Performance Evaluation of AODV Protocol Using NS2 Simulator

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ABSTRACT - Mobile ad hoc networks (MANETs) represent complex distributed systems that comprise wireless mobile nodes which can dynamically self-organize into arbitrary and temporary, "ad-hoc" network topologies. This allows people and devices to seamlessly internetwork in areas with no pre-existing communication infrastructure. One interesting research area in MANET is routing. Routing in the MANETs is a challenging task and has received a tremendous amount of attention from researchers. This has led to development of many different routing protocols for MANETs. A mobile node is a collection point in the network which uses a particular protocol to forward data from source to destination. The nodes are free to move about and organize themselves into a network. The requirement of routing protocol is to send and receive information among the nodes with best suited path with the minimum delay. Correct and efficient route establishment between a pair of nodes is the primary goal of routing protocol. This paper is a simulation based analysis of Ad hoc on demand Distance Vector (AODV). The mobility models used in this work is Random Waypoint using network simulation tool NS2. The results presented in this work illustrate the performance of AODV routing protocols in an ad hoc environment.

Keywords: *MANET, Reactive protocols, AODV, Performance metrics*

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1 INTRODUCTION

In Computer terminology, the definition for networks is similar as a group of computers logically connected for the sharing of information or services (like print services, multi-tasking, etc.). Initially Computer networks were started as a necessity for sharing files and printers. Later this has moved from that particular job of file and printer sharing to application sharing and business logic sharing. Networks can be classified into two categories wire and wireless networks. Wireless networks are also named as ad hoc networks. In ad hoc networks all nodes are mobile and can be connected dynamically in an arbitrary manner. All nodes of these networks behave as routers and take part in discovery and maintainers of routes to other nodes in the network. The main advantages of ad hoc networks are flexibility, low cost, and robustness. MANET is a collection of mobile nodes, which forms a temporary network without the aid of centralized administration or standard support services regularly available on conventional networks. The nodes are free to move randomly and organize themselves arbitrarily; thus the network's wireless topology may change rapidly and unpredictably. The most basic operation in MANET is to successfully transmit data packets from one source to one destination. Routing has been a challenging task ever since the wireless networks came into existence. The major reason for this is the constant change in network topology because of high degree of node mobility. A number of routing protocols have been developed for accomplish this task.

Routing protocols can be classified into three major categories based on the routing information update mechanism. Proactive, reactive and hybrid protocols. The focus of our study is on-demand routing protocols. One of the on-demand routing protocol is AODV. The main advantage of this protocol is that routes are established on demand i.e., only when it is required by a source node for transmitting data packets. But due to the dynamic change of network topology, links between nodes are not permanent. When a link breaks, a node cannot send packets to the intended next hop node resulting in packet loss. If the lost packet is a route reply packet it brings much more problems as the source node needs to reinitiate route discovery procedure. Therefore in most of the cases performance analysis is carried out using various popular simulators like NS-2 on behalf of different performance metrics and by using some specific network parameters.

The primary objective of this paper is to evaluate the performance of AODV protocol and study its effects with respect to performance metrics that may influence network performance. The metrics like Packet Delivery Ratio, End to End Delay, Route Overhead, Throughput, and Energy Consumption are verified using the number of nodes, Simulation Time, Packet Size and Mobility. The paper is organized as follows: Section 2 presents the overview of AODV. Section 3 provides the Network Simulators (ns2). The simulation parameters and metrics are described in Section 4. Section 5 presents the Simulation Results. Finally Section 6 concludes the paper.

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2 OVERVIEW OF AODV

Routing protocols for Mobile ad hoc networks can be broadly classified into three main categories such as Proactive or table-driven routing protocols, Reactive or on-demand routing protocols, and Hybrid Routing protocols.

