

Traffic Pattern Based Performance Analysis of Routing Protocols in Adhoc Networks

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Abstract: Ad-hoc networks are characterized by wireless connectivity, continuous topology change, distributed operations and ease of deployment. Routing in ad-hoc networks is a challenge due to mobility. Several routing protocols for ad-hoc networks have been proposed in the literature. These protocols differ depending on the routing mechanism used, the process of storing routing information, etc. It is therefore very essential to have comparative study of these protocols in order to develop protocols suitable to a given situation and also to overcome the deficiencies of the existing protocols. In this paper we have presented performance comparison of reactive (DSR, AODV) and proactive (DSDV) routing protocols to bring out their relative merits. DSDV being proactive routing protocol store information of all the nodes, in their routing table. But AODV and DSR both are reactive routing protocols and they initiate their routing activities when required. The motivation behind this comparison was to understand their internal working mechanism and bring out situations where one is preferred over the other.

Keywords: Mobility, Routing, Ad-hoc Network, Routing Protocols, TCP, CBR

1. Introduction

Several routing protocols for ad-hoc networks have been proposed in the literature. These protocols differ depending on the routing mechanism used, the process of storing routing information, etc. Broadly speaking, these have been classified as proactive and reactive protocols. It has been generally observed that the performance of ad-hoc routing protocols is not consistent in all situations. The same protocol may perform well in one situation and worst in some other situation. It is therefore essential to find which protocol

is suitable for a given situation. To achieve this, we have compared the performance of DSDV, DSR, and AODV by varying the type of traffic, number of nodes, terrain size, taking different values of workload by varying the number of traffic sources, and the mobility of nodes. The comparison of these protocols is done to test their suitability in various situations. The following are some of the essential parameters which are changed to measure the performance of these protocols:

- **Network Size:** Measured in the number of nodes.
- **Network Connectivity:** The average degree of a node (i.e. the average number of neighbors of a node).
- **Topological Rate of Change:** The speed with which topology of a network is changing.
- **Traffic Patterns:** The efficiency of a protocol in adapting to non-uniform or bursting traffic patterns.

2. Related Work

Several performance evaluation studies of MANET routing protocols have been done in the literature¹⁻⁶. In these studies authors have taken different traffic patterns, such as CBR and TCP, and also considered various parameters such as mobility, network load and pause time.

Samba Seasy et. al.⁷ have compared the relative performance of four ad-hoc routing protocols DSDV, TORA, DSR and AODV. They have simulated these routing protocols in an area of 1200m x 300m by taking 30 and 60 nodes moving with an average speed of 1.5m/s and 20 m/s. They have taken 10 CBR traffic sources with packets sending rate as two packets per second and packet size of 512 bytes. They concluded that DSDV is most suitable for small networks where changes in the topology are limited. DSDV could also be considered for delay constraint networks. TORA is suitable for operation in large highly dynamic mobile network environment with dense population of nodes. The main advantage of TORA is its support for multiple routes and multicasting. Thus TORA often serve as the underlying protocol for lightweight adaptive multicast algorithms. Further, DSR is suitable for networks in which the nodes move at moderate speed. It has lowest control overheads in terms of number of control packets, which makes it suitable for low bandwidth and power constrained networks. However, in terms of byte transfer rate, DSR has significant overheads as its packets size is large carrying full routing information. In their simulations, they found that AODV has the best all round performance.

Reddy and Reddy⁸ analyzed the performance of various routing protocols for ad-hoc networks using TCP traffic. Their simulation environment consists of 50 wireless nodes forming an ad-hoc network in the terrain of size 670m x 670m. The simulation was run for 200 seconds. They found that at low mobility performance of DSDV is better than DSR and AODV considering its ability to maintain connection by periodic exchange of information, which is required for TCP based traffic.

Kumar Arun B. R. et. al.⁴ have analyzed the performance of routing protocols such as DSDV, OLSR, AODV and DSR by using Variable Bit Rate (VBR) traffic by simulating the network in an area of 1000m x 1000m for 1000 seconds. They found that both reactive protocols DSR and AODV performed well in high mobility scenarios than proactive protocols DSDV and OLSR. In fact, high mobility results leads to highly dynamic topology i.e. frequent route failures and route changes, and therefore increase the overheads in proactive protocols.

Broch et al.¹ have analyzed the performance of different ad-hoc routing protocols by simulation. The protocol evaluations were based on the simulations with 50 nodes moving in a rectangular terrain of size (1500m x 3000m) and the simulation run for 900 seconds. Two different maximum node movement speeds were also used (1 m/s and 20 m/s). The communication model was based on Constant Bit Rate (CBR) traffic sources. Three different send-ratios, three different numbers of CBR sources and two packet sizes (64 and 1024 bytes) were used.

Das S. R. et. al.² have discussed the performance of two on-demand ad-hoc routing protocols: AODV and DSR. The simulation model was similar to that of Broch¹. Each node in the network maintained a buffer of 64 packets and used FIFO process queue. However, the routing packets were given higher priority than data packets. Two different simulations were done: In the first case they have taken 50 nodes moving in terrain of size 1500m x 300m, and the simulation was run for 900 seconds. For the second scenario they have taken 100 nodes moving in a terrain of size 2200m x 600m. The movement speed was randomly selected between 0-20m/s and the simulations were run for 500 seconds.

