Performance study of Broadcast based Mobile Adhoc Routing Protocols AODV, DSR and DYMO

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Abstract

The Mobile Ad-hoc Network (MANET) is a collection of self-configuring mobile node without any infrastructure. The mobile nodes with wireless radio interface are connected by wireless links where each device in a MANET is free to move independently and randomly with the capability of changing its links to other devices frequently. It is a multihop process because of the limited transmission range of energy constrained mobile nodes and thus each device in network topology acts as a router. Many protocols are reported in this field but it is difficult to decide which one is efficiently best. In this paper on demand routing protocols AODV, DSR and DYMO based on IEEE 802.11 are examined and characteristic summary of these routing protocols is presented. With MAC and physical layer model their performance is analyzed and compared on performance measuring metrics throughput, jitter, packet delivery ratio, end-to-end delay and error reply packets and dropped packets due to non availability of routes by varying CBR data traffic load using QualNet 5.0.2 network simulator.

Keywords-*Adhoc networks; wireless networks; CBR; routing protocols; route discovery; simulation; performance evaluation; MAC; IEEE 802.11.*

1. Introduction

The Mobile Ad-hoc Network (MANET) is a collection of self-configuring mobile node without any infrastructure. The mobile nodes with wireless radio interface are connected by wireless links where each device in a MANET is free to move independently and randomly with capability of changing its links to other devices frequently. It is a multihop process because of the limited transmission range of energy constrained mobile nodes and thus each device in network topology acts as a router [1]. With dynamic nature of network topology the routes changes very fast and frequent and so the efficient routing protocols plays important roles in handling it. They should be capable to ensure the delivery of packets safely to their destinations. MANETs are also capable of handling topology changes and malfunctions in nodes through network reconfigurations.

The mobile adhoc networks are very flexible and suitable for several types of applications, as they allow the establishment of temporary communication without any pre installed infrastructure (fig.1). Beside the disaster and military application domain the deployment of mobile ad-hoc networks for multimedia applications is another interesting area. With newly

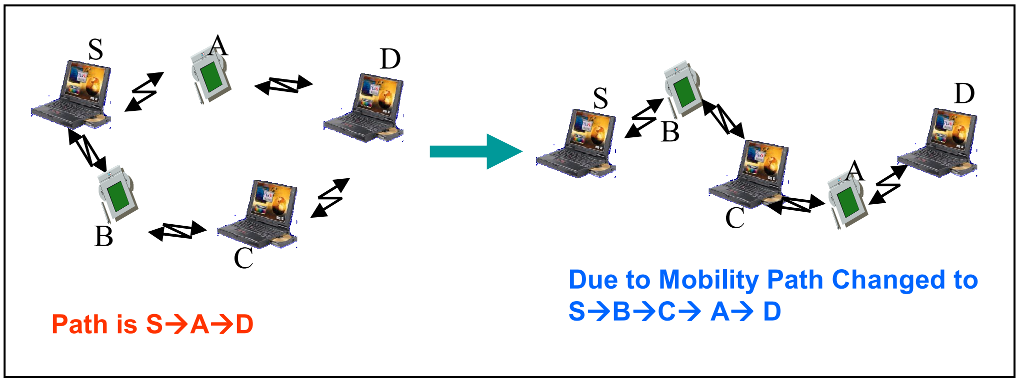


Fig. 1 The dynamic scenario of network topology with mobility

emerging radio technologies, e.g. IEEE 802.11[3] and bluetooth, the realization of multimedia applications over mobile ad-hoc networks becomes more realistic.

To find a route between the end-points is a major problem in mobile multi hop ad-hoc dynamic networks. The problem is further aggravated because of the nodes mobility. Many different approaches are reported to handle this problem in recent years, but it is very difficult to decide which one is best routing algorithm. It is also reported in the performance analysis of different routing protocols [4,5,6] in literature. Other aspects of ad-hoc networks are also subject to current research, especially the dynamic changing network topology of nodes.

In this paper the characteristic comparison and performance analysis of DYMO, AODV, and DSR on-demand routing protocol based on IEEE 802.11 is presented. This paper explores the performance with the parameters metrics data throughput, jitter, end-to-end delay and packet delivery ratio in environments with varying data traffic CBR (Constant Bit Ratio) load over UDP using Qualnet 5.0.2 simulator [2].

