Chapter 3

Performance Analysis of Three Routing Protocols in MANET Using the NS-2 and ANOVA Test with Varying Speed of Nodes

Subhrananda Goswami, Subhankar Joardar,
Chandan Bikash Das, Samarajit Kar and
Dibyendu Kumar Pal

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/66521

Abstract

In this chapter, we analyzed ad hoc on demand distance vector (AODV), dynamic source routing (DSR), and destination-sequenced distance vector (DSDV) routing protocols using different parameters of QoS metrics such as packet delivery ratio (PDR), normalize routing overhead, throughput, and jitter. The aim of this chapter is to determine a difference between routing protocol performance when operating in a large-area MANET with high-speed mobile nodes. After the simulations, we use AWK to analyze the data and then Xgraph to plot the performance metric. After that we use one-way ANOVA tools to confirm the correctness of the result. We use NS-2 for the simulation work. The comparison analysis of these protocols will be carrying out and in the last, we conclude that which routing protocol is the best one for mobile ad hoc networks.

Keywords: AODV, DSR, DSDV, MANET, throughput, packet delivery ratio, jitter, NS-2, ANOVA

1. Introduction

The existing literature on MANETs is very extensive. An extremely comprehensive work is presented in Refs. [1, 2], which extensively covers most issues related to the subject, whereas in Refs. [3, 4], authors provide a brief introduction. MANET design issues such as a routing architecture in the light of the nature of MANETS, unidirectional link support, QoS routing, and multicast support are discussed in Refs. [5, 6]. In Ref. [7], the authors cover some of the same design issues as mentioned in Ref. [5], but they augment them with some additional ones, such as limited bandwidth, energy constrained operation, and limited physical security.

Communication networks are evolving with a great pace witnessing increase in infrastructure and applications too. A mobile ad hoc network is the latest outcome in this research. The mobile ad hoc network, also known as MANET [8], is a network without any available infrastructure.

Nodes are mobile and can move whenever and wherever they want, because there is no centralized control or any other infrastructure is needed in any MANET. Each node in an MANET must be capable of functioning as a router to relay the traffic of other nodes.

A number of protocols have been developed for accomplish this task. Various dedicated routing protocols have been proposed to the Internet Engineering Task Force (IETF) MANET Working Group [8]. Some of these protocols have been studied, and their performances have been analyzed in detail. Broch et al. [9] evaluated four protocols using mobility and traffic scenarios similar to those we used. They focused on packet loss, routing message overhead, and route length. In Ref. [10], Johansson et al. compare three routing protocols, over extensive scenarios, varying node mobility, and traffic load. They focus on packet loss, routing overhead, throughput, and delay, and introduce mobility measures in terms of node relative speed. Finally, in Ref. [11], Das and coworkers compare the performance of two protocols, focusing on packet loss, packet end-to-end delay, and routing load. They obtained simulation results consistent with previous works and conclude with some recommendations for improving protocols. In this chapter, we measure and compare three performance parameter behaviors of two routing protocols, respectively, ad hoc on demand distance vector (AODV) [12] and destination-sequenced distance vector (DSDV).

2. MANET routing protocols

This is the leading routing protocol proposed so for in the category of on demand or reactive routing protocols. Unlike table-driven protocols, it does not maintain status of the network via continuous updates [13]. This approach assists in minimizing the flooded messages and also size of route tables. It was designed after a distance vector routing protocol (DSDV) but is much efficient than DSDV. Actually, AODV is a combination of DSDV and dynamic source routing (DSR). It has the actual on-demand technique of discovering the route and also route maintenance from DSR but uses sequence numbering and also the periodic beacons of DSDV. New routes are found through the process of RREQ and RREP where RREQ packets are broadcast and RREPs are unicast in nature. While route maintenance uses RERR packets for remedy of route breaks, routing information is kept afresh by the usage of sequence numbers, which is the idea borrowed from DSDV [14].

The DSDV [15] is a proactive routing algorithm based upon a well-known classical distance vector algorithm of Bellman-Ford. Routing tables are maintained and updated accordingly, so broadcast periodic routing table update packets consume the bandwidth. So, the main weakness of DSDV is that when network grows these packets also increase. The main improvement here to the Bellman-Ford algorithm is loop freedom, which is made possible by assigning the sequence number to each entry in the routing table, which avoids stale routes.

The dynamic source routing (DSR) [10] is an on-demand or reactive routing protocol. Therefore, unlike other proactive routing protocols, DSR involves no updates of whichever type at any stage inside the network. The DSR uses source routing for forwarding data packets, which distinguishes DSR from other reactive routing protocols. It is lightweight on inner routers due to source routing, the maintaining routing information is not needed at every host. The sender becomes aware of complete destination address before transmission and appends this address in the header of the routing data packet at the beginning. It is loop free due to source routing. Extensive use of cache and promiscuously listening are the main optimizations to DSR when network is at low mobility.

3. Simulation model

The simulation software used in this chapter is the network simulator, NS-2 [16, 17]. The software version used is the latest release at the time of the commencement of simulation, namely, ns-2.34, which can be downloaded from Ref. [17]. In addition, many existing ad hoc routing protocol modules have already been implemented in NS-2. Three such protocols are AODV, DSR, and DSDV. NS-2 is a discrete-event-driven simulation software targeted for network simulation. This software is currently maintained by the Information Science Institute of University of Southern California.

