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International Journal Of Engineering And Computer Science ISSN:2319-7242

Volume 2 Issue 6 June, 2013 Page No. 1981-1987

SIMULATION BASED STUDY OF TWO REACTIVE ROUTING PROTOCOLS

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***Abstract*— Ad hoc networking allows mobile devices to establish communication path without having any central infrastructure. There is no central infrastructure and the mobile devices moves randomly which gives rise to various kinds of problems such as routing and security. In this dissertation the problem of routing is considered. Because of highly dynamic and distributed nature of nodes routing is one of the key issues in MANETs. There are three main classes of routing protocols are proactive, reactive and hybrid.In this paper an effort has been made to compare the performance of two reactive routing protocols- AODV (Ad-hoc on-demand distance vector) and DSR (Dynamic source routing).**

AODV and DSR are reactive protocols where each node sends routing packets only when communication is needed. Both the protocols have different mechanisms which lead to significant performance differentials. The protocols are analyzed using four performance metrics- packet delivery ratio, throughput, routing load and end-to-end delay by varying number of nodes, pause time and simulation time.

***Keywords*— MANET, AODV, DSR, RREQ, RREP**

I. INTRODUCTION

A Mobile Ad Hoc Network (MANET) is a wireless network in which all nodes can freely and arbitrary move in any direction. In MANET, routing takes place without the existence of fixed infrastructure. The network can scale from tens to thousands of nodes in an ad hoc manner providing the nodes are willing to take part in the route discovery and maintenance process. MANET is a growing new technology that will allow users to access services and information electronically despite of their geographic position. MANET is a kind of wireless ad-hoc network and it is a self-configuring network of mobile routers (and associated hosts) connected by wireless links – the union of which forms a random topology. The participating nodes that act as router are free to move arbitrarily and manage themselves randomly so the network's wireless topology may change rapidly and unpredictably. Routing protocols use several metrics as a standard measurement to calculate the best path for routing the packets to its destination that could be number of hops that are used by the routing algorithm to determine the optimal path for the packet to its destination.

A. Properties of MANET routing protocols:

The properties that are desirable in Ad-Hoc Routing protocols are:

- **Distributed operation:** The protocol should be distributed and should not be dependent on a centralized controlling node. The nodes in an ad-hoc network can enter or leave the network very easily and because of mobility the network can be partitioned.
- **Loop free:** The routing protocol should assurance that the routes supplied are loop free to improve the overall performance. This avoids any misuse of bandwidth or CPU consumption.
- **Demand based operation:** To minimize the control overhead in the network and thus not misuse the network resources the protocol should react only when needed and should not periodically broadcast control information.
- **Unidirectional link support:** The radio environment can cause the formation of unidirectional links. Deployment of these links and not only the bi-directional links improves the routing protocol performance.
- **Security:** The radio environment is especially vulnerable to impersonation attacks so to ensure the wanted behavior of the routing protocol we need some sort of security measures. One way is authentication and encryption but problem lies within distributing the keys among the nodes in the ad-hoc network.
- **Power conversation:** The nodes in the ad-hoc network can be laptops and thin in structure and work on battery power that can also be put on standby mode when required to save the power. The routing protocol should have support for these sleep modes.
- **Multiple routes:** To reduce the number of reactions to topological changes and congestion multiple routes can be employed. If one route becomes invalid then

another stored route could still be valid and thus saving the routing protocol from initiating another route discovery procedure.

- **Quality of Service Support:** Some sort of Quality of service is necessary to incorporate into the routing protocol. This assists us to find where these networks can be used for instance real time traffic support.