AODV is a reactive routing protocol that does not require maintenance of routes to destination nodes that are not in active communication. Instead, it allows mobile nodes to quickly obtain routes to new destination nodes. Every mobile node maintains a routing table that stores the next hop node information for a route to the destination node. When a source node wishes to route a packet to a destination node, it uses the specified route if a fresh enough route to the destination node is available in its routing table. If such a route is not available in its cache, the node initiates a route discovery process by broadcasting a *RouteRequest* (RREQ) message to its neighbors. On receiving a RREQ message, the intermediate nodes update their routing tables for a reverse route to the source node. All the receiving nodes that do not have a route to the destination node broadcast the RREQ packet to their neighbors. Intermediate nodes increment the hop count before forwarding the RREQ. A *RouteReply* (RREP) message is sent back to the source node when the RREQ query reaches either the destination node itself or any other intermediate node that has a current route to the destination. As the RREP propagates to the source node, the forward route to the destination is updated by the intermediate nodes receiving a RREP.
The RREP message is a unicast message to the source node.

AODV routing path will be set based on the nearest nodes which reply first to the source node (28^{th}). This scenario is followed for every node while receiving reply from the destination node. The path is shown in green colour in the below figure 1. Now the first route is created with the following nodes: 28-35-3-6-0-9-19-24-36. Once the route is set, then the source node will initiate the packet transmission to the destination node.

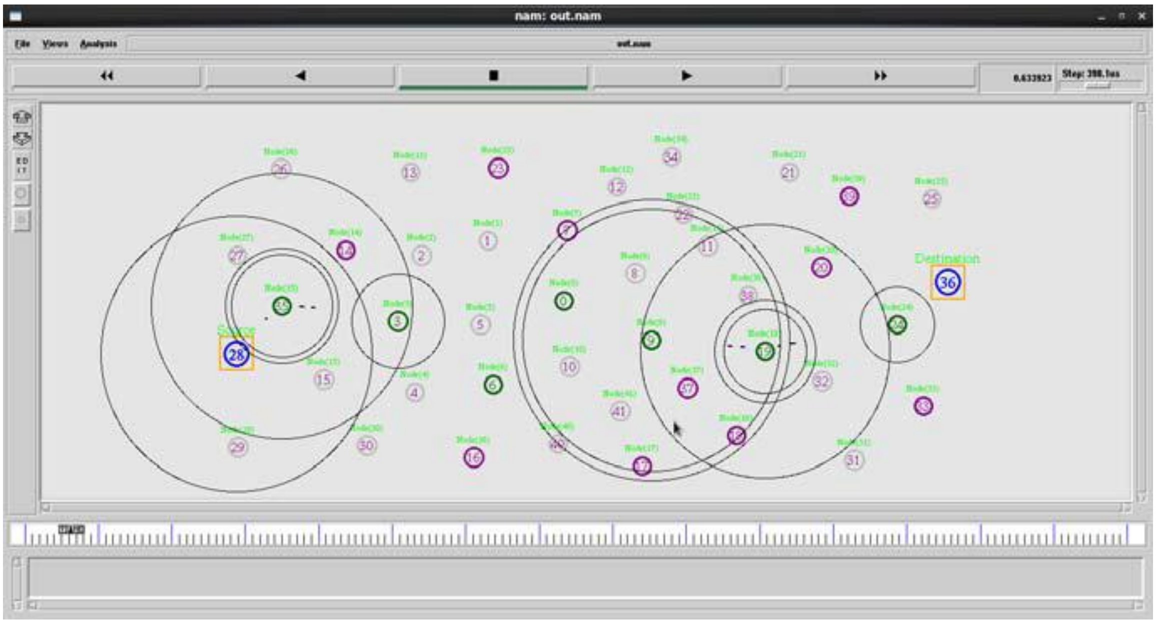

Figure1. AODV Routing path

AODV uses sequence numbers to determine the freshness of routing information and to guarantee loop-free routes. In case of multiple routes, a node selects the route with the highest sequence number. If multiple routes have the same sequence number, then the node chooses the route with the shortest hop count. Timers are used to keep the route entries fresh. When a link break occurs, *RouteError* (RERR) packets are propagated along the reverse path to the source invalidating all broken entries in the routing table of the intermediate nodes. AODV also uses periodic *hello* messages to maintain the connectivity of neighboring nodes.

