

IMPROVING PERFORMANCE OF AODV USING ANT AGENTS

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degree of*

Master of Engineering
in
Computer Science and Engineering

Submitted By
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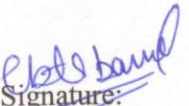
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ACKNOWLEDGEMENT CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "*Improving Performance of AODV using Ant Agents*", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Computer Science and Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Anil Kumar Verma* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.


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ABSTRACT

MANETs is a wireless infrastructure-less network, where nodes or station are not fixed and nodes are communicated without any centralized structure. Due to large mobility of nodes, limited bandwidth, dynamic network topology and limited resources in MANET routing become inefficient and nfeasible. So, routing protocols have been developed or communication between the nodes can be done in an efficient and effective manner.

The proposed work implements the feature of both Ad hoc on demand routing protocols and ant based routing strategy. The proposed protocol has been then simulated using NS2 and results have been compared against different-different performance parameters.

The proposed protocol has been named as (ANT-AODV USING AGENTS) in order to improve the performance of AODV. This algorithm make use of ant-like mobile agents have been generated, and these agents are implemented on Ad-hoc on demand distance vector routing protocol (AODV). ANT-AODV USING AGENTS protocol is simulated under mesh topology, as this topology can withstand high traffic and provide multiple alternative paths in case of node failure in network. From the available multiple paths, the best alternative routes can be found in minimum time by applying Ant-Agents. Hence ANT-AODV USING AGENTS as compared to AODV do not use the route-discovery procedure again when there is failure of route. The comparison is presented in the form of graphs between ANT-AODV USING AGENTS and AODV by different-different number of nodes using different performance measures. Thus projected work evaluated and analysis the performance of ANT-AODV USING AGENTS and an work has been made to attain reduced end to end delay, less routing overhead, increased throughput and more packet delivery fraction during its simulation. Finally, it is concluded that ANT-AODV USING AGENTS performs better than AODV protocol.

Keywords: MANETs, Routing Protocol, AODV, Agent Paradigm

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CHAPTER 1

INTRODUCTION

1.1 Mobile Ad Hoc Network

Wireless networks are network which are used to communicate between computers and their devices by using radio frequency. These networks are decentralized. These networks must be in their range and have equal status for communication between nodes otherwise the nodes cannot be communicated. The wireless network can be classified into two types: Infrastructure or Infrastructure less networks. Infrastructure networks the nodes are mobile but base stations are fixed. But in Infrastructure less networks the nodes can move but base stations are also not fixed.

Wireless Ad Hoc networks are classified on the basis of application:

- Mobile Ad Hoc Networks
- Wireless Mesh Networks
- Wireless Sensor Networks

Mobile Ad Hoc Networks (MANETs) are not centralized means in this network the nodes are operating in distributed manners. These are self-organized networks. MANETs are infrastructure less networks because the nodes are mobile. All the nodes can move in any direction while communicating and these nodes can act as both router and host. So, these networks are dynamic in nature means can change their topology. This may cause problems like overhead traffic, memory consumption etc. MANETs also possess multi hop routing means packets are allowed to forward to destination through multiple nodes thus creating each node act as terminal as well as router . There are some issues in MANET include limited resources, changing network topology, QOS, scalability etc. Routing is task of transferring data from source to destination while maximizing network performance. So it becomes a challenge in MANETs. Because of changing topology and network density, limited resources changes paths which were initially efficient but can quickly become inefficient and infeasible. These nodes have to interconnect from source to destination via intermediate node because these networks have limited bandwidth. To overcome these problems related with MANET, a number of routing protocols have been developed for different scenario.

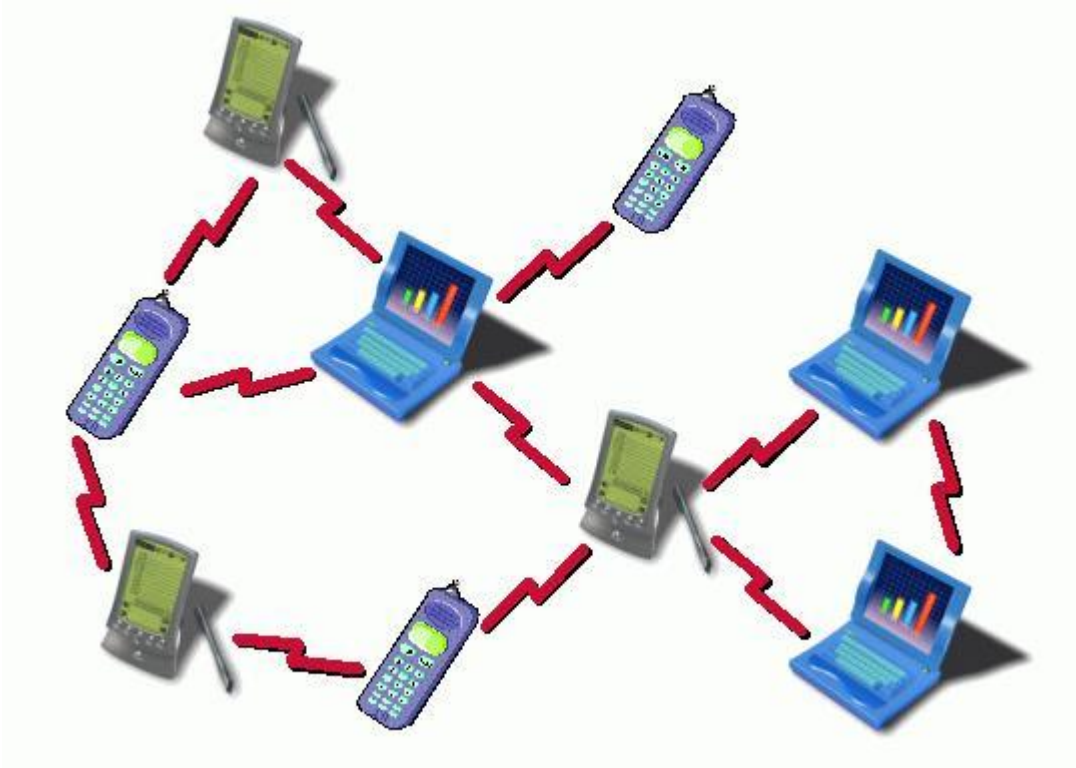


Fig 1.1 Mobile Ad-Hoc Network [2]

1.2 Advantage of MANETs:

The MANETs have many advantages:

- Firstly, organization of network is easy and speedy
- Secondly, the network is vigorous and low-cost so there is no dependence on infrastructure.

1.3 Disadvantage of MANETs:

The disadvantages of MANETs are:

- Flooding
- Unstable Network topology

1.4 Characteristics of MANETs:

In MANET, it is self-organized in nature as each node act as both host and router. It has distributed nature for security, routing and host configuration because it is not centralized. Multi-hop radio communicating- When a source node and destination node for a message is out of the radio range, the MANETs are accomplished of multi-hop routing. Mobile nodes are characterized with power, less memory and light weight features. The nodes are mobile means can join or leave the network anytime, means network topology dynamic in nature. The reliability, efficiency, stability and capacity of wireless links are often inferior when compared with wired connections. This indicates the unstable link bandwidth of wireless links. Mobile and spontaneous nature which demands minimum human intervention to configure the network. It creates a completely symmetric environment because all nodes have same features with similar abilities and responsibilities. High user density and large level of user movements. Node connectivity is discontinuous.

1.5 Routing of MANETs:

In this user data is send from sender to destination through network. The routing functions are:

- Path Generation
- Path Selection
- Data transmission
- Path Maintenance

1) Path Generation- In this path is generated from scattered environment of network. There are multiple path generated from sender to destination.

2) Path Selection- In the previous phase, there were multiple path and from them suitable path are chosen for data transmission so that time, memory and overhead will be less and performance is better.

3) Data transmission: In this data is transmitted from sender to destination on that selected path

4) Path Maintenance- The suitable path must have to maintain using control messages like “Hello”. If the link is broken and not active then using hello messages, maintenance of the route is done.

1.6 Application of MANETs:

The applications of MANETs are:

Sensor Networks- These networks are made up of small sensors which is very large in numbers. These are used to sense properties like pollution, temperature, pressure etc.

Personal Area Network - This network is formed between different mobile devices mainly in ad-hoc manner like creating a home network.

Military Field- When wireless base station is destroyed by enemy and if the called party is not within the radio range then the fighter will be forbidden from communicating with other militaries. So ad hoc networks are robust when nodes disappear because of mobility or destruction. The fighters can interconnect to remote fighters through multi hop (data hopping) and data forwarding from one device to another.

Commercial Sector- Ad-hoc networks can be used in emergency, saving operations for catastrophic liberation efforts like fire, flood. These operations must be used where spoiled or non-existing interconnections infrastructure and fast arrangement of a communication network is needed.

Automotive Application- These applications should be allowed cars to communicate on road, to traffic lights and to each other, creating Ad- hoc network of different sizes. The network will deliver the drivers with information about jamming, accident-ahead advices and road conditions, helping to optimize traffic flow.

1.7 Problems in Routing in MANETs

Routing Overhead- In MANETs, the nodes are not fixed. The nodes are mobile i.e nodes can move any time. If the route is already discovered then it will become invalid because of mobility of nodes. Then it leads to unwanted routing overhead.

Dynamic Nature- In MANETs, the nodes are not Stationary. The nodes are mobile i.e nodes can move any time from the network. So there must be change in corresponding routing table and update frequency is very low in ad hoc network.

Bandwidth Consumption- Wireless networks will have meaningfully lower capacity. The recognized throughput of wireless communications like fading, multiple access, noise, and interference condition has regularly much less than a radio's maximum diffusion rate.

Limited physical security- Mobile wireless networks are generally more disposed to physical security threats than are fixed-cable networks. The increased possibility of overhearing, denial-of-service attacks and spoofing should be wisely considered. Some Existing security techniques like authentication, cryptography are used for wireless networks to reduce security attacks.

1.8 Characteristics of Routing Protocols

The Routing protocols should be:

- Adaptable of an grouping data
- Application specific
- Adaptable of improving energy consumption
- Data centric

1.9 Properties of ad-hoc Routing Protocols

The properties of the routing protocols are listed as following:

- 1) Unicast routing
- 2) Multipath routing
- 3) Loop free
- 4) Scalability
- 5) Quality of Service
- 6) Secure routing
- 7) Scattered Operation

Unicast Routing: Most uses in the ad-hoc routing protocols are based upon unicast communication. Thus, the most basic property of the ad-hoc routing protocol is to successfully send data packets from one source to one destination end. This forwarding procedure is quite easy using the routing table, the communicate node just uses the destination address in the data packet. If the longest matching destination address is found in the table, the packet is sent to the

next hop. In the unicast routing one replicated copy sends to each receiver node from the sender node. Data packet is duplicated at the source node and then delivered to each destination node.

Loop Free: These Protocols must confirm that routes must be loop free for optimal performance. If the route is loop free then there is no wastage of memory, bandwidth and time.

Scalability: These protocols also support large number of nodes in the network. All these protocols have different-different scalability.

Secure Routing: It also includes security measures like digital signature and cryptography so that the network is secure from attacks like black worm attack and sniffing etc.

Scattered Operation: These Protocols is not centralized and the nodes are operating in distributed manner. So, if one node or link fails then the whole system will not dead.

Quality of Service: QOS is important for these protocols because to support throughput and improve the delay, overhead of routing and traffic.

Multi-path Routing: It also supports multi-path routing. If primary link or path fails then there are multiple paths for routing and uses the alternative path for routing.

1.10 Objectives of Routing Protocols

Routing Protocols, all have the same basic objectives but different in behavior. Routing Protocols are developed with the following objectives:

- Ease of Use
- Rapid Convergence
- Optimal Routing
- Stability
- Flexibility

Ease of Use

Routing Protocols are designed to be as simple as possible. It is also capable to support difficult internetwork arrangements, routing protocols should yield the resources need to run the Protocols. Some routing Protocols need more hardware or software resources, e.g. memory and control, to process than others and they are able of providing more functions than any other simple Protocol.

