International Journal of Scientific Research in Computer Science and Engineering
Research Paper
Vol.9, Issue.4, pp.36-43, August (2021)
E-ISSN: 2320-7639

Exploiting Packet Travel Time and Energy factor in delay sensitive application of MANET

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Available online at: www.isroset.org

Received: 03/Jul/2021, Accepted: 14/Aug/2021, Online: 31/Aug/2021

***Abstract*—**There are various threats in mobile ad-hoc networks. Among these threats packet drop and delays are serious threats that have to be controlled or reduced if not. Delay sensitive applications are typical applications of mobile ad-hoc network. These applications are sensitive to delay (requires low end-to-end delay) as their name suggests and else results in the data that they carry being meaningless and less effective. Apart from this, since they hold sensitive information there should be no or low packet loss rate. Typical examples of these applications are live video streaming, voice over IP, emergency applications, and multimedia teleconferencing. In this paper, we are trying to minimize the delay and packet drop caused by the routing protocols used in this application. For our simulation work, we uses the multiple-path selection protocol called AOMDV, and then we compare it with the two most recent works using the NS2 network simulator and the Xgraph for evaluation purposes.

***Keywords*—** AOMDV, Delay, Disjoint, Teleconferencing, NS2, Xgraph.

I. INTRODUCTION

In data communication, wireless networks are classified into cellular networks and wireless ad-hoc networks. In contrast with cellular networks, Mobile Ad-hoc Net-works (MANETs) aim to achieve communications without relying on a fixed infrastructure (without network infrastructure) [1]. MANET is a wireless mobile node dynamically establishing a temporary and self-configuring network without the use of central infrastructure. Communication among nodes in the MANET is limited to a certain transmission range. However, if the two nodes that are found in the network are not within the same communication range they use two or more intermediate nodes to deliver the information from source to destination nodes[2].

There are various applications of MANET among which Delay sensitive applications are one them. These applications such as live video streaming, multimedia teleconferencing and voice over Internet Protocol(VoIP) require a low end to end delay in order to maintain its meaningfullness, interactivity and their streaming nature. These applications are getting more popularity due of technological development. Various routing protocols are designed for them. This can be pro-active, re-active and a hybrid routing protocols [3]. In proactive protocols (such as OLSR) routes are table driven, predefined and updated frequently. However, in the reactive protocols (such as AOMDV and DSR) routes are on demand. The hybrid routing schemes take the advantage of both reactive routing and proactive routing schemes (i.e. ZRP). Among the reactive AOMDV is one of them with Multipath, Link and node disjoint paths [4]. Since it uses multipath for route selection and it is an on demand by nature, it is suitable for delay sensitive applications. However, it originally uses hop count metrics i.e. those with minimum hop-count values are used for routing, this might have high delay and high rates of packet drop, and hence it is not advisable to use them as they are.

In addition to this, there is an ever-growing need for fast delivery of a message in Ad-hoc Networks that uses sensors such as Biosensors, which are used in delay-sensitive applications. Biosensors are biological sensors that gather delay-sensitive biological data (life-threatening medical condition i.e. pressure, heart rate, blood sugar level). All conditions require immediate care. But configuring an ad-hoc network for such data using the existing protocol would result in low performance network and hence routing becomes a central issue i.e. no strong guarantees of timely delivery which indirectly result in the death of the patient in this scenario. In our work here, we focus on the reactive routing scheme from which AOMDV is one of them and thus we are trying to improve the performance of this routing protocols route selection strategy.

The remainder of this paper is structured as follows: Section 2 introduces highlight of the existing routing protocols that are related to our work. Section 3 presents the proposed approach, architecture, and the algorithms used. Section 4 deals with the simulation work and performance evaluation of the proposed approach. Finally, conclusions and feature recommendations are presented.

II. RELATED WORK

In networks having multiple hops, intermediate nodes do the forwarding of packets from the sender node to the receiver node (hop by hop). This forwarding process is known as routing [4]. However, in choosing a path from S to D nodes, various path selection rules were suggested for ad-hoc networks and these rules are called routing protocols. This section discusses various existing works that are done on routing protocols of mobile ad-hoc networks.