3 NETWORK SIMULATORS (NS2)

Ns-2 is a discrete event simulator targeted at networking research. It provides substantial support for simulation of TCP, routing and multicast protocols over wired and wire-less networks. The network simulator (ns) contains all commonly used IP protocols. Ns-2 fully simulates a layered network from the physical radio transmission channel to high-level applications. NS2 (2.34 & 2.35) simulator is used for simulating different reactive routing protocols. The simulator is written in C++ and a script language called OTcl. NS uses an OTcl interpreter towards the user. This means that the user writes an OTcl script that defines the network (number of nodes, links) the traffic in the network (sources destinations, type of traffic) and which protocols it will use. This script is then used by ns during the simulations.

The result of the simulations is an output trace file that can be used to do data processing (calculate delay, throughput etc) and to visualize the simulation a program called Network Animator (NAM) used. NAM is a very good visualization tool that visualizes the packets as they propagate through the network. NAM is a Tcl/AWK based animation tool for viewing network simulation traces and real world packet trace data. The first step to use NAM is to produce the trace file. The trace file contains topology information, e.g., nodes, links, as well as packet traces. During an NS simulation, a user can produce topology configurations, layout information, and packet traces using tracing events in NS. When the trace file is generated, it is ready to be animated by NAM. Upon startup, NAM will read the trace file, create topology, pop up a window, do layout if necessary.

4 SIMULATION PARAMETERS

The goal of our experiments is to examine and quantify the effects of various factors and their interactions on the overall performance of ad-hoc networks. Every run of the simulator accepts a scenario file as input that describes the exact motion of each node using Random Waypoint mobility model. The exact sequence of packets originated at each node together with exact time during change in packet or motion origination occurs.

Table 1: Simulation Parameter

Experiment Parameter	Experiment value	Description
Simulation Time	0 – 10 mps	Simulation Duration
Terrain Dimension	[1050*600]m	X,Y Dimension of motion
No. of mobile nodes	42	No. of nodes in a network
Node Placement	Random Waypoint	Change Direction randomly
Mobility Speed	0 – 10 mps	Mobility of nodes
Packet Size	256,512,625,712,850	Size of packets
Mobility Model	Random	Mobility direction
Routing Protocols	AODV, DSR, TORA	Path-finding
MAC Protocol	802.11	Wireless Protocol
Channel Type	Wireless Channel	Types of Channel
Maximum Packets	50	No. of packets

In all our experiments we considered five sample points of a particular factor and verified for AODV protocol. Therefore 15 simulation runs were conducted to analyze the performance. Standard statistics of the packet delivery ratio, packet end to end delay, routing overhead, throughput and energy consumption for the entire MANET is examined. In our simulations, the MAC layer runs on the IEEE 802.11 Distributed Coordination Function (DCF). The bandwidth is set to 2 Mbps and the transmission range is set to 250 m. The evaluations are conducted using 42 nodes that are randomly distributed in an area covering 1050m x 600m. The traffic sources are CBR (continuous bit –rate). The mobile nodes and the server were spread randomly within the geographic area. In this project, we used TCP traffic to study the effects of the ad hoc protocol. In the Random Waypoint model, each node starts to move from its location to a random location with a randomly chosen speed from a minimum speed equal to 5 m/s and maximum speed equal to 30 m/s. In each test, the simulation lasts for 600 seconds. Once the destination node is reached, the node takes a break

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for a certain period of time in seconds and another random destination is chosen after that pause time. The model parameters that are used in the experiments are summarized in Table 1. The size of each Constant Bit Rate (CBR) packet is 1000 bytes and packets are generated at a fixed interval rate of 4 packets per second. 15 flows were configured to choose a random source and destination during the simulation.

4.1 Performance metrics

Packet delivery ratio: The ratio between the number of packets originated by the CBR sources and the number of packets received by the CBR sink at the final destination. It describes the loss rate seen by the protocol.