3.1. Simulation evaluation methodology

In order to analyze and compare the performance of the three routing protocols AODV, DSR, and DSDV, simulation experiments were performed. The purpose of the simulations was to compare the efficiency of the routing protocols based on different simulation parameters. The focus was concentrated on four performance metrics:

(1) Packet delivery ratio (PDR).

(2) Throughput.

(3) Normalized routing overhead.

(4) Jitter.

3.2. Results

Generated trace file that is (.tr)

r -t 2.046566484 -Hs 1 -Hd -1 -Ni 1 -Nx 454.33 -Ny 337.37 -Nz 0.00 -Ne 9.996194 -Nl RTR -Nw — -Ma 0 -Md ffffffff -Ms 4 -Mt 800 -Is 1.255 -Id 9.255 -It DSR -Il 48 -If 0 -Ii 17 -Iv 32 -P dsr -Ph 2 -Pq 1 -Ps 2 -Pp 0 -Pn 2 -Pl 0 -Pe 0->16 -Pw 0 -Pm 0 -Pc 0 -Pb 0->0

3.3. NAM file output

NAM is a Tcl/TK-based animation tool for viewing network simulation traces and real-world packet traces. Taking data from network simulators (such as ns) or live networks, NAM was one of the first tools to provide general purpose, packet-level, and network animation, before starting to use NAM, a trace file needs to create [16]. This trace file is usually generated by NS. Once the trace file is generated, NAM can be used to animate it. A snapshot of the simulation topology in NAM for 15 mobile nodes is shown in **Figure 1**, which is visualized the traces of communication or packet movements between mobile nodes [17].

Figure 1. A simple NAM file output.

The NAM file output for packet dropping is shown in **Figure 2**.

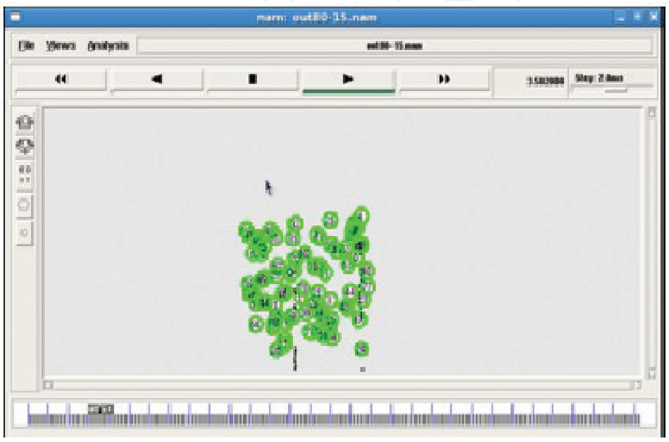

Figure 2. A NAM output with packet dropping.

http://dx.doi.org/10.5772/66521

4. Simulation results and observation

4.1. Packet delivery ratio (PDR)

Packet delivery ratio (PDR) is defined as the ratio of data packets delivered successfully to destination nodes and the total number of data packets generated for those destinations. PDR characterizes the packet loss rate, which limits the throughput of the network. The higher the delivery ratio, better the performance of the routing protocol. The ratio of the data delivered to the destination to the data sent out by the source. PDR is determined as

$$PDR = \left(\frac{\text{Received packets}}{\text{Sent packets}}\right) * 100 \quad (1)$$

Figures 3–6 clearly indicate that the AODV routing protocol outcomes are better with the CBR traffic. AODV protocol performs better in comparison of other two selected routing protocols in such a network environment with varying speeds of nodes. So, we conclude that AODV is better in most of the PDR cases.

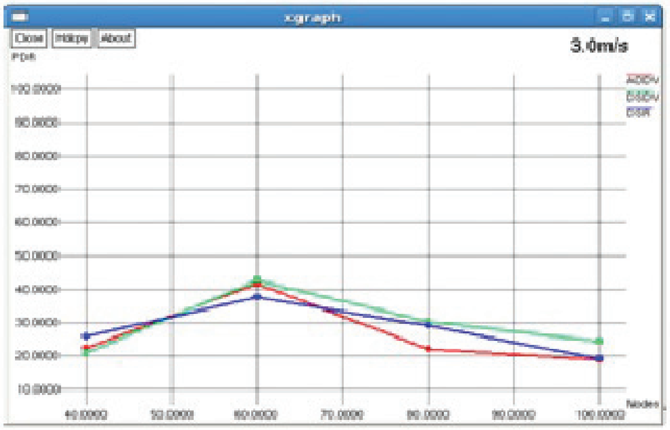

Figure 3. Packet delivery ratio (PDR) at 3 m/s.

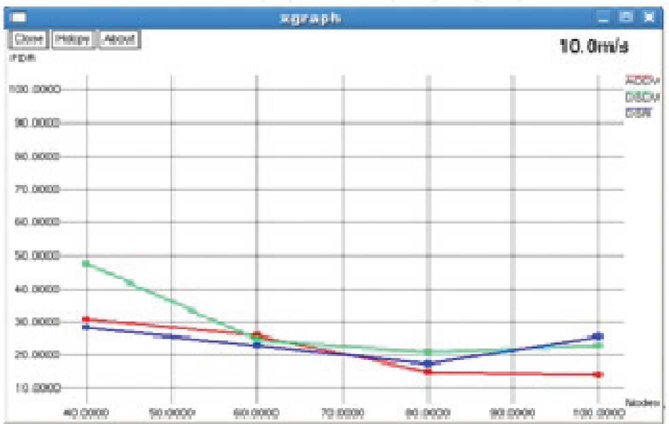

Figure 4. Packet delivery ratio (PDR) at 10 m/s.