3. Traffic Patterns Considered

Ad-hoc network have been used for communication in wide range of applications with even diverse requirements/objectives. In some applications the time factor may be very important such as in video-conference or chatting, whereas in some applications information loss may be intolerable, like in emails or bank transactions. In chatting etc fast communication is

essential and the response time between sender and the receiver of information (packet) has to be very small, though to some extent packet loss (loss of few words) can be ignored or taken as understood. In case of email etc., the communication from the source node to the destination node may take some time but it should not be lost. Thus in ad-hoc networks there are situations where data is being generated continuously and has to be routed fast from one node to another, whereas there are other situations where data may be generated irregularly or in unspecified pattern, but it has been ensured that the data packets reach the destination.

However, most of the work on comparison of routing protocols has been done either using CBR traffic or TCP traffic and sometimes compared the performance for both types of traffic. We have taken both these traffic patterns for the performance analysis of the protocols. We have generated 50 scenarios (5 for each pause time) with varying number of sources for each type of traffic pattern (CBR and TCP) resulting into total of 400 simulation scenarios. We have kept packet size as 512 bytes and packets are being generated at a constant rate of 4 packets per second. The simulation is run using these scenarios and by using both the traffic patterns. To overcome the effect of randomness in the output we have taken the averages of the results of three simulations on same parameters to get their realistic values.

4. Simulation Parameters and Scenarios Considered

The goal of our simulations was to evaluate the performance differences of DSR, AODV and DSDV routing protocols. We have varied mobility and the number of sources to measure their performance. The simulations were carried out by varying the number of traffic sources as 10, 20, 30 and 40. The pause time was varied from 0 seconds (high mobility) to 900 seconds (no mobility) in an interval of 100 seconds.

We have analyzed the traffic pattern based performance of DSR, AODV and DSDV routing protocols by considering both CBR and TCP traffic patterns. For this we have taken two experimental scenarios to cover a wide range of situations in which these protocols functions. The first scenario is relatively small/medium having terrain of size 1500m x 300m with 50 nodes. The second scenario is relatively large having terrain of size 2500m x 1000m with 100 nodes. CBR and TCP traffic patterns were used in both the scenarios.

The source-destination pairs are spread randomly over the network. The Random Waypoint model is used as the mobility model for the simulation. In this model, each node starts its journey from a random

location to a random destination with a randomly chosen speed (uniformly distributed between 0–20m/s). Once the destination is reached, another random destination is targeted after the specified pause time. When the nodes are continuously moving (0sec pause time) the number of link changes are very high and decreases with increase in pause time and converge to 0 when pause time is 900 seconds. At this stage the network becomes stable as shown in Figure 1.

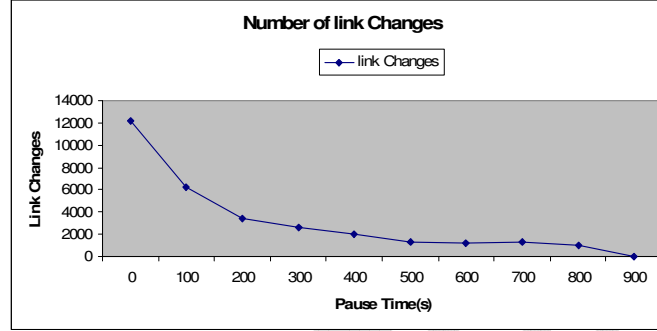


Fig. 1: Number of Link Changes with Pause Time

In the first case we have done simulations of all the scenarios for 900 seconds in a rectangular field of size 1500m x 300m with 50 nodes and varying the degree of connectivity among nodes. In the second case, we have taken the larger scenario of size 2500m x 1000m with 100 nodes. The simulation parameters are shown in Table 1.

Table 1: Simulation Parameters

S. No.	Parameter	Scenario-A	Scenario-B
1	Routing Protocols	DSR, AODV, DSR	DSR, AODV, DSDV
2	MAC Layer	802.11	802.11
3	Terrain Size	1500m x 300m	2500m x 1000m
4	Nodes	50	100
5	Node Placement	Random	Random
6	Mobility Model	Random Waypoint	Random Waypoint
7	Data Traffic	CBR, TCP	CBR, TCP
8	No. of Traffic Sources	10, 20, 30, 40	10, 20, 30, 40
9	Pause Time	0-900 (intervals of 100s)	0-900 (intervals of 100s)
10	Speed	0-20m/s	0-20m/s
11	Simulation Time	900s	900s

5. Simulation Results

We have carried out the simulation for scenario-A and scenario-B by taking both CBR and TCP traffic patterns for comparative performance of three protocols: DSDV, AODV, and DSR. We have varied the number of traffic sources from 10, 20, 30 and 40 for all the three protocols but we present results of 10 and 40 sources only.

A. Performance Comparison (CBR Traffic) Based on Scenario-A

We have considered the results obtained from NS2 for various situations of scenario-A, which consider CBR traffic. We briefly describe the results such as Packet Delivery Fraction, Routing Overheads, End-to-End delay and Packet Loss.

Packet Delivery Fraction: In case of CBR traffic both DSR and AODV protocols deliver almost all the originated data packets when node mobility is low (at large pause time) and the number of sources is kept small (say at 10), converging to 100% delivery when there is no node motion. But the delivery rate starts decreasing when there is increase in the number of sources and goes down up to 30% when the number of sources is large (say at 40) as shown in Figure 2. Further, DSDV protocol has low delivery when the number of sources is small as compared to DSR and AODV. But the performance of DSDV is better than DSR and AODV when the number of sources is large.