B. *Classification of routing protocols*

There are mainly three types of Routing protocols used in MANET:

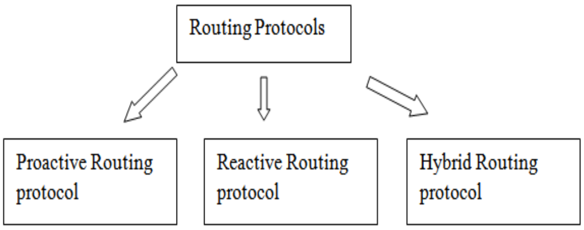

Figure 1: Classification of routing protocols

Proactive Routing Protocol (Table Driven): It periodically updates the routing table. Proactive protocols continuously learn the topology of the network by exchanging topological information among the network nodes. When there is a need for a route to a destination then the route information is available immediately. And if the network topology changes too frequently the cost of maintaining the network might be very high. But if the network activity is low then the information about actual topology might even not be used e.g. Optimized Link State Routing (OLSR), Dynamic Destination-Sequenced Distance-Vector Routing Protocol (DSDV) , Cluster-head Gateway Switch Routing (CGSR) Fish-eye State Routing (FSR).

Reactive Routing Protocol (On Demand): The reactive routing protocols are based on some sort of query-reply dialog. These protocols proceed for establishing route(s) to the destination only when the need arises. It does not periodically update the routing table e.g. Ad-hoc On-demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA), Associativity Based Routing (ABR).

II. REACTIVE ROUTING PROTOCOLS

Reactive Protocols are known as On-demand protocols. Routing information acquired only when there is a need for it. This saves the overhead of maintaining unused routes at each node. Reactive routing protocols flood the network to discover the route so they scale well in the frequency of topology change and are suitable for high mobility networks. Examples of reactive routing protocols for MANET are AODV (Ad-hoc on-demand distance vector) and DSR (Dynamic source routing).

A. *AD HOC ON-DEMAND DISTANCE VECTOR (AODV)*

The AODV routing protocol is a reactive routing protocol so the routes are determined only when needed. AODV protocol allows mobile nodes to quickly obtain routes for new destinations, and it does not require nodes to maintain routes to destinations that are not in active communication. When a source has data to transmit to an unknown destination, it broadcasts a Route Request (RREQ) for that destination. If the receiving node is the destination or has a current route to the destination, it generates a Route Reply (RREP). AODV routing protocol allows mobile nodes to respond link breakages and changes in network topology in a timely manner. If data is flowing and a link break is detected, a Route Error (RERR) is sent to the source of the data in a hop-by-hop fashion. Each node in the network maintains a route table entry for each destination in its route table.

- Number of hops (Hop count)
- Destination sequence number
- Destination IP address
- Active neighbors for this route
- Lifetime (Expiration time of the route)
- Next hop

Route discovery and Route maintenance:

When a node called the source node has data to send to another node in the network, called the destination the source looks in its routing table to find a route to the destination. If there is no such route or the route is marked as invalid by an appropriate flag, the source propagates a RREQ message to its neighbouring nodes. The source node before sending the RREQ message increments the RREQ ID by one and the source sequence number in the message header. In this manner, each RREQ message is uniquely identified by combining the above numbers with the source IP address. Any intermediate node that receives an RREQ message takes one of the following three actions: Firstly, the intermediate node discards the RREQ message if it has previously received the same RREQ message. If the intermediate node has a valid route to the destination node then it reverses a RREP message back to the source node. If the intermediate node does not have a valid route to the destination then it further broadcasts the message to its neighbouring nodes. The destination node, which finally receives the RREQ message increments the destination sequence number and reverses an RREP message back to the source node. Once the source node receives the RREP message, it updates its routing table with the fresh route. Figure 2 shows the route discovery process from source node A to destination node F.

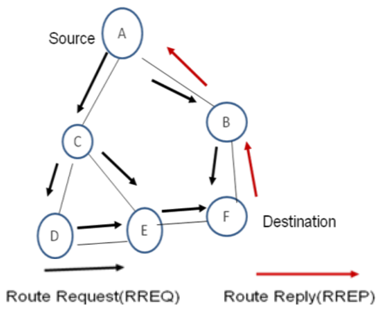

Figure 2: AODV Route discovery process

The route maintenance process in AODV is very easy. When the link in the path between node A and node F breaks (Figure 3) the upstream node that is affected by the break, in this case node C generates and broadcasts a RERR message. The message ends up in source node A. Upon receiving the REER message, node A will generate a new RREQ message.

