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Comparative Study of Routing Protocols in Mobile ADHOC Networks

Muhammad Safdar, Izaz Ahmad Khan, Farman Ullah
Department of Computer Science
Bacha Khan University Charsadda, Khyber

Fazlullah Khan, Syed Roohullah Jan
Department of Computer Science
Abdul Wali Khan University, Mardan, Khyber
Pakhtunkhwa - Pakistan

ABSTRACT

A Mobile Ad-Hoc Network (MANET) Is An Infrastructure-Less, Self-Organized, Self-Configuring Network Consists Of A Number Of Wireless Mobile Nodes. MANET Has No Centralized Control. In MANET The Mobile Nodes Move Arbitrarily And Acts Like A Router. Routing Is A Critical Issue In MANET And An Efficient Routing Protocol Makes The MANET Reliable. For Almost Last 10 Years, A Number Of Routing Protocols Have Been Studied And Their Performance Comparisons Are Made By Many Researchers. Most Of The Previous Research On MANET Routing Protocols Have Focused On Simulation Study By Varying Various Parameters, Such As Network Size, Pause Times, Node Mobility Independently Etc. In This Work A Study Has Been Carried Out On The Behavioural Aspect Of Four Different MANET Routing Protocols I.E. AODV (Ad Hoc On-Demand Distance Vector), DSDV (Destination Sequenced Distance-Vector), DSR (Dynamic Source Routing) And OLSR (Optimized Link State Outing Protocol) Using The NS-2 Simulation Tool. The Performance Of These Routing Protocols Is Analysed In Terms Of Their Average Throughput; Average End To End Delay & Normalized Routing Overhead And Their Results Are Shown In Graphical Form. The Main Objective Of This Study Is To Create A Choice Guide Of Routing Protocol For A Given Network Scenario, Based On The Relative Performance Of The Protocols Under Various Scenarios.

Keywords:- MANET, NS-2, routing protocols.

I. INTRODUCTION

MANET is an infrastructure-less wireless network consist of mobile nodes forming a temporary network [2]. MANETs are self-configuring and self-organizing multi-hop wireless networks. Its structure or topology changes dynamically because of the mobility (continuous movement) of the nodes in the network [3]. Every node in this type of network uses the same wireless channel in a friendly manner to perform multi-hop forwarding. Every node in the network acts as a host as well as like a router that route the packets to and from the other nodes in the network [4].

In mobile ad-hoc network the destination might be out of range of a source node, then routing will always be needed to find the path between the source and destination for exchanging packets [5]. Some recent work can be studied in [36-44].

II. ROUTING PROTOCOLS FOR MOBILE AD-HOC NETWORKS

Routing protocols for MANETs can b categorized on the basis of routing strategy and network structure [3, 6].

According to the routing strategy the routing protocols are categorized as table driven and source initiated, while depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing [3]. Both table driven and source initiated protocols comes under flat routing as shown in the figure below:

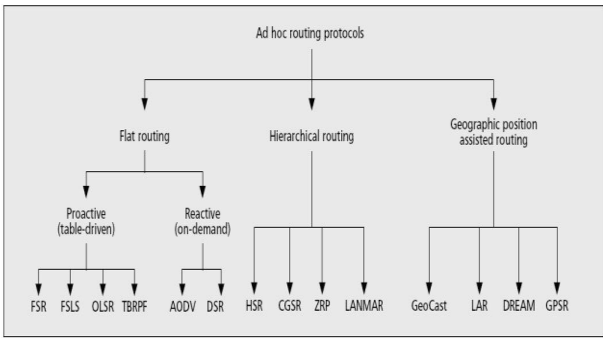


Figure 1: Classification of routing protocols in MANET [3]

III. TABLE DRIVEN (PROACTIVE) ROUTING PROTOCOLS

These protocols are also known as proactive routing protocols because they maintain the routing information up-to-date before it is required [7] [45-49]. Each and every node keeps updating the routing information in the routing table to every other node in the network as the network topology changes. This kind of protocols falls in the category of link state routing [3]. On the basis of routing table updating there exist some differences in the routing protocols of this category. These protocols keep different tables up-to-date. Proactive routing protocols are not useful for large networks because they maintain the routing information of each and every node in the routing table of every node in the network. This leads to more routing overhead and more bandwidth consumption [1].