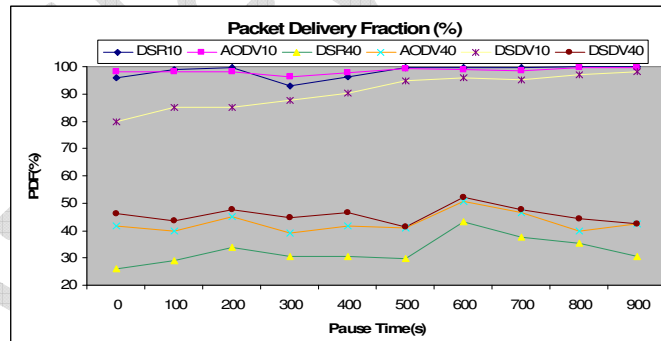


Fig. 2: Packet Delivery Fraction for CBR Traffic

Normalized Routing Load: Our simulation results show that for CBR traffic, DSR protocol has significantly lower routing load than AODV, with the factor increasing with growing number of sources as shown in Figure 3. It is observed that, when the number of sources is low, the performance of DSR and AODV is similar regardless of mobility. But with large numbers of sources, DSR starts outperforming AODV for high-mobility scenarios.

Further, we find that DSR always have lower routing load than AODV. The trace files of NS2 indicate that the major contribution to AODV routing overheads is from route-requests packets, whereas in DSR route-replies packets contribute to large fraction of routing overheads.

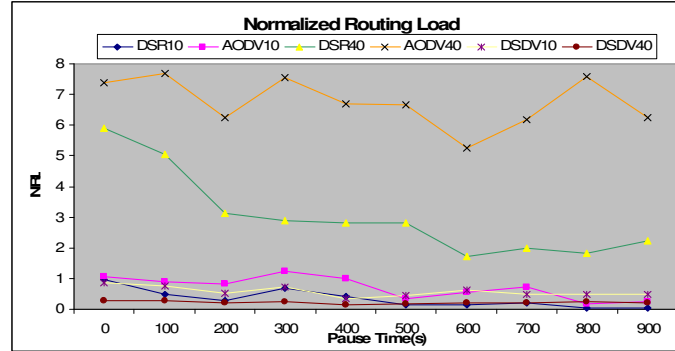


Fig. 3: Normalized Routing Load for CBR Traffic

Routing Overheads: The simulation results reveals that the Routing Overheads in DSR and AODV increase with the increase in the number of traffic sources as shown in Figure 4. The routing overheads in DSR are significantly low as compared to AODV. We observe that Routing Overheads in DSDV are initially larger than DSR and AODV. But with increase in the traffic sources, the Routing Overheads in DSDV are significantly lower than DSR and AODV. This is because DSDV always have route to all destinations, therefore no extra routing packets are generated when number of sources are large. Further, in DSR and AODV with increase in number of sources new routes have to be discovered resulting in increase in the Routing Overheads.

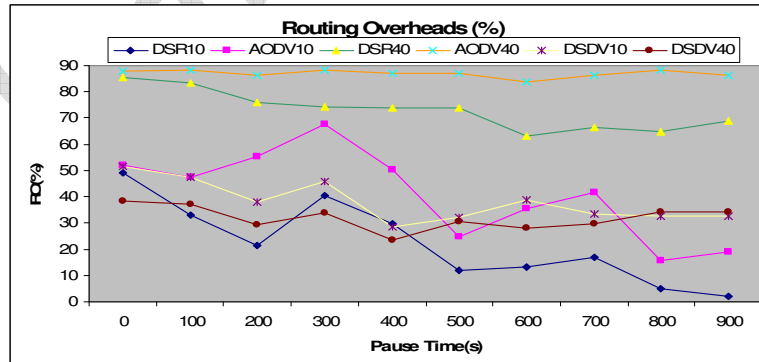


Fig. 4: Routing Overheads for CBR Traffic

Average End-to-End Delay: Simulation results show that the Average End-to-End delay in DSR is comparable to AODV when the number of sources is small as shown in Figure 5. But with the increase in the network load (number of sources), End-to-End delay in DSR becomes at least double as compared to the delay in AODV. Average End-to-End delay in DSDV is very small it is due to the very nature of proactive routing protocols as they always have route to every destination in the network. Therefore initial route establishment time in DSDV is negligible whereas reactive routing protocols discover route on-demand therefore significant delay is introduced.

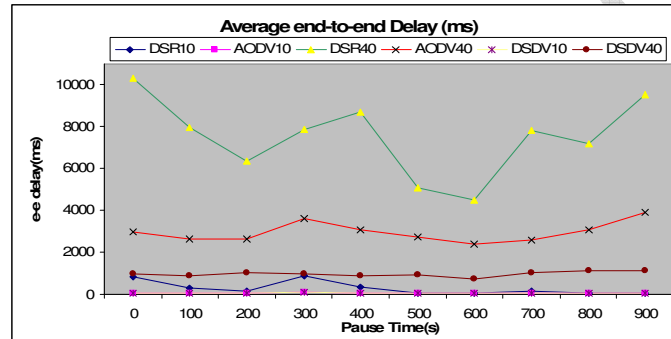


Fig. 5: Average End-to-End Delay for CBR Traffic

Packet Loss: The simulation results in Figure 6 show that when the number of sources is small the Packet Loss is comparable for both DSR and AODV. But with the increase in the network load the Packet Loss in DSR is much less than Packet Loss in AODV. The reason appears to be that DSR always has more than one route for a destination.

