International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 3, March - 2013

A Significant Study And Comparison Of DSDV, AODV And DSR Protocols In MANET Using NS2

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Abstract

A mobile ad-hoc network is a dynamic network of mobile devices in which the devices locate themselves randomly in a self configuring manner. These mobile devices are connected through some wireless channel and they exchange data if they are within the communication range, otherwise the devices are declared as unreachable nodes. Consequently, routing in ad-hoc network is difficult and hence, there are separate routing protocols in ad-hoc network which handle the broken link problem. These protocols determine the loop free shortest path from source to destination. The paper examines the three main ad-hoc routing protocols - DSDV, AODV and DSR. It provides an overview of these three protocols by discussing their characteristics, functionality and then a qualitative comparison among them. It also discusses the network performance of these protocols through simulation results in NS2 simulator, and considers the various performance metrics- packet delivery ratio, end-to-end delay and packet loss percentage with varying network nodes per number of connections.

Keywords—DSDV, AODV, DSR, NS2, packet delivery ratio, average end-to-end delay, packet loss percentage.

1.Introduction

A mobile wireless network (MANET) is an infrastructure less network with no fixed locations of routers, hosts or wireless base stations. Here, nodes are free to move in any random fashion. The ad-hoc network is an extension of a wireless cellular network that have been in use since 1980s and has several advantages over it- on-demand set up, fault tolerance and unconstrained connectivity. In Manet, mobile nodes can directly communicate with one another through some wireless radio channel. As a result, the interconnection topology changes dynamically and also, the communication link fails when a communicating node moves out of transmission range.

However, routing protocols used in conventional wired networks are not well suited for routing in the mobile environment as they converge slowly to the topological changes. Secondly, they may lead to an infinite loop problem if broken link exists. Thirdly, the mobile devices may drain out their battery power in a short time due to excessive periodic broadcast of updates as devices change their location randomly. Consequently routing in manet has emerged as a major research area. Numerous ad-hoc routing protocols have been proposed by the Internet Engineering Task Force (IETF) Mobile Ad-hoc Networks (MANET) Working Group. Ad-hoc routing protocols are designed to provide a loop free path for data transmission. A discussion of Manet can be found in RFC2501[16].

Elizabeth M. Royer[3] broadly divided the ad-hoc routing protocols in two categories- proactive and reactive routing protocols. Then, theoretically compared various proactive and reactive protocols on the basis of some metrics. Shefali Goyal et. al[8] has discussed AODV, DSDV and DSR along with their advantages and limitations. The paper compared protocols with respect to parameters- packet delivery ratio, average end-to-end delay and normalized routing load with varying number of nodes per connection through the simulation results in NS2. Luis Girone Quesada [9] discussed the characteristics and mechanism of various ad-hoc routing protocols- AODV, DSR, OLSR and ZRP. The thesis analyzed the protocols for various network conditions- network size, mobility and network load. S.R. Das et. al[10] evaluated AODV and DSR protocols in manet with three parameters- packet delivery fraction, end-to-end delay and normalized routing load with respect to varying pause time through NS2 simulator. S.Mohapatra and P.Kanungo[11] evaluated AODV, DSR , OLSR and DSDV ad-hoc routing protocols with control overhead, packet delivery ratio, end-to-end delay and throughput with respect to varying number of nodes, pause time and simulation area. Samyak Shah et al[12] compared the protocols on the basis of packet delivery fraction, average end to end delay and normalized routing load parameters with varying pause time and number of nodes using NS2 simulator.

The paper evaluates the three ad-hoc routing protocols- DSDV, AODV and DSR in Manet. The rest of paper is organized into several sections. Section 2 introduces the table driven and on-demand protocols along with the functional details of DSDV, AODV and DSR protocols. Also, the qualitative comparison among them is shown on the basis of some metrics. Section 3 discusses about the general introduction to NS2 and the various performance parameters used for analysis of protocols. Section 4 discusses the performance of protocols through the simulation results with respect to packet delivery ratio, end-to-end delay and packet loss percentage.

