Performance Analysis of MANET Routing Protocols for various Traffic Patterns

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Abstract: The research thesis is aimed towards the performance analysis of the MANET (Mobile Ad hoc networks) Routing Protocols for various traffic patterns. Wireless communication has shown a lot of development over the years. MANET is based on the infrastructure less, self-configured network architecture. In the infrastructure-less network architecture the nodes (electronic devices) do not have any fixed base station (access points). Similarly the network architecture is not fixed as all the times the network nodes are moving from one place to the other. Hence each node is basically considered as a host, or in terms of network, a router receiving and forwarding the information/data on the network. As the propagation distance is limited with continuous shifting of locations/topology, the routing protocols hold the key to successful communication. The routing protocols generally used include Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR). We have specifically looked into these protocols for our research. The parameters selected for the performance measurement include throughput, delay, packet delivery ratio & packet loss. Simulation is done using Network Simulator 2 (NS2) and Optimized Network Engineering Tool (OPNET/Modeler 14.5). The results of NS2 and OPNET are analyzed to ascertain the performance of each tool.

Introduction & Literature Review

1.1 Introduction & Background

Mobile Ad hoc Networks Routing Protocols (MANETs) are very rapidly deployable protocols which are based on the framework of being infrastructure less and have the capability of being self-organizing. It has many applications, especially in the areas which are not covered by wireless infrastructures. The mobile hosts/nodes form a temporary network consisting of various wireless electronic devices without having to rely on a central server or any specific centralized authority. As the network structure is changing all the time hence the concepts of self-configuration and self-organization takes root while dealing with multiple hops in the links.

Various nodes in the network use the random access wireless access channel for the multi-hop communication. The nodes in the network are also referred to as routers because of their nature of working. The electronic movable devices in the network keep on changing their positions hence making new links all the time and in turn forwarding the traffic to the other nodes/routers which are not directly related to them. In MANETs we encounter constant mobility; hence effective routing protocols need to be deployed to accomplish error free transmissions.

It is also important for us to understand the concept of routing here. Routing involves the selection and forwarding of the network traffic by making intelligent decisions. The routing tables for forwarding the packets to the destined destinations from the sending nodes have to be kept and managed in a proper format on logical basis. Hence the selected routing protocols should ensure control of how the nodes are forwarding/transmitting the information/data on the network. As the network topology is not fixed, hence the nodes have to self-discover their topology. Whenever any new node is added into the network, it also has to synchronize with the existing neighboring nodes (listening to broadcast announcements) thus; each node learning from the other nearby node for effective connections.

1.2 MANET Routing Protocols

Here we will look at the classification of the MANET routing protocols. This classification depends on many factors which include the routing strategy, communication model, network architecture etc. On the basis of the routing strategy, they are divided into the following;

(a) ***Table Driven (proactive)***
(b) ***Source Initiated (also called "on demand", reactive)***

However if we are looking at the network structures, their classification is;

(a) ***Flat Routing***
(b) ***Hierarchical Routing***

(c) Geographic Position Assisted Routing

Let's discuss first the two main categories.

1.2.1 Table Driven

Table Driven routing protocols are also referred to as being proactive. They maintain up-to-date information regarding the routing information of data from every node to the other in the network. In order to store the routing information, one (or more) routing tables are maintained. The information is stored in them and is constantly being updated throughout the network if there is any change (in network topology) takes place. Some of the proactive routing protocols coming under them are;

(a) Wireless Routing Protocol
(b) Cluster- head Gateway Switch Routing
(c) Global State Routing
(d) Destination Sequenced Distance Vector

1.2.2 On Demand

On demand routing protocols are also referred to as being reactive. They are called reactive because the routes are created on demand i.e. as and when they are required in the network. Whenever a node (source) wishes to send the information to another node (destination), a route discovery mechanism is initiated which leads to the selection of the route or the path. This is achieved through a close examination of all the routes and the section of the best passible path. The selected route is subsequently maintained till the point any node becomes non-available.

Some of the protocols used are;

(a) Signal Stability Routing
(b) Temporally Ordered Routing Algorithm
(c) Ad-hoc On-Demand Distance Vector
(d) Associatively-Based Routing
(e) Dynamic Source Routing

Figure 1 summarizes the classification of MANET protocols.

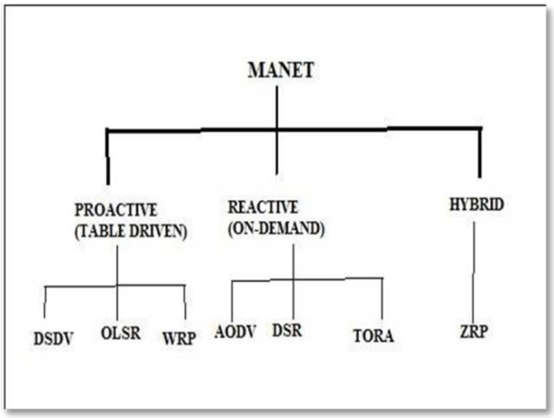

Figure-1: MANET Routing Protocols (Classification)

In our research we shall be using Ad-hoc On-Demand Distance Vector (AODV) & Dynamic Source Routing (DSR) reactive on-demand protocols.

