Evaluating Reactive Routing Protocols of VANETs using $2^K$ Factorial Analysis

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Abstract

Background/Objectives: The capabilities of vehicular communications technology is ever expanding and due to this reason, vehicular Ad-hoc networks are known as the most essential devices for significant progressions in modern era. The main purpose is to entertain, to ensure safety and take precautionary measures in case of emergency. The enhanced network performance is always subjected to efficient routing in the networks. In fact, routing information is based on the routing protocols in every network system. This research aims to modify further to improve the implementation of routing protocols including Ad hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Dynamic MANET On-demand (DYMO) intended for VANETS which are viewed as progressively helpful and appropriate for Ad-hoc systems.

Methods: The upgraded adaptation of AODV, DSR and DYMO are called as MOD-AODV, MOD-DSR and MOD-DYMO. Ad-hoc networks specifically in VANETs rely on simulation because of the complication and level of intricacy in deployment of such networks. However, for validation of such proposals the most important and representative factors are overlooked during the experiments. Moreover, a statistical analysis is presented that is based on $2^K$ factorial that revealed the technique so as to decide the most extreme model viewpoints influencing the working of routing protocols under the system density and traffic loads. Three reactive routing protocols including Packet Delivery Ratio (PDR), Average End-to-End Delay (AE2ED) and Network Routing Overhead (NRO) are selected to break down the execution for the implementation of estimating parameters. Findings: At last, the outcomes show that at the expense of higher NRO, MOD-DYMO accomplished the better PDR and AE2ED than other routing protocols on varying nodes thickness and number of Constant Bit Rate (CBR) connections in all considered scenarios.

Keywords: Optimized Link State Routing (OLSR), Routing, Routing Congestion, Wireless Multi-hop

1. Introduction

Time by time, driving on the road becomes more difficult due to growth of vehicles on road. In order to avoid the road accidents and ensure road safety it is essential that vehicles should be more intelligent for correspondence with different vehicles. The Vehicular Ad-hoc Networks are self-composed with foundation less systems in which vehicles are important elements and they can speak with one another in the network through a wireless radio channel.
Any fixed predefined infrastructure is not merely required for communication in VANETs. However, range of communication is restricted to few hundred meters while, may be called as sub-network. Vehicles can speak with one another through self-arranged systems of networks. Definitely, VANETs might be called as sub-arranged entities of MANETs because of quick vehicles mobility and rapidly change in network topology. Moreover, VANETs played a vital role for increasing road safety thereby reduction in road accident especially in high ways. Although, in real time scenarios the transmission of data between vehicles should be appropriately transferred to avoid road accident, to provide the multimedia entertainment service to passengers and generate and broadcast an alert for traffic jam especially in emergency circumstances.

Adequately, high cost and labor is required when installing and testing VANETs, being unaffordable in most scenarios. Therefore, prior to actual implementation simulation is useful alternative. However, new architecture and technologies are developed and designed for VANETs simulation. While, the most prominent and important factors are ignored for validation of new architecture design.

The protocols operating in an ad hoc network may have some factors affecting the overall performance. The prominent factor is node mobility which causes link failure particularly in case of VANETs when vehicles are moving in opposite direction, which results in poor quality of service. Though, network density, routing overhead and traffic load/number of connections will have a substantial influence on network scalability. These factors along with essential fundamental highlights of Ad-hoc networks may result in irregular varieties in the general network execution. The essential target of this investigation is to assess and upgrade the execution of reactive routing protocols based on AODV, DSR as well as DYMO in support of VANETs; furthermore, break down impacts on different factors in network execution. Nonetheless, the announced research assessed the execution of directing conventions for VANETs while the persuasive components which impact by and large executions of Ad-hoc network are disregarded network are overlooked. In addition, $2^k$ factorial analysis determines the impact of four factors: 1. nodes density, 2. number of connections, 3. default routing protocols, and 4. modified routing protocols on the performance of VANETs. Moreover, the researchers evaluated and investigated the impact of four factors that include PDR, AE2ED, and NRO on three performance metrics. These factors provide the guide line for design choices and tradeoffs by computing the effects.

Furthermore, the performances based on the reactive routing protocols on performance metrics are evaluated in urban scenario for VANETs. For urban scenario, NS-2 does not work well with Two-Ray-Ground model. The disadvantage of Two-Ray-Ground is that it assumes perfect line of sight and signal strength for subsequent transmission range and over sight environmental complications. That is why it produces the inaccurate simulation results for this scenario. So, we need a propagation model that gives us accurate simulation results. Further studies in suggest about the propagation model. The Nakagami model performs better than all available models.

