e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

Research Paper

A STUDY ON SECURITY IN MOBILE Ad- Hoc NETWORK

PRABHU KUMAR.P
Research Scholar
M.Phil Computr Science
Bharath Institute Of Higher Education And Research
Mail Id: prabukumar23@yahoo.co.in

Guide Name: **Dr.KANNAN**
Assistant Professor, Department Of Computer Science
Bharath Institute Of Higher Education And Research

Address for Correspondence

PRABHU KUMAR.P
Research Scholar
M.Phil Computr Science
Bharath Institute Of Higher Education And Research
Mail Id: prabukumar23@yahoo.co.in

Guide Name: **Dr.KANNAN**
Assistant Professor, Department Of Computer Science
Bharath Institute Of Higher Education And Research

ABSTRACT

A **Mobile Ad-hoc NETwork** (**MANET**) Is an self reliant series of mobile users that communicate over exceedingly bandwidth constrained wireless hyperlinks. One of the primary issues in such networks is performance- in a dynamically changing topology; the nodes are expected to be strength-aware because of the bandwidth restrained network. Another trouble in such networks is protection - given that every node participates within the operation of the community similarly, malicious nodes are difficult to come across. There are numerous packages of cell ad hoc networks together with catastrophe healing operations, warfare area communications, etc. To study those problems, a situation based simulation evaluation of a comfortable routing protocol is performed and is in comparison with conventional non-cozy routing protocols. The situations used for the experiments depict essential actual-international packages which includes battlefield and rescue operations, which generally tend to have contradicting desires. An analysis of the

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

tradeoffs between overall performance and safety is finished to advantage an insight into the applicability of the routing protocols beneath consideration.

Introduction

Over the past few years there has been a growing interest in the research community for simulation study of performance in MANETs since there is a lack of necessary infrastructure for MANETs to be deployed in a realistic scenario. A simulation study gives us an idea of how a protocol performs when it is practically employed. This approach is similar to the prototyping model in software engineering realm. However, the main challenge in the simulation study of MANETs is the dynamic nature of the network topology and the physical environment in which the nodes operate. In order to gain an insight of how a protocol performs when deployed in a realistic scenario, it is imperative that the simulation capture the exact nature of the physical environment and the movement of the nodes in the network, which might not be possible in all cases. For example consider a scenario where a set of nodes are deployed in a rescue operation. Even though the mobility of the nodes can be captured with certain realistic mobility models, the node doesn't capture the exact physical environment in which the nodes operate, such as uneven terrains, catastrophic failure of the nodes, etc.

This chapter discusses the simulation study of performance in MANETs using the network simulator ns-2 and certain realistic mobility models used to model the movement of the nodes. It is followed by a step-by-step tutorial for simulation study of MANET routing protocols using ns-2. A set of experiments conducted to study the performance of AODV in a battlefield scenario is then explained.

The ns-2 network simulator

Ns-2 is an open source discrete event simulator used by the research community for research in networking [30]. It has support for both wired and wireless networks and can simulate several network protocols such as TCP, UDP, multicast routing, etc. More recently, support has been added for simulation of large satellite and ad hoc wireless networks. The ns-2 simulation software was developed at the University of

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

Berkeley. It is constantly under development by an active community of researchers. The latest version at the time of writing this thesis is ns-2 2.28.

The standard ns-2 distribution runs on Linux. However, a package for running ns-2 on Cygwin (Linux Emulation for Windows) is available. In this mode, ns-2 runs in the Windows environment on top of Cygwin as shown in the figure 4.1. The simulations performed (discussed in following sections) have been run in this environment.

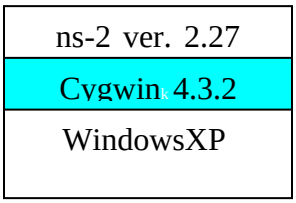


Figure.4.1: ns-2 over Cygwin

NS-2 provides a split-programming model; the simulation kernel is implemented using C++, while the Tcl scripting language is used to express the definition, configuration and the control of the simulation. This split-programming approach has proven benefits over conventional programming methods. Also, NS-2 can produce a detailed trace file and an animation file for each ad hoc network simulation that is very convenient for analyzing the routing behavior.

Wireless Support

The Monarch research group at Carnegie-Mellon University developed support for simulation of multi-hop wireless networks complete with physical, data link, and medium access control (MAC) layer models on NS-2. It provides tools for generating data traffic and node mobility scenario patterns for the simulation. Also, four ad hoc network routing protocols (AODV, DSDV, DSR and TORA) have been implemented.

In NS-2, the Distributed Coordination Function (DCF) mode of IEEE 802.11 for wireless LANs is used as the MAC layer protocol. The radio model uses characteristics similar to a commercial radio interface, Lucent's WaveLAN [30]. WaveLAN is modeled as a shared-media radio with nominal bit rate of 2Mb/s and a

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

nominal radio range of 250 meters. The signal propagation model combines both a free space propagation model and a two-ray ground reflection model.

Other add-on utilities

The standard ns-2 distribution comes with several "add-on" utilities which can be used to model the motion of the nodes, specify the traffic flow between them or visualize the network topology and traffic flow as an animation. Some of these utilities used for the experiments are further described below-

(i) cbrgen.tcl: The ns –package comes with a traffic generator utility which can be found in the folder **~ns/indep-utils/cmu-scen-gen/** (where ~ns denotes the ns-directory, for example, **/home/administrator/ns-allinone2/ns-2.27/** for the ns-2.27 version) **.** This utility is used to generate trace files for specifying the type, duration and the rate of traffic flow in the network. The utility can be invoked by calling the Tcl script **cbrgen.tcl** as follows-

$ ns cbrgen.tcl [*list of parameters*]

List of Parameters:

- Type of traffic: CBR or TCP
- Seed: starting number for random number generator
- Nr: number of node
- Nc: maximum number of connection
- Rate: number of packet per second (bit rate)

The output values can be written to a file using the > directive on the command line. This file can be used as an input to the Tcl script which is described in a later section.**(ii)setdest utility**: The setdest utility developed at CMU is used to generate node movements according to the Random Waypoint Model [31]. It is available under **~ns/indep-utils/cmu-scen-gen/setdest** directory and consists of setdest{.cc,.h} and Makefile. The utility can be run with the following arguments-

**./setdest [-n num_of_nodes] [-p pausetime] [-s maxspeed] [-t simtime] **
[-x maxx] [-y maxy] > [outdir/movement-file]

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

The outdir/movement file specifies the output file which can be integrated with the simulation script as described in the tutorial section.