1.3 DSR

The on-demand Dynamic Source Routing protocol is a "source" routing protocol. The nodes/routers have to maintain the routing tables (containing the source routes caches) which are constantly updated all the time as and when the new routes are discovered. DSR Protocol is responsible for the following two;

(a) Route Discovery
(b) Rout Maintenance

Ever node/router maintains in its routing tables a route cache and about the information it has gathered regarding the followed route. So whenever there comes a time to send data, it looks at the route cache which consists of all the details pertaining to the number of intermediate nodes which will be involved in the process of transmission. This information is then placed in the "packet header" and then passed on to the next hop. The node receiving it examines the packet header and then forwards it to the next node by adding the details next to its own node id. However in case no route is found, the sending node initiates the route discovery process by buffering the data.

To put it simply, if a packet needs to be sent, the node will first look at the route cache for any existing available route. If there exists any route which is unexpired (still can be used), the same is chosen.

However there can be a situation when there exists no route, in that case, it initiates (through broadcasting) a route discovery process ("route request packet") with the following information;

(i) ***Address of the Source node***
(ii) ***Destination Address***
(iii) ***Unique Identification Number***

When this request is seen by the destination or the intermediary node which has any route information in its cache, the routing tables are updated accordingly for the transmission of the packet to its destination.

As far as the route maintenance procedure is concerned, a "route error packet" along-with acknowledgement procedure is followed. As detailed above, the DSR adopts a reactive approach. It is also to be noted that through these mechanisms, the "control overheads" are substantially reduced. However the disadvantage in using the Dynamic Source Routing protocol is the non-availability of some centralized mechanism to in case of repairing any broken links/connections. With increasing mobility, this task becomes daunting.

1.4 AODV

Ad-hoc On-Demand Distance Vector is an algorithm which employs a dynamic and self-starting mechanism to deal with the multi-hop mobile nodes environment. In AODV, does not require the nodes/routers to maintain the details of the routes and using another mechanism to ascertain routes much more quickly. This is achieved by using two steps;

(i) ***Route Discovery***
(ii) ***Route Maintenance***

In case of route discovery, the route is first sought by the sending node. If the route is found in the table, the communication starts immediately, else route discovery mechanism comes into play. As is the case with DSR, route request message is launched. If any node in the network as a valid address in its table, a route reply message is generated by entering the number of hops, source node address and the next hop's address. However there exists a cap here with the name "life time" i.e. if the route is somehow not discovered within that "life time" period, the same is removed accordingly.

In the next step "route maintenance" procedure is invoked. It consists of two further steps;

(i) ***Source Node initiating new route discovery***
(ii) ***Destination/Intermediate node initiates route error message to the source node***

Through the effective use of "Route Discovery" and "Route Maintenance" procedures, the transmissions between the nodes take place effectively.

1.5 Literature Review

Various works were studied in the literature review which was primarily focused on the performance analysis of AODV and DSR routing protocols. In addition to this the investigation into the MANET protocol while keeping the factors of mobility and scalability in mind.

The literature study included Gargi Pandey, Sanjay Kumar, V. K. Patle, "Effect Of Pause Time And Network Size In Various Routing Protocol: MANET", Proceeding of the National Conference of Educational and Research Scenario of Mathematical and Computer Sciences, Rajim, during January 29-30, 2013. [1], Mobile Ad Hoc Networking Working Group – AODV, http://www.ietf.org/rfc/rfc3561.txt, retrieved on January 11, 2013 [2], Pratik Gite, Sanjay Thakur, "Comparative Study and Simulation Based Analysis of MANET Routing Protocols Using NS-2", International Journal of Emerging Science and Engineering (IJESE) ISSN: 2319–6378, Volume-2, Issue-3, January 2013 [3], JianliPan, "A Survey of Network Simulation Tools: Current Status and Future Developments", project report,jp10@cse.wustl.edu, retrieved on Jan, 2013 [4] and OPNET Modeler, http://www.opnet.com/ , January 2013[5].

Basis of Research

2.1 Research Problem

With the advancement in the wireless technology, there grew the need to understand the performance relating to MANET protocols. MANET has application both in the civilian and military side. As the traditional protocols are not designed for mobility whereas the location of the node changes, hence there exists a need to study their behavior using top of the line simulators. There is a lack of study in the area of evaluating the performance of the MANET protocol sets over varied traffic patterns. In addition, no study has been done to check verify the results of these varying performance parameters using different network analysis tools to establish the gaps.

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2.2 Aims and Objectives

The main objectives of the research are:

- To generate Simulation results for MANET Routing Protocols for various traffic patterns.

- Analysis of Simulation results on different Simulators (Commercial & Open Source)

- To determine variation of results and recommend most effective and accurate simulator.

2.3 Research Methodology

- Literature Review
- Use of Commercial Simulator, OPNET
- Use of Open Source Simulator, NS2.
- Analysis of generated Simulations.

Simulation Tools

3.1 Simulators

In order to achieve the analysis of ad-hoc routing protocols, we need powerful tools to come up with a performance metrics. By definition, a simulator is a software tool which is responsible for imitating the behavior of the real network on to the machine for the purpose of research and development. These are used by academic researchers for the purpose of designing, verification, analysis and simulation of the network protocols for accessing the performance factors. With the help of the simulators, various network types and different network topologies can be designed.