In addition, this research is centered on execution assessment of three reactive routing protocols including AODV, DSR, and DYMO intended for VANETs in urban situation. In any case, reactive routing protocols have been broke down with execution measurements (AE2ED, PDR and NRO) on broadening with number of associated connectivity and the thickness of node.

This research study is comprised on seven sections. Section 1 is about introduction following related work for the study in section 2. Similarly, section 3 is about Motivation. Moreover, section 4 shows $2^k$ Factorial Design Analysis. Section 5 presents Experiments and Discussions. In Section 6, the tradeoffs made by routing protocols are described and finally overall article is concluded in Section 7.

2. Literature Survey

Currently researchers heavily depend on simulation prior to deployment of any network. Hence, Simulations played a vital role to validate the research work for scholars especially in VANETs. However, in simulations the most significant factors are undermined. In critically analyzed radio propagation models for urban scenario and deducted the conclusion about the factors which directly affect the results (the variables which legitimately influence the outcomes) of vehicular routing protocols. The researchers also compared the performance based on radio propagation models which include Two Ray Ground model as well as the Corner model. Subsequently, they
find out the factors that impact directly on the preciseness of the Two Ray Ground model, for (propagation models; two Ray Ground propagation models demonstrate and the Corner model. Alongside, it was discovered that variables that sway legitimately on the exactness of the Two Ray Ground model, for example, propagation disturbance due to buildings presence and availability of hidden terminals within the network. In this study, researchers also changed the map size, radio communication range and the type of radio propagation model. However, they maintained parameters as constant based on the size of the packet and the thickness of vehicles to appraise the execution network system.

Similarly, this research work examined AODV and OLSR routing protocols for improving the connection state routing thoroughly and benchmarked the execution of AODV as well as OLSR. For the augmentation of the execution of such routing protocols, some state of art schemes were undertaken under certain portable models for vehicle-node thickness parameter in VANET. Consequently, simulated results showed that as the network density increase thereby routing protocols gives slightly better performance around the receiver end. On the other hand, authors considered only common parameters; mobility models and network density to analyze the performance whereas, parameters which directly affect the performance are overlooked like; simulation area, packet size, mobility models, transmission range and radio propagation model.

In10 presented architecture of vehicle to vehicle communication and proposed a vehicular dissemination protocol which assures vehicles to share their information in detail with other vehicle regarding traffic jam, accidents or hindrances on roads and available parking spaces through intelligent interaction with other vehicles. In this study, authors also varied vehicles density and their speed for evaluation of the proposed scheme however; they maintained some parameter including communication radio range, radio propagation model, map size, simulated road map and packet size.

Evaluated radio propagation models that perform better for VANETs. Authors analyzed and evaluated the performance of Nakagami model which concludes that Nakagami model gives perfect simulation results for VANETs in realistic scenarios as compared to other available models.

Further, studying on Nakagami model, researchers found one study on NoW project11 and reviewed in detail. The routing protocols were evaluated for VANETs in terms of highway scenario by using Nakagami modeling. In urban scenario, vehicle communication becomes so hard because of having more fading affects than highways, due to large buildings, trees and other environmental factors that affect communication.

In14 evaluated the performance of one proactive routing protocol along with two reactive routing protocols that included DSDV in contrast to AODV and DSR respectively in VANETs. These routing protocols are simulated in highway scenarios with performance parameter; PDR, AE2ED and NRO. In conclusion, authors contrary stated that the dedicated and designed protocols for MANETs are not suitable for VANETs.

In15 discussed about the routine assessment of AODV as well as OLSR routing protocols designed for VANETs in an urban scenario. Moreover, PDR, AE2ED and NRO are taken as the performance measuring parameter with accordance to different node densities and different CBR connections.

In16 evaluated the ad-hoc routing protocols and its conventional performance in line with the vehicle network environment. The study presented the routing protocols performance in diverse scenarios including city scenario and highway scenario. This study work used Vanet Mobisim (an intelligent driver model based tool) to make realistic mobility traces to it. Generally, PDR, NRL, AE2ED and throughput are considered as performance measuring metric for breaking down the execution of proposed scheme.