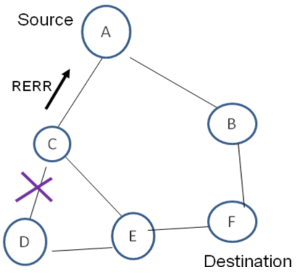

Figure 3: AODV Route maintenance

Advantages and Disadvantages of AODV
The two main advantages of AODV are its reactive nature, which reduces the routing overhead in the network and the use of destination sequence numbers that helps in avoiding loops. A disadvantage of this protocol is that intermediate nodes can lead to inconsistent routes if the sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number. The overhead of control message can be introduced when every intermediate node originates a RREP message to satisfy a route discovery request if it has a valid route to the destination causing a RREP messages storm. Another disadvantage of AODV is that the propagation of periodic HELLO messages from a node to maintain connectivity with its neighboring nodes will lead to bandwidth consumption. AODV are well suited for large networks.

B. DYNAMIC SOURCE ROUTING (DSR)

Dynamic Source Routing is a simple reactive protocol that is based on two main mechanisms: route discovery and route maintenance. Both mechanisms are implemented in an ad-hoc fashion and in the absence of any kind of periodic control messages. DSR [5] uses the concept of source routing in which nodes places the route that the packet must follow from a source to a destination in the header of a packet. Each node caches the routes to any destination it has recently used or discovered by overhearing its neighbours. When there is not such route, a route discovery process is initiated. DSR can provide interconnection of wireless devices with multiple network interfaces.

Route Discovery
Each node in the network maintains a route cache in which it caches the routes it has learned. When a node wants to send a data packet to another node in the network, it first looks in its route cache to find a route to the destination. If such a route exists source node attaches to the packet header the complete route to the destination and forwards the packet to the next node. Then that node checks the packet header and forwards the packet to the next node. The procedure terminates when the packet reaches the destination. If the source node cannot find a route to the destination in its route Cache then it initiates a route discovery process that is it broadcasts a route request (RREQ) to its neighbouring nodes and add a unique request ID to prevent other nodes from transmitting the same request. Each of the neighbouring nodes checks in its Route Cache and if it finds such a route then it sends a Route Reply (RREP) message back to the source node with the complete path to the destination or else the destination node is obliged to do this task. AODV also uses these two mechanisms.
In Figure 4, we assume that there is no path from source node A to destination node F, so node A initiates the routing discovery process. Node E discards the RREQ message forwarded by node D, as it has already received the same message from node C. In the same way all nodes follow the same process.

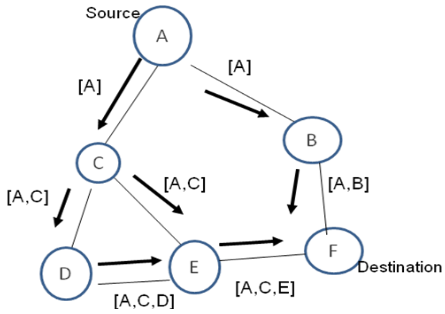

Figure 4: DSR RREQ broadcasting

When node F receives the RREQ message, it initiates a RREP message and attaches in the packet header the reverse path to node A. Figure 5 shows the RREP message process.

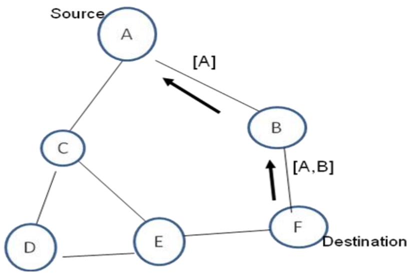

Figure 5: DSR RREP message

The wireless network device can contribute to the routing discovery process by setting itself in a promiscuous mode, in which a node overhears transmission from neighboring nodes. DSR takes advantage of this mode by caching for future use any new route or multiple routes to the same destination. Thus, when a link breaks during transmission, the originator may be able to find an alternate route to the destination before sending a RREQ message.