2. Routing Protocols: Classification in brief

Routing is the process of finding a path from a source to destination among randomly distributed routers. The broadcasting [7, 8, 9] is inevitable and a common operation in ad-hoc network. It consists of diffusing a message from a source node to all the nodes in the network. Broadcast can be used to diffuse information to the whole network. It is also used for route discovery protocols in ad-hoc networks. The routing protocols are classified as follows on the basis of the way the network information is obtained in these routing protocols.

2.1 Proactive (or Table-driven) routing protocol

The proactive protocols maintain routing information about each node in the network. The information is updated throughout the network periodically or when topology changes. Each node requires to store their routing information.

For example

1. Destination sequenced Distance vector routing (DSDV) [10]
2. Source Tree Adaptive Routing (STAR) [11]

2.2 Reactive or On-demand routing protocol

The reactive routing protocols look for the routes and are created as and when required. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destination.

For example

1. Ad-Hoc On-demand Distance Vector (AODV) [12]

2. Dynamic Source Routing (DSR) [13, 14]
3. Dynamic MANET On-demand (DYMO) [15]

2.3 Hybrid Protocols

These protocols are using the best features of both the on-demand and table driven routing protocols.
For example
1. Temporally ordered routing algorithm (TORA) [16]
2. Zone Routing Protocol (ZRP) [17]

These classes of routing protocols are reported but choosing best out of them is very difficult as one may be performing well in one type of scenario the other may work in other type of scenario. In this paper it is observed with the simulation of AODV, DSR and STAR routing protocols. These three protocols are briefly described below. The characteristic summary of these routing protocols is also presented in this paper in table 2.

3. Dynamic Source Routing Protocol

The key feature of DSR [13, 14] is the use of source routing. The source (sender) knows the complete hop-by-hop route to the destination. These routes are stored in a route cache. The data packets carry the source route in the packet header. It is an on-demand routing protocol and composed of two parts:

A. Route Discovery
B. Route Maintenance.

3.1 Route Discovery

When a node in the ad hoc network attempts to send a data packet to a destination for which route is not known, it uses a route discovery process to find a route. Route discovery uses simple flooding technique in the network with route request (RREQ) packets. Each node receiving an RREQ rebroadcasts it further, unless it is the destination or it has a route to the destination in its route cache. Such a node replies 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 so far. 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.

3.2 Route Maintenance

The periodic routing updates are sent to all the nodes. If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source if this route is still needed. Also, any forwarding node caches the source route in a packet it forwards for possible future use. Some of the techniques that are evolved to improve it are:

i) Salvaging: an intermediate node can use an alternate route from its own cache, when a data packet meets failed link on its source route.
ii) Gratuitous route repair: a source node receiving a RERR packet piggybacks the RERR in the following RREQ.

This helps cleaning up the caches of other nodes in the network that may have the failed link in one of the cached source routes.

4. Dynamic MANET On-demand (DYMO)

The Dynamic MANET On-demand (DYMO) [15] is a reactive, multihop, unicast routing protocol. The DYMO is a memory concerned routing protocol and stores minimal routing information and so the Control Packets is generated when a node receives the data packet and it doesn't have any valid route information. The basic operations of DYMO are:

A. Route Discovery
B. Route Maintenance

4.1 Route Discovery

The source router generates Route Request (RREQ) messages and floods them for destination routers for whom it doesn't have route information. Intermediate nodes store a route to the originating router by adding it into its routing table during this dissemination process. The target node after receiving the RREQ responds by sending Route Reply (RREP) message. RREP is sent by unicast technique towards the source. An intermediate node that receives the RREP creates a route to the target and so finally it reaches to originator. Then routes have been established between source and destination in both directions.

4.2 Route Maintenance

Route maintenance consists of two operations. It avoids expiring good routes and so it updates reverse route lifetime on data reception and forward route lifetime on data transmission. The DYMO nodes monitors link over which traffic is flowing in order to cope up with dynamic network topology. A Route Error (RERR) message is generated when a node receives a data packet for the destination for which route is not known or the route is broken. This RERR notifies other nodes about the link failure. The source node reinitiate route discovery quickly as it receives this RERR. Hello messages are used by all nodes to maintain routes to its neighbor nodes

The sequence numbers are used in DYMO to make it loop free. These sequence numbers are used by nodes to determine the order of route discovery messages and so avoid propagating stale route information.

The DYMO routing protocol is designed for memory constrained devices in mobile ad hoc networks (MANETs) as it quickly determines route information dynamically.

5. Ad-Hoc On-demand Distance Vector (AODV)

The Adhoc On-Demand Distance-Vector Protocol (AODV) [12] is a distance vector routing for mobile ad-hoc networks. AODV is an on-demand routing approach, i.e. there are no periodical exchanges of routing information. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network.