In [2] the radical growth in the use of portable devices coupled with users' desire for real-time application and challenge in the design of MANET protocols was stated. Among these challenges allowing real time applications for mobile ad-hoc network integrating support for QoS (quality of service), specifically meeting the delay constraints since in delay-sensitive applications and video communication such as video conferencing delay was a major challenge. This may directly affect the network performance and the QoS as well. Thus, it is necessary that routing protocols contain techniques for path selection and maintenance to enable end to end QoS considering delay and distance as a parameter.

The authors in [5] [6] considers node mobility as a metrics to enhance AOMDV protocol reducing chances of Link Failure in Mobile Ad-hoc Network. They consider the link failure problem caused by the mobility nature of nodes. As both papers try to discuss, link failure causes performance degradation and lowers the reliability of the network. As their is no central controller in MANET, nodes are mobile, self-configuring and this would result in congestion issues when the data move from source to destination. Thus, they propose a new route selection algorithm based on link failure localization for route maintenance. Their approach takes decisions based on the location of the failure link in the source route. This algorithm improves the packet drop rate, packet delivery rate and salvaging of AOMDV. However, in some application areas considering the energy of nodes as metrics is the first and foremost to prevent the packet loss caused by a drain in energy to process the data sent over the network.

Even though various works are done on energy-aware routing mechanisms, the paper[7] come up with a multi-metric approach using energy efficient, bandwidth-aware routing. Here the sender node selects the best route for data transmission based on the minimal residual energy and available bandwidth. The main aim of the authors work is to modify the AOMDV protocol: finding an energy-efficient and maximum available bandwidth, shortest path between sender and receiver node. As a result, they reduced the overall energy consumed by the network, routing overhead, average end to end delay and bandwidth efficiency. Apart from this, they improved the rate of packet drop and data delivery in comparison to the original AOMDV protocol.

Fault-tolerant routing protocol for multi-path on-demand routing approach is defined in [8]. The main goal of the paper is to enable the system to perform its function in an efficient manner even when there is an existence of internal faults and it is needed to increase the system reliability in the network. They try to address problems of fault in the network by finding redundant network through multi-path routing. Thus, they proposed to design a fault-tolerant multi-path on-demand routing protocol so as to decrease the packet drop formed as a result of link failure. Accordingly, multiple disjoint paths that have more battery power and remaining energy will be determined, to all active available destinations. The multiple routes are stored in the node to all active destinations. In case when the downstream node encounters forwarding error, the upstream node that contain the same data in its catche can re-transmit the data through alternative route.

In [9] new enhanced AODV routing protocol, ED-AODV, has proposed for route selection considering two main metrics the so-called nodal energy metrics and the node's distance from its transmitting, predecessor node. According to their assumption the nodes energy factor which is the ratio of residual energy to initial energy has been used as a metric to prolong the life of the selected route, while the distance information is a metrics used to maintain the stability of the selected route with relatively minimum hop-count in addition to minimizing routing control packets. Since their work is to enhance the original single path AODV[10] routing protocol and this protocol is susceptible to single path failure unlike that of multi-path the routing protocol that provides multiple paths for single route discovery and it's not recommended for the application area in which we are working on.

After reviewing all the previous work that we have listed in our related work section and all the others, we understood that the integration of Packet travel time, energy factor and the original hop count as metrics for route selection would improve the performance of the AOMDV routing protocol in MANET applications, especially in delay-sensitive applications. Here our research is centered upon the following research question:

1. What traffic classes are used in this application and what requirements do they impose?
2. Does the current design of AOMDV support these requirements?
3. How can the required parameter be implemented in AOMDV?
4. How does the implemented DSA-AOMDV perform?

III. METHODOLOGY

Ad-hoc on-demand Multiple-path Distance Vector Routing protocol (AOMDV) is an extended version of AODV protocol but with multiple loop-free and link-disjoint paths. Since it uses the catching mechanism [11] it is advisable to use such a protocol for delay-sensitive applications than those of uni path protocols such as AODV. Nevertheless, due to various reason: insufficient energy (nodes are prone to link failures), the delay between sender and receiver being large (link breaks more frequently) and large packet travel time data may not deliver timely (may be lost). In our work, we tried to improve the performance of this protocol by considering remaining nodal energy and the packet travel time metrics in combination with the original hop count metrics.