Rapid Convergence

Rapid convergence is second objective of all routing Protocols. As convergence happens when all routers in the network contain the same view and settle on optimal routes. When convergence proceeds a long time to occur, then loss of connectivity and discontinuous packet loss may be practiced between remote networks. Slow conjunction can result in absolute network outages and network routing loops.

Optimal Routing

One of the major objectives of all routing protocols is to select the most optimal path through the network from the source to the destination nodes. The most optimal routes are influenced by on the metrics used by the routing protocols. A route that may be deliberated the best by one protocol may not essentially be the most optimal route from the view of another protocol.

Stability

Network stability, is another major objective for routing Protocols. Routing Protocols should be stable enough to house unpredicted network events, such as hardware failures and even incorrect applications. While this is usually a characteristic of all routing Protocols, the way and time in which they answer to such events makes some better than other and thus more favored in modern day networks.

Flexibility

In addition to providing routing functionality, routing algorithms should provision to other networks with different needs so it contains many features-rich. This ability comes at the outlay of other structures, such as merging.

1.11 Introduction to AODV

It was proposed by Perkins and Royer [4]. AODV is reactive protocol. It means whenever routes are needed these protocols are available. This Protocol is based on DSDV and DSR algorithm i.e. it was developed for the variation of DSDV and DSR. AODV uses the sequence method of DSDV and route discovery method of DSR. AODV maintain the full destination address, sequence number whereas DSR maintain the full routing information of every node along the route [2]. So, AODV has no additional overhead on data packets. AODV also adjust with the changing behavior of the routes. AODV also require beaconing frequently [2]. The key steps of this algorithm are: Route Discovery and Route Maintenance

1.11.1 Route Discovery: During Route discovery, it manages with two control packets-RREQ, RREP [4]. Firstly, when a packet transmission occurs from source to destination, then routing table is checked to confirm whether route is available or not. If there is already a route from source to destination then there is no need of discovery procedure and data packet is transmitted to next hop along the route. If route is not present then the procedure is initialized by using RREQ and RREP packets. This RREQ has destination address, ip address, broadcast ID and its sequence number [5]. The source node broadcast a RREQ packet for that unknown destination and set up a timer. At each intermediate node, RREQ request is received then route to source is created. If that intermediate node has not RREQ before, it means it is not destination [13]. So the source rebroadcast RREQ request and if the node is received with that destination address and a RREQ reply is generated. RREQ also set a reverse route from destination to source and when RREQ is generated, it propagates towards the source and a route is created and data packets are transmitted along that route [5]. The routing information is stored in routing table.

1.11.2 Route Maintenance: By using route discovery procedure, route is generated. When data packets are transmitted from source to destination then a timer is connected with every node so that routes can manage in routing table [4]. If the timer expire and not sure about the route then that route entry delete from the routing table. Because the nodes are mobile and if source node moves from that route session then resend the RREQ request. If the intermediate or destination node moves, then the link is broken and sends RERR message to all neighbor nodes or source node [5]. Then the source node stops transmitting the data packets and if that route is still required the rebroadcast the RREQ otherwise stop the link.

1.11.3 Limitation of AODV

Routes can become invalid at any time because the nodes in this network are mobile and it is uncertain when these routes will be invalid.[5] When the number of nodes increases in a network then AODV consumes more bandwidth and also creates additional delay.

1.12 Problem statement

Now these days, MANETs have been growing rapidly because of wireless networks. There were some issues like routing, bandwidth constrained, dynamic topology. So routing protocols have been developed but they were very difficult. These protocols have been established but these have problems like low bandwidth, high error rate, power consumption and packet dropping. There have been evolved many techniques like swarm intelligence. In swarm intelligence there were chosen a best procedure that has better scalability, adaptability and self-organized which has adaptability on life time changes and robustness also.

Some hard work has been done to resolve these problems of packet dropping which has occurred in MANETs by using ANT agents. For Mobile Ad Hoc networks there are characteristics like system organization and resulting properties which encounter the essential and required property.

In wireless network the evolved ant based Mesh Ad hoc on demand distance vector routing protocol the ant mobile agents are combined with AODV is known as ANT-AGENTS WITH AODV. These protocols work under mesh topology which develop the routing problem, find alternative paths in case of failure in least time and survive with high traffic.

In this work, it has the application and assessment of AODV and it uses AODV with Ant agents so that overall performance will be improved. All the performance measures of ANT-AGENTS WITH AODV can be evaluated and comparing the results with AODV. The all problems have solved while using these agents. The measures like end to end delay, routing overhead, average throughput and packet delivery ratio.

1.13 Objective

The objective of this thesis is to do conjunction of ant agents on AODV. ANT-AGENTS WITH AODV protocols works under mesh topology which develop the routing problems, find alternative paths in case of failure in least time, find the shortest path and survive with high traffic where Ant agents is used. Packet delivery ratio is improved in ANT-AGENTS WITH AODV and it uses the AODV mechanism to maintain the link failure and packet dropping. It has objective to Compares the AODV and ANT-AGENTS WITH AODV protocols by using performance measures. In this work throughput is increased and end to end delay decreases and optimize the overall performance.

The main objectives of this thesis are:

- To survey of MANETs and its routing protocols, with special emphasis on AODV
- To Review of ACO protocols
- Conjunction of ACO and ant agents on AODV
- Simulation Study of AODV with Ant using agents
- Comparison of the AODV and AODV with Ant agents
- To report the results

1.15 Thesis Outline

This thesis has been structured in to 5 different chapters. These are Introduction, Literature Survey, Implementation, results and Conclusion and future scope.

In first chapter it includes introduction to MANETs, characteristics of MANETs, advantages and disadvantages of MANETs, problems and applications. It also contains properties of ad-hoc routing protocols and routing of ad-hoc protocols. It also discusses the characteristics of routing protocols, objective of routing. It also gives introduction of AODV and advantage, limitation of AODV. There is also description of all network topologies and problem statement is also defined followed by objectives of the thesis.

In second chapter, discuss the various routing protocols of MANETs is carried out. These protocols are broadly classified as proactive protocol, reactive protocol and hybrid protocol. Overview of these protocols, highlighting their advantages and disadvantages is presented.

Further, an introduction of Swarm intelligence with characteristics and its advantages is carried out and brief discussion of agent paradigm is also done.

In chapter 3, there is introduction of NS2, NAM, X-graph, and Trace Files. Brief overview of the performance metrics in this work. There is complete description of AODV and Conjunction of AODV and ant agents on AODV.

In chapter 4, results are explained. These are explained in the representation of graph and compare the results of AODV with ANT-AGENTS WITH AODV using agents.

In chapter 5, conclusion and future scope is presented by concluding the result and highlighting the future scope.

CHAPTER-2

Literature Review

2.1 Mobile Ad-Hoc Network and Protocols

Mobile Ad-hoc wireless devices are rapidly becoming favorite because of recent improvement in the power and portability of these devices. MANET refers to a network that is self-organized and collection of multi-hop having mobile nodes that communicate with each other operating in distributed manner without centralized control and these mobile nodes are not fixed i.e. all the mobile nodes are free to move in any direction while communicating and this node act both as a router and as a host. MANET has characteristics like bandwidth constrained, limited physical security and routing and dynamic network topology. Accordingly, nodes have limited bandwidth; it employs end to end communication. There are some issues in MANET include limited resources, changing network topology, network size, QOS, scalability etc. Routing is task of transferring data from source to destination while maximizing network performance. So, it becomes a challenge in MANET. Because of changing topology and network density, limited resources changes paths which were initially efficient but can quickly become inefficient and infeasible. To overcome these problems related with MANET, a number of routing protocols have been developed and performance simulation is made. These routing protocols can be broadly categorized in to three groups:

1. Table Driven or Proactive protocol
2. On Demand or Reactive Protocol
3. Hybrid protocol

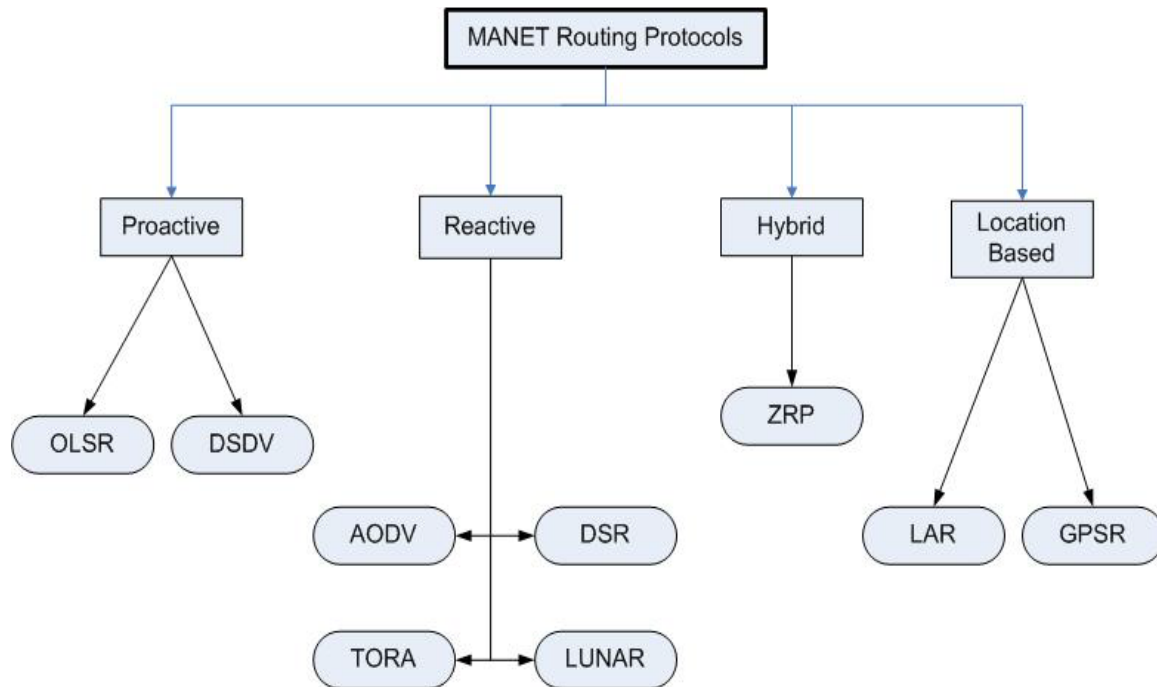


Fig 2.1 Classification of Routing Protocols [6]

2.1.1 PROACTIVE (TABLE DRIVEN) PROTOCOLS IN MANETS:

In Table driven protocols each node contains a number of routing tables which maintain routing information to every other node in the network at every times. The routes to all destinations are determined at start up and preserved by using a periodic route update process. The information in the table is updated throughout the network periodically or when network topology changes. When there is need for a route, the route information is available at that time .If the network [3] topology changes too often; the cost of preserving the network might be high. Different [2] protocols in this category keep track of different routing state information. So, these differences can be identify using the routing information is updated, detected, the number of tables and type of information kept in routing table during routing. Moreover, each routing protocol may maintain different number of routing tables. When information about a node have to be updated, while changing the topology a complimentary overhead may be generated to maintain the routing table. This protocol works best where the nodes have low mobility. If there is already a route to destination then there is no initial delay. This protocol has disadvantages like it require exclusive amount of data and slow acknowledgement on restructuring and failures.

Example of Proactive Routing Protocols are :

1. Destination-Sequenced Distance Vector (DSDV)
2. Wireless Routing protocol (WRP)
3. Global State Routing (GSR)
4. Cluster-Head Gateway Switch Routing (CGSR)

Destination Sequence Distance Vector Routing [31]. Table driven routing protocol for MANET based on Bellman-Ford algorithm. Every node in the network shares packet with its entire neighbor. Packet contain information such as node's IP address, last known sequence number, hop count. Whenever there is topology change in network each node advertises its routing status after a fixed time or immediately.

