IJISCS (International Journal of Information System and Computer Science)

Full Paper
eISSN 2598-246X
pISSN 2598-0793

NETWORK SIZE SIMULATION-BASED STUDY OF ROUTING PROTOCOLS IN WIRELESS AD HOC NETWORK

Augustine Chidiebere Onuora[1], ***Eyo E. Essien[2]***, ***Felix U. Ogban[3]***
[1]Department of Computer Science, Akanu Ibiam Federal Polytechnic Unwana. Ebonyi State, Nigeria.
[2,3]Department of Computer Science, University of Calabar, Cross-River State, Nigeria.

*Corresponding author
holyaustin@yahoo.com
aconuora@akanuibiampoly.edu.ng

Article history:
Received July 13, 2021
Revised October 30, 2021
Accepted November 6, 2021

Keywords:
Ad hoc;
Wireless;
MANET;
Performance;
Simulation;
NS3;
Network Size.

Abstract
The extensive potential of wireless ad hoc networks in many different fields has recently gained significant research attention. Multihop routing is an important aspect that determines the whole network performance to a great magnitude. Multiple wireless ad hoc network routing protocols have been proposed with the aim of optimizing various aspects of network routing. As networks grow in size, computer network performance analysis becomes increasingly necessary. A simulation approach is often very useful. This research studies three different wireless ad hoc networks routing protocols and compared the performance as it relates to network size. Protocols considered in this study are; Optimized Link-State Routing Vector (OLSR), Destination-Sequenced Distance Vector (DSDV) and Ad hoc On-Demand Distance Vector (AODV) routing protocol classified as proactive routing protocol (OLSR and DSDV) and reactive routing protocol (AODV). These protocols were simulated using the Network Simulator 3 (NS3) using a performance-compared scenario on the size of the network. Varying network sizes of 30, 60 and 100 nodes were simulated. The result showed that AODV performed better as the network size increases.

1.0. INTRODUCTION

Ad Hoc which is a Latin phrase means "for this purpose," and is a term used often to describe flying solutions for a specific purpose. Ad hoc networks are formed when devices connect and communicate without using a router or a wireless computer base station [1]. Ad hoc networks are predominantly local wireless networks (LANs). Devices communicate directly with each other instead of using a base station or access points, such as Wi-Fi LANs, for coordinating data transfer. Routing operations are carried out by each device, which determines the path using the routing algorithm and transmits data to other devices to complete the routing task. A Wireless Ad hoc Network is a wireless network that is not framed by a network infrastructure. It also includes Vehicular ad hoc networks (VANET), Mobile ad hoc networks (MANET), Wireless Sensor Networks (WSN) and wireless mesh networks (WMN) are all examples of ad hoc networks. [2] categorized wireless ad hoc networks into five namely: MANET, WMN, VANET, WSN, and SPAN.

MANET: This network have no fixed nodes, they are mobile in nature including the routers (nodes) themselves. Each MANET device is free to move around, changing its connections with other devices regularly. Each packet of data must be forwarded to its destination, and thus must be a router. Where the wired network is unavailable, MANETs are employed. Battlefield communication, destructive recovery, and rescue operations rely on MANET network.

WMN: Wireless mesh networks are communications networks that contain radio nodes within a mesh topology. Connection to all nodes are done in a mesh style connecting the entire network nodes. The network includes devices such as gateways, nodes, customers, routers etc. The mesh networks are often less mobile, as redirecting results in data transmission delays that are less difficult to predict. The effectiveness of WMNs depends heavily on the selection and the application quality of the routing convention. Mesh clients can be wireless, such as mobile phones and laptops, desktop computers, etc [3].

VANET: A new form of MANET is Vehicle Ad Hoc Network (VANET). Vehicles serve as mobile nodes in the VANET. Applications such as active security and smart transportation need appropriate communication technology for vehicle-to-vehicle interaction especially during vehicular routing. Vehicular ad hoc networks are an expanded technology that incorporates cellular technology to deliver outstanding communication and improve security and effectiveness on road transport [4].

WSN: As a self-configured wireless network that does not require any infrastructure, WSN tracks and transfers data to a central location or sink where it may be monitored and analyzed. It is possible to monitor physical or environmental variables, such as temperature and sound through the use of a wireless sensor network. Individual nodes in a wireless sensor network (WSN) are bound by design in terms of storage capacity, processing speed and bandwidth. The sensor nodes are in charge of self-organizing the network infrastructure utilized in communication once they've been deployed [5]. Its sensors operate in event-driven mode or in continuous mode. The local positioning algorithm and the global positioning system can be used to obtain information on the location and the position of devices.

