PERFORMANCE EVALUATION OF GENERIC ROUTING PROTOCOLS IN MOBILE AD HOC NETWORKS

Bachelor of Technology

In

Computer Science & Engineering

By

ARUN LAKRA

110CS0129

Department of Computer Science and Engineering

National Institute of Technology, Rourkela

Rourkela, Sundargarh,

Odisha, 769008

May, 2014

PERFORMANCE EVALUATION OF GENERIC ROUTING PROTOCOLS IN MOBILE AD HOC NETWORKS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Computer Science & Engineering
By

ARUN LAKRA
110CS0129

Under the guidance of:
Prof. P.M. Khilar

Department of Computer Science and Engineering
National Institute of Technology, Rourkela
Rourkela, Sundargarh,
Odisha, 769008
May, 2014

Department of Computer Science and Engineering
National Institute of Technology, Rourkela
Rourkela – 769008, Odisha

Certificate

This is to certify that the work in the thesis entitled "**Performance Evaluation of Generic Routing Protocols in Mobile Ad Hoc Networks**" submitted by **Arun Lakra**, is a record of authentic and original research work carried out under my supervision and guidance in partial fulfilments of the requirements for the award of Bachelor of Technology Degree in the department of Computer Science and Engineering at National Institute of Technology, Rourkela.

Place: NIT Rourkela
Date: May, 2014

Prof. P.M. Khilar
Dept. of Computer Science and Engineering
National Institute of Technology, Rourkela
Odisha-769008

Acknowledgement

I would like to express my sincere and earnest gratitude and thanks to my advisor Prof. P.M. Khilar for giving me continuous support and guidance for my research. His inspiration, timely suggestions and immense knowledge to helped me in this thesis research and writing, all the time. This project would not have been completed without him.

Along with my advisor, I also thank all other faculty members of Computer Science and Engineering, NIT Rourkela branch and would like to convey my deep respect.

I also thank my parents for the full support of my thesis work.

I also would like to thank all those who helped in this work who I haven't mentioned here but have helped me accomplish this project.

Arun Lakra
110CS0129
arun.lakra15@gmail.com

Abstract

Mobile Ad hoc Network or MANET in short is a self-configuring and infrastructure-less network of mobile nodes or devices that are connected wirelessly. There is no local base yet every device in a MANET is allowed to move autonomously in any pattern, consequently changing its connection to different devices much of the time. Each must act as a router and forward traffic. Each device or node participating in a MANET forwards data for other nodes, so the nodes forwarding data are dynamically determined on the basis of network connectivity. Ad hoc networks can use flooding for forwarding data. Mobile Ad-hoc networks generally have a routable systems network environments on top of the link layer.

Mobile ad hoc networks have a dispersed nature which makes it suitable for a mixture of applications. Here local nodes cannot be depended on and can enhance versatility of interconnected systems in correlation from wireless networks which are managed.

In my thesis, I've evaluated and implemented mobile ad hoc protocols in NS2 simulator and simulated the protocols under different network parameters. The following protocols have been taken from three different categories:-

i) Reactive Routing – DSR, AODV
ii) Hybrid Routing – ZRP

Contents

List of Figures

CHAPTER 1
INTRODUCTION

1.1 MOBILE AD-HOC NETWORKS (MANETs)

Mobile Ad hoc Network (MANET) simply stating, is a collection of mobile nodes, with no necessary support from existing infrastructure of existing network or any other kind of fixed stations. A formal statement can be made defining an ad hoc network with a stand-alone or autonomous and infrastructure-less system of mobile hosts or routers wirelessly connection, collectively forming an arbitrary graph like communication network. Communication between two mobile nodes-in a cellular network model supporting wireless communications by base stations as access points rely completely on the fixed base stations and wired backbone. However, such infrastructures doesn't exist in a mobile ad hoc and might involve unpredictable and dynamic change in network topology because nodes can move arbitrarily and freely [10].

Basically, MANETs are multi hop peer-to-peer mobile networks of wirelessly connected nodes where transmission of information packets take place in a keep and forward way through intermediate nodes from source to a destined node. As nodes start moving, topology change in the network that is incurred should be made aware to other nodes so that the out of date topology information of the network can be improved or removed [10, 1].

Recent advancements in wireless technologies and portable computing are opening up future possibilities for wireless networking. MANETs are considered as promising communication networks where self-configuration plays an essential role. Ad hoc networks have several applications. In fact, everyday applications like file transfer or email can easily be deployed in an environment of wireless ad hoc. It was originally developed for military applications, such as battle-field in a hostile territory where infrastructure connection is infeasible to maintain. Ad hoc networks have the feature of self-structure and organization which can also be used efficiently and effectively used. Its best use comes where different innovations either fall flat or can't be conveyed viably. Advance features includes global roaming capability and network structure coordination [8, 3].

Also, the ever popular Wi-Fi i.e. IEEE 802.11 protocol provides capability of ad hoc networking, although no access point is available. Here in IEEE 802.11, it restricts the nodes to receive and send packets however they don't participate in routing anything within the network [2, 4].

MANETs can be of several types such as, Vehicular Ad hoc Networks (VANETs), Internet based mobile ad hoc networks (iMANETs), and Intelligent vehicular ad hoc networks (InVANETs) [10].

1.2 PROJECT OUTLINE

Popular routing protocols include DSR and AODV. ZRP is a hybrid protocol which uses both reactive and proactive protocols while sending information in the network.