Advantage DSDV: It prevent the formation of loops in networks [31].

Limitation Great control overhead in large networks because each node in the network share its information with other nodes periodically or whenever there is topological changes. Because of great overhead it cannot scale very well and in MANET scalability matters a lot.

Optimized link State Routing (OLSR)[32]: The protocol is an optimization of the classical link state algorithm. In OLSR every node use "HELLO" message to know about their neighbors. Flooding of message to sense the neighbor node is very expensive process therefore to reduce the cost of flooding to sense neighbors OLSR use multipoint relay (MPR) technique [10].

Advantage [32]: Very good for low mobile medium scale ad-hoc network.

Limitation [34] : It is optimized but still it imposes great burden in large network. Even Though it is optimized but it cannot scale very well in case of MANET because of overhead.

Fisheye State Routing (FSR) [33]: FSR uses the fisheye technique proposed by Klein-rock and Stevens. In FSR link state packets are not flooded but it allows to share link state message at

different intervals for nodes within different fish-eye scope distance and thus reduce the size of link state message size.

Advantage: FSR is more scalable [33] to large network and have less overhead

Limitation [2]: As mobility increases, routes to remote destinations become less accurate. Since accuracy is reduced as mobility increases thus this protocol can-not be suitable for MANET because if route accuracy is not proper then it may cause accidents.

2.1.2 REACTIVE ROUTING PROTOCOLS (ON-DEMAND ROUTING PROTOCOLS):

In this, routes are established when needed. These protocols are designed to minimize the network traffic overhead in table driven (proactive) protocol by preserving the information of active routes. There is no need of periodic transmission of routing information like proactive routing protocol. These protocols are based on “request-reply” procedure and nodes have to wait until route is established. This route remains valid until route is used or destination is discovered. In this protocol the route will be discovered when a node wants to communicate with another node and there is no route between them. In this protocol the procedure is invoked by flooding the route request packet throughout the network and it starts with immediate neighbors of that node. When destination is reached using route request and Route reply is sent back to source node using link reversal if it has bi-directional link or piggy-backing the route in RRQ using flooding. If there are multipath for destination in reply message then shortest route is preferred. When link reversal is possible then the route discovery overhead will grow by $O(N+M)$ (in the worst scenario) and for unidirectional link it will grow by $O(2N)$ [2] where N is number of nodes in the network and M is number of nodes in the localized region.

This protocol can be classified into two groups: Source routing and hop-by-hop routing [2]. Both of these routing protocols differs in some manner. In Source routing protocol, each data packet carry the full address of source and destination and the packet contain the header which contain the information that where these intermediate node should forward the packet. So there is no need to keep up-to-date information to intermediate node to forward packet for every active

route. The major issue of this routing is scalability. The probability of failure increases as the number of intermediate node increases. Another drawback, with increase in the intermediate node the amount of overhead carried in the header of packet also grows accordingly.

In hop by hop routing, each data packet contains the destination address and next hops address. Each node maintain routing table. Each intermediate node forwards the data packet toward destination by using routing table. The advantage of this routing is versatility of dynamically changing topology of network because when a node receive the fresh information and send the packet from that fresh and better route. The disadvantage of this routing is that each intermediate node must store and maintain the information regarding active routes[2].This protocol has disadvantages like Latency time is very high in route finding and extreme flooding can lead to network congestion.

Examples of Reactive protocol:

1. Ad-hoc On-demand Routing Protocol
2. Flow Oriented Routing Protocol
3. Dynamic Source Routing Protocol

Ad Hoc On Demand Distance Vector (AODV) [35]: It is an reactive routing protocol which capable of both unicast and multicast. In AODV, like all reactive protocols, is that where on demand information is only transferred by nodes. When source has something to send then initially it propagates RREQ message which is forwarded by intermediate node until destination is reached. A route reply message is unicasted back to the source if the receiver is either the node using the sender address, or it must have a valid path to the requested address.

Advantage [35]: The advantage of AODV is that it is adaptable to highly dynamic networks.

Limitation [2]: There may be delays during route construction, and link failure may introduce another route discovery, which generates extra delays and consumes more bandwidth as the size of the network increases. And we know that MANET is a very large network and delay in this network may cause serious problem and also it consumes very large bandwidth.

Dynamic Source Routing (DSR) [36]: It is also an reactive routing protocol it uses source routing. When a node has something to send it broadcast a rout request message to its 1-hop

neighborhood if receiver is not a valid destination then it forward the updated RREQ message in which they add their address in this way all the intermediate node update RREQ message with their address and thus message along with updated route reach to destination. When RREQ reach to destination it returns a route reply message to source

Advantage: An advantage of DSR is that nodes can store multiple routes in their route cache, which means that the source node will check its route cache for a shortest route before initiating route discovery, and if there is a valid route then there is no need of flooding for route discovery.

Limitation: Since DSR require each packet to carry information about intermediate node thus in dynamic network more bandwidth is consumed by overhead leaving very less bandwidth for application services.

2.1.3 HYBRID ROUTING PROTOCOLS

It is new generation protocol. It combines the basic properties of two protocols in to one which is both proactive and reactive in nature. Since the property of proactive or reactive protocols were not enough suitable for every scenario, so by mixing these protocols gives better solution. It provides higher scalability than proactive or reactive protocols because it [2] allows nodes to work together in close proximity to form backbone so that it can reduce the route discovery overhead. This can be done by using routing strategy, determining and maintaining the routes proactively for so far nodes also. In this protocol we define two zones i.e. “intra-zone” and “inter-zone” which reduce the rebroadcasting of nodes. In intra-zone it is carried out proactively and inter-zone is performed reactively. Some protocols are zone based as network is divided into different zones and number of nodes seen by each node. Others combine the nodes into tree or cluster also. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. This algorithm has disadvantages like Benefits of these depends on number of mathvan nodes activated and acknowledge to traffic demand depends on slope of traffic volume.

Examples of Hybrid Routing protocol

1. Zone Routing Protocol (ZRP)
2. Zone-Based Hierarchical Link State (ZHLS)

Zone Routing Protocol (ZRP) [37]: It is based on the concept of zone. Each routing zone has radius 'r' which mean a zone include all the nodes whose distance from node is at most 'r' hops. Nodes inside the zone whose minimal distance from centre node is 'r' hops are known as peripheral nodes and rest are known as interior nodes. Proactive routing protocols is used to route packet within a zone which is known as Intra-Zone routing protocol whereas reactive routing protocol is used to route packet outside zone which is termed as Inter-Zone routing protocol.

Advantage [37]: It significantly reduce the overhead associated with proactive routing and also reduce the delay associated with reactive routing.

Limitation: It act like proactive routing protocols if number of zones are less and if number of zones are more it act like reactive.

Zone-based Hierarchical Link state (ZHLS)[38]: ZHLS implements hierarchical structure. Whole network is composed of non-overlapping zone based on geographical information. Each zone and each node has their own id which is calculated by GPS. Like ZRP for Intra-Zone routing ZHLS use proactive routing protocol and reactive routing protocol for Inter-Zone routing. There exist two kind of link state update, node level and zone level. Node level LSP contain node ids of its neighbor in the same zone and the zone ids of all other zone. When node has to send packet it checks its intra-zone routing table to make sure if destination is in same zone or not. If it is not there then source sends a location request to all other zones through gateway node.

Advantage: Since there is no cluster head therefore there is no processing overhead. Another advantage is that it has less overhead as compared to other reactive protocols.

Limitations[2]: All node must have programmed static zone map in order to function

Scalable Location Update Routing Protocol [39]: Like ZHLS network is divide in to non-overlapping zones. Each node in the network is assigned home region which is determined by

many to one static mapping function $f(\text{node}) \rightarrow \text{region ID}$. For each node home region can be calculated by using this function. To determine the current location of any node to each node unicast a location discovery packet to home region.

Advantage: Elimination of global route discovery reduce the cost of maintaining routing information.

Limitations [2]: All nodes must have programmed static zone map in order to function

Distributed Spanning Trees Based Routing Protocol [40] : Network is divided into number of trees. Each tree has two types of nodes root node and internal node. Root node is responsible to handle the structure of tree and whether a tree can be merged with another tree in the network. Each node has three different stages router, merge and configure depending what kind of task has to be performed by node. To determine a path DST focus on two different routing strategy Hybrid-Tree Flooding in which control packets are sent to all the spanning tree where each packet is held for a period of time called holding time. and another one is Distributed Spanning Tree here control packets are disseminated from source are broadcasted again along the tree edge.

Advantage: Better performance than reactive protocols

Limitations [2]: It relies on root node which may be the reason for single point of failure. Another disadvantage is that holding time may cause an extra delay.

Distributed Dynamic Routing [41]: Unlike DST, in DDR tree don't have root node.. To construct a tree periodic beaconing messages are used which is exchanged by neighbor nodes only. Tree in the network create forest which is connected together by gateway nodes. Each tree is assigned a zone id each tree are non-overlapping zones. DDR algorithm has six phases

1. Preferred Neighbor Selection –it is a node with maximum neighbors
2. Forest Construction-
3. Intra-tree clustering
4. Inter-tree clustering
5. zone naming
6. zone partitioning.

Advantage : It does not relies on static zone map to perform routing and also it does not require cluster head .

Limitation : Preferred neighbor may become performance bottleneck because they would have more data to send.

2.1.4 COMPARISON OF ROUTING PROTOCOLS:

In this section, a comparison of various routing protocols is being performed. The parameters focused here are availability of route, number of nodes, routing structure, frequency of update and delay. These routing protocols have different routing mechanism. The following table compares the proactive, reactive and hybrid routing protocols.

Table 2.1: Comparison of Routing Protocols

Parameters	Proactive protocol	Reactive protocol	Hybrid protocol
Routing Structure	Flat and Hierarchical	Flat	Hierarchical
Availability of routes	Always available	Created when needed	Depend on the destination location
Scalability	100 nodes	>100	>1000
Routing Structure	Flat and Hierarchical structure	Used many time flat instead of CBR	Hierarchical many times
Frequency of update	Periodic	Aperiodic	Periodic inside each zone or between gateway
Route Mobility	Low	High	Very High
Delay	Small(routes are already known)	High(routes are discovered on demand)	For local destination small, for inter-zone it may be large as reactive protocol
Information of routing	Information Stored in routing tables	Is not stored	According to need if required then delivered

2.2 Swarm Intelligence (SI)

It is the gathering of insects of self-organized or no centralized nature. It [42, 43] appears in biological crowd of some social insect species such as ants. It is [19] inventive distributed intellectual model for solving optimization problems that originally took its inspiration from the biological examples like flocking, swarming and herding phenomena in vertebrates. It becomes optimized because in this ants communicate with each other in their environment in the neighborhood.

2.2.1 Characteristics of SI

1. It maintains the multiple paths while accomplishing load balancing. It supports load balancing instead of shortest path
2. It uses pheromone table for user agents. User agents are autonomous and communicate each other through stigmergy. [20]
3. It has adaptive feature and also creates multiple path for routing. These algorithms are adaptable for change in network environment and traffic and it will give comparable performance. .
4. It collects local information for congregation and observing. It also gathers non local information about all possible paths.

2.2.2 Advantages of SI [20]

- a) Distributed and Fault Tolerance** – These are fundamentally distributed means no centralized control mechanism, so if any node or link fails, there is no loss of information or in transmission.
- b) Multipath Routing** – It creates multiple paths between pairs of nodes.
- c) Speed** – It adapts changing network very fast.
- d) Scalability and Adaptation**– Population of ants may change depend on the size of network. The agents may die or reproduce, that have little impact on performance.
- e) Fast Route Recovery** – There are multiple path favored by ants. If best path fails, then data packets can transmitted to other neighbor's stable computing next hop i.e., choosing secondary best path.

