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Analyzing Link and Path Availability of Routing Protocols in Vehcular Ad-hoc Networks

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ABSTRACT

In this paper, a novel framework is presented through link and path duration for link availability of paths. Further, we evaluate and analyze our work by varying the number of nodes, pause time and speed in VANETs. We select three routing protocols namely Ad-hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Fish-eye State Routing (FSR). Performance of these protocols is analyzed using Packet Delivery Ratio (PDR), Normalized Routing Overhead (NRO), End-to-End Delay (E2ED), Average Link Duration (ALD) and Average Path Duration (APD) against varying scalability, pause time and speed as performance metrices. We perform these simulations with NS-2 implementing Nakagami radio propagation model. The SUMO simulator is used to generate a random mobility pattern for VANETs. To find link duration and path duration we also use MATLAB. From the extensive simulations, we observe that AODV and DSR outperform better among all three routing protocols.

KEY WORDS: AODV, DSR, FSR, packet delivery ratio, end-to-end delay, normalized routing load, link duration, path duration, VANETs.

I. INTRODUCTION

Nowadays, the communication means via roads have become very fast. The driving on road has become more challenging and difficult due to large number of vehicles on the road. It increases the risk of traffic accidents. It is necessary to avoid such incidents and to increase the road safety for the vehicles. A very effective approach to avoid such incidents is to make the vehicles capable of communicating with each other. It is of great importance that information transmitted should be sufficient for safety and without latency. Vehicular Ad-hoc NETworks (VANETs) are the wireless networks that are formed between vehicles. In VANETs, there is no need of any permanent infrastructure because vehicles communicate with each other through self-organized network within the limited range of few hundred meters. VANET is a special case of MANETs. The main features of this wireless network are to provide safety to vehicles to avoid accidents or collisions, awareness of traffic jam, access of Internet for passengers and multimedia entertainment services.

While dealing with urban scenario for communication, The vehicles should move in the same direction. Because if they are moving in the opposite direction, they will get themselves out of the communication range of each other, but they can still be connected through intermediate vehicles(nodes).

In this paper, we deal with the performance of both proactive and reactive routing protocols in accordance with the performance parameters; link duration and path duration for VANETs urban scenario. For the real world simulation, we need a simulation tool. To make it possible, we perform extensive simulations in NS-2 at Vanet Mobi Sim software. For link and path duration, MATLAB is also used.

As vehicles on roads are increasing sharply in the recent years. The driving is becoming more and more challenging. It increases the risk of road accidents. To avoid such incidents, it is a very effective approach to make the vehicles capable of communicating with each other. It is of great importance that information transmitted should be sufficient for safety and without latency.

Vehicular Ad Hoc NET works (VANETs) bring a new concept of wireless ad hoc network environment in which the exchange of information between communicating vehicles without any fixed infrastructure, like access points or base stations is an intensive field of research. Vehicles equipped with wireless communication

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technologies will be on the roads very soon and this will revolutionize the concept of traveling. [1] This new concept can be deployed in different applications such as active safety, traffic management and entertainment.

NS-2 is one of the simulation tools, in which Two Ray Ground model is present by default that does not give accurate results because it neglects obstacles present in the environment and assumes perfect signal strength for any transmission range. [2] NS-2 by default does not correctly model radio propagation for urban scenario. There are many types of probabilistic propagation models. Nakagami gives experimentally very good results in wide range of scenarios. [3] In this paper, Nakagami model is used as it is most suited to the urban scenario. The latest version of NS-2 also includes Nakagami model [4] making it easy to evaluate each of three AODV, DSR and FSR routing protocols.

In this paper we have evaluated the performance of both routing protocols reactive and proactive. Ad hoc On demand Distance Vector (AODV) [5] and Dynamic Source Routing (DSR) protocols [6] are reactive routing protocols. It discovers routes through the network when needed. While Fisheye State Routing (FSR) protocol [7] is an example of proactive routing protocols in which a route is continuously maintained for all possible destinations. The interested reader is advised to read [5], [6] and [7] in detail to know about the protocol functioning. We evaluate the performance of routing protocols in VANETs under the dynamic topology scenarios. Link Duration (LD) is a parameter that is related to the movement of the nodes and is also as of today one of the parameters that are most popular in terms of tracking node mobility. LD is a period for which the nodes communicate with each other and is related to the mobility of nodes. Hence, LD is a period of time where two nodes are within the transmission range of each other. Also it is the time period for which two nodes start the communication and end when the signal strength of a node to another node is decreased than threshold. And this threshold varies according to the network topology and scenario. Also, link duration depends on the nature and family of routing protocols. Reactive protocols have higher link duration than proactive protocols. This is because for link sensing and neighbour sensing, DSR sends *HELLO* messages. If the link is available, the source receives ACK message. Whereas, if the link is not available, the source receives NACK. For the control random change of topology there is no mechanism defined in AODV. Therefore at maximum speed link, duration of AODV degrades. AODV uses two attempts for link sensing, while DSR uses 100 attempts for link sensing and each message is sent after each 0.08 seconds in DSR.

When the node density is low in the network, link duration of protocols degrades. In a network of constant area, fewer number of nodes means fewer number of hops between source and destination. In this case, the delay will be minimum. But if the link breakage occurs, then there will be minimum nodes in precursor list of AODV through which AODV can reestablish its path. On the other hand, in case of DSR, there will be less number of available paths in *Route Cache* of intermediate nodes through which DSR can establish its broken link. So, the link duration of reactive protocols degrades in less denser networks. Whereas FSR have more link availability period in case of less denser network.

In case of higher density, more number of hops exist between source to destination. Intermediate nodes will have more available paths to a particular destination. AODV maintains precursor list to establish broken path. Whereas, DSR maintains Route Cache at the intermediate nodes to establish broken link, while FSR due to its proactive nature, keep available active routes in its routing table to reestablish broken link.

In this paper, Section II describes Related Work. In section III, we discuss motivation. Section IV explains the Simulation results. In section V, we describe simulation results. In section VI, we conclude our results.

II. RELATED WORK

Many recent efforts have been done in last few years in the field of routing protocols and their different scenarios. [Parnav Kumar Singh, 2011] presented a comprehensive study of the radio propagation models and mobility models. They evaluated the performance of these models. It is concluded that Nakagami radio propagation model is better among all the models because it is able to form perfect free channel, moderate free channel on highway and even in urban scenario.

[XIONG Wei, 2008] presented the performance of routing protocols in VANETs. They have done the extensive simulation studies for the comparison of the routing protocols; AODV, DSDV and DSR, in highway scenarios. They concluded simulation results of routing protocols with performance parameters; PDR, AE2ED and NRL, and concluded that the routing protocols are unsuitable for VANETs, which are dedicated for MANETs.

A paper by [Imran Khan, 2009], in which they evaluated the performance of routing protocols AODV and OLSR in highly fading vehicular ad hoc networks environments using Nakagami fading model. They evaluated the performance of routing protocols with performance parameters; PDR, AE2ED and NRL, with varying node densities and different number of connections.