Route Maintenance
Route maintenance in DSR is based on a distributed manner by means of which each node that originates or forwards a packet to the next node is responsible for monitoring the validity of the link between the two nodes. This task can be achieved with or without the exchange of acknowledgment messages between the two nodes. DSR may use such an acknowledgment mechanism when it is already in place or by overhearing the next node’s retransmission of the packet passive acknowledgment provided there is a bidirectional link between the transmitting and receiving node. If such mechanisms are not present, the transmitting node can explicitly request an acknowledgment from the receiving node. When the link between the two nodes breaks and the transmitting node does

not receive an acknowledgment from the receiving node it retransmits the packet a number of times up to a threshold limit. When after a certain number of retransmissions the node does not receive an acknowledgment, it first removes the route from its cache and then originates a Route Error (RERR) message to inform all other nodes that use this link to remove the route from their caches.

DSR has additional route maintenance features to improve its functionality. A packet salvaging mechanism includes the actions taken by any intermediate node when a link-break event is detected. Then the intermediate node after sending the Route Error (RERR) message may search in its own route cache to find new route to the destination. When such a route exists, the intermediate node replaces the original source route on the packet with the new route and marks the packet as salvaged to prevent unnecessary retransmissions of the same packet by other nodes, and forwards the packet to the new next node. An automatic route shortening mechanism starts when any node in a route from a source to a destination detects that there is a shorter path than the one indicated in the packet header from that node to the destination then node replaces the original source route with the new one and sends a Route Reply message back to the source node to update its route cache.

Advantages and disadvantages of DSR

The main advantage of DSR is the absence of any periodic control messages that would take over a portion of the available bandwidth. The intermediate node utilizes the route cache information efficiently to reduce the control overhead. DSR has information of multiple routes. The route discovery and maintenance optimization techniques further eliminate the propagation and dissemination of control messages. DSR does not employ any local repair of a broken link and as any intermediate node can respond with a RR EP message to a RERR message based on its route cache there is a possibility for unstable routes in the network. DSR was designed for a network with a limited number of nodes. The networks with high mobility will cause frequent link breaks that results in high routing overhead.

III. Simulation Parameters

Two routing protocols are compared AODV and DSR. The performance simulation environment used is based on NS-2, a network simulator that provides support for simulating multi-hop wireless networks complete with physical and IEEE 802.11 MAC layer models. A free space propagation channel is assumed. The mobility model uses the random waypoint model in a rectangular field. Random waypoint model has been the choice in almost every prior Ad-Hoc routing protocol analysis.

TABLE I

PARAMETERS	**SCENARIO 1**	**SCENARIO 2**	**SCENARIO 3**
Number of Nodes	20,30,40,50,100,150	50	50
Pause Time	2 sec	2, 4, 6, 8, 10 sec	2 sec
Simulation Time	100 sec.	100 sec.	100, 400, 700 sec.
Terrain Region	1000m x 500m	1000m x 500m	1000m x 500m
Node Placement	Random	Random	Random
Mobility	20 m/sec.	20m/sec.	20m/sec.
Channel Type	Wireless Channel	Wireless Channel	Wireless Channel
Max. Packet in ifqueue	50	50	50

The various movement scenario files for different number of nodes are: Scenario 1
scene_20_2sec_20mps_100sim_x_1000_y_500
scene_30_2sec_20mps_100sim_x_1000_y_500
scene_40_2sec_20mps_100sim_x_1000_y_500
scene_50_2sec_20mps_100sim_x_1000_y_500
scene_100_2sec_20mps_100sim_x_1000_y_500
scene_150_2sec _20mps_100sim_x_1000_y_500

Traffic Files: Scenario 1
cbr_20nod_10con_1rate.
cbr_30nod_10con_1rate.
cbr_40nod_10con_1rate.
cbr_50nod_10con_1rate.
cbr_100nod_10con_1rate.
cbr_150nod_10con_1rate.