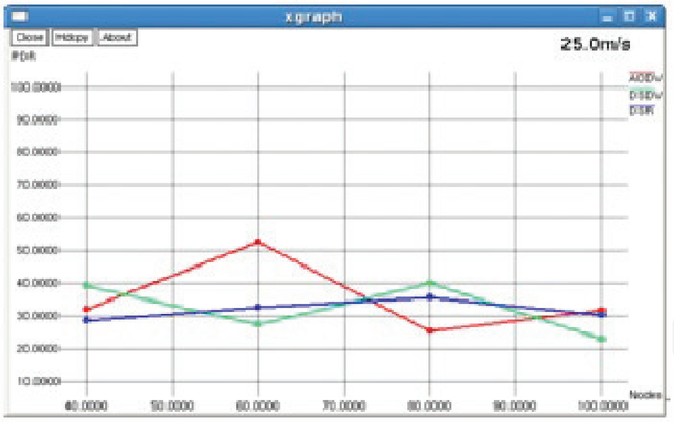

Figure 5. Packet delivery ratio (PDR) at 25 m/s.

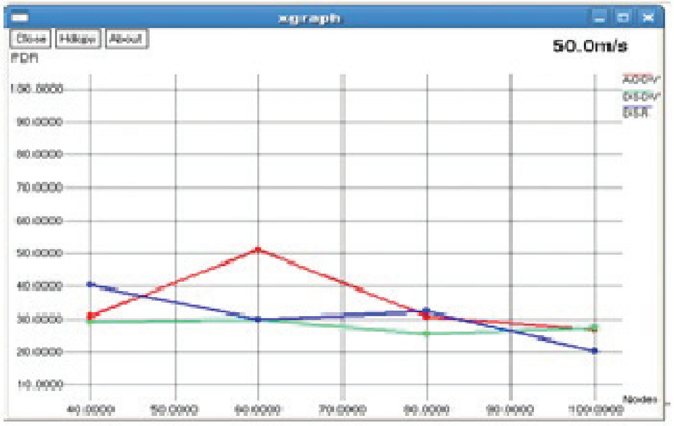

Figure 6. Packet delivery ratio (PDR) at 50 m/s.

4.2. Throughput

Throughput is defined as the ratio of the total data reaches a receiver from the sender. The time it takes by the receiver to receive the last message is called as throughput. Throughput is expressed as bytes or bits per sec (byte/sec or bit/sec). Some factors affect the throughput as; if there are many topology changes in the network, unreliable communication between nodes, limited bandwidth available, and limited energy. A high throughput is absolute choice in every network. Throughput can be represented mathematically as in equation. This represents the number of packets received by the destination within a given time interval. It is a measure of effectiveness of a routing protocol.

$$\text{Throughput} = \frac{\text{File size}}{\text{Transmission time (bps)}} \tag{2}$$

$$\text{Transmission time (bps)} = \frac{\text{File size}}{\text{Bandwidth (sec)}} \tag{3}$$

The analysis of **Figures 7–10** shows that performance of AODV is better than DSR and DSDV. Another characteristic that has come to the notice is that pause time does not have significant bearing on the throughput, whereas the performance is dictated only by the density of the network.

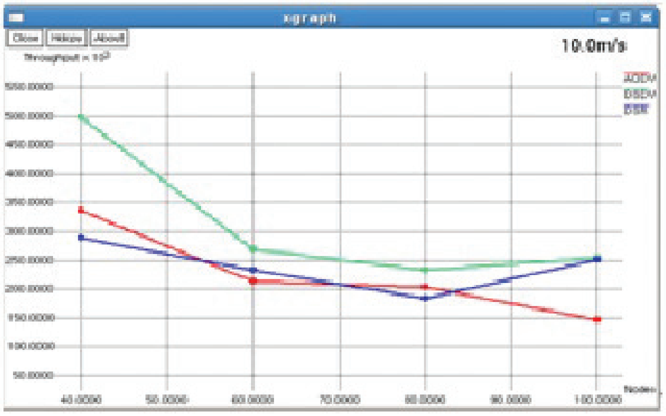

Figure 7. Throughput at 3 m/s.

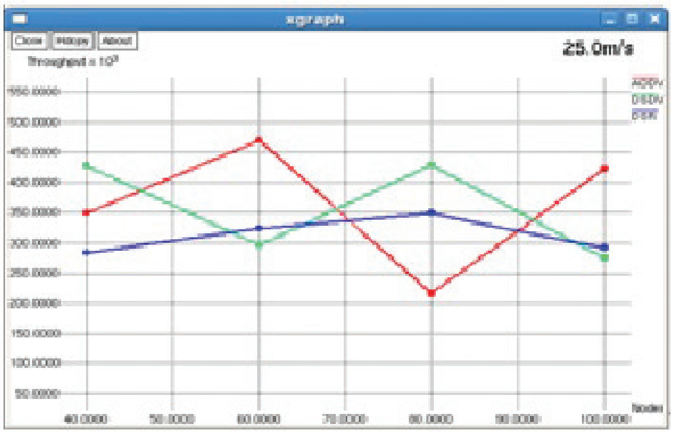

Figure 8. Throughput at 10 m/s.