There are various types of network simulators used in the market. Some of them come under the umbrella of commercial use while others come under the Open Source. Table 1 indicates the available simulators in the market.

Type	Network simulators name
Commercial	OPNET, QualNet
Open source	NS2, NS3, OMNeT++, SSFNet, J-Sim

Table 1: classification of Network Simulators

For our research, we have selected one simulator form the Open source (NS2) and the other one from the Commercial side (OPNET).

3.1.1 Network Simulator- 2 (NS2)

The Simulator used for the research is NS2. It is the second version of the NS simulator. As the accuracy of the results by using the basic simulator was less, hence NS2 has been chosen to evaluate MANET. It is used for simulations for Routing, Transmission Control Protocol (TCP) & multicast protocols for wireless/wired networks. It is a discrete UNIX based event simulator. T is widely used by the research community.

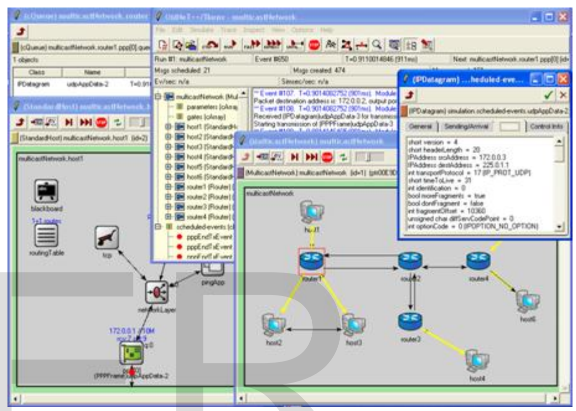

Figure 2: NS2 Simulator Generic Snapshot

3.1.2 OPNET (modeler 14.5)

OPNET is a commercial simulator which is being used widely by research community because of its long-term use and maturity level. The basic simulation methodology is shown in figure-3.

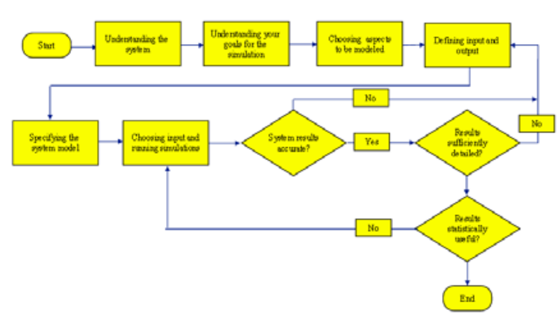

Figure 3: Basic Simulation Methodology (Source: http://www.sce.carleton.ca/faculty/lambadaris/courses/5001/opnet_tutorial.pdf)

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3.2 Simulators Setup

In order to do the performance analysis, an operating system based on Linux Kernel, Fedora was used. Network Simulator NS2 (Version: 2.35) was installed. OPNED Modeler, version 14.5 was also installed over windows XP platform. Table 2 describes the complete simulation setup.

Seed	1.0
Simulation Tools	- NS-2.35 - OPNET Modeler 14.5
Simulation Time	100 Seconds
Simulation Area	1000 * 1000
Rate	5.5 Mbps
Traffic Type	Transmission Control Protocol (TCP)
Number of Nodes	100
Routing Protocols	- DSR - AODV
Mobility	Random Way Point

Table 2: Setup for Simulation

3.3 Performance Metrics

In order to do the performance analysis, an operating system based on Linux Kernel, Fedora was used. Network Simulator NS2 (Version: 2.35) was installed. OPNET Modeler, version 14.5 was also installed (over windows XP platform). Table 2 describes the complete simulation setup.

Four factors are selected for the performance metrics (figure: 4).

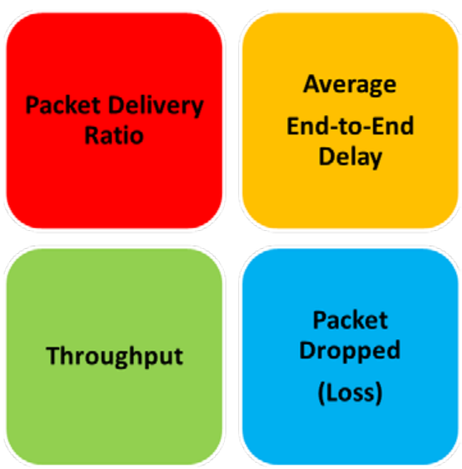


Figure 4: Performance Metrics

3.3.1 PDR

Packet Delivery Ratio (PDR) is defined as the ratio of the total number of packets that have been received successfully at the destination point/node divided by the total number of packets send by the nodes during the process of simulations.

Packet delivery Ratio (PDR) = No of Packets received ÷ No of Packets Sent

3.3.2 End to End Delay (Average)

There is a time taken for the packets to travel from the source to the destination in the network. Average End-to-End Delay defines this time length. There can be many delays occurring because of the following factors;

- ***(i)*** ***Route Discovery***
- ***(ii)*** ***Queuing Delay***
- ***(iii)*** ***Propagation Delay***
- ***(iv)*** ***Transfer Time Delay***

Mathematically it can be expressed as;

Average End to End Delay = (Time Received – Time Sent) ÷ Total Received Data Packets

3.3.3 Throughput

It is defined as the average rate of the data packets which are successfully received at the destination.