In17 assessed AODV, DSR, FSR as well as TORA in urban situations as the execution of two reactive along with two proactive routing protocols. This research work structured a model (realistic city architecture) to analyze the performance of such routing protocols. They concluded that contrary to other protocols for VANETs TORA is completely unrealistic for real time environment. However, DSR attains the high AE2ED while AODV and FSR perform better as compared to other routing protocols.

In18 compared the performance of AODV, DSR, FSR and TORA by making them as two reactive along with two proactive routing protocols intended for VANETs in terms of the highway scenario in this study. Subsequently, they also designed a sophisticated real time freeway mobility model for evaluation of these protocols and concluded that AODV outperforms in traffic situations while TORA is not applicable for VANETs.
3. **Motivation**

This study undertook AODV, DSR as well as DYMO as the reactive routing protocols and was simulated in line with the urban scenarios designed for VANETs. However, in the authors evaluated routing protocols using Nakagami radio propagation model. Due to realistic approach of Nakagami model it is concluded that Nakagami is the most effective amongst reported available models. As inspired by the work based on AODV, DSR along with DYMO as the reactive routing protocols were appraised comparing them in terms of urban scenario by means of the $2^K$ factorial analysis method.

4. **$2^K$ Factorial Analysis**

For authenticity purpose the validity of architecture before implementation is considered as the cost-effective methodology. Subsequently, simulations are very essential for designing realistic models for any system. However, simulations specifically in VANETs frequently employed extensive and heterogeneous situations for legitimacy before usage continuously for various applications. The conceivable variables which sway the execution of the frameworks could be large as far as their qualities or levels. The utilization of $2^K$ factorial method for deciding the most of the components emphatically influence the framework execution. The utilization of $2^K$ factorial investigation is vital for a few reasons: 1. overall reduction in simulation count except needed; 2. to find out the association among the significant parameters; and 3. to limit the length of simulations. The fundamental methodology of this method is to decide two extreme dimensions and select $k$ parameters set. However, an experiment was undertaken using $2^K$ possible combine of the parameters for its running effectively. Moreover, also proposed how to discover the most important factors affect VANETs and its performance. The strategy also finds the independencies and relationship between these factors and depends on the selection of $k$ parameters because it determines the maximum level of 2, i.e. -1 and 1. Similarly, the researchers analyzed the performance of the parameters based on AODV, DSR as well as DYMO as being the reactive routing protocols by undertaking the same methodology. Instead of two factors in (Default and Modified) and network density (Node Density (node density and mobility), researchers selected the routing protocols and Number of Connections). In order to analyze the impact of the two factors; researchers choose the performance of the parameters PDR, AE2ED as well as NRO using $2^K$ factorial method. Table 1 demonstrates the four different computations defined by $2^K$ Factorial design; while, Table 2 and 3 illustrates the simulation results of routing protocols (Default and Modified) in terms of performance parameter against these two factors.

![Table 1](image)

| Experiment | A | B | U |
|------------|---|---|---|
| 1          | -1| -1| u1|
| 2          | 1 | -1| u2|
| 3          | -1| 1 | u3|
| 4          | 1 | 1 | u4|

![Table 2](image)

| Specifications                                      | Specifications                                      | Specifications                                      |
|-----------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------|
| Software                                            | Network Simulator 2.34                              |                                                     |
| Implementation of Ad-hoc on demand distance         | Default Settings                                    |                                                     |
| Implementation of Dynamic source routing            | Default Settings                                    |                                                     |
| Implementation of dynamic MANET on demand           | DYMO-UM Patch                                      |                                                     |
| Mobility model generator version                    | 2.81                                                |                                                     |
| Simulation of urban mobility version                | 0.12.3                                              |                                                     |
| Number of nodes                                     | 20, 40, 60, 80, 100                                 |                                                     |
| Number of constant bit rate sessions                | 6, 12, 18, 24, 30, 36, 42                          |                                                     |
| Range of transmission                               | 300meters                                           |                                                     |
| Area of simulations                                 | 8.5 Km$^2$                                         |                                                     |
| Uniform speed                                       | 40 key stroke per hour                              |                                                     |
| Type of data                                        | CBR                                                 |                                                     |
| Packet size of data                                 | 1000 bytes                                          |                                                     |
| MAC Protocol                                        | IEEE 802.11 Overhauled                             |                                                     |
| PHY Standard                                        | IEEE 802.11p                                        |                                                     |
| Radio Propagation Model                             | Nakagami                                            |                                                     |