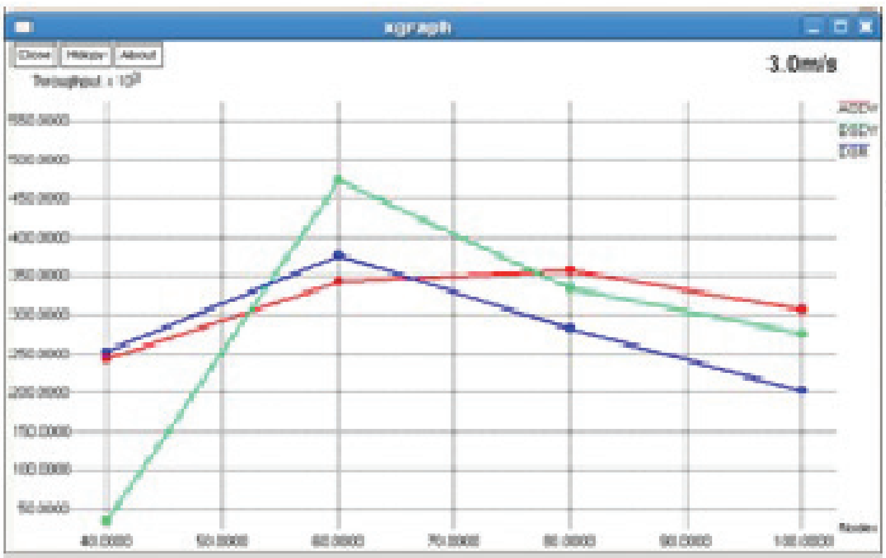

Figure 9. Throughput at 25 m/s.

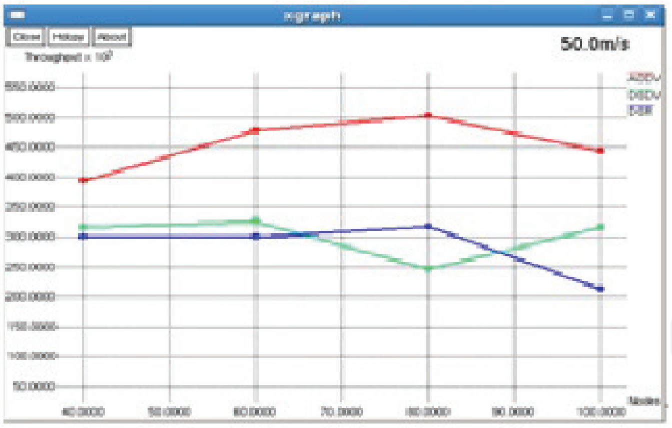

Figure 10. Throughput at 50 m/s.

4.3. Normalized routing overhead

This is the ratio of routing-related transmissions (RREQ, RREP, RERR, etc.) to data transmissions in a simulation. A transmission is one node either sending or forwarding a packet. Either way, the routing load per unit data successfully delivered to the destination.

It is the total number of control or routing (RTR) packets generated by routing protocol during the simulation. All packets sent or forwarded at network layer is consider routing overhead.

$$\text{Routing overhead} = \text{Number of RTR packets} \tag{4}$$

Based on the result of simulation, **Figures 11–14** show that the performance of DSDV is better than AODV and DSR. At all the considered mobility, DSDV is the best protocol as compared to other protocols.

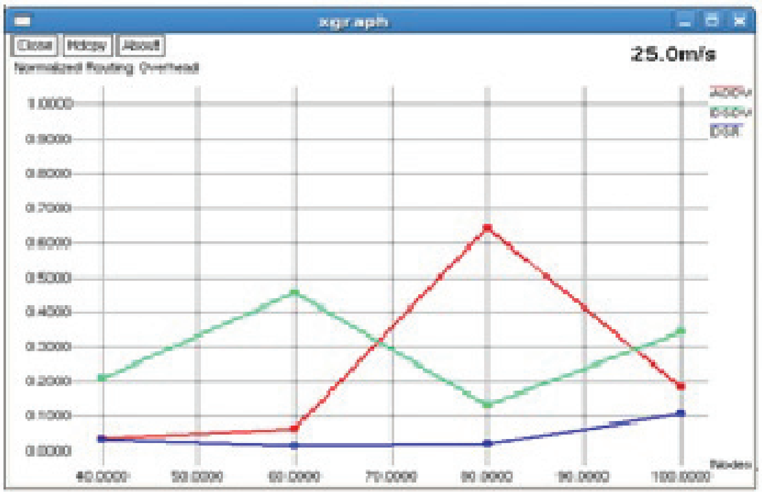

Figure 11. Normalized routing overhead at 3 m/s.