The various movement scenario files for different pause time are: Scenario 2
scene_50_2sec_20mps_100sim_x_1000_y_500
scene_50_4sec_20mps_100sim_x_1000_y_500
scene_50_6sec_20mps_100sim_x_1000_y_500
scene_50_8sec_20mps_100sim_x_1000_y_500
scene_50_10sec_20mps_100sim_x_1000_y_500

Traffic Files: Scenario 2
cbr_50nod_10con_1rate.

The various movement scenario files for different simulation time are: Scenario 3
scene_50_2sec_20mps_100sim_x_1000_y_500
scene_50_2sec_20mps_400sim_x_1000_y_500
scene_50_2sec_20mps_700sim_x_1000_y_500

Traffic Files: Scenario 3
cbr_50nod_10con_1rate.

The simulation was performed with different pause time, simulation time and numbers of nodes. Simulation are carried out in such a way that when pause time is varied then all other parameter are kept constant like number of nodes are taken 50 and simulation time is taken as 100 sec. Each node starts its journey from a random location and moves to a random destination with a randomly selected speed that is uniformly distributed 20m/sec. Upon reaching the destination, the node pauses again for pause time seconds, selects another destination, and proceeds there as previously described, repeating this behavior for the duration of the simulation.

A. Performance metrics

Packet Delivery Ratio
The packet delivery ratio is defined as the fraction of all the received data packets at the destinations over the number of data packets sent by the sources.

End-to-End Delay
End-to-end delay includes all possible delays in the network caused by route discovery latency, retransmission by the intermediate nodes, processing delay, queuing delay, and propagation delay. To average the end-to-end delay we add every delay for each successful data packet delivery and divide that sum by the number of successfully received data packets. This metric is important in delay sensitive applications such as video and voice transmission. Lower delay means better performance.

Throughput: It is the rate of successfully transmitted data packets in a unit time in the network during the simulation.

Normalized Routing Load (NRL)
The normalized routing load is defined as the fraction of all routing control packets sent by all nodes over the number of received data packets at the destination nodes. This metric discloses how efficient the routing protocol is. Proactive protocols are expected to have a higher normalized routing load than reactive ones. The bigger this fraction is the less efficient the protocol.

IV. RESULTS

Results of scenario 1

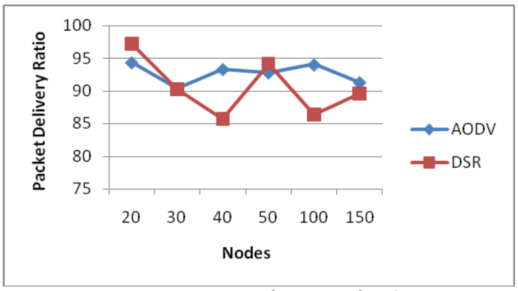

Figure 6: PDR as a function of nodes

In DSR, packet delivery ratio is high when nodes are 20 but when nodes increases from 20 then packet delivery ratio goes down. This ratio is less than other routing protocols. AODV shows higher packet delivery ratio as the number of nodes increases. This is because it takes on demand route establishment feature of DSR and Hop-to-Hop count feature of DSDV.

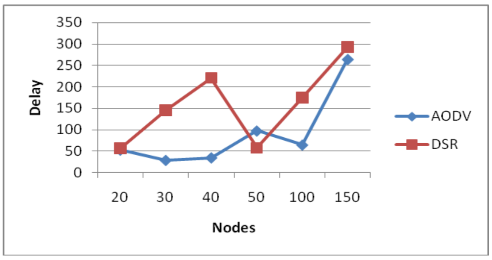

Figure 7: Delay as a function of nodes

AODV show the good performance because of lower end-to-end delay as shown in Figure7.This end-to-end delay performance metric defines all possible delays. There are many factors causing delay in network, such as- queuing delay, buffering during routes discovery, latency and retransmission delay. Because of buffering feature of AODV the end- to end delay is low as compare to DSR.