(iii) Network Animator (nam): The network animator (nam) is a graphical tool used to visualize the simulation results graphically and trace the packet flow in a network as shown below -

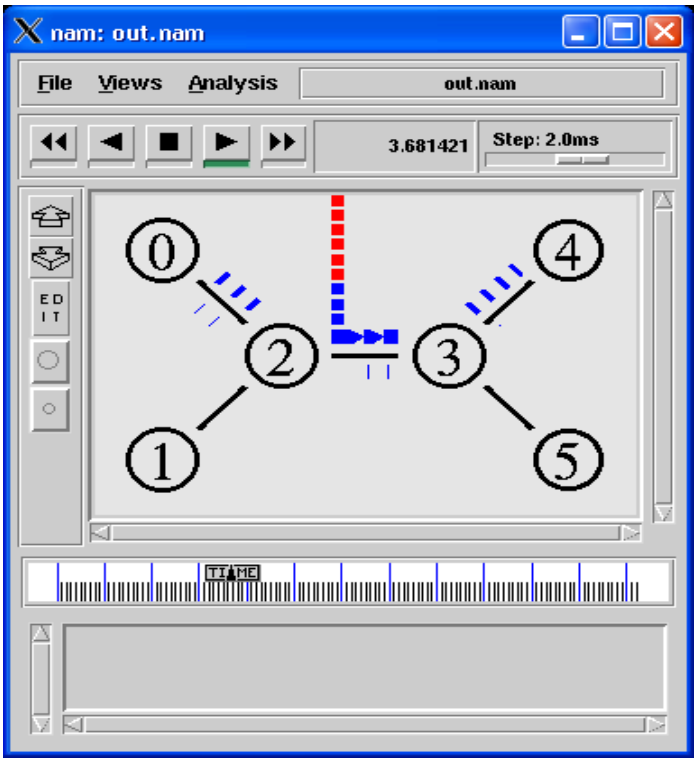


Figure 4.2: Screenshot of Nam window

Advantages and Disadvantages of ns-2

The main advantage of the ns-2 simulator is that it is an open-source software and hence freely available. Further, it is also easily extensible; any addition or modification to existing routing protocols is relatively easy. However, the flip side is the complexity of coding – An understanding of two languages, C++ and Tcl is

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

needed to develop any new protocols due to the split-programming approach. Besides, the user interface is also not attractive and the learning curve is steep.

Mobility Modeling

In order to simulate the movement of nodes in an ad hoc network, several mobility models have been proposed [31]. It is quite important that the mobility model chosen represent the movement of the nodes exactly since the mobility of the nodes impacts their performance. The mobility models can be classified into two categories based on the temporal and spatial dependency between the nodes in the network – *entity mobility models* and *group mobility models*. The following sections describes these mobility models in detail –

Entity mobility models

The entity mobility models represent the movement of nodes where each node's movement is independent of other node's movement. Many such mobility models have been proposed. This section discusses a few of them used for research.

i. Random Waypoint Mobility Model :

As the name suggests, the random waypoint mobility model represents the random motion of nodes in a terrain. The movement pattern of a node in this model is as follows – first, the node stays in a location for certain period of time called the *pause time*. Once this time expires, it chooses a random destination in the simulation area and a velocity that is uniformly distributed between *[minspeed, maxspeed]*. The mobile node then travels towards the newly chosen destination with a uniform speed. After reaching the destination, it is again static for the duration of *pause time* and continues the process. The RWM has been extensively used in modeling the movement of nodes for the study of protocol performance [5] [10] [11] [16].

The RWM has found to be insufficient to capture the realistic movement of nodes. Further, it also fails to converge when the pause time increases and the average speed of the nodes decreases over time [31]. One of the solutions proposed for this

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

problem is to set a non-zero minimum speed for the nodes. Another solution is to "cut off" some initial part of the simulation so that the nodes' movements stabilize.

Group mobility models

The entity mobility models depict independent motion of the nodes in a MANET. However, there are scenarios in which the nodes form clusters, and the movement of the nodes within the clusters is dependent on the movement of other nodes. For example consider the battlefield scenario where groups of soldiers are deployed in a battlefield. In this case every soldier's movement in the group is dependent upon the troop leader. The group mobility models capture such movements of nodes. In this section, one of the group mobility models- the Reference Point Group Mobility (RPGM) model is explained.

i. The Reference Point Group Mobility (RPGM) Model

The RPGM model represents the random motion of a group of nodes as well as the motion of the individual nodes within the group. An individual node in a group moves randomly depending upon the direction and velocity of its "logical center", which is updated at predefined time intervals. The logical center of a group is used to calculate a *group motion vector*, which completely characterizes the movement of the nodes within its group. Further, each node also selects is direction and velocity according to a *random motion vector* and a fixed reference point. The random motion of both the logical center and the individual nodes are calculated using the Random Waypoint Model.

The RPGM model can be used to depict several scenarios of deployment such as movement of soldiers in a battlefield, avalanche rescue, etc.