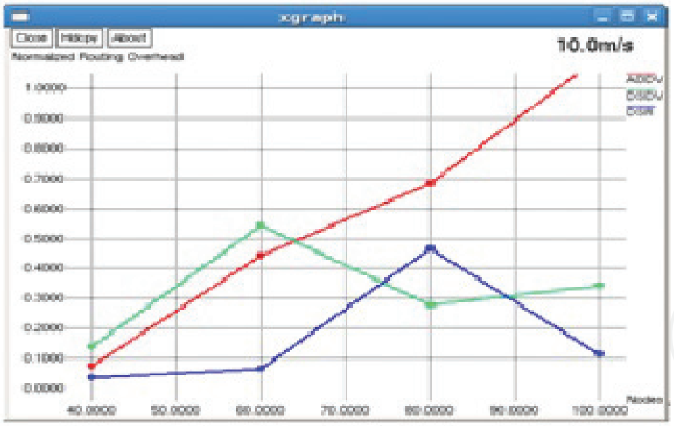

Figure 12. Normalized routing overhead at 10 m/s.

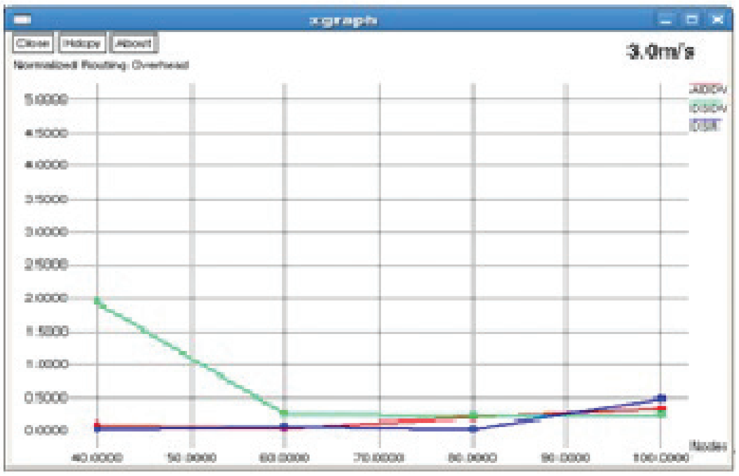

Figure 13. Normalized routing overhead at 25 m/s.

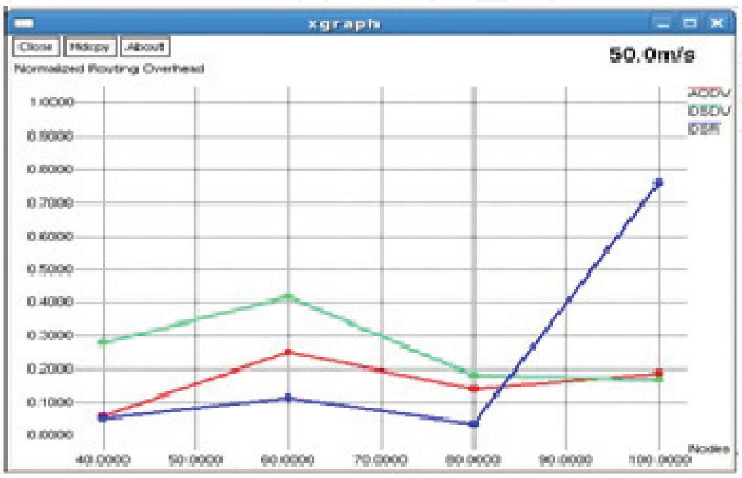

Figure 14. Normalized routing overhead at 50 m/s.

4.4. Jitter

The term jitter is often used as a measure of the variability over time of the packet latency across a network. A network with constant latency has no variation (or jitter). Packet jitter is expressed as an average of the deviation from the network mean latency. However, for this use, the term is imprecise [13]. Or in other words, jitter is the variation of the packet arrival time. In jitter calculation, the variation in the packet arrival time is expected to minimum. The delays between the different packets need to be low if we want better performance in mobile ad hoc networks.

Based on the result of simulation, **Figures 15** and **16** show that the performance of AODV and DSR gives the better result. **Figures 17** and **18** show that DSR gives the better performance.

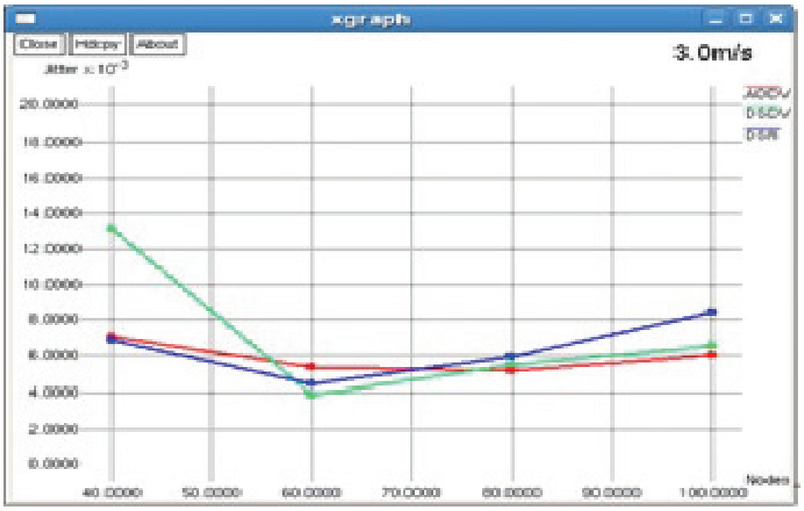

Figure 15. Jitter at 3 m/s.

