QoS Metrics Analysis of Routing Protocols in MANET using FIS and ANOVA Test with Varying Speed of Nodes

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Abstract: - In this paper, we analyzed AODV,DSR and DSDV routing protocol using different parameter of QoS metrics such as packet delivery ratio(PDR), Normalize Routing overhead, and Energy. The goal of this work is to determine if there is a difference between routing protocol performance when operating in a large-area MANET with high-speed mobile nodes. After the simulations, we will use Fuzzy Infurrence System to plot the performance metric. After that we use one-way ANOVA tools for that the result is correct or not. We use Matlab for simulation work. The comparison analysis will be carrying out about these protocols and in the last the conclusion will be presented, that which routing protocol is the best one for mobile ad hoc networks.

Key-Words: - MANET, Energy, Packet Delivery Ratio and Normalize Routing Overhead,FIS, ANOVA .

1 Introduction

Communication networks are evolving with a great pace witnessing increase in infrastructure and applications too. Mobile Ad Hoc Network is the latest outcome in this research. Mobile Ad Hoc Network also known as MANET [1] is a network without any available infrastructure.Nodes are mobile and can move whenever and wherever they want. Because there is no centralized control or any other infrastructure is needed in any MANET. Each node in a MANET must be capable of functioning as a router to relay the traffic of other nodes.

A number of protocols have been developed for accomplish this task. Various dedicated routing protocols have been proposed to the Internet Engineering Task Force (IETF) MANET Working Group [1]. Some of these protocols have been studied and their performances have been analysed in detail. J. Broch et al [2] evaluated four protocols using mobility and traffic scenarios similar to those we used. They focused on packet loss, routing message overhead and route length. In [3], P. Johansson et al, compare three routing protocols, over extensive scenarios, varying node mobility and traffic load. They focus on packet loss, routing overhead, energy and delay, and introduce mobility measures in terms of node relative speed. Finally, in [4] S. R. Das et al, compare the performance of two protocols, focussing on packet loss, packet end to end delay and routing load. They obtained simulation results consistent with previous works and conclude' with some recommendations for improving protocols. In this work, we measure and compare three performance parameter behavior of two routing protocols; respectively Ad-hoc On Demand Distance Vector (AODV) [5] and Destination-Sequenced Distance Vector (DSDV).

2 MANET Routing Protocols

This is the leading routing protocol proposed so for in the category of on demand or reactive routing protocols. Unlike table driven protocols, it does not maintain status of the network via continuous updates [6]. This approach assists in minimizing the flooded messages and also size of routes tables. It was designed after a distance vector routing protocol DSDV but is much efficient than DSDV. Actually AODV is a blend of DSDV and DSR. It has the actual on-demand technique of discovering the route and also route maintenance from DSR, but uses sequence numbering and also the periodic beacons of DSDV. New routes are found through the process of RREQ and RREP where RREQ packets are broadcast and RREP are unicast in nature.While route maintenance uses RERR packets for remedy of route breaks, routing information is kept afresh by the usage of sequence numbers, which is the idea borrowed from DSDV [7].

The DSDV [8] is a Proactive routing algorithm based upon well known classical distance vector algorithm of Bellman-Ford. Routing tables are maintained and updated accordingly, so broadcast periodic routing table update packets consume the bandwidth. So the main weakness of DSDV is that when network grows these packets also increase. The main improvement here to Bellman-Ford algorithm is loop freedom, which is made possible by assigning sequence number to each entry in routing table, which avoids stale routes.

The Dynamic Source Routing (DSR) [3] is an on-demand or reactive routing protocol. Therefore unlike other proactive routing protocols, DSR involves no updates of whichever type at any stage inside the network. The DSR uses Source routing for forwarding data packets which distinguishes DSR from other reactive routing protocols. It is lightweight on inner routers as due to source routing, the routing information keeping is not needed at every host. The sender becomes aware of complete destination address before transmission and appends this address in header of the routing data packet at the beginning. It is loop free due to source routing. Extensive use of cache and promiscuously listening are the main optimizations to DSR when network is at low mobility.