2. Existing Routing Protocols

Ad-hoc routing protocols determine the appropriate path from the source to destination and efficiently notify the network with link failure, if it occurs. These protocols are broadly divided into two categories[3] –

- Table-driven routing protocols.
- Source-initiated on-demand driven routing protocols.

Table-driven routing protocols are also known as proactive routing protocols. These protocols desire to maintain consistent and up-to-date routing information in the network. The nodes exchange the routing information periodically and also when there is even a minor change in the network topology and thus, every node maintains one or more routing table to store routing information about every other node in the network.

As a result, these protocols are not preferred in large network. The highly dynamic network also avoids it, as there is lot of message exchanges and it will create congestion and delay in the network. The protocol evolves periodic exchanges even when there is no change in topology and this is simply the wastage of network resources. The mobile devices may also drain out their battery power sooner in such cases. In spite of several drawbacks, these protocols also have the advantage that there is no initial delay as routing information is always available. Some of the popular examples of table-driven routing protocols are – DSDV, CGSR (Clusterhead gateway switch routing protocol) and WRP (Wireless routing protocol).

Source-initiated on-demand driven routing protocols are also known as reactive routing protocols. These protocols initiate route discovery only when the source node requires an appropriate path to transmit data. On demand routing protocols establish route in two main steps-

- Route discovery.
- Route maintenance.

Whenever a source node desires a path, it initiates route discovery procedure. Once the path is determined, route maintenance procedure is carried out to detect the broken link or unreachable node along the routing path. If a link failure is detected on underlying path, all upstream nodes are notified and route discovery procedure is reinitiated. Finally, an appropriate route from source to destination is established and maintained through these steps.

These protocols are preferred to proactive protocols especially in large or dynamic mobile ad-hoc network as routes are established on demand basis. These protocols also evolve less traffic overhead as number of exchanges is lesser. Thus, they consume lesser network resources and may have larger battery life. But, the drawback is that the routing information is not always available and there is a significant start up delay due to route discovery. Still, Reactive protocols are preferred over proactive protocols. Some of the popular examples of on-demand driven routing protocols are –AODV, DSR, TORA (Temporally-ordered routing protocol) and ABR (Associativity-based routing protocol).

2.1 Destination-Sequenced Distance-Vector Routing Protocol (DSDV)

Destination-Sequenced Distance-Vector Routing Protocol (DSDV) is a table-driven routing protocol. It is basically an improvement to Bellman Ford algorithm[5][6][7] as it handles infinite loop problems. Here, each node maintains consistent and up-to-date routing information by means of periodic exchange of routing updates even if there is no change in topology. Also, the nodes broadcast routing updates to their immediate neighbors whenever there is a minor change in network topology.

Here, each node maintains the routing table that comprises:

< Destination IP address, next node IP address, cost metric, sequence number, install time >

Destination IP address includes the IP address of all the known destinations in the network. The next node IP address is the IP address of the immediate neighbor of the source node. Cost metric demonstrates the number of hops from source to destination node. DSDV solves the problem of routing loops by associating each route entry with a sequence number. A sequence number is linked to the destination node, and usually originated by that node. The originator of the sequence number is also known as the owner node. The owner increments the sequence number after each broadcast. The only case that a non-owner node updates a sequence number is when it detects a link break on that route. An owner node always uses even number as sequence number while, a non-owner node always uses odd-number. Sequence number is used to distinguish freshest or newer routes from the stale routes and thus handles link failure. A route with a newer sequence number is the most preferable route in Manet but if two routes have the same sequence number, then the one with a better cost metric is preferred. Install time is the time when entry is made in routing table and it is used to delete the unwanted routes. The nodes broadcast the routing updates and it comprises[9]:

<Destination IP address, next node IP address, cost metric, sequence number >.

The routing information can employ two ways to update:

- Full dump update
- Incremental update[3].

A full dump update is the entire routing table to be propagated in the network, whereas in an incremental update, only those entries from the routing table are sent that has a metric change since the last update. When the network is relatively stable, incremental updates are sent to avoid extra traffic otherwise; full dumps can be used in high dynamics.