In study [9], they evaluated the performance of routing protocols; AODV, DSR, FSR and TORA, in urban scenarios. They developed a realistic city model, which was used to analyze the performance of routing protocols. They have also analyzed the differences in the performance of routing protocols and found that TORA is completely unsuitable for VANETs, whereas DSR experienced high AE2ED. Overall among all four protocols, they showed that AODV and FSR perform better.

DR-LEACH [10] was proposed by K. Latif *et al*. In this technique, the network area is divided into different regions. The data routing is based on the distance of the nodes from the BS. Nodes of the region which is closest to the BS use direct communication for the transmission of the data. All other regions implement clustering for efficient consumption of energy. DR-LEACH also uses multi-hop communication between clusters. In this way, energy utilization efficiency is also increased and hence, lifetime and stability region of the network is enhanced.

Aslam *et al*. [11] proposed CEEC in which the network area is divided into three regions. Each region contains same energy level nodes. But the energy level of the nodes of each is different from the other regions i.e. normal, advance and super nodes. Base Station (BS) centrally selects optimum number of CHs. The regions are arranged in ascending order from the BS in terms of their initial energy. Simulation results showed that CEEC efficiently consumes the energy of nodes and improves the network lifetime.

HEER [12] was proposed for both homogeneous and heterogeneous environments. In this technique, the CH selection is dependent upon the initial and residual energy of the nodes. Data transmission in HEER depends on two threshold values, i.e., Hard Threshold (HT) and Soft Threshold (ST). In this technique, the nodes transmit their data only if the threshold conditions are fulfilled. It results in reduced number of transmissions. In this way, energy of nodes is efficiently utilized.

B. Manzoor *et al*. [13] proposed Q-LEACH for the efficient energy consumption of nodes. In this protocol, the network is divided into four regions and sensor nodes are deployed in a territory. In order to acquire better clustering, optimum positions of CHs are also defined. Also, transmission load of other transmitting nodes is also reduced. Hence, this protocol results in better coverage of the whole network.

In [14] authors improved network lifetime and stability region by adapting both open-loop and closed-loop feedback processes. By using this approach, they divided the whole network area into three logical regions on the basis of threshold for each region. In this way, the authors were also able to achieve minimized packets overhead. This protocol proved very efficient in energy consumption of nodes.

In [15] authors introduce adopted authentication approach for the protection of ad-hoc wireless network by even- odd function. In this function, mobile node computes and generates random even or odd number during signaling process. If first node generates random odd number then next node computes and generates a random even number. This scheme will secure the whole wireless network from the outsider attack because there are number of attacks existing in wireless communication in different application of communication field.

[38] used LP modeling for maximizing throughput in proactive protocols in wireless multi-hop networks. so that the maximum data will be gathered at the base station. This LP model also resulted in minimizing routing delay. This delay minimizing problem is very important to be solved because in time critical applications, this is a quite significant and is needed to be solved as is.

In [39] N. Javaid *et al.* proposed EDDEEC. It is a three level heterogeneous protocol which assigns different probabilities to each energy level node to become CH, so, that nodes with high energy become CHs more frequently as compared to the nodes with less energy. In EDDEEC, authors defined a residual energy level threshold. Under that threshold, all normal, advance and super nodes have same probability for CH selection. EDDEEC [20] is adaptive energy aware protocol which dynamically changes the probability of nodes for the selection of CHs. This is a balanced and efficient way to distribute equal amount of energy between sensor nodes. Setting a threshold can be very useful in efficient consumption of energy.

In [40] authors used Error Control Coding (ECC) for efficient energy consumption. Z.Abbas *et al.* presents the efficient encoder selection that transmits power with respect to its critical distance which results in energy saving in WSNs. Encoder selection is performed by using critical distance which is estimated from coding gain of that encoder. ECC in this context, becomes energy efficient as encoders and their transmit powers are selected adaptively, that results in energy saving to these particular encoders.

So, a routing protocol improves the lifetime of a network and specifically the stability period of a network. Protocols [16], [17], [18], [19], [20], [21], [22], and [23]
are also proposed to achieve these goals.

III. MOTIVATION

In this paper, the scenario we have presented is through the motivation of [24] and [25]. In [26], they have done evaluation of protocols through radio propagation model Nakagami which is well suited for all these models.

We also implement it in our simulation work. In this paper, we evaluate the performance of routing protocols; AODV, DSR and FSR in urban scenario with respect to, link and path duration. And in [26], they found path duration by varying the transmission range of nodes, they did not evaluate any protocol. Here, we analyze link duration and path duration of routing protocols AODV, DSR and FSR in VANETs with performance parameter of PDR, AE2ED, NRL, link duration and path duration.

IV. LINK AND PATH DURATION

In [26], authors find link and path duration. The source first selects the relay node, whose distance from the source is less as compared to other nodes which are also in the transmission range of source. After selecting the relay node, the distance between relay node and destination node is calculated using the intersection area of source transmission range and destination transmission range. By using the distance and relative velocity of a node, link duration between the nodes and the path duration by choosing the minimum link available time between the nodes, is calculated.

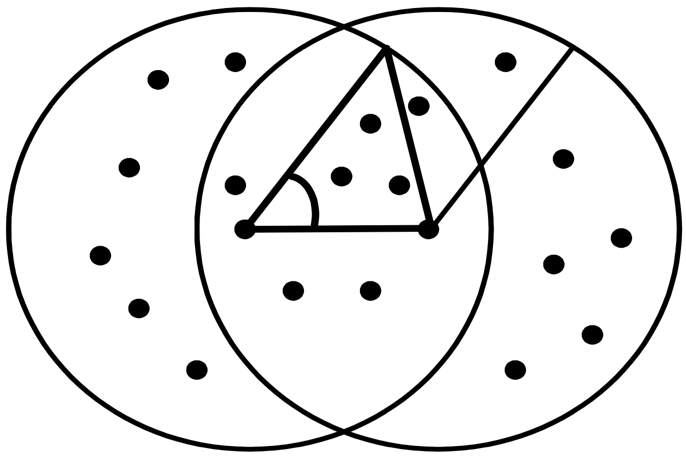

Figure 1: Link connectivity model for two nodes

In this paper, we calculate the link duration by using distance and relative velocity of the nodes, which is

$$t = \frac{v_r}{R} \quad (1)$$

where v_r is the relative velocity of the nodes and R is the distance between the source node and the next forwarding node N .

A. DISTANCE

The source S first selects the next forwarding node N from its neighbor. The next forwarding node is the node whose distance from the source is maximum and within the transmission range of S . At time t_0 the distance between the S and N is R_{t_0} . And x is the distance from next forwarding node to the transmission range of S depending on the angle, as shown in fig.1.

To calculate R_{t_0} , we have to find x which is the distance between transmission range r of source node S and next forwarding node N . After finding x in eq. 2, we find the distance R_{t_0} using cosine law as depicted in fig.2.

