Investigating Energy Efficiency of Mobile Ad-hoc Network Routing Protocols

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Mobile Ad-hoc Network (MANET) is a wireless network that comes with a few routing protocols which have varied mechanisms. Studies show that routing operations consume energy while current research focuses more on MANET routing protocol operation and its performance evaluation, the required energy for successful routing operations equally demands quality attention of researchers. Hence, the need to expand the scope of study on MANET routing protocols to the neglected area of study. To bridge the research gap between MANET routing protocols and energy consumption, this paper used residual energy to analyze routing protocols' energy efficiency as a metric to analyze selected routing protocols; Destination Sequence Distance Vector (DSDV) and Ad-hoc On-demand Distance Vector (AODV) via simulation. It also compared the amount of energy required to transmit the data packets to their destinations in DSDV and AODV. Results, in terms of energy efficiency, indicated that AODV was better than DSDV because it consumed less energy for its successful routing operations.

Povzetek: Analizirana je energijska učinkovitost raznih protokolov mobilnih omrežij MANET.

1 Introduction

The Mobile ad-hoc network (MANET) is a wireless network. It can connect several mobile network interfaces to create a temporary network to facilitate the effortless transmission of data. Routing in MANET, like other network research, has been studied in recent years, and one of the major issues is the changing nature of its environment [1]. The changing environment should be addressed by opting for the best route to securely send source node data to a defined destination, routing protocol makes this task effortless. It requires no centralized infrastructure to run its functions. Being a self-configured and organized network, MANET aids efficient transmission and reception of nodes via its communication links without any barrier [2]. It's a good network arrangement where a wired network is practically impossible, and its setup process is effortless. At times, the wired network infrastructure may fail due to certain issues such as battlefield, hostile terrain operations, decision making, emergency search-and-rescue operations, and data acquisition [3]. Such issues could pose installation, financial, and security challenges for the creation of wired networks but communication is still possible through the MANET, or what is simply known as MANET. Each mobile node within the network runs both host and router functions by transporting packets to other mobile nodes in the network, especially those lying directly within each node's transmission range [4].

Continuous operations of routing protocols broadcasting in the network tend to increase energy consumption, in evaluating a routing protocol, many researchers have ignored the network's energy consumption. Those who look along that line are so few that no significant studies have been carried out on a protocol's energy consumption, and metrics parameters such as Dropped Packet Vs Time, and Packet Delivery Fraction (ratio of the packet received/packet sent), and Residual Energy Vs Time, being key performance indicators neglected in previous studies. There is a need to expand already conducted studies and pay keen attention to factors of energy consumption metrics ignored in previous studies. Hence, this paper shows an investigation of MANET routing protocols' energy efficiency. This study aims at bridging the research gap by investigating the efficiency of routing protocols mainly in the area of energy consumption. It will use simulations to compare and contrast the performance of DSDV and AODV

Our research contribution focus on:

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(1) Investigating the energy efficiency of the DSDV and AODV MANET.

(2) Compare and contrast the performance of DSDV and AODV with important efficiency indicators such as Dropped Packet Vs Time, and Packet Delivery Fraction (ratio of the packet received/packet sent), and Residual Energy Vs Time.

The remaining part of this research is organized as follows: section 2 contained the review of related works, section 3 discusses the methodology employed, and section 4 presents experimental results and discussion on an investigation of MANET routing protocols' energy efficiency. Finally, section 5 concludes the paper

2 Review of related works

MANET has limits but is not volatile to the challenges of similar networks which include dynamic topology, security, computing, and communication resources such as bandwidth, time, memory, and energy or energy efficiency [5]. Designing a routing protocol could be negatively affected by the challenges raised above, as pointed out by a few studies. A major determinant of the efficiency of a routing protocol in a network is energy consumption. Time-tested routing protocols are known for their efficient energy capacity since a periodic update of routing protocols against malicious activities poses more energy burden on the performance of the network, especially the MANET wireless network. So, the rate at which energy is consumed on the MANET network tends to increase due to up-to-date processing of routing information across all nodes and broadcasting topology which is updated at regular time intervals. The updating operations, which could be termed Proactive and Reactive routing protocols, have a significant effect on the network's overall energy consumption [6].