Our proposed approaches do consider multi-metrics approach for the route selection and guarantees the network through by adding the metrics such as: node residual energy and Packet travel time into the original metrics for best-path selection. Since MANET protocol stack constitutes 5 layers i.e. Application, Transport, Network, Data Link layer and Physical layer[12] in which each layer is designed to support ad-hoc network connectivity our work mainly focuses on the Network layer that contains ad-hoc routing protocols. The module for best path selection (combined metrics of node energy factor, packet travel time and hop count) is used here. Thus after integrating our new module into AOMDV, the MANET's protocol stack looks as indicated in figure below.

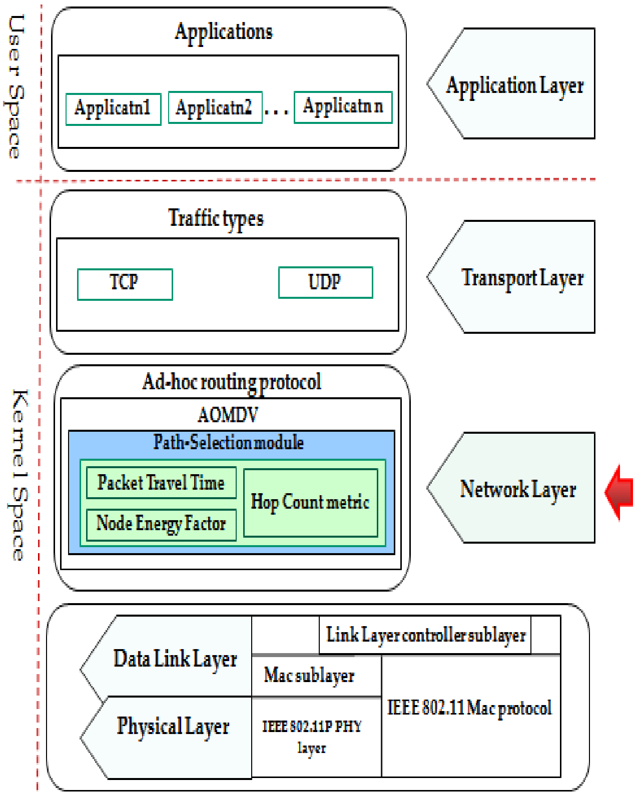

Figure 1. Architecture of our proposed approach

The proposed DSA-AOMDV protocol will select the best path from the available paths by using the combined route selection principle rather than the hop count metrics only. Thus, we modify the algorithm for path selection. Apart from this, the packets: Route Request and Route Reply packets and the routing tables are modified for the success of our work. The RREQ now contains the original AOMDV's RREQ + Packet Travel Time and Node Energy Factor. The detail is indicated in the below tables:

Table 1: RREQ packet format of our proposed approach

Type	Last hop	Hop count
RREQ id		
Destination IP Address		
Destination sequence number		
Source IP address		
Source sequence number		
Packet travel time		
Node Energy Factor		

The RREP of DSA-AOMDV contains the total Packet Travel Time of each path in the network and the nodes minimum residual energy of each path. Thus, this information will be used for path selection later. This information will also be cached in the routing table of the protocol for further use.

The route discovery was started with the new parameters added on. When the RREQ packet move from one node to the other node on the same path, the packet travel time, which is the difference between delivery times to the sent time, is calculated and added together until the it reaches the sink. The same is true for the node energy factor except in this case the minimum energy factor will be stored every time when the RREQ packet pass from one node to the other node on the same path. Then when the RREQ found the required destination, that information will return back along the RREP packet. That is when the RREQ packet is arrives the intermediate nodes it calculates the residual energy of its own and then compares with the residual energy in the RREQ packet and then store in the RREQ and then forward it till the it reaches the required destination. Once this RREQ packet is reached the required destination node, the packet travel time of RREQ packet will be calculated, stored on the corresponding RREQ field and along with the minimum residual energy of the nodes sent back to the sender node via the RREP packet. I.e the new values that will be copied to RREP.