End-to-End Delay: Average amount of time taken by a packet to go from source to destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission on delays at MAC, and propagation and transfer times.

Route overhead: The total number of routing packets transmitted during the simulation. If control and data traffic share the same channel, and the channels capacity is limited, then excessive control traffic often impacts data routing performance. This is the ratio between the total control packets generated to the total data packets during the simulation time.

Throughput: It is defined as total number of packets received by the destination. It is a measure of effectiveness of a routing protocol. There is two representations of throughput one is the amount of data transferred over the period of time expressed in kilobits per second (Kbps). The other is the packet delivery percentage obtained from a ratio of the number of data packets sent and the number of data packets received.

Energy Consumption: Energy consumption of a node is mainly due to the transmission and the reception of data or controlling packets. To measure this amount of energy consumed during the transmission process (noted txEnergy), we should multiply the transmission power (txPower) by the time needed to transmit a packet:

txEnergy = txPower x (packetsize/bandwidth)

And for a received packet:

rxEnergy = rxPower x (packetsize/bandwidth)

5 SIMULATION RESULTS

5.1 AODV Performance with respect to Simulation Time

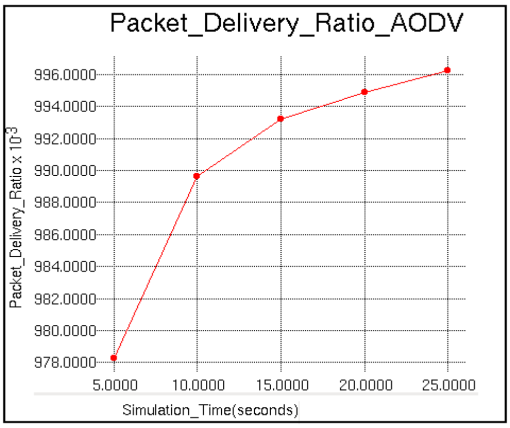
The performance of AODV routing protocol is evaluated in same simulation environment with 42nodes. Simulation results are collected from different scenarios of reactive protocols. They are revealed in the subsequent section in the form of X-graph taking simulation time along X-axis and the performance metrics in Y-axis. A study of performance metrics of AODV reactive protocol is done with respect to Simulation time 5, 10, 15, 20 and 25seconds. A table of performance metric values with respect to simulation time was created & shown below Table 2.

AODV-Simulation Time					
Values	**PDR**	**E2E**	**Rout-over-head**	**Throughput**	**Egy-consum**
5	0.9783	56.3343	0.490	337.48	18.3259
10	0.9896	55.7085	0.232	332.27	38.7326
15	0.9932	55.474	0.152	330.66	59.3181
20	0.9949	55.4052	0.230	324.73	78.9898
25	0.9962	49.7328	0.376	319.01	87.6023

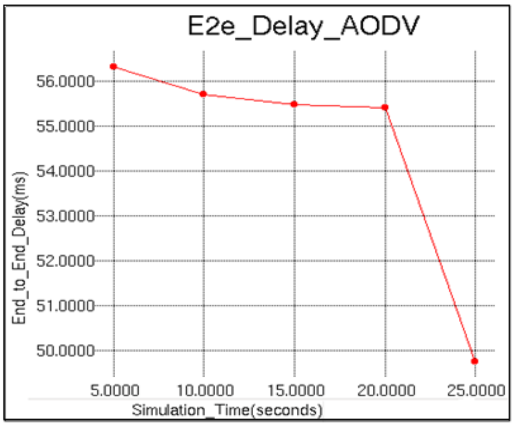
Table 2: AODV – Simulation Time

The X-Graphs Shown in figure 2 represents performance metrics of AODV Vs Simulation time. Figure (a) illustrates the results of Packet Delivery Ratio with Simulation time, taking simulation time along the X-axis and Packet Delivery Ratio in the Y-axis. Figure (b) shows the results of End to End Delay with Simulation time, taking simulation time along the X-axis and End to End Delay in the Y-axis. This graph indicates End to End Delay in ms. In this the delay is more when the simulation time is less and the delay reduces as the simulation time increases.