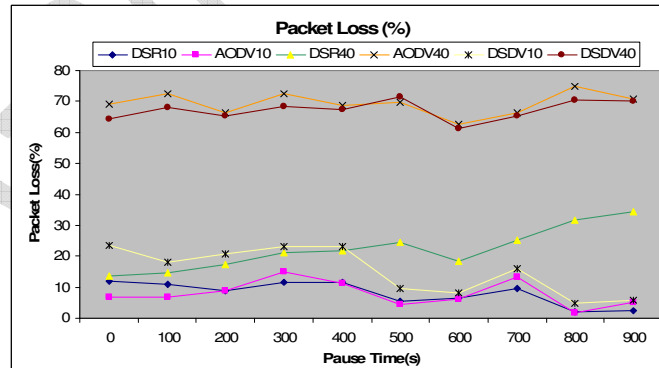


Fig. 6: Packet Loss for CBR Traffic

If one route fails, then route discovery is not started and the packet is sent using alternate route. Packet Loss in DSDV is large as compared to both DSR and AODV.

B. Performance Comparison (TCP Traffic) Based on Scenario-A

Next we take up the performance of the protocols in scenario-A when traffic pattern is TCP and discuss the output results of various parameters.

Packet Delivery Fraction: For TCP traffic all the three protocols DSDV, DSR and AODV protocols deliver more than 90% of all the originated data packets. However, performance of both DSDV and DSR protocols are better than that of AODV as shown in Figure 7.

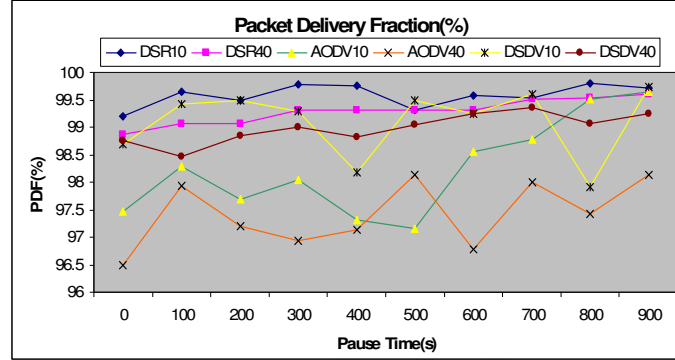


Fig. 7: Packet Delivery Fraction for TCP Traffic

Normalized Routing Load: Our simulation results show that DSR and AODV both protocols have comparable routing load, whereas DSDV shows significantly low routing load than both DSR and AODV as shown in Figure 8. For high mobility both DSR and AODV have large routing load, which decreases with increase in pause time (low mobility). However, for DSDV this variation is not much large.

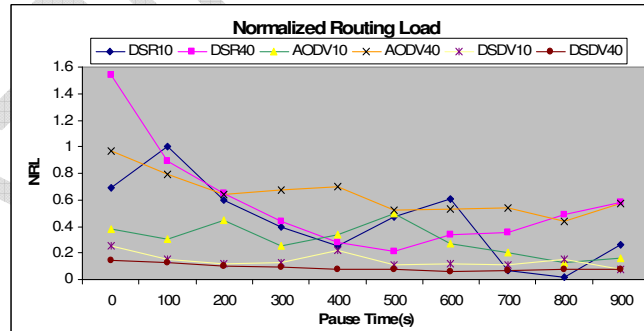


Fig. 8: Normalized Routing Load for TCP Traffic

Routing Overheads: Routing Overheads in DSR and AODV increase with increase in the number of traffic sources as shown in Figure 9. The Routing Overheads in DSR are comparable to AODV. In DSDV the Routing

Overheads are significantly lower than both DSR and AODV. In DSR and AODV, with increase in number of sources, more routes have to be discovered resulting in increase in the routing overheads.

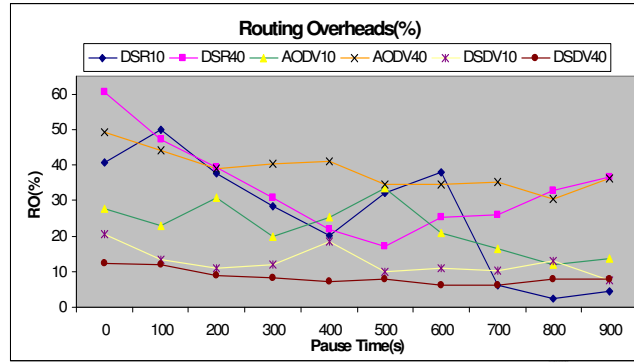


Fig. 9: Routing Overheads for TCP Traffic

Average End-to-End Delay: The simulation results show that End-to-End delay in DSDV is comparable to that in AODV as shown in Figure 10. However, when number of sources is large, the End-to-End delay in DSR protocol is very large as compared to the delay in AODV and DSDV. Further, Average End-to-End delay in DSDV is very small. It is due to the fact that proactive routing protocols always route to every destination in the network. Therefore initial route establishment delay in DSDV is negligible whereas DSR and AODV discover the route on-demand therefore significant delay is introduced in reactive routing protocols.