*Throughput = (No of delivered Packets * Packet Size * 8) ÷ Total duration of Simulation*

3.3.4 Packet Dropped (Loss)

And finally we have the loss due to the dropping of the packets.

Packet Dropped (Loss) = Total Packets Sent – Total Packets Received

Simulations & Analysis

4.0 Simulations Analysis

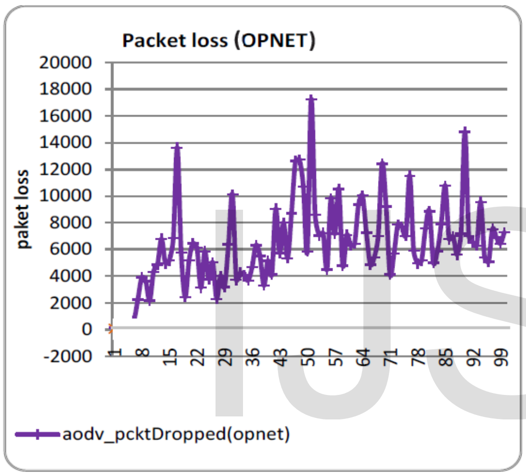
In this section the analysis will be done pertaining to the comparison between the performance of OPNET and NS2 simulators results. The graphs will represent various parameters for the AODV and DSR protocol suits. The following parameters will be plotted for OPNET/NS2 comparisons;

- *(i)* ***Packet Loss***
- *(ii)* ***Packet Delivery Ratio***
- *(iii)* ***Throughput***
- *(iv)* ***Average End-to-end Delay***

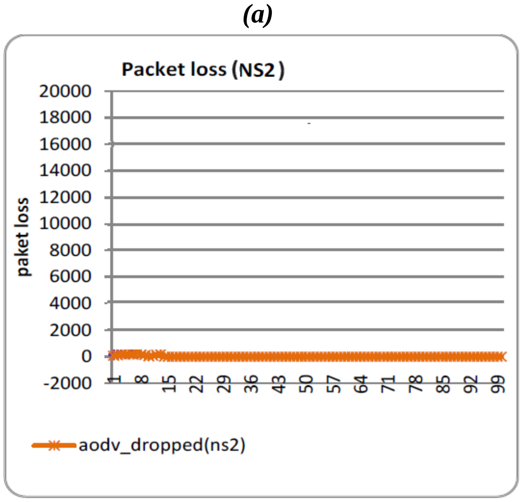
The graphical representation will be much easier to analyse and understand for a large population of researchers/audience.

4.1 Packet loss

Let's first look at the Packet loss independently for AODV (OPNET) & AODV (NS2) in figure 5.



(a)



(b)

Figure 5: (a) Packet Loss (AODV, OPNET) (b) Packet Loss (AODV, NS2)

In figure 6 & figure 8, the packet loss is shown for the routing protocols (AODV & DSR). If we look closely at figure 6, it is observed that the packet loss (AODV protocol) when calculated on NS2 is very small as compared to that of the OPNET. However when we look at figure 8 (DSR protocol), the packet loss is seen as being opposite i.e. constant.

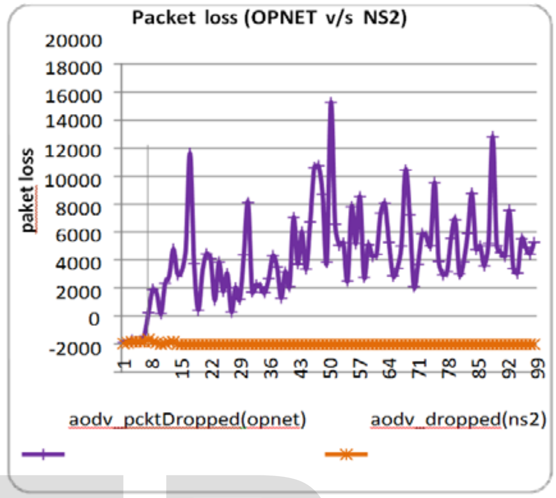
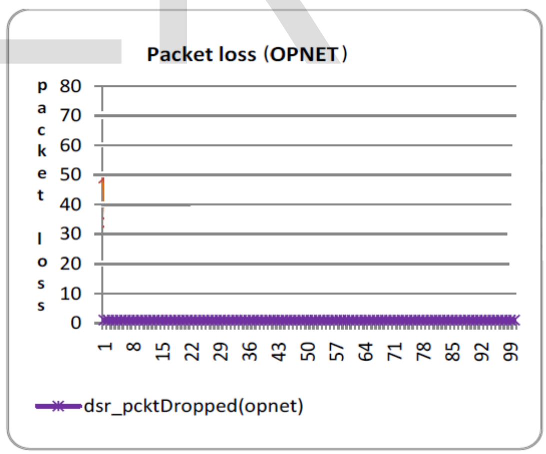
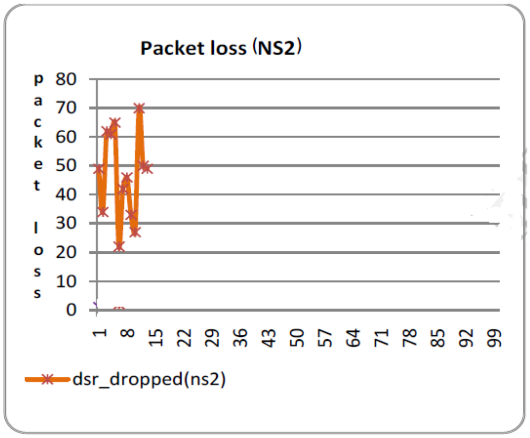


Figure 6: Packet Loss (AODV)



(a)



(b)

Figure 7: (a) Packet Loss (DSR, OPNET) (b) Packet Loss (DSR, NS2)

Packet loss in NS2 analysis however shows an increase. In case of AODV protocol, we observe a high level of packets loss (for OPNET) thus showing the non-accuracy in terms of dropped packets for the transmitted data.