IV. ON DEMAND (REACTIVE) ROUTING PROTOCOLS

On demand routing protocols are also known as reactive routing protocols. They don't maintain the routing tables of the network node up-to-date when there is no communication between the nodes. When a node in the network wants to send some data to any other node in the network then this protocols finds the route from that source node to the intended destination node and establishes connection for exchange of data or packets [8]. The route discovery occurs by flooding the route request packet throughout the network [1].
In this research paper i will describe the two table driven (proactive) routing protocols OLSR and DSDV, and two on-demand (reactive) routing protocols DSR and AODV. Then i will compare these protocols with each other in different scenarios with respect to some performance metrics like end-to-end delay, normalized routing load and throughput.

V .OUTLINE

In the remaining portion of this research is as follows: In section 2, I will describe the above mentioned protocols one by one. Then in section 3, I will define 2 different simulation scenarios. I will also define some performance metrics in this section. Then in section 4, I will present the simulation results of the protocols along with their comparative analysis.

VI. OLSR (OPTIMIZED LINK STATE ROUTING)

Optimized link state routing (OLSR) protocols is a link state proactive routing protocol for mobile ad hoc networks (MANETs). The main idea of this protocol is to minimize the control overhead by minimizing the number of broadcasts in contrast of pure flooding. The concept of multi-point relays MPRs is used to implement this idea in OLSR [9, 10]. MPRs are those routers or nodes that can forward broadcast messages during the flooding process. To minimize the size or number of broadcast messages, every router defines only a small set of its directly connected neighbours. "This protocol is particularly suitable for large and dense networks" [9].
MPRs acts like intermediate routers in the path finding process. The path found by the OLSR may not be the optimal or shortest path. This is the potential drawback of OLSR [9].
OLSR performs three main functions: packet forwarding, neighbour sensing and topology discovery. Through packet forwarding and neighbour sensing the routers come to know about their neighbours and an optimized way of flooding messages in the OLSR network using MPRs. The router floods its information in the whole network during neighbour sensing process. The topology of the network is discovered and routing tables are calculated during the topology discovery process. OLSR uses four types of messages: hello message, topology control (TC) message, and multiple interface declaration (MID) message and host and network association (HNA) message. Hello messages are used for neighbour sensing. TC messages are used for topology declaration. MID performs the task of multiple interface declarations. Since hosts have multiple interfaces connected with different subnets, HNA messages are used to declare host and associated network information [11].
Figure 2 shows the basic idea of OLSR protocol:

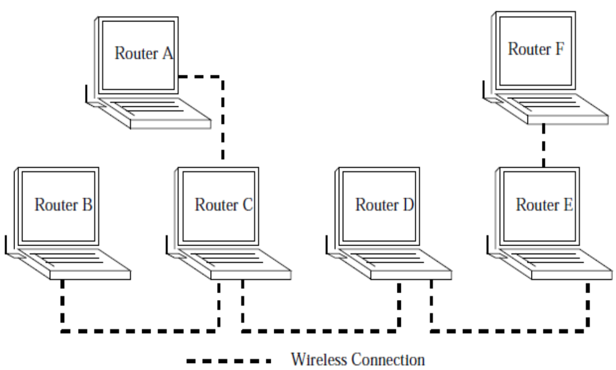


Figure 2: Example of OLSR protocol [9]

Firstly, we'll discuss some concepts used in OLSR, namely one-hop neighbours set, two-hop neighbours set, MPR set, and MPR selector (MPRS). The one-hop neighbour set is consisting of all adjacent routers. For example, Router C forms the one-hop neighbours set of Router A. A two-hop neighbours set is the set of routers that are two hops away. Routers B and D form the two-hop neighbours set for Router A. The MPR set of a router is a subset of neighbouring routers that are responsible for forwarding control messages sent by that router. The MPR set should be able to cover all the two-hop neighbours of that router. For example, Router D is a neighbouring node to Router C. It covers Router C's two-hop neighbours, Router E. Therefore, {Router Dg} is the MPR set of Router C. Since the MPR set of a router is responsible for rebroadcasting messages sent by that router, the routing protocol is closer to optimal with a smaller MPR set. Qayyum, et al. [10] give a simple algorithm to select MPRs, together with an example. The MPR selector (MPRS) set of one router is formed by routers that select this router as one of their MPR routers [11].