Kanellopoulos, (2019) [7] while studying MANET and other emerging technologies that run as host and router in the network, proposed the AODV routing protocol. They concluded that the AODV showcased tremendous improvement, especially in the areas of stability and lifespan, as well as its many network paths. The focus was mainly directed to its lifespan because it was widely believed that residual energy poses little or no challenge to the AODV routing protocol, energy efficiency was not considered in this work.

AL-Dhief, et a, [8] and Al-khati & Hassan, [9] argued that MANET has several routing protocols. They confessed that these protocols have different mechanisms of make-up and performance. So, while studying the performance parameters of these protocols across varied environmental conditions, the researchers compared and contrasted AODV, DSDV, and the Dynamic Source Routing (DSR) protocols. The study was to ascertain the efficiency of the selected protocols. Simulation and evaluation of the selected protocols were carried out via the Network Simulator NS2.35 and the focus was on their average end-to-end delay, packet delivery ratio, packet loss ratio, and average throughput. While the variable number of nodes was considered in the course of an evaluation, the researchers have not paid attention to factors such as residual energy Vs time and dropped packet Vs Time, the key parameters of MANET evaluation that will be focused on in this research.

It is hard to point out the QoS and energy efficiency for MANET routing protocols. Studies show that different routing protocol features have been proposed recently and their scope of performance has been carefully evaluated. Evaluation focus has mostly focused on metrics like routing overhead, packet delivery ratio, and delay. Although, routing protocols were briefly examined alongside energy consumption and QoS. The energy consumption requirement of the network was analyzed with the aid of network simulator 2, also known as the NS2. A few mobility and traffic models were used in analyzing the energy consumption requirement of the network [10]. However, there is a need for a performance comparison of DSDV and AODV to arrive at a more correct evaluation.

Jamali, Rezaei, and Gudakahriz, (2013) [11] studied and compared the basic proactive, reactive, and hybrid features of the selected protocols, which were the AODV, DSDV, and the improved AODV protocols, and the study only addressed the selected protocols' end-to-end delay and packet delivery ratio. Though it was reported that the DSDV has a better result since it comes with enhanced functionality for optimum performance, the evaluation was not based on energy efficiency and its important parameters. An implementation of the above research was done with the NS 3 simulator to rate the performance of AODV, DSDV showed an improved performance than AODV routing protocols. The research did not study the energy efficiency of the network. Gopinath & Nagarajan, (2015) [12] worked on energy conservation on mobile nodes since they usually fall prey to battery issues. Transmission of packets and signal reception from interfering nodes require a bunch of energy. So, the researchers were inclined to study nodes' overall energy consumption to mitigate transmission and reception issues due to low energy and boost the lifespan of the network. Results, however, showed that simulating the network regularly could help save energy and limit undue interference from unauthorized protocols.

Researchers have shown through their studies in the last decade, the raw potential of MANET. One of these studies is [13] which studied the MANET and focused on the energy consumption and performance metrics without addressing it from the known examples of MANET which are AODV and DSDV. Also, the Energy Efficient Ad Hoc Distance Vector protocol (EE-AODV), could be a significant routing protocol to boost the available AODV routing protocol. The RREQ and RREP can be used to save energy in mobile devices and are also products of the algorithm that brought about the Energy Efficient Ad-hoc Distance Vector protocol (EEAODV). Any node that wants to act as an intermediate node will require minimum energy consumption and the energy requirement of the EE-AODV is fairly considerable. Simulation results indicated that the EEAODV increased the lifetime of the network, unlike the AODV [14]. However, the research did not look at the research from the known examples of MANET which are AODV and DSDV.

Gayathri, et al, 2013 [15] opined that DSDV performed better than AODV in a comparative study on AODV and DSDV energy consumption and QoS from the different network simulation results, and it was showed that the enhanced protocol performs more than the EQ-AODV (Energy and QoS supported AODV), while the regular AODV had significant energy dissipation. It can be argued that the energy issue affected some services within the network. Janani, et al, [16] like other studies, have evaluated both proactive and reactive performance of routing protocols through a few evaluation methods. Different results were arrived at since studies took place in different simulation environments.