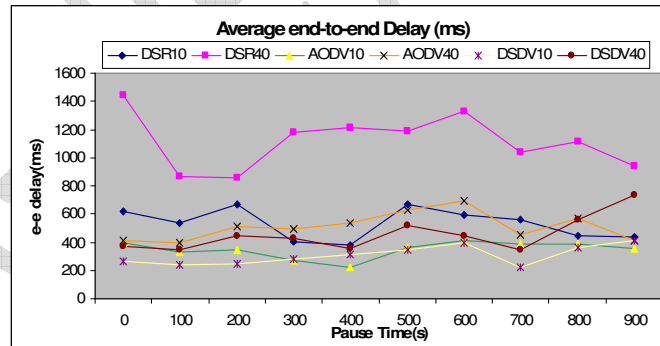


Fig. 10: Average End-End Delay for TCP Traffic

Packet Loss: The packet loss is comparable for all the three protocols DSDV, DSR and AODV as shown in Figure 11. But with the increase in the network load the Packet Loss in DSR is much less than packet loss in AODV. The DSR protocol may have more than one route for a destination in their cache. If one route fails, then packet is sent using other available route.

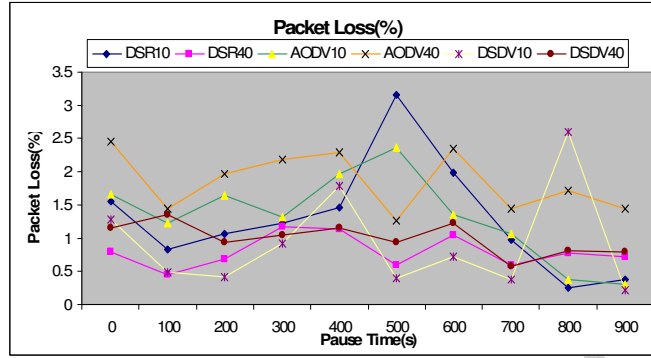


Fig. 11: Packet Loss for TCP Traffic

C. Performance Comparison (CBR Traffic) Based on Scenario-B

Next we take up the simulation results obtained for scenario-B using CBR traffic. We have varied the number of traffic sources varying from 10, 20, 30 and 40 for all the three protocols: DSR, AODV and DSDV. We briefly describe the results such as Packet Delivery Fraction, Routing Overheads, End-to-End Delay and Packet Loss.

Packet Delivery Fraction: In case of CBR traffic both DSDV and AODV protocols deliver 70-80% of the originated data packets when node mobility is low (i.e., at large pause time) and the number of sources is kept small (say at 10), converging to 95% delivery when there is no node motion. DSR protocol initially deliver 20-30% of the data packets at small pause time (high mobility) but packet delivery increases with increase in pause time (low mobility). However the delivery rate starts decreasing when there is increase in the number of sources and goes down up to 30% when the number of sources is large (say at 40) as shown in Figure 12. We conclude that as far as packet delivery is concerned both AODV and DSDV protocols performs better than DSR.

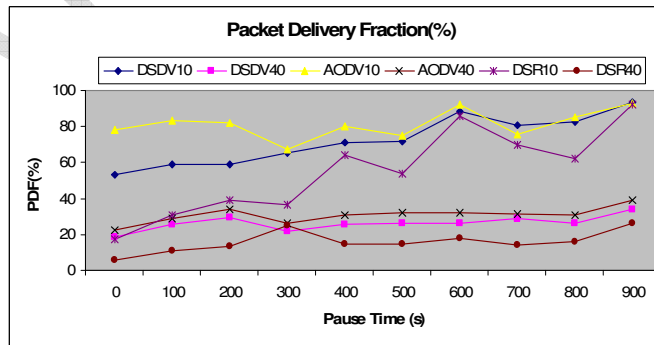


Figure 12: Packet Delivery Fraction for CBR Traffic

Normalized Routing Load: The simulation results shows that for large number of nodes with CBR traffic, DSR protocol have significantly higher routing load than AODV and DSDV both when the nodes are continuously moving (low pause time) and is decreasing gradually with increase in the pause time (high pause time) as shown in Figure 13. We observed that when the number of sources is low, the performance of DSDV and AODV is better than DSR protocol.

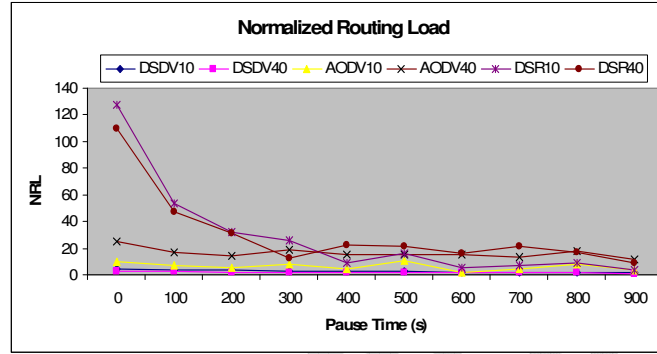


Fig. 13: Normalized Routing Load for CBR Traffic

Routing Overheads: The Routing Overheads in DSR and AODV increases with increase in the number of traffic sources as shown in Figure 14 and that the Routing Overheads in DSR are comparable to AODV. We observe that Routing Overheads in DSDV are significantly lower than both DSR and AODV. This is because DSDV always have route to all destinations, therefore no extra routing packets are generated when number of sources are large. The Routing Overheads in all the protocols decrease with increase in pause time.

