Comparative Performance Evaluation of Mobile Ad-hoc Network Routing Protocols using NS2 Simulator

Amena Begum, Md. Zahidur Rahman, Nurunnahar Nancy, Md. Enamul Haq

Abstract**: *A Mobile Ad-hoc Network (MANET) is an independent assortment of mobile users that communicate over moderately bandwidth constrained wireless links. MANET's topology is dynamic that can change rapidly because the nodes move freely and can organize themselves randomly; has the advantage of being quickly deployable. Although numerous routing protocols have been proposed for mobile ad hoc networks, there is no universal scheme that works well in scenarios with different network sizes, traffic loads and node mobility patterns, so mobile ad hoc routing protocol election presents a great challenge. In this paper, an attempt has been made to compare the performance of three routing protocols in Mobile Ad-hoc Networks – Ad-Hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Destination Sequenced Distance Vector (DSDV). We have evaluated the performance of these routing protocols with varying the number of mobile nodes and packet sizes on the basis of four important metrics such as packet delivery ratio, average end to end delay, normalized routing overhead and throughput. Network Simulator version 2.35 (NS-2.35) is used as the simulation tool for evaluating these performance metrics. The outcome of this research shows that AODV protocol outperforms DSDV and DSR protocols.***

Keywords**: *MANET, AODV, DSR, DSDV, NS2, Performance Metrics, Analysis.***

I. INTRODUCTION

Over the previous decade, there has been a growing interest in wireless networks, as the expense of mobile devices, for example, PDAs, laptops, cellular phones and so forth have diminished radically. The latest trend in wireless networks is towards pervasive and ubiquitous computing - taking into account both nomadic and fixed users, anytime and anywhere. Today, wireless Internet access is offered in various places such as universities, companies, cafeterias, airports and similar facilities. Notwithstanding, there is as yet a need for communication in several scenarios of deployment where it is not feasible to deploy fixed wireless access points due to physical constraints of the medium. For instance, think about communication among warriors in a war zone, including troops spread out over a huge region. For this situation, it is not only feasible to deploy a fixed wireless access point, yet in addition risky since an enemy attack would bring down the whole network. This problem has led to a growing interest among the research community in mobile ad-hoc networks (MANET).

Routing, as a demonstration of moving data from source to destination through intermediate nodes, is a principal issue for networks. Effectiveness of any network, including mobile ad hoc network, depends on routing protocol. Finding more efficient protocol is actual research area, because efficiency requirements are constantly increasing.

This paper presents a comparative performance evaluation of three routing protocols based on results analysis obtained by running simulations with different scenarios in Network Simulator version 2 (NS-2) [1]. Scenarios differ in the number of mobile nodes and packet sizes on the basis of four important metrics such as packet delivery ratio, average end to end delay, normalized routing overhead and throughput. Classification and description of Wireless Networks are given in Section II. Classifications of routing protocols are given in Section III. Simulation environment, simulation parameters and performance metrics are described in Section IV. Results and analysis are presented in Section V. Finally, section VI concludes this paper.

II. WIRELESS NETWORKS

A wireless network in general consists of a set of mobile hosts which communicate to other mobile hosts either directly or via an access point (base station). It is a rising innovation that permits users to access information and services electronically, paying little heed to their geographic position. Wireless networks can be classified in two types.

A. *Infrastructure Networks*

Infrastructure network comprises of a network with fixed and wired gateways. A mobile host communicates through a bridge in the network (called base station) inside its communication radius. The mobile unit can move geologically while it is communicating.

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***** Correspondence Author
Amena Begum*, Department of ICT, Comilla University, Cumilla - 3506, Bangladesh. Email: amenacou@gmail.com
Md. Zahidur Rahman, Department of CSE, Britannia University, Cumilla - 3500, Bangladesh. Email: mzahidur.bd@gmail.com
Nurunnahar Nancy, Department of ICT, Comilla University, Cumilla - 3506, Bangladesh. Email: naharict544@gmail.com
Md. Enamul Haq, Department of ICT, Comilla University, Cumilla-3506, Bangladesh. Email: enamul.cou@gmail.com

At the point when it leaves scope of one base station, it connects with new base station and starts communicating through it. This is called handoff. In this methodology the base stations are fixed.