Chaphekar, Sonkar, & Gupta, (2014) [17] proposed a method to increase data availability and reduce data traffic in the MANET. Each mobile node was provided a buffer for temporarily storing data for a particular moment. The overhead of the server and data traffic in the server zone was reduced according to [18]. The proposed approach reduces the time consumed by multiple nodes and data availability was increased. A similar method was the lifetime ratio (LR) of the active route for the intermediate node that was introduced to increase the number of unsuccessful packets delivery. The results focused on the improvement of the packet delivery in the routing protocol. In the course of evaluating the mobility of MANET nodes, parameters used include the packet delivery, average end-to-end, overhead, and energy consumption. Routing protocols' complexity is increased while the connection experienced some forms of flexibility due to the mobility of the nodes [19].

3 Methodology

An attempt was made to compare the reactive Ad-hoc On-Demand (AODV) routing protocol with the proactive DSDV. GloMoSim, the academics simulator for MANET, is used to simulate the two main environmental scenarios created. While the first is MANET scalability was represented by a few mobile nodes, the second had users' mobility and got represented by mobile nodes with pause time, minimum, and maximum speeds. Reactive versus proactive routing protocols' energy consumption in MANET is the major focus of this study, and it is carried out from MANET's different sizes and users' mobility conditions. The research procedure followed, and material used viz-a-viz other research tools for this study, simulation design, the simulator, and selection of routing protocols were discussed under research methodologies.

3.1 Routing protocols

Selected routing protocols are the DSDV and AODV. These protocols were selected because they cut across the divide between Proactive and Reactive routing protocols, being requisite demands of studies of this magnitude.

3.2 Study design

For this study, four basic approaches of Network Simulation namely; model design, configure parameters, run simulation, and result and analysis were employed in this research, the Network Simulation has four parts that can be deployed in the energy-related study. Obtained results will be remodeled if what was got turned out to be incorrect. Figure 1 shows the Block Diagram of the Simulation Model, which doubles as the basic working flow of the Network simulation.

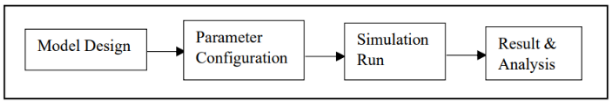

Figure 1: Block diagram of simulation model.

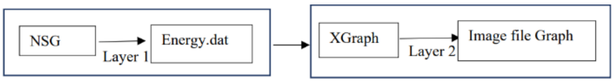

Figure 2: System design diagram.

3.3 Study design flow diagram

The tasks include writing or modification of TCL Scripts for the network simulator, as well as the integration of the routing algorithm. Hence, in this research work, the researcher used the NS scenario generator to write the scripts for the network, a move that is in line with some of the objectives of the study as presented in Figure 2. Layer 1 has the TCL generator, also known as NS2 Scenario Generator, while Layer 2 comes with the graph plotter (xGraph) and image file graph. Below is the design flow for the project and each block are further explained.

The Network Simulator 2(NS-2) framework aided the centered surface creation. Right parameters are set in the NS-2 to design a raw text file to house energy dissipation information on the network, while the XGraph refers to a plotting program used in creating graphic representations of simulation results. In other words, the XGraph houses the results of the NS-2 simulations. It is a tool used to plot the results. It is significant since it aids the basic animation of data sets, and also helps users view, understand, and appreciate the information in the NS-2 text file graphically. Overall simulation results will be hard to view if they do not come in graphical format. Image files used could be lines, curves, bars, or other symbols, but they show the measured relationships very clearly.

3.4 Performance of DSDV and AODV

The simulation of AODV and DSDV routing protocols was run on 10 nodes. The chosen nodes were made to

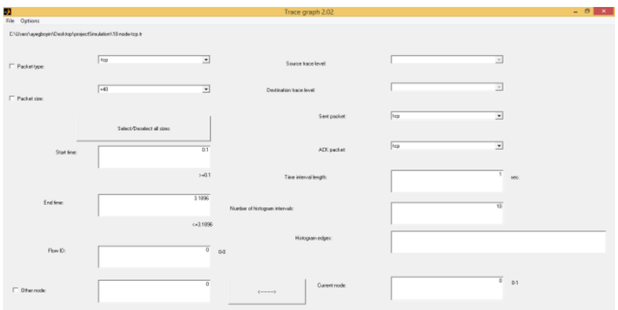
Figure 3: Trace graph graphical interface.