The protocol consists of two phases:

i) Route Discovery, and
ii) Route Maintenance.

5.1 Route Discovery

A node wishing to communicate with another node first seeks for a route in its routing table. If it finds one the communication starts immediately, otherwise the node initiates a *route discovery* phase. The route discovery process consists of a route-request message

(RREQ) which is broadcasted. If a node has a valid route to the destination, it replies to the route-request with a route-reply (RREP) message. Additionally, the replying node creates a so called *reverse route* entry in its routing table which contains the address of the source node, the number of hops to the source, and the next hop's address, i.e. the address of the node from which the message was received. A lifetime is associated with each reverse route entry, i.e. if the route entry is not used within the lifetime it will be removed.

5.2 Route Maintenance

The second phase of the protocol is called route maintenance. It is performed by the source node and can be subdivided into: i) source node moves: source node initiates a new route discovery process, ii) destination or an intermediate node moves: a route error message (RERR) is sent to the source node. Intermediate nodes receiving a RERR update their routing table by setting the distance of the destination to infinity. If the source node receives a RERR it will initiate a new route discovery. To prevent global broadcast messages AODV introduces a local connectivity management. This is done by periodical exchanges of so called HELLO messages which are small RREP packets containing a node's address and additional information.

5.3 Main Features

Each AODV router is essentially a state machine that processes incoming requests from the SWANS network entity. When the network entity needs to send a message to another node, it calls upon AODV to determine the next-hop.

Whenever an AODV router receives a request to send a message, it checks its *routing table* to see if a route exists. Each routing table entry consists of the following fields:

- Destination address
- Next hop address
- Destination sequence number
- Hop count

If a route exists, the router simply forwards the message to the next hop. Otherwise, it saves the message in a message queue, and then it initiates a route request to determine a route.

Upon receipt of the routing information, it updates its routing table and sends the queued message(s). AODV nodes use four types of messages to communicate among each other. *Route* Request (RREQ) and Route Reply (RREP) messages are used for route discovery. Route Error (RERR) messages and HELLO messages are used for route maintenance.

The destination sequence number is used to make this routing protocol loop free.

6. Simulation Setup

The Qualnet 5.0.2 [2] network simulator is used for the analysis. The animated simulation is shown in fig. 2. The IEEE 802.11[10] for wireless LANs is used as the MAC layer protocol. In the scenario UDP (User Datagram Protocol) connection is used and over it data traffic of Constant bit rate (CBR) is applied between source and destination. The 100 nodes are placed uniformly over the region of 1500mx1500m. The mobility model uses the random waypoint model in a rectangular field. The multiple CBR application are applied over 13 different source nodes – 4,53,57,98,100,7,5,49,10,93,1,92,9) and destinations nodes - 51,91,94,59,60,96,58,97,100,54,45, 44,38 respectively. The data traffic load is varied as 1, 2, 4, 5, 10 packets per sec to analyze the performance of AODV, DSR and DYMO routing protocols. The simulations parameters are shown in table 1.

Table 1. Simulation Parameters

Parameter	Value
Area	1500mX1500m
Simulation Time	90,120, 200 sec
Channel Frequency	2.4 Ghz
Data rate	2.Mbps
Path Loss Model	Two Ray Model
Mobility Model	Random-Way Point
Packet size	512 bytes
Physical Layer Radio type	IEEE 802.11b
MAC Protocol	IEEE 802.11
Antenna Model	Omni-directional

6.1 Performance Metrics

Throughput: Throughput is the average rate of successful data packets received at destination. It is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second.
End-to-End Delay: A specific packet is transmitting from source to destination and calculates the difference between send times and received times. Delays due to route discovery, queuing, propagation and transfer time are included in the delay metric.
Jitter: Jitter is the variation time in the packet arrival. It is different from the delay and caused due to congestion, topology change etc. in network. It is expected to be low for better performance in ad-hoc networks. It becomes a matter of concern if it is more than the threshold value which is different for each type of transmission as data, voice or video.
Packet Deliver Ratio (PDR): The (PDR) is defined as the ratio between the amount of packets sent by the source and received by the destination.