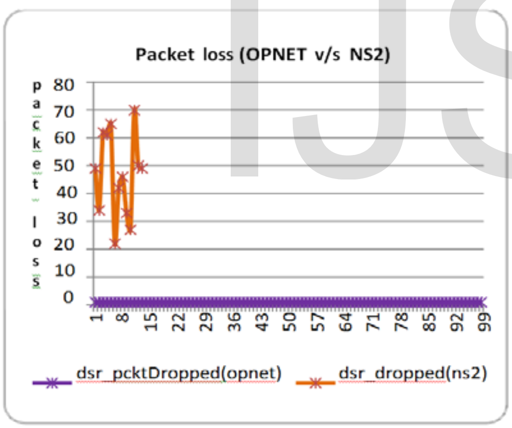
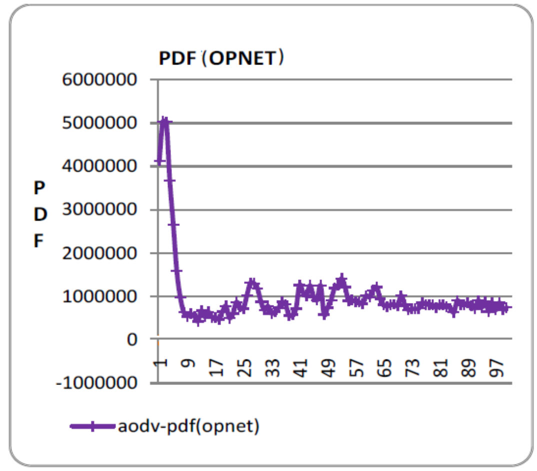


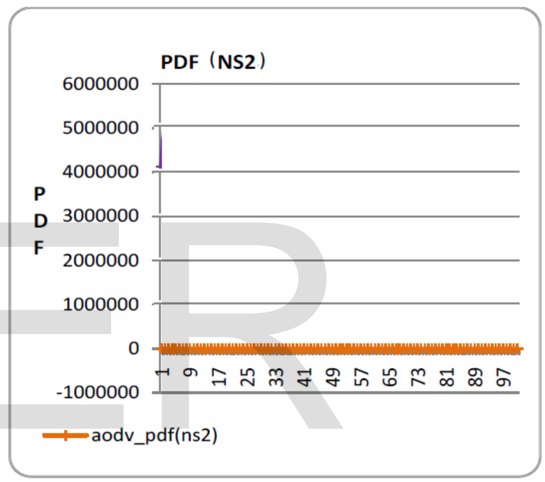
Figure 8: Packet Loss (DSR)

4.2 Packet Delivery Ratio

To start with, we independently plot PDF on the OPNET simulator and PDF on the NS2 simulator against the number of nodes (figure 9).



(a)



(b)

Figure 9: (a) PDF (AODV, OPNET) (b) PDF (AODV, NS2)

In figure 10 and figure 12, Packet Delivery Ratios are shown (NS2 and OPNET). It is observed that the packet delivery ratio measured using NS2 simulator is low (almost constant) for both the protocols (AODV & DSR). Similarly when we used OPNET simulation, although the packet delivery ratio is not that good but it is still a lot better than the NS2 simulation.

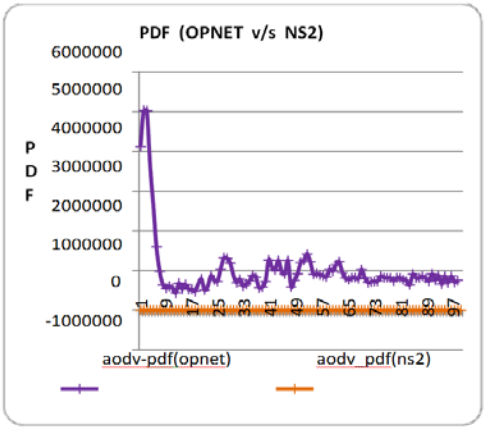
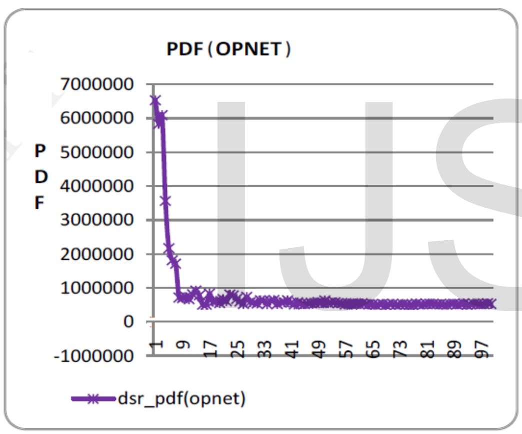
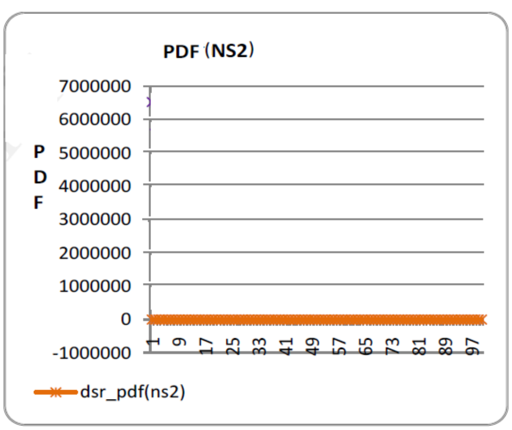