Scenario-based Experiments for Performance Evaluation ofMANET Routing Protocols

In order to analyze the performance of routing protocols in MANETs in the real world, a scenario based simulation analysis is needed since there is a lack of necessary infrastructure for their deployment. Most of the earlier work done in this area [5] [10] [11] have assumed the Random Waypoint model, which fails to capture the realistic movement of the nodes. In this section, we describe a set of experiments

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

conducted to analyze the performance of the AODV routing protocol in a battlefield scenario. Initially an explanation of the experimental metrics and the setup is described, followed by the scenarios used for our simulations. The results give an idea of how the protocol behaves in the given scenario and helps identify the metrics for optimal performance of the protocol.

Performance evaluation of AODV in a battlefield scenario

As explained in section 2.4.2, the AODV routing protocol uses a combination of table-driven and reactive methods to achieve optimal performance. It has been found previously, that AODV achieves a higher packet delivery fraction and lower latency than the table-driven protocols. Further, it also adapts well to node mobility and link changes. In following sections we describe the experiments carried out to analyze the performance of AODV in a battlefield scenario. It is found that AODV achieves high packet delivery fraction, low end to end delay and normalized routing loads in medium size networks with lower mobility of nodes.

Experimental Setup and Metrics

The ns-2 simulator was used for the experiments. We now describe the traffic pattern, the scenario description and the metrics that were used for the experiments.

(i) The traffic pattern

The traffic pattern file was generated using the "cbrgen.tcl" script (explained in section 4.2.2). The parameters used were as follows –

Type of traffic	Constant Bit Rate
Packet Size	512 bytes
Packet Rate	4 pkts/sec
Maximum number of connections	20

Table 4.1: Traffic pattern

(ii) Scenario description

The scenario was generated using the BonnMotion software. BonnMotion is a Java-based software which creates and analyses mobility scenarios. It generates the

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

movements of nodes in an ad hoc network as a trace file which can be imported into ns-2 (explained in the tutorial provided in appendix-B). It has support for several mobility models such as the RPGM, Random Waypoint model, Gauss Markov mobility model, etc. The following metrics were used to depict a battlefield scenario.

Dimensions	2000*2000
Mobility Model	Reference Point Group Mobility Model (RPGM)
No. of nodes	50
Min. speed	1 m/s
Max. speed	5 m/s
Average number of nodes in a group	10
Probability of group change	0.01
Pause time	60 sec

Table 4.2: Parameters for the battlefield scenario

(iii) Metrics:

The following metrics were used for performance evaluation-

a. *Packet Delivery Fraction (PDF)*: This is the ratio of total number of packets successfully received by the destination nodes to the number of packets sent by the source nodes throughout the simulation.

$$PDF = \frac{numberOf\ \text{Re}ceivedPack\ ets}{numberOfSe\ ntPackets}$$

This estimate gives us an idea of how successful the protocol is in delivering packets to the application layer. A high value of PDF indicates that most of the packets are being delivered to the higher layers and is a good indicator of the protocol performance.

b. *Normalized Routing Load (NRL)*: This is calculated as the ratio between the no. of routing packets transmitted to the number of packets actually received (thus accounting for any dropped packets).

$$NRL = \frac{numberOfRo\ utingPacke\ tsSent}{numberOfDa\ taPackets\ \mathrm{Re}\ ceived}$$

This metric gives an estimate of how efficient a routing protocol is since the number of routing packets sent per data packet gives an idea of how well the protocol maintains the routing information updated. Higher the NRL, higher the overhead of routing packets and consequently lower the efficiency of the protocol.

c. *Average end to end delay (AED)* : This is defined as the average delay in transmission of a packet between two nodes and is calculated as follows-

$$AED = \frac{\sum_{i=0}^{n} (timePacket\ \mathrm{Re}\ ceived_{\mathrm{i}} - timePacket\ Sent_{i})}{totalNumbe\ rOfPackets\ \mathrm{Re}\ ceived}$$

A higher value of end-to-end delay means that the network is congested and hence the routing protocol doesn't perform well. The upper bound on the values of end-to-end delay is determined by the application. For example multimedia traffic such as audio and video cannot tolerate very high values of end-to-end delay when compared to FTP traffic.

(iv) Research methodology

Three parameters in the battlefield scenario were varied - pause time, the total number of nodes and average number of nodes in a group and their impact on the three metrics described above were studied. The results are discussed in the next section.

Results

i. Effect of varying the number of nodes

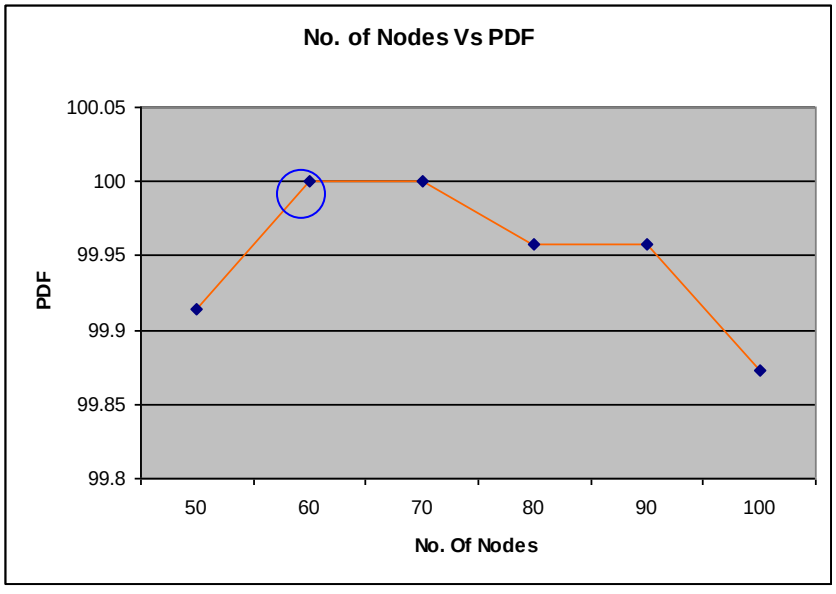
The number of nodes was varied from 50 to 100 and the effect on PDF, NRL and AED was studied. The results can be found in table 4.3 and figures 4.3, 4.4 and 4.5.