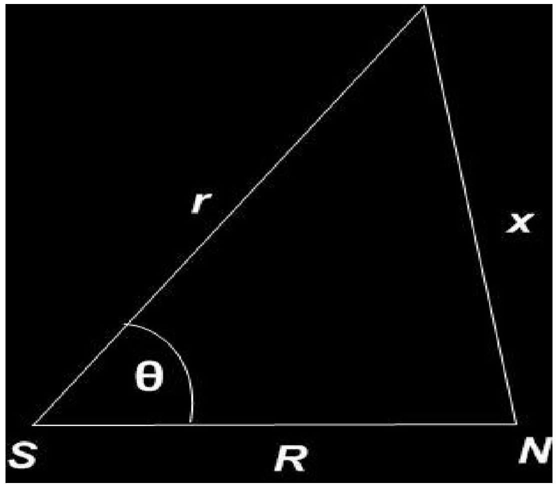

Figure 2: Link connectivity model for two nodes

$$x = r\theta \times \frac{\pi}{180^o} \tag{2}$$

and

$$x = \sqrt{r^2 + R_{t_0}^2 - 2rR_{t_0} cos(\beta)} \tag{3}$$

As, we want to find the distance (R_{t_0}) between S and N, by solving eq: (2) and eq: (3), we get

$$R_{t_0}^2 + 2rcos(\theta)R_{t_0} - (r^2 - x^2) = 0 \tag{4}$$

As eq: (4) is the quadratic equation then by using quadratic formula, we get

$$R_{t_0} = rcos(\theta) \pm \sqrt{(rcos(\theta))^2 - (r^2 - x^2)} \tag{5}$$

The PDF (Probability Distribution Function) of distance R_{t_0} is given in eq.6,

$$f_D(R_{t_0}) = \frac{r^2 - x^2 - R_{t_0}^2}{2rR_{t_0}} \tag{6}$$

We consider an urban scenario in VANETs, in which nodes (vehicles) are moving at different angles with different relative velocities v_r. Link duration and path duration depends on the speed of vehicles and distance covered by each vehicle after time t_1. In case of high speed, the links between vehicles depend upon the direction of vehicles. Vehicles moving in the same direction with maximum speed will have greater link duration than the vehicles moving in the opposite direction with moderate speed. Link duration also depends on the angle at which the vehicle coveres some distance after some time interval t. Here we will discuss two cases. In first case, vehicles move at their obtuse angle after time interval t_1 from the initial position. Whereas in second case, vehicles move at their acute angle after time interval t_1 from the initial position. We also find the distance covered by the vehicles after time t_1 in each case.

Case-1:

Suppose the source node S is at initial position S_{t_0} and the next forwarding node N is at an initial position N_{t_0}, the distance R_{t_0} between them is calculated by eq. 5. Both nodes, S and N, move from their initial position S_{t_0} and N_{t_0} to the next position S_{t_1} and N_{t_1} at obtuse angles α_0 and β_0 respectively after time t_1, as shown in fig. 3. The distance R_{t_1} after the movement of vehicles is calculated by eq. 7

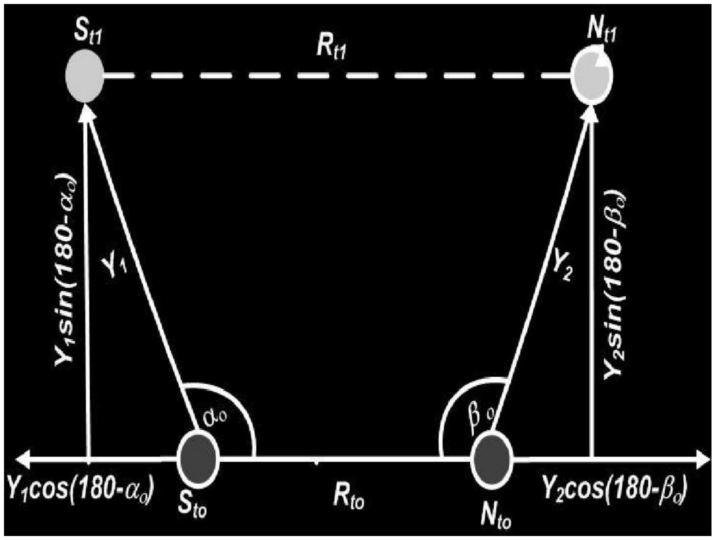

Figure 3: S and N are moving with obtuse angles

$$R_{t_1} = R_{t_0} + y_1 cos(180-\alpha_0) + y_2 cos(180-\beta_0) \tag{7}$$

PDF of R_{t_1} is given in eq. 8.

$$f_D(R_{t_1}) = \frac{r^2 - x^2 - R_{t_1}^2}{2rR_{t_1}} \tag{8}$$

Case-2:

In first case, vehicles are moving at obtuse angles (greater than 90) with respect to each other. Here, the case is opposite due to the movement of vehicles at acute angles (less than 90) from each other. Suppose the source node S is at initial position S_{t_0} and next forwarding node N at initial position N_{t_0}. The distance R_{t_0} between them is calculated by eq. 5. Both nodes S and N move from their initial positions S_{t_0} and N_{t_0} to next position S_{t_1} and N_{t_1} at acute angles α_A and β_A respectively after time t_1, as shown in fig. 4. The distance R_{t_2}, after movement of vehicles is calculated by eq. 9

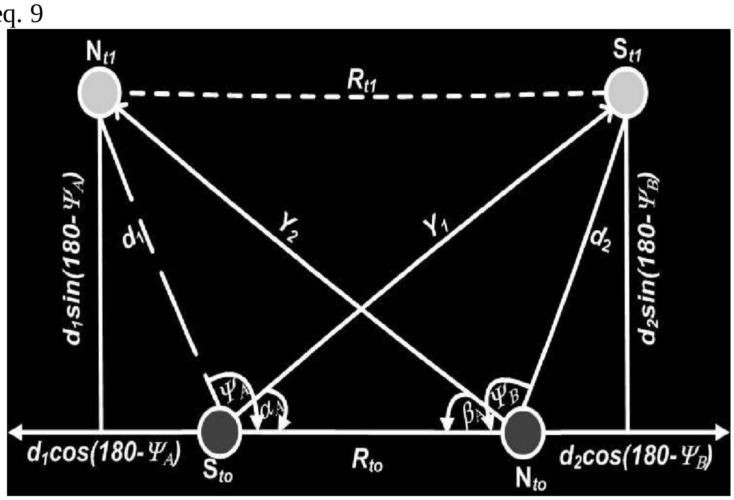

Figure 4: S and N are moving with acute angles

$$R_{t_2} = R_{t_0} + d_1 cos(180-\psi_A) + d_2 cos(180-\psi_B) \tag{9}$$

where $d_1 = y_2 sin(\beta_A)$ and $d_2 = y_1 sin(\alpha_A)$

PDF of R_{t_2} is given in eq.10

$$f_D(R_{t_2}) = \frac{r^2 - x^2 - R_{t_2}^2}{2rR_{t_2}} \tag{10}$$

B. RELATIVE VELOCITY

Now, we find the relative velocity between the source and the next forwarding node. There are two cases: **Case-1:** relative velocity (v_r) of both nodes is same, **Case-2:** v_r of both nodes is different.