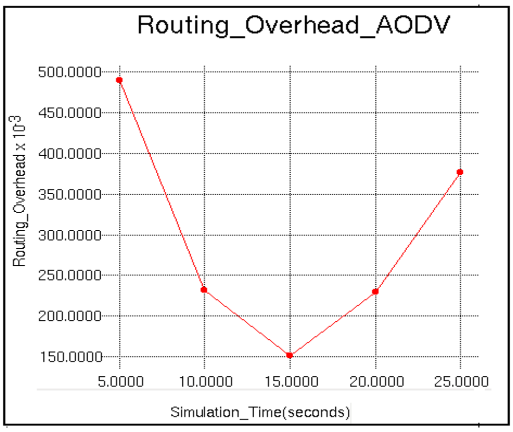
Figure (c) illustrates the results of Route Overhead with Simulation time, taking simulation time along the X-axis and Route Overhead along the Y-axis. In this Route Overhead decreases at 15sec and gradually increases as simulation time is increased. Figure (d) illustrates the effect of Throughput with Simulation time, taking simulation time along the X-axis and Throughput in the Y-axis. This graph shows Throughput in kbps. Here the Throughput is reduced as the simulation time increases. Figure (e) illustrates the outcome of Energy Consumption with Simulation time, taking simulation time along the X-axis and Energy Consumption along the Y-axis. The unit is in joules which increase as simulation time increases.



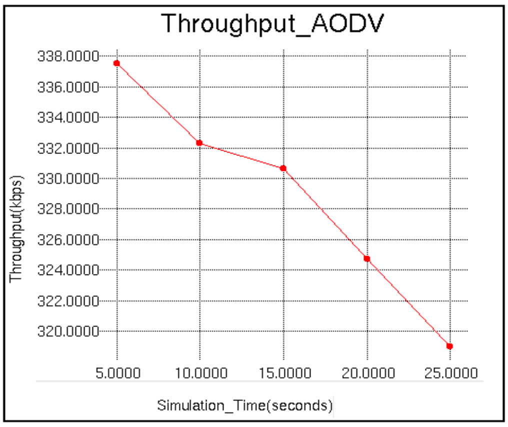
a). Packet Delivery Ratio



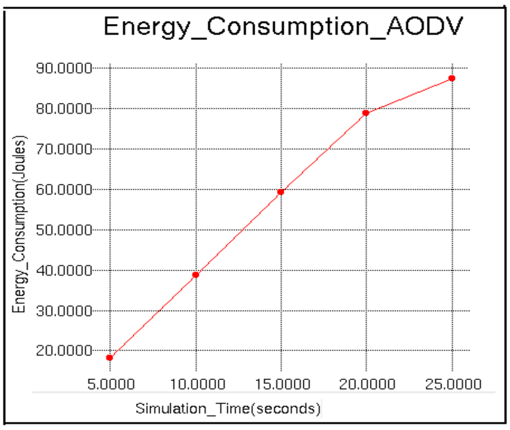
b). End to End Delay



c). Routing Overhead



d). Throughput



e). Energy Consumption

Figure 2: Graphical representation of performance metrics in AODV Vs Simulation Time

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5.2 AODV Performance with respect to Packet Size

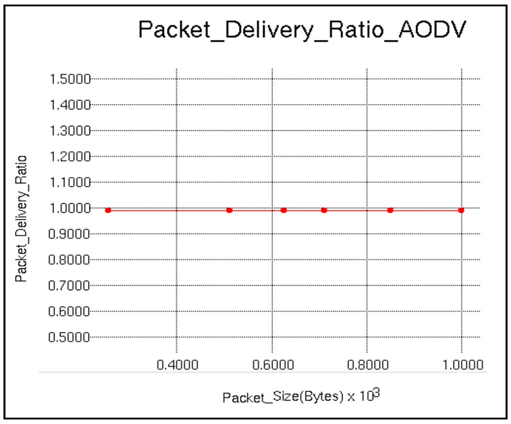
The performance of AODV routing protocol is evaluated in same simulation environment with 42nodes. Simulation results are collected from different scenarios of reactive protocols. The effects of simulation are exposed in the subsequent section via X-graph. X-axis shows the packet size and y-axis shows the metrics. A study of performance metrics of AODV reactive protocol is done with respect to packet size 256, 512, 625, 712, 850 & 1000 bytes. A table of performance metric values with respect to packet size was created & shown in below table 3.