e-ISSN 2320 –7876 www.ijfans.org
Research Paper
Vol.11, Iss.9, Dec 2022

No. Of Nodes	Packet Delivery Fraction (%)	Average End-end delay (sec)	Normalized Routing Load
50	99.91438	0.006738278	0.2570694
60	100	0.006566893	0.3088803
70	100	0.013576984	0.42168674
80	99.95756	0.032688957	0.47558385
90	99.95761	0.010179137	0.49618322
100	99.872444	0.010737591	0.553427

Table 4.3: Effect of varying the number of nodes

It is found that the packet delivery fraction decreases as the number of nodes in the network increases. This is due to the fact that as number of nodes increases, the congestion in the network also increases and hence the number of lost packets due to retransmission also increases. Further, since AODV uses a table driven approach, the processing delay at the nodes also increases with an increase in the size of the network thereby accounting for the higher end-to-end delay. The normalized routing load increases with an increase in number of nodes due to an increase in the routing packets in the network.



e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

Figure 4.3: Effect of varying the number of nodes on the pause time

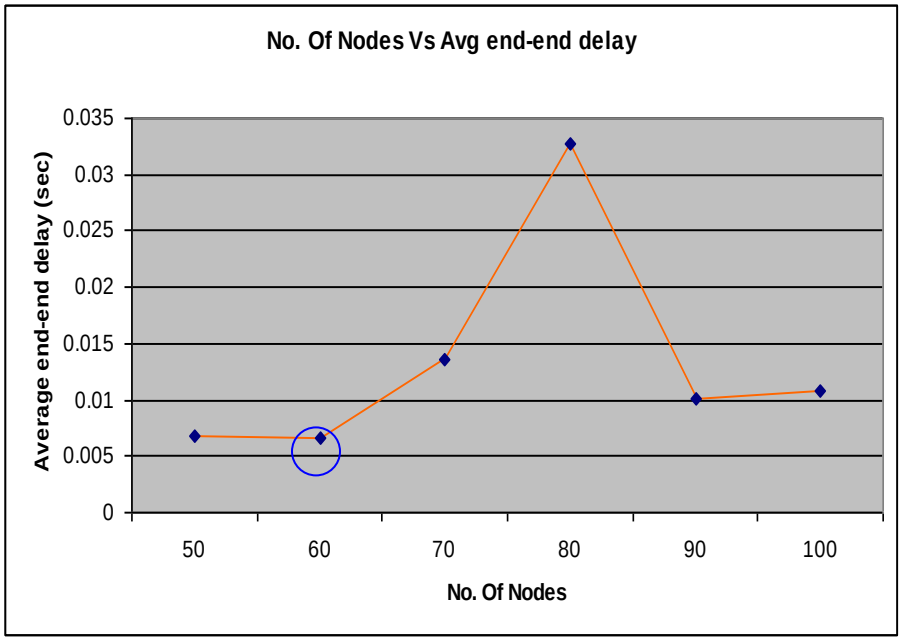


Figure 4.4: Effect of varying the number of nodes on the Average end-end delay

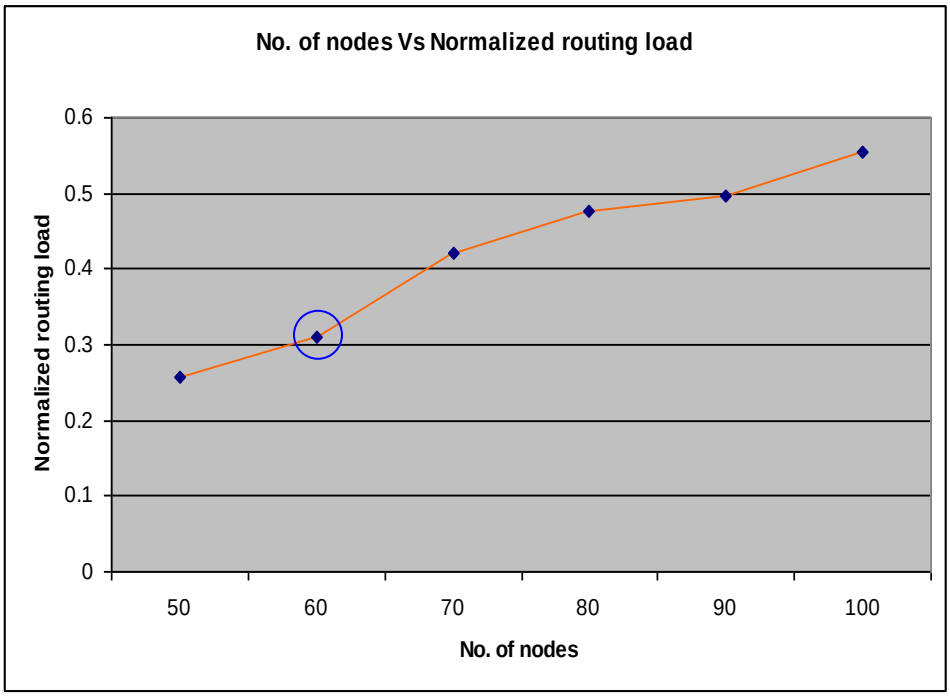


Figure 4.5: Effect of varying the number of nodes on the Normalized Routing Load

The blue circles in figures 4.3, 4.4 and 4.5 represent the "optimal points" which corresponds to the highest PDF, lowest end-to-end delay and the lowest normalized routing load. It is found that for 60 nodes we achieve this optimal point.

ii. Effect of varying the pause time

The effect of varying the pause time on the three metrics are shown in table 4.4 and the corresponding graphs are shown in figures 4.6, 4.7 and 4.8. It can be inferred that as pause time varies, the packet delivery fraction also increases. This is due to the fact that as pause time increases, the relative mobility of the nodes decreases, and hence the congestion also decreases in the network.