SPAN: is referred to as Smart Phone Ad hoc Network. When other infrastructures are unavailable, overwhelmed, or untrustworthy, Mobile phones and tablets are turned into routers as part of the Smart Phone Ad hoc Networking (SPAN) initiative. [6].

The impact of wireless technology on society is revealing. Wireless ad hoc network research has continued for decades. The origins of the Wireless ad hoc network may be traced back to the Defense Advanced Research Project Agency (DARPA) and packet radio networks (PRNet), which subsequently evolved into the survivable assistive radio networks (SURAD) program [7]. The goal of this study is to compare and assess the performance of the DSDV, OLSR, and AODV protocols in Wireless Ad hoc Networks.

2.0. REVIEW OF RELEVANT LITERATURES

In the 1990s, researchers began studying ad-hoc networks. An Ad hoc network's nodes can link dynamically to each other in whatever way they see fit. Ad hoc networks require routing techniques that are different from those used of regular wired networks because to their dynamic nature. MANETs are ad hoc networks that incorporate mobile nodes. A broad number of routing protocols were proposed by [8] to overcome the constraints of wired networks in MANETs and described MANET routing protocols' operating mechanics. The work of [9] showed the simulation of two routing protocols. An Optimized Link-State Routing (OLSR) and Ad hoc On-Demand Distance Vector (AODV). The performance of these two protocols was simulated and performance compared. The NS2 simulator was used to execute this simulation using the Tcl (Tool Command Language) Network programming language.

Another survey by [10] examined and compared two simulation-based performance evaluation papers: “A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols” and “Simulation-based Performance Evaluation of Routing Protocols for Mobile Ad Hoc Networks.” Each simulation's selection choices were questioned. The simulation techniques DSDV, TORA, DSR, and AODV were used to study ad hoc network routing protocols. The first study has shown to be more methodical, realistic, and has a higher degree of information in its performance evaluation than the second, including the MAC and link-layer data. They also discovered that the first paper's 'end-to-end delay' metric is superior to the second paper's 'path optimality' metric since it is more dependent on the method than the load.

A comprehensive survey of current network simulators for the newly emerging research area of three-dimensional wireless ad hoc and sensor networks, including airborne ad hoc networks and underwater sensor networks, was presented by [11], reviewing the major existing simulators and presenting their main features. Time Step-based Wireless Ad Hoc Network Simulator (TimSim) was developed by [12]. Its goal is to make it easier for simulation programs to migrate to real devices by offering useful APIs with the actual device driver. The Simulation engine was a discrete event processor with time step based features, and data may be sent at bit-level. One of TimSim's unique features is its ability to simulate multi-threaded programming.

Wormhole attacks are the most dangerous attack on ad hoc networks where an attacker node accepts packets at one point and rebroadcast them latter on at other points [13]. Further in their work, they studied and made Comparism to DSR, AODV and ZRP performance under the influence of several wormholes. Different scenarios are modeled by an average of 50 nodes. They analyzed the simulation for performance evaluation. Packet loss, Packet delivery ratio, Jitter delay and average end-to-end delays were statistically studied placing several wormhole nodes across the network.

In simulation-based studies, [14] tested MANET routing protocols' performance as node density increased. Their research examined the performance of proactive (fisheye state routing), reactive (ad hoc on-demand distance vector), and hybrid (zone routing protocol) routing protocols in terms of packet delivery ratio, average throughput, and average end-to-end latency. Network Simulator 2 (NS 2) was used to simulate protocols in order to assess their performance under various situations.

3.0. METHODOLOGY AND AD HOC NETWORK SIMULATION TOOLS

The research method used is known as the prototyping methodology. Experimentation is frequently used in conjunction with the prototyping model methodology. This research modeled various network sizes and observed their effect on the network through a network simulator. Network test-beds were used in the past testing network models. It came with a lot of challenges and then network simulators came to the rescue. Simulators are not affected by any of the test-bed flaws. More precisely, because simulators allow the network to be managed as a whole, they are much easier to use and monitor. Furthermore, because experiments are described as scenarios files, they can be replicated. The simulated network's size is only limited by the computational power available. Simulators use a variety of techniques to improve their accuracy, speed, scalability, and usability [15].