AODV-Packet Size					
Values	**PDR**	**E2E**	**Rout-over-head**	**Throughput**	**Egy-consump**
256	0.9896	32.182	0.232	332.89	21.3221
512	0.9896	48.4404	0.232	332.53	33.3037
625	0.9896	55.7085	0.232	332.27	38.7326
712	0.9896	61.2479	0.232	332.07	42.7442
850	0.9896	70.0306	0.232	331.76	49.1433
1000	0.9896	79.5817	0.232	331.42	56.0569

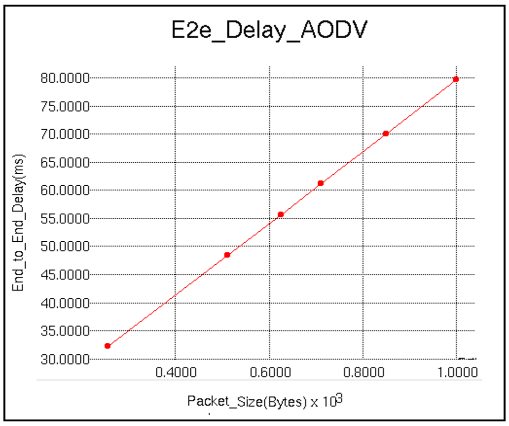
Table 3: AODV – Packet Size

The X-Graphs Shown in figure 3 represents performance metrics of AODV Vs Packet Size. Figure (a) illustrates the results of Packet Delivery Ratio with Packet Size, taking former along the X-axis and the later in Y-axis. This graph depicts PDR as constant for all packet sizes. Figure (b) shows the results of End to End Delay with Packet Size, taking Packet Size along the X-axis and End to End delay in the Y-axis. This graph indicates End to End Delay in ms. In this the delay is more as the packet size increases. Figure (c) illustrates the results of Route Overhead with Packet Size, taking Packet Size along the X-axis and Route Overhead in the Y-axis. This graph shows Route Overhead which is constant for all packet sizes.

Figure (d) illustrates the results of Throughput with Packet Size, taking Packet Size along the X-axis and Throughput in the Y-axis. This graph shows Throughput in kbps where it decreases slightly as packet size increases. Figure (e) illustrates the results of Energy Consumption with Packet Size, taking Packet Size along the X-axis and Energy Consumption in the Y-axis. This graph shows the Energy Consumption in joules which increases as packet size increases.