move under the area of 500m x 500m, while the transmission range was fixed at 250m. Each node in the network had initial energy of 1000 Joules, and the simulation results of the two routing protocols will be analyzed on the *.tr file, as well as these performance metrics: Residual Energy Vs Time, Dropped Packet Vs Time, Packet Deliver Fraction

Energy Efficiency. This study wants to measure and calculate the energy consumption of a node in the DSDV and AODV routing protocols, being one of the aims of the study. Nodes on these protocols will be compared and analyzed. In their study, Eiman, A., Biswanath, M., (2012) [20] proposed the Energy factor, an energy-efficient routing metric. The energy factor is used to calculate energy consumption in the current study, and it is defined thus:

$$E = E_{Remaining} / E_{Initial} \quad (1)$$

where remaining energy in (1) is defined as:

$$E_{Remaining} = E_{Initial} - E_{Consumed} \quad (2)$$

This metric was used to run the multipath concept, being the most energy-efficient concept, while the shortest path was used for data packets' transmission. Equation (2) of this metric is the proposed method to be used in the study to calculate the residual energy once the packets have gone through the transmission. To compare the two protocols, the evaluation was based on these simulation metrics:

- Packet delivery fraction refers to the packets data ratio, as delivered to desired destinations generated via the sources. Packet delivery fraction is calculated by dividing the total number of packets sent by the total number of packets received.
- Packet Drop points to the number of packets not received at the destination node.
- Total energy consumption in the network refers to the total energy used by nodes within the network for the transmission and reception of packets.
- Total Residual Energy of the network sums up the total residual energies of the nodes on the network. Residual Energy is calculated by subtracting Consumed Energy from the Initial Energy.

3.5 Software tool for implementation

The design and implementation of this study are rooted in the Network Simulator, also known as the NS-2. Being a network simulator, the NS-2 offers a significant virtual network communication environment that is compatible with MANET routing protocols. It is designed to provide an efficient power management system, unlike regular sensor networks and enhancement network platforms like MPLS and Ipv6. The NS-2 can be installed with Cygwin, a LINUX lookalike platform, on 64-bit versions of Windows 7 upwards. Host computers must have at least 7,500 GB Hard-disk and 4 GB Ram. Available packets that support the Simulator include Tool Command Language (TCL/TK), TCL with Classes (TCLCL), and Object-Oriented Extension of TCL (OTCL). The TK, a cross-platform and open-source widget toolkit, is a storehouse of a graphical interface for users. All the components complement one another, and they function in the orders that were built. NAM and Xgraph are two of the amazing tools that come with the NS-2 software packets.

Built on the NS 2.35 simulator software, Trace graph, NSG 2.1, Xgraph, and other easy-to-use supportive software components, the Network simulator aids the effortless generation of names for files, as well as their tracing. Already, NAM, as a Tool Command Language (TCL), uses an animation tool to view network simulation or monitor the packet trace. NAM animates the trace file being generated through the NS2 software. NAM, like some other tools, is used for packet-level, network animations, and other general-purpose operations.

3.6 Trace graph graphical interface

Trace files for this performance evaluation were all fed into the trace graph. While loading the files, TRACE GRAPH recognized and recorded the shown attributes and features in the trace graph window, as shown in Figure 3.

Packet Type: It enables calculations created for the packet types (+ to select and - to deselect) to either select or deselect a packet type. Users may select or deselect packet type by default, depending on what they want. Check the appropriate option or all the types will be used for calculations.

Packet Size: It enables calculations to go with the packet types. While the + option is used to select a packet size, the - option is used to deselect it. Feel free to either select or deselect the packet size by default. All the available types will be used for calculations when the user fails to select any of the options.

Start Time: Time interval begins with the start time.

End Time: Time interval ends with the end time.

Sent Packet: Right from the source, tap on this option will select the required sent packet type.

Ack Packet: Right there at the destination, users can tap this option to select ACK packet data.

Time interval length refers to a specified time interval, just for the .tr file. It takes a few seconds to load data via this option.