3 Fuzzy System:

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. Fuzzy logic includes 0 and 1 as extreme cases but also includes the various states of truth in between. Fuzzy based methodology is applied in many automated machines like washing machine, refrigerator etc [11]. There are two types of Fuzzy logic inference system (FIS). One is Mamdani type and the another is Sugeno type FIS. Mamdani type system is very popular and is commonly used. Both systems are very similar in their function but the main difference between them is: in Mamdani inference system the fuzzy output is neither linear nor constant and in Sugeno type inference system the fuzzy output is linear or constant. In this paper, mamdani type FIS has been used because it gives non linear and variable fuzzy outputs.

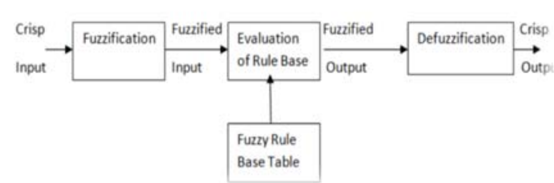

Figure 1: Fuzzy Logic Inference system

The FIS consist of four parts shown in Fig. 1 which are fuzzifier, inference engine, fuzzy rule base and defuzzifier. The function of fuzzifier in FIS is to convert the crisp input data values to the fuzzy sets that are defined through fuzzy rule base. Fuzzy rules can be made through human thinking and can be defined by their membership function. The role of defuzzifier is to convert the output fuzzy sets to a crisp output value.

4 Fuzzy Inference System (FIS):

Fuzzy Logic (FL) was introduced by Prof. Zadeh in 1965.Basically; FL is a multi-valued logic allowing in-between values to be defined between predictable valuations like true/false, yes/ no, high/low, etc. Ideas like rather tall, very fast are expressed mathematically and processed by computers, to put on a more gentle way of thinking in computer programming . In a bid to devise a concise logic theory and later mathematics, the so-called "Laws of Thought", were stated. Of these, the "Law of the Excluded Middle", states that every proposition must be either true or false. Fuzzy Logic is a tool for controlling of systems and complex industrial processes, as also household and entertainment electronics and other expert systems.

4.1. Simulation Evaluation Methodology

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

1. Packet delivery ratio.
2. Normalized Routing Overhead.
3. Energy

4.2. Simulation Evaluation Methodology

The most paramount reasons justifying use of fuzzy systems are Annabelle Mercier [21]:

- The sophistication of natural world which leads to an approximate description or a fuzzy system for modelling.
- Necessity of providing a pattern to formulate mankind knowledge and applying it to the actual systems.

Thus, the following procedure is considered to define expert fuzzy system:

- Defining input-output sets which accept normalized input-output pairs.
- Generating if-else fuzzy rules based on input-output pairs.
- Creating fuzzy rule base.
- Implementing fuzzy system based on fuzzy rules

4.3. Parameters of fuzzy system:

A Mamdani neuro-fuzzy system uses a supervised learning technique (backpropagation learning) to learn the parameters of the membership functions.

In Fuzzy system, we use 1 factor of the number of nodes has been used in this system for evaluation of three AODV, DSDV and DSR routing protocols as input parameter and based on this input factor, effect of the factor on three AODV, DSDV and DSR routing .Therefore, the above fuzzy system has three outputs which show efficiency of three AODV ,DSDV and DSR routing protocols based on different input states. In this paper, Fuzzy system tools were used in Matlab software to determine efficiency of test technique and its general diagram is shown in Figure 1.

This system has 1 input field which relates to factor affecting evaluation of three AODV ,DSDV and DSR routing protocols and three classes i.e. min, normal and max verbal words have been assigned to each factor and 3 output fields which show efficiency of three AODV,DSDV and DSR routing protocols and the output has been classified into three groups and low, normal and high verbal words have been assigned to each factor. In Figures 2 and 3, one of the membership functions of input and output parameters is shown.

A simple method for generation of fuzzy rules is clustering of input features with specified number of fuzzy membership functions (for example, triangular membership function and assignment of verbal words to each cluster). With the classified space for each model, one way for generation of fuzzy rules is to consider all possible combinations of antecedents (input features) and this method has been also used in this research.

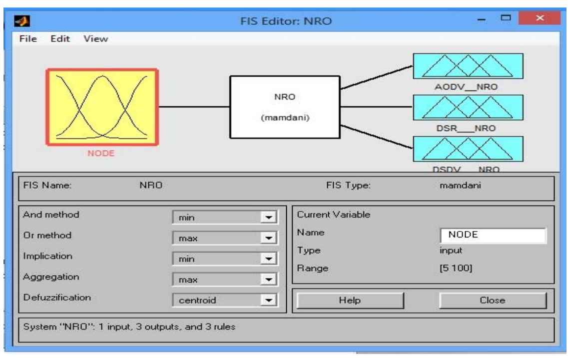

Fig. 2: General model of fuzzy expert System for evaluation of three routing Protocol.