Pause Time (sec)	Packet Delivery Fraction (%)	Average End-to-end delay (sec)	Normalized routing load
10	99.87218	0.006634372	0.25597268
20	99.957466	0.006683255	0.25531915
30	99.91536	0.006524965	0.25412962
40	100	0.010312819	0.27754056
50	100	0.010314601	0.2742616
60	99.91438	0.006738278	0.2570694

Table 4.4: Effect of varying the pause time

The end-to-end delay also decreases as the pause time is increased. This can be explained as follows – as the pause time increases, the network topology is relatively stable and hence the number of stale routes in the routing tables decreases. Thus route discovery and maintenance take less time. This also reduces the number of routing packets in the network, thereby decreasing the NRL.

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

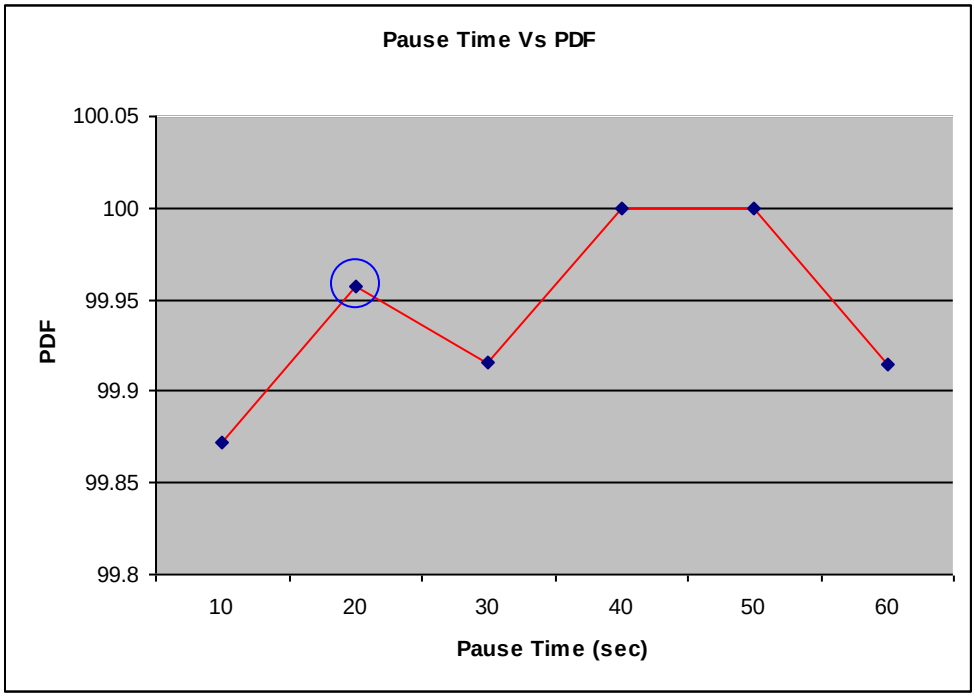


Figure 4.6: Effect of varying the pause time on PDF

Figure 4.7: Effect of varying the pause time on average end to end delay

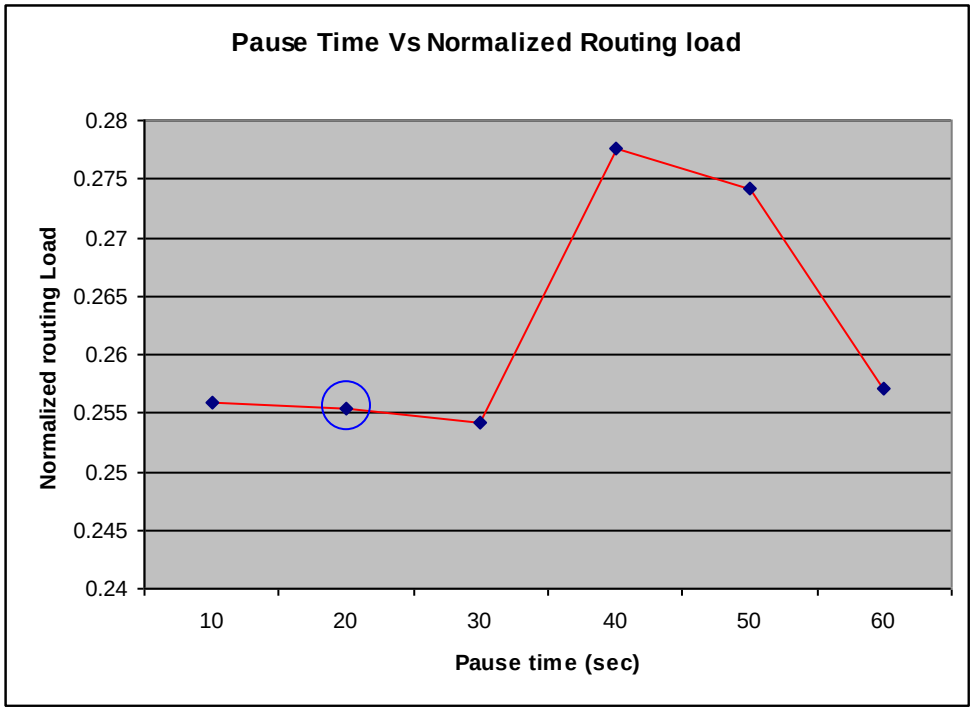


Figure 4.8: Effect of varying the pause time on NRL

From figures 4.6, 4.7 and 4.8 it can be inferred that for a pause time of 20 sec (represented by a blue circle), we obtain optimal values for the three metrics.

iii. Effect of varying the average number of nodes

The effect of varying the average number of nodes on the three metrics is shown in table 4.5.