$$v_r = \sqrt{v_1^2 + v_1^2 - 2v_1v_2cos(\alpha)} \tag{11}$$

Case-1: when ($v_1 = v_2 = v$)

$$v_r = v\sqrt{2 - 2cos(\alpha)} = 2vsin(\alpha/2) \tag{12}$$

PDF of the relative velocity related to case-1 is given by,

$$f_{v_r}(v_r) = \frac{1}{\pi\sqrt{4v^2 - v_r^2}} \tag{13}$$

Case-2: when ($v_1 \neq v_2$)

$$v_r = \sqrt{v_1^2 + v_2^2}\sqrt{1 - \frac{2v_1v_2}{v_1^2 + v_2^2}cos(\alpha)} \tag{14}$$

which can be approximated as,

$$v_r = \sqrt{v_1^2 + v_2^2}(1 - \frac{2v_1v_2}{v_1^2 + v_2^2}cos(\alpha)) \tag{15}$$

PDF of v_r in this case will be,

$$F_V(v_1, v_2) = 1 - \frac{1}{v_1v_2} - v_r\sqrt{v_1^2 + v_2^2} \tag{16}$$

then,

$$f_V(v_1, v_2) = \frac{\partial^2 F_V(v_1, v_2)}{\partial v_1 \partial v_2} \tag{17}$$

$$= \frac{-1}{v_1^2 v_2^2} - \frac{v_r v_1 v_2}{v_1^2 + v_2^2} \tag{18}$$

C. LINK DURATION

Link duration is the time in which two nodes are within the communication range of each other. Both nodes have active link in that time interval. Hence, $f_T(t)$ is the ratio of PDF of distance $f_D(R)$ and the PDF of relative velocity of nodes $f_V(v_1, v_2)$. PDF of distance and relative velocity can vary depending upon the speed of the nodes. In case of distance, nodes either move at obtuse angle or acute angle, depending on the movement of the nodes. The general formula for link duration is given by,

$$f_T(t) = \frac{f_D(R)}{f_V(v_1, v_2)} \tag{19}$$

D. PATH DURATION

Path duration t_{path} is derived from the PDF of the link duration. If the number of hops needed to reach the destination is h, then t_{path} can be written as,

$$f_{T_{path}}(t_{path}) = hf_{T_{path}}(t_{path})(C_{T_{path}})^{h-1} \quad (20)$$

Where, $C_{T_{path}} = 1 - F_{T_{path}}$ is the complementary cumulative distribution function (CDF) of T_{path} , and $F_{T_{path}}$ represents the CDF.

V. SIMULATION RESULTS

We have used the following performance parameters to evaluate and compare the performance of each of three AODV, DSR and FSR routing protocols. Performance parameters are PDR, AE2ED and NRO.

A. SCALABILITY

i. PDR

In fig. 5, it is clear that AODV outperforms DSR and FSR. AODV and DSR give almost same results and perform better than FSR. The PDR of AODV increases as the number of nodes increase. Because, when link breakage occurs, it chooses the shortest path to destination and uses local link repair mechanism. It also consumes less bandwidth. As the number of nodes increases, the PDR of DSR also increases. Route reversal keeps away from the overhead of a possible second route discovery. DSR gives slightly better PDR than AODV for high node density. Because valid routes are available in Route Cache. Whereas FSR shows less PDR than both routing protocols due to proactive nature.

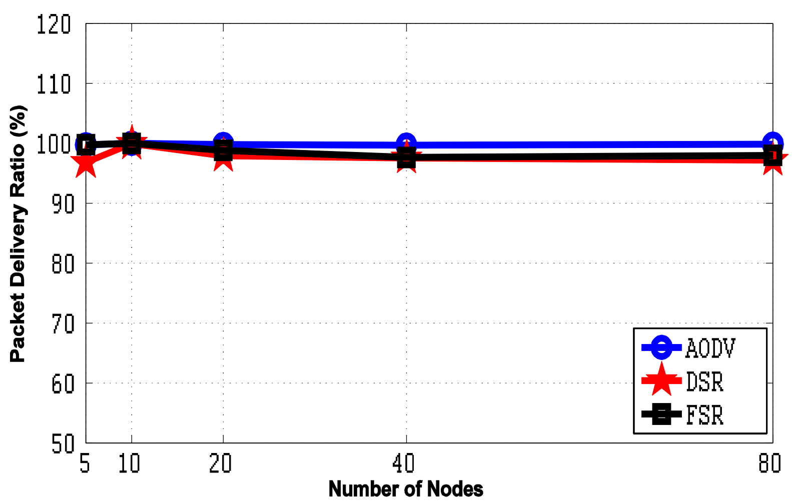

Figure 5: PDR v/s Node Density

ii. AE2ED

Fig. 6 shows the AE2ED against the node density. Although AE2ED of AODV is steady, but it is always more than DSR and FSR. While AE2ED of DSR is less than both AODV and FSR. We observe that as the node number increases, AODV performs better. Whereas the overall performance of DSR is better than both routing protocols; AODV and FSR. As the number of CBR sources increases, there is an increase in the number of packets contending for a common wireless channel, which leads to more collisions and more bandwidth is utilized. So there is a significant drop in the delivery ratio and a corresponding increase in the AE2ED. As the number of connections increases, the flow in AODV also increases due to more routing. The AE2ED of FSR is more than DSR because whenever link breakage occurs, the source has to broadcast information of its neighbors to spread the routing information to whole topology. As long as all paths are established, the data packets are transmitted to specified destination. In this way, the delay is marginally constant after the path establishment.

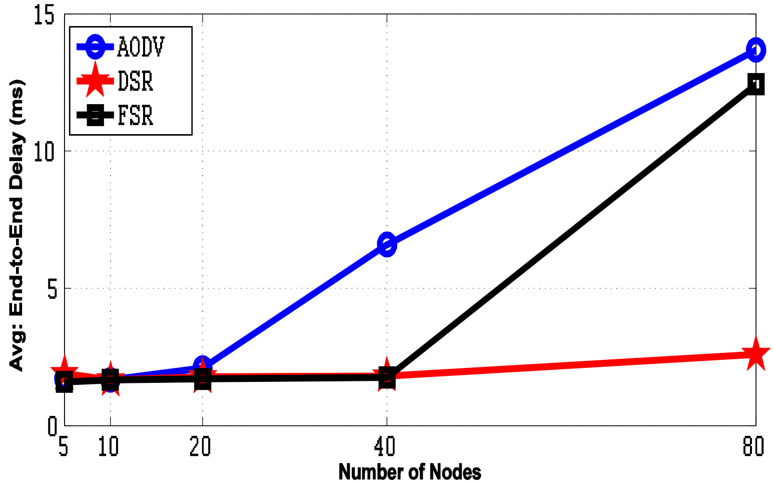

Figure 6: AE2ED v/s Node Density

iii. NRO

In fig. 7, it is observed that NRO of FSR is higher than both the reactive routing protocols. AODV shows the second highest NRO value. As the node density increases, NRO of FSR and AODV also increases. DSR shows average behavior. FSR has the highest value among these routing protocols due to the use of periodic updates to exchange topology map and also reducing the control messages. The reason for second highest NRO for AODV is that it uses large number of control packets which causes more NRO as compared to DSR. Whereas, the behavior of DSR can be explained by the fact that it generates Gratuitois Route Reply(grat. RREP) for large number of nodes.