2.3 Ant Colony Optimization

It is one of most successful and distributed algorithm of swarm intelligent. It is meta-heuristic algorithm for solving combinatorial problems. It uses the principle searching behavior of real ants. These ants do not communicate directly, but communicate through a chemical substance called pheromone. The ants deposit it when they are going from nest to that food source. This chemical substance makes the path for other ants. The ant walks toward food source and follow the path where pheromone substance value is maximum. The other ants find that substance through their smell. These agents (ants) moving around in the network from one node to the other, updating routing tables (called pheromone table) of the nodes that they visit with what they have learned in their traversal so far [4]. The path is chosen according to amount of pheromone. The ant follows that path also add their pheromone and increases the amount and mostly shorter path have more concentration of pheromone. The longer path has less than shorter. This substance fades (decreases) their concentration if that path is not in use for long time then it disappears.

2.3.1 Working of ANT AGENTS

1. Ants works in parallel like they collect the information as well as building optimizing solution and also increase the value of pheromone.
2. These ants make their path through pheromone and then follow that path step by step
3. The ants may also favor the investigation of new paths.
4. It also increases the robustness of network because there are multiple path for routing, also adaptable according to network size because some time to find the shortest path the ants change, die or reproduce for the colony [20].
5. As there are multiple paths then information is distributed toward all trails and it increases throughput and utilize the resources.
6. These pheromone update their value by appropriate ants.

CHAPTER 3

IMPLEMENTATION

3.1 Network simulator [24, 25]

These days, there are many network simulators which are used as a platform for MANETs and AODV. NS 2.35 select as a simulator to implement AODV and ANT-AGENTS WITH AODV protocols in this thesis.

3.1.1 INTRODUCTION TO NS2

Network Simulator (Version 2), is an event driven simulation tool which is useful in learning the dynamic nature of communication networks is known as NS2. It is defined as “imitating and estimating how events occur in real circumstances”. So, It is flexible and segmental in nature. With ns2 we can simulate wired as well as wireless protocols. The researcher also uses many protocols like OPNET, GLoMo-Sim and ns2 so that can estimate the protocols. Ns2 is also open source means freely available and using C++, OTcl, Tcl/Tk. It uses two tools which are nam and ns. It covers all common IP protocols.

It is written in OTcl and C++. It also uses class and its hierarchy that uses OTcl translator. C++ class hierarchy is known as compiled hierarchy and OTcl has interpreted hierarchy. OTcl and C++ has one to one correspondence between the interpreted hierarchy and compile hierarchy. It uses two languages and it depend on the parameters where C++ is used and where OTcl is used. It writes in C++ when event requires high speed and OTcl is used that requires fast and regular change.

It is highly extensible. It also support more protocols because it permits the users to extend and then implement their protocols. Now new versions can support new protocols and also add influential trace functionality. The full ns2 can be downloaded and it uses on different-difference platforms like Linux, Cygwin and windows.

NS2 consists of following modules:

- C++ : for backup
- NAM : Network Animator
- X-Graph : for analysis

- OTcl : Network protocol design
- TCL : creating layout
- TclCL: Linking C++ and Tcl code

NS2 can be extended by using two ways like OTcl or C++ code. It is core of simulator and compiled C++ is very effective and efficient for adding new components and modification of any event. In this it also has some variables and functions and by using compiled C++ it is easy to use these functions and variables and capable to modify.

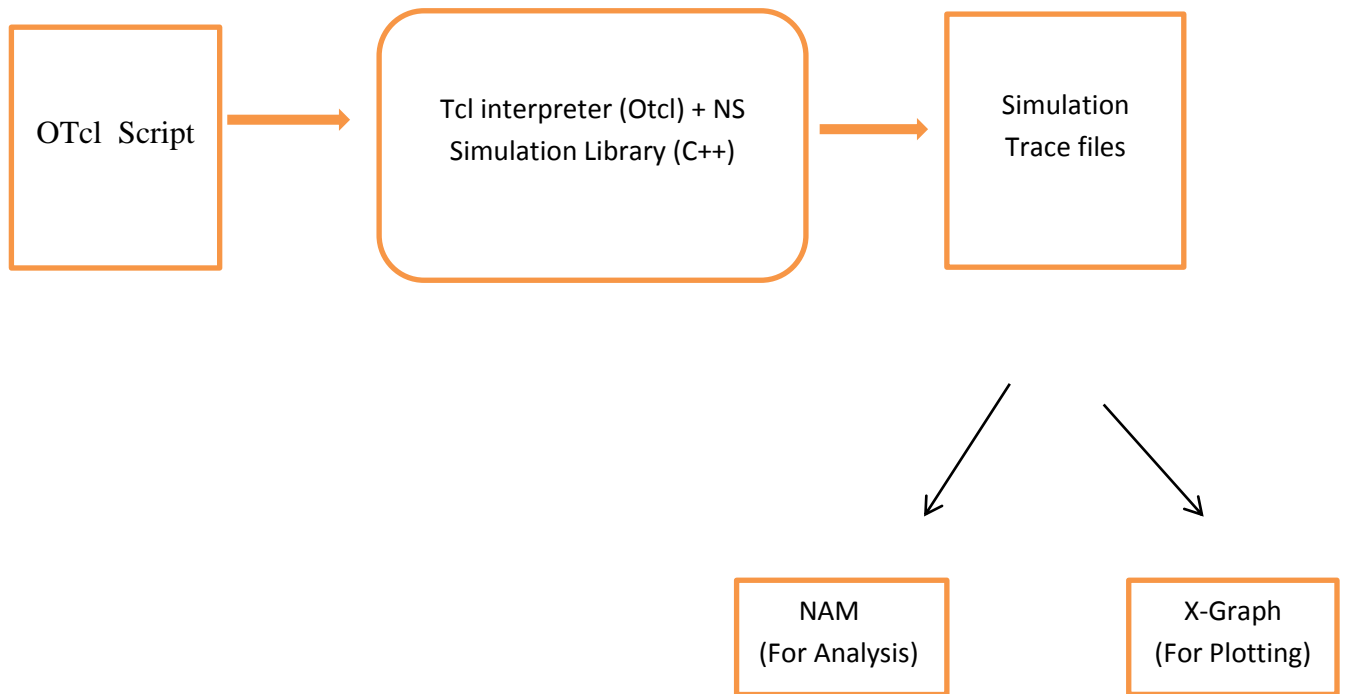


Fig 3.1 NS2 Architecture

The event scheduler has the following responsibilities [1]:

- Arranges the simulation time
- Runs or updates event in the event queue
- Entreats network components in the simulation

3.1.2 TCL (TOOL COMMAND LANGUAGE)

TCL [27] was created by John Ousterhout. It is a scripted language, advanced means growing language and which is easy to study or learn dynamic languages. It is used in administration, desktop applications, networking, testing and more. It is truly cross platform which is highly extensible and arranged.

It has following features:

- It is open source language.
- Everything can be dynamically redefined and outweighed.
- It has simple syntactic rules.
- All data types can be used as strings, containing source code
- All commands definite by TCL themself which create error messages on incorrect procedure.
- Extensibility, by using these languages C, C++, Java, and TCL.
- Platform independent: Linux, Mac, Unix, Win 32

3.1.3 OTCL (OBJECT TOOL COMMAND LANGUAGE)

It is an advanced version of TCL/TK for object oriented programming [26].

An OTcl script has the following:

- It starts an event scheduler
- It uses the network object to set up the topology of network
- Using event scheduler it gives information to sources of traffic when should start or stop the transmission

3.1.4 The Tcl Interpreter

It is a language which is used to offer link between OTcl and C++. These scripts are used to form topologies of network. It offers linking property to variable binding, object instantiation and class hierarchy. It is also used for triggered or periodic. The Tcl interpreter control the member function of C++ objects and member variables of OTcl objects as shown in fig. it can also update, insert and maintain the C++ and OTcl objects.

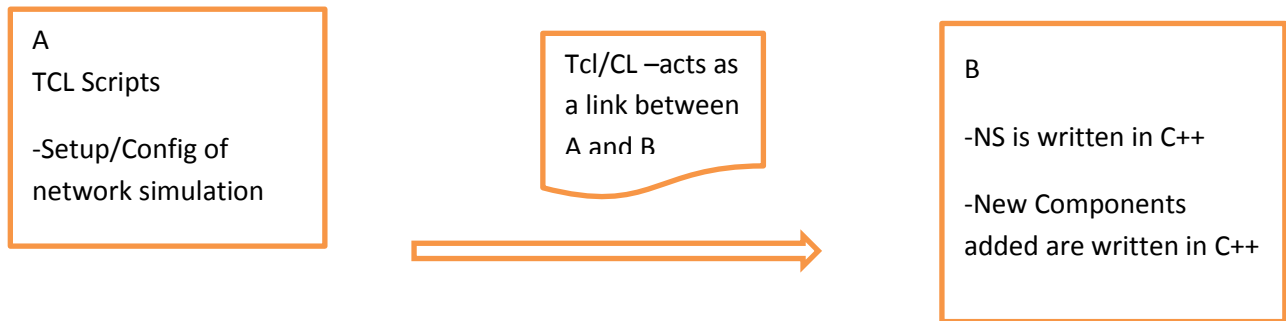


Fig 3.2 The TCL/CL Linkage

3.1.5 The AWK Scripting Language [27]

AWK is a programming language which used for extracting information from text and data files. AWK language gets the name from three authors (Aho, Weinberger, Kernighan). It is tool which is very easy to run than any other language and used to process rows, columns. It is an interpreter which makes the file executable. It has minimum number of instructions which is used to run complicated text processing tasks. It has arrays which are inconceivable. It also has string functions which is used to search and modify the output.

The general syntax of this language is:

Awk [program | -f program file] [flags/variables] [files]

-f program file: The -f option instructs awk to fetch the program from the named file. It denotes specified files instead of using program files.

Variable: initiates the awk variable with the specified file

The awk program contains commands separated by a semi-colon or /n.

E.g

```
{
B= $3;
Print 'hello'
}
```

3.2 NAM [26]

NAM creates a visual representation of network topology. This figure defines the Nam components:

- Creates a visual representation of network topology
- It has option of play, pause, stop, rw, ff, display speed controller and packet monitoring facility
- Creates drag and drop boundary
- It process from a Tcl script directly
- Represent information about throughput, packets

NAM is animated tool which creates ns2 scripts. When we start NAM it starts with a console window. In the one NAM instance there are many animations. There is a menu bar at the top. There are files, view and help menu. In file menu there are commands like new, open, Win list, Quit. With using new can create new editor. An open command is used to open existing NAM files and Win list is used to see all the names of NAM files. Quit exits the NAM. The Help menu has a popup window as a help screen, patent information and display the version. It also has a save command which is used to save the NAM file and when Trace-file has encumbered then animation window will act. In this it also has print command which will print the current outline. The view menu has following button :

- New view button: it generates a new view of animation. New views can zoom and scroll.