Project objectives include:

i) Simulating the pre implemented DSR, AODV and ZRP protocols.

ii) Compare the performance of these three protocols

iii) Compare Ad-AODV with AODV

1.3 MOTIVATION AND OBJECTIVES

Many people today carry numerous portable devices including laptops, mp3 players and PDAs, mobile phones, for extensive use in their private and professional lives. Mostly, applications of these devices do not interact, rather they are used separately. Only if they could interact directly and interactively: such as sharing documents or presentations at a meeting between participants; business cards automatically finding their way into the address register on a laptop and the number register on a mobile phone, laptops turning online as commuters exiting a train. In the same manner, incoming email could now be diverted to their PDAs. As people enter their office, all communication could automatically be routed through the wireless corporate campus network [10, 1].

CHAPTER 2
LITERATURE REVIEW

2.1 MOBILE AD-HOC NETWORK OVERVIEW

MANETs are essentially different or not quite the same as traditional routing in infrastructure networks. Routing in MANETs relies on several factors which includes topology, router selection, request initiation and heuristic characteristics in discovering way rapidly and effectively. A mobile ad hoc network requires proficient usage of assets and subsequently it cultivates the inspiration for the idea of optimal routing and efficient energy usage. Additionally, the exceptionally alterable nature of such systems force extreme imperatives on routing protocols particularly and discretely intended for them. Therefore, it motivates and encourages the study of protocols aiming at achieving routing stability [3, 6].

2.2 CHALLENGES

Major challenges in a routing protocol originates when a node tries to find at any rate the information to reach its neighbours to decide a route. In an ad hoc network, network topology can change quite frequently. Discovering routes to the destinations also requires frequent and large exchange of control information among the nodes, as the number of network nodes can be large. Hence, the amount of update can be surprisingly high, and it increases to even greater heights in the presence of mobility nodes. These high mobile nodes can affect a router's maintenance overhead in such a manner, to the point that no data transfer capacity may stay extra for the transmission of information packet [11, 6].

2.3 PROACTIVE AND REACTIVE ROUTING PROTOCOLS

Proactive (table-driven) protocol or Reactive (on-demand) are two categorical classifications of Mobile Ad hoc routing protocols.

Proactive protocols generally need to sustain precise structured information in route entries in table. It continuously evaluates all the routes periodically in the network. Proactive protocol distributes routing tables throughout the network periodically in an effort so that routes are immediately known when a data packet needs to be forwarded. However, substantial amount of data is needed for maintaining routing information and it reacts slowly on rebuilding network and distinct node failures. Proactive protocols aren't appropriate as they use substantial network capacity fraction continuously to maintain the routing information current.

Reactive Routing protocols on the other hand does not maintain routes, but build them on demand. It employs a lazy approach where nodes only discover routes on demand. A reactive protocol searches for a route on demand by flooding the network with RREQ packets. It doesn't incur big overheads for global routing table maintenance unlike proactive protocols. Also, it reacts quickly for network restructuring and node failures. However, it involves high latency time when finding a route and extensive flood of packets can lead to network congestion. Reactive protocols often consume less bandwidth than proactive protocols. However, the delay to determine and use a route can be significantly higher than proactive protocols. In brief, no protocol is best suited for all environments [10, 11].

2.4 DYNAMIC SOURCE ROUTING (DSR)

Route cache stores routes that specifies to the destination, complete hop by hop route. Thus, the routes are source routed [4].

DSR protocol consists of route discovery and route maintenance procedure. When a source node attempts to send a data packet to a destination node for which it doesn't already have a route in its routing table, then the node invokes the route discovery procedure to determine that route. It works by flooding and broadcasting the network with route request queries. Each node getting the route request queries subsequently floods it to its neighbouring nodes unless the node is the destination node or has a route to the destination node in question. Such node which has route to the destination or is the destination itself replies with a RREP packet that is routed back to the original source node. These RREP and RREQ packets are source routed. The router carried by the RREP is then cached in the route-cache at the source [2, 4].

Route Reply packets are generated by a node that has unexpired route to the destination in its route cache or is either the destination. Route record is placed into the RREP from RREQ by the node generating the RREP. If a source node has in its route cache, the source route to the destination, then it may use it. A node may initiate its own route discovery if symmetric links are not supported [7].

Route maintenance procedure is carried by the use of route error packets and acknowledgements. Route error packets are generated at a node when the data link layer encounters a fatal transmission problem. When a node receives a route error packet, it removes the hop in error from its route cache and all routes containing the hop are truncated at that point [9].

2.5 AD HOC ON-DEMAND DISTANCE VECTOR (AODV)

RREQ are flooded in the network in order to determine a route to a destination from source node. RREQ is broadcasted to its neighbours by the originating node, which further floods the message to its neighbours and the process continues. A node receiving a RREQ sends an RREP through the reverse path if the node is itself the destination or knows a fresh enough route [2].

A node generating RREQ may receive multiple RREP message from nodes. The node then finds the route with greatest sequence number and updates its routes with most recent information [2, 8].

Each node here maintains a route request buffer which contains a list of recently broadcasted route requests, which prevents the ad hoc devices from sending same RREQs again. A node that attempts to forward a route request checks its buffer to know if it has already forwarded the RREQ [2, 13].

To send only one RREP even for multiple RREQ received, RREQ buffers are also maintained by nodes originating a RREP message. To identify the originated request uniquely, a value pair consisting of source address and RREQ identification number are used [4, 13].