Figure 1 represents renovation of link failure[13]. In this, nodeA detects link failure to intermediate nodeB (Fig 1.a). So, it sets the cost metric as infinity as well as increases the sequence number to next odd digit and broadcasts the update to its neighbors (Fig 1.b). Eventually, the nodes recognize the unreachable path and the other appropriate route is established (Fig 1.c).

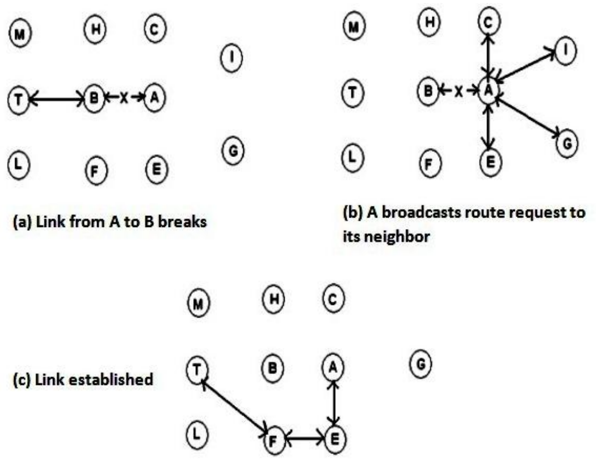

Fig 1. Resolving failed links in DSDV[13]

The major drawback of the periodic or event driven broadcast is the route fluctuation. The route fluctuation is defined as the unwanted broadcasting of any inappropriate route if there is some better route in the near future. To handle this problem, the node waits for a certain period before broadcasting the route updates. The waiting time is approximately length of network settling time. The Network settling time is the time required for mobile nodes to automatically organize it and transmit the first task reliably.

2.2 Ad-hoc On-Demand Distance Vector Routing Protocol (AODV)

Ad-hoc On-demand distance vector routing protocol (AODV) is a reactive routing protocol. AODV is classified as pure on-demand route acquisition system[5], as nodes that are not on a selected path neither maintain routing information nor participate in routing table exchanges. The basic operation of AODV includes the two main steps-

- Path Discovery
- Path Maintenance.

2.2.1 Path Discovery

The Path Discovery process is initiated whenever a source node wants to transmit data to the destination and it has no valid routing information. Here, each node maintains two separate counters[9]:

< node sequence number and broadcast id >

AODV borrows the concept of sequence number from DSDV protocol to determine the freshest route in the network. Broadcast id is initiated by the source node and it is incremented when broadcast starts from the node. The source node initiates path discovery by broadcasting a route request (RREQ) packet to its neighbors. Figure 2 represents the flow of RREQ in the network from source to the destination node. The contents of RREQ packet are:

<Source IP address, source sequence number, broadcast id, destination IP address, destination sequence number, hop count>

The pair < source IP address, broadcast id> uniquely identifies a RREQ[9]. Whenever a node receives multiple copies of RREQ from the different intermediate nodes, it keeps the first RREQ packet and ignores all other RREQs. The intermediate node can reply to the source node if it has a route to the destination with equal or greater sequence number than the destination sequence number in the RREQ packet.

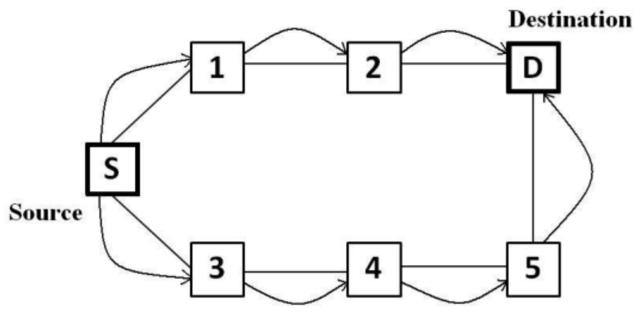

Fig 2. Route Request propagation

The routing path can be established in two steps- reverse path set up and forward path setup.