B. *Infrastructure Less (Ad-hoc) Networks*

In ad-hoc networks [2] all nodes are mobile and can be connected dynamically in an arbitrary manner. As the scope of each host's wireless transmission is restricted, so to communicate with hosts outside its transmission scope, a host needs to enlist the aid of its close by hosts in forwarding packets to the destination. So all nodes of these networks act as routers and participate in discovery and maintenance of routes to other nodes in the network. Ad hoc Networks are valuable in emergency search-and rescue operations, meetings or conventions in which persons wish to rapidly share data and information. MANET is a sort of Ad-hoc network, is a collection of independent mobile nodes that can communicate to each other via radio waves. [3]

III. MOBILE AD-HOC NETWORK ROUTING PROTOCOLS

Mobile Ad-hoc Network Routing Protocols are mainly of three types proactive, reactive and hybrid protocol. Hybrid protocol is mainly combined form of proactive and reactive protocol.

A. *Proactive Routing Protocols*

Proactive routing protocols are also known as 'table driven' routing protocols. In proactive routing protocols, the nodes maintain an active list of routes to every other node in the network in a routing table. The tables are periodically updated by broadcasting information to different nodes in the network. Thus, they are an extension to the wired network routing protocols such as the Routing Internet Protocol (RIP). Any node wishing to communicate with another node has to obtain the next hop neighbor on the route to the destination from its routing table. Some examples of proactive routing are Destination Sequenced Distance-Vector routing protocol (DSDV) [4], Wireless Routing Protocol (WRP) [5], Cluster Switch Gateway Routing protocol (CGSR) [5], etc. In this paper, proactive routing protocol considered in detail is DSDV routing protocol.

A.1. Destination Sequenced Distance Vector (DSDV) Routing Protocol

The Destination Sequenced Distance Vector (DSDV) protocol is based upon the distributed Bellman Ford algorithm [4], which suffers from the count-to-infinity problem. In this routing protocol, each mobile host maintains a table that lists all available destinations, the number of hops to reach the destination and the sequence number assigned by the destination node. The sequence number is incremented upon every update sent by the host. All the hosts periodically broadcast their tables to their neighboring nodes in order to maintain an updated view of the network. The tables can be updated in two ways – either incrementally or through a full dump. DSDV guarantees loop free routes to each destination and also finds the optimal path. It uses an average settling delay to prevent frequent routing table updates and any fluctuations caused by two similar routing advertisements which are in an incorrect order of the sequence numbers.

B. *Reactive Routing Protocols*

For mobile ad-hoc networks, reactive routing protocols are also known as 'on-demand' routing protocols. In contrast to proactive routing protocols, reactive routing protocols find route to a destination only when it is required. The reactive protocols have two phases in common – route discovery and route maintenance. In the route discovery procedure, a node wishing to communicate with another node starts a discovery mechanism if it doesn't have the route as of now in its cache. The destination node replies with a valid route. The route maintenance phase includes checking for broken links in the network and updating the routing tables. In this paper, in detail considered reactive routing protocols are AODV and DSR routing protocols.

B.1. Ad-hoc On-demand Distance Vector (AODV) Routing Protocol

In Ad-hoc On-demand Distance Vector (AODV) routing protocol, routes are established when they are required. It [7] inherits the good features of both DSDV and DSR. It uses a reactive approach to finding routes and a proactive approach for identifying the most recent path. More specifically, it finds routes using the route discovery process similar to DSR and uses destination sequence numbers to compute fresh routes. AODV protocol works in two phases: route discovery and route maintenance.

During the route discovery process, the source node broadcasts Route Request (RREQ) packets to its neighbors. The RREQ packet includes the source identifier (SId), the destination identifier (DId), the source sequence number (SSeq), the destination sequence number (DSeq), the broadcast identifier (BId) and TTL fields. When an neighbor receives a RREQ packet, it either forwards it or prepares a Route Reply (RREP) packet if it has a valid route to the destination in its cache. This process continues until a route has been found.