AODV nodes maintain destination sequence numbers which is attached in a route entry to indicate the time at which the route was created. Furthermore, every node in an effort to indicate a logical time, maintain a sequence number that monotonically increases [3].

2.6 ZONE ROUTING PROTOCOL (ZRP)

Zone Routing Protocol was the first hybrid routing protocol with both the features of a proactive and a reactive routing component. ZRP is proposed to reduce control overhead and latency caused by protocols i.e. reactive and proactive respectively. Zone Routing Protocol defines a zone for each node consisting of its k-neighbourhood. A routing zone is defined for each node and includes the nodes whose minimum distance in hops from the node in question is at most or within some predefined number i.e. the distance and a node, all nodes within a particular hop distance belongs to the routing zone of the node [5].

ZRP constitutes of two sub-protocols, IARP and IERP. The proactive routing protocol, IARP which stands for Intra-zone Routing Protocol is used inside routing zones. IERP stands for Inter-Zone Routing Protocol and is used by the nodes to find routes between distinct routing zones. Whereas, IARP which stands for Intra-Zone Routing Protocol is used to maintain routing tables for destination nodes in the same routing zone; it can be established with a routing protocol that is proactive. For IARP, most of the pre-existing proactive protocol can be used efficiently [5, 9].

Route discovery beyond the local zones happen reactively. Source node initiates route discovery with sending RREQs to its border/peripheral nodes, containing its own address, the destination address and a unique sequence number. Peripheral nodes are the nodes whose minimum distance to the node in question is equal exactly to the zone radius. The peripheral nodes check their local zone for the destination. If the destination node is not a member of this peripheral node's local zone, the nodes add their own address to the RREQ packet and forward the packet to their peripheral nodes and the process continuous. If a destination node is found within the local zone of a peripheral node, it sends a RREP on the reverse path back to the source [2].

2.7 SUMMARY

Routes are immediately when a packet is needed to be forwarded, since a route is already known. This is possible because of the Proactive protocol's endeavour to constantly assess the courses inside the network. Whereas, on the other hand, route determination procedure are invoked only on demand by Reactive protocols.

In case of Proactive protocols, there is an added advantage that there is little delay when a data packet needs to be sent since the route has already been established. However, in Reactive protocols, the delay incurred can be substantial as compared to the Proactive protocols because the route information isn't available instantly; they're obtained on demand [11].

CHAPTER 3
NETWORK SIMULATION AND SETTINGS

NS2 is a widely used tool to simulate the behaviour of wired and wireless networks. It is an open-source event-driven network simulator designed specifically for research in computer communication networks. It was developed in 1989, since then it has been widely used and gained substantial interest in academics and industry. Since its inception, it has constantly been enhanced and improved for years. It contains numerous network component modules for routing, transport layer applications, etc. DSR, AODV and ZRP routing protocols can be simulated using NS2 simulator [12].

3.1 SIMULATION PARAMETERS FOR AODV DSR and ZRP

PARAMETERS AND VALUES

PARAMETERS	**VALUES**
Protocols	AODV, DSR, ZRP
Simulation time	100s
No. of Nodes	50
Simulation Area	500 x 500 m^2
Pause time	0s
Traffic Type	CBR
Maximum Speed	(05, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65) m/s
Network Simulator	NS2.35

3.2 TCL SCRIPT STRUCTURE

3.2.1 ARGUMENTS TO TCL SCRIPT

```
if {$argc != 5} {
	puts "Usage: ns simulate.tcl <Routing_Protocol> <Scenario_file>
<Traffic> <Trace_file> <Nodes>"
	puts "Example: ns simulate.tcl AODV scenario trace.tr 50"
	exit 1
}
set routingProc [lindex $argv 0]
set scenario [lindex $argv 1]
set traffic [lindex $argv 2]
set traceFile [lindex $argv 3]
set val(nn)    [lindex $argv 4]
```

Here, the simulate.tcl script takes 5 arguments, which are as follows: Routing Protocol, Scenario file, Traffic File, Trace file and number of nodes. Since, a common script is run to simulate all the protocols mentioned, an argument has been reserved for specifying the protocol name [3].

3.2.2 NODE CONFIGURATION AND NS2 OBJECT VARIABLES

```
set value(channel) Channel/WirelessChannel
set value(propagation)    Propagation/TwoRayGround
set value(antenna)        Antenna/OmniAntenna
set value(ll)        LL
set value(ifqlen)    50
set value(netif)          Phy/WirelessPhy
set value(mac)            Mac/802_11
set value(routing)        $routingProc
set value(xValue)         500
set value(yValue)         500
set value(stop)           100
set value(energyModel) EnergyModel
set value(initialEnergy) 100

set ns_ [new Simulator]
set tracefd [open $traceFile w]
```

```
$ns_ trace-all $tracefd
$ns_ use-newtrace
set topo [new Topography]
$topo load_flatgrid $value(xValue) $value(yValue)
set god_ [create-god $value(nn)]
set chan_l_ [new $value(channel)]
$ns_ node-config -adhocRouting $value(routing)
                 -llType $value(ll) \
                 -macType $value(mac) \
                 -ifqType $value(ifq) \
                 -ifqLen $value(ifqlen) \
                 -antType $value(antenna) \
                 -propType $value(propagation) \
                 -phyType $value(netif) \
                 -channel $chan_l_ \
                 -topoInstance $topo \
                 -agentTrace ON \
                 -routerTrace ON \
                 -movementTrace OFF \
                 -energyModel $value(energyModel) \
                 -initialEnergy $value(initialEnergy) \
                 -rxPower 35.28e-3 \
                 -txPower 31.32e-3
for {set i 0} {$i < $value(nn) } {incr i} {
        set node_($i) [$ns_ node]
}
```

3.2.3 SCENARIO AND TRAFFIC FILE

```
source $scenario
source $traffic
```

The scenario and traffic patterns are generated using the tools in ns2. Traffic pattern is generated using a tcl pattern called “cbrgen.tcl”. To define and specify the scenario movements of nodes, we used a “setdest” executable file in NS2 [3].