The reverse path is established with the propagation of the route reply packets (RREP) in the network from the destination to the source node. When the RREQ is sent in the network, the intermediate nodes forward the RREQ after increasing the number of hops in the RREQ packet by one and also they record the address of the node from which they receive the first RREQ packet. Once the RREQ is reached at the destination node, the eligible intermediate nodes as well as the destination node propagate RREP from the destination to the source. Once the RREP reaches the source node, it establishes the reverse path. Figure 3 shows the propagation of RREP in the network from destination to the source node. The content of RREP is:

< Destination IP address, source IP address, number of hops, expiration time, destination sequence number>

The reverse path routing information is maintained only till the reverse path is established and this duration is represented by the expiration time.

Once the reverse path is established, the forward path is established by the means of RREP propagation as the intermediate nodes record the address of the previous nodes in reverse path from destination to source node in a similar manner as the reverse path setup.

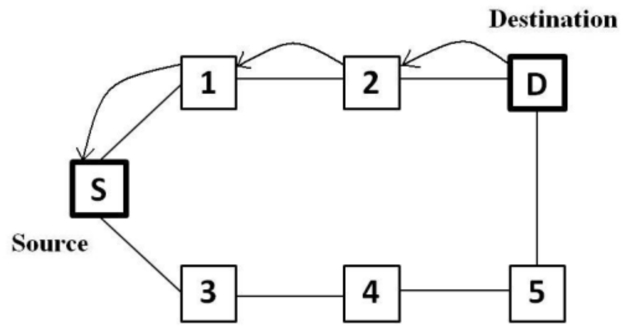

Fig 3 Route Reply

2.2.2 Path Maintenance

The route from source node to destination is affected by the movement of active nodes lying on that path. If the source node moves during an active session, it can reinitiate the route discovery procedure. On the other hand, when the destination or some intermediate node moves, the communication link fails. So, to handle the link failure problem, the node that detects unreachable node or broken link, sets infinity as number of hops in RREP and also attach the link failure notification message (RERR) to each of its active upstream neighbor on underlying path. Once RERR reaches the source, it reinitiates the route discovery procedure. Local connectivity among the nodes can be maintained with the help of periodic broadcasting of HELLO messages but this increases traffic overhead in the network.

2.3 Dynamic Source Routing Protocol (DSR)

Dynamic Source Routing protocol (DSR) is an on-demand routing protocol that is based on the concept of source routing.

Source routing represents that the source has the knowledge of entire route to the destination before transmitting data. Here, the entire hop sequence till the last traversed node is carried in the route record which is attached to the route request packet header. Also, each node maintains a route cache where it records all possible learned routes from itself in the manet. The protocol performs operation in two main steps-:

- Route discovery
- Route maintenance[7].

2.3.1 Route Discovery

Route Discovery is initiated whenever a source node desires a route to the destination and it does not have a valid hop sequence in its route cache. If it finds a valid hop sequence in its route cache then, it simply sends the data along that path. otherwise, it broadcasts the route request message (RREQ) in the network that comprises[9]:

<Source IP address, destination IP address, request identification number>

The request identification number is unique for each request and is initiated by the source node when it broadcasts a new request. Both request identification number and source IP address uniquely identifies the request.

When an intermediate node receives RREQ, it first searches its route cache for route to destination and if no route is found, it appends its own address to the route record of the RREQ and then broadcast it in the network. In order to minimize the RREQ in network, the intermediate or destination node discards the

duplicate RREQ identified by the same request identification number and common source. The RREQ message propagates through the network until it reaches either the destination node or an intermediate node that has a valid route to the destination in its route cache. The destination or intermediate node, initiates the route reply (RREP) message back to the source node along the same hop sequence found in the route record of RREQ but, in reverse order. The destination node can directly attach the entire hop sequence from the source to the destination present in route record of RREQ to the RREP and sent it back but, the intermediate node that has a direct route to the destination, appends that route from its route cache to the hop sequence in the route record of RREQ thereby combining them to have the entire hop sequence from source to the destination node and sends it back to source. Figure 4 shows the formation route record as RREQ propagates in the network.
Figure 5 represents the propagation of RREP that carries the entire hop sequence. Once RREP reaches the source node, it learns the entire hop sequence to the destination. Once path is known, the data can be transmitted but, it needs to be maintained against link failure.