Avg. No of Nodes	Packet Delivery Fraction (%)	Average end-end delay (sec)	Normalized routing load
5	100	0.011443271	0.27754056
6	99.95726	0.015179819	0.2992732
7	99.91536	0.006548823	0.25477707
8	100	0.006707324	0.25575447
9	99.87288	0.018596672	0.3182011
10	99.91438	0.006738278	0.2570694

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

Table 4.5: Effect of varying the average number of nodes

The graphs for the three metrics are shown in figures 4.7.4.8 and 4.9.

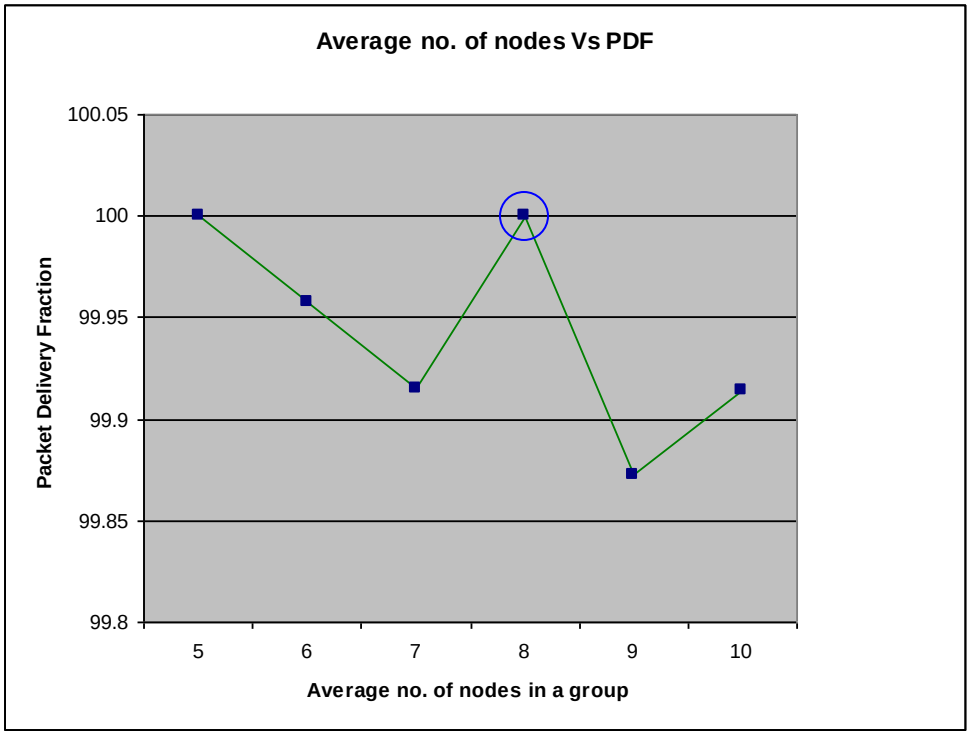


Figure 4.9: Effect of varying the average number of nodes on the PDF

From figure 4.9 it can be inferred that the PDF decreases as the average number of nodes in a group is decreased. This is due to the face that as the average number of nodes increases, the density increases, thereby causing more congestion in the network. Since AODV uses HELLO messages for neighbor detection, as the node density increases, the number of such packets also increases, thereby decreasing the PDF.

The effect of increasing the average number of nodes on the average end-to-end delay is shown in figure 4.10. It is found that the delay decreases the density increases, thereby indicating that AODV scales well to the network density. Further by not using source routing, it achieves lower latency due to a lesser packet overhead.