3.2.4 ENDING SIMULATION

```
$ns_ at [expr $val(stop)+0.1] "puts \"Ending Simulation...\"; $ns_ halt; exit 0"
proc stop {} {
        global ns_ tracefd
        $ns_ flush-trace
        close $tracefd
}
$ns_ run
```

3.3 PERFORMANCE METRICES AND PARAMETERS

We used the three most commonly used quantitative indicators to judge the performance of the routing protocol: Packet Delivery Ratio, Average End-to-End Delay and Throughput.

3.3.1 PACKET DELIVERY RATIO

Packet delivery ratio is defined as the ratio of the number of delivered data packet to the destination. This illustrates the consistency of delivery of data to the destination.

∑ Number of packet receive / ∑ Number of packet send

3.3.2 END TO END DELAY

End-to-End Delay can be defined as the average delay experience by data packets to arrive in the destination. It is composed of the queue in data packet transmission and the delay caused by route discovery process. Data packets that successfully make it to the destination are only counted.

∑ delay of each packet / ∑ Total connections

3.3.3 ROUTING LOAD

Normalized Routing Load (or Normalized Routing Overhead) can be defined as the total number of routing packet transmitted per data packet. It is calculated as a ratio of the total number of routing packets sent which includes forwarded routing packets as well, to the total number of data packets received.

∑ Routing packet transmitted / ∑ Total data packets

3.4 SIMULATION PLOTS

3.4.1 PACKET DELIVERY RATIO

DSR aggressively uses route caching. It may incur possible pollution in caches in other nodes. Such caching may provide significant benefit only up to a certain extent. Under higher loads, the benefit isn't substantial. Even though more latency often indicates worse congestion, both the on demand protocols choose routes using hop wise path lengths. AODV replies only to the first RREQ that arrives, and hence has a better technique.

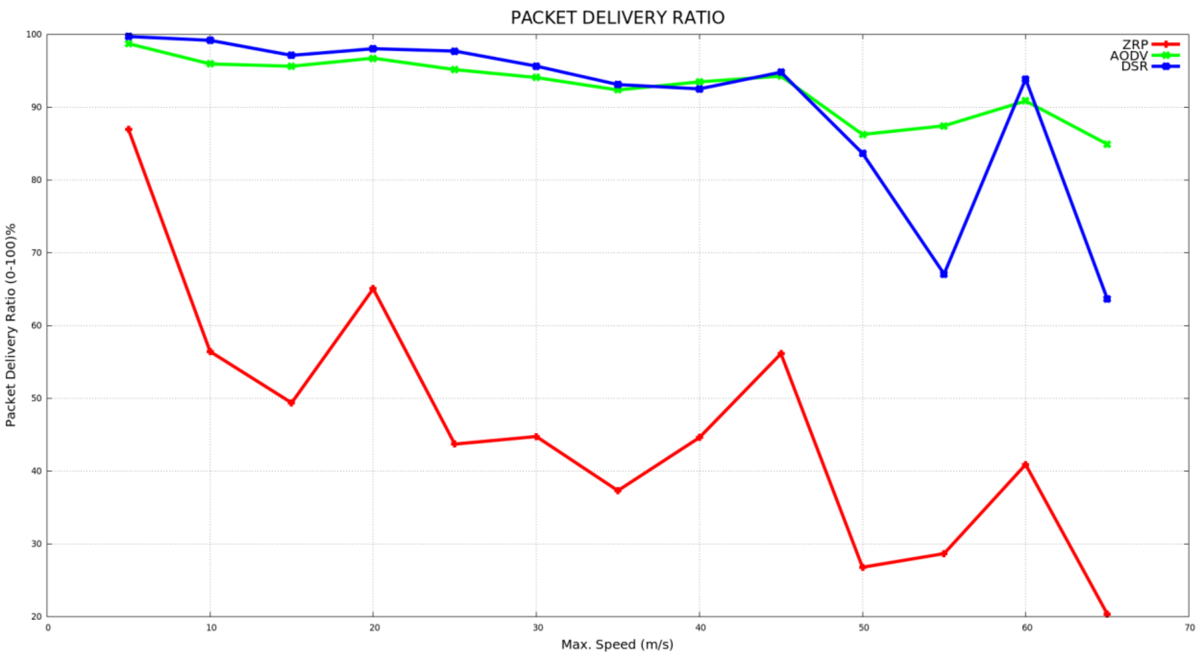


Fig 3.1 – Packet Delivery Ratio

3.4.2 END TO END DELAY

The route discovery in ZRP uses extra time, and generates more number of control packets as it is composed of three protocols i.e., BRP, IERP and IARP. The source device initializes IERP if a destination node isn't found in the routing zone. What follows, is intercommunication between IERP and IARP. IARP facilitates a node's maintenance of routing tables in its local zone. The intercommunication causes traffic in the network that is unnecessary causing route acquisition delay. As compared to DSR, AODV is less prone to network congestion. However, the congestion cause by route reply is more in case of AODV. Higher number of route error messages in AODV implies that there are more chances of error as compared to DSR. According to the simulation results, ZRP performed poorly through the entire simulation. It was easily outperformed the two on-demand protocols, hence putting itself out of competition. Also, DSR almost always has lower routing load than AODV.