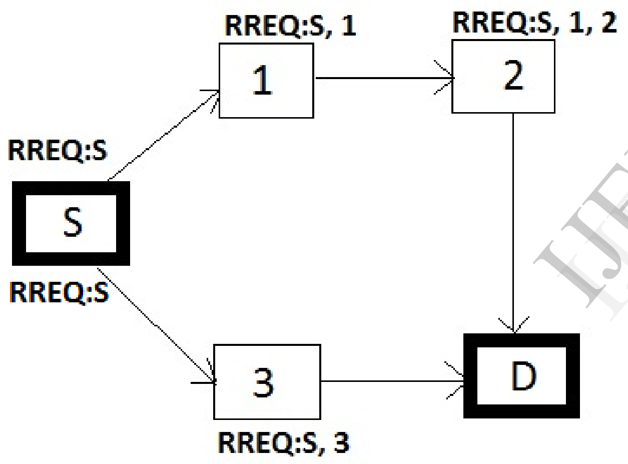

Fig 4. Route Request in DSR

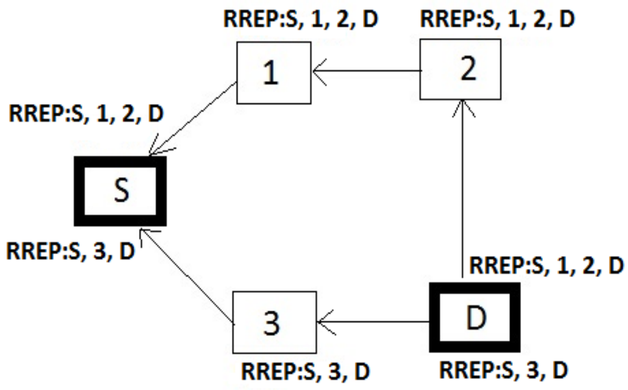

Fig 5. Route Reply in DSR

2.3.2 Route Maintenance

Route Maintenance is done by the propagation of route error packets (RERR). When an active node detects the link failure, it propagates the route error message to its upstream neighbors along the reverse path till it reaches the source node. When a route error packet is received by the intermediate or the source node or when it detects link failure, the node truncate that unreachable hop entry along with all the routes containing that hop, from its route cache.
HELLO messages and acknowledgment messages can also be used to verify the correct operation of the router links or to maintain the local connectivity in an ad - hoc network.

2.4 Qualitative Comparison

Each of the three protocols provides the loop free path but they differ in their performance in some network scenarios. Table 1 shows the general comparison among DSDV, AODV and DSR ad-hoc routing protocols with respect to some metrics.

Metrics	DSDV	AODV	DSR
Routing Metric	Shortest Path	Freshest & Shortest Path	Shortest Path
Routes Maintained in	Routing Table	Routing table	Route Cache
Routing update transmission	Periodically & as needed	When needed	When needed
Loop free	Yes	Yes	Yes
Multicasting	No	Yes	No
Mobility	Does not perform well	Performs well in high mobility	Does not perform well in high mobility
Network Size	Not Suitable in large network	Can be preferred to DSR in large network	Performs better than DSDV
Delay	Least	Lesser than DSR	Greater than AODV
Suitable in VANET	No	Yes	No
Resource Consumption	Maximum	lesser than DSR	greater than AODV
Communicatio n Link	Unidirection al	Bidirectio nal	Bidirection al
Routing overload	Least	Greater than DSR	Lesser than AODV
Repair of Broken Links	Handled in least time	Time consumin g	Consumes less time

Table 1 Comparison among ad-hoc routing protocols (DSDV, AODV, DSR)

All the three protocols establish path on the basis of minimum number of hops. But, AODV employs the use of sequence number to find the freshest route also. It supports multicasting too. DSR carries the entire hop sequence with RREQ, so it is not suitable for highly dynamic or large network and, for similar reason not preferably used in VANET. DSDV also creates unnecessary periodic exchanges of routing information and thus, unsuitable for large or dynamic networks. Routing information is always available in DSDV. DSR also allows nodes to record multiple routes in their cache. So, they incur less overhead in case of broken links whereas, AODV incur largest overhead in such cases. However, the routing load is least for DSDV as it does not employ route discovery. Likewise, DSR also maintains route cache and hence, impose lower routing load than AODV.

