International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:2, No:12, 2008

Performance Comparison and Analysis of Table-Driven and On-Demand Routing Protocols for Mobile Ad-hoc Networks

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Abstract**—**Mobile ad hoc network is a collection of mobile nodes communicating through wireless channels without any existing network infrastructure or centralized administration. Because of the limited transmission range of wireless network interfaces, multiple "hops" may be needed to exchange data across the network. In order to facilitate communication within the network, a routing protocol is used to discover routes between nodes. The primary goal of such an ad hoc network routing protocol is correct and efficient route establishment between a pair of nodes so that messages may be delivered in a timely manner. Route construction should be done with a minimum of overhead and bandwidth consumption. This paper examines two routing protocols for mobile ad hoc networks– the Destination Sequenced Distance Vector (DSDV), the table- driven protocol and the Ad hoc On- Demand Distance Vector routing (AODV), an On –Demand protocol and evaluates both protocols based on packet delivery fraction, normalized routing load, average delay and throughput while varying number of nodes, speed and pause time.

Keywords**—**AODV, DSDV, MANET, relative performance

I. Introduction

MOBILE ad hoc networks are formed by autonomous system of mobile nodes connected by wireless links without any preexisting communication infrastructure or centralized administration. Communication is directly between nodes or through intermediate nodes acting as routers. The advantages of such a network are rapid deployment, robustness, flexibility and inherent support for mobility. Ad hoc networks, due to their quick and economically less demanding deployment, find applications in military operations, collaborative and distributed computing, emergency operations, wireless mesh networks, wireless sensor networks and hybrid networks.

Due to node mobility, routes between two nodes may change. Therefore, it is not possible to establish fixed paths for delivery between networks. Because of this, routing is the most studied problem in mobile ad hoc networks and a number of routing protocols have been proposed [1-13], which are derived from either *distance-vector* [14] or *link-state* [15] based on classical routing algorithms.

Routing protocols for Mobile ad hoc networks can be classified into two main categories: Proactive or table driven routing protocols and Reactive or on-demand routing protocols. In proactive protocols, every node maintains the network topology information in the form of routing tables by periodically exchanging routing information. They include the Destination Sequenced Distance Vector (DSDV) [2], the Wireless Routing Protocol (WRP) [3], Source-Tree Adaptive Routing (STAR) [5] and Cluster-head Gateway Switch Routing protocol (CGSR) [4]. On the other hand, reactive protocols obtain routes only on demand, which include the Dynamic Source Routing (DSR) protocol [6], the Ad hoc On-demand Distance Vector (AODV) protocol [7], the Temporally Ordered Routing Algorithm (TORA) [8], and the Associativity Based Routing (ABR) protocol [10].

The rest of the paper is organized as follows: Section II presents an overview of the two main categories of mobile ad hoc routing protocols and a general comparison of the both. Section III provides an overview and general comparison of the routing protocols used in the study. The simulation environment and performance metrics are described in Section IV and then the results are presented in Section V. Finally Section VI concludes the paper.

II. ROUTING PROTOCOLS FOR MOBILE AD HOC NETWORKS

As shown in Figure.1, routing protocols for Mobile ad hoc networks can be classified into two main categories:

- Proactive or table-driven routing protocols and
- Reactive or on-demand routing protocols.

A. Table-Driven Routing Protocols

Table-driven routing protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. The routing information is kept in a number of different tables and they respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent

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network view. The areas in which these protocols differ are the way the routing information is updated, detected and the type of information kept at each routing table.

B. On-Demand Routing Protocols

On-demand routing protocols were designed to reduce the overheads in Table-Driven protocols by maintaining information for active routes only. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from the source or until the route is no longer desired. Route discovery usually occurs by flooding a route request packets through the network. When a node with a route to the destination (or the destination itself) is reached a route reply is sent back to the source node using link reversal if the route request has traveled through bi-directional links or by piggy-backing the route in a route reply packet via flooding.

On-Demand routing protocols can be classified into two categories: source routing and hop-by-hop routing. In Source routed on-demand protocols each data packets carry the complete path from source to destination. Therefore, each intermediate node forwards these packets according to the information in the header of each packet. The major drawback with source routing protocols is that in large networks they do not perform well. This is due to two main reasons; firstly as the number of intermediate nodes in each route grows, then so does the probability of route failure. Secondly, as the number of intermediate nodes in each route grows, then the amount of overhead carried in each header of each data packet will grow as well.