Network Simulation Software simulates the behavior of a modeled network in a repeatable and controllable environment for a variety of testing purposes. It makes use of simulation to figure out how different changes affect performance during a future configuration or application deployment. The following steps were followed to conduct this research. Firstly, Network Simulator 3 (NS3) was downloaded and installed. Secondly, the selection of three wireless Ad Hoc routing protocols which are OLSR, DSDV, and AODV. Thirdly, the scenario file was written in C++ for simulation of these protocols, and lastly Configuration and setting up the system for simulation based on some parameters. In our case study in this research, three different network sizes was modeled (30, 60 and 100).

3.1. Network Simulator 3 (NS3)

Ns3: Intended for academic and research purposes, ns-3 simulates Internet networks using discrete-event network simulation (DENS). In accordance with the GNU GPLv2 license, Ns-3 is freely available for research, development, and usage. A powerful simulation core that is well-documented, easy to use and debug, and satisfies the demands of the full simulation workflow, from simulation configuration to trace collecting and analysis, is at the heart of the ns-3 project's mission. Furthermore, this software architecture enables developers to create simulation models that are realistic enough to be utilized as a real-time network emulator that is connected with the actual world and that reuses many existing real-world protocol implementations, such as TCP/IP [16].

3.2. Routing Protocols

Three protocols were selected for simulation. A member of the reactive routing protocol named Ad hoc on-demand distance vector (AODV) and two proactive routing protocols which are Optimized link state routing (OLSR) and Destination sequenced distance vector (DSDV) protocols.

3.3. Network Size

The size of the network is varied from 30 nodes to 100 nodes. The number of nodes is increased by 30 nodes, then 40 nodes, and so on. It was decided to simulate an area of 300 x 1500 m, which is large enough for nodes to move about and be far enough away to examine the impact of multihop routing. To ensure that protocol behavior scales with network size, network sizes are changed. However, the likelihood of a connection (or a route) breaking increases as the network size grows.

3.4. Simulation Scenario and Parameters

Throughout the simulation, on all platforms, IEEE MAC is utilized for MAC layer communication during the simulation phase. Two control frameworks are taken over by the distributed coordination function (DCF), which is included in the MAC type layer. They are Request for Transmission (RTS) and Clear-to-Transmission (CTS). Number of nodes varied between 30, 60, and 100 nodes dispersed over a network size of 300 to 1500 meters in this simulation. For this example, the simulation settings are presented in Table 1. In a simulation environment, the distinctive behavior of an ad hoc network may be described by a variety of parameters, which can be manipulated in various ways. As indicated in the table below, the following parameter is of relevance to this investigation.

Table 1: Scenario Simulation Parameters.

Parameters	Properties
Operating System	Ubuntu 20.04 LTS
Network Simulator	Network Simulator 3 (NS3)
Protocols	AODV, DSDV, OLSR
Number of Nodes	30, 60, 100 nodes
Simulation Time	120 s
Map Size	300×1500 meters
Node Speed	20 m/s
Mobility Model	Random waypoint
Traffic Type	Constant bitrate (CBR)
Packet Size	512 bytes 2Kbps
Node Pause Time	0 s
Mac	Adhoc Wifi MAC
Bandwidth of links	2Mbit
Mac Standard	802.11B
No of Sinks	10
Physical mode	DsssRate11Mbps
Propagation Model:	Constant Speed Propagation Delay
Propagation Loss Model	Friis
Position Allocator:	Random Rectangular Position Allocator

4.0. RESULANTS AND DISCUSSION

Using a simulated area of 300*1500 sq. units, this research work presents a wireless Ad-Hoc network simulation of various existing protocols to ascertain their reaction on various network size. As the number of nodes increases, so does the complexity of the routing protocols. A routing protocol must be able to handle big and small networks equally well. In order to test the routing protocol's scalability, we'll change the size of the nodes and routes.