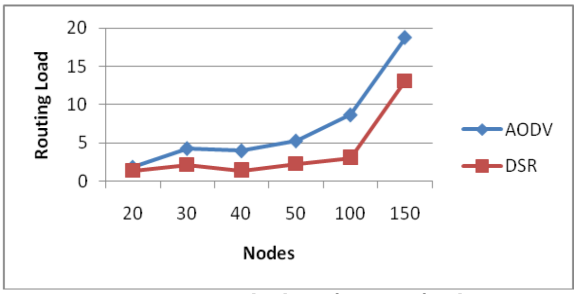

Figure 8: Routing load as a function of nodes

DSR always has a lower routing load than AODV due to aggressive caching, DSR will most often find a route in its cache and therefore rarely initiate a route discovery process unlike AODV. But because these routes are most often not valid anymore, a lot of packets get dropped. DSR's routing overhead is dominated by route replies, while AODV's routing load is dominated by route requests (broadcast packets). Therefore, DSR performs very well when looking at the routing overhead.

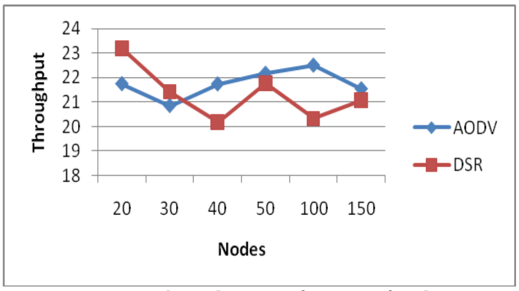

Figure 9: Throughput as a function of nodes

Figure 9 shows the throughput of each protocol when the nodes are varied. Throughput is the rate of successfully transmitted data packets in a unit time in the network during the simulation. Initially DSR has higher throughput than AODV, but as the number of nodes increases to 40 AODV starts outperforming DSR.

Results of scenario 2

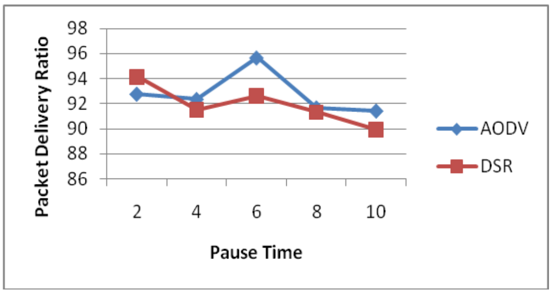

Figure 10: PDR as a function of pause time

Figure 10 shows the packet delivery ratio of each protocol when the pause time varies. DSR performs better when pause time is less as it makes aggressive use of caching. Such caching provides a significant benefit up to a certain extent. With higher pause time, stale routes are chosen as the route length. Picking stale routes causes' two problems- consumption of additional network bandwidth and filling up of interface queue resulting in more packet drops. In AODV smaller numbers of packets are dropped as compared to DSR when mobility is increased (higher pause time) so at higher pause time, AODV shows higher packet delivery ratio than DSR.

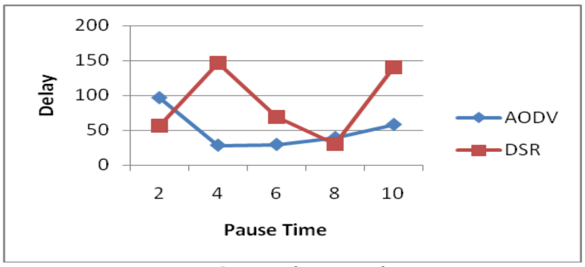

Figure 11: Delay as a function of pause time

AODV show the good performance because of lower end-to-end delay as shown in Figure 11. In AODV the destination replies only to the first arriving request whereas DSR replies to all requests making it difficult to determine the least congested route. AODV always favours the least congested route so, AODV has low end- to end delay as compare to DSR.