3.7 Add-on for NS-2

All the Trace files used to evaluate performance were lodged into the Trace graph. While loading these files, TRACE GRAPH recognized and recorded the shown attributes of the parameters in the trace graph window, as shown in Figure 3.

Packet Type: It enables calculations made for selected packet types (+ for selected and - for deselected) to either select or deselect a packet type. But, depending on what the user wants, select, or deselect operations have default options. The preferred option must be selected, or all types will fall under calculation operations.

Packet Size: It enables calculations to go with all the selected types (+ for selected and - for deselected) to either select or deselect a packet size. Also, the desired packet size can be selected or deselected by default, depending on what the user wants. All the types will be used in calculations if the user fails to select the appropriate option.

Start Time: This points to the start of the operations' time interval.
End Time: This refers to the end of the operations' time interval.
Sent Packet: Users tend to use this option to select desired sent packet type from the operations' source.
Ack Packet: The ACK packet type is selected at the destination when this option is used.
Time interval length refers to the operations' specified time, especially the .tr file. It takes a couple of seconds to load data from the operations' beginning or end.

4 Experimental results and discussion

The experimental result in this study was based on a comparison of the performance of the two protocols (AODV and DSDV) under distinct and varied environmental conditions.

4.1 Residual energy VS time

Certain energy of nodes dissipates after they have been used to send data to neighbors or receive data from them, with time, the residual energy of nodes began to decrease or reduce. Figure 4 presents the relationship between Time and Residual Energy for the DSDV Routing Protocol. While residual energy takes the y-axis, data on time occupies the x-axis. Analysis from the graph shows that the residual energy reduces gradually with time. Further analysis indicated that, since the DSDV runs a proactive routing protocol, each node could only use its routing tables to transmit a packet to its neighbors, and this has a significant effect on energy consumption. Figure 5 presents the relationship between Residual Energy and Time for AODV, the Ad-hoc Demand Distance Vector Routing Protocol. While the Residual Energy occupied the y-axis, Time took the x-axis part. One could see from the graph the rapid loss rate of the initial energy. The loss was due to the vast REQUEST/REPLY operations within the protocols that require a large volume of data packets for effortless transmission. Gradually, the energy residue began to decrease in the two protocols, as portrayed in Figures 4 and 5, but the rate of decrease of the residual energy in DSDV is lower than AODV. Further analysis showed that the DSDV consumed more energy than the AODV.

4.2 Dropped packet VS time

As the energy level reduces, destination nodes became unreachable and die prematurely since some packets had to drop off from the race. So, over time, a decrease in energy led to an increase in the rate of dropped packets, but this depends solely on used routing algorithms. The relationship between the dropped Packets and Time in the DSDV. Routing Protocol, as indicated by the y-axis and x-axis, respectively.

Figures 6 and 7 above showed the initial phase of some dropped packets. Then, gradually, the number of dropped packets began to increase in figure 7 than figure 6. At time 30secs, the number of drop packets is 350 in figure 7 while it is still 150 in figure 6 suggesting that lack of sufficient energy led to an increase in the number of dropped packets. So, the amount of energy used by routing operations in figure 7 is more than that of figure 6 and that is the reason why some nodes were less active in transmitting packet data thereby resulting in packet drop.

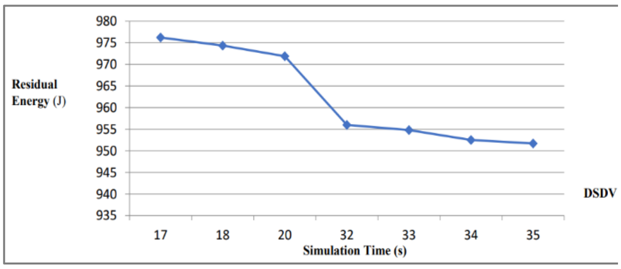

Figure 4:Residual energy Vs time in DSDV.