4.1. Performance Metrics

Performance indicators such as these were taken into account throughout the simulation. Performance calculation was done for some metrics. NS3 simulator was used to simulate the metrics below:

a. Sent Packets
b. Received Packets
c. Lost Packets
d. Packet Loss Ratio
e. Packet Delivery Ratio
f. Average Throughput
g. End to End Delay
h. End to End Jitter Delay

Table 2: Simulated data for a network with 30 nodes

Metrics (30 Nodes)	AODV	DSDV	OLSR
Total sent packets	1554	772	464
Total Received Packets	1013	152	152
Total Lost Packets	541	620	312
Packet Loss ratio (%)	34%	80%	67%
Packet delivery ratio	65%	19%	32%
Average Throughput	35.2767Kbps	1.02527Kbps	4.07126Kbps
End to End Delay	+9.52608e+10ns	+3.1118e+10ns	+3.16297e+09ns
End to End Jitter Delay	+4.92324e+10ns	+9.22011e+09ns	=+2.79221e+09ns
Total Flod id 10	155	10	8

Table 3: Simulated data for a network with 60 nodes

Metrics (60 Nodes)	AODV	DSDV	OLSR
Total sent packets	2690	773	503
Total Received Packets	2169	215	224
Total Lost Packets	521	558	279
Packet Loss ratio (%)	19%	72%	55%
Packet delivery ratio	80%	27%	44%
Average Throughput	20.8256Kbps	1.11774Kbps	1.35484Kbps
End to End Delay	+1.63881e+11ns	+3.20226e+08ns	+4.12753e+09ns
End to End Jitter Delay	+9.08434e+10ns	+3.35946e+08ns	+3.75242e+09ns
Total Flod id 10	432	10	7

Table 4: Simulated data for a network with 100 nodes

Metrics (100 Nodes)	AODV	DSDV	OLSR
Total sent packets	4548	775	714
Total Received Packets	3680	276	389
Total Lost Packets	868	499	325
Packet Loss ratio (%)	19%	64%	45%
Packet delivery ratio	80%	35%	54%
Average Throughput	12.8241Kbps	1.2096Kbps	1.50603Kbps
End to End Delay	+5.01019e+11ns	+7.26394e+09ns	+3.07469e+09ns
End to End Jitter Delay	+2.34614e+11ns	+3.2264e+09ns	+4.94914e+09ns
Total Flod id 10	1169	10	10