Figure 3 shows the MPR set and MPR selector set for each router in Figure 2. Consider Router *D* as an example. Its neighbours set is *{C, E}* and the two-hop router set is *{A, B, F}*. The MPR set of Router *D* can cover the entire set of two-hop routers only if it includes Router *C* and Router *E*. Similarly, Router *C* and Router *E* select *D* as one of their MPR routers, so the MPR selector set of *D* is *{C, E}*.

Router ID	MPR Set	MPR Selector(s)
A	C	NULL
B	C	NULL
C	D	A, B, D
D	C, E	C, E
E	D	D F
F	E	NULL

Figure 3: MPR Sets and Selectors in the OLSR Example [11]

OLSR routers periodically broadcast hello packets to one-hop neighbors. Each router builds a list of neighbors and a list of two-hop neighbors based on received hello messages. Each router also creates one MPR set and one MPR selector set. Routers that have non-empty MPRS lists broadcast their MPRS sets to neighbors via TC packets [11-22].

Therefore, the size of control messages is reduced compared with broadcasting a list of all neighbor routers. A router rebroadcasts received packets if and only if the sender of that packet is in its MPR selector set. This helps to reduce the frequency of flooding. Routers build routing tables based on received TC packets. For example, assume Router *A* wants to set up a routing entry with destination Router *F*. It searches for MPR routers of *F* in the received TC packets, which is Router *E* in our example. Since *E* is not in any known route, MPR routers of *E* are also searched. Note that a route found by OLSR is always formed by hops from MPR selectors to corresponding MPR routers. Thus, Router *A* can eventually figure out the next router to *F* is Router *C*. Routing entries are reset once paths become invalid due to a link failure. This is similar to other link state routing protocols [23-38] .

VII. DESTINATION SEQUENCED DISTANCE VECTOR (DSDV)

The DSDV routing protocol (algorithm) is the modified form of Distributed Bellman Ford algorithm, which provide routes free of looping. It selects a single path from source to destination using the distance vector shortest path routing algorithm. For reducing the amount of overhead in the network, two types of update packets are transmitted, "full dump" and "incremental" packets. The full dump packets contain all the available routing information and the incremental packets contain only the information updates or changed since the last full dump. The incremental update packets are sent more frequently as compared to the full dump packets. DSDV produces a very large amount of overhead in the network because of the periodic update messages. Therefore DSDV does not scale in large network otherwise large part of the network bandwidth will be consumed in updating procedures [12].

VIII. ROUTING TABLE MANAGEMENT

The routing table in each node consists of a list of all available nodes, their metric, the next hop to destination and a sequence number generated by the destination node. With the help of routing table packets are transmitted through the ad hoc network. All the nodes have to update the routing table periodically to keep the routing table up-to-date with the continuously changing topology of a mobile ad hoc network or when there is a significant change occurs in the network. Therefore mobile nodes advertise their routing information by broadcasting a routing table update packet. The metric of an update packet starts with metric one for one-hop neighbors and is incremented by each forwarding node and additionally the original node (destination node) tags the update packet with a sequence number. The receiving nodes update their routing tables if the sequence number of the update is greater than the current one or it is equal and the metric is smaller than the current metric. Delaying the advertisement of routes until best routes have been found may minimize fluctuations of the routing table. On the other hand the spreading of the routing information has to be frequent and quick enough to guarantee the consistency of the routing tables in a dynamic network [12] [23-29].

XI. RESPONDING TO TOPOLOGY CHANGES

When a link is broken, DSDV responds to that broken link by invalidating all routes that contain this link. The routes are immediately assigned an infinite metric and an incremented sequence number. Broken links can be detected by link and physical layer components or if a node receives no broadcast packets from its next neighbors for a while. Then the detecting node broadcasts immediately an update packet and informs the other nodes with it. If the link to a node is up again, the routes will be re-established when the node broadcasts its routing table [39-51]].

X. DSR (DYNAMIC SOURCE ROUTING)

The Dynamic Source Routing Protocol (DSR) is a reactive routing protocol. Using this protocol each node can discover dynamically a source route to any destination in the network over multiple hops. It provides a loop free route from source to destination by providing an ordered list of the nodes (i.e stored in the packet header) through which the packet must pass. The two main mechanisms of DSR are Route Discovery and Route Maintenance, which work together to discover and maintain source routes to arbitrary destinations in the network [30-35] [52-54].