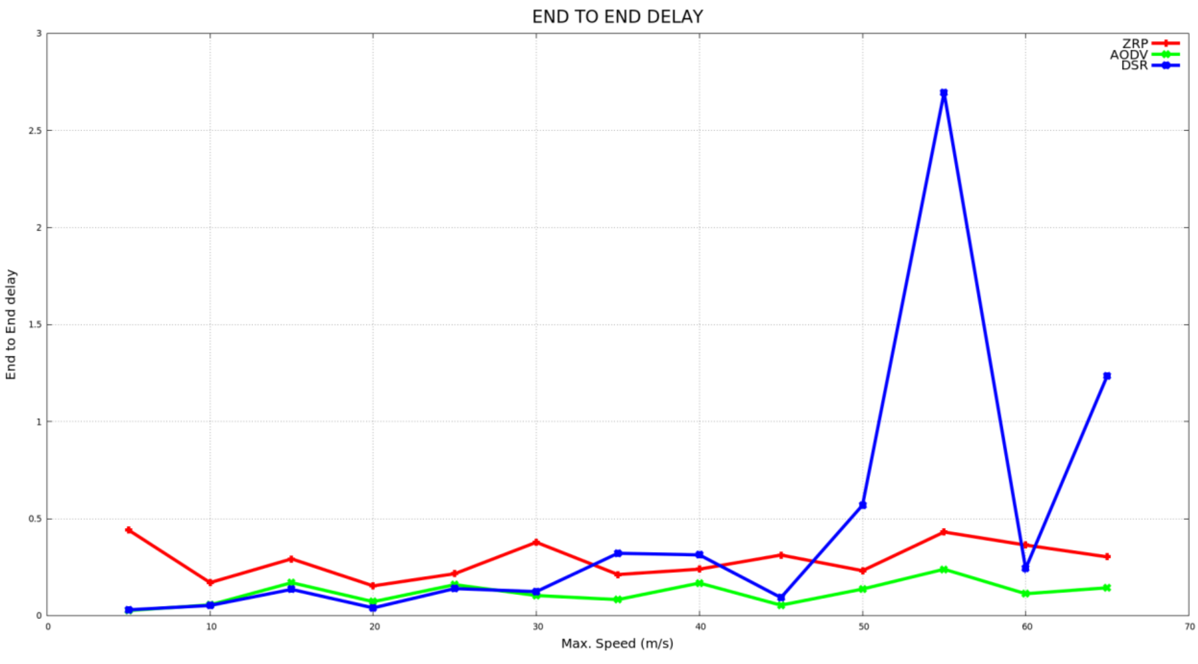


Fig 3.2 – End-to-End Delay

3.4.3 THROUGHPUT

Route discovery becomes more complicated as node's number increases in a network since there would be high amount of overlapping in routing zones. This results in heavy flooding of route request queries in the network. Intermediate nodes sending the same route request queries also becomes inevitable, hence the route acquisition delay in case of ZRP protocol will be on the higher side as the number of nodes increase.