3. Simulation Methodology

Network simulator assists in analyzing the network performance under certain scenario, so that the user can learn its consequences before applying it in real time applications. There are various network simulators- QualNet, NS2, NS3, OMNET++. NS2 is one of the most popular discrete event simulator and its results are world wide acceptable. We have used NS2.34 for analyzing the performance of DSDV, AODV and DSR in an ad-hoc network.

NS2 uses two languages- C++ and tool command language (TCL) and each has its own significance. C++ is used in back-end for detailed implementation of protocols and TCL is used in front for writing the simulation scripts. The nam and trace files are generated as output to TCL script. NAM file is a network animator file and it shows the entire topology of network. Trace file records the event sequence at each instance of time as specified in TCL file. The performance parameters can be observed or evaluated from the trace file content. Table2 shows the simulation parameters which are set in TCL script for generating the network scenario.

3.1 Performance Metrics

The three performance metrics are observed to study the network performance of these protocols- packet delivery ratio, average end-to-end delay and packet loss percentage.

Packet delivery ratio: It is the ratio of the total number of packets received by CBR application at the destination node to the total number of packets sent by the UDP agent at source node. It can be expressed as:
Packet delivery ratio = ∑ Packets received at the destination ÷ ∑ Packets sent by the source .

Average end to end delay: Delay is the total time taken by the packets to reach from the source to destination. The delay is basically the total of transmission time, time taken for path discovery, queuing delay of packets, propagation delay and time taken by CPU processor. It is expressed as:

Average end-to-end delay = ∑ (time at which the packet is received by the destination– time at which the packet is sent by the sender) ÷ Total number of recieved packets.

Packet loss percentage: It is the percentage of number of lost packets during transmission, within the entire simulation time. It is expressed as:
Packet loss percentage = (number of lost packets/ Total number of sent packets)*100

4. Results and Discussion

The simulation results show the performance behavior of the protocols in terms of packet delivery ratio, end-to-end delay and packet loss percentage. These performance parameters are observed from the trace files and results are shown through the graph for comparative study of protocol's performance with respect to varying number of nodes per number of connections.

Network simulation model Parameters	*Value of parameters*
Network type	Mobile
Radio propagation model	Two ray ground propagation
Antenna	Omni directional
Motion	Random
Queue length	50
Number of nodes/number of connections	10/2, 20/4, 30/6, 40/8, 50/10
Traffic Type (Application/Agent)	CBR/UDP
Simulation time	100 simulation runs
Simulation area	800 X 800

Table 2 Simulation model parameters

Figure 6 shows the performance behavior of DSDV, AODV and DSR through simulation in NS2.34.

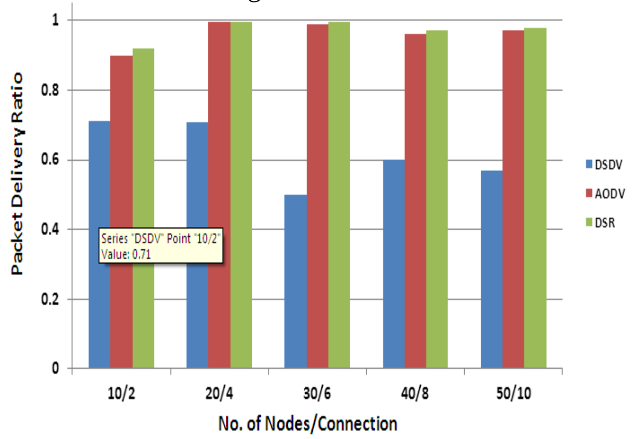

Fig 6(a)

Figure 6(a) represents the performance on the basis of packet delivery ratio with varying number of nodes per connections. DSDV has a lower packet delivery ratio than the other two on-demand protocols. However, it performs better in smaller network than larger one. The reason is that it posses least initiation routing delay and can transmit more packets within smaller network. Also, each node maintains entire routing information that grows with the size of network and transmit it periodically, so the packets received at the destination is always much lesser than the total number of sent packets in large network. AODV and DSR performs better than DSDV as they do not exchange so much routing information. Moreover, DSR has slightly greater packet delivery ratio than AODV. This is due to the availability of routes in route cache, so it can transmit more packets in the same simulation time if it has routes in its route cache unlike, AODV. However, in large networks, AODV improves its performance as unlike DSR, it doesn't carry the load in its RREQ header.