Figure 1 shows an example of route discovery mechanism in AODV. Let us suppose that node 1 wants to send a data packet to node 7 but it doesn't have a route in its cache. At that point it starts a route discovery process by broadcasting a RREQ packet to all its neighboring nodes which contains the SId, DId, SSeq, DSeq, BId, and TTL fields. When nodes 4, 3 and 2 receive this, they check their route caches to see if they already have a route. If they don't have a route, they forward it to their neighbors. In figure 1, node 3 has a route to 7 in its cache; so, it sends a RREP back to the source node 1. Thus the path 1-3-6-7 is stored in node 1.

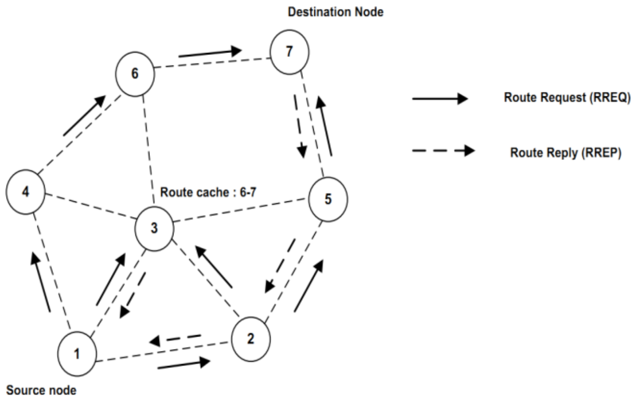


Figure 1: Route discovery in AODV

The route maintenance mechanism works as follows – whenever a node detects a link break by link layer acknowledgements, the source and end nodes are notified by propagating a Route Error (RERR) packet. This is shown in figure 2. If the link between nodes 3 and 5 breaks on the path 1-3-5-7, then both 5 and 3 will send RERR packets to notify the source and destination nodes.

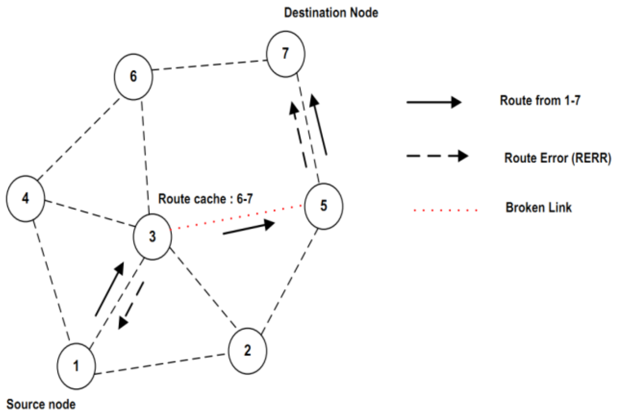


Figure 2: Route Maintenance in AODV

The main advantage of AODV is that it avoids source routing subsequently diminishing the routing overload in large networks. Further, it additionally gives destination sequence numbers which allows the nodes to have more up-to-date routes.

B.2. Dynamic Source Routing (DSR) Protocol

The Dynamic Source Routing Protocol [8] based on the concept of source routing. In source routing, a sender node specifies in the packet header, the complete list of nodes that the packet must traverse to reach the destination node. This essentially means that every node just needs to forward the packet to its next hop specified in the header and need not check its routing table as in table-driven routing protocols. Furthermore, the nodes don't have to periodically broadcast their routing tables to neighboring nodes. The DSR protocol works in two phases: route discovery and route maintenance.

In the route discovery phase, the source node sets up a route by broadcasting Route Request (RREQ) packets to all its neighbors. Each neighboring node, in turn rebroadcasts the packets to its neighbors if it has not already done so. When the packet reaches the destination node, it unicasts a reply packet (RREP) on the reverse path back to sender. This reply packet contains the route to that destination. Figure 3 shows an example of the route discovery mechanism. When node 1 wants to communicate with node 7, it starts a route discovery mechanism and broadcasts request packet RREQ to its neighboring nodes 2, 3 and 4 as shown. When the packet reaches node 7, it inserts its own address and reverses the route in the record and unicasts it back on the reverse path to the destination.