a). Packet Delivery Ratio



b). End to End Delay

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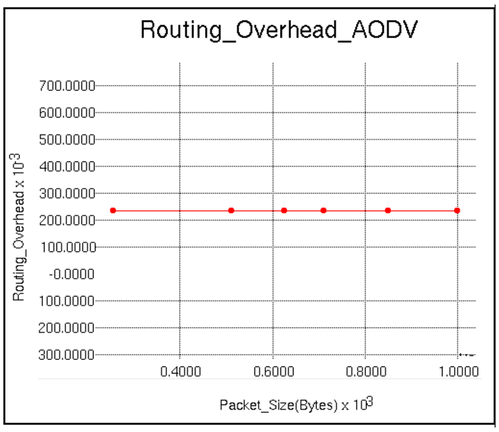
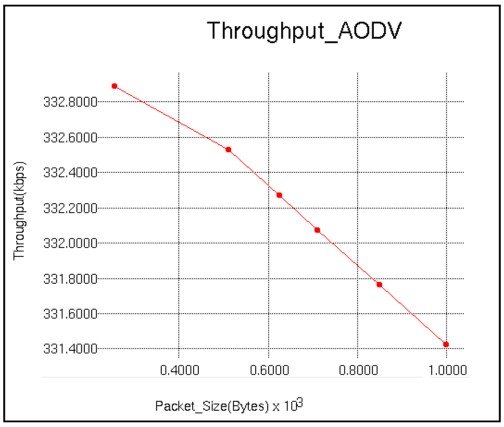
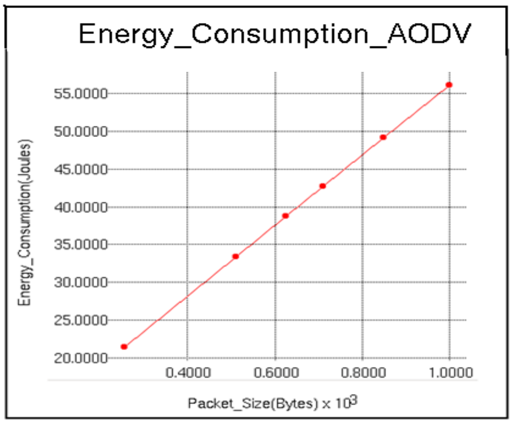


c). Routing Overhead



d). Throughput



e). Energy Consumption

Figure 3: Graphical representation of performance metrics in AODV Vs Packet Size

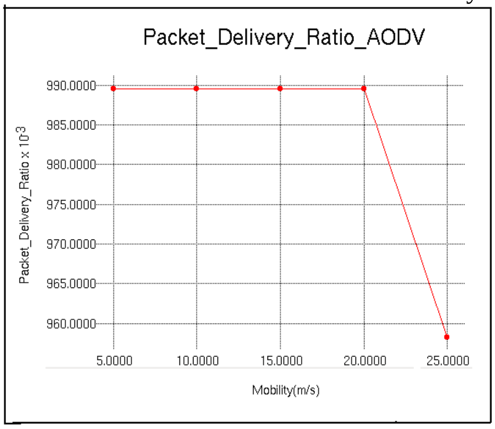
5.3 AODV Performance with respect to Mobility

The performance of AODV routing protocol is evaluated in same simulation environment with 42nodes. Simulation results are collected from different scenarios of three reactive protocols. The simulation results are revealed in the subsequent section via X-graph taking mobility along X-axis and the performance metrics in Y-axis. A study of performance metrics of AODV reactive protocol is done with respect to mobility speed 5, 10, 15, 20 & 25m/s. A table of performance metric values with respect to mobility speed was created & shown below Table 4.

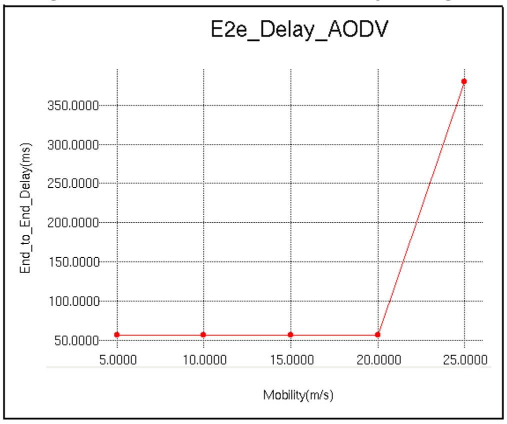
AODV-Mobility					
Values	**PDR**	**E2E**	**Rout-over-head**	**Throughput**	**Egy-consump**
5	0.9896	56.0344	0.232	332.38	38.3366
10	0.9896	56.0342	0.232	332.38	38.3738
15	0.9896	56.0337	0.232	332.38	39.7197
20	0.9896	56.0335	0.232	332.38	39.4864
25	0.9583	379.148	1.061	324.91	40.1338