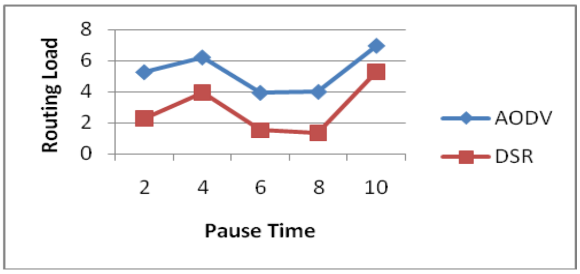

Figure 12: Routing load as a function of pause time

DSR always has a lower routing load than AODV as DSR will most often find a route in its cache and therefore rarely initiate a route discovery process unlike AODV. DSR rarely resorts to a route discovery process. AODV's routing load is dominated by RREQ packets. Therefore, DSR performs very well when looking at the routing overhead.

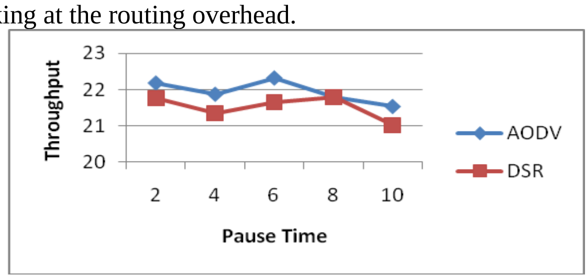

Figure 13: Throughput as a function of pause time

In AODV routing protocol when the pause time increases throughput also increases due to availability of large number of routes but when pause time crosses 8 sec throughput starts decreasing. DSR also shows the same behavior but has smaller throughput than AODV.

Results of scenario 3

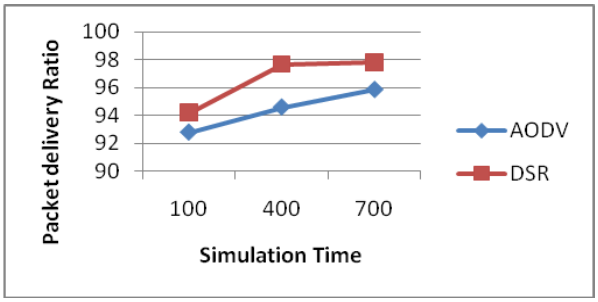

Figure 13: PDR as a function of Simulation time

Figure 13 shows the packet delivery ratio as a function of simulation time. When simulation time is increases packet delivery ratio of both the protocols increases, but DSR performs better than AODV. The reason for this is the aggressive use of route caching built in this protocol.

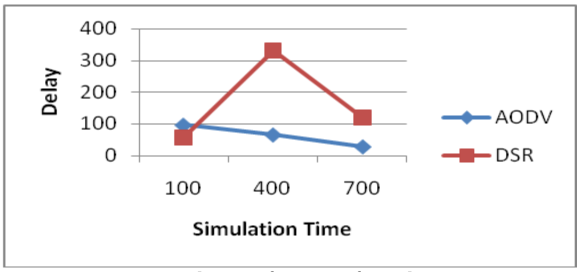

Figure 14: Delay as a function of simulation time

As AODV replies to the first arrived RREQ packet and discards other RREQs which arrive later from other sources which automatically favors the least congested route instead of the shortest path. While DSR replies to all the RREQs that arrived and it will be difficult for the protocol to select the least congested path which results in increasing delay of packets. In AODV hop-by-hop initiation helps in reduction of end-to-end delay.