XI. ROUTE DISCOVERY

Route discovery process takes place by flooding the network with *route request* (RREQ) packets. Each node receiving an RREQ packet rebroadcasts it, unless it is the destination or it has a route to the destination in its route cache. Such a node replies or responds to the RREQ with a *route reply* (RREP) packet that is routed back to the original source. RREQ and RREP packets are also source routed. The RREQ builds up the path traversed across the network. The RREP routes itself back to the source by traversing this path backward. The route carried back by the RREP packet is cached at the source for future use [13].

XII. ROUTE MAINTENANCE

If any link on a source route is broken or down, the source node is informed by a *route error* (RERR) packet. The source node removes all those routes which are using this link from its cache. A new route discovery process must be initiated by the source node if this route is still needed [13].

XIII. AD HOC ON-DEMAND DISTANCE VECTOR (AODV)

The Ad hoc on demand Distance Vector routing protocol (AODV) combines the mechanisms of DSR and DSDV. The periodic beacons, hop-by-hop routing and sequence numbers (guarantee of loop-freedom) of DSDV and the pure on-demand mechanism of Route Discovery and Route Maintenance from DSR are combined [12].

Route Discovery:

If there is already a valid route between the two communication peers, then AODV will not initiate any route discovery process. But if the route has become invalid or missing between the two communicating partners or nodes, e.g. whenever a new route to a destination is needed, a link is broken, or the route has expired, then source node will broadcast a RREQ message in order to discover a route to the destination [12].

Simulations

Introduction to NS2

A discrete event simulator NS2 is developed mainly for networking research purpose. NS2 provides great support for simulation of TCP, routing, and multicast protocols over wired and wireless networks.[14]

Purpose of Simulation

The purpose of these simulations is to compare and analyze the performance of different MANET routing protocols.
These simulations will be performed using Network Simulator 2 version 2.34. NS2 is an open source software that provides scalable simulations of Wireless Networks.

Simulation scenarios:

Two simulation scenarios are given below:

Scenarios 1:

In simulation scenario1, we consider a network of 50 nodes that are placed randomly within a 1000x1000ms^2 area. Multiple runs with varying node speed (i.e 5 m/s, 15 m/s and 30 m/s) and number of flows (i.e 5 and 10), are conducted and collected data is averaged over those runs. Simulation time is 500 seconds.

Scenario 2:

In simulation scenario1, we consider a network of 100 nodes that are placed randomly within a 1000x1000ms2 area. Multiple runs with varying node speed (i.e 5 m/s, 15 m/s and 30 m/s) and number of flows (i.e 5 and 10), are conducted and collected data is averaged over those runs. Simulation time is 500 seconds.

Performance evaluation metrics:

To evaluate the performance of routing protocols, both qualitative and quantitative metrics are required. The performance metrics that i have considered in this simulation are as follows:

Throughput:

Throughput is the ratio of the packets delivered to the total number of packets sent.

End to end delay:

End to end delay is the time taken by the packets to reach the destination.

Normalized routing overhead:

Normalized routing overhead is the number of routing packets transmitted per data packet delivered at the destination.

Results and Discussions

Scenario 1:

The characteristics of AODV, DSR, DSDV and OLSR routing protocols in a network of 50 nodes at different node speeds and 5 number of flows are shown in Table 1.

Table 1: Characteristics of AODV, DSR, DSDV and OLSR

Number of Flows = 5				
Parameters	Protocol	Speed m/s		
		5	15	30
Throughput (Kbps)	AODV	787.06	693.33	546.6
	DSR	935.73	732.08	521.07
	DSDV	963.68	606.53	371.54
	OLSR	903.71	643.19	335.79
Delay (ms)	AODV	25.6	22.15	33.84
	DSR	20.3	60.73	137.83
	DSDV	13.59	16.27	66.95
	OLSR	19.38	20.08	36.63
NRO	AODV	0.23	0.46	0.72
	DSR	0.08	0.35	0.48
	DSDV	0.2	0.46	0.9
	OLSR	1.25	1.76	3.8