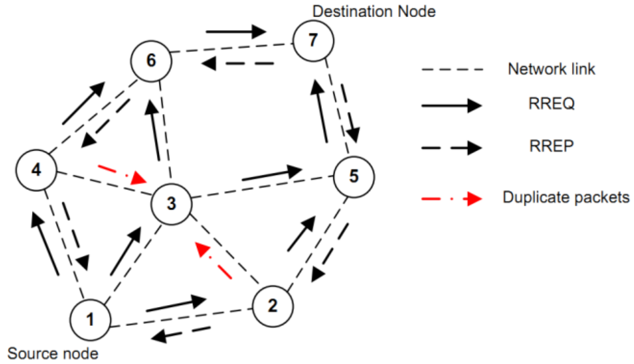


Figure 3: Route Discovery in DSR

The route maintenance phase is conveyed at whenever there is a broken link between two nodes. A failed link can be detected by a node by either passively monitoring in promiscuous mode or actively monitoring the link. As shown in Figure 4, when an intermediate node in the path moves away, causing a wireless link to break (6-7), a route error packet (RERR) is sent by the intermediate node back to the originating node. The source node re-starts the route discovery procedure to find a new route to the destination. It also removes any route entries it may have in its cache to the destination node.

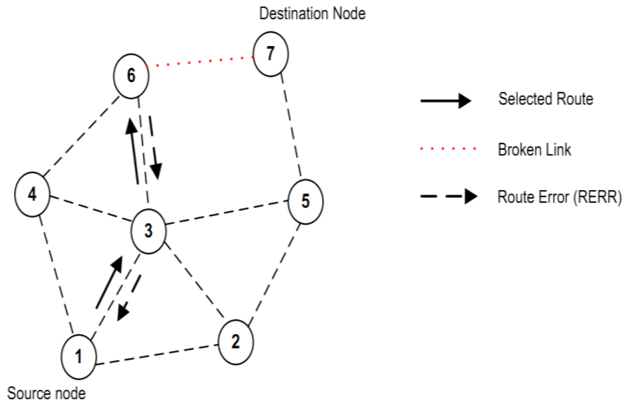


Figure 4: Route Maintenance in DSR

DSR benefits from source routing since the intermediate nodes need not maintain up-to-date routing information in order to route the packets that they forward. There is also no requirement for any periodic routing advertisement messages.

C. *Hybrid Routing Protocols*

Hybrid routing protocols inherit the characteristics of both proactive and reactive routing protocols. Such protocols are intended to minimize the control overhead of both proactive and reactive routing protocols. The working of hybrid routing protocols is illustrated with an example – the Zone Routing Protocol (ZRP).

C.1. Zone Routing Protocol (ZRP)

The Zone Routing Protocol [9] is a hybrid protocol which combines the best features of both reactive and proactive routing protocols.

The protocol itself consists of three components: (i) the Intra Zone Routing Protocol (IARP), (ii) the reactive Inter zone Routing Protocol (IERP), and (iii) Border cast Resolution Protocol (BRP). The working principle of ZRP is as follows.

The whole network is effectively divided into zones, where each zone represents a small part of the network. Every node in the zone maintains a routing table having an entry for every other node in its zone. It also specifies a zone radius which represents the maximum number of hops to reach the farthest node in the zone. Within a zone, the routing is done by a table-driven mechanism using the IARP protocol. A node can belong to more than one zone. Between zones, the communication occurs using the IERP, in which a node wishing to communicate with a node in a different zone sends a route request packet to all nodes on the border of the zone. To find the border node, the BRP is used. If a border node finds the route entry to the destination node in its intra zone routing table, then it sends a reply packet directly to the source node, else it rebroadcasts the request to its peripheral nodes. The process continues until the destination node is reached, which unicasts a reply back to the source node with the route in its header.

IV. SIMULATION ENVIRONMENT

Simulation is the imitation of real world entity. In our simulation process, a C++ based tool Network simulator is used.