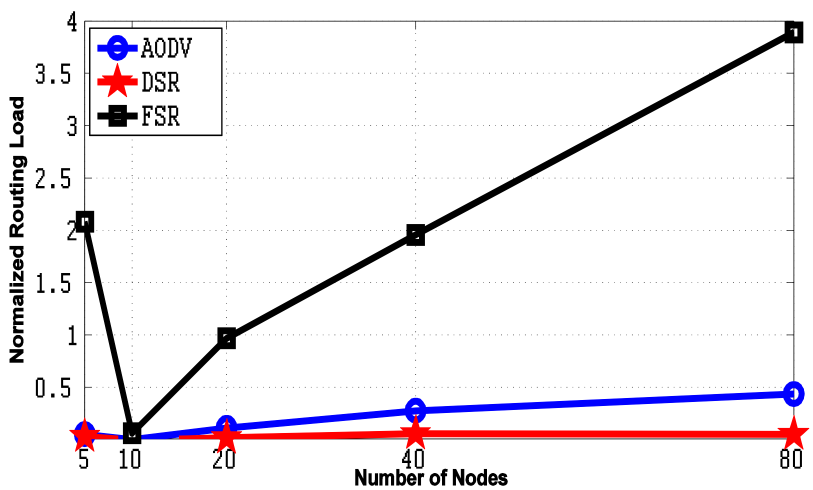

Figure 7: NRO v/s Node Density

iv. AVG: LINK DURATION

Fig. 8 shows that the link duration of both reactive routing protocols is better than FSR due to its reactive nature. This is because they form a route on on-demand and they don't need to do more calculation like proactive protocols. AODV and DSR show best result for link duration due to Expanding ring search (ERS) algorithm. On the other hand, FSR shows worst results due scope concept. Another reason for the availability of link in reactive protocols is due to high PDR. This is because link availability time will be increased as the packets received at destination will also be increased.

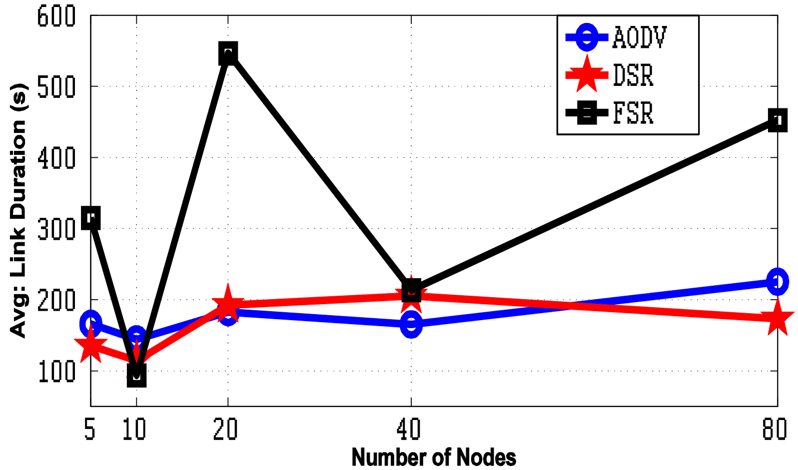

Figure 8: Avg: Link Duration v/s Node Density

v. AVG: PATH DURATION

It is clear from fig. 9 that DSR shows better results for path duration than FSR and AODV due to high routes available in route cache. Whereas AODV shows second highest value of path duration due to reactive nature and routes availability. Both reactive protocols show better result than FSR because proactive routing protocols use table driven method for route selection.

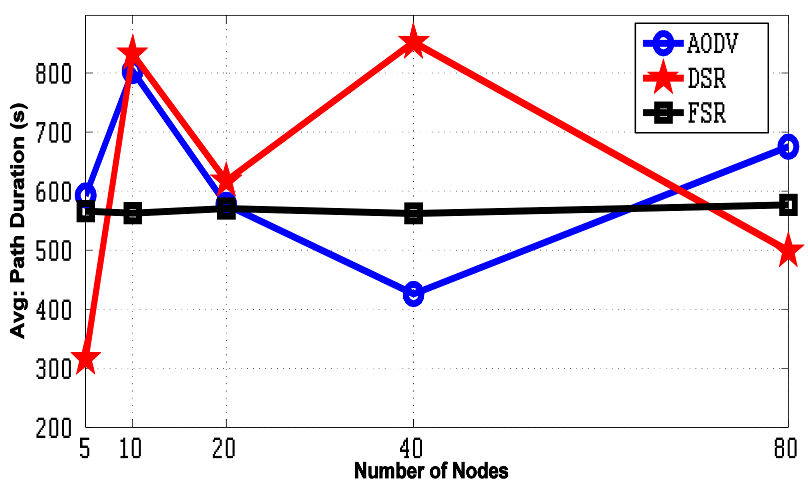

Figure 9: Avg: Path Duration v/s Node Density

B. SPEED

i. PDR

Fig. 10 depicts that AODV shows more appreciable PDR as compared to DSR and FSR. It is also very consistent with respect to varying the speed. This is because it uses gratuitous Route Replies (grat. RREPs) and time based routing activities which help in choosing best end to end path. Due to its reactive nature, it establishes path on demand which also causes an increase in PDR. Its PDR decreases at the speed of 80m/s because links become weaker at higher speed and cause link breakages. It also uses Route Error RERR packet in case of link breakage. This approach confirms the deletion of current route and establishes new path which guarantees the long time communication and high PDR. FSR attains high PDR than DSR but less PDR than AODV with varying speed. Its PDR decreases as mobility increases, because at high mobility the links between nodes become weaker and there is not any mechanism to detect expired stale routes or freshness of routes when multiple routes are available. It implements scope update scheme which may benefit it in reducing the routing update packets and achieve high PDR. DSR achieves less PDR as compared to other two protocols and it attains high PDR at speed 5 m/s but its

PDR decreases as mobility increases. This is because mobility causes link breakages which generates a storm of RERR messages. All this scenario results in more drop rate and ultimately increases bandwidth and utilization.