7. Result & Discussion

The Qualnet 5.0.2 network simulator [2] is used to analyze the parametric performance of Dynamic Source Routing (DSR) [13,14], Ad Hoc On-Demand Distance-Vector Protocol (AODV) [12] and DYMO [15] routing protocols. The animation of broadcasting, nodes mobility and transmission of data of one of the scenario is shown in figure 2. The performance is analyzed with different variation of traffic load. In this analysis thirteen different CBR (Constant Bit Rate) traffic applications over the UDP (User Datagram Protocol) connection are generated as described in simulation setup. These are applied on different source to destination nodes. The results are shown in figures from 3 to 8.
Packet Deliver Ratio: PDR performance is analyzed and it is observed that AODV routing protocol performs better than both DSR and DYMO and DSR performs inferior to both AODV than DYMO. Though, initially on low traffic load DSR is performing better than DSR as shown in figure 3. The lower performance of DSR is attributed to use of aggressive caching.
Throughput: With the varying CBR data traffic the throughput is analyzed. The successful packet delivery in an adhoc network is observed with increasing MAC based CBR traffic load over UDP. It is found that DYMO performs better than both DSR and AODV. AODV performs better than DSR. DYMO better performs is attribute to its ability to search route

quickly as it avoids expiring good route by updating route lifetime appropriately. The performance of DSR is week as it doesn't have proper technique to update stale roués as shown in figure 4.

End-to-End Delay: When a packet is transmitted from source to destination it takes time to reach. This time includes different delay as described in its definition above. In this analysis it is observed as expected the delays are increasing as the traffic load is increasing. The average end-to-end delay is very high in DSR than DYMO and AODV protocols. The AODV also has least end-to-end delay. For heavy load DYMO has more end-to-end delay because of congestion problem. The performance is low because of excessive use of cache. The analysis is shown in figure 5.

Jitter: Jitter, the variation of the packet arrival time, is an important metrics for any routing protocol. In this analysis with the varying traffic load, it is observed DSR has largest jitter. But for high traffic load DYMO has more jitter again due to congestion problem. AODV has satisfactory jitter. The performance is shown in figure 6.

Packet drops due to no route: The Packets are dropped when it is not able to find the proper route to deliver the packets. It happens when the route are broken or congested. It is observed in this analysis that dropped packets are more in case of the DYMO routing protocol because the routes are broken quickly due to mobility of the routers. It is shown in figure 7.

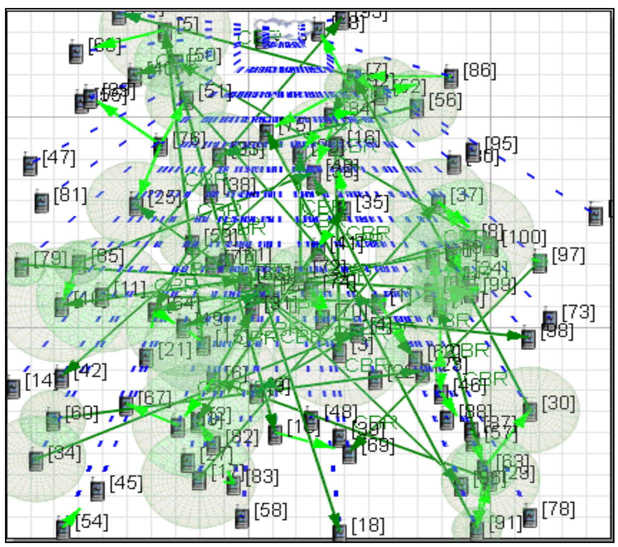


Fig 2 Animation view of simulation

Error reply packet: In routing protocols the nodes generates error reply packets when the route is interrupted or broken. These packets are diffused to nearby nodes which are affected due to route break. It is observed that DYMO has diffused more number of error reply packets to the neighbors. It is due to the broken routes due to the mobility and it is also found when number of dropped packets is analyzed in figure 7. The analysis of error reply packets is shown in figure 8.