In hop-by-hop routing each data packet only carries the destination address and the next hop address. Therefore, each intermediate node in the path to the destination uses its routing table to forward each data packet towards the destination. The advantage of this strategy is that routes are adaptable to the dynamically changing environment of MANETs, since each node can update its routing table when they receiver fresher topology information and hence forward the data packets over fresher and better routes. Using fresher routes also means that fewer route recalculations are required during data transmission. The disadvantage of this strategy is that each intermediate node must store and maintain routing information for each active route and each node may require being aware of their surrounding neighbors through the use of beaconing messages.

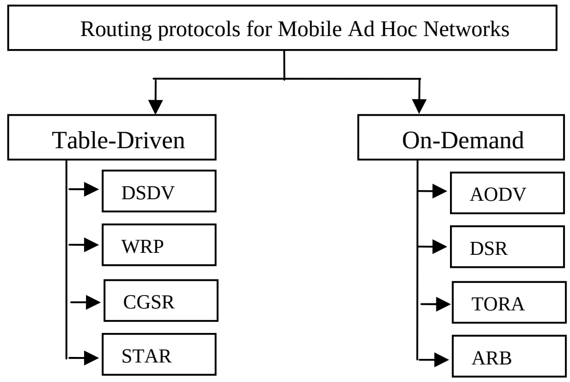


Fig. 1 Classifications of mobile ad hoc routing protocols.

C. Comparison of Table-Driven and On-Demand Routing Protocols

The table-driven ad hoc routing approach is similar to the connectionless approach of forwarding packets, with no regard to when and how frequently such routes are desired. It relies on an underlying routing table update mechanism that involves the constant propagation of routing information. This is not the case, however, for on-demand routing protocols. When a node using an on-demand protocol desires a route to a new destination, it will have to wait until such a route can be discovered. On the other hand, because routing information is constantly propagated and maintained in table-driven routing protocols, a route to every other node in the ad hoc network is always available, regardless of whether or not it is needed. This feature, although useful for datagram traffic, incurs substantial signaling traffic and power consumption. Since both bandwidth and battery power are scarce resources in mobile computers, this becomes a serious limitation. Table 1 lists some of the basic differences between the two categories of mobile ad hoc routing protocols.

TABLE I
COMPARISON OF TABLE-DRIVE AND ON-DEMAND ROUTING PROTOCOLS

Parameters	Table-Driven	On-Demand
Route availability	Always available irrespective of need	Computed when needed
Routing philosophy	flat, except for CGSR	flat, except for CBRP
Periodic updates	Always required	Not required
Handling mobility	Updates occur at regular intervals	Use localized route discovery
Control traffic generated	Usually higher than On-Demand	Increases with mobility of active routes
Storage requirements	Higher than On-Demand	Depends on the number of routes maintained or needed
Delay	Small as routes are pre-determined	High as routes are computed when needed
Scalability	Usually upto 100 nodes	Usually higher than Table-Driven

III. OVERVIEW OF DSDV AND AODV

As each protocol has its own merits and demerits, none of them can be claimed as absolutely better than others. Two mobile ad hoc routing protocols – the Destination Sequenced Distance Vector (DSDV), the table- driven protocol and the Ad hoc On- Demand Distance Vector routing (AODV), an On –Demand protocol are selected for study.

A. Destination-Sequenced Distance Vector (DSDV)

DSDV [2], an enhanced version of the distributed Bellman-Ford algorithm, belongs to the proactive or table driven family where a correct route to any node in the network is always maintained and updated.

In DSDV, each node maintains a routing table that contains the shortest distance and the first node on the shortest path to every other node in the network. A sequence number created by the destination node tags each entry to prevent loops, to counter the count –to-infinity problem and for faster convergence. The tables are exchanged between neighbors at regular intervals to keep an up to date view of the network topology. The tables are also forwarded if a node finds a significant change in local topology. This exchange of table imposes a large overhead on the whole network. To reduce this potential traffic, routing updates are classified into two categories. The first is known as "full dump" which includes all available routing information. This type of updates should be used as infrequently as possible and only in the cases of complete topology change. In the cases of occasional movements, smaller "incremental" updates are sent carrying only information about changes since the last full dump. Each of these updates should fit in a single Network Protocol Data Unit (NPDU), and thus significantly decreasing the amount of traffic. Table updates are initiated by a destination with a new sequence number which is always greater than the previous one. Upon receiving an updated table a node either updates its tables based on the received information or holds it for some time to select the best metric received from multiple versions of the same update from different neighbors.