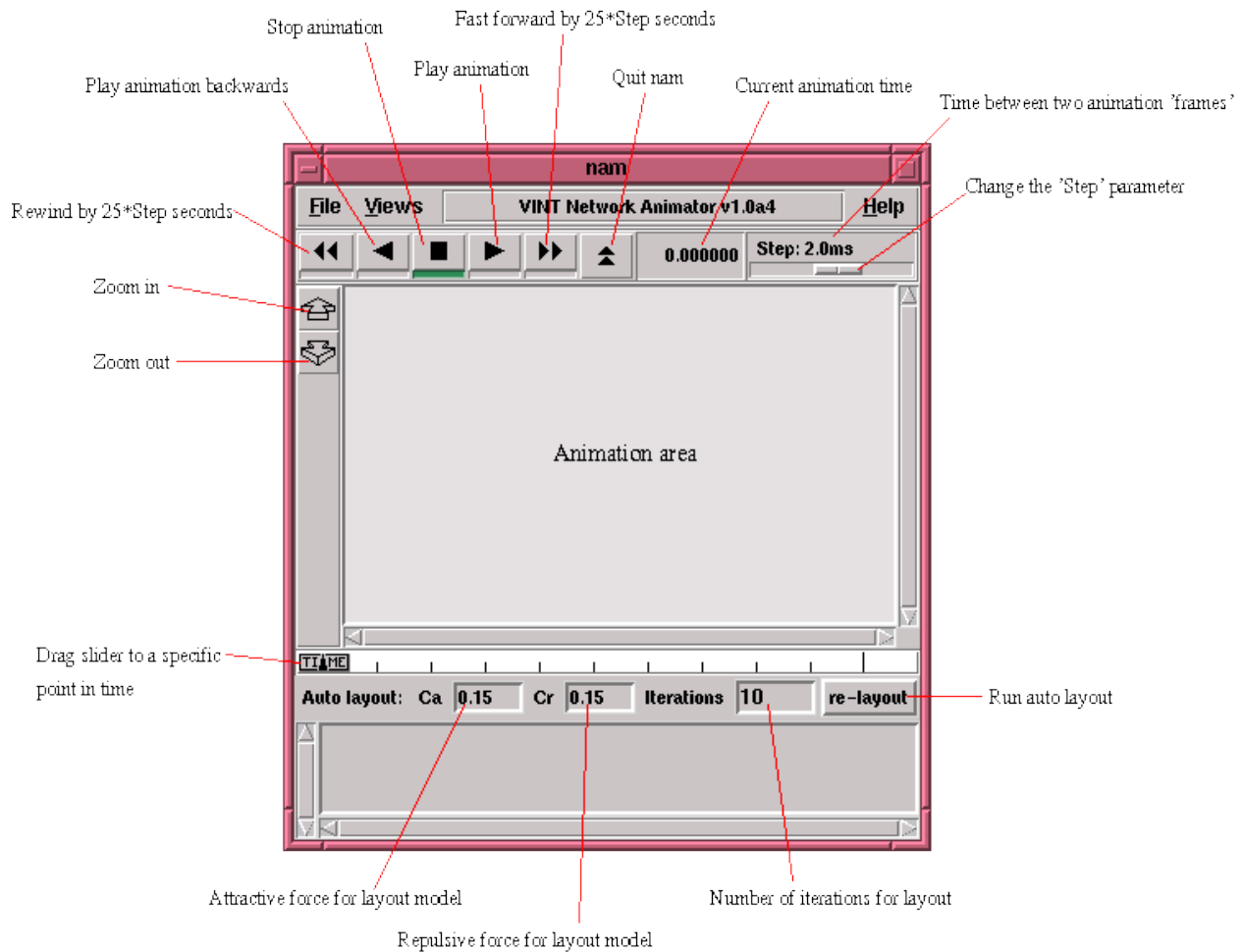


Fig 3.3 NAM Editor

- Show monitors checkbox: it will display the window at the lower half of the window when checked where monitors will be displayed.
- Show annotation checkbox: it will display the show a list box at the lower half of the window when checked which is used to list.
- Annotation in the time of ascending order

There is control bar below the menu bar which contains 6 buttons.

- Button 1 (<<): Rewind
- Button 2 (<): Backward play
- Button 3 (Square) : stop, pause
- Button 4 (>): Forward play

- Button 5 (>>): Fast Forward
- Button 6 (Logo): Close (quit)

There are labels and scrollbar which are:

Time Label – Shows the current animation time

Rate Slider- Controls the rate of screen update

3.3 Trace Files

Trace files i.e Trace means monitoring it record the packet details like when it reaches, send or it is in queue or released. In network topology these objects are pretend as nodes and these objects bowed with TCL channel which denotes endpoint of collected data.

event	Time	From node	To node	Pkt type	Pkt size	Flags	Fid	Src addr	Dst addr	Seq num	Pkt id
-------	------	-----------	---------	----------	----------	-------	-----	----------	----------	---------	--------

Fig 3.4 Trace File format

Event

r Received, d dropped, + enqueue, - dequeue

Time

Time stamp (telling the time about event)

From / To Nodes:

Packet is between these nodes

Packet types

Which types of packet (CBR, TCP) generates traffic

Flags:

Kind of flag like flow control or congestion control

Flow Id:

Flow identity of IPV6 means which traffic is separately off

Source or Destination Address:

The source or destination end points of packet

Sequence Number:

Used in TCP windowing and acknowledging

Packet Id:

Gives the unique identity of the packet

3.4 XGRAPH

It includes:

- Interactive plotting and graphing
- Animation and derivatives

Trace graph is graph analyzer which runs under linux, unix, windows. It supports the following file formats:

- Wireless
- Wired
- Satellite

3.5 INSTALLATION OF NS2:

The installation of ns2 on Ubuntu 12.0 is in following steps:

Step 1:

Download NS-2.35

step 2:

Put this file ns-allinone-2.35.tar.gz

step 3:

Run this command in terminal

```
tar zxvf ns-allinone-2.35.tar.gz
```

step 4:

Run these command in terminal

```
sudo apt-get update ( means you need to keep your pc updated )
```

```
sudo apt-get install build-essential autoconf automake libxmu-dev
```

step 5:

Run this command in terminal

```
cd ns-allinone-2.35
```

step 6:

```
./install
```

the only error I got was something related to linkstate/ls.h

in this file (location is ns-allinone-2.35/ns-2.35/linkstate/ls.h)

execute command

```
sudo gedit ns-allinone-2.35/ns-2.35/linkstate/ls.h
```

on line number 137 change

```
void eraseAll() { erase(baseMap::begin(), baseMap::end()); }
```

to

```
void eraseAll() { this->erase(baseMap::begin(), baseMap::end()); }
```

execute

ctrl + s(saving ls.h changes)

ctrl + q(quitting text editor)

again run ./install

after installation of successful ns2.35 after this it would set ld_library_path.

Now go to gedit ~/.bashrc

And add the lines at the end of it and change the path with your path name “your/path” by “/home/ekta” and change the version number according to ns.

```
#LD_LIBRARY_PATH
```

```
OTCL_LIB=/home/installations/ns-allinone-2.33/OTcl-1.13
```

```
NS2_LIB=/home/installations/ns-allinone-2.33/lib
```

```
X11_LIB=/usr/X11R6/lib
```

```
USR_LOCAL_LIB=/usr/local/lib
```

```
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:
```

```
$OTCL_LIB:$NS2_LIB:$X11_LIB:$USR_LOCAL_LIB
```

```
# TCL_LIBRARY
```

```
TCL_LIB=/home/installations/ns-allinone-2.33/Tcl8.4.18/library
```

```
USR_LIB=/usr/lib
```

```
export TCL_LIBRARY=$TCL_LIB:$USR_LIB
```

```
# PATH
```

```
XGRAPH=/home/installations/ns-allinone-2.33/bin:/home/installations/ns-allinone-2.33/Tcl8.4.18/unix:/home/installations/ns-allinone-2.33/tk8.4.18/unix
```

```
NS=/home/installations/ns-allinone-2.33/ns-2.33/
```

```
NAM=/home/installations/ns-allinone-2.33/nam-1.13/
```

```
export PATH=$PATH:$XGRAPH:$NS:$NAM
```

6. Validate it.

```
$cd ns-2.35
```

```
$ ./validate
```

7. Create symlink.

```
$ sudo ln -s /home/installations/ns-allinone-2.33/ns-2.33/ns /usr/bin/ns
```

8. Run it.

```
$ ns
```

3.6 Performance Metrics

The performance metrics are given below:

- **Routing Overhead-** Routing overhead means the number of routing packets send during simulation.
- **End-to-End delay-** It is average time which is utilized in receiving a packet from source to destination.
- **Throughput-** The number of packets reached at the destination or receiver which is useful.
- **Packet delivery Ratio** – It is the ratio of data packets received at the destination to the send by the source.

3.7 AODV Implementation

It was developed by Perkins and Royer [12]. AODV is reactive protocol. It means whenever routes are needed these protocols are available. This Protocol is based on DSDV and DSR algorithm i.e. it was developed for the variation of DSDV and DSR. AODV uses the sequence method of DSDV and route discovery method of DSR. AODV maintain the full destination address, sequence number whereas DSR maintain the full routing information of every node along the route [10]. So, AODV has no additional overhead on data packets. AODV also adjust with the changing behavior of the routes. AODV also require beaconing frequently [10]. The key steps of this algorithm are: Route Discovery, Route Maintenance

Route Discovery: During Route discovery, it manages with two control packets-RREQ, RREP [12]. Firstly, when a packet transmission occurs from source to destination, then routing table is checked to confirm whether route is available or not. If there is already a route from source to destination then there is no need of discovery procedure and data packet is transmitted to next hop along the route. If route is not present then the procedure is initialized by using RREQ and RREP packets. This RREQ has destination address, IP address, broadcast ID and its sequence number [9]. The source node broadcast a RREQ packet for that unknown destination and set up a timer. At each intermediate node, RREQ request is received then route to source is created. If that intermediate node has not RREQ before, it means it is not destination [14]. So the source

rebroadcast RREQ request and if the node is received with that destination address and a RREQ reply is generated. RREQ also set a reverse route from destination to source and when RREQ is generated, it propagates towards the source and a route is created and data packets are transmitted along that route [9]. The routing information is stored in routing table.

Route Maintenance: By using route discovery procedure, route is generated. When data packets are transmitted from source to destination then a timer is connected with every node so that routes can manage in routing table [12]. If the timer expire and not sure about the route then that route entry delete from the routing table. Because the nodes are mobile and if source node moves from that route session then resend the RREQ request. If the intermediate or destination node moves, then the link is broken and sends RERR message to all neighbor nodes or source node [9]. Then the source node stops transmitting the data packets and if that route is still required the rebroadcast the RREQ otherwise stop the link.

3.7.1 File dependency of AODV Protocols [28]

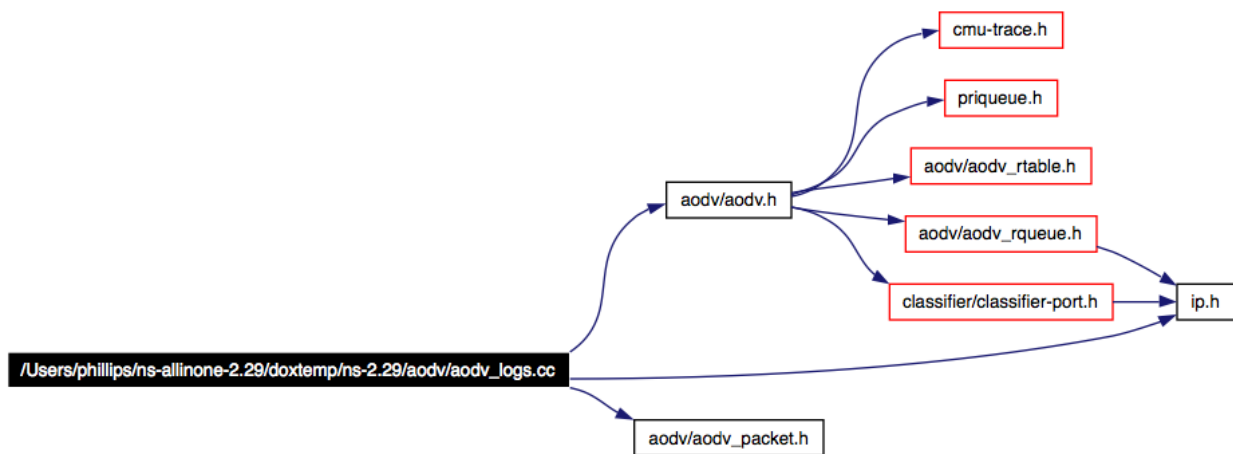


Fig 3.5 File Dependency in AODV[28]