A. *Software Description*

Network simulator version 2 (NS-2) [10] is an open source discrete event simulator used by the research community for research in networking [11]. It has support for both wired and wireless networks and can simulate several network protocols such as TCP, UDP, multicast routing, etc. More recently, support has been added for simulation of large satellite and ad hoc wireless networks. The ns-2 simulation software was created at the University of Berkeley. It is continually under development by an active community of researchers. The latest version at the time of writing this thesis is ns-2 (NS-2.35). The standard ns-2 distribution runs on Linux. We have used Ubuntu as an operating system.

B. *Simulation Parameters*

Table 1 shows the general parameters that we have used in the research with the specifications. In this work the performance analysis is carried out in an ad-hoc network by varying two parameters i.e., number of nodes and packet sizes while keeping other parameters constant. Three protocols i.e. DSDV, AODV, and DSR are considered for the comparison purpose. We choose 1100 X 800 as a simulation area. Moreover, we chose Omni Antenna, Random waypoint mobility model, CBR/UDP connection etc. for the simulation purposes.

Table 1: General parameters for simulation

Parameters	Values
Routing Protocols	AODV, DSDV and DSR
Mobility Model	Two Ray Ground
Antenna	Omni Antenna
Simulation Time	160 sec
Channel	Wireless Channel
Mobility Model	Random Way Point
Simulation Area	1100 X 800
Traffic	CBR/UDP
Packet Size	1500 Bytes
MAC	MAC/802-11
Mobile Nodes	30
Mobility Speed	6 m/s
Data Rates	0.1 Mbps
Performance Metrics	Packet Delivery Ratio, End-to- end Delay, Normalized Routing Overhead, Throughput
Simulator	NS 2.35

Table 2 shows the variation of nodes and packet size that are used in this work.

Table 2: Variation of Parameters

Parameters	Values
Mobile Nodes	20, 30,40, 50 and 60
Packet Sizes	512, 1000, 1500, 1700 and 2000 Bytes

C. *Performance Metrics*

The following metrics are used for performance evaluation-

C.1. Packet Delivery Ratio (PDR): This is the proportion of total number of packets successfully received by the destination nodes to the number of packets sent by the source nodes throughout the simulation.

$$PDR = \frac{\textit{Total packet received}}{\textit{Total packet sent}} \times 100\% \qquad (1)$$

This estimate gives us a thought of how fruitful the protocol is in delivering packets to the application layer. A high value of PDF shows that most of the packets are being delivered to the higher layers and is a good indicator of the protocol performance.

C.2. Average end to end delay (AED) : This is defined as the average delay in transmission of a packet between two nodes and is calculated as follows -

$$AED = \sum_{i=1}^{n} \frac{Received\ time - Sent\ time}{Number\ of\ packets\ received} \quad (2)$$

A higher estimation of end-to-end delay implies that the network is congested and subsequently the routing protocol doesn't perform well.

The upper bound on the estimations of end-to-end delay is determined by the application. For example, multimedia traffic such as audio and video cannot tolerate very high estimations of end-to-end delay when compared to FTP traffic.

C.3. Normalized Routing Overhead (NRO): This is calculated as the proportion between the no. of routing packets transmitted to the number of packets really received (subsequently accounting for any dropped packets).

$$NRO = \frac{Total\ data\ packets\ sent}{Total\ data\ packets\ received} \quad (3)$$

This metric provides an estimate of how efficient a routing protocol is since the number of routing packets sent per data packet gives an idea of how well the protocol maintains the routing information updated. Higher the NRO, higher the overhead of routing packets and consequently lower the efficiency of the protocol.

C.4. Throughput (T-put): The average throughput refers to how fast we can actually send packets through network. High t-put is desirable for every network. It is directly proportional to PDR. Higher throughput means higher delivery probability.