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

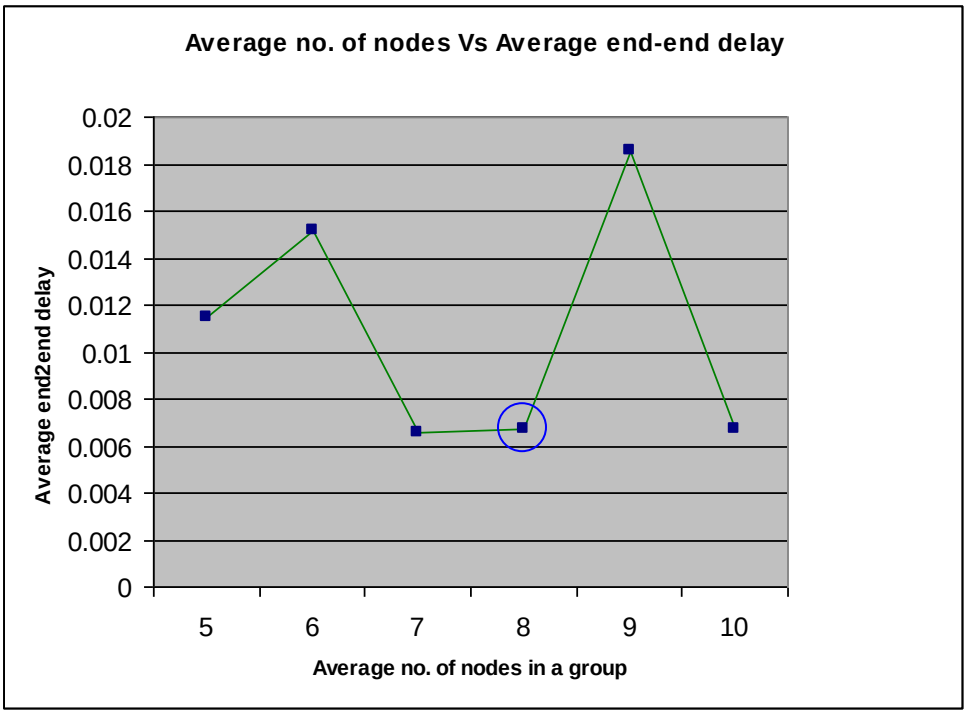


Figure 4.10: Effect of varying the average number of nodes on the AED

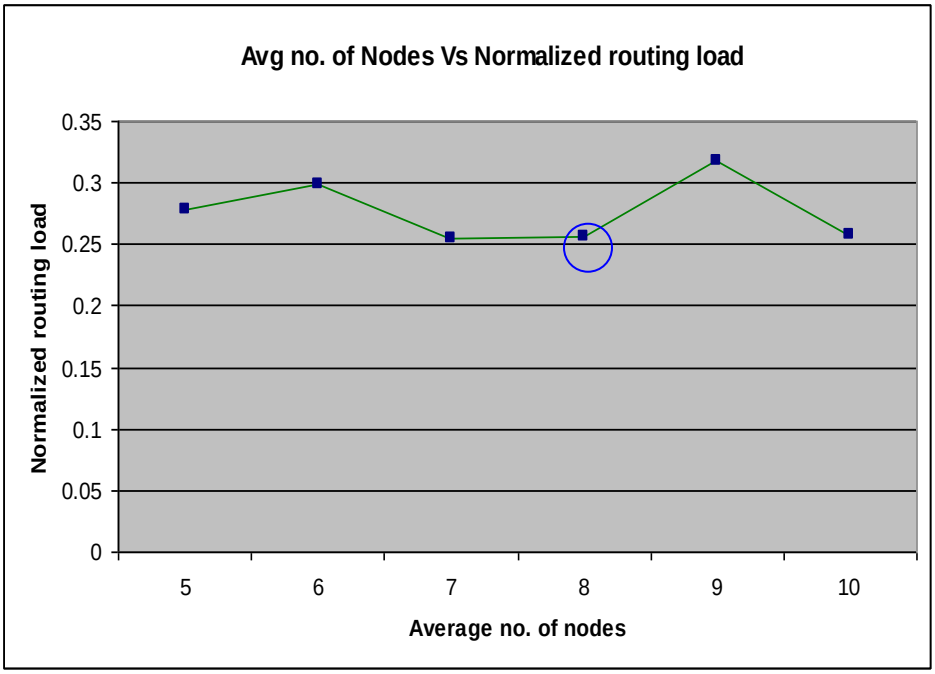


Figure 4.11: Effect of varying the average number of nodes on the NRL

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

Figure 4.10 shows the effect of varying the average number of nodes in a group on the routing load. In general, AODV has less routing overhead achieving a peak load of about 0.32 when the average number of nodes in a group is 9 (represented by blue circles in the graphs). From the graphs, it can be inferred that the optimal point corresponds to 8 nodes per group.

Conclusion

For the battlefield scenario, AODV has found to perform well for lower pause times (20 sec), higher density of nodes (9 per group) and smaller networks. As the network size increases, the performance drops due to a table-driven approach. However, since it does not use source routing, it has a much lower end to end delay for In order to analyze the performance of routing protocols in practice, such a scenario-based approach is vital. It also helps identify the suitable routing protocol for an optimal network size, the mobility of the nodes, the network density and a given traffic pattern. A more comprehensive study of other routing protocols such as DSR, TORA, DSDV, etc. is needed to choose the right protocol for a given scenario. This chapter discusses about the simulation-based approach to performance study of routing in MANETs. It gives an introduction to the ns-2 simulator and describes some useful utilities for ad hoc networking research. Some of the pros and cons of the ns-2 simulator are then described.

The chapter also discusses some mobility models used for simulating the movement of nodes in an ad hoc network. Several other mobility models are being developed which try to mimic the environment in which the nodes are deployed. Such models are very useful in gaining a deeper understanding of the performance of routing protocols in realistic deployments.

The rest of the chapter describes a set of scenario-based experiments carried out to analyze the performance of AODV protocol in a battlefield scenario. The experiments give an insight into the working of the protocol in such an environment.

REFERENCES

[1]C. Siva Ram Murthy, B.S. Manoj, "*Ad Hoc Wireless Networks : Architectures and Protocols*", Prentice Hall Publishers, May 2004, ISBN 013147023X

[2] C.-K. Toh, "*Ad Hoc Mobile Wireless Networks: Protocols and Systems*", Prentice Hall publishers, December 2001, ISBN 0130078174[3] C. Perkins and P. Bhagwat, *Highly Dynamic Destination-Sequenced Distance-Vector Routing* (*DSDV*) for Mobile Computers. In Proc. of the ACM SIGCOMM, October 1994.http://www.cs.umass.edu/~mcorner/courses/691M/papers/perkins.pdf

[4] Shree Murthy, J.J. Garcia-Luna-Aveces, "*A Routing Protocol for Packet Radio Networks*," Proc. ACM International Conference on Mobile Computing and Networking, pp. 86-95, November, 1995 http://www.pdos.lcs.mit.edu/decouto/papers/dube97.pdf

[5] C.-C. Chiang, "*Routing in Clustered Multihop, Mobile Wireless Networks with Fading Channel*," Proc. IEEE SICON '97, Apr. 1997, pp. 197–211. http://www.ics.uci.edu/~atm/adhoc/paper-collection/gerla-routing-clustered-sicon97.pdf

[6] [online] The Secan Lab, University of Luxembourg, Luxembourg. http://wiki.uni.lu/secan-lab/Distributed+Bellman-Ford.html

[7] [online] The Secan Lab, University of Luxembourg, Luxembourg. http://wiki.uni.lu/secan-lab/Count-To-Infinity+Problem.html

[8] D B. Johnson, D A. Maltz, and Y. Hu, "*The dynamicsourcerouting protocol for mobile ad hoc network*," Internet-Draft, April 2003. http://www.ietf.org/internet-drafts/draft-ietf-manet-dsr-09.txt

[9] C.E. Perkins, E. Royer, and S.R. Das, "*Ad hoc on demand distance vector (AODV) routing*," Internet Draft, March 2000. http://www.ietf.org/internetdrafts /draft-ietf-manet-aodv-05.txt

[10] Samir R. Das, Charles E. Perkins, Elizabeth M. Royer and Mahesh K. Marina. *"Performance Comparison of Two On-demand Routing Protocols for Ad hoc Networks."* IEEE Personal Communications Magazine special issue on Ad hoc Networking, February 2001, p. 16-28.

http://www.ronai.hu/././library/Performance_comparison_of_AODV_and_DSR-Perkins.pdf

[11] David B Johnson and David A Maltz. "*Dynamicsourcerouting in adhocwirelessnetworks"*. In Imielinski and Korth, editors, Mobile Computing, volume 353. Kluwer Academic Publishers, 1996.