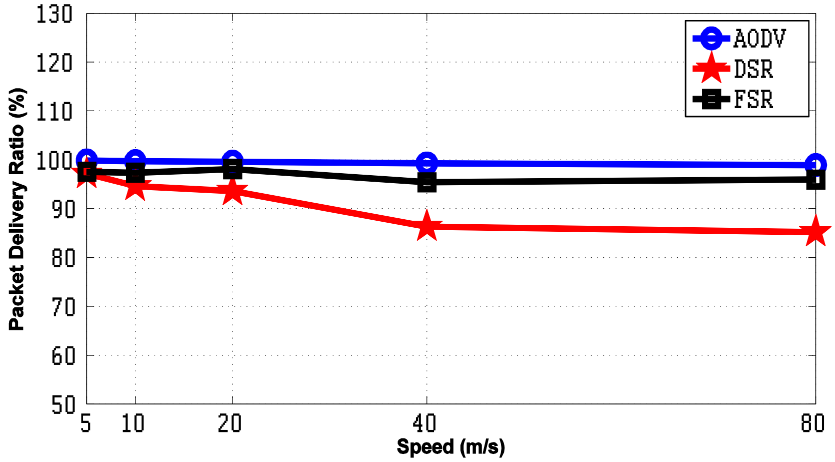

Figure 10: PDR v/s Speed

ii. AE2ED

According to fig. 11, AODV attains more AE2ED as compared to DSR and FSR because of its reactive nature and use of hop by hop routing. Its AE2ED initially decreases between 5-10 m/s because when link breakage occurs, it uses local link repair mechanism to repair the route to the destination. Whereas, AE2ED increases from 10 to 20 m/s because it uses routing packets to establish the path. After this increment in the value of AE2ED, its value becomes constant for higher mobility. DSR initially attains lower AE2ED as compared AODV and FSR from 5 to 10 m/s. But its AE2ED increases with mobility because links become weaker at higher mobility. For path calculation it uses routing packets. Overall it attains less AE2ED than AODV and higher AE2ED than FSR because the routes are available in Route Cache. FSR attains least AE2Ed because of its proactive nature. It does not need to calculate routes on demand for communication. Its AE2ED decreases from 5 to 10 m/s and then increases with the mobility.

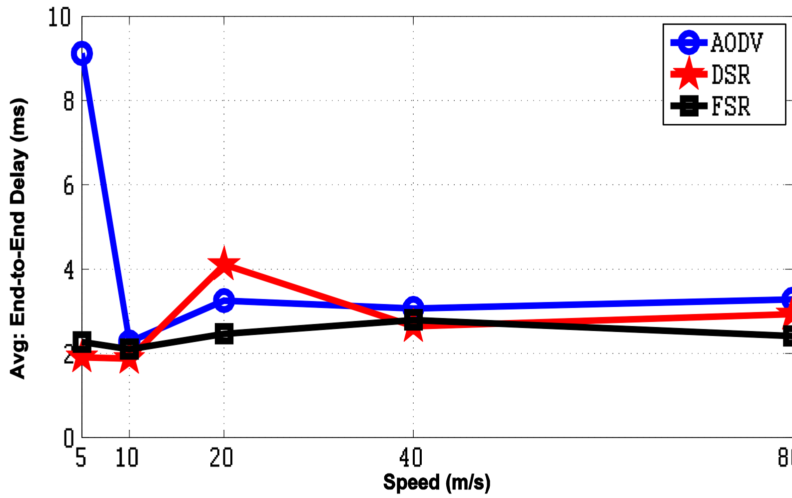

Figure 11: AE2ED v/s Speed

iii. NRO

In fig. 12, FSR attains higher NRO as compared to AODV and DSR because packets are sent from source without any insurance of whether they reach the destination or not. As the mobility increases, the connection between nodes becomes weaker which results in increase in NRO. AODV attains higher NRO as compared to DSR but lower than FSR because it uses routing packets during route calculation which causes increase in overhead. As mobility increases links get weaker which generates storm of RERR messages for the cancelation of current route or to repair it. While DSR attains less overhead than both routing protocols because it uses packet salvaging technique and routes are available in Route Cache RC.

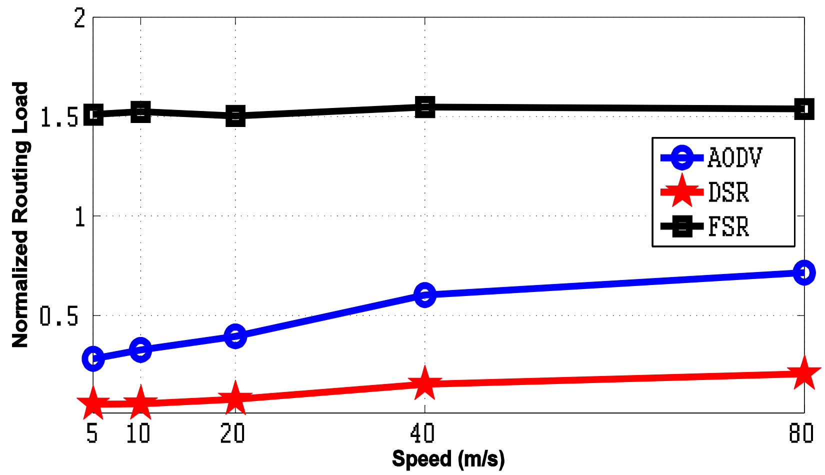

Figure 12: NRO v/s Speed

iv. AVG: LINK DURATION

Fig. 13 shows that in case of speed all three routing protocols show almost the same results with some slight changes. One reason of showing same results is that we taking number nodes as constant. We observe that as the mobility rises up, the link availability also goes up. This shows that the link duration is directly proportional to the speed. Critically analyzing results it seems clear that in low mobility, AODV performs better than DSR and FSR. Whereas in case of medium speed, DSR outperforms the other two protocols. But when we are considering high mobility, FSR shows better results as compared to AODV and DSR.

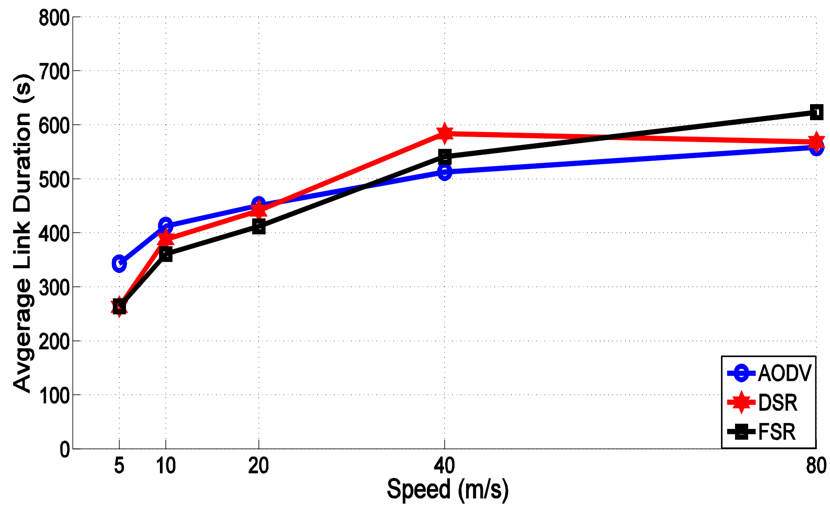

Figure 13: Avg: Link Duration v/s Speed

v. AVG: PATH DURATION

As shown in fig. 14, DSR attains higher path duration as compared to AODV and FSR from 5 -10 m/s. This is because Route Cache is available in DSR. Path duration decreases from 5 to 40 m/s as mobility increases. It increases from 40 to 80 m/s because route is calculated before the packets are transferred. FSR attains lower path duration than DSR but higher path duration than AODV. The path duration of AODV decreases as mobility increases because it uses shortest path to destination.