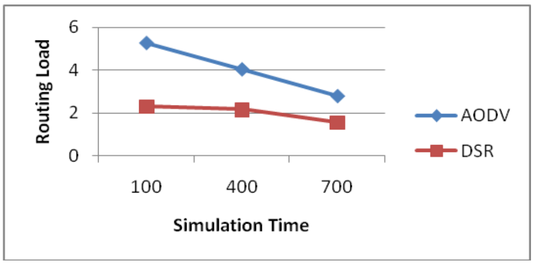

Figure 15: Routing load as a function of simulation time

DSR protocol generates significantly less routing load than AODV as Fig. 15 shows. In high simulation time, AODV routing protocols sends larger number of routing packet since nodes have only one route per destination in their routing table. That is the reason why a major contribution to AODV's routing overhead comes from RREQ packets. In DSR plenty of cached routes are present at each node. That is the reason why RREQ packets don't contribute so much to DSR's routing overhead.

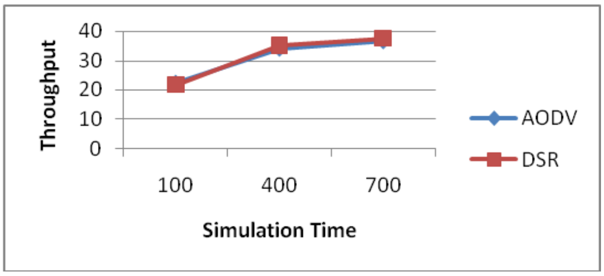

Figure 16: Throughput as a function of simulation time

Figure 16 show that both the protocols almost have similar values when throughput is considered as a function of simulation time.

V. Conclusion

Two protocols AODV (Ad-hoc on-demand distance vector routing) and DSR (Dynamic source routing) have been compared using simulation. AODV and DSR both use on-demand route discovery, but with different routing mechanics. DSR uses source routing and route caches and does not depend on any periodic or timer-based activities. DSR make use of caching aggressively and maintains multiple routes per destination. On the other hand, AODV uses routing tables that stores one route per destination and uses destination sequence numbers to prevent loops and to determine freshness of routes.

Effect of varying Network Size(number of nodes)

When the number of nodes are varied as in Scenario 1, it can be easily seen that AODV performs better than DSR. In DSR, packet delivery ratio is high only when the nodes are 20 but when nodes increases from 20 the packet delivery ratio goes down. This is because of aggressive route caching and picking up of stale routes which lead to more packets dropped as the interface queue being full. AODV shows higher packet delivery ratio, less end-to-end delay and also higher throughput than DSR. In small networks DSR shows good performance but in case of large networks the difference is less and AODV considerably performs better than DSR.

Effect of Mobility(pause time)

In Scenario 2, the pause time was varied from 2 sec to 10 sec. High mobility means the nodes have less or zero pause time and low mobility means higher pause time that is nodes are holding a position for more time. In case of high mobility link failures can happen very frequently. Link failures causes new route discoveries in AODV since it has at most one route per destination in its routing table. Thus the routing load of AODV increases. The reaction of DSR to link failures in comparison is mild and causes route discovery less often as there are plenty of cached routes at each node. However with high mobility, the probability of the caches being stale is quite high in DSR. When a route discovery is initiated in DSR large number of replies received in response causes increased interference to data traffic. Therefore, the cache staleness result in significant degradation in performance for DSR. In low mobility scenarios DSR performs better than AODV as the chances to find the route in one of the caches is much higher.

Effect of varying Simulation time

The simulation time was varied from 100 sec, 400 sec and 700 sec (Scenario 3). If the MANET has to set up for small amount of time then AODV should be preferred because of low end-to-end delay. And if the MANET has to set up for longer duration than DSR should be preferred as it has high ratio of packet delivering and low routing load. The reason for this is the aggressive use of route caching built in this protocol. DSR always has a lower routing load than AODV. This is because of the caching strategy used by DSR. DSR aggressivly uses caching and is more likely to find a route in the cache and so less route discoveries than AODV.

Acknowledgment

I would like to thank Mrs. Ritu Saluja and Manav Rachna College of Engg. for their support and guidance.

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