The availability of routes to all destinations at all times implies that much less delay is involved in the route setup process. The mechanism of incremental updates with sequence number tags makes the exiting wired network protocols adaptable to mobile ad hoc networks. Hence, an existing wired network protocol can be applied to mobile ad hoc networks with fewer modifications. DSDV suffers from excessive control overhead that is proportional to the number of nodes in the network and therefore is not scalable in mobile ad hoc networks. Another disadvantage is stale routing information at nodes.

B. Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV [7] is an improvement on the DSDV. AODV uses an on- demand approach for finding routes. Since it is an on - demand algorithm, a route is established only when it is required by a source node for transmitting data packets and it maintains these routes as long as they are needed by the sources.

AODV uses a destination sequence number, created by the destination, to determine an up to date path to the destination. A node updates its route information only if the destination sequence number of the current received packet is greater than the destination sequence number stored at the node. It indicates the freshness of the route accepted by the source. To prevent multiple broadcast of the same packet AODV uses broadcast identifier number that ensure loop freedom since the intermediate nodes only forward the first copy of the same packet and discard the duplicate copies.

To find a path to the destination, the source broadcasts a *Route Request* (RREQ) packet across the network. This RREQ contains the source identifier, the destination identifier, the source sequence number, the destination sequence number, the broadcast identifier and the time to live field. Nodes that receives RREQ either if they are the destination or if they have a fresh route to the destination, can respond to the RREQ by unicasting a *Route Reply* (RREP) back to the source node. Otherwise, the node rebroadcasts the RREQ.

When a node forwards a RREQ packet to its neighbors, it also records in its tables the node from which the first copy of the request came. This information is used to construct the reverse path for the RREP packet. AODV uses only symmetric links because the route reply packet follows the reverse path of route request packet. When a node receives a RREP packet, information about the previous node from which the packet was received is also stored in order to forward the data packets to this next node as the next hop toward the destination. Once the source node receives a RREP it can begin using the route to send data packets.

The source node rebroadcasts the RREQ if it does not receive a RREP before the timer expires. It attempts discovery up to some maximum number of attempts. If it does not discover a route after this maximum number of attempts, the session is aborted.

If the source moves then it can reinitiate route discovery to the destination. If one of the intermediate nodes move then the moved nodes neighbor realizes the link failure and sends a link failure notification to its upstream neighbors and so on till it reaches the source upon which the source can reinitiate route discovery if needed.

The main advantage of AODV is that routes are obtained on demand and destination sequence numbers are used to find the latest route to the destination. One of the disadvantages of AODV is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby causing stale entries. Also multiple *Route Reply* (RREP) packets in response to a single *Route Request* (RREQ) packet can lead to heavy control overhead. Another is that periodic *hello* message leads to unnecessary bandwidth consumption.

Table 2 lists some of the basic differences between the two routing protocols.

TABLE II
COMPARISON OF DSDV AND AODV ROUTING PROTOCOLS

Parameter	DSDV	AODV
Routing structure	Flat	Flat
Hello messages	Yes	Yes
Frequency of updates	Periodic and as needed	As required
Critical nodes	No	No
Loop –free	Yes	Yes
Multicasting capability	No	Yes
Routing metric	Shortest path	Freshest and shortest path
Utilizes sequence number	Yes	Yes
Time complexity	O (D)	O (2D)
Communication complexity	O (N)	O (2N)
Advantages	Small delays	Adaptable to highly dynamic topology
Disadvantages	Large overhead	Large delays

Abbreviations:
D = Diameter of the network
N = Number of nodes in the Network

IV. SIMULATION AND PERFORMANCE METRICS

The simulations were performed using Network Simulator2 (NS-2) [16], particularly popular in the ad hoc networking community. The traffic sources are CBR (continuous bit – rate). The source-destination pairs are spread randomly over the network. The packet rate is 4 packets per second for 15 and 30 sources, 3 packets per sec for 45 sources. The data packet size is 512 bytes. The mobility model uses *random waypoint model* in a rectangular filed of 500m x 500m with 50 nodes. In this mobility model, each node starts its journey from a random chosen location to a random chosen destination. Once the destination is reached, another random destination is chosen after a pause time. The speed of nodes is varied between 0 to 25m/s and pause time between 0 to 100 seconds. Different network scenario for different numbers of node, pause time and speeds are generated. Simulations are run for 100 seconds. The propagation model is the Two way ground model [17]. Simulation parameters are listed in table 3.