Figure 10: Packet Delivery Ratio (AODV)

It is further observed that the packet delivery ratio is much better in case of AODV as compared to DSR. It is pertinent to mention here that we have taken hundred nodes for our analysis purposes.



(a)



(b)

Figure 11: (a) PDF (DSR, OPNET) (b) PDF (DSR, NS2)

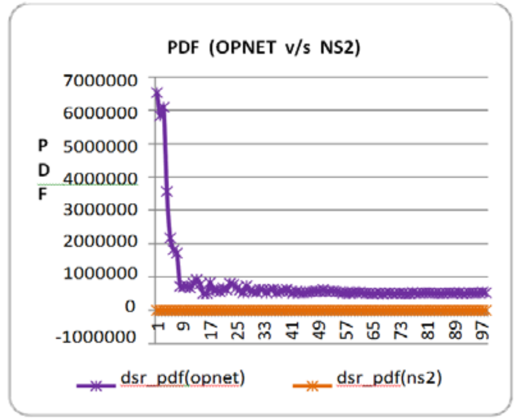
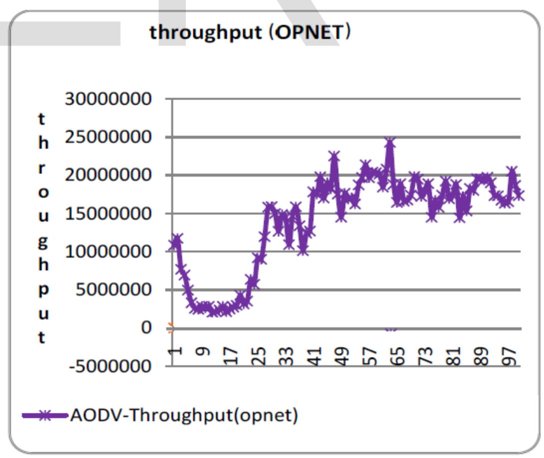


Figure 12: Packet Delivery Ratio (DSR)

Another interesting observation relates to the number of nodes. If the total number of nodes in the network is less, the packet delivery ratio for DSR shows good result patterns (NS2).

4.3 Throughput

Let's now have a look at the independent plots of throughput in AODV suit for OPNET & NS2 (figure 13) and DSR suit for OPNET & NS2 (figure 15).



(a)

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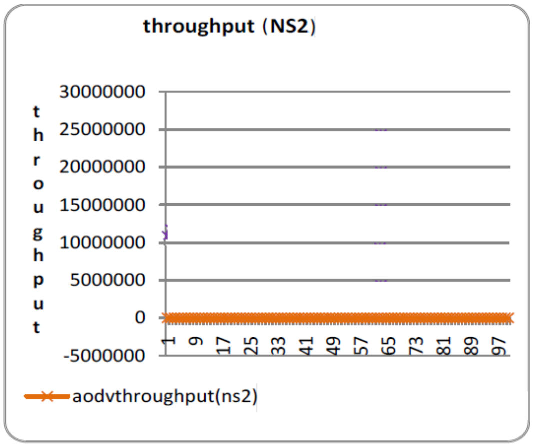


(b)

Figure 13: (a) Throughput (AODV, OPNET) (b) Throughput (AODV, NS2)

Now consider the throughput parameter (figure 14 & figure 16). It is observed that the values of throughput levels using the OPNET simulator are very promising. The use of AODV protocol (OPNET) results in better throughput as compared to that of NS2.