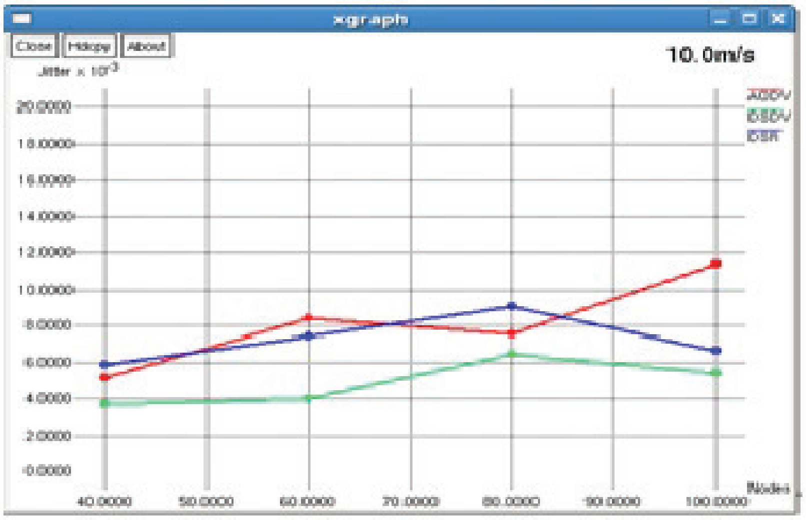

Figure 16. Jitter at 10 m/s.

http://dx.doi.org/10.5772/66521

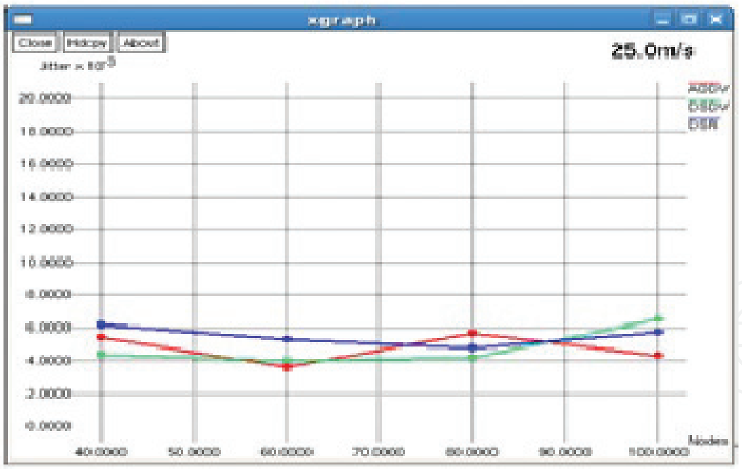

Figure 17. Jitter at 25 m/s.

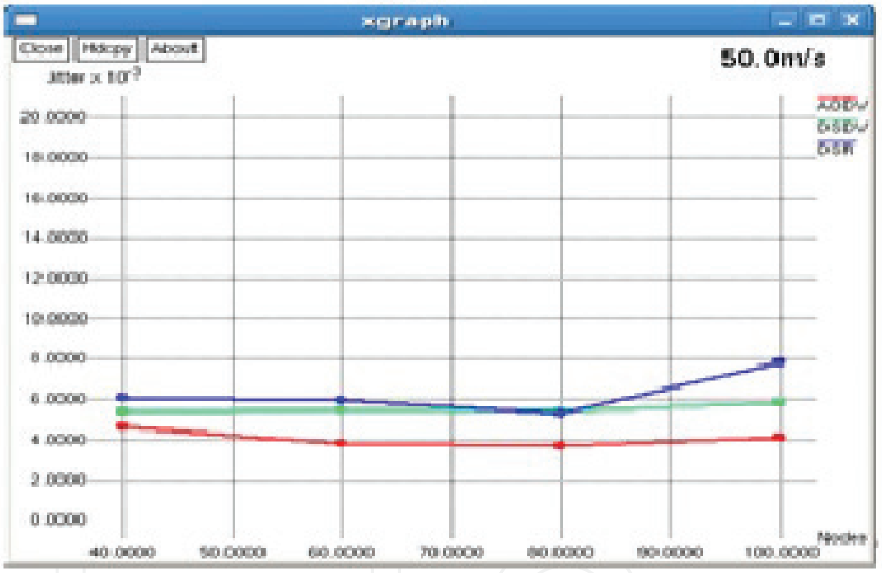

Figure 18. Jitter at 50 m/s.

5. ANOVA test

Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups), in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation [18].

In this chapter, we have use one-way ANOVA. One-way ANOVA is used to study the effect of ($k > 2$) levels of a single factor. A factor is defined as characteristics under consideration, thought to influence the measured observation. A level is defined as a value of a factor.

5.1. Output of the test for different parameters

5.1.1. Packet delivery ratio

The packet delivery ratio (PDR) is very much related to the throughput metric. The destination records the number of data packets it received and estimates the PDR delivery ratio in the network from the count of the data packets sent. The ANOVA hypothesis test is shown in **Table 1**, there is sufficient evidence to reject the null hypothesis. We see that there is a significant different in PDR performance when the network adopts different routing methods (P-value > 0.05).