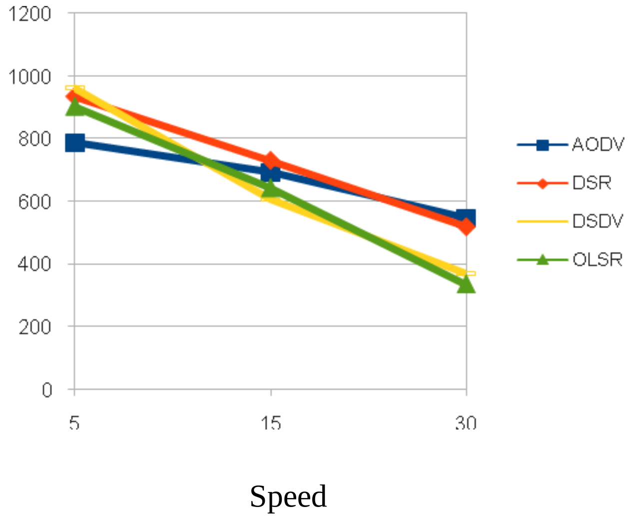


Figure 4: Throughput vs speed and 5 number of flows

Figure 4 shows that when mobility speed increases the throughput of DSDV and OLSR drops more as compared to the AODV and DSR. The throughput of DSR is more affected by the increase in mobility speed as compared to the throughput of AODV. So in this case AODV provides good throughout as compared to the rest of three protocols.

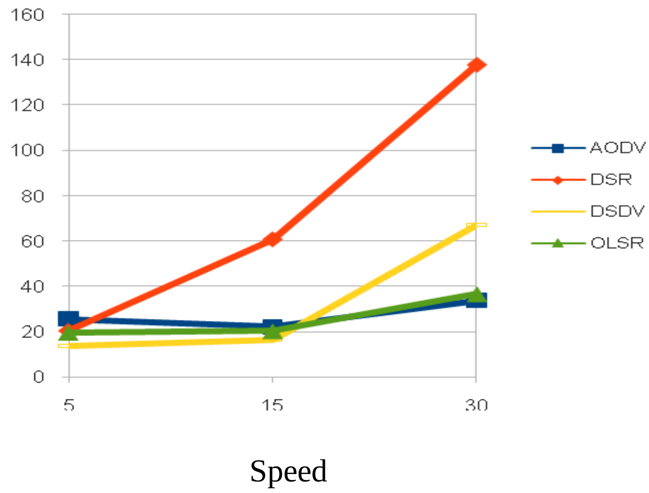
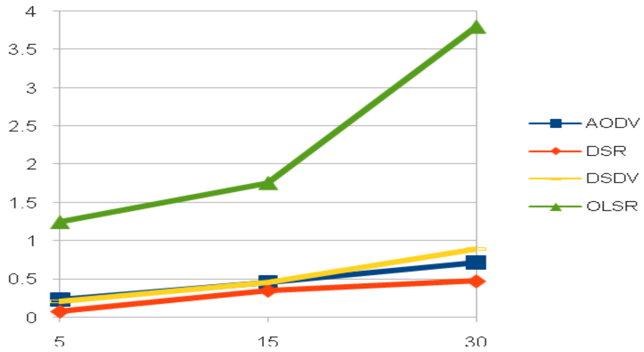


Figure 5: End to End delay vs speed and 5 number of flows

Figure 5 shows that when mobility speed increases the end-to-end delay increases. DSR causes more delay as compared to other protocols. AODV causes the minimum delay. So AODV and OLSR perform well in this case.



Speed

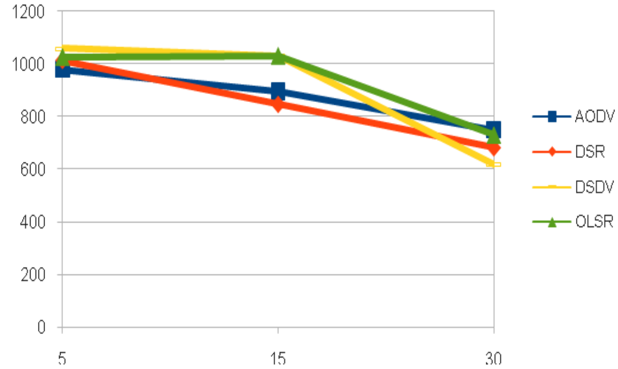
Figure 6: Normalized routing overhead vs speed and 5 number of flows

Figure 6 shows that when speed increases normalized routing overhead increases. OLSR causes the maximum normalized routing overhead, while DSR causes the minimum normalized routing overhead. The performance of AODV is better than DSDV and OLSR. So in this case DSR and AODV perform better.