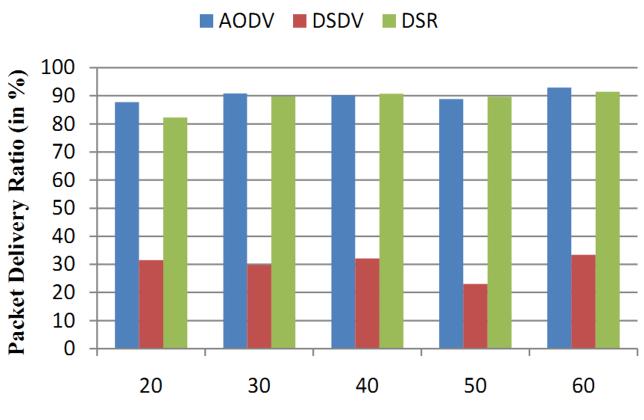
V. RESULTS AND ANALYSIS

We will evaluate four parameters for the comparison of our study on the overall network performance. These parameters are Packet Delivery Ratio, End-to-end Delay, Normalized Routing Overhead and Throughput for protocols evaluation. These parameters are important in the consideration of evaluation of the routing protocols in a communication network. These protocols should be checked against specific parameters for their performance.

In general, higher delivery is desirable to network engineers in network building. If the routing protocol gives much end-to-end delay so presumably this routing protocol is not efficient as compare to the protocol which gives low end-to-end delay. Essentially, a routing protocol offering low network load is called efficient routing protocol. Moreover, low overhead routing protocols are also desirable to design an efficient network. The same is the case with the throughput as it represents the successful deliveries of packets in time. If a protocol shows high throughput so it is the efficient and best protocol than the routing protocol which have low throughput. These parameters have incredible impact in the determination of an efficient routing protocol in any communication network.

A. *Performance analysis through node variation*

Figure 5 depicts that, by varying number of nodes, AODV protocol shows the best delivery probability among three protocols considered here. We also notice that delivery probability is likely in increasing order with the increase of number of nodes. Among the protocols, DSDV provides the least performance in case of delivery.



.Figure 5: PDR with varying Nodes

From figure 6, it is obvious that DSDV outperforms AODV and DSR in term of end-to-end delay with varying number of nodes. DSDV shows less delay than others protocols. Here, DSR shows high latency.

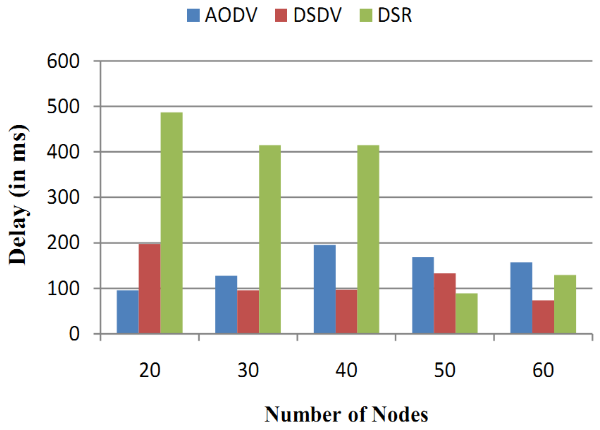


Figure 6: Delay with varying Nodes

With the increase of mobile nodes as shown in figure 7, we can see that normalized routing overhead is increasing for both AODV and DSDV. Here, DSDV shows the highest overhead value and DSR exhibits the least overhead value. DSR shows zero overhead.

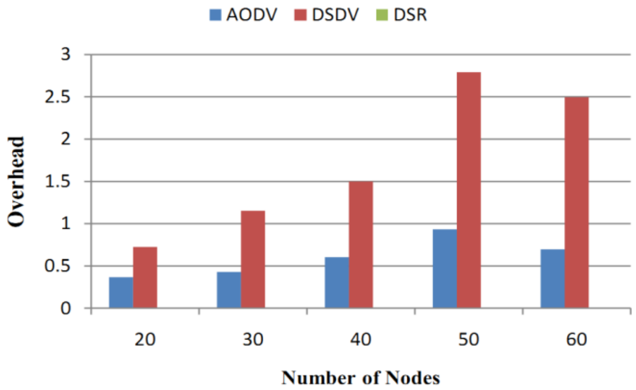


Figure 7: Overhead with varying Nodes

For varying number of nodes as shown in figure 8, it can be seen that AODV provides bit more throughput value than DSR and DSDV. DSDV provides lower throughput value. Moreover, throughput is proportional to delivery. Here, AODV shows higher throughput since its delivery is also high.