3.7.2 Flow of AODV [28]

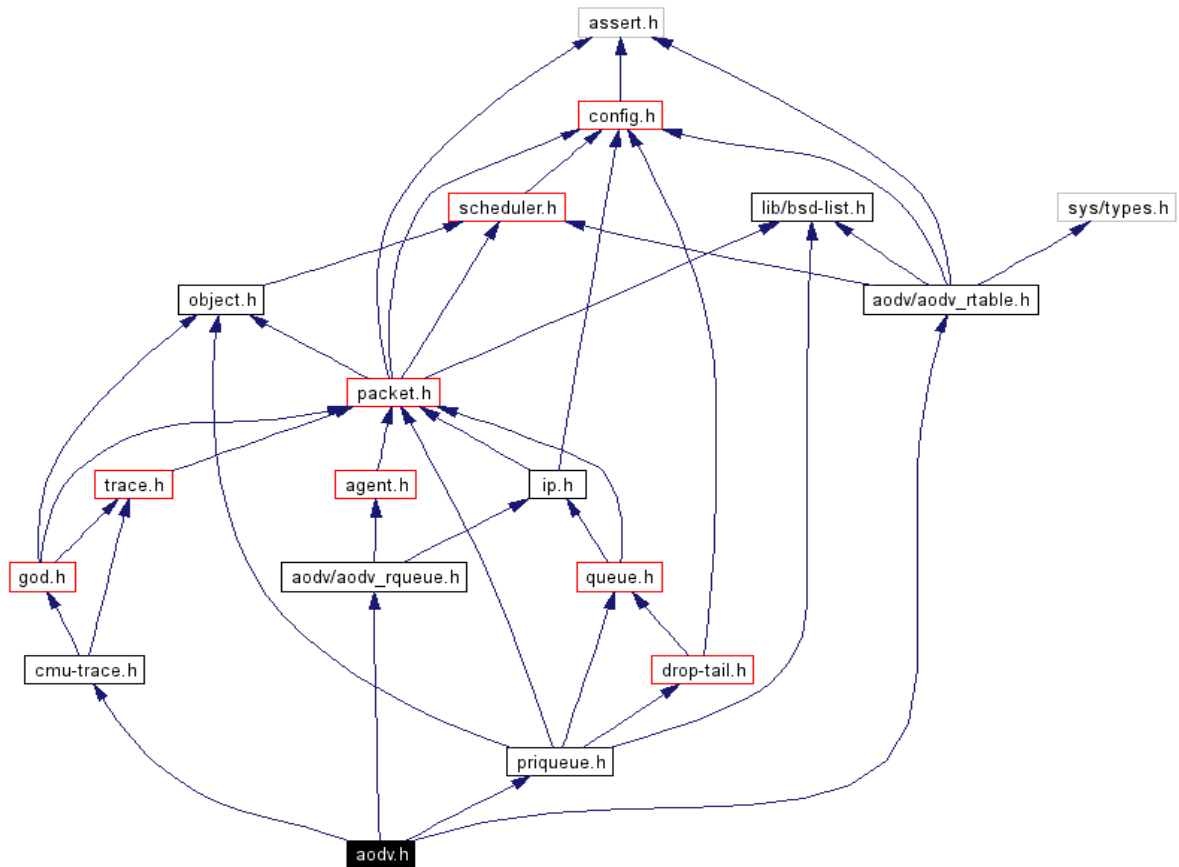


Fig 3.6 File Reference of ‘AODV.H’

1. In the TCL script, when the user configures AODV as a routing protocol by using the command,

\$ns node-config -adhocRouting AODV the pointer moves to the “start” and this “start” moves the pointer to the Command function of AODV protocol.

2. In the Command function, the user can find two timers in the “start”

```
* btimer.handle((Event*) 0);
```

```
* htimer.handle((Event*) 0);
```

3. Let’s consider the case of htimer, the flow points to HelloTimer::handle(Event*)

function and the user can see the following lines:

```
agent -> sendHello(); double interval = MinHelloInterval + ((MaxHelloInterval - MinHelloInterval) * Random::uniform()); assert(interval -> = 0); Scheduler::instance().schedule(this, &intr, interval);
```

These lines are calling the sendHello() function by setting the appropriate interval of Hello Packets.

4. Now, the pointer is in AODV::sendHello() function and the user can see Scheduler::instance().schedule(target , p, 0.0) which will schedule the packets.

5. In the destination node AODV::recv(Packet*p, Handler*)

6. AODV::recv(Packet*p, Handler*) function then calls the recv AODV(p) function.

7. Hence, the flow goes to the AODV::recvAODV(Packet *p) function, which will check different packets types and call the respective function.

8. In this example, flow can go to case AODVTYPE HELLO: recvHello(p); break;

9. Finally, in the recvHello() function, the packet is received.

3.7.3 Trace Format of AODV [28]

In NS-2, the general trace format is given as below:

```
s 0.000000000 0 RTR — 0 AODV 44 [0 0 0 0] —— [0:255 -1:255 1 0] [0x1
1 [0 2] 4.000000] (HELLO)
```

```
s 10.000000000 0 RTR — 0 AODV 48 [0 0 0 0] —— [0:255 -1:255 30 0]
[0x2 1 1 [1 0] [0 4]] (REQUEST)
```

```
s 21.500000000 0 RTR — 0 AODV 48 [0 0 0 0] —— [0:255 -1:255 30 0]
[0x2 1 4 [1 0] [0 12]] (REQUEST)
```

```
r 21.501260809 2 RTR — 0 AODV 48 [0 ffffffff 0 800] —— [0:255 -1:255
30 0] [0x2 1 4 [1 0] [0 12]] (REQUEST)
```

The interpretation of the following trace format is as follows:

```
r 21.501260809 2 RTR — 0 AODV 48 [0 ffffffff 0 800] —— [0:255 -1:255
30 0] [0x2 1 4 [1 0] [0 12]] (REQUEST)
```

Node ID 2, receives a packet type REQUEST (AODV protocol), at layer RTR (routing), at time 21.501260809. This packet have sequence number 0.

Table 3.1 Trace Format of AODV

Column number	What happened?	Values for instance.....
1	It shows the occurred event	's' SEND, 'r' RECEIVED, 'D' DROPPED
2	Time at which the event occurred?	10.000000000
3	Node at which the event occurred?	Node id like 0
4	Layer at which the event occurred?	'AGT' application layer, 'RTR' routing layer, 'LL' link layer, 'IFQ' interface queue, 'MAC' mac layer, 'PHY' physical layer
5	Show flags	-
6	Shows the sequence number of packets	0
7	Shows the packet type	'cbr' CBR packet, 'DSR' DSR packet, 'RTS' RTS packet generated by MAC layer, 'ARP' link layer ARP packet.
8	Shows size of the packet	Packet size increases when a packet moves from an upper layer to a lower layer and decreases when a packet moves from a lower layer to an upper layer
9	Show flags	it shows information about packet duration, mac address of destination, the mac address of source, and the mac type of the packet body.
10	Show flags	-
11	Show flags	It display the information about source node IP: port number, destination node IP (-1 means broadcast): port number, I header title, and IP of next hop (0 means node 0 or broadcast).

3.8 ANT-AGENTS WITH AODV Implementation:

There were many problems in ad-hoc protocols like packet sinking during link failure. So when link fails then there are secondary paths so that packet will not be sinked by implementing ANT-AGENTS WITH AODV in ns2.35 simulator.

3.8.1 Network model [29]

a) Packet Classes and Structure

In this network the packets can be distributed into three classes:

- **Data packets:** It contains the information that end-users interchange with each other. It practice the information which is stored at routing tables for transmitting from the source to the destination node but data packets do not keep any routing information in this ant routing.
- **Forward and Backward ants:** These are control packets which contain information about the traffic load in the network and bring up-to-date the routing tables and distribute information.
- **Neighbor Control Packets:** These packets conserve a list of available nodes by using hello messages to which forward packets broadcasted frequently from each node to all its neighbors.

b) Node Structure

The node consists of two data structures which are:

- **Routing table and Neighbor list:** A routing table T_k which has three fields destination address d , a next hop n used to reach that destination d and pheromone value P_{nd} . It also contains information about neighbors in the list.
- **Local Traffic Model-** Local traffic model M_k , it has the statistics about the network topology and traffic distribution by means of the measured delay.

3.8.2 Working of ANT-AGENTS WITH AODV [30]

Ant Colony Based Routing Algorithm (ANT-AGENTS WITH AODV) [21] which reduces overhead, because routing tables are not interchanged among nodes. It consist of three phases namely Route Discovery phase, Route Maintenance and Route Failure Handling. The Route Discovery phase consist of two mobile agents that is Forward Ant (FANT) for route request and

other agent is Backward Ant (BANT) for route reply to create new routes. FANT packets have unique sequence number and source address is broadcasted by the sender and will be passing on by the neighbors of the sender. Node receiving the FANT for the first time generates a record with entries of destination address (Source address of FANT), next hop (address of previous node), and pheromone value (number of hops the FANT needed to reach this node). The destination node extracts information of FANT, destroys it and creates BANT which establish pheromone track to destination node.

In Route Maintenance phase, DUPLICATE ERROR flag is set for duplicate packets to prevent from looping problems. It also allows for the evaporation of pheromone by decrementing factor [42] in route table. In Route Failure Handling phase, node deactivates the path by reducing pheromone value to 0 in corresponding route table entry and go to the Route Discovery phase for selecting path and sending packets to the destination over that path.

ANT-AGENTS WITH AODV algorithm:

Step1: Set metrics:

Initialize pheromone values =0

Create FANT(forward ant) agent

Step2: do

Broadcast request

Create record

Update (increases) pheromone value

Visit every node

While

Reached at destination

Step 3:

Create BANT and sends reply

Update pheromone value

Create new route

Set duplicate error flag=1

If (Pheromone value=1)

 Route active

Else

 Route failure and Go to step 2

Step 4: Update values in routing table

Step 5: Print Routing table

End

SIMULATION, EVALUATION AND ANALYSIS

4.1 Simulation Scenario

Ns2 is used to simulate the ANT agents with AODV. For physical layer there is radio propagation model is used. MAC layer is used for link layer. By using some performance metrics like Routing overhead, throughput, End to End delay, Packet delivery fraction, evaluate the performance and compare the results.

We should take some deliberation for the AODV and ANT-AGENTS WITH AODV:

- The number of nodes must be retained equal to number of ant agents for simulation of ant based routing protocol.
- It defines network mobility of nodes in flat grid area of 800×800 with delay of 8ms and bandwidth of 5M bits/sec is simulated for all defined protocols.
- Constant Bit Rate (CBR) traffic source is occupied with packet size taken is of 1100 bytes which send at the interval of .010 sec.
- Simulation stops at 600.0 second.
- The useful data is haul out from trace file using awk scripts and then the graphs are created using word excel.

The following table shows the scenario of the network which has parameters and their values

Table 4.1 Network Scenario

Parameter	Value
Number of Nodes	10,12,16,25
Traffic Type	CBR
MAC Type	802.11 MAC Layer

Mobility Model	Random Way Point
Topological dimension	800-800
Radio Propagation Model	Two-Ray Ground Model
Packet Size	1000 bytes

The following figure shows the 12 nodes from node 0 to node 11. There are control messages and connection which is shown as following figure. It also shows that there is packet sinking when nodes moving from the network.