The characteristics of AODV, DSR, DSDV and OLSR routing protocols at different node speeds and number of flows is shown in Table 2.

Table 2: Characteristics of AODV, DSR, DSDV and OLSR

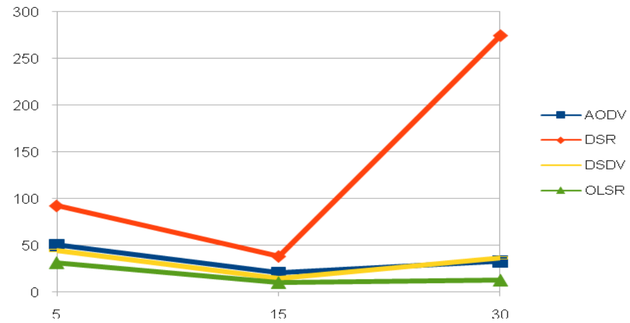
Number of Flows = 10				
Parameters	Protocol	Speed m/s		
		5	15	30
Throughput (Kbps)	AODV	979.11	895.03	749.96
	DSR	1013.91	846.66	681.76
	DSDV	1058.81	1030.58	617.49
	OLSR	1026.48	1031	730.22
Delay (ms)	AODV	50.35	20.49	33
	DSR	92.55	38.52	274.82
	DSDV	44.25	14.87	36.29
	OLSR	31.24	9.94	12.6
NRO	AODV	0.38	0.55	0.99
	DSR	0.34	2.73	2.86
	DSDV	0.18	0.28	0.52
	OLSR	1.06	1.06	1.67



Speed

Figure 7: Throughput vs speed and 10 number of flows

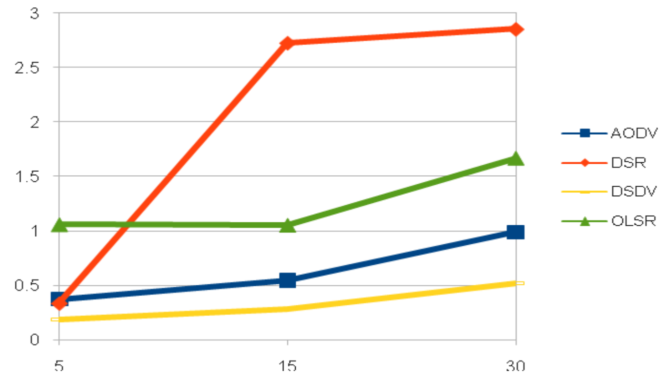
Figure 7 indicates that when speed increases then throughput decreases. DSDV and OLSR perform better in up to 15m/s mobility speed. AODV provides good throughput as compared to the DSR. So in this case OLSR and AODV perform better.



Speed

Figure 8:: End to End delay vs speed and 10 number of flows

FIGURE 8 INDICATES THAT WHEN SPEED INCREASES, END TO END DELAY ALSO INCREASES. DSR CAUSES THE MAXIMUM DELAY. OLSR CAUSES THE MINIMUM DELAY. AODV AND DSDV PERFORM BETTER IN UP TO 15M/S SPEED. IN THIS CASE OLSR PERFORMS VERY WELL.



Speed

Figure 9: Normalized routing overhead vs speed and 10 number of flows

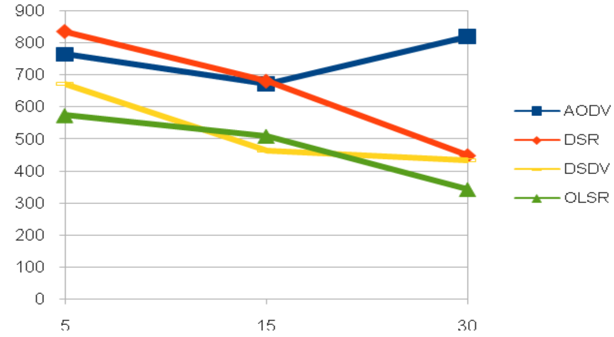
Figure 9 indicates that when speed increases, normalized routing overhead also increases. DSR causes maximum normalized routing overhead, while DSDV causes minimum normalized routing overhead. AODV performs better than DSR and OLSR. So in this case DSDV performs better as compared to the other protocols.