TABLE III
SIMULATION PARAMETERS

Parameter	Value
Simulator	ns-2
Studied protocols	DSDV and AODV
Simulation time	100 seconds
Simulation area	500 m x 500 m
Transmission range	250 m
Node movement model	Random waypoint
Speed	0 – 25 m/s in steps of 5 m/s
Traffic type	CBR (UDP)
Data payload	512 bytes/packet
Packet rate	4 packets/sec for 15 and 30 sources 3 packets/sec for 45 sources
Node pause time	0 - 100 s in steps of 20s
Bandwidth	2 Mb/s

Performance Metrics

The following performance metrics are considered for evaluation:

Packet Delivery Fraction (PDF): The ratio of the data packets delivered to the destinations to those generated by the sources.

Average end-to-end delay: This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times.

Normalized routing load: The number of routing packets "transmitted" per data packet "delivered" at the destination.

Simulation metrics are listed in Table 4.

TABLE IV
SIMULATION METRICS

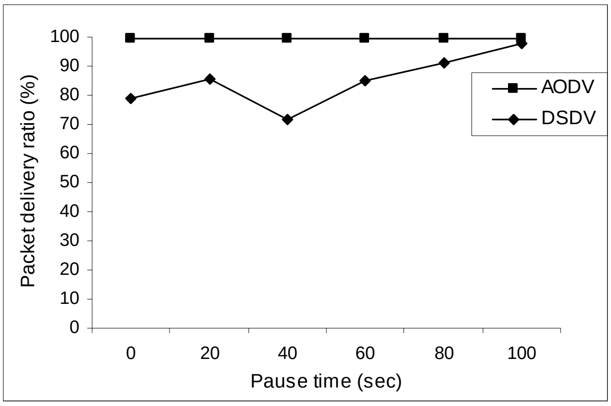
ID	metrics	definition	formula	Example value
PS	packet sent	total number of packets sent by the source node	computed from trace file	2000
PR	Packet Received	Total number of packets received by the destination node	Computed from trace file	600
PDF	Packet Delivery Fraction	Ratio of packets received to packets sent	PDF = (PR/PS)*100%	88.5%
TD	Total Delivery Time	Time spent to deliver packets (PR)	Computed from trace file	1567.2
AD	Average end-to- end Delay	Delay spent to deliver each data packet	AD = TD/PR	6.235
RF	Routing Packets	Number of routing packets sent or forwarded	Computed from trace file	44
NRL	Normalized Routing Load	Number of routing packets per data packets	NRL = RF/PR	2.5

V. SIMULATION RESULTS

The simulation results are shown in the following section in the form of line graphs. Graphs show comparison between the two protocols by varying different numbers of sources on the basis of the above-mentioned metrics as a function of pause time and speed.

A. Packet Delivery Fraction (PDF)

Figure 2 shows a comparison between both the routing protocols on the basis of packet delivery fraction as a function of pause time and using different number of traffic sources.



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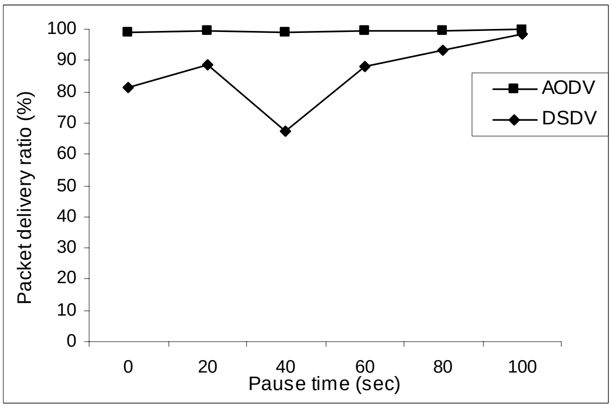

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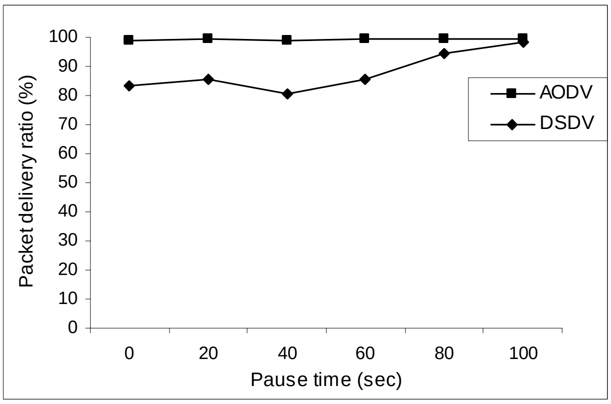


(c)