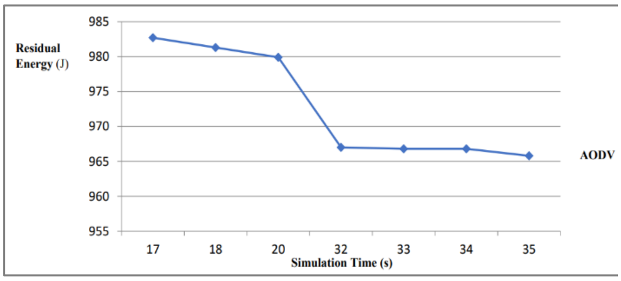

Figure 5: Residual energy Vs time in AODV.

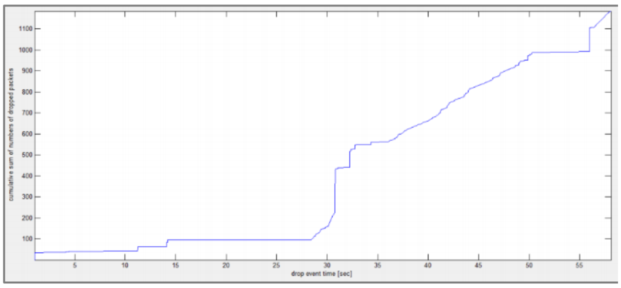

Figure 6: Dropped packet Vs time in DSDV.

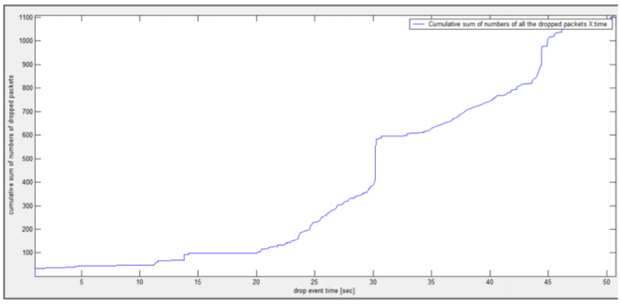

Figure 7: Dropped packet Vs time in AODV.

4.3 Packet delivery fraction

The ratio between sent and received packets is presented below. Sent packets were received at the destination generated in the traffic source.

In Figure 8, the Packet Delivery Fraction shows that AODV performs better than DSDV, and this result attested

Routing Protocol	№ of loss Packet	№ of Packet Send	№ of Packet Received
DSDV	2976	6832	3856
AODV	3314	6964	3650

Table 1: Packet delivery fraction of various routing protocols in MANET's network.

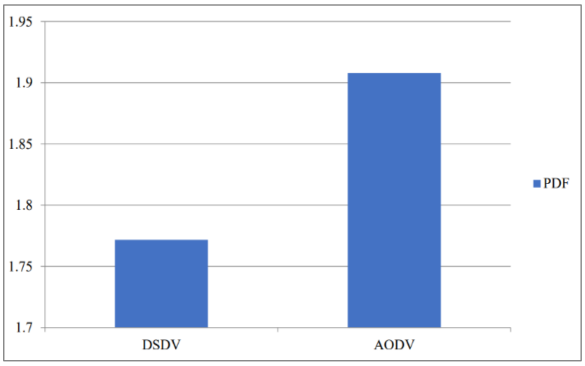

Figure 8: Packed delivery fraction of AODV against DSDV.

that DSDV does not always do well under all parameters. The packet delivery fraction of AODV was high than DSDV.

5 Conclusions

One notable challenge of the changing environment is its adverse effect on the energy consumption of the network. If care is not taken, it can drastically drain the energy and halt the network. To address this, the focus should be on energy capacity when one wants to choose a routing protocol, as this will aid efficient calls and transmissions of data within the network. This work sought to study the energy efficiency of the MANET routing protocol. To achieve its objectives, the study introduced and focused on two new evaluation parameters — residual energy Vs time and dropped packet Vs time — and the available methods. Two routing protocols — DSDV and AODV— were experimented and their performances were studied based on the raised parameters. A simulation was used to compare and contrast their performances and the results showed that AODV did well than DSDV, as presented in Figure 4-8. So, this study recommends the AODV routing protocol for use in a network design where energy for transmission of packet data is considered important. We hope to introduce the use of internet of things (IoT) applications and deep learning (DL) approach to mitigate the effects of energy consumption on MANET routing protocol at work station from the based station in our future work.

Acknowledgments

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