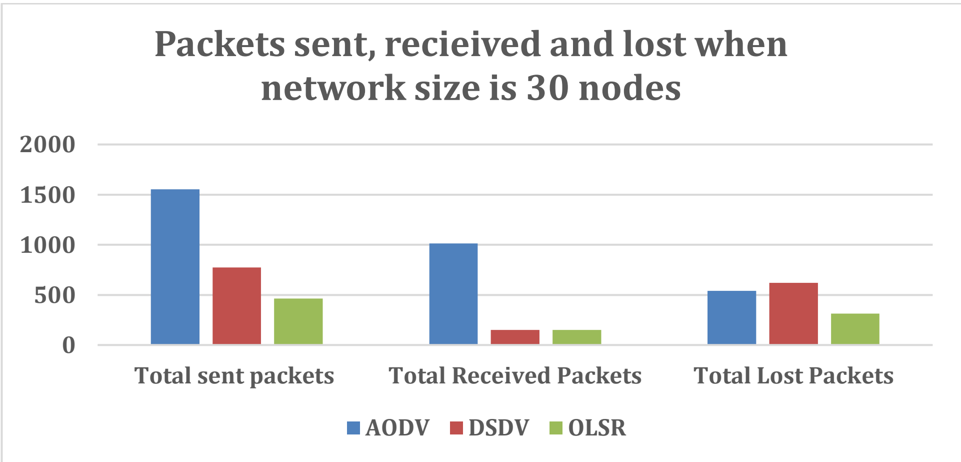

Fig 1: Total packet sent, received, and lost chart for 30 nodes

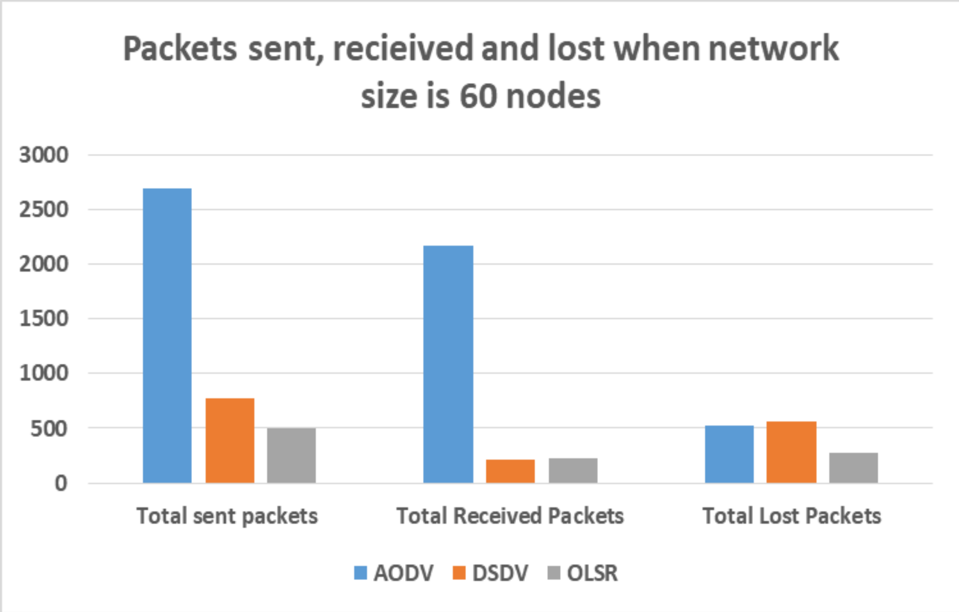

Fig 2: Total packet sent, received, and lost chart for 60 nodes

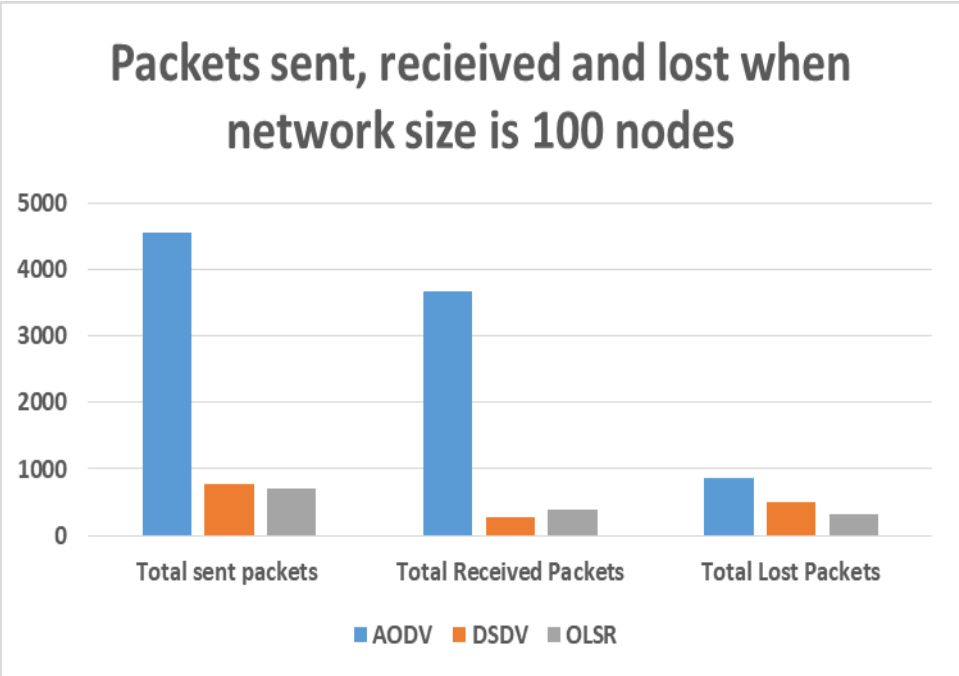

Fig 3: Total packet sent, received and lost chart for 100 nodes

From Fig1 (30 nodes), fig 2 (60 nodes) and Fig3 (100 nodes) above, AODV showed the highest packet data sent. AODV also showed that it was able to receive more packets than DSDV and OLSR. DSDV has the highest percentage of packet loss. OLSR is second best to AODV. The routing technique AODV employs (on-demand routing) gives it a better throughput performance than the rest which relies on the input in their various routing tables. Mobility changes as the network size increases. This makes DSDV and OLSR to find it difficult to maintaining and having an up-to-date routing table for efficient pack data transmission.

Table 5: Throughput data for network size 30, 60 and 100 nodes

Protocols	30 Nodes	60 Nodes	100 Nodes
AODV	35.2767	20.8256	12.8241
DSDV	1.02527	1.11774	1.2096
OLSR	4.07126	1.35484	1.50603

The associated chart for the table 5 above is shown below.