Two variables $y_A$ as well as $y_B$ are defined for routing protocols and vehicles densities respectively. This research work used the simulation parameters as shown in Table 2. Nakagami propagation model is used due to its...
realistic approach. However, AODV and DSR protocols are available as default with NS-2. In addition, patch of DYMO is implemented as DYMOUM-patch using the approach discussed in. While, the map is scaled down to \((4 \times 4)\) km in terms of its size in support of the realistic simulation environment and was introduced in mobility model generator for vehicular network (MOVE). Conversely, mobility patterns including MOVE as well as SUMO are produced at random. Moreover, simulation parameters used for this study are described in Table 2.

\[
y_A = \begin{cases} 
-1 & \text{Default Protocols} \\
1 & \text{Modified Protocols}
\end{cases}
\]

\[
y_B = \begin{cases} 
-1 & \text{Node Density} \\
1 & \text{Connection}
\end{cases}
\]

When analyzing the performance parameters against above variables, we use regression model that is given below.

\[
p_0 + p_A y_A + p_B y_B + p_{AB} y_A y_B = U
\]

As we take four different observations, so, by substituting these experiments in this model, we get following four equations:

\[
p_0 - p_A - p_B + p_{AB} = u_1
\]

\[
p_0 - p_A + p_B - p_{AB} = u_2
\]

\[
p_0 - p_A + p_B - p_{AB} = u_3
\]

\[
p_0 + p_A + p_B + p_{AB} = u_4
\]

On solving above equations, we get:

\[
p_0 = \frac{1}{4} \left( u_1 + u_2 + u_3 + u_4 \right)
\]

\[
p_A = \frac{1}{4} \left( - u_1 + u_2 - u_3 + u_4 \right)
\]

\[
p_B = \frac{1}{4} \left( - u_1 - u_2 + u_3 + u_4 \right)
\]

\[
p_{AB} = \frac{1}{4} \left( u_1 - u_2 - u_3 + u_4 \right)
\]

In the obtained results \(p_0\) is interpreted as mean performance, \(p_A\) as mean effect of routing protocols (Default and Modified), \(p_B\) as mean effect of vehicles’ density and \(p_{AB}\) as interaction between both the routing protocols (Default and Modified) and vehicles density.

| Protocol   | (PDR) avg (%) | (E2ED) avg(s) | (NRO) avg | (PDR) avg (%) | (E2ED) avg(s) | (NRO) avg |
|------------|---------------|---------------|-----------|---------------|---------------|-----------|
| AODV       | 61.92         | 0.402         | 1.878     | 65.84         | 0.21          | 2.36      |
| MOD-AODV  | 64.15         | 0.327         | 1.908     | 66.064        | 0.19          | 2.608     |
| DSR        | 64.84         | 0.0118        | 1.088     | 65.9          | 0.0142        | 1.461     |
| MOD-DSR   | 71.53         | 0.0109        | 1.576     | 72.69         | 0.025         | 1.687     |
| DYMO       | 71.703        | 0.00164       | 2.456     | 71.802        | 0.00160       | 2.582     |
| MOD-DYMO  | 78.402        | 0.00162       | 2.288     | 78.531        | 0.00172       | 2.367     |
4.1 Calculating Effects of Factors through Variation

Here, we discuss how total variation of \( y \) can be explained by each factor, as:

\[
Total Variation of \ U = SST = \sum_{i=1}^{2^k} (u_i - \bar{u})^2 \tag{12}
\]

However, “\( u \)” denotes the average value of four experiments. By expanding equation (12) we get:

\[
SST = (u_1 - \bar{u})^2 + (u_2 - \bar{u})^2 + (u_3 - \bar{u})^2 + (u_4 - \bar{u})^2 \tag{13}
\]

\[
SST = 2^2 q_A^2 + 2^2 q_B^2 + 2^2 q_{AB}^2 \tag{14}
\]

As Eq (14) shows the variation occurred by these factors, and which one has more impact on the performance parameters. These fractions of variation explained independently as follow:

\[
Fraction of Variation Explained by A = \frac{SSA}{SST} \tag{15}
\]

\[
Fraction of Variation Explained by B = \frac{SSB}{SST} \tag{16}
\]

\[
Fraction of Variation Explained by AB = \frac{SSAB}{SST} \tag{17}
\]