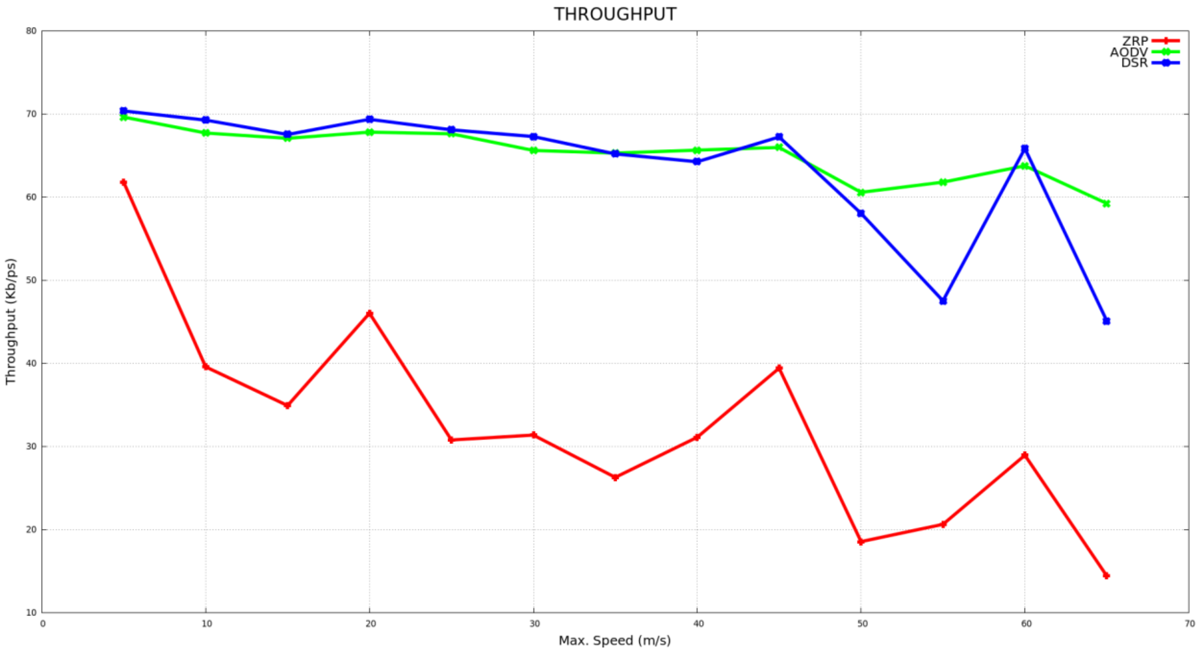


Fig 3.3 – Throughput

3.5 SUMMARY

According to the above graph plots, we can see that ZRP is outperformed by the two reactive protocols by a huge margin. Also, AODV marginally outperforms DSR.

CHAPTER 4
Ad-AODV vs AODV

4.1 Ad-AODV OVERVIEW

AODV doesn't consider the residual energy and load level of the nodes in route discovery stage in order to reduce the time of route establishment. This makes the selected routes instable. Ad-AODV as proposed by Zuhong Feng, Long Wang and Xiujuan Gao [9] is the modified AODV which considers the residual energy and load level-in the route discovery stage-of node. The improvements are the following: in the route discovery process, the generation of the broadcasted RREQ delay of the node depends on the current energy and load situation of the node. The delay calculation is based on energy and load as parameters [9].

Energy = Power x Time
Time = 8 x PacketSize / Bandwidth

Therefore,
$E_t = P_t$ x 8 x PacketSize / Bandwidth
$E_r = P_r$ x 8 x PacketSize / Bandwidth

where,
P_t = Transmission Power
P_r = Receiving Power

Total energy consumed by a node forwarding a data packet,

$E_{full} = E_t + E_r$

If the total energy at a node is E_{full}, and current residual energy is $E_{current}$, then the energy delay weights W_a is,

$W_e = 1 – E_{current}/E_{full}$

Also, if a node can hold Q_{max} packets in the buffer queue, and the current packet number is $Q_{current}$ in the buffer queue of the node, then the load delay weights W_q is,

$W_q = Q_{current}/Q_{max}$

According to the node's current residual energy and the current load of the nodes, the formula to calculate the delay time T is:

$T = (\alpha \times W_e + \beta \times W_q) \times \mu$

where,

α and β are two constants with values, $\alpha = \beta = 0.5$

μ is a delay constant with $\mu = 0.01$

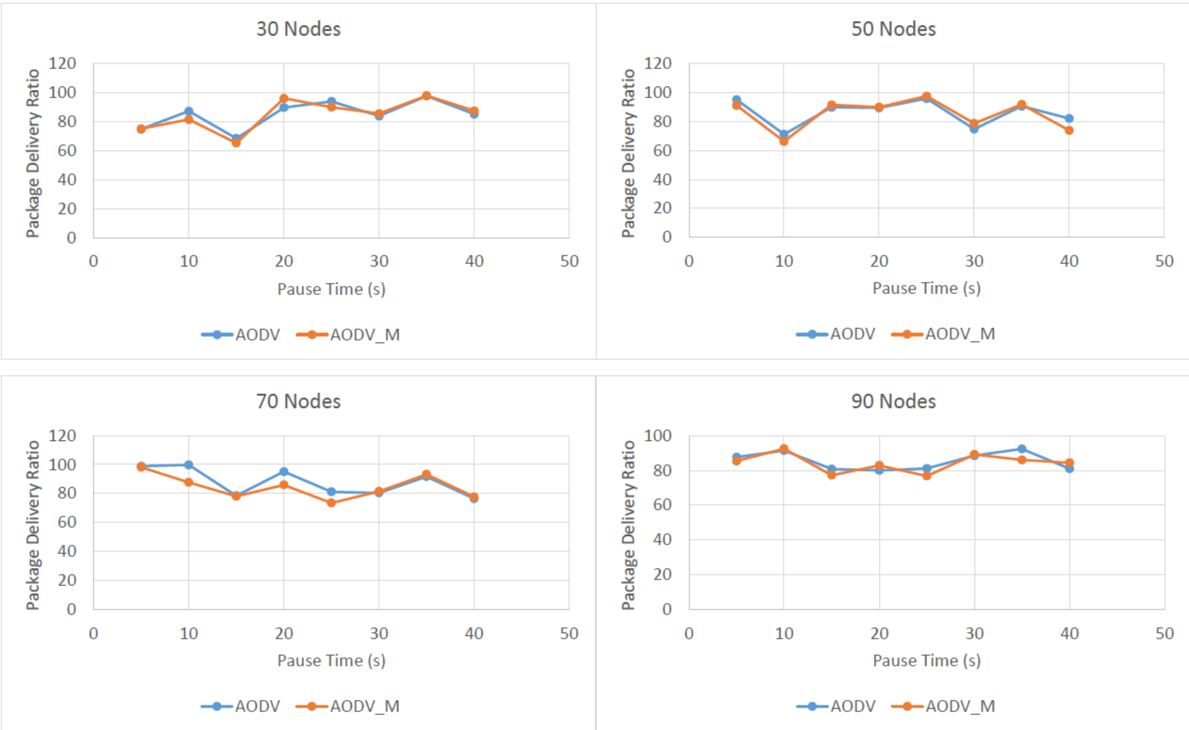
We then simulate this modified Ad-AODV with pre-existing AODV protocol and compare performances.