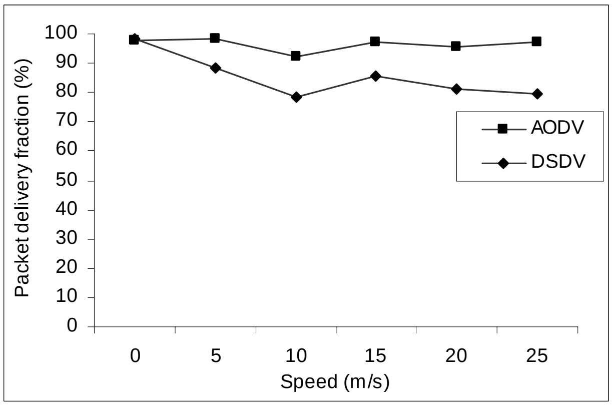
Fig. 2 Packet delivery fraction vs. Pause time for 50-node model with (a) 15 sources, (b) 30 sources and (c) 45 sources.

Both of the protocols deliver a greater percentage of the originated data packets when there is little node mobility, converging to 100% delivery ration when there is no node motion.

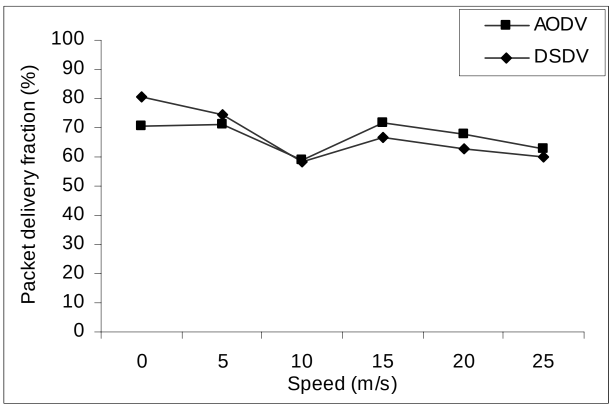
The On-demand protocol, AODV performed particularly well, delivering almost 100% of the data packets regardless of the mobility rate. The packet delivery of AODV is almost independent of the number of sources that is varying number of sources does not effect AODV that much.

DSDV performance is worst when mobility is high. This poor performance is because of the reason that DSDV is not a On demand protocol and it keeps only one route per destination, therefore lack of alternate routes and presence of stale routes in the routing table when nodes are moving at higher rate leads to packet drops. The packet delivery of DSDV protocol depends on the number of sources, as it is obvious from figure 2.

Figure 3 shows a comparison between both the routing protocols on the basis of packet delivery fraction as a function of pause time and using different number of traffic sources.



(a)



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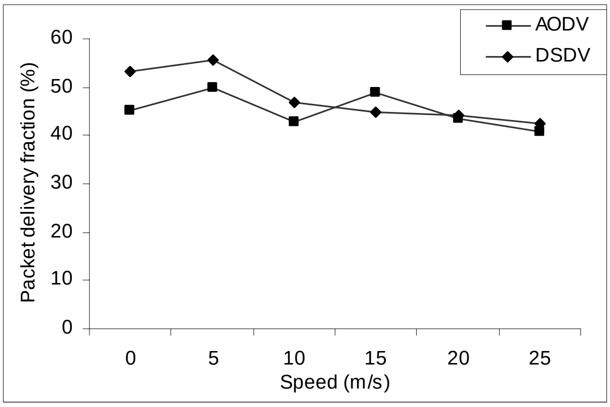


(c)

Fig. 3 Packet delivery fraction vs. Speed for the 50-node model with (a) 15 sources, (b) 30 sources and (c) 45 sources.

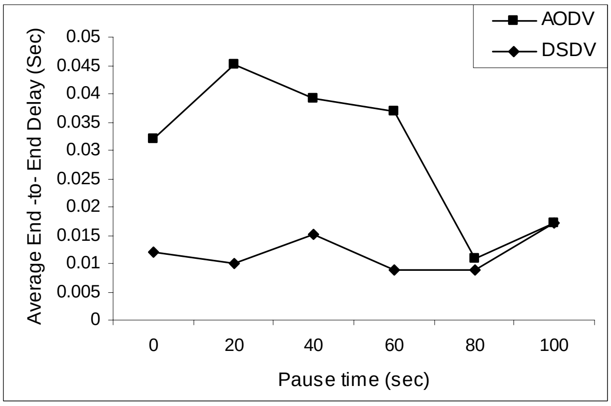
As expected, Packet delivery fraction for AODV decreases as speed increases, since finding the route requires more and more routing traffic. Therefore less and less of the channel will be used for data transfer, thus decreasing the packet delivery. Furthermore, as the number of nodes increases, more routing traffic will be generated (because AODV uses flooding for route discovery), which makes the packet delivery fraction decrease as the number of nodes increases.