4.2 Analyzing AODV

For Analyzing AODV protocol in terms of PDR, using above methodology the results is given below:

\[
p_0 - p_A - p_B + p_{AB} = 61.920 \tag{18}
\]

\[
p_0 + p_A - p_B - p_{AB} = 64.150 \tag{19}
\]

\[
p_0 - p_A + p_B - p_{AB} = 65.840 \tag{20}
\]

\[
p_0 + p_A + p_B + p_{AB} = 66.064 \tag{21}
\]

By solving above equations we get:

\[
p_0 = 64.4935 \tag{22}
\]

\[
p_A = 0.61350 \tag{23}
\]

\[
p_B = 1.45850 \tag{24}
\]

\[
p_{AB} = -0.5015 \tag{25}
\]

The result interpreted as the mean PDR is 64.4935%, the effect of routing protocols (Default and Modified) is 0.6135, the effect of vehicles density is 1.4585 and the interaction between them is -0.5015. From this result we conclude that vehicle density has more impact on PDR.

Same is case for AE2ED of AODV; we use same methodology and find the following results.

\[
p_0 - p_A - p_B + p_{AB} = 0.402 \tag{26}
\]

\[
p_0 + p_A - p_B - p_{AB} = 0.327 \tag{27}
\]

\[
p_0 - p_A + p_B - p_{AB} = 0.210 \tag{28}
\]

\[
p_0 + p_A + p_B + p_{AB} = 0.190 \tag{29}
\]

By solving above equations we get,

\[
p_0 = 0.28225 \tag{30}
\]

\[
p_A = 0.02375 \tag{31}
\]

\[
p_B = 0.08225 \tag{32}
\]

\[
p_{AB} = 0.01375 \tag{33}
\]

From the above results we find that mean AE2ED is 0.28225, the effect of routing protocols (Default and Modified) is -0.02375, the effect of vehicles density
is - 0.08225 and the interaction between them is 0.01375. Hence this is observed that vehicle density has more impact on AE2ED.

For Analyzing AODV protocol in terms of NRL, using above methodology the results is given below:

\[ p_0 - p_A - p_B + p_{AB} = 1.878 \]  \hspace{1cm} (34)

\[ p_0 + p_A - p_B - p_{AB} = 1.908 \]  \hspace{1cm} (35)

\[ p_0 - p_A + p_B - p_{AB} = 2.630 \]  \hspace{1cm} (36)

\[ p_0 + p_A + p_B + p_{AB} = 2.608 \]  \hspace{1cm} (37)

By solving above equations we get,

\[ p_0 = 2.1885 \]  \hspace{1cm} (38)

\[ p_A = 0.0695 \]  \hspace{1cm} (39)

\[ p_B = 0.2955 \]  \hspace{1cm} (40)

\[ p_{AB} = 0.0545 \]  \hspace{1cm} (41)

The result interpreted as the mean NRL is 2.1885, the effect of routing protocols (Default and Modified) is 0.0695, the effect of vehicles density is 0.2955 and the interaction between them is -0.0545. From this result we conclude that vehicle density has more impact on NRL.

4.3 Calculation of Total Variation in AODV

In case of PDR of AODV, we interpret variation of these factors and find that vehicles density has more impact that is 77.21% of the total variation on PDR AODV, routing protocols (Default and Modified) has 13.66% and their combination has 9.13% impact on PDR of AODV. Hence, the total variation (SST) is of 11.02.

Hence, we also find the total variation for AE2ED AODV. We conclude our results as factor B plays major role for high value of AE2ED and that impact is 90% of its total variation. Whereas routing protocols (Default and Modified) has less value 7.5% and their combination has less value than both these factors (A and B) that is 2.5%, so they have less impact than factor B. And total variation (SST) is 0.03001.

When we calculate the total variation for NRL of AODV, it is observed that, factor B has also more impact on NRL of AODV that is 91.8%, routing protocols (Default and Modified) has 5.08% and their combination has 3.12% impact on NRL of AODV. Total variation (SST) is calculated as 0.3805.

5. Experiments and Discussions

The following are the performance measuring parameters evaluating the routing protocols’ (AODV, DSR as well as DYMO) efficiency.

**PDR:** Packet delivery ratio is used for the ratio concerned to the data packet at the end which generates the total data packets.

**AE2ED:** It is the average end-to-end delay in which time is needed for a packet to be reached at certain destinations.