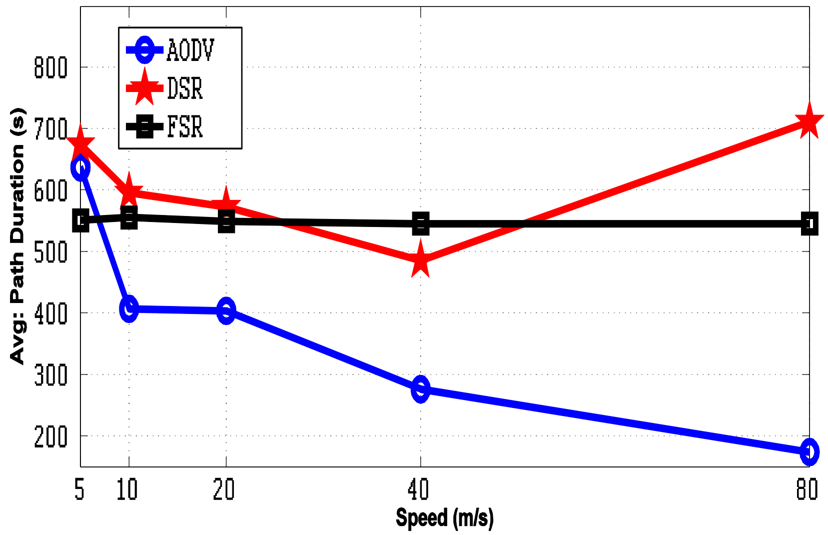

Figure 14: Avg: Path Duration v/s Speed

C. PAUSE TIME

i. PDR

Reactive protocols attain higher PDR than proactive. This is because proactive protocols perform route calculation before data transmission unlike the reactive ones. So, if a data packet is on a calculated route and due to mobility, a link breaks, the respective proactive protocol has to perform route calculation from the scratch. RT calculation phase first takes place and then response to data request phase is given which degrades the performance. In fig. 15, the increment of pause time does not affect PDR because the node density and relative speed of nodes are constant. There are less link breakages in all these three protocols if the nodes are moving with constant speed. In DSR and FSR, there is no predefined mechanism to link repair. While AODV uses LLR in case of link breakage which makes the better performance of AODV in terms of PDR. To check the connectivity of nodes AODV uses local HELLO messages unlike DSR. Whereas, FSR uses periodic updates. In this way, the PDR of FSR and AOSV is slightly higher than that of DSR.

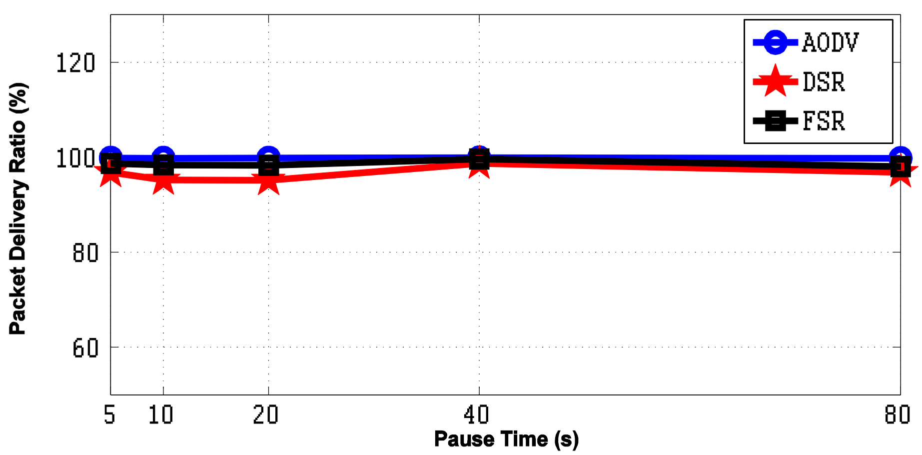

Figure 15: PDR v/s Pause Time

ii. AE2ED

In Fig. 16, AODV attains the highest delay among two reactive and one proactive protocol. Because AODV uses LLR for link breaks in routes. Route Cheche in DSR and Routing Table in AODV are cheaked before Route discovery through ERS attains some delay in reactive protocols. Also AODV and DSR sustain more delay due to reactive nature. FSR due to proactive nature have more AE2ED as compared to the reactive ones. This is because they calculate RT before data transmission. As the pause increases, DSR attain less delay. Because it first searches the desired route in RC if route is available in RC. No need to search a new route. If route is not available it starts from the scratch. DSR does not implement LLR, so its AE2ED is lower than AODV and FSR. FSR, at higher mobilities, possesses the highest AE2ED as compared to AODV and DSR. Due to GF mechanism, when mobility increases, routes to remote destinations become less accurate. FSR's delay increases because GF algorithm helps to achieve higher throughputs and lower E2ED and routing overheads for large number of nodes. But GF algorithm produces large latencies for distant nodes. Secondly, for link breaks, FSR does not trigger any control messages, for newly available routes. FSR uses only periodic updates.

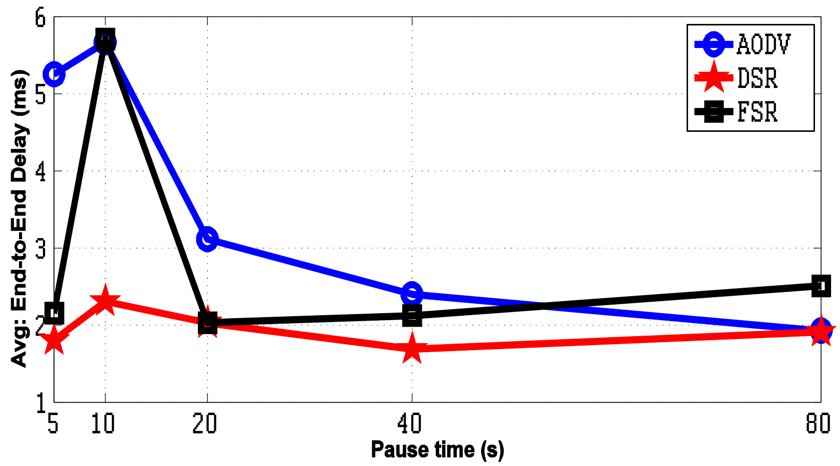

Figure 16: AE2ED v/s Pause Time

iii. NRO

As the size of the network and the relative speed of nodes is constant, the routing overhead is also almost constant as shown in fig. 17. AODV possesses more NRO than DSR, because an AODV broadcasts local HELLO messages for node connectivity unlike DSR. While FSR uses periodic updates for exchange topology map. Every node in the network maintains a link state table based on the up-to-date information received from neighbor nodes. This is periodically exchanged with its local neighbors only. It results in more routing overhead than reactive protocols. RC strategy further reduces NRO of DSR as compared to AODV. FSR sustains higher NRO than other two protocols because, there is no mechanism defined to delete expired stale routes from route chache. Also, when multiple routes are available, FSR does not determine the freshness of the routes. There is lack of any mechanism to delete the expired stale routes in FSR or to determine the freshness of routes when multiple routes are available in route cache. These multiple routes not only increase the NRO but also affect the throughput.