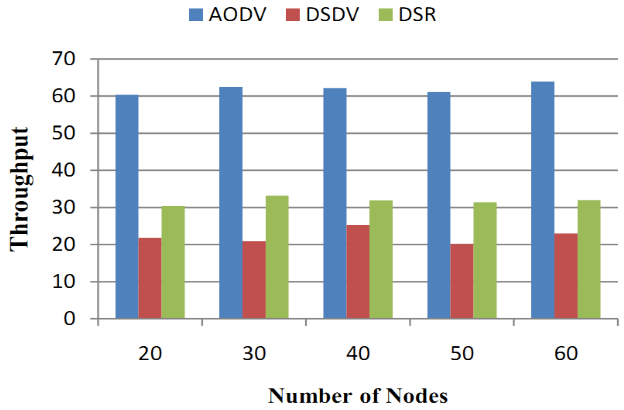


Figure 8: T-put with varying Nodes

B. *Performance analysis through packet size variation*

Here, we can see that AODV presents higher delivery ratio with respect to packet sizes than all other protocols considered here (figure 9). It is also noticeable that DSDV shows the lowest packet delivery with varying packet sizes.

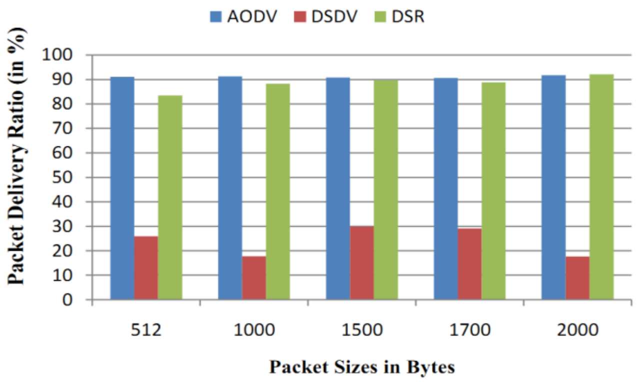


Figure 9: PDR with varying Packet Sizes

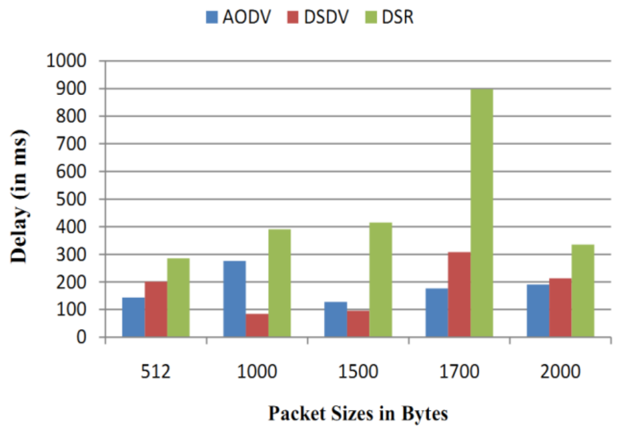


Figure 10: Delay with varying Packet Sizes

Figure 10 shows that average end-to-end delay is low for AODV and DSDV in case of packet sizes variation where DSR shows the higher value of delay. On average, AODV shows low latency for specified simulation area.

As like node variation, packet size variation also shows that DSR has the minimum overhead value. DSR routing protocol shows the zero overhead. DSDV shows the highest overhead value among all the protocols. Here, AODV shows low overhead as compared to DSDV routing protocol as depicted in figure 11.

