Can't be relied upon

5 Significance of results

We can see that throughput parameter shows marked improvement in mobility management scheme. In pairwise comparison of AODVMM to AODV, we can see end to end delay shows insignificant variance so as to be considered and we can clearly conclude that AODVMM clearly scores when throughput is the parameter of interest without any causal effects on end to end delay of the network. The same is not found for pairwise comparison of AODVMMRR with AODV as this leads to higher end to end delay witnessed in the case of MM scheme. Hence this gain in throughput comes with a trade-off of higher end to end delay. The pairwise comparisons for AODVMMRRLB with AODVRRLB shows significant gains for throughput parameter but again at the cost of higher end to end to delay.

For all other pairwise comparisons the throughput gains observed under MM schemes like AODVMMLB, AODVMMRR in comparison to AODV the end to end delay does not show any change on higher or lower side. Hence, we can conclude that AODVMM schemes when coupled with RR and LB give higher throughput at the cost of longer delays but when MM scheme is coupled with RR (AODVMMRR) and LB (AODVMMLB) and compared against AODV the it shows higher throughput but end to end delay parameter is not disturbed, hence the gains made are not at the cost of higher end to end delay.

Higher end to end delay in MM schemes when coupled both with RR and LB, is being witnessed because nodes when are in close proximity, they work within a small area and owing to lower buffers the node transmits more packets to intermediate nodes before the packet is delivered to destination nodes. The nodes being in close proximity to each other facilitate this forwarding function more efficiently when relatively degree of sparseness is higher, and the moment the network population is increased for the same area of operation, the presence of more nodes under guided mobility schemes leads to creation of more network traffic within the same area and the depleted buffers cannot handle as much traffic and it is a kind of flooding phenomenon that will happen within the sparse deployment. Hence, as expected this will lead to more packet loss and hence lower throughput.

6 Conclusions and future scope

We can conclude with a fair degree of surety that deployment of AODVMM leads to higher throughput witnessed in the network in comparison to AODV under sparse deployment conditions. This gain is witnessed without any improvement in end to end delay but this also does not lead to higher end to end to delay under AODVMM which is very encouraging.

But the gains in throughput under AODVMMRR and AODVMMLB in comparison to AODVMM scheme come at a cost of higher end to end to end delay under sparse deployment conditions.

Similarly, the gains are extremely significant for AODVMMRRLB under sparse deployment in comparison to AODVRRLB. One would assume RR and LB should not have any effect on end to end delay as the comparison should be similar to AODVMM vs. AODV. But when we reduce transmission range and nodes have lower buffer AODV protocol shows higher end to end delay under MM than without MM at the cost of higher end to end delay. This shows that MM scheme does provide higher throughput under degraded nodes within a sparse deployment but the gain does not come with improvement in end to end to delay.

In our future works we will try to modify the MM scheme so that end to end delay does not increase. Also since in other scenarios the end to end delay is insignificant we would explore the effect of MM scheme on battery consumption as it is our assumption that when more throughput is achieved it will result in less power consumption. We shall also compare the effect of MM schemes on proactive and hybrid protocols.

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