For DSDV, as was the case with AODV, packet delivery fraction decreases as speed increases, since finding the route requires more and more routing traffic as speed increases thus making a lesser portion of the channel useful for data transfer.

Although the packet delivery fraction of both the protocols decreases as speed increases, but DSDV's packet delivery fraction decreases in a more steeper and more rapid fashion. This is due to excessive channel used by regular routing table updates. Furthermore, as mobility speed increases, more event-triggered updates are generated, resulting in even more packet delivery fraction decrease. This problem is not present in AODV since routes are only generated on-demand.

B. *Average End to End Delay*

Figure 4 shows comparison between both the routing protocols on the basis of average end-to-end delay as a function of pause time, using different number of sources.



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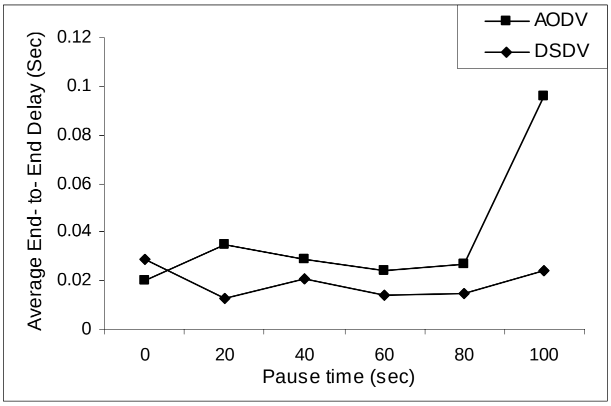

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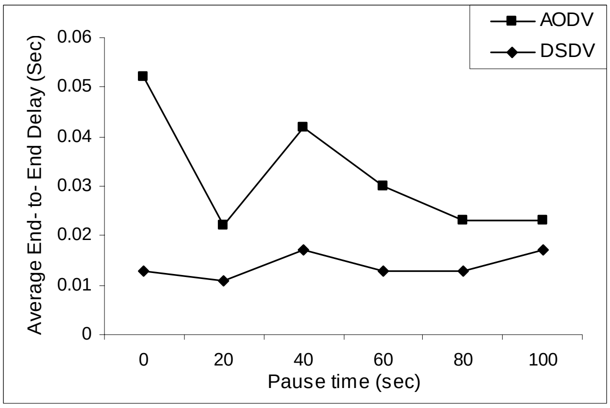


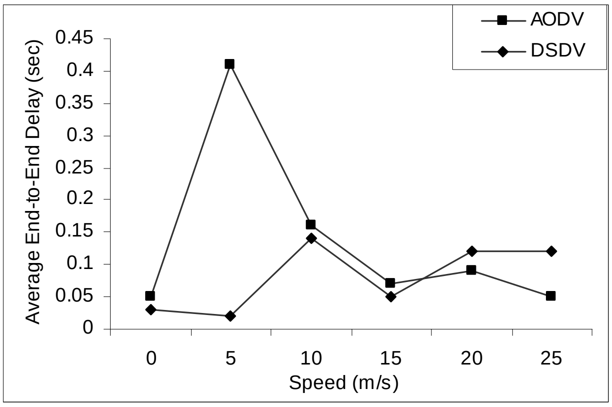
(c)

Fig. 4 Average End-to-End Delay vs. Pause time for the 50-node model with (a) 15 sources, (b) 30 sources and (c) 45 sources.

DSDV performed pretty stable and the delay kept about 0.04 seconds when pause time increased from 0 seconds to 100 second. The reason is that it is a table driven protocol, so a node does not need to find a route before transmitting packets. So the delay is quite stable.

For AODV the delay is much more then the DSDV. As AODV is On-demand protocol, with an increased number of sources and high mobility there are more link failures therefore there are more route discoveries. AODV takes more time during the route discovery process as first it finds the route hop by hop and then it gets back to the source by back tracking that route. All this leads to delays in the delivery of data packets.

Figure 5 shows comparison between both the routing protocols on the basis of average end-to-end delay as a function of speed, using different number of sources.