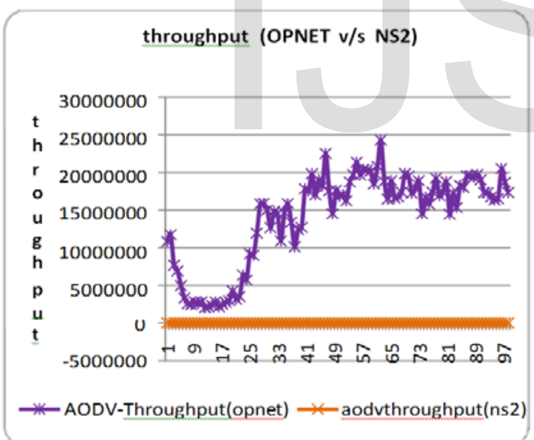
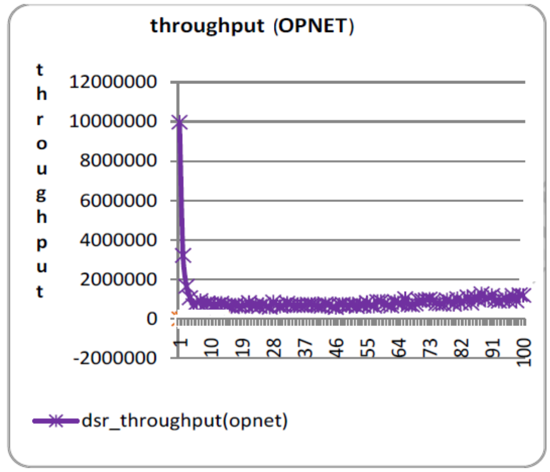
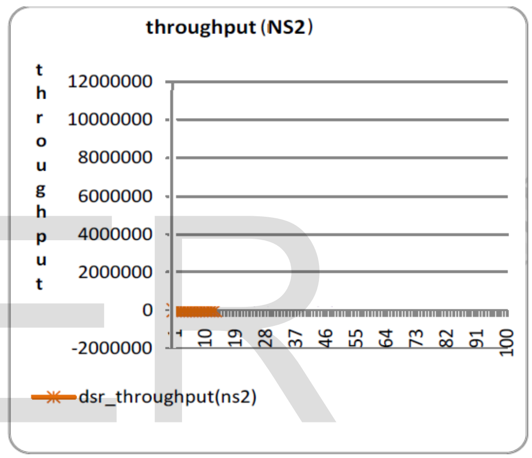


Figure 14: Throughput (AODV)

Similarly when we use the DSR protocol (OPNET), the throughput becomes less. However it is still better than the results of NS2 simulator.



(a)



(b)

Figure 15: (a) Throughput (DSR, OPNET) (b) Throughput (DSR, NS2)

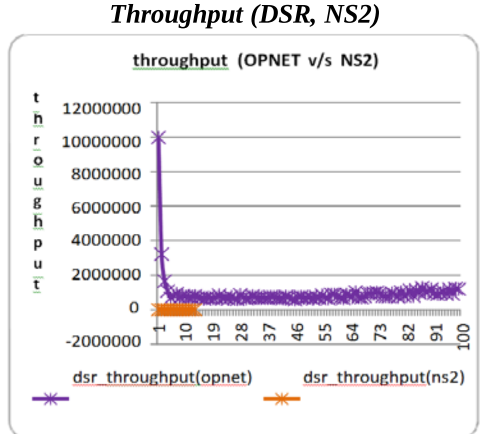


Figure 16: Throughput (DSR)

In essence it is observed that whenever we are measuring the throughput, the AODV protocol gives better results as compared to that of DSR protocol.

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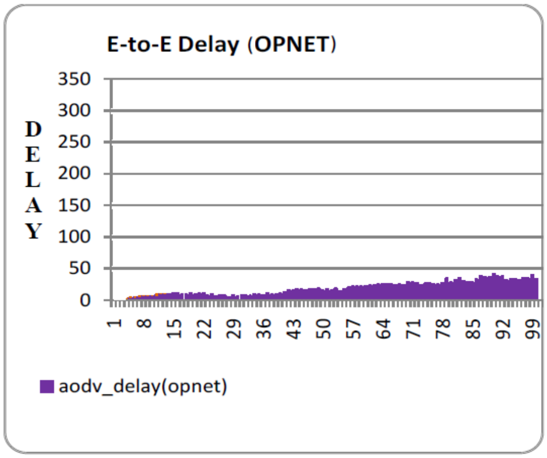
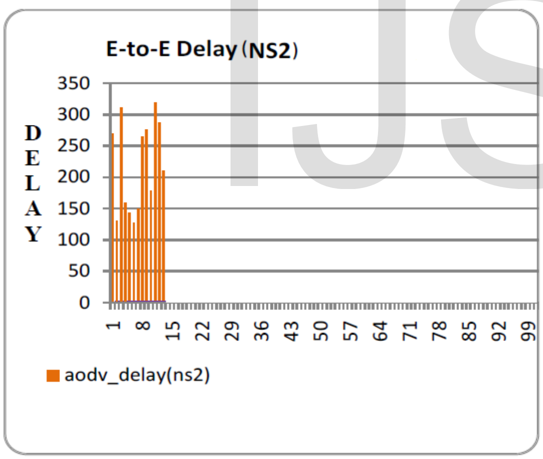
4.4 Average End-to-End Delay

For both the protocol suits, the end-to-end delay is calculated (figure 18 & figure 20). It is observed that no matter what the protocol is, the performance results of OPNET simulator are better than that of the NS2 simulator.