4.2 SIMULATION PARAMETERS FOR Ad-AODV and AODV

PARAMETERS	**VALUES**
Protocols	AODV, Ad-AODV
Simulation time	100s
No. of Nodes	30, 50, 70, 90
Simulation Area	500 x 500 m^2
Pause time	(05, 10, 15, 20, 25, 30, 35, 40)s
Traffic Type	CBR
Maximum Speed	20 m/s
Network Simulator	NS2.35

4.3 SIMULATION PLOTS

4.3.1 PACKET DELIVERY RATIO



Packet Delivery Ratio reflects the stability of selected routes. Higher is the stability of the routing protocol, higher the packet delivery ratio.

For simulation of 30 nodes, we get a performance decrease of 2.28%.

For simulation of 50 nodes, we get a performance decrease of 1.31%.

For simulation of 70 nodes, we get a performance decrease of 8.02%.

For simulation of 90 nodes, we get a performance decrease of 1.99%.

Fig 4.1 – Packet Delivery Ratio

4.3.2 END-TO-END DELAY

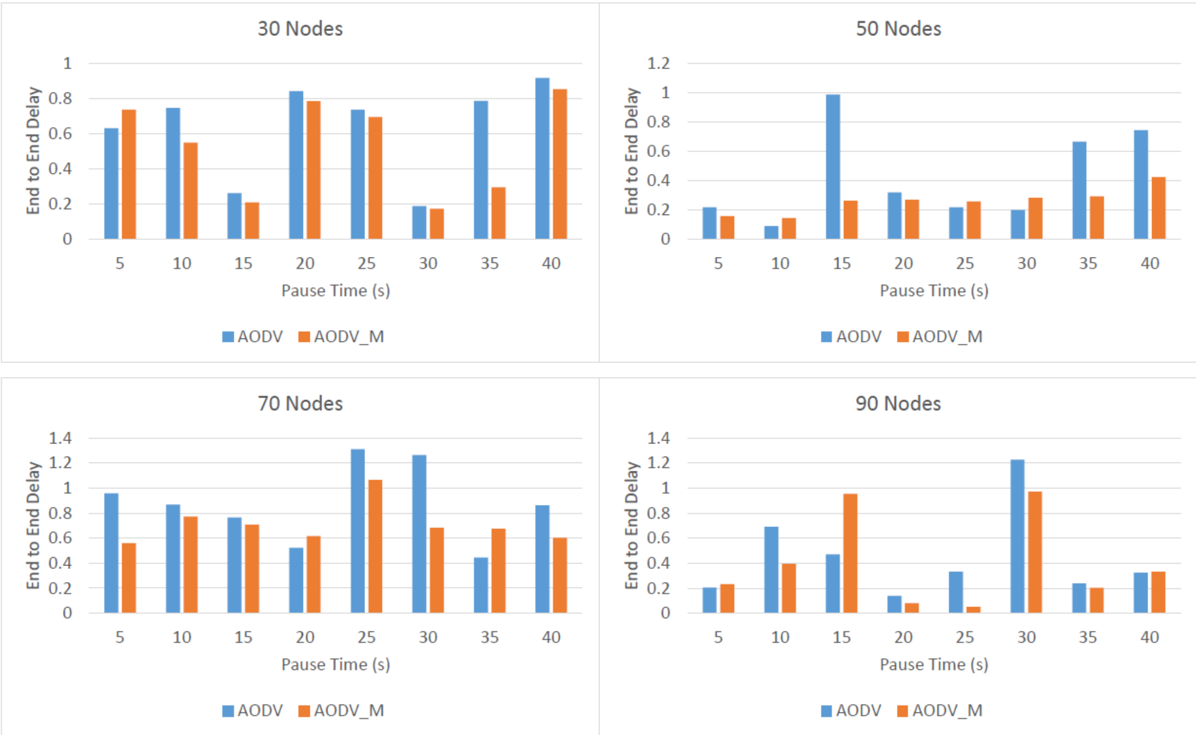


Fig 4.2 – End-to-End Delay

End-to-End Delay refers to the average delay incurred for a packet or time taken to reach the destination from source. It consists of queuing delay, transmission delay, processing delay, and propagation delay.

For simulation of 30 nodes, we get a performance increase of 15.93%.

For simulation of 50 nodes, we get a performance increase of 39.31%.

For simulation of 70 nodes, we get a performance increase of 18.74%.

For simulation of 90 nodes, we get a performance increase of 11.34%.