**NRO:** Normalized routing overhead can be called to the numbers of routing packets; however, it is transmitted through per data packet delivering at the certain destinations as shown in Table 4.

5.1 PDR

Figure 1 reveals the normal percentage related to PDR versus (number of Constant Bit Rate (CBR) connections and node density). Precisely, results illustrate that the DYMO outperforms than AODV and DSR due to the prevention of route calculation stratagem prior to the transmission of data. Additionally, when CBR connections are raised thereby AODV and DSR both attain the linear increase in PDR. Likewise, modified DYMO is also performs better than original DYMO because of decrease in network diameter and decrease in request wait time. On the other hand, AODV and DSR both provide nearly similar results. In addition, in case of link breakage AODV employs unsweaving path to end point and applies local link repair mechanism to reconstruct the route and also it consumes less bandwidth. Decisively, in result AODV attains the higher PDR as the CBR connections and nodes density increase. In contrast, DSR attains somehow better PDR as compared to AODV due to presence of valid routes in Route Cache. However, route reversal technique
preserves DSR from generating additional overhead for second route discovery in case of link breakage. So that, DSR also achieves the increasing PDR as the CBR connections and nodes density increase.

5.2 AE2ED

Figure 2 illustrates the AE2ED versus CBR connections along with density of nodes. Generally, the packets of routing in the protocols for the establishment of path can decrease the delay as number of CBR connections increase. Specifically, in case of AODV, AE2ED is more as compared to DSR as well as DYMO. Conversely, AE2ED related to DSR is a smaller as compared to both AODV as well as DYMO in this study.

AE2ED of AODV is higher due to CBR’s increasing number in terms of connections; a packets’ number holding in support of a wireless channel can also be raised directing towards collisions of more packets with more consumption of bandwidth. In result, packet delivery ratio is dropped to some extent a significant rise in AE2ED. As it is obvious from Figure 2, the AE2ED stream of AODV routing protocol can be raised when the nodes number increased due to two facts. Primarily, in case of link breakage the AODV protocol uses three type of message; Route REQuest (RREQs) for establishing a path from originator node by applying intermediate node using source to the destination. It is followed by Route REPlies (RREPs) back to the originator since the intermediate node takes a valid route towards destination itself in case where a valid route is not available in the cache of intermediate node. Route ERRors (RERRs) packets are used to notify the neighbor nodes when next-hop link breaks. However, each previous node intimate to all its predecessors nodes using RERR packet to erase all routes to broken link. In order to establish valid route or path from originator to destination node these packets cause much delay. Secondary, Local Link Repair (LLR) mechanism in AODV also causes adequate increase in path length which leads more delay when link breakage occurs.

Generally, DSR attains less AE2ED as compared to AODV and DYMO. Initially, in case of lower CBR connection its delay decreases when the connection increases (6 to 12) due to availability of valid paths in route cache. However, the link breakage transpires DSR by verifying its route cache using a new route for data transmission. However, its delay slightly increases as CBR connection increases from 18 to 42 due to lack of valid routes in route cache and trace out new routes

![Figure 1. Packet delivery ratio.](image1)

![Figure 2. Average E2E delay.](image2)

### Table 4. Results from performance parameters (PDR, AE2ED and NRO) through variation of two factors

| Protocol | Performance Parameters | \( p_o \) | \( p_A \) | \( p_B \) | \( p_{AB} \) | SST |
|----------|------------------------|----------|----------|----------|----------|-----|
| AODV     | PDR                    | 64.49    | 0.6135   | 1.458    | -0.502   | 11.02 |
|          | AE2ED                  | 0.2823   | -0.024   | -0.08    | 0.01375  | 0.03 |
|          | NRO                    | 2.189    | 0.0695   | 0.2955   | 0.545    | 0.3805 |
| DSR      | PDR                    | 68.74    | 3.37     | 0.555    | 0.025    | 46.66 |
|          | AE2ED                  | 0.0155   | 0.0025   | 0.0041   | 0.0029   | 0.2x10^{-3} |
|          | NRO                    | 1.453    | 0.1785   | 0.121    | -0.0655  | 0.203 |
| DYMO     | PDR                    | 75.1095  | 3.357    | 0.057    | 0.0075   | 45.09 |
|          | AE2ED                  | 0.00164  | 1x10^{-4} | 1x10^{-4} | 1x10^{-4} | 8.3x10^{-9} |
|          | NRO                    | 2.423    | -0.09575 | 0.05125  | -0.01175 | 0.0477 |
for data transfer and broadcast new RREQ for establishment of fresh route.