Scenario 2:

The characteristics of AODV,DSR,DSDV and OLSR routing protocols in a network of 100 nodes at different node speeds and 5 number of flows is shown in Table 3.

Table 3: Characteristics of AODV, DSR, DSDV and OLSR

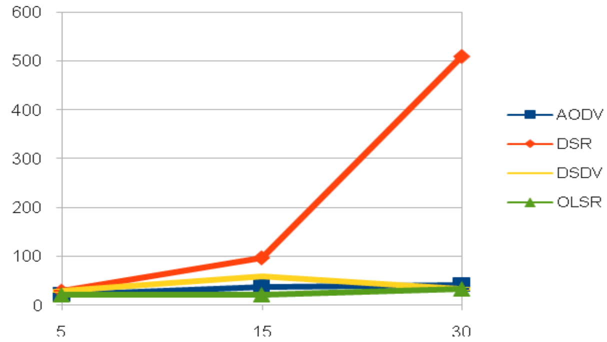
Number of Flows = 5				
Parameters	Protocol	Speed m/s		
		5	15	30
Throughput (Kbps)	AODV	762.5	670.02	818.37
	DSR	835.07	680.22	447.94
	DSDV	672.48	463.69	433.76
	OLSR	573.2	508.05	341.22
Delay (ms)	AODV	21.83	37.19	41.02
	DSR	28.29	96.45	508.73
	DSDV	28.56	58.32	32.83
	OLSR	21.01	21.44	33.09
NRO	AODV	1.13	1.11	1.1
	DSR	0.08	0.39	40.48
	DSDV	1.22	1.88	2.13
	OLSR	6	6.8	8.21



speed

Figure 10: Throughput vs speed and 5 number of flows

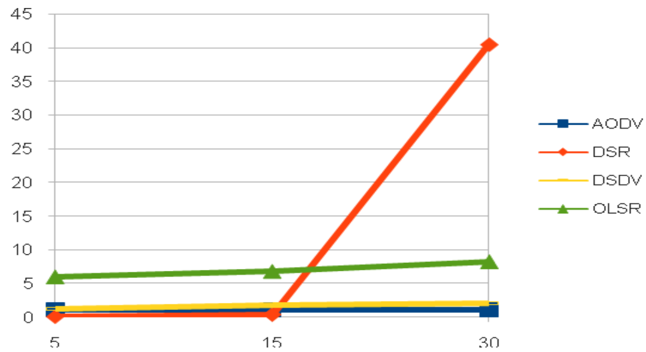
Figure 10 show that when speed increases, throughput of DSR, DSDV and OLSR decreases while AODV throughput increases. So in this case AODV performs best.



Speed

Figure 11: End to End delay vs speed and 5 number of flows

Figure 11 indicates that when speed increases the end-to-end delay of DSR increases. AODV, DSDV and OLSR give good performance in this case.



Speed

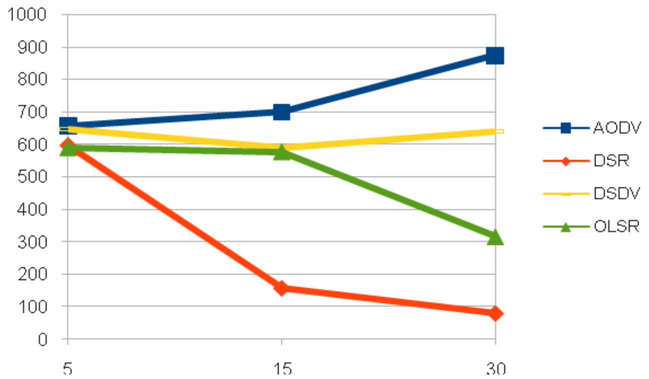
Figure 12: Normalized routing overhead vs speed and 5 number of flows

Figure 12 show that when speed increases, DSR causes the maximum normalized routing overhead. AODV causes the minimum normalized routing overhead. So in this case AODV performs well.