[12] Haas Z.J, " *A new routing protocol for the reconfigurable wireless network"*. In Proceedings of the 1997 IEEE 6th International Conference on Universal Personal Communications, ICUPC '97, San Diego, CA, October 1997; pp. 562 -- 566. http://www.ics.uci.edu/~atm/adhoc/paper-collection/haas-routing-protocol-icupc97.ps.gz

[13] Kimaya Sanzgiri, Bridget Dahill, Brian Neil Levine, Clay Shields and Elizabeth M. Belding royer. *"A Secure Routing Protocol for Ad Hoc Networks" (ARAN)* In International Conference on Network Protocols (ICNP), Paris, France, November 2002. www.cs.ucsb.edu/~kimaya/icnp2002.pdf

[14] Stefano Basagni, Marco Conti, Silvia Giordano, Ivan Stojmenovic, "*Mobile Ad Hoc Networking*", ISBN: 0-471-37313-3, Wiley-IEEE Press: *Chapter 12: Ad hoc networks Security* Pietro Michiardi, Refik Molva http://www.eurecom.fr/~michiard/pub/michiardi-adhoc.pdf

[15] Hongmei Deng, Wei Li, and Dharma P. Agrawal, "*Routing Security in Wireless Ad Hoc Network*," IEEE Communications Magzine, vol. 40, no. 10, October 2002.

[16] Yih-Chun Hu, David B. Johnson, Adrian Perrig. *"SEAD: Secure Efficient Distance Vector Routing for Mobile Wireless Ad Hoc Networks"*, Fourth IEEE Workshop on Mobile Computing Systems and Applications (WMCSA '02), pp: 3-13, Jun 2002. http://www.cs.colorado.edu/~rhan/CSCI_7143_001_Fall_2002/Papers/Perrig2002_wmcsa02.pdf

[17] Yih-Chun Hu, Adrian Perrig, David B. Johnson. *"Ariadne: A secure On-Demand Routing Protocol for Ad hoc Networks"* MobiCom 2002, September 23-28, 2002, Atlanta, Georgia, USA. http://lambda.cs.yale.edu/cs425/doc/ariadne.pdf

e-ISSN 2320 –7876 www.ijfans.org
Vol.11, Iss.9, Dec 2022

[18] A. Perrig, R. Canetti, D. Tygar, and D. Song, "*The TESLA Broadcast Authentication Protocol*," Cryptobytes,, Volume 5, No. 2 (RSA Laboratories, Summer/Fall 2002), pp. 2-13.http://www.rsasecurity.com/rsalabs/cryptobytes/

[19] P. Papadimitratos and Z. Haas. *"Secure routing for mobile ad hoc networks" (SRP)* SCS Communication Networks and Distributed Systems Modeling and Simulation Conference, pp. 27--31, January 2002.
http://wnl.ece.cornell.edu/Publications/cnds02.pdf

[20] Internet X.509 Public Key Infrastructure Certificate and CRL Profile - *RFC 2459*

[21] S. Capkun, L. Buttyan and J-P Hubaux. "*Self-Organized Public-Key Management for Mobile Ad Hoc Networks* ", *IEEE Transactions on Mobile Computing, Vol. 2, No. 1*, Jan-Mar 2003, pp. 52-64

[22] Weihong Wang, Ying Zhu, Baochun Li. "*Self-Managed Heterogeneous Certification in Mobile Ad Hoc Networks* ", *in the Proceedings of IEEE Vehicular Technology Conference (VTC 2003)*, Orlando, Florida, 10/6-9, 2003.

[23] J. Kong, P. Zerfos, H. Luo, S. Lu, and L. Zhang. "*Providing robust and Ubiquitous Security support for Mobile Ad Hoc Networks* ", *Proceedings of the 9th International conference on Network Protocols (ICNP)*, Riverside, California, USA, November 11-14 2001.

[24] Edith C. H. Ngai and Michael R. Lyu. "*Trust- and Clustering-Based Authentication Services in Mobile Ad Hoc Networks*", 24th International Conference on Distributed Computing Systems Workshops - W4: MDC (ICDCSW'04), Hachioji, Tokyo, Japan, 3/23-24, 2004.

[25] L. Zhou and Z. Haas. "*Securing Ad Hoc Networks*", IEEE Network magazine, special issue on networking security, Vol. 13, No. 6, November/December 1999.

[26] Matei Ciobanu Morogan, Sead Muftic. "*Certificate Management in Ad Hoc Networks*", 2003 Symposium on Applications and the Internet Workshops (SAINT'03 Workshops), January 27 - 31, 2003, pp. 337.

[27] F. Stajano and R. J. Anderson. "*The resurrecting duckling: Security issues for ad-hoc wireless networks*" In 7th Security Protocols Workshop, volume 1796 of Lecture Notes in Computer Science, Cambridge, United Kingdom, 1999. Springer-Verlag, Berlin Germany.

[28] Dirk Balfanz, D. K. Smetters, Paul Stewart and H. Chi Wong: "*Talking To Strangers: Authentication in Ad-Hoc Wireless Networks*", Symposium on Network and Distributed Systems Security (NDSS'02), Xerox Palo Alto Research Center, Palo Alto, USA, 2002.