For all the nodes (intermediate or other) in a disjoint path, the node energy factor, NEF, will be calculated using (1) below and minimum of all is stored in the RREQ packet.

$$NEF = E_r / E_i \quad (1)$$

E_i, E_r: assigned nodes initial energy and node residual energy respectively.

The MinRE, Minimum Remaining NEF, which is always a number in between 0 and 1 which is due to the value of numerator (the remaining energy of node) less than the value of denominator. This MinRE value of all paths is compared with certain threshold value during path selection. Accordingly, the neighbor can be chosen as next-hop in the bath from source to destination if and only if its node energy factor is above declared threshold value (which we assumed to be 50% of the original since there is no standard as stated by different scholars) and then other metrics are considered along the path. The destination node calculates the Packet Travel Time, which is the amount of time from the beginning until the end of a message transmission [13] since it is the time until the end of message as indicated in (2) below:

$$PTT = CT_{Stamp} - OT_{Stamp} \tag{2}$$

Where, PTT is the Packet Travel Time, CT_{Stamp} is the Current Time Stamp: when the packet reaches the desired receiver and OT_{Stamp} is the Packet origination Time Stamp. Then using a weight based routing scheme assigning weight **w** for each metric **m** used in our approaches route selection, which is assigned depending on their priority level[13] as in delay sensitive applications. Those metrics used in this scheme contribute additively to the weight computation with some multiplicative factors. Thus the Weight of Path, WoP, is calculated using (3):

$$WoP_{\langle p \rangle} = w1m1 + w2m2 + w3m3 + ... + wnmn \tag{3}$$

Equation (3) is for **n** number of metrics and hence we do have **n** number of weights too. **j** runs for all **n** number of metrics, and $\mathbf{w_j}$ is the weight assigned to metric $\mathbf{m_j}$. This can be generalized using the following (4).

$$WoP_{\langle p \rangle} = \sum_{j=1}^{n} w_j m_j \tag{4}$$

In addition, since we use the combination of three metrics for path selection and we use the threshold comparison for node energy NEF, factor and hence here we are about to find the weight of path using the other two metrics (Packet travel time and Hop count). Thus, equation (4) can be equated as follows:

$$WoP_{\langle p \rangle} = w1m1 + w2m2 \tag{5}$$

And letting the m1 stands for packet travel time, m2 stands for hop count metrics;

$$WoP_{\langle p \rangle} = w1Ptt\langle p \rangle + w2Ptt\langle p \rangle \tag{6}$$

Where **WoP** is the weight assigned to every individual paths. In addition, the weights w1 and w2 were chosen based on application requirements [13].

In this our work, since the application area that we are developing for is delay sensitive application, a metric that affect delay must be given higher priority than others. That is, the packet travel time has high priority than the hop count metric and hence, we uses 0.75 for M1 and 0.25 for M2 such that M1+ M2 =1 condition is satisfied. That is 0.75 + 0.25 = 1.

Thus, the sum of the two combined sum has to be minimum for the path to be selected as best path as per our proposed work. To find the path with minimum values of the combined packet travel time and hop count values (Selected best path), **SP**, we use the following (7):

$$SP(P_n) = \min(WoP(P_1), WoP(P_2).., WoP(P_n)) \tag{7}$$

Then the path with minimum values will be selected for data transmission. These values, Weight of path, which is the combined multiplicative factor of both packet travel time and the hop count, along with the minimum remaining energy factor of path will be stored and/or catched in the routing table entries. Afterwards it will be used as information for feature use in path selection.

Route Maintenance in the Proposed Scheme

According to our proposed scheme route, maintenance strategy might takes place if conditions are not fulfilled. That is, when any nodes energy is below the specified threshold in an ongoing communication then DSA-AOMDV restarts route finding procedure and notifies the upstream node for new route by eliminating energy depleted node i.e. the node sends RERR message to the source node for a new path search.