Table 4: AODV – Mobility

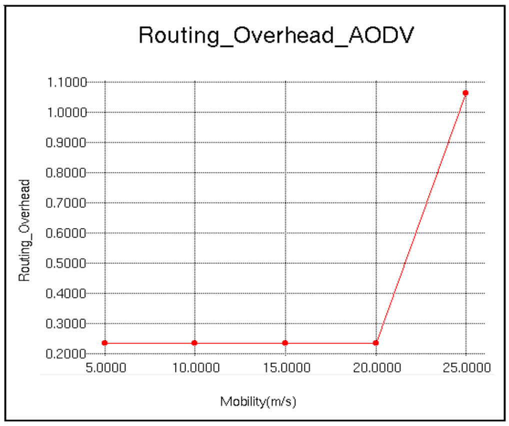
The X-Graphs Shown in figure 4 represents performance metrics of AODV Vs Mobility. Figure (a) illustrates the results of Packet Delivery Ratio with Mobility, taking mobility along the X-axis and Packet Delivery Ratio in the Y-axis. In this graph the PDR is constant up to 20m/s and decreases substantially for 25m/s. Figure (b) shows the results of End to End Delay with Mobility, taking Mobility along the X-axis and End to End delay in Y-axis. The unit is in ms. In this the delay is lesser up to 20m/s and increases substantially for 25 m/s. Figure (c) illustrates the results of Route Overhead with Mobility. X-axis represents mobility with Route Overhead in Y-axis. This graph shows Route Overhead which is constant up to 20m/s and increases substantially for 25 m/s. . Figure (d) illustrates the results of Throughput with mobility, taking Mobility along the X-axis and Throughput in Y-axis. This graph shows Throughput in kbps. Here the throughput decreases for 25m/s. Figure (e) illustrates the results of Energy Consumption with Mobility, taking Mobility along the X-axis and Energy Consumption in the Y-axis. This graph shows the Energy Consumption in joules which is irregular but increases substantially at high mobility speed.



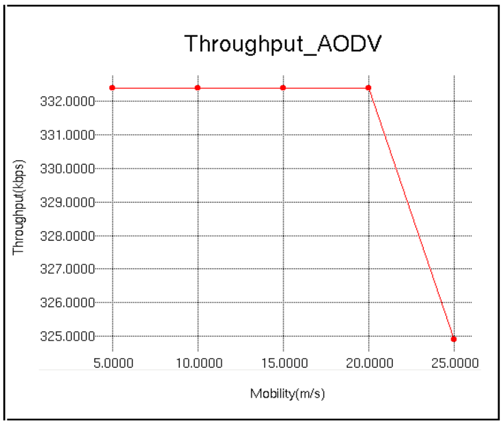
a). Packet Delivery Ratio



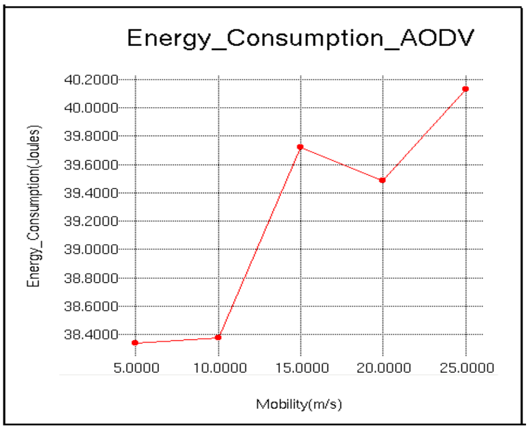
b). End to End Delay



c). Routing Overhead



d). Throughput



e). Energy Consumption

Figure 4: Graphical representation of performance metrics in AODV Vs Mobility

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CONCLUSION

This work is an attempt towards a comprehensive performance evaluation of AODV routing protocols using the latest simulation environment NS 2. The simulation characteristics used in this research are unique in nature, and are very important for detailed performance evaluation of any networking protocol. Implementation of AODV reactive routing protocol is done. Basically the five performance metrics packet delivery ratio, end to end delay, routing overhead, throughput and energy consumption are discussed. The trace files are generated and results are shown via X-Graphs. The results are projected by varying the simulation time, packet size and mobility using trace files. AODV has its excellent support for multiple routes and multicasting.

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