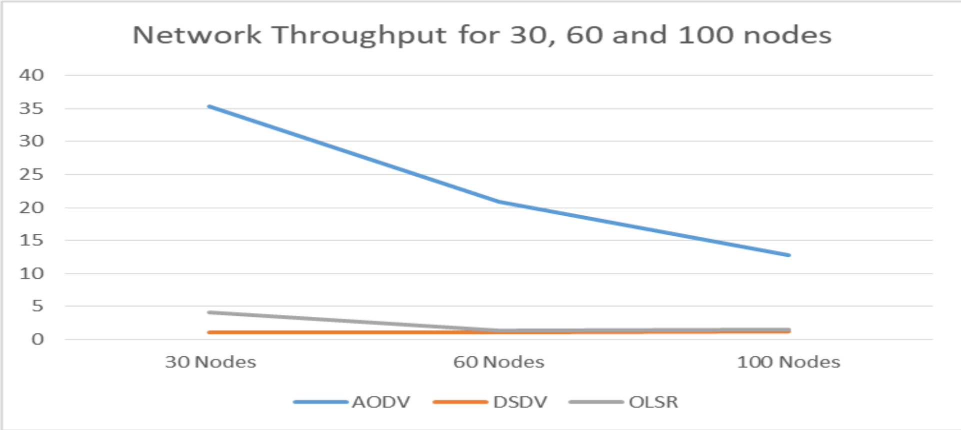

Fig 4: Network throughput chart

From the fig4 above, we can observe that AODV have the best throughput for 30 nodes, 6 nodes and 100 nodes with respective values of 35.2767 kb/s, 20.8256 kb/s and 12.8241kb/s. OLSR from the figure above showed that it is the second best with the values of 4.07126 kb/s, 1.35484 kb/s and 1.50603kb/s while DSDV has the worst throughput with 1.02527 kb/s, 1.11774 kb/s and 1.2096 kb/s.

Table 6: End-to-end delay data for network size of 30, 6kb0, 100 nodes

Protocols	30 Nodes	60 Nodes	100 Nodes
AODV	163.881	501.019	501.019
DSDV	0.320226	7.26394	7.26394
OLSR	4.12753	3.07469	3.07469

The associated chart for the table 6 above is shown below.

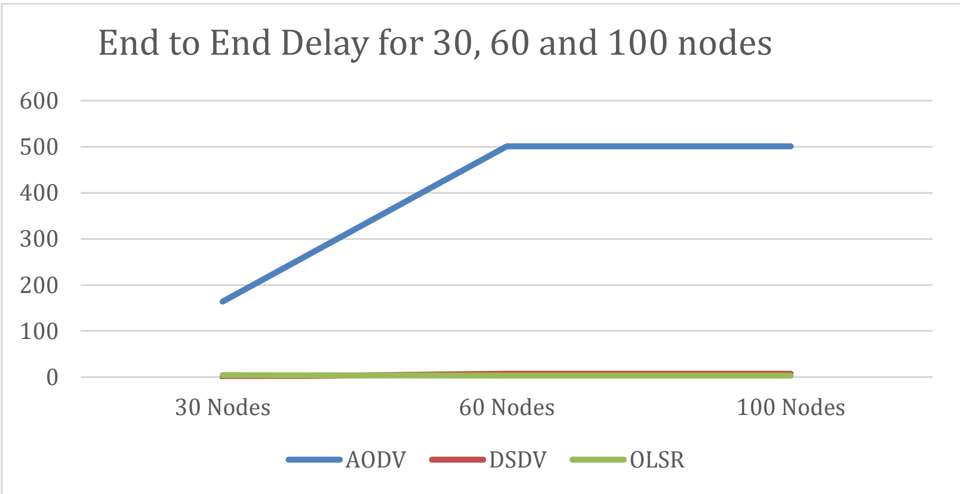

Fig 5: End to end delay chart

Even though the core purpose of this study is to ascertain the effect of network size on selected routing protocols, the end-to-end delay charts above showed that OLSR has the best end-to-end delay statistics for 30, 60 and 100 nodes followed by DSDV. AODV has the worst end-to-end delay.

5.0. CONCLUSION

This worked showed three ad hoc network protocols from the reactive and proactive category. From the results shown above, we can say that AODV routing protocol scalable and performed better as the network size is incremented. The analysis focused on the Network size increment while other parameters are constant. The effectiveness of the AODV (reactive routing protocol) from the simulation showed that the protocol is scalable. Various network sizes and number of nodes have been simulated. DSDV and OLSR did not function well when simulated as results showed that AODV perform better. For protocol comparisons and performance testing, the NS3 Simulator was utilized.