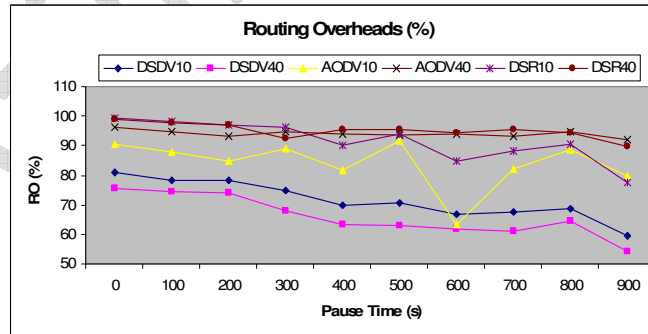


Fig. 14: Routing Overheads for CBR Traffic

Average End-to-End Delay: Simulation results show that the Average End-to-End delay in DSR is significantly larger than AODV and DSDV protocols

irrespective of number of sources as shown in Figure 15. Average End-to-End delay in DSDV is very small it is due to the fact that proactive routing protocols as they always have route to every destination in the network. The Reactive routing protocols discover route on-demand therefore significant delay is introduced in reactive routing protocols.

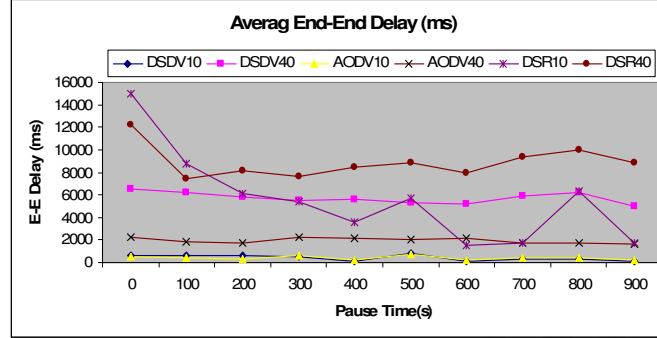


Fig. 15: Average End-End Delay for CBR Traffic

Packet Loss: The simulation results show that Packet Loss in DSR is much less than the Packet Loss in AODV. The reason appears to be that DSR always has more than one route for a destination. If one route fails, then route discovery is not started and the packet is sent using alternate route. Packet Loss in DSDV is large as compared to both DSR and AODV as shown in Figure 16.

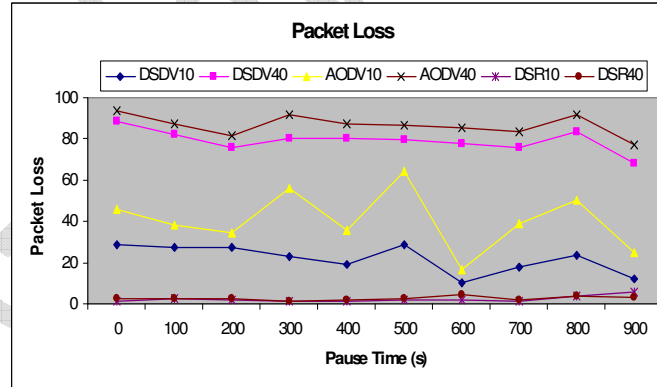


Fig. 16: Packet Loss for CBR Traffic

D. Performance Comparison (TCP Traffic) Based on Scenario-B

We have also considered scenario-B under TCP traffic. The simulation results obtained for TCP traffic are analyzed. We have varied the number of traffic sources varying from 10, 20, 30 and 40 for all the three protocols:

DSR, AODV and DSDV. We briefly describe the results such as Packet Delivery Fraction, Routing Overheads, End-to-End Delay and Packet Loss.

Packet Delivery Fraction: For TCP traffic all the three protocols DSDV, DSR and AODV protocols deliver almost 95% of the originated data packets. However, performance of both DSDV and DSR protocols are better than that of AODV as shown in Figure 17.

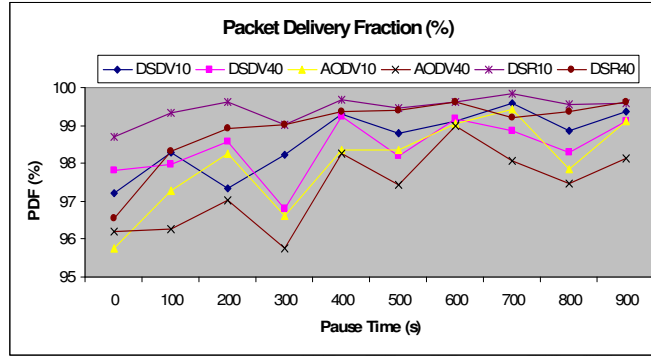


Fig. 17: Packet Delivery Fraction for TCP Traffic

Normalized Routing Load: Our simulation results show that DSR has very large routing load when the pause time is low and it decreases with increase in pause time, whereas DSDV shows significantly low routing load than both DSR and AODV as shown in Figure 18. For high mobility both DSR and AODV have large routing load, which decreases with increased pause time (low mobility). However, as we see from Figure 18 that for DSDV this variation is not much large.