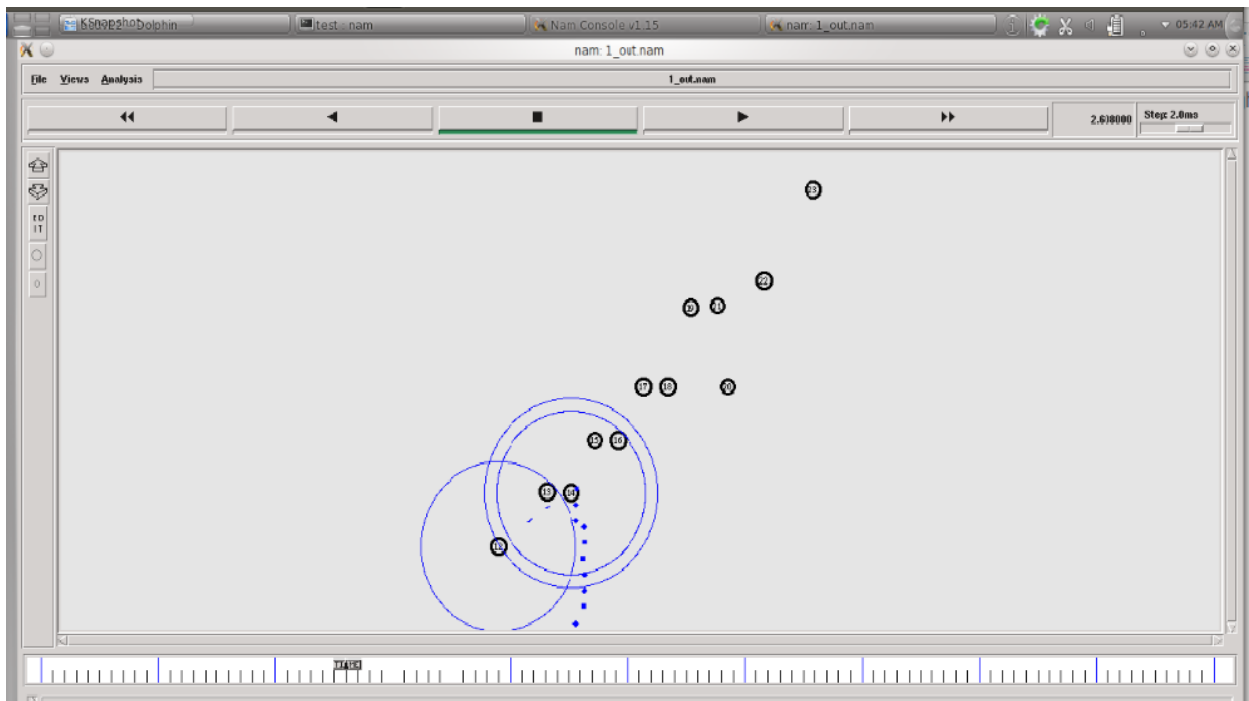


Fig 4.1 Nam file of 12 nodes

Trace-Files:

```

s 1.1000000000 _0_ AGT --- 2 Ant 27 [0 0 0 0] ----- [0:0 1:0 32 1] [ant 27 0 0]
r 1.1000000000 _0_ RTR --- 2 Ant 27 [0 0 0 0] ----- [0:0 1:0 32 1] [ant 27 0 0]
s 1.1000000000 _1_ AGT --- 10 Ant 27 [0 0 0 0] ----- [1:0 5:0 32 5] [ant 27 0 0]
r 1.1000000000 _1_ RTR --- 10 Ant 27 [0 0 0 0] ----- [1:0 5:0 32 5] [ant 27 0 0]
s 1.1000000000 _2_ AGT --- 7 Ant 27 [0 0 0 0] ----- [2:0 6:0 32 6] [ant 27 0 0]
r 1.1000000000 _2_ RTR --- 7 Ant 27 [0 0 0 0] ----- [2:0 6:0 32 6] [ant 27 0 0]
s 1.1000000000 _3_ AGT --- 7 Ant 27 [0 0 0 0] ----- [3:0 2:0 32 2] [ant 27 0 0]
r 1.1000000000 _3_ RTR --- 7 Ant 27 [0 0 0 0] ----- [3:0 2:0 32 2] [ant 27 0 0]
s 1.1000000000 _4_ AGT --- 15 Ant 27 [0 0 0 0] ----- [4:0 5:0 32 5] [ant 27 0 0]
r 1.1000000000 _4_ RTR --- 15 Ant 27 [0 0 0 0] ----- [4:0 5:0 32 5] [ant 27 0 0]
s 1.1000000000 _5_ AGT --- 9 Ant 27 [0 0 0 0] ----- [5:0 4:0 32 4] [ant 27 0 0]
r 1.1000000000 _5_ RTR --- 9 Ant 27 [0 0 0 0] ----- [5:0 4:0 32 4] [ant 27 0 0]
s 1.1000000000 _6_ AGT --- 11 Ant 27 [0 0 0 0] ----- [6:0 2:0 32 2] [ant 27 0 0]
r 1.1000000000 _6_ RTR --- 11 Ant 27 [0 0 0 0] ----- [6:0 2:0 32 2] [ant 27 0 0]
s 1.1000000000 _7_ AGT --- 6 Ant 27 [0 0 0 0] ----- [7:0 3:0 32 3] [ant 27 0 0]
r 1.1000000000 _7_ RTR --- 6 Ant 27 [0 0 0 0] ----- [7:0 3:0 32 3] [ant 27 0 0]
s 1.1000000000 _8_ AGT --- 2 Ant 27 [0 0 0 0] ----- [8:0 12:0 32 12] [ant 27 0 0]
r 1.1000000000 _8_ RTR --- 2 Ant 27 [0 0 0 0] ----- [8:0 12:0 32 12] [ant 27 0 0]
s 1.1000000000 _9_ AGT --- 3 Ant 27 [0 0 0 0] ----- [9:0 10:0 32 10] [ant 27 0 0]
r 1.1000000000 _9_ RTR --- 3 Ant 27 [0 0 0 0] ----- [9:0 10:0 32 10] [ant 27 0 0]
s 1.1000000000 _10_ AGT --- 9 Ant 27 [0 0 0 0] ----- [10:0 14:0 32 14] [ant 27 0 0]
r 1.1000000000 _10_ RTR --- 9 Ant 27 [0 0 0 0] ----- [10:0 14:0 32 14] [ant 27 0 0]
s 1.1000000000 _11_ AGT --- 2 Ant 27 [0 0 0 0] ----- [11:0 10:0 32 10] [ant 27 0 0]
r 1.1000000000 _11_ RTR --- 2 Ant 27 [0 0 0 0] ----- [11:0 10:0 32 10] [ant 27 0 0]
s 1.1000000000 _12_ AGT --- 0 Ant 27 [0 0 0 0] ----- [12:0 13:0 32 13] [ant 27 0 0]
r 1.1000000000 _12_ RTR --- 0 Ant 27 [0 0 0 0] ----- [12:0 13:0 32 13] [ant 27 0 0]
s 1.1000000000 _13_ AGT --- 5 Ant 27 [0 0 0 0] ----- [13:0 9:0 32 9] [ant 27 0 0]
r 1.1000000000 _13_ RTR --- 5 Ant 27 [0 0 0 0] ----- [13:0 9:0 32 9] [ant 27 0 0]
s 1.1000000000 _14_ AGT --- 8 Ant 27 [0 0 0 0] ----- [14:0 10:0 32 10] [ant 27 0 0]
r 1.1000000000 _14_ RTR --- 8 Ant 27 [0 0 0 0] ----- [14:0 10:0 32 10] [ant 27 0 0]
s 1.1000000000 _15_ AGT --- 2 Ant 27 [0 0 0 0] ----- [15:0 11:0 32 11] [ant 27 0 0]
r 1.1000000000 _15_ RTR --- 2 Ant 27 [0 0 0 0] ----- [15:0 11:0 32 11] [ant 27 0 0]
s 1.1000000000 _0_ RTR --- 0 AODV 48 [0 0 0 0] ----- [0:255 -1:255 30 0] [0x2 1 1 [1 0] [0 4]] (REQUEST)
s 1.1000000000 _1_ RTR --- 0 AODV 48 [0 0 0 0] ----- [1:255 -1:255 30 0] [0x2 1 1 [5 0] [1 4]] (REQUEST)
s 1.1000000000 _2_ RTR --- 0 AODV 48 [0 0 0 0] ----- [2:255 -1:255 30 0] [0x2 1 1 [6 0] [2 4]] (REQUEST)
s 1.1000000000 _3_ RTR --- 0 AODV 48 [0 0 0 0] ----- [3:255 -1:255 30 0] [0x2 1 1 [2 0] [3 4]] (REQUEST)

```

Fig 4.2 Trace Format of ANT-AGENTS WITH AODV

4.2 Throughput Comparison

The number of packets reached at the destination or receiver which is useful. The formula for throughput is given below:

$$\text{Throughput} = (\text{RecdSize}/(\text{StopTime}-\text{StartTime})) * (8/1000) \quad \text{----- eqn- 4.1}$$

Where recd size is the size of packet received at the receiver, stop time is the time where packet transmissions are stopped and start time is where sending of packets are taking place and this 8/1000 means 8 as number of bits transmitted over 1000 size of packet. So from the figure we conclude that while number of node increases then throughput also increases in both cases. This graph and values shows that the ANT-AGENTS WITH AODV is better than AODV.

Table 4.2 Throughput Data (kbps)

No. of nodes	AODV	ANT- Agents with AODV
10	730.924	995.191
12	731.278	1570.45
16	900.289	2078
25	981.36	2387

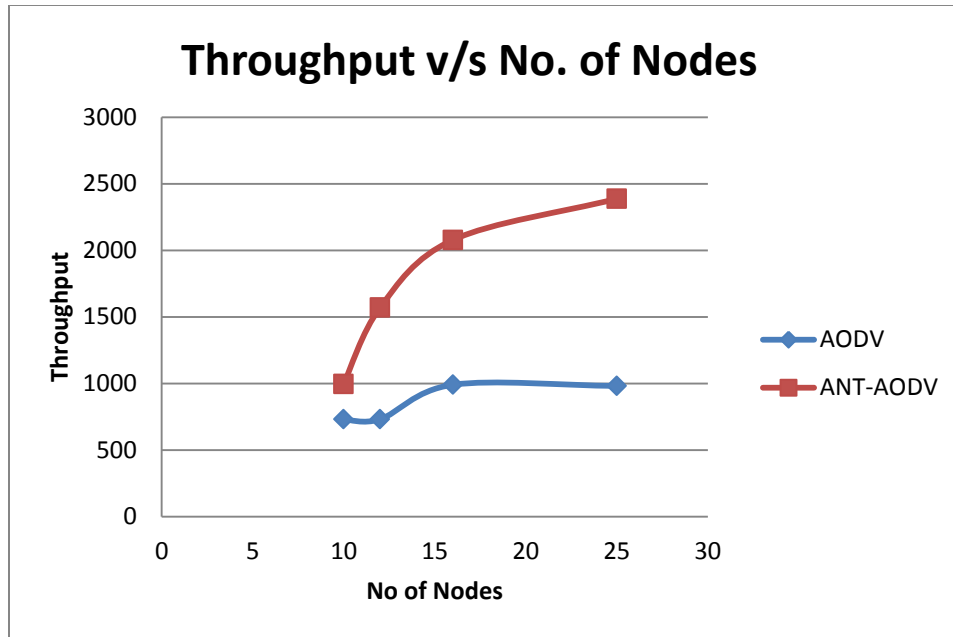


Fig 4.3 Throughput v/s No. of Nodes

4.3 End-to-End delay Comparison:

It is average time which is utilized in receiving a packet from source to destination (delay generated in route reply procedure + delay in data communication queue). The following formula represent the end to end delay:

$$EED = (\text{Time packet received} - \text{Time packet sent}) / \text{Total number of packets received} \text{---eqn- 4.2}$$

Table shows data of the end to end delay introduced after the simulation of AODV and ANT-AGENTS WITH AODV. Using these values, build the graph for these protocols. The end to end delay is less for ANT-AGENTS WITH AODV than AODV because it uses ant agents which find optimal path as well as introduce alternative and multiple routes using when links are broken or fails. There is no need of route discovery when links will break in ANT-AGENTS WITH AODV because it already has route information stored in pheromone table. So, it has been conclude that when number of nodes increases then end to end delay decreases in ANT-AGENTS WITH AODV rather than in AODV.