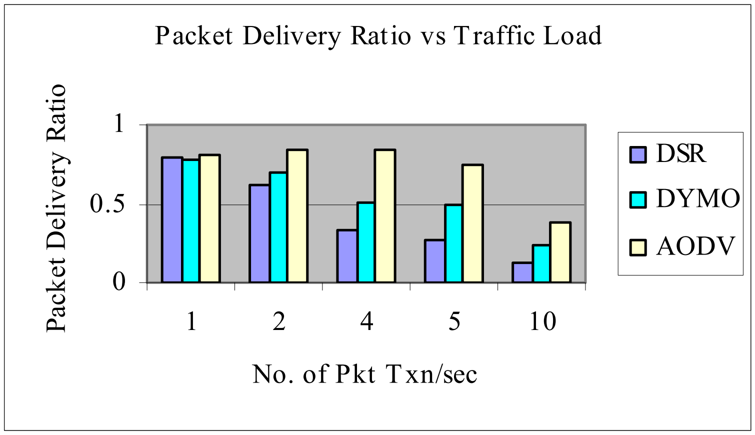


Fig 3: Packet Delivery Ratio vs Traffic Load

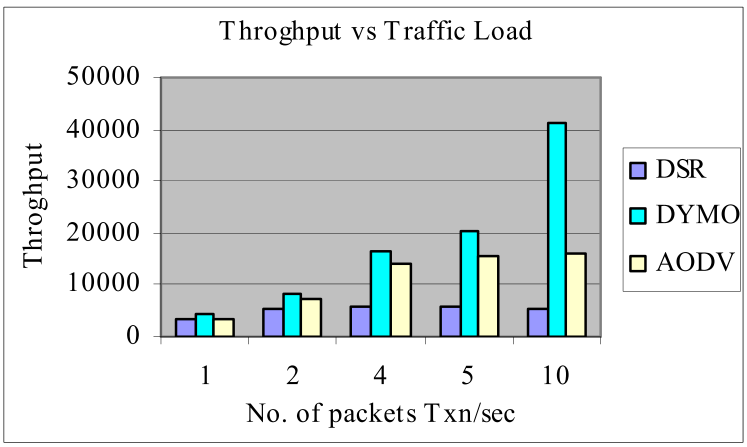


Fig 4: Throughput Vs Traffic Load

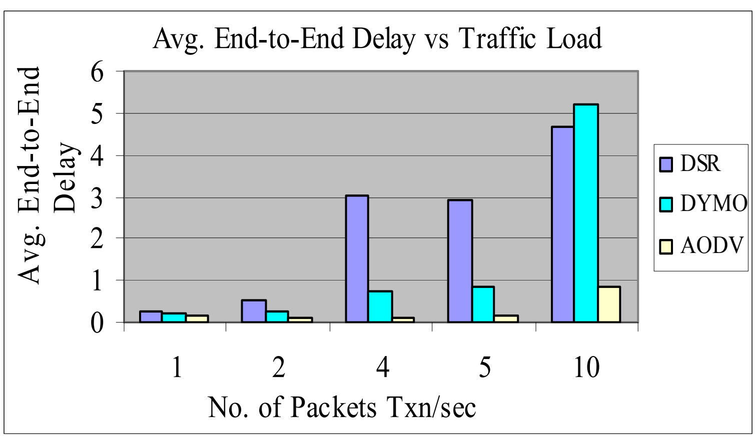


Fig 5: Average End-to-End Delay vs Traffic Load

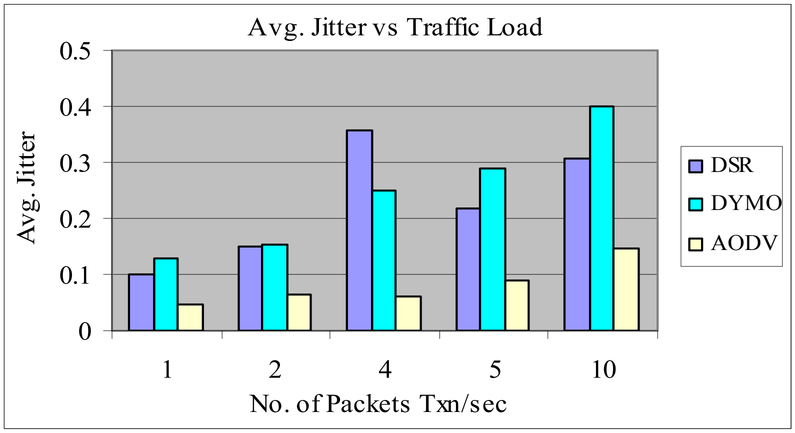
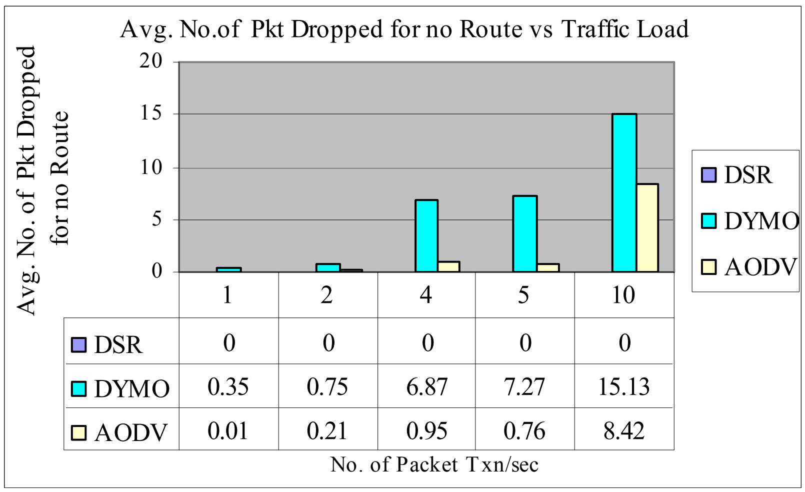
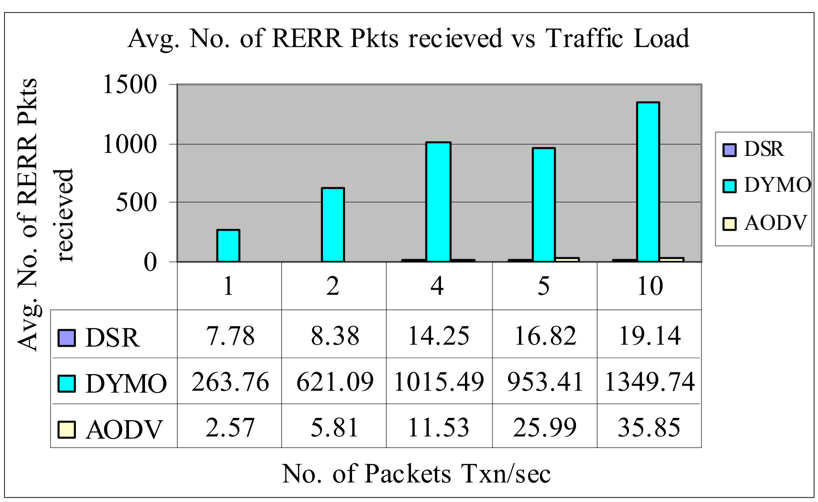


Fig. 6 Average Jitter vs Traffic Load



	1	2	4	5	10
DSR	0	0	0	0	0
DYMO	0.35	0.75	6.87	7.27	15.13
AODV	0.01	0.21	0.95	0.76	8.42

Fig. 7 Avg. no. of Packet dropped for no Route vs Traffic Load



	1	2	4	5	10
DSR	7.78	8.38	14.25	16.82	19.14
DYMO	263.76	621.09	1015.49	953.41	1349.74
AODV	2.57	5.81	11.53	25.99	35.85

Fig. 8. Avg. no .of Error Reply Packet received vs Traffic Load

Table 2 Characteristic Summaries of DSR, AODV, DYMO Routing Protocols

Protocol	Dynamic Source Routing (DSR) [13,14]	Ad hoc On-Demand Distance Vector (AODV)[12]	Dynamic MANET on demand (DYMO) routing protocol. (DYMO) [15]
Authors	Josh Broch, David Johnson, and David Maltz	Charles Perkins, Elizabeth Royer, and Samir Das	Ian D. Chakeres and Charles E. Perkins
Category	Reactive	Reactive	Reactive
Metrics	Shortest path, next available	Newest route, shortest path	Shortest path
Route Recovery	New route, notify source	Same as DSR, local repair	Local repair
Route repository	Route cache	Routing table	Routing table
Broadcasting	Simple	Simple	Simple
Multiple paths	Yes	No	No
Loop freedom maintenance	Source route	Sequence number	sequence numbers
Communication Overhead	High	High	High
Feature	Completely on demand	Only keeps track of next hop in route	Only keeps track of next hop in route

8. Conclusion

It is observed that AODV outperforms both of the DSR and DYMO routing protocols in terms of the packet delivery ratio as it uses fresh routes and DSR performs poorer because of aggressive use of cache. The throughput is best in case of the DYMO as it avoids good routes and outperforms both DSR and AODV. It is also performs better with heavy load. The DSR performs poorer than both because of aggressive use of cache. The poor performance of DSR is also attributed to absence of proper mechanism to expire the stale routes and therefore the jitter and the average end-to-end delay is also very high in comparison to AODV and DYMO. The dropped packets due to no routes and error replies are more in case of DYMO as routes breakages are more than both AODV and DSR due to route maintenance and mobility. It is found that the Packet deliver is better in case of AODV with increased traffic load and mobility.

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