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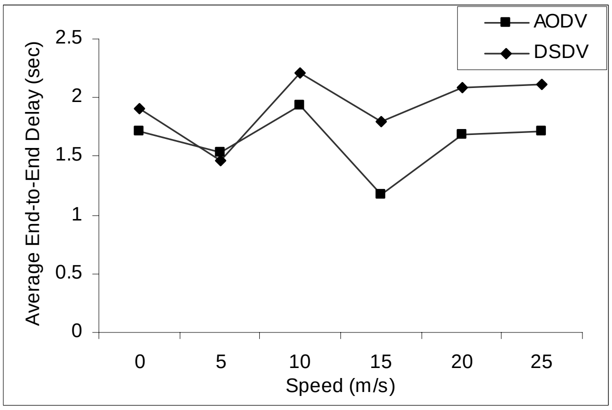

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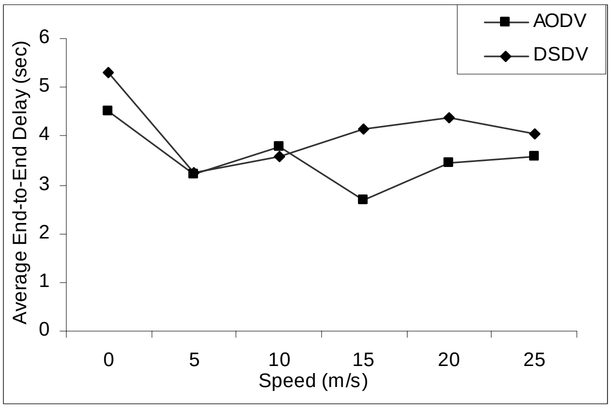


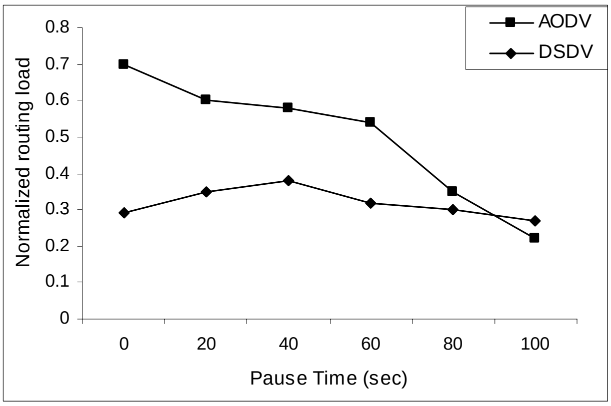
(c)

Fig. 5 Average End-to-End Delay vs. Speed for the 50-node model with (a) 15 sources, (b) 30 sources and (c) 45 sources.

AODV has less average end-to-end delay when compared to DSDV. This poor performance of DSDV is because of the reason that DSDV is not a On demand protocol and it keeps only one route per destination, therefore lack of alternate routes and presence of stale routes in the routing table when nodes are moving at higher rate leads to large delay.

C. Normalized Routing Load

Figure 6 shows a comparison between both the routing protocols on the basis of normalized routing load as a function of pause time, using a different number of sources.



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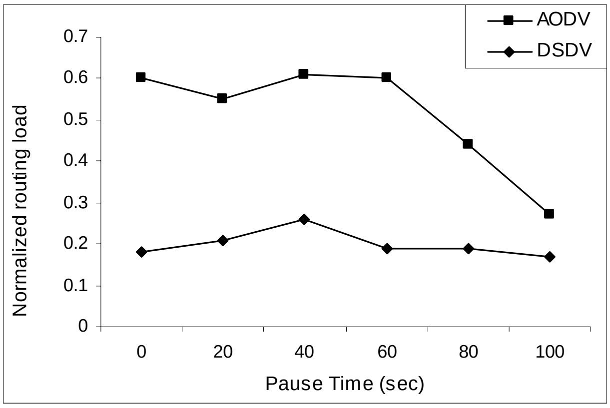

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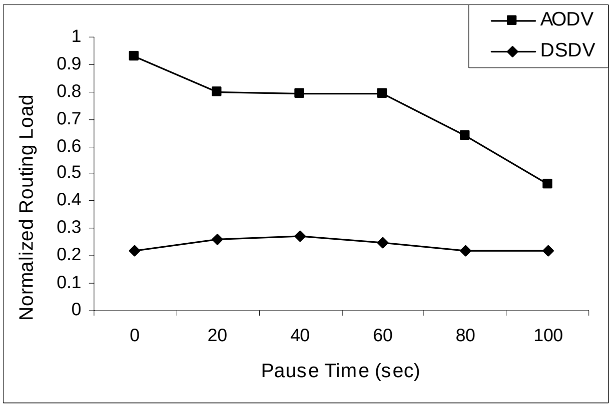