REFERENCES

[1] Christensson. 2006. Ad hoc network definition. The Tech Terms Computer Dictionary. https://techterms.com/definition/adhocnetwork

[2] Onuora, A. C., Njoku, C. C., Ogbunude, F. O. and Osu, C. M. 2021. A Comparative Study of Simulation Tools for Ad hoc Networks [Conference session]. School of Engineering Technology (SET), AIFPU International Conference 2021, Ebonyi, Nigeria.

[3] Parvin, R. J. 2020. An overview of wireless mesh networks. Wireless Mesh Networks - Security, Architectures and Protocols. https://doi.org/10.5772/intechopen.83414

[4] Gaikwad, D. S. and Zaveri, M. 2011. VANET routing protocols and mobility models: A survey. Trends in Network and Communications, 197(1), 334-342. https://doi.org/10.1007/978-3-642-22543-7_34

[5] Matin, M. and Islam, M. 2012. Overview of wireless sensor network. Wireless Sensor Networks - Technology and Protocols. https://doi.org/10.5772/49376

[6] MITRE Corporation. 2014. Smart phone ad hoc networking (SPAN). The MITRE Corporation. https://www.mitre.org/research/technology-transfer/technology-licensing/ smart-phone-ad hoc-networking-span

[7] Omari, S. A. and Sumari, P. 2010. An overview of mobile ad hoc networks for the existing protocols and applications. International Journal on Applications of Graph Theory In wireless Ad Hoc Networks and sensor Networks, 2(1), 87-110. https://doi.org/10.5121/jgraphhoc.2010.2107

[8] Lakshmi, M. V., Swathi, K. and Venkatachalam, S. 2012. Comparative study of routing protocols in Adhoc networks. National Congress on Communications and Computer Aided Electronic Systems. https://www.researchgate.net/publication/282652111_Comparative_ study_of_routing_protocols_in_Adhoc_networks

[9] Shaik, J. S. 2014. Simulation-Based Comparative Study of Routing Protocols for Wireless Ad-Hoc Network [Master's thesis]. https://www.diva-portal.org/smash/get/diva2:830376/ FULLTEXT01.pdf

[10] Alsaqour, O., Alsaqour, R., Alahdal, T., Saeed, R. and Al-Hubaishi, M. (2015). Comparative Study of Simulation Based Performance Evaluation of Routing Protocol for Ad-Hoc Networks [PDF document]. Lecture Notes in Electrical Engineering 313:215-221. DOI: 10.1007/978-3-319-06773-5_29

[11] Kang, S., Aldwairi, M., and Kim, K. 2016. A survey on network simulators in three-dimensional wireless ad hoc and sensor networks. International Journal of Distributed Sensor Networks, 12(9), 155014771666474. https://doi.org/10.1177/1550147716664740

[12] Xia, H., Yu, J., Wang, G. and Pan, Z. 2016. TimSim: An efficient simulator for wireless ad hoc networks. International Journal of Future Generation Communication and Networking, 9(4), 301-314. https://doi.org/10.14257/ijfgcn.2016.9.4.27

[13] Kaur, P., Kaur, D. and Mahajan, R. 2017. Simulation based comparative study of routing protocols under Wormhole attack in Manet. Wireless Personal Communications, 96(1), 47-63. https://doi.org/10.1007/s11277-017-4150-2

[14] Sultan, M. T., Yasen, K. N. and Saeed, A. Q. (2019). Simulation-based evaluation of mobile ad hoc network routing protocols: Ad hoc on-demand distance vector, fisheye state routing, and zone routing protocol. Cihan University-Erbil Scientific Journal, 3(2), 64-69. https://doi.org/10.24086/cuesj.v3n2y2019.pp64-69

[15] Kabir, M. H., Islam, S., Hossain, M. J. and Hossain, S. (2014). Detail Comparison of Network Simulators. International Journal of Scientific & Engineering Research, Volume 5, Issue 10, October-2014, 5(10), 203-218. https://www.ijser.org/researchpaper/Detail-Comparison-of-Network-Simulators.pdf

[16] Nsnam. (2011). NS3- a discrete-event network simulator for internet systems. ns-3. https://www.nsnam.org/