(a)



(b)

Figure 17: (a) End-to-End Delay (AODV, OPNET) (b) End-to-End Delay (AODV, NS2)

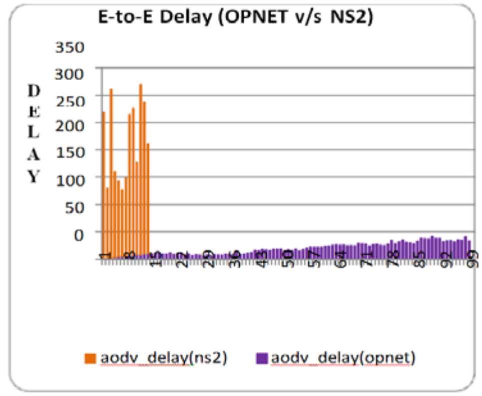
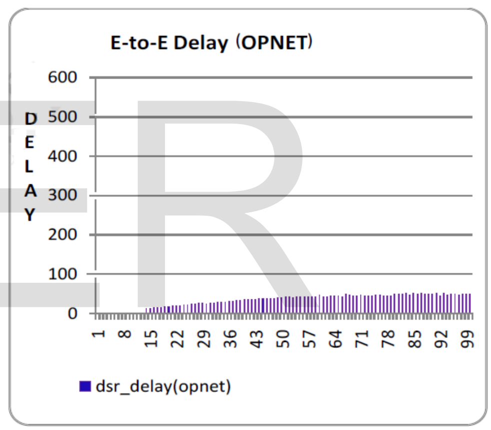
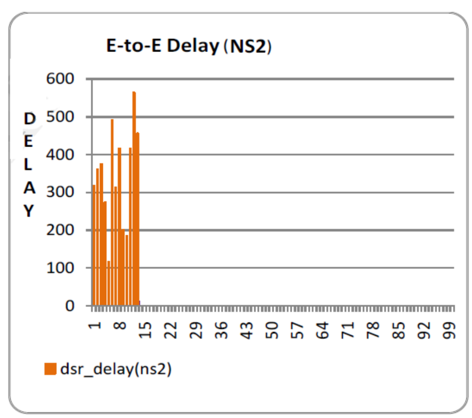


Figure 18: End-to-End Delay (AODV)

We observe lower levels of delays with fewer variations in OPNET. More variations with high delays are observed with time when analysing NS2 results.



(a)



(b)

Figure 19: (a) End-to-End Delay (DSR, OPNET) (b) End-to-End Delay (DSR, NS2)

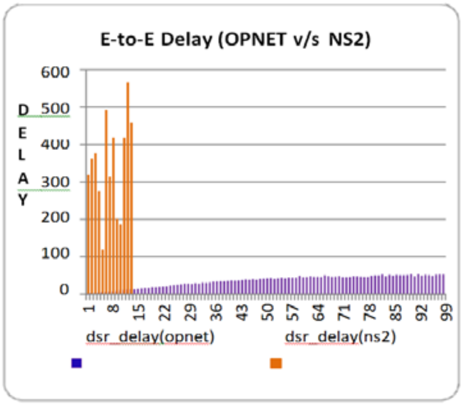


Figure 20: End-to-End Delay (DSR)

It is to be kept in mind that if we are looking at good data transmissions, the end-to-end delay should always be low. With more end-to-end delay (as is the case with NS2 results), accuracy of data transfer is a major concern.

The above analysis gives us some important insight which can be summarized as;

- The simulation results using the OPNET simulator are certainly better than that of NS2.
- The graphical interface of OPNET is much easier to comprehend.
- Time consumption in case of ONET is however more (updating of files/features)

The features comparison for both is detailed in Table 3. NS2 is readily available owing to being an open source product. Similarly it supports varied platforms like UNIX and Windows. On the other hand, OPNET is a commercial simulator whereas its kernel code is not open source based. However this is only supported on Windows platform.

NS2	OPNET
Open source (easily available)	Commercial level simulator
Kernal code is open source.	OPNET modeler kernel code is not open source.
Command based	GUI and drag and drop function based
Supported by both platform : Windows (CygWin) and UNIX	Supported by only Windows version
No extra requirement are needed for NS2	Visual studio and C++ library are must for OPNET

Table 3: Features Comparison (Simulators)

The parameters comparison for both is detailed in Table 4. It depicts that the end-to-end delay comes out to be worst in case of NS2 as compared to that of OPNET. The same goes for the throughput. There are frequent changes observed in OPNET for Packet Data Ratio.

	NS2	OPNET
E-to-E Delay	Worst	Very Good
PDR	Constant (bad)	Frequently change
Packet Loss	Less in AODV, but very much for DSR	More data loss in AODV, but in DSR negligible
Throughput	Worst	good

Table 4: Parameters Comparison (Simulators)

Conclusions/Recommendations

5.0 Conclusions/Recommendations

The study was based on analyzing various parameters coming under the protocol suits of AODV and DSR. Two common network simulation tools, one from the commercial side and one from the open source were selected. NS2 and OPNET were tested against various metrics parameters. The results have shown very interesting views as the same parameters were analyzed & compared with two different effective and well known tools.

On the basis of the results obtained and the data analysis for different MANET options, the generally the trends were found to be consistent despite the fact that at times the values (absolute) obtained were quite different. Furthermore we came to the conclusion that OPNET simulator shows better results for the MANET routing protocol. Furthermore in OPNET, there is no need to remember various commands as it is very user friendly. However the availability of NS is very easy, hence is being used more often.

In short, the following conclusions were drawn;

- The simulation results using the OPNET simulator are certainly better than that of NS2.
- The graphical interface of OPNET is much easier to comprehend.
- Time consumption in case of ONET is however more (updating of files/features)

It should also be noted that this work is done for only few parameters, hence other parameters can also be incorporated in the future works.

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