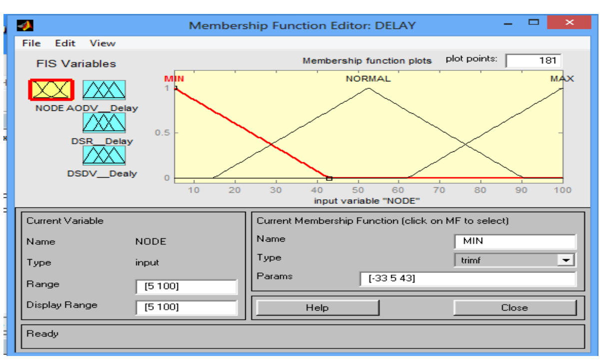

Fig. 3: Membership function relating to input of the number of node.

4.4 Result Comparison in Matlab:

A. **Normalized Routing Overhead**:

Normalized Routing Overhead is defined as the ratio of total number of routing packets transmitted (including forwarded routing packets also) to the total number of data packets received at the destination nodes .

Fuzzy if–then rules

1. If (Node is min) then (AODV-NRO is min) (DSR-NRO is normal) (DSDV-NRO is normal).
2. If (Node is normal) then (AODV-NRO is min) (DSR-NRO is normal) (DSDV-NRO is normal).
3. If (Node is max) then (AODV-NRO is min) (DSR-NRO is normal) (DSDV-NRO is normal).

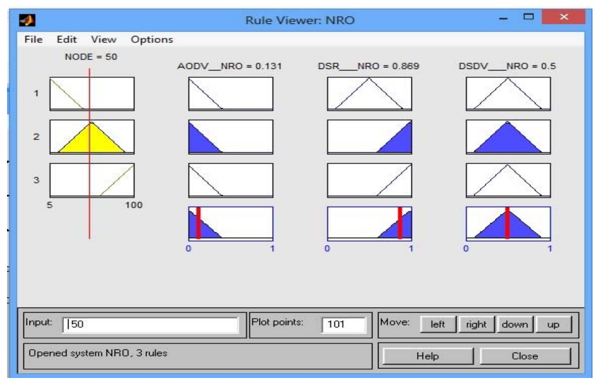

Fig. 4: Result of simulation with 50 nodes output of normalized routing overhead.

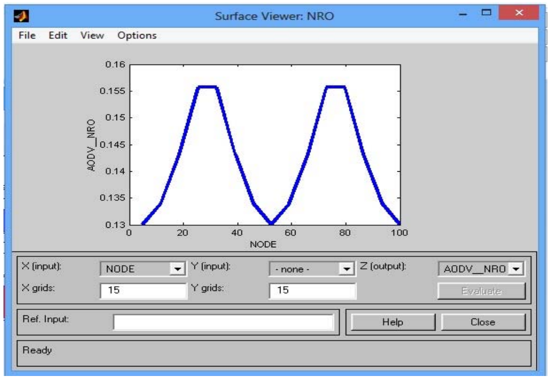

Fig.5: Effect of number of node on overhead in AODV protocol.

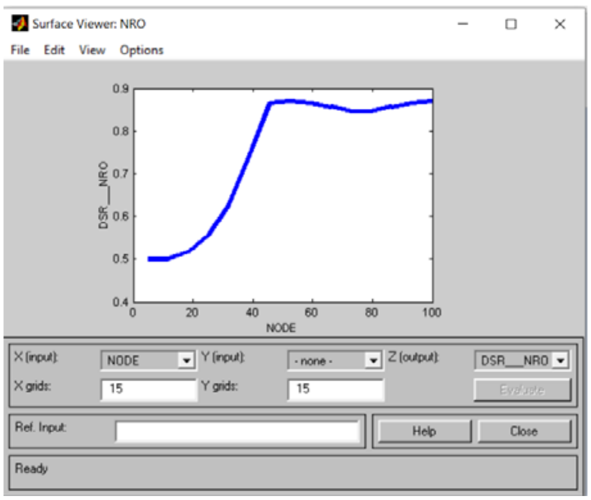

Fig.6: Effect of number of node on overhead in DSR protocol.