Algorithm: Route update of proposed DSA-AOMDV protocol

```
INPUT: N sets of node, S source and D Destination nodes
OUTPUT: Select Best Path, SP
For all N in neighbor list,
SendRREQ(With PTT and NEF added on)
Calculate NEF using (1) then, MinRE of nodes along
 path will be used.
If ( MinRE < ThrEn ) {
Free (Packet P);
If ( rto->rt_SeqNum < rq->rq_SeqNum ) {
Update route_entry to rq->rq_SeqNum ;
End
Else if
 ((rto->rt_SeqNum = = rq->rq_SeqNum) &&
 (rt->rt_WoP > rq->rq_WoP ) )  {
Then
Update route_entry to rq->rq_WoP
Then, the selected best path will be rq->rq_WoP
Endif
```

This process continues every time when there is a packet to be sent and it is called route update procedure.

IV. PERFORMANCE EVALUATION AND RESULT

In this section, we discuss performance evaluation; metrics and performance comparison with the help of graphs. For our simulation purpose, we use network simulator NS2 due to its simplicity and appropriateness with our work. We used a scenario of different number of nodes (10, 15, 20, 30, and 50) each node having the same transmission range. The area of topology used in all case is 500 X 500m^2. We compare our proposed work against AOMDV and EE-BWA-AOMDV.

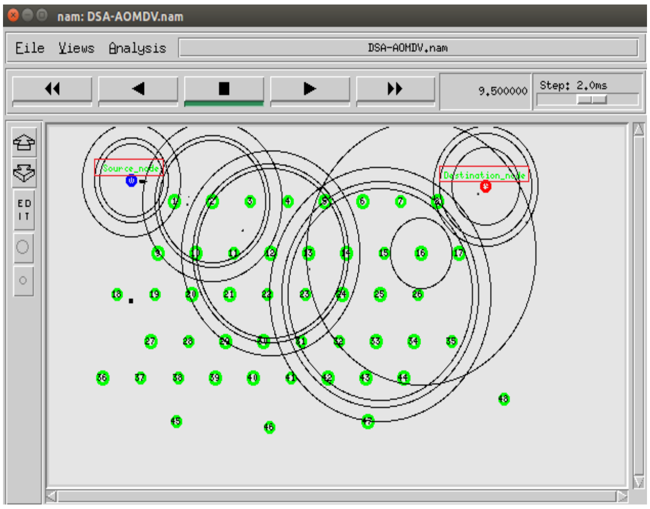

Figure 2. Sample simulation scenario of our protocol

In our system, we propose different performance evaluation metrics.

Table 2: Parameter type and values used in proposed approach

Para. No	Parameter type	Assigned values
1	Topology	Fixed
2	Area(m^2)	500X500
3	Channel type	Channel/Wireless channel
4	Maximum Speed	15m/se
5	MAC type	MAC/802_11
6	Routing Protocol	AOMDV, EE-BWA-AOMDV, EP-AOMDV
7	No of Nodes	10, 15, 20, 30, 50
8	Antenna model	Antenna/omniAntenna
9	Simulation time	45s
10	radio-propagation model	Propagation/TwoRayGround
11	Packet Size(byte)	1500
12	Transmission range	250m

A. Throughput performance metric

As the result of simulation shows DSA-AOMDV seem to achieve better performance than EE-BWA-AOMDV and AOMDV in terms of average throughput. The one related and recent EE-BWA-AOMDV routing protocol brought slight improvement when compared with the AOMDV protocol. But since it (EE-BWA-AOMDV) takes into account bandwidth and residual energy information only, the packet has no guarantee still resulting in low performance as compared to DSA-AOMDV protocol. That is there exist some paths which seems good but experience large delay (packet travel time).

And hence, these things are considered in addition to energy factor and hop count metrics in our DSA-AOMDV routing protocol and this cause DSA-AOMDV to outperform better than both. Note here that at pause time 15s the throughput of AOMDV degraded which is due to the path chosen at that time might lacks energy resulting in the throughput to fall down.