4.3.3 ROUTING LOAD

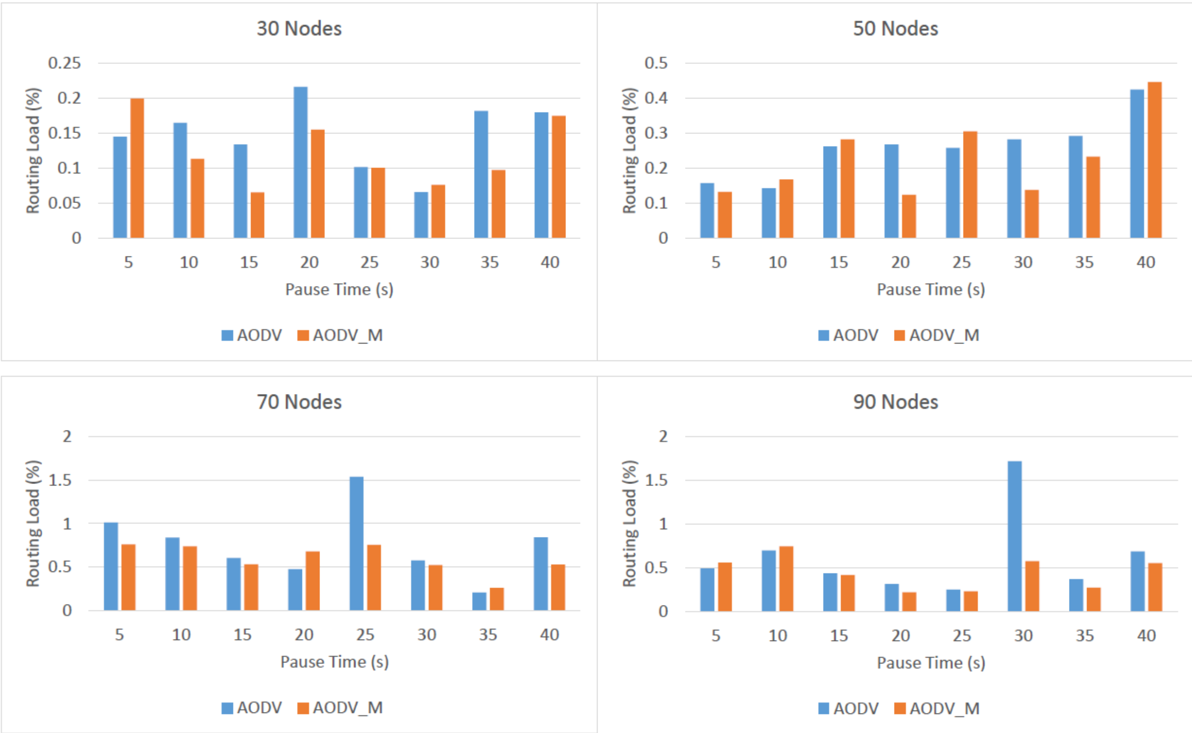


Fig 4.3 – Routing Load

Routing Load determines a node's load in generating routing packets for each data packet. Higher the generation of routing packets per data packets received, higher is the routing load of a node.

For simulation of 30 nodes, we get a performance increase of 17.41%.

For simulation of 50 nodes, we get a performance increase of 12.42%.

For simulation of 70 nodes, we get a performance increase of 21.54%.

For simulation of 90 nodes, we get a performance increase of 28.23%.

4.4 SUMMARY

According to the above graph plots, Ad-AODV definitely has an upper hand in normalized routing load. However, it doesn't do much better when we consider packet delivery ratio and end-to-end delay.

CHAPTER 5
CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

According to the simulation of pre-existing protocols, AODV outperforms every other protocol. Therefore, it's the most advantageous protocol to be used in practice. Also, Ad-AODV which is based on original AODV considers two metrics for delay calculation, which are the current residual energy and the load balancing of the nodes in the route discovery process of AODV [9]. When compared with AODV, Ad-AODV marginally provides improvement on average end-to-end delay and normalized routing load.

5.2 FUTURE SCOPE

All the protocols here are efficient. However, AODV outperforms the rest. However, if we include all the metrics of hop count, energy and load in route determination, it may improve the protocol. Also, it may decrease the load further.

REFERENCES

1. Mobile Ad hoc Networks (MANET). URL: http://www.ietf.org/html.charters/manetcharter.html. (2000-05-28). Work in progress.
2. Charles E. Perkins, Ad Hoc On Demand Distance Vector (AODV) Routing. Internet draft, draft-ietf-manet-aodv-02.txt, November 2001.
3. www.isi.edu/nsnam/ns/tutorial Marc Greis tutorial on ns2
4. Josh Broch, David B. Johnsson, David A. Maltz, “The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks”. Draft, draft-ietf-manet-dsr-00.txt, July 2004.
5. Zygmunt J. Haas, Marc R. Pearlman, “The Zone Routing Protocol (ZRP) for Ad Hoc Networks”. Draft, draft-ietf-manet-zone-zrp-00, November 1997
6. Z. J. Haas and M. R. Pearlman, “Zone Routing Protocol for Ad Hoc Networks”, tech. rep., Internet Engineering Taskforce (IETF), Nov. 1997
7. J. Broch, David A. Maltz, David B. Johnson, Y-Ch Hu and J Jetcheva, “A performance Comparison of Multi-hop Wireless Ad Hoc Network for mobile ad hoc networks”, in Proc. 4th annual IEEE/ACM international conference on Mobile Computing and Networking, Dallas, Texas, U.S.Oct. 1998, pp. 85-97.
8. Rekha Patil, A. Damodaram,Rupam Das, “Cross Layer AODV with Position based Forwarding Routing for Mobile Adhoc Network”, Fifth IEEE Confer- ence on Wireless Communication and Sensor Networks (WCSN) , 2009
9. An improved routing protocol Ad-AODV Based on AODV by Zuhong Feng, Long Wang and Xiujuan Gao
10. Mobile Ad hoc Networking by Carlos de Morais Cordeiro and Dharma P. Agarwal
11. http://en.wikipedia.org/wiki/Mobile_ad_hoc_network
12. http://en.wikipedia.org/wiki/Ns_(simulator)
13. Authenticated Routing for Ad-Hoc On-Demand Distance Vector Routing Protocol by Preeti Sachan, Pabitra Mohan Khilar