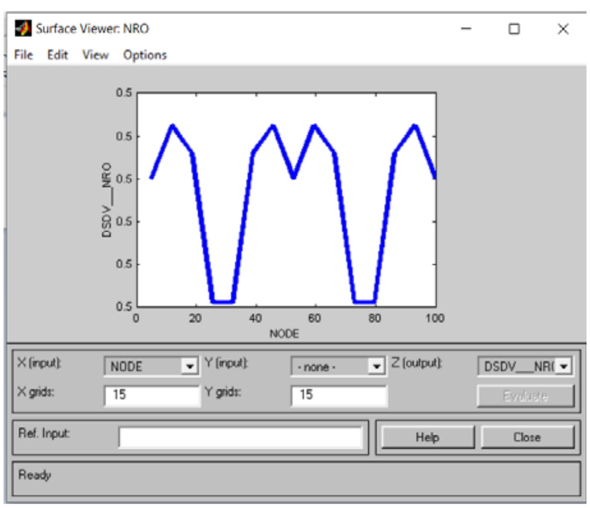

Fig.7: Effect of number of node on overhead in DSDV protocol.

B Packet Delivery Ratio:

Packet Delivery Fraction is defined as the ratio of data packet delivered to destination to those generated by the CBR source.

Fuzzy if–then rules

1. If (Node is min) then (AODV-PDR is Average) (DSR-PDR is Average) (DSDV-PDR is max).
2. If (Node is normal) then (AODV-PDR is min) (DSR-PDR is Average) (DSDV-PDR is Average).
3. If (Node is max) then (AODV-PDR is min) (DSR-PDR is min) (DSDV-PDR is Average).