Table 4.3 End to End delay data (in sec)

No. of Nodes	AODV	ANT-Agents with AODV
10	1.92	0.67
12	1.48	0.46
16	0.81	0.26
25	0.61	0.1

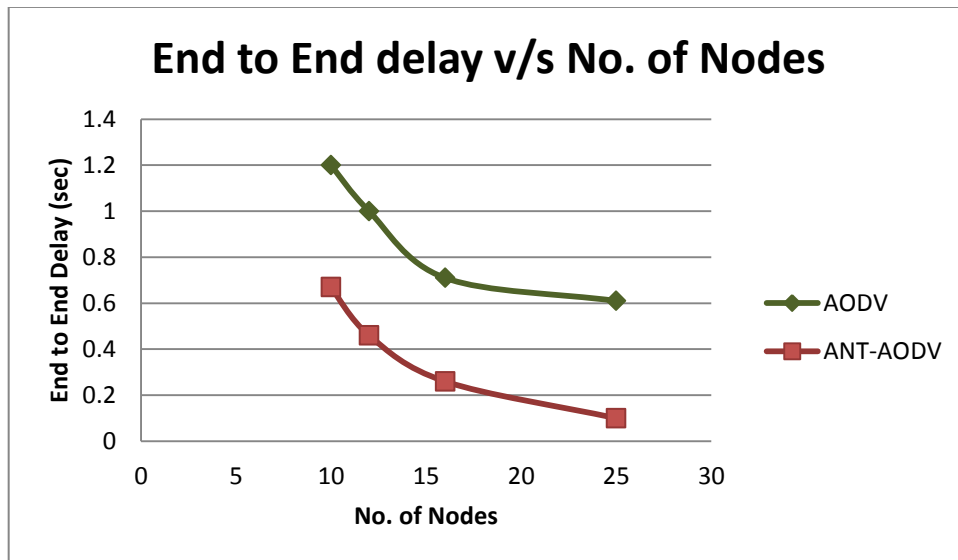


Fig 4.4 End to End Delay v/s No. of Nodes

4.4 Packet Delivery Ratio Comparison:

The fraction of packet received at destination that is the ratio of packet received to the packet transmitted by sender. The packet delivery ratio is:

$$PDF = (\text{recvs}/\text{sends}) * 100 \quad \text{-----} \quad \text{eqn- 4.3}$$

Where recvs is the number of packets received at the receiver end and sends is the number of packets created by sender.

The packet delivery ratio of ANT-AGENTS WITH AODV varies when number of nodes increases but AODV ratio first increases and then decreases. So, it has been concluded that ANT-AGENTS WITH AODV has high packet delivery ratio than AODV.

Table 4.4 Packet Delivery Fraction Data (%)

No. of Nodes	AODV	ANT- Agents with AODV
10	182.61	153.99
12	192.67	234.54
16	154.99	198
25	148.59	294.69

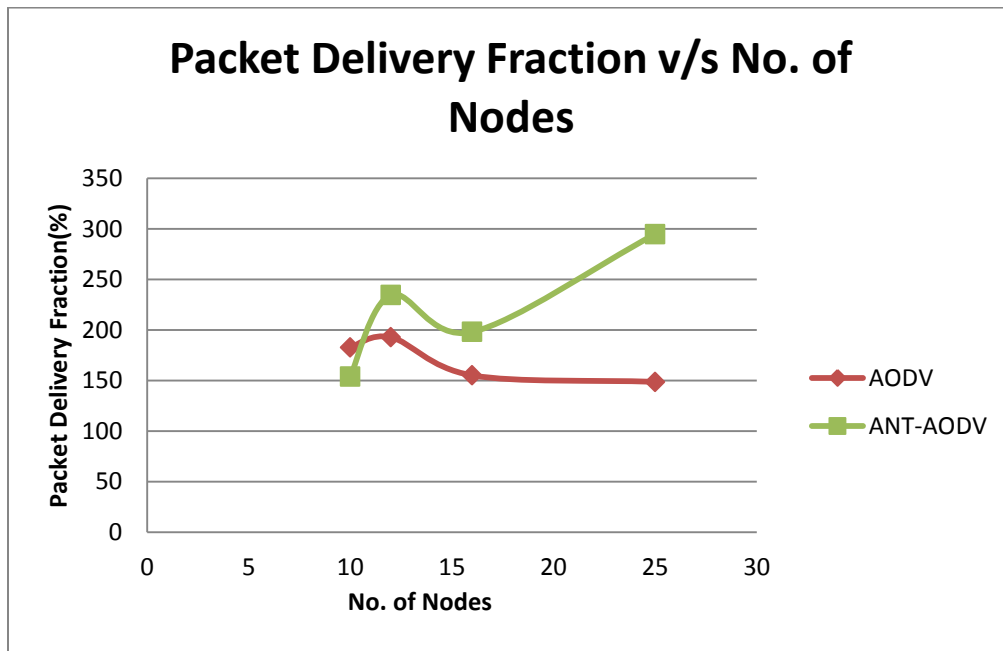


Fig 4.5 Packet Delivery Fraction v/s No. of Nodes

4.5 Routing Overhead Comparison

Routing overhead means the number of routing packets send during simulation. The routing overhead uses the following formula

$$\text{Routing overhead} = \sum \text{Transmission of routing packets (1,n)} \text{ -----eqn- 4.4}$$

Where n is total number of routing packets. Table 4.5 shows data of the routing overhead introduced after the simulation of AODV and ANT-AGENTS WITH AODV. Using these values, build the graph 4.5 for these protocols. The routing overhead increases when number of node increases in every protocol but the routing overhead is less for ANT-AGENTS WITH AODV than AODV because it uses ant agents which find optimal path as well as introduce alternative and multiple routes using when links are broken or fails. There is no need of route discovery when links will break in ANT-AGENTS WITH AODV because it already has route information stored in pheromone table.

Table 4.5 Routing Overhead Data (no. of packets per second)

No. of Nodes	AODV	ANT-Agents with AODV
10	197	91
12	233	139
16	384	231
25	693	602

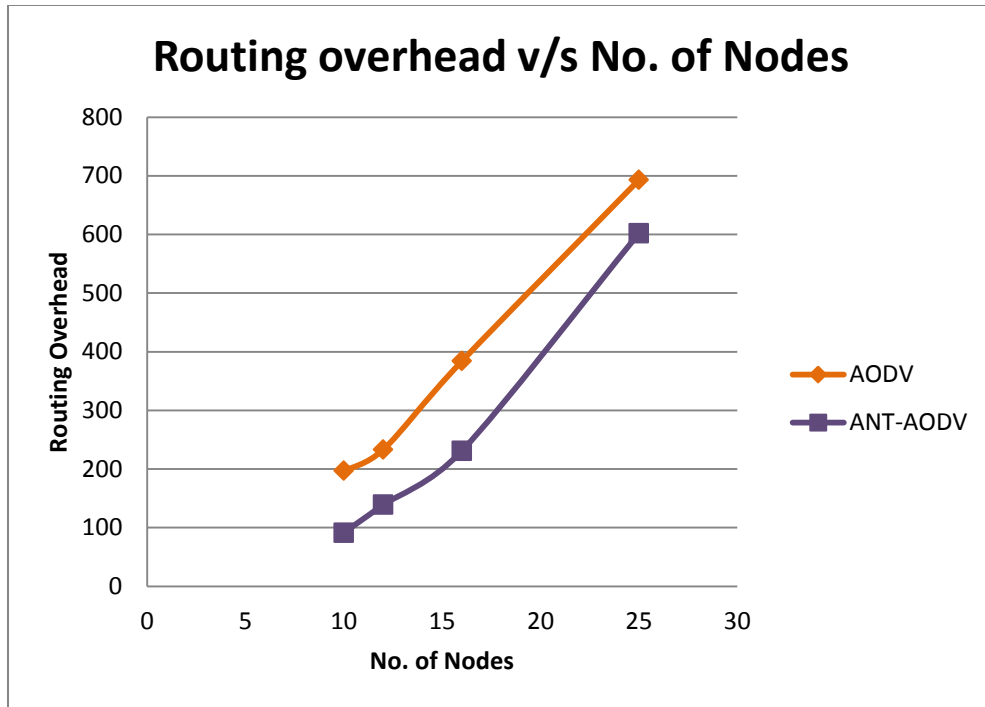


Fig 4.5 Routing Overhead v/s No. of Nodes

4.6 Analysis of AODV and Ant-Agents with AODV

There is comparison of AODV and ANT-AGENTS WITH AODV. ANT-AGENTS WITH AODV is better as compared to AODV. The comparison is given as following:

Table 4.6 Analysis of AODV and ANT- Agents with AODV Protocols

Network Parameters	AODV	ANT- Agents with AODV
End to End delay	More	Less (approx. 50%)
Packet delivery ratio	Less	More (approx. 16%)
Throughput	Less	More (approx. 27)
Routing Overhead	More	Less (approx. 50%)

5.1 Conclusion

Manets have been growing rapidly and became popular because of wireless network. There were some matters like routing, bandwidth constrained, dynamic topology. So routing protocols have been developed but they were very difficult. These protocols have been established but these have problems like low bandwidth, high error rate, power consumption and packet sinking. There have been evolved many techniques like swarm intelligence. In swarm intelligence there were chosen a best procedure Ant agents with AODV that solve the all above problem specially routing problem. It uses a chemical substance which is known as pheromone and its value is used to find the shortest path from the source to destination and store it in routing table.

Some hard work has been done to resolve these problems of packet sinking which has occurred in MANETs by using Ant agents. These MANETs have dynamic behavior and bandwidth constrained and has problems like more overhead and more routing and it has better scalability, adaptability and self-organized which has adaptability on life time changes and robustness also. While using this ant colony optimization it gives the shortest path and offer best secondary paths. The ant based Mesh Ad hoc on demand distance vector routing protocol the ant mobile agents are combined with AODV is known as ANT-AGENTS WITH AODV. These protocols works under mesh topology which develop the routing problem find alternative paths in case of failure in least time and survive with high traffic and for multimedia communication and real time data it gives high connectivity.

In the presented work, the simulation of AODV is shown on different-different node numbers and ANT-AGENTS WITH AODV has also same procedure. There will be packet dropping because of link failure and in this ant based protocol there is no local connection maintenance as in mobile ad hoc protocol. But in mobile ad-hoc protocol takes more time to detect and develop a path because of using RREQ/RREP control messages and there is more delay than ANT-AGENTS WITH AODV because it detect and established the path and also provide alternative and multiple routes.

In this work, it has the application and assessment of AODV and it uses Ant agents so that overall performance will be improved. ANT-Agents with AODV has high packet delivery than AODV because it has link failure detection mechanism and manages the link failure and decreases the drooping of packets.

So, we can see after comparison, end to end delay decreases in ANT-AGENTS WITH AODV and increases in AODV and routing overhead is low in ANT-AGENTS WITH AODV and optimizes the overall performance of network.

Future Scope

The future work of research can be considered in the following areas:

There could be interesting to observe the performance of DSDV, DSR by making use of Ant agents. The performance will be measured of proposed ant routing protocol under various measures such as available energy at each node in the network. Further, the different simulation models (such as – Manhattan model, Random way-point group mobility etc.) can also be considered.

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LIST OF PUBLICATIONS

1. A.K.Verma, Ekta Bansal “Routing Protocols For MANETs: A Survey” National Conference On Futuristic Trends in Computing, Communication and Information System at Yamuna Nagar (2013)
2. A.K.Verma, Ekta Bansal “Modifying AODV For Better Performance” , National Conference On Science and Technology at DAV Jalandhar (2013)
3. A.K.Verma, Ekta Bansal “A Novel routing protocol for MANET using ANT Agents”, Communicated in International Journal Of Computer Science and Technology (2013)