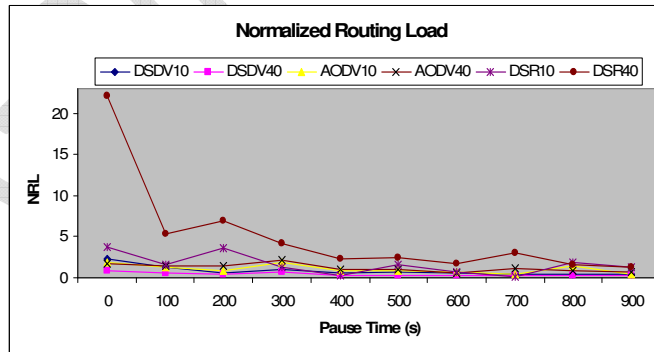


Fig. 18: Normalized Routing Load for TCP Traffic

Routing Overheads: The simulation results show that Routing Overheads in DSDV are low as compared to both DSR and AODV protocols. This is because DSDV always have route to all destinations, therefore no extra

routing packets are generated when number of sources are large. The overheads in DSR and AODV increase with increase in the number of traffic sources as shown in Figure 19. The Routing Overheads in DSR are comparable to AODV.

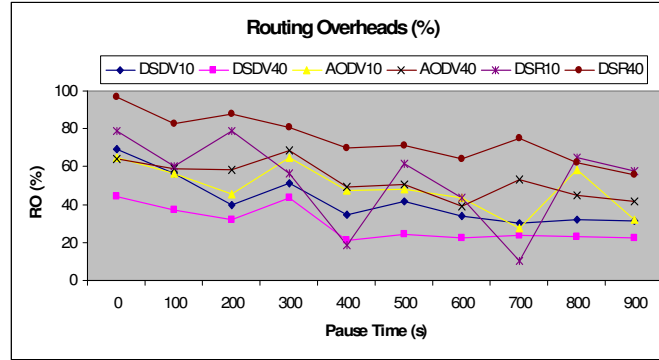


Fig. 19: Routing Overheads for TCP Traffic

Average End-to-End Delay: The simulation results show that Average End-to-End delay in DSDV is comparable to AODV as shown in Figure 20. However, the Average End-to-End delay in DSR protocol is very large as compared to the End-to-End delay in DSDV. Further, Average End-to-End delay in DSDV is very small. It is because of the nature of proactive routing protocols as they have always route to every destination in the network.

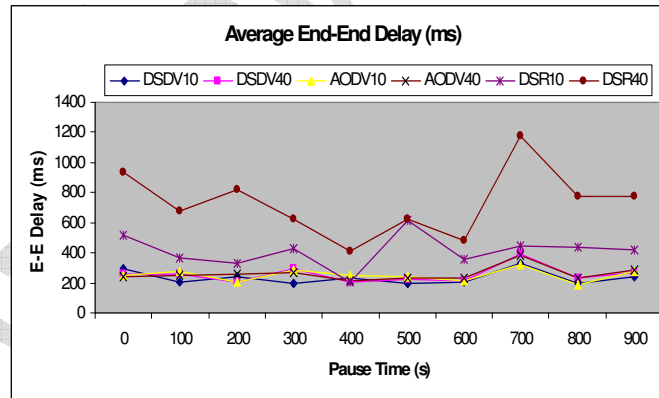


Fig. 20: Average End-End Delay for TCP Traffic

Packet Loss: Our simulation results show that the Packet Loss is comparable for all the three protocols DSDV, DSR and AODV as shown in Figure 21. But with the increase in the network load the Packet Loss in DSR is much less than Packet Loss in AODV.

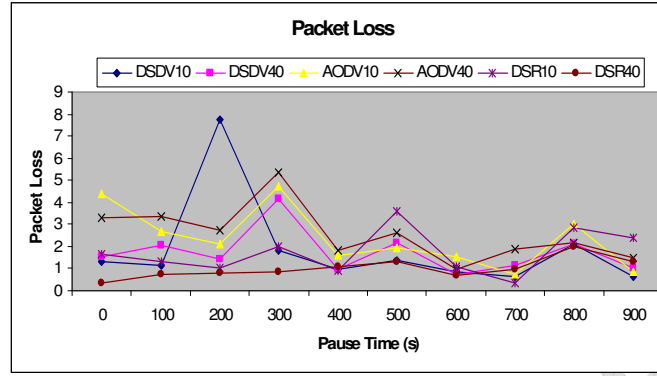


Fig. 21: Packet Loss for TCP Traffic

6. Results and Concluding Remarks

We have analyzed the performance of protocols by varying network load, mobility and type of traffic (CBR, TCP). A detailed simulation has been done using NS2. We have considered Packet Delivery Fraction, Normalized Routing Load, Average End-to-End delay, Routing Overheads, and Packet Loss as metrics for performance analysis of these protocols.

The simulation results reveal some important characteristic differences between the routing protocols. The presence of high mobility implies frequent link failures and each routing protocol reacts differently during link failures. The different basic internal working mechanism leads to the performance differences in these protocols.