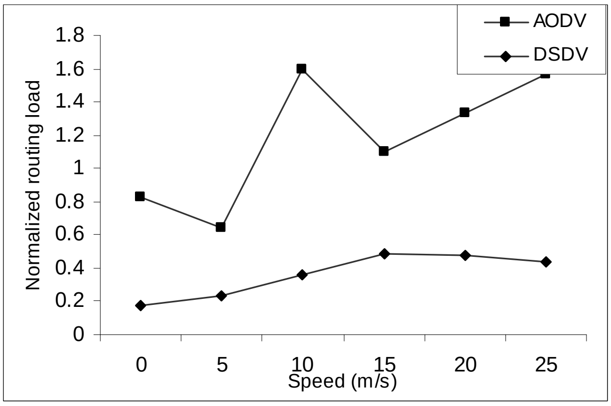
(c)

Fig. 6 Normalized routing load vs. Pause time for the 50-node model with (a) 15 sources, (b) 30 sources and (c) 45 sources.

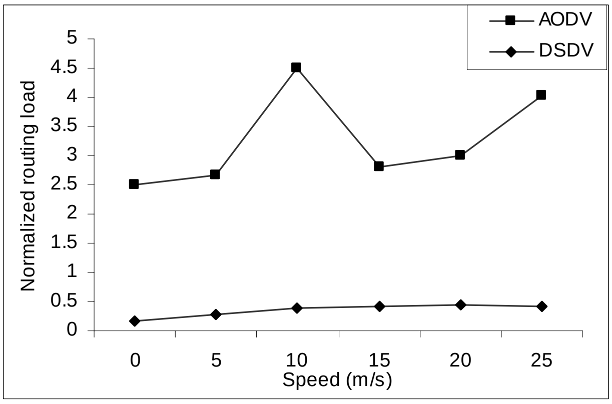
As DSDV is a table driven routing protocol its overhead is almost the same with respect to node mobility.

In cases of AODV, as the pause time increases, route stability increases, resulting in a decreased number of routing packet routing packet transmissions, and therefore a decrease in the routing overhead. A relatively stable normalized routing load is a desirable property for scalability of the protocols.

Figure 7 shows a comparison between both the routing protocols on the basis of normalized routing load as a function of pause time, using a different number of sources.



(a)



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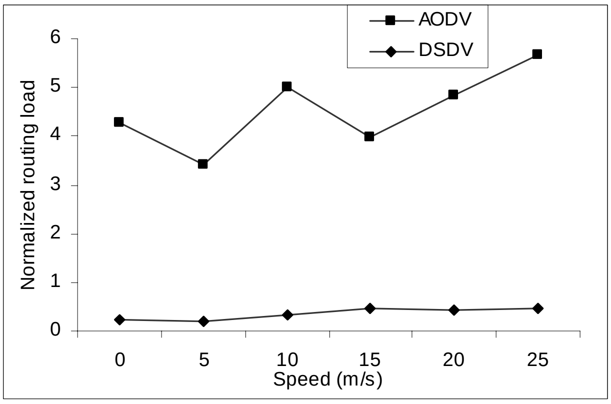

(c)

Fig. 7 Normalized routing load vs. Speed for the 50-node model with (a) 15 sources, (b) 30 sources and (c) 45 sources.

In case of AODV the normalized routing load drastically increases as the number of nodes increases. The routing load also increases as the node mobility increases. As the number of nodes increases, more nodes will be flooding the network with route request and consequently more nodes will be able to send route reply as well. As the node speed increases, a source node will have to generate more route requests to find a fresh enough route to destination node.

In case of DSDV the normalized routing load is almost the same with respect to node speed. The reason is that it is a table driven protocol, so a node does not need to find a route before transmitting packets.

VI. Conclusion

This paper compared the two ad hoc routing protocols. AODV an On – Demand routing protocol, and DSDV a table driven protocol.

Simulation results show that both of the protocols deliver a greater percentage of the originated data packets when there is little node mobility, converging to 100% delivery ration when there is no node motion. The packet delivery of AODV is almost independent of the number of sources. DSDV generates less routing load then AODV. AODV suffers from end to end delays. DSDV packet delivery fraction is very low for high mobility scenarios.

Packet delivery fraction of both the protocols decreases as speed increases, but DSDV's packet delivery fraction decreases in a steeper and more rapid fashion. AODV has less average end-to-end delay when compared to DSDV. The normalized routing load for AODV increases drastically as the number of nodes increases. The routing load also increases as the node speed increases. But for DSDV the normalized routing load is almost the same with respect to node speed

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