At some instance, it prompts little decline in delay when data packets are transmitted, afterwards, its performance in terms of delay, degrades and attain high AE2ED due to multiple rechecks to find out valid routes in route cache. In case of unavailability of valid routes the source broadcast RREQ to create new route for data transmission. On the other hand, DYMO uses Expanding Ring Search (ERS) Algorithm for route creation before data transmission due to the fact that DYMO has less AE2ED than AODV but somehow equal to DSR.

### 5.3 NRO

Figure 3 illustrates that DYMO intensifies more NRO than both AODV and DSR routing protocols. DYMO uses ERS algorithm for path establishment and retrieval in place of LLR. It is capable in terms of less delay along with more NRO as compared to the further routing protocols. Subsequently, behavior of DSR is average; as, the density of node is raised so the NRO is moreover be enlarged. Since, it generates Gratuitous Route Reply for route retrieval that consumes more bandwidth. Moreover, AODV uses large number of control packet before data packet transmission which generates marginally higher NRO. Generally, in high scalability and node density all three studied protocols attain the highest NRO.

### 6. Proportional Efficiency Trade-Offs Results of Routing Protocols

MOD-DYMO can act upon well again as compared to all protocols of routing for PDR as well as AE2ED at the expense of NROs high value in line with the different connections as well as density of node in all considered scenarios. However, the performance of AODV and MOD-AODV declined PDR along with AE2ED by means of NROs moderate rate. Conversely, DSR executes better as compared to the AODV in addition to DYMO within NRO due to router reversal technique which restricts it to discover second possible route and limits to generate excessive routing overhead. Due to presence of valid routes in route cache DSR attains somewhat better PDR as compared to the AODV in support of higher nodes density as shown in Table 5.

#### 7. Conclusion

In wireless multi-hop networks, routing becomes a challenging issue when number of nodes or network loads increase. Routing protocols in this regard, perform an efficient role to calculate routes for data transmission. In this paper, three widely used protocols AODV, DSR and DYMO are thoroughly discussed and evaluated. Furthermore, this research work has measured the performance of different routing protocols used for the destination. Mainly, routing overhead obtained by a protocol is based upon control traffic and data traffic. In general, control traffic may somehow be generated by control packets while the use of non-optimal path length for data transfer causes the high data traffic. Precisely, different scalability and different CBR connections are taken to appraise the performance used for the routing protocols. Further, PDR, AE2ED as well as NRO by being performance parameters have calculated along with assessed under the $2^k$ factorial analysis methodology.

### Table 5. Proportional efficiency trade-off results of routing protocols

| Results                | Efficiency (%) CBR Connections | Efficiency (%) Nodes Density |
|------------------------|--------------------------------|------------------------------|
| MOD_AODV > AODV        | 0.1680                         | 1.7720                       |
| MOD_DSR > DSR          | 4.8970                         | 4.9040                       |
| MOD_DYMO > DSR         | 9.3700                         | 9.3400                       |
| MOD_AODV < AODV        | 5.2830                         | 10.2000                      |
| MOD_DSR > DSR          | 27.6700                        | 4.0250                       |
| MOD_DYMO < DSR         | 28.530                         | 1.0900                       |
| MOD_AODV > DSR         | 4.9910                         | 0.7930                       |
| MOD_DSR > DSR          | 7.1680                         | 18.3200                      |
| MOD_DYMO < DSR         | 8.3220                         | 6.8000                       |

![Figure 3. Normalized routing overhead.](image-url)
using a well-known simulator; NS-2. Moreover, this study has observed that overall MOD-DYMO and DYMO execute better as compared to the AODV, MOD-AODV, and DSR along with MOD - DSR. All NRO DYMO as well as MOD - DYMO executes better at high cost using PDR along with AE2ED as compared to the default versions of AODV along with DSR; since, the DYMO requires no route calculation prior to the data transmission. Further, it also seems clear that MOD-DYMO do better as compared to the innovative DYMO based on network diameter in addition to the request wait time minimization. However, AE2ED of AODV and MOD - AODV is more than DYMO and DSR. In AODV, the CBR connections are raised the packets’ number using for the wireless channel by raising consequences to higher bandwidth consumption with more packet collision. In result, the delivery ratio is slightly dropped which indicate significant rise in AE2ED.

8. References

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