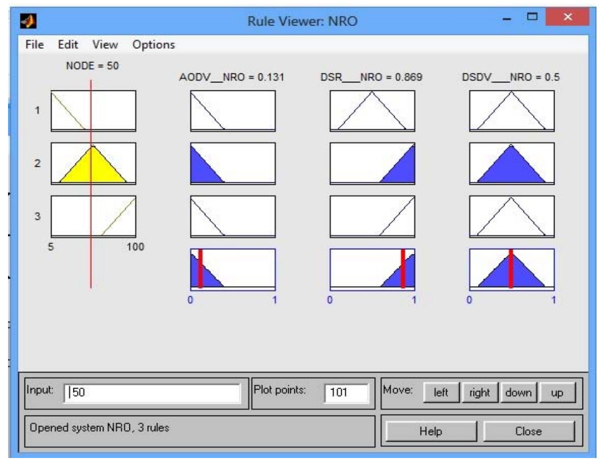

Fig. 8: Result of simulation with 50 nodes output of PDR

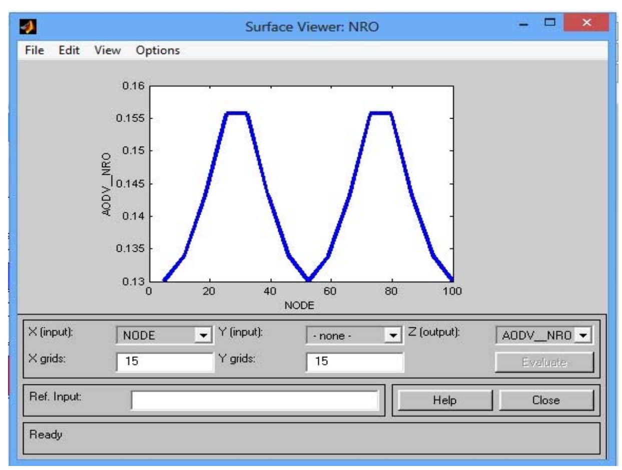

Fig.9: Effect of number of node on output of PDR in AODV protocol

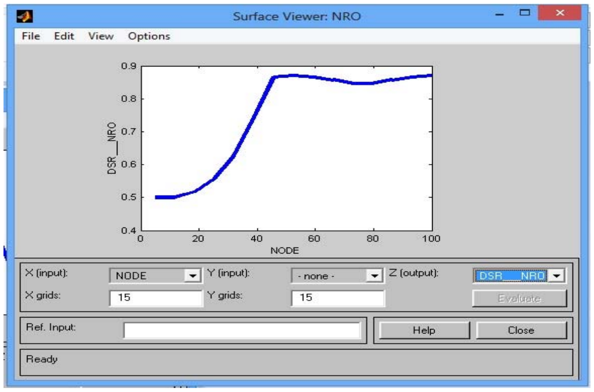

Fig.10: Effect of number of node on output of PDR in DSR protocol

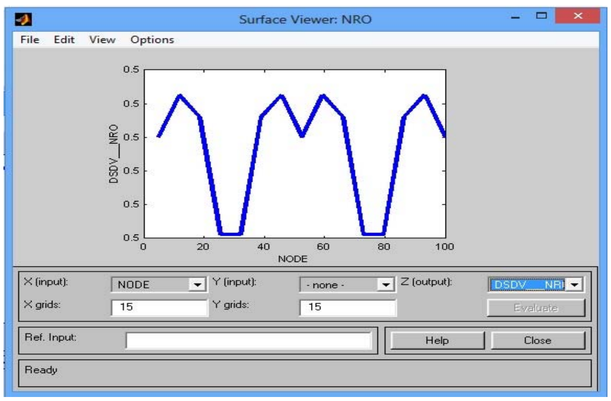

Fig.11: Effect of number of node on output of PDR in DSDV protocol.

C Energy Consumption:

Energy consumption refers to the amount of energy that is spent by the network nodes within the simulation time. This is obtained by calculating each node's energy level at the end of the simulation, factoring in the initial energy of each one. The following formula will produce the value for energy consumption: Energy Consumption = $\sum_{i=1}^{n}(ini(i) - ene(i))$

Fuzzy if–then rules

1. If (Node is min) then (AODV-energy is min) (DSR-energy is normal) (DSDV-energy is average).
2. If (Node is normal) then (AODV-energy is min) (DSR-energy is normal) (DSDV-energy is normal).
3. If (Node is max) then (AODV-energy is min) (DSR-energy is normal) (DSDV-energy is min).