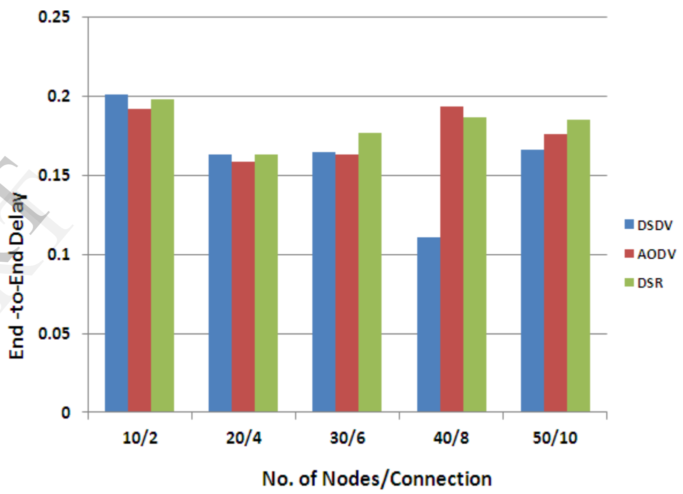

Fig. 6(b)

The lower the average end-to-end delay is, the better is the network performance. Figure 6(b) shows the average end-to-end delay values for DSDV, AODV and DSR with respect to varying number of nodes per connections. DSDV shows an average performance as it does not initiate path discovery procedure for route establishment. DSR has lower delays as it can get the valid route from route cache. However, AODV performs worst in terms of end-to-end delay as it needs to initiate route discovery whenever source desires to transmit to destination.

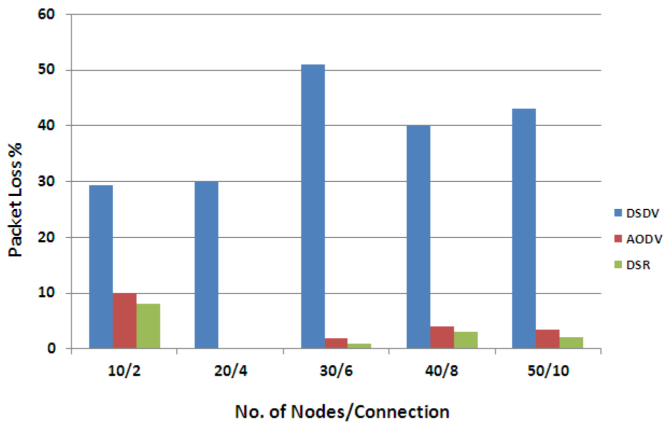

Fig. 6(c)

Figure 6(c) measures the packet loss percentage in the network with varying number of nodes per connections. Packet loss occurs whenever the buffering capacity of queue is full. The packet loss is maximum in DSDV as, there is large routing information exchanges and in this simulation, the queue limit is 50 only. So, It might be possible the queue overflows and drops out excess packets. However, DSR has lower packet loss percentage than AODV, as it involves a lesser number of routing exchanges due to availability of routes in route cache.

5. Conclusion

The paper has successfully discussed the operation of the three main protocols in manet followed by a qualitative comparison among them. From the study of simulation results under the given scenario, it is observed that DSR performs best in terms of the packet delivery ratio whereas; DSDV has lowest average end-to-end delay and DSR outperform the other two in terms of packet loss percentage. However, AODV increases its performance in terms of packet delivery ratio when there is growth in network size. Thus, it is concluded that each protocol has some merits and demerits for certain network scenario. In future, we can consider some more important performance metrics-routing load and throughput for comparison, on some other network scenarios. Also, the network performance of these protocols can be analysed in VANET.

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