DSR and AODV both use on-demand route discovery, but with different routing mechanisms. The general observation from the simulation results is that for application-oriented metrics such as Packet Delivery Fraction and End-to-End delay, AODV outperforms DSR in stressful situations (high load and/or high mobility), with widening performance gaps with increasing stress. DSR protocol, however, consistently generates less routing load than AODV for CBR traffic scenarios. But it has been observed that for TCP traffic scenarios, performance of DSDV and AODV is much better than DSR. DSDV protocol has significantly lower End-to-End delay as compared to both DSR and AODV.

In summary, it can be said that for the scenarios where mobility is high, area is large, the amount of traffic is more and network is for longer period, AODV performs better. For the normal scenarios where a network is of general nature with moderate traffic and moderate mobility, DSR would be the right choice for UDP applications, as it delivers more packets at the

destination with lowest Routing Overheads. For TCP applications AODV is found to be a better choice.

Further, we find that for our results are comparable with those obtained by Das S. R.² for CBR traffic. We have analyzed much large scenario than analyzed by Reddy and Reddy⁸ for TCP traffic. Our results give much closer view of the performance of the protocols for Packet Delivery Fraction, End-to-End delay, and Packet Loss metrics than by them.

We have done rigorous simulations to obtain better understanding of these protocols in more diverse conditions, which may subsequently helps in the development of new protocols or modification in the existing protocols for optimum deployment in application specific scenarios. Our future work will include the modification of DSR and AODV to reduce the Routing Overheads for performance optimization.

References

1. J. Broch, D. A. Maltz, D. B. Johnson and Y.C. Hu: A Performance Comparison of Multi-Hop Wireless Ad-Hoc Network Routing Protocols. *Proceedings of the ACM/IEEE International Conference on Mobile Computing & Networking (MobiCom)*, October 1998.
2. S. R. Das, C. E. Perkins and E. M. Royer: Performance Comparison of two On-demand Routing Protocols for Ad-Hoc Networks, *INFOCOM 2000*, March 26 -30, 2000.
3. Ioannis Broustis, Gentian Jakllari, Thomas Repantis and Mart Molle: A Comprehensive Comparison of Routing Protocols for Large-Scale Wireless MANETs, *Proceedings of the 3rd International Workshop on Wireless Ad-Hoc and Sensor Networks (IWWAN)*, 2006.
4. B. R. Arun Kumar, L. C. Reddy and P. S. Hiremath: Performance Comparison of Wireless Mobile Ad-Hoc Network Routing Protocols, *International Journal of Computer Science and Network Security (IJCSNS)*, **8 (6)** (2008) 337-343.
5. H. Liu,: *Topology Control, Routing Protocols and Performance Evaluation for Mobile Wireless Ad-Hoc Networks*, Ph. D. Thesis, Georgia State University, 2005.
6. R. Misra and C.R. Mandal: Performance Comparison of AODV/DSR On-Demand Routing Protocols for Ad-Hoc Networks in Constrained Situation. *Proceedings of IEEE International Conference on Personal Wireless Communications (ICPWC 2005)*, 23-25 Jan. (2005) 86-89.
7. S. Samba, Zongkai Yang, Biao Qi and Jianhua He: Simulation Comparison of four Wireless Ad-hoc Routing Protocols , *Information Technology Journal*, **3(3)** (2004) 219-226.
8. P. Chandrasekhar Reddy and P. C. Reddy: Performance Analysis of Ad-hoc Network Routing Protocols, *Academic Open Internet Journal*, **17** (2006). www.acadjournal.com.
9. P. Bhagwat and C. E. Perkins: Highly Dynamic Destination Sequenced Distance-Vector Routing (DSDV) for Mobile Computers, *ACM Computer Communications Review*, **24 (4)** (1994) 234-244.

10. T. Camp, J. Boleng and V. Davies: A Survey of Mobility Models for Ad Hoc Network Research. *Wireless Communication & Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking: Research, Trends and Applications*, **2(5)** (2002) 483-502.
11. S. R. Chaudhry, A. A. Al-Khwildi, Y. Casey, H. Aldelou and H. S. Al-Raweshidy: A Performance Comparison of Multi On-Demand Routing in Wireless Ad-Hoc Networks. *Proceedings of IEEE International Conference on Wireless and Mobile Computing, Networking and Communications*, 2005 (WiMob'2005), 22-24 Aug. 2005, **3** (2005) 9-16.
12. Suresh Kumar, R. K. Rathy and D. Pandey: Design of an Ad-hoc Network Model for Disaster Recovery Scenario using Various Routing Protocols. *Proceedings of International Conference on Advances in Computing, Communication and Control-09*, 23-24 January (2009)100-105.
13. Suresh Kumar, R. K. Rathy and D. Pandey: Traffic Pattern Based Performance Comparison of two Reactive Routing Protocols for Ad-Hoc Networks using NS2. *Proceedings of 2nd IEEE International Conference on Computer Science and Information Technology (IEEE ICCSIT 2009)*, Beijing, China, 8-12 August, (2009) 369-373.
14. Suresh Kumar and R K Rathy: Performance Comparison of Two Reactive Routing Protocols for Ad Hoc Networks, *MR International Journal of Engineering and Technology*, **1(1)** (2009)15-18.
15. Suresh Kumar, R. K. Rathy and Geeta Narang: Optimization of dynamic source routing protocol using fuzzy logic, *Second IEEE International Conference on Advances in Computer Vision and Information Technology, (ACVIT-2009)*, 16-19 December 2009, Dr. Babasaheb Ambedkar Marathwada University Aurangabad (MS) , India.