Groups	Count	Sum	Average	Variance
AODV	23	802.8693	34.90736	121.3164733
DSDV	23	744.1666	32.35507	171.2711624
DSR	23	729.8366	31.73203	56.06334723

Table 1. Summary of packet delivery ratio.

The one-way ANOVA test for PDR is shown in **Table 2**.

In this case, F_{crit} = 3.135918 at α = 0.05. Since F = 0.560241875 < 3.135918, the results are significant at the 5% significance level. So, we will accept the null hypothesis, and conclusion can be drawn that there is strong evidence that the expected values in the three groups do not differ. The variation is quite small and can be eliminated at this significance level. The P-value for this test is 0.573763.

Source of variation	SS	Df	MS	*F*	*P*-value	F_{crit}
Between groups	130.21925	2	65.10963	0.560241875	0.573763	3.135918
Within groups	7670.3216	66	116.217			
Total	7800.5409	68				

Table 2. ANOVA of packet delivery ratio.

5.1.2. Throughput

Data throughput is defined as the total number of packets delivered over the total simulation time. ANOVA statistical computation shows that we do not reject the null hypothesis. That is, there is no significant difference for the different methods in terms of throughput performance (P-value > 0.05) (**Table 3**).

Groups	Count	Sum	Average	Variance
AODV	23	7990941	347432.2	8201779957
DSDV	23	8094695	351943.3	20237752574
DSR	23	7267943	315997.5	5554377965

Table 3. Summary of throughput.

The one-way ANOVA test for throughput is shown in **Table 4**.

Source of variation	SS	df	MS	F	P-value	F_{crit}
Between groups	1.764E+10	2	8.82E+09	0.778278814	0.463364	3.135918
Within groups	7.479E+11	66	1.13E+10			
Total	7.655E+11	68				

Table 4. ANOVA of throughput.

In this case, F_{crit} = 3.135918 at α = 0.05. Since F = 0.778278814 < 3.135918, the results are significant at the 5% significance level. So, we will accept the null hypothesis, and conclusion can be drawn that there is strong evidence that the expected values in the three groups do not differ. The variation is quite small and can be eliminated at this significance level. The P-value for this test is 0.463364.

5.1.3. Normalized routing overhead

Using the ANOVA hypothesis testing, the simulation results show a significant difference among methods used in terms of normalized routing overhead (P-value > 0.05). Thus, normalized routing overhead can be used as a metric to measure the performance of different algorithms (**Table 5**).

Groups	Count	Sum	Average	Variance
AODV	23	2.19207	0.095307	0.01199388
DSDV	23	13.66286	0.594037	0.846600923
DSR	23	0.528887	0.022995	0.000264522

Table 5. Summary of normalized routing overhead.

The one-way ANOVA test for normalized routing overhead is shown in **Table 6**.

Source of variation	SS	df	MS	F	P-value	F_{crit}
Between groups	4.4470485	2	2.223524	7.766781596	0.000935	3.135918
Within groups	18.894905	66	0.286286			
Total	23.341954	68				

Table 6. ANOVA of normalized routing overhead.

In this case, F_{crit} = 3.135918 at α = 0.05. Since F = 7.766781596 > 3.135918, the results are significant at the 5% significance level. So, we will reject the null hypothesis, and conclusion can be drawn that there is strong evidence that the expected values in the three groups differ significantly. The *P*-value for this test is 0.000935.

5.1.4. Jitter

The term jitter often used as a measure of the packet of the variability over time of the packet latency across a network. A network with constant latency has no variation (or jitter). Packet jitter is expressed as an average of the derivation from the network mean latency. ANOVA statistical computation shows that we do not reject the null hypothesis. That is, there is no significant difference for the different methods in terms of throughput performance (*P*-value > 0.05) (**Table 7**).

Groups	Count	Sum	Average	Variance
AODV	23	0.129171	0.005616	2.07E−06
DSDV	23	0.125752	0.005467	5.9E−06
DSR	23	0.131442	0.005715	1.91E−06

Table 7. Summary of jitter.

The one-way ANOVA test for jitter is shown in **Table 8**.

Source of variation	SS	df	MS	F	P-value	F_{crit}
Between Groups	7.14E−07	2	3.57E−07	0.108241	0.89757	3.135918
Within Groups	0.000218	66	3.3E−06			
Total	0.000218	68				

Table 8. ANOVA of jitter.

In this case, F_{crit} = 3.135918 at α = 0.05. Since F = 0.108241 < 3.135918, the results are significant at the 5% significance level. So, we will accept the null hypothesis, and conclusion can be drawn that

http://dx.doi.org/10.5772/66521

there is strong evidence that the expected values in the three groups do not differ. The variation is quite small and can be eliminated at this significance level. The *P*-value for this test is 0.89757.

6. Conclusion

The results indicate that the performance is better especially when the number of nodes in the network is higher. In this chapter, we have used a simulator that provides the virtual environment for the testing different parameters. Reactive routing protocol AODV performance is the best considering due to its ability to maintain connection by periodic exchange of information. Using NS-2 simulator we created the scenarios under which using tcl script, it is run. After analyzing the X-graphs, we concluded that AODV indicates its highest efficiency and performance under high mobility than DSR and DSDV, and the performance of TCP and UDP packets with respect to normalized routing overhead, jitter, throughput, and PDR, and the performance of AODV is better than DSDV and DSR routing protocol for real-time applications from the simulation results.