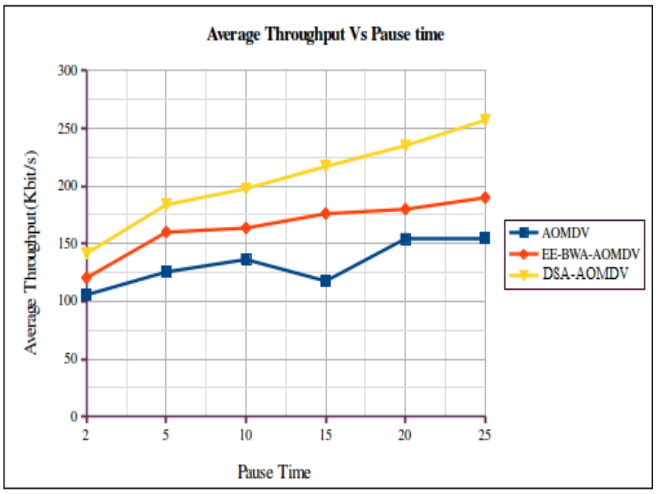

Figure 3. Average Throughput Vs Pause time

In figure below different network scenarios with varied number of mobile nodes (10, 15, 20, 30 and 50) keeping same initial energies for each, throughput plays a significant role in comparing different approaches. And hence changing the network size has its own impact on throughput performance, and graph shows that increased in number of node resulted into decreased throughput.

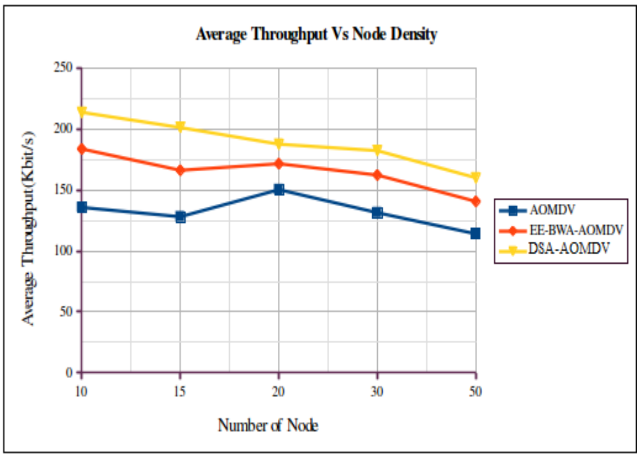

Figure 4. Average Throughput Vs Node density

DSA-AOMDV protocol is showing improved throughput performance as compared to EE-BWA-AOMDV and

AOMDV routing protocol nearly at all the different networks which is due to the path selection metrics we used in our approach (packet travel time, hop count and node energy factor) have a direct impact in improving throughput.

B. Packets Drop ratio performance metric

The Average Packet drop or loss rate is the average number of packets that are failed to reach the destination. In all DSA-AOMDV(our approach), EE-BWA-AOMDV and AOMDV protocols the packet drop rate increases with an increase in the time of simulation (5, 10, 15, 20 and 25's) and network size (10, 15, 20, 30 and 50 nodes) as shown in Figure 5 and Figure 6 respectively.

In contrast with EE-BWA-AOMDV and AOMDV protocols, DSA-AOMDV performs well with increase in time of simulation. That is since our path selection scheme do consider metrics that cause the packet to be lost during its path selection, the probability of packet loss is very small as the time of simulation increases.

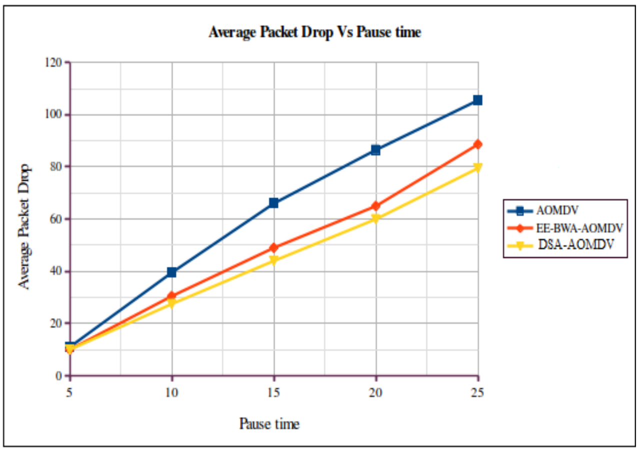

Figure 5. Average Packet drop Vs Pause time

In figure below we illustrated the comparison of average packet drop rate for DSA-AOMDV, EE-BWA-AOMDV and AOMDV taking different simulation scenario.