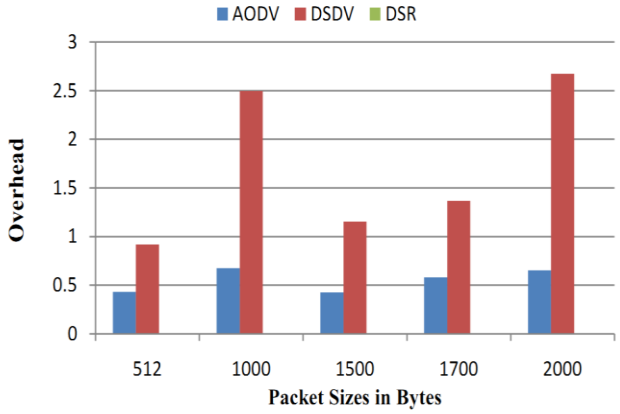


Figure 11: Overhead with varying Packet Sizes

From figure 12, we can see that AODV shows slightly higher throughput value than DSR. Here, DSDV shows the lowest throughput value among the three routing protocols.

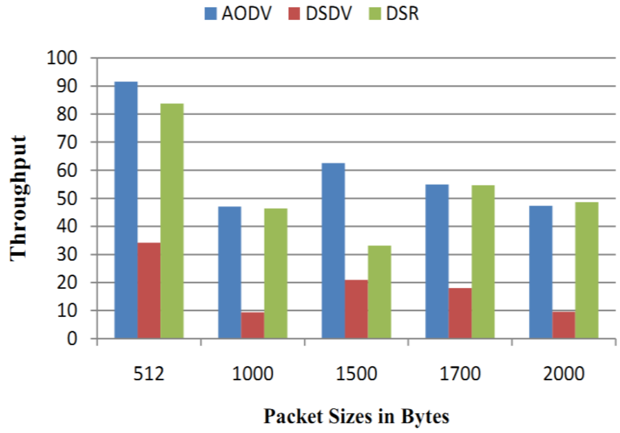


Figure 12: T-put with varying Packet Sizes

VI. CONCLUSION

In this research, we have investigated the performance of mobile ad-hoc routing protocols such as AODV, DSDV and DSR in terms of some important performance metrics of networks like as packet delivery ratio, end-to-end delay, normalized routing overhead and average throughput with varying number of mobile nodes and packet sizes within a specified simulation area. The simulation is performed through a well-known network simulator - NS2. The graphical results and analysis shows that AODV protocol performs better than DSDV and DSR in terms of packet delivery ratio. Also, AODV shows higher throughput among all the routing protocols considered here. Hence, we can say that delivery probability is directly proportional to throughput. Here, simulation results also show that DSR routing protocol has no overhead during simulation for specified small area and parameters. At the same time, we observe that overhead is much significant in DSDV than AODV; AODV shows low overhead. Again, graphical results of protocols state that DSDV protocols achieve desirable less delay among all the protocols considered here in terms of node variation; but for packet size variation, we can see that AODV shows less delay with small area. Considering all circumstances, we can conclude that AODV outperforms DSR and DSDV routing protocols.

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AUTHORS PROFILE

Amena Begum is a faculty member in Faculty of Engineering; Comilla University, Bangladesh. Currently working as a Lecturer at the Department of Information and Communication Technology. She obtained Master of Science (M.Sc) in Engineering degree with thesis and Bachelor of Science (B.Sc) in Engineering degree from Department of Information and Communication Technology, Comilla University, a renowned public university of Bangladesh. Her current research interest includes Network Design and Optimization, Network Forensic and Cybersecurity, Secure Group Communication. She published her research articles in various international journals. She is actively engaged in educational activities.

Md. Zahidur Rahman passed M.Sc (Engg.) and B.Sc (Engg.) from Department of Computer Science and Engineering, Comilla University. Zahid does research in Data Science, Machine Learning, Image Processing, Information Science and Artificial Intelligence. Currently working as a Lecturer in Britannia University, Cumilla, Bangladesh.

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Nurunnahar Nancy is currently a student in the Department of Information and Communication Technology of Comilla University, Bangladesh. Her research interest includes Computer Network Technology, Information Security Technology and Cloud Computing Technology.

Md. Enamul Haq passed M.Sc (Engg.) and B.Sc (Engg.) from Department of Information and Communication Technology, Comilla University. His research interest includes the areas of Routing and Monitoring in Wireless Sensor Networks, Network Design and Optimization and IoT.