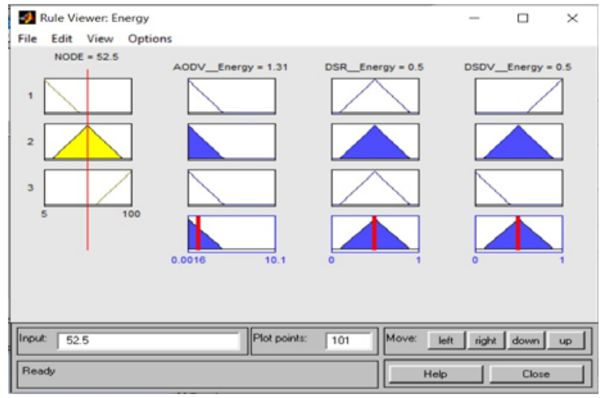

Fig. 12: Result of simulation with 50 nodes output of Energy

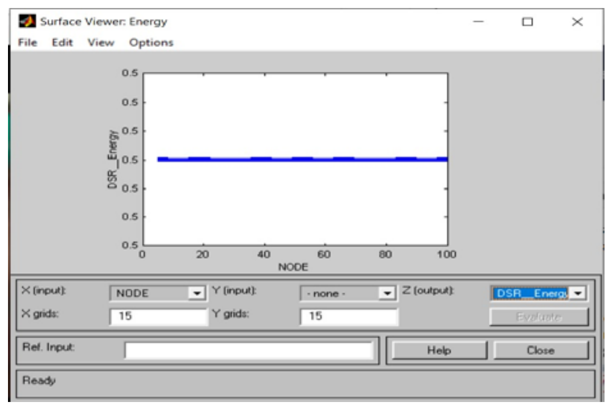

Fig.13: Effect of number of node on output of Energy in DSR protocol

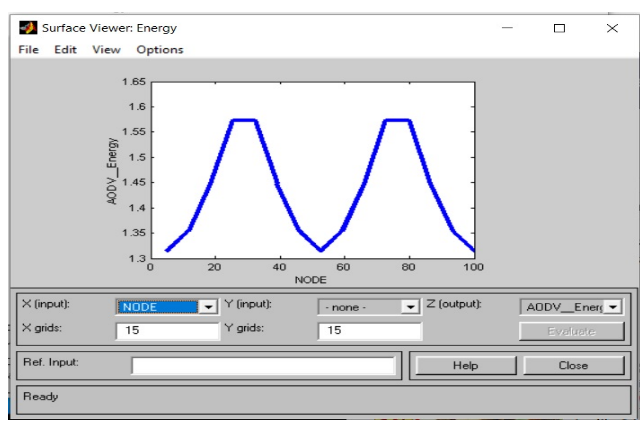

Fig.14: Effect of number of node on output of Energy in AODV protocol

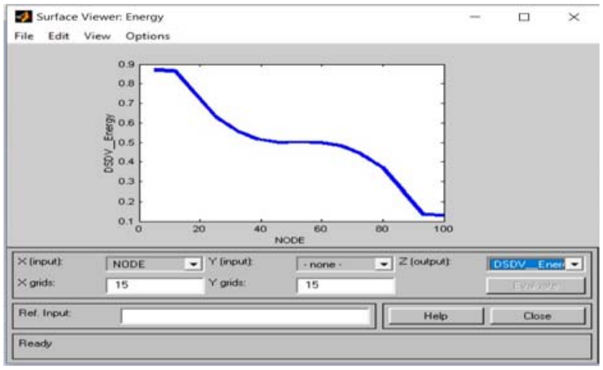

Fig.15: Effect of number of node on output of PDR in DSDV protocol.

5. ANOVA Test

Analysis of variance(ANOVA) is a collection of statistical models used to analysis the differences between groups means and their associated procedures(such as "variation" among and between groups), in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation[12].

In this paper we have use One Way ANOVA. One Way ANOVA is used to study the effect of $(k > 2)$ levels of a single factor. Factor is defined as a characteristics under consideration, thought to influence the measured observation. Level is defined as a value of a factor.

5.1. Output Of The Test For Different Parameters

5.1.1. Packet Delivery Ratio

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

Table 1: Summary of Packet Delivery Ratio

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

Table for One way ANOVA test in Appendix A

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

5.1.2 Erengy Consumption

Data Energy Energy consumption refers to the amount of energy that is spent by the network nodes within the simulation time. ANOVA statistical computation shows that we do not reject the null hypothesis. That is, there is no significant difference for the different methods in terms of energy performance($\mathrm{P-value} > 0.05$).

Table 2: Summary of Energy

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

Table for One way ANOVA test in Appendix A

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

5.1.3. Normalized Routing Overhead

Using the ANOVA hypothesis testing, the simulation results show a significant difference among methods used in terms of Normalized Routing Overhead ($\mathrm{P-value} > 0.05$). Thus, Normalized Routing Overhead can be used as a metric to measure the performance of different algorithms.

Table 3: Summary of Normalized Routing Overhead

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

Table for One way ANOVA test in Appendix A

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

6 Conclusion

The results indicate that the performance is better especially when the number of nodes in the network is higher. For this work we have used a simulator which provides the virtual environment for the testing different parameters. Reactive routing protocol AODV performance is the best considering its ability to maintain connection by periodic exchange of information.Using matlab simulator we created the scenarios . After analyzing the simulation we concluded that AODV indicating its highest efficiency and performance under high mobility than DSR and DSDV, and the performance of TCP and UDP packets with respect to normalized routing overhead, energy and PDR, and the performance of AODV is better than DSDV and DSR routing protocol for real time applications from the simulation results.

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

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APPENDIX-A

5.1.1. Packet Delivary Ratio

The one way ANOVA test for PDR is

Table 4: ANOVA of Packet Delivery Ratio

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	130.21925	2	65.10963	0.560241875	0.573763	3.135918
Within Groups	7670.3216	66	116.217			
Total	7800.5409	68				

5.1.2 Erengy Consumption

The one way ANOVA test for Energy is

Table 5: ANOVA of Energy

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.764E+10	2	8.82E+09	0.778278814	0.463364	3.135918
Within Groups	7.479E+11	66	1.13E+10			
Total	7.655E+11	68				

5.1.3. Normalized Routing Overhead

The one way ANOVA test for Normalized Routing Overhead is

Table 7: ANOVA of Normalized Routing Overhead

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.4470485	2	2.223524	7.766781596	0.000935	3.135918
Within Groups	18.894905	66	0.286286			
Total	23.341954	68				