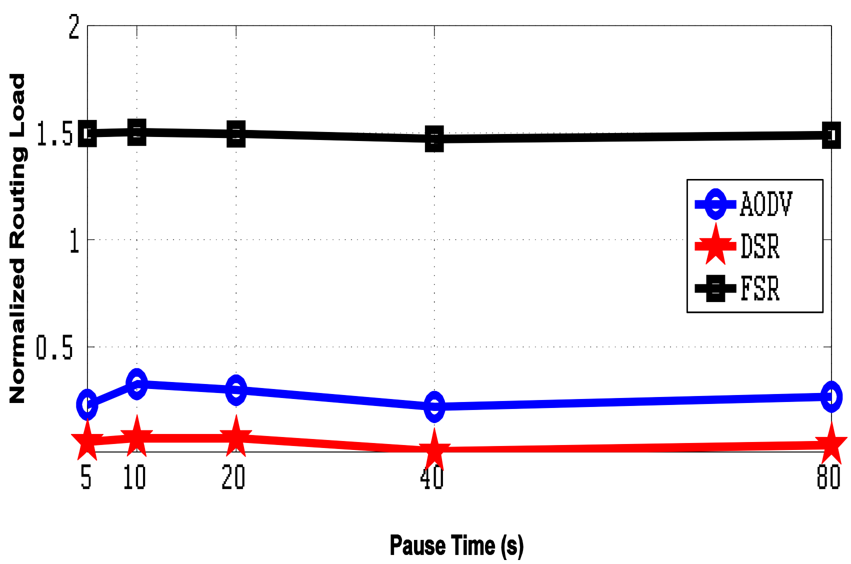

Figure 17: NRO v/s Pause Time

iv. AVG: LINK DURATION

ALD is the time interval for which two neighbor nodes have an active route between each other. Fig. 18 shows that for less pause time, AODV performs well because it broadcast HELLO messages for neighbor sensing and link monitoring. Whereas, the link duration of FSR is better than DSR because FSR generates periodic updates. So. AODV in its RT has one active route for single destination in its RT. DSR has multiple active routes in its RC. So, if link breakage occurs, AODV will use LLR for repairing the link. Whereas, DSR will search for another active route in its route cache and starts the transfer of data from scratch. As the pause increases, ALD of all three protocols also increases. But for low pause time, AODV outperforms the others two protocols. But as the pause time increases, FSR outperforms the reactive protocols.

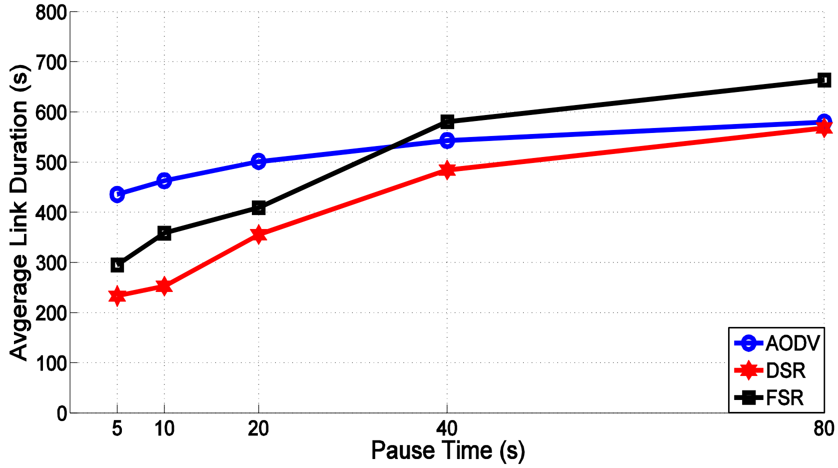

Figure 18: Avg: Link Duration v/s Pause Time

v. AVG: PATH DURATION

In fig. 19, proactive protocols perform route calculation before data transmission unlike reactive ones. So FSR has constant path stability and has no effect of pause time. But reactive protocols establish routes on demand. So its APD varies as the pause time varies. For initial time, APD of DSR decreases but as pause time increases from average 40 sec, its path duration increases. Whereas in AODV, path duration increases as the pause time increases. When pause time crosses the average line, its APD decreases. AODV and DSR both perform better than FSR in case of APD. Because both AODV and DSR use ERS algorithm for path calculation, whereas, FSR uses flooding mechanism.

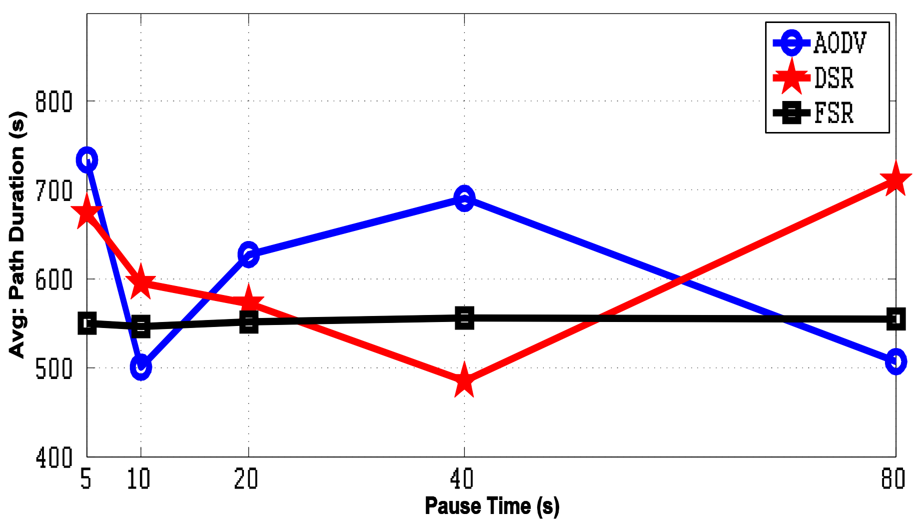

Figure 19: Avg: Path Duration v/s Pause Time

VI. CONCLUSIONAND FUTURE WORK

In this paper, we evaluate the performance of AODV, DSR and FSR in VANETs using NS-2 simulator and Nakagami radio propagation model. Moreover, link availability time and the path availability time is also calculated. Path stability of reactive protocols is higher than proactive protocols. The SUMO simulator and Vanet MobiSim is used to generate a mobility pattern for VANET to evaluate the performance of selected routing protocols for three performance parameters, E2ED, NRO and PDR. Our simulation results show that AODV and DSR perform better at the cost of delay in VANETs.

In future, routing link matrices can also be applied on this proposed technique. Routing can be done by adapting many different approaches as done in [29], [30] and [31]. Application of routing link matrices on the proposed scheme can be useful in achieving efficient consumption of energy in the network. We aim to introduce multiple QoS parameters [32]. Mobility constraints also help to achieve better network lifetime similar to [33, 34]. In future, we also aim to improve the network energy utilization in the light of wireless ad-hoc networks [35], [36], [37], [38], [39] and [40].

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