After that in one-way ANOVA test, AODV exhibits better routing performance compared with conventional routing methods such as DSDV and DSR. By performing an ANOVA analysis at the initial stage, we conclude that there is a significant difference in the performance metrics when using different routing algorithms. From there, we analyze the difference of the means and boundaries in 95% confidence interval. In all simulation scenarios, we see that AODV shows a lower packet loss and lower delay. It offers higher throughput and ensures higher packet delivery ratio.

Author details

Subhrananda Goswami[1,*], Subhankar Joardar[2], Chandan Bikash Das[3], Samarajit Kar[4] and Dibyendu Kumar Pal[5]

*Address all correspondence to: subhrananda_usca@yahoo.co.in

1 Department of Information Technology, Global Group of Institutions, Haldia, Purba Midnapore, West Bengal, India

2 Department of CSE, Haldia Institute of Technology, Haldia, Purba Medinipur, West Bengal, India

3 Department of Mathematics, Tamralipta Mahavidyalaya, Tamluk, Purba Midnapore, West Bengal, India

4 Department of Mathematics, National Institute of Technology, Durgapur, Burdwan, West Bengal, India

5 Department Of Computer Application, Asansol Engineering College, Asansol, Burdwan, West Bengal, India

References

[1] Murthy R.S.C. and Manoj B.S. Ad Hoc Wireless Networks- Architectures. Prentice Hall, Upper Saddle River, NJ, 2004.

[2] Goswami S., Joardar S., Das C.B., and Das B. A simulation based performance comparison of AODV and DSDV mobile ad hoc networks. Information Technology and Computer Science. 2014;**6**(10):11–18.

[3] Remondo D. Tutorial on wireless ad hoc networks [Internet]. 2004. Available from: www.comp.brad.ac.uk/het-net/HET-NETs04/CameraPapers/T2.pdf

[4] Goswami S., Joardar S., and Das C.B. Performance Comparison of Routing Protocols of MANET Using NS-2. 1st ed. Germany: LAP LAMBERT Academic Publishing; 2014, 141p.

[5] Chun Y.L. and Lin S.M. Routing protocols overview and design issues for self-organized-network [sic]. International Conference on Communication Technology Proceedings; Beijing, China. 2000, pp. 1298–1303.

[6] Goswami S., Joardar S., and Das C.B. Reactive and proactive routing protocol performance metric comparison in mobile ad hoc networks using NS 2. International Journal of Advanced Research in Computer and Communication Engineering. 2014;**3**(1):4908–4914.

[7] Macker J.P. and Corson M.S. Mobile ad hoc networking (MANET):Routing protocol performance issues and evaluation considerations (Internet-draft), in: *Mobile Ad-hoc Network (MANET) Working Group, IETF*. 1998.

[8] Internet Engineering Task Force MANET Working Group Charter. Available from: www.ietf,org/html.charters/manet-charter.html; 1999

[9] Broch J., Maltz D.A., Johnson D.B., Hu Y.C., and Jetcheva J. A performance comparisonof multi-hop wireless ad hoc network routing protocols. Proceedings of the Fourth Annual ACM; IEEE International Conference on Mobile Computing and Networking; 1998, pp. 85–97.

[10] Broch J., Maltz D.A., and Johnson D.B. The dynamic source routing protocol for mobilead hoc networks. Internet Draft, MANET Working Group. 1999.

[11] Perkins C.E., Royer E.M., and Das S.R. Performance comparison of two on-demand routing protocols for ad hoc networks. in *IEEE Personal Communications*. vol. 8. no. 1. pp. 16–28. 2001.

[12] Perkins C.E. and Royer E.M. Ad hoc on-demand distance vector (AODV) routing. Internet Draft, MANET Working Group. 2000.

[13] Belding-Royer E.M., Perkins C.E., and Chakeres I. *Ad hoc On-Demand Distance Vector (AODV) Routing: Work in progress*. July 2004. Internet Draft, RFC 3561bis-01, http://moment. cs. ucsb. edu/pub/draft-perkins-manet-aodvbis-02. txt.

[14] Papadimitratos P. and Haas Z.J. Secure on-demand distance vector routing in ad hoc networks. *IEEE/Sarnoff Symposium on Advances in Wired and Wireless Communication.* Princeton, NJ, 2005, pp. 168–171.

[15] Gorantala K. Routing protocols in mobile ad hoc networks [thesis]. Sweden: Umea University; 2006.

[16] nsnam web pages. Network simulator-ns-2 [Internet]. Available from: www.isi.edu/nsnam; 1989.

[17] NS Manual/Documentation-The VINT Project Collaboration between researchers at UC Berkeley, LBL, USC/ISI and Xerox. PARC.KevinFall_kfall@ee.lbl.gov, Kennan Varadhan_kannan@catarina.usc.edu, 1996.

[18] Barman S., Ghosh A., and Biswas S. A transparent tree root identification scheme to support route-optimization and network mobility in PMIPv6 Domain. *IEEE 2nd International Conference on Recent Trends in Information Systems (ReTIS),* Kolkata. 2015. pp. 532–537.