The characteristics of AODV,DSR,DSDV and OLSR routing protocols in a network of 100 nodes at different node speeds and 10 number of flows is shown in Table 4.

Table 4: Characteristics of AODV,DSR,DSDV and OLSR

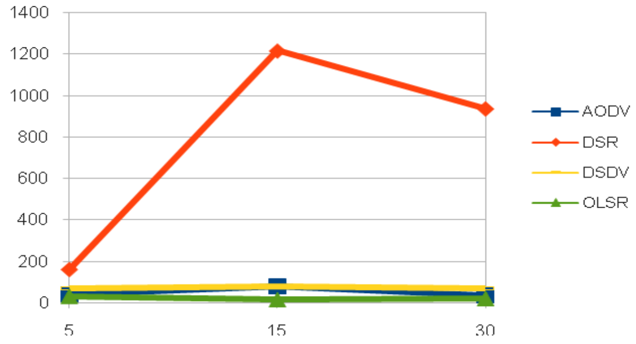
Number of Flows = 10				
Parameters	Protocol	Speed m/s		
		5	15	30
Throughput (Kbps)	AODV	656.01	699.27	874.23
	DSR	596.36	157.65	80.45
	DSDV	646.29	588.95	640.51
	OLSR	590.63	577.71	315.64
Delay (ms)	AODV	40.79	79.21	34.16
	DSR	158.35	1214.5	934.82
	DSDV	67.2	76.46	66.73
	OLSR	31.63	15.8	21.14
NRO	AODV	2.55	1.83	1.54
	DSR	1.65	60.52	165.36
	DSDV	1.27	1.47	1.43
	OLSR	6.13	6.18	6.32



Speed

Figure 13: Throughput vs speed and 10 number of flows

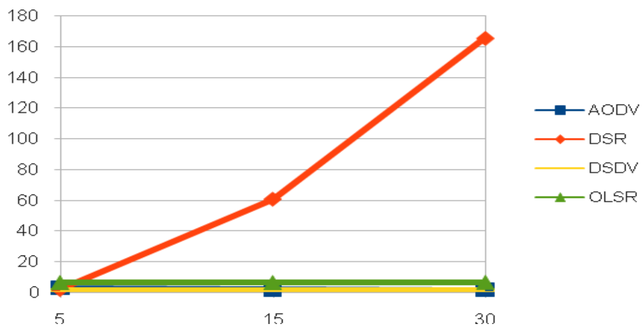
Figure 13 indicates that when mobility speed increases the throughput of DSR and OLSR decreases while the throughput of AODV and DSDV increases. In this case AODV gives maximum throughput.



Speed

Figure 14: End to End delay vs speed and 10 number of flows

Figure 14 shows that when speed increases, DSR causes very large amount of end-to-end delay. AODV, DSDV and OLSR performs very well in this case. OLSR causes minimum end-to-delay delay in this case.



Speed

Figure 15: Normalized routing overhead vs speed and 10 number of flows

Figure 15 indicates that when speed increases, DSR causes a huge normalized routing overhead. AODV, DSDV and OLSR perform very well in this case.

XIV. CONCLUSION

This research work presents a brief description of AODV, DSR, DSDV and OLSR routing protocols and also provides a classification of these protocols according to the routing mechanism (i.e. table driven, on-demand routing protocol). It has also presented a comparison of AODV, DSR, DSDV and OLSR, and reveals their features and characteristics. The performance of these protocols is analyzed with NS2 simulator with two scenarios. One is of 50 nodes with 5 and 10 number of flows and second is of 100 nodes with 5 and 10 number of flows. The observations are made with variation in node speed in network. On the basis of simulation results I have made the following observations:

- AODV is best in terms of average throughput, average end-to-end delay and routing overhead with respect to mobility speed.
- DSR is best in terms of throughput and routing overhead if mobility speed is less than 15m/s and number flows are 5 or less.
- DSDV performs better in terms of average throughput, average end-to-end delay and routing overhead as compared to DSR and OLSR.
- OLSR is best in terms of end-to-end delay with respect to the mobility speed.

On the basis of the above observations we can conclude that AODV is the best suitable routing protocol for MANET in term of average throughput, average end-to-end delay and routing overhead with respect to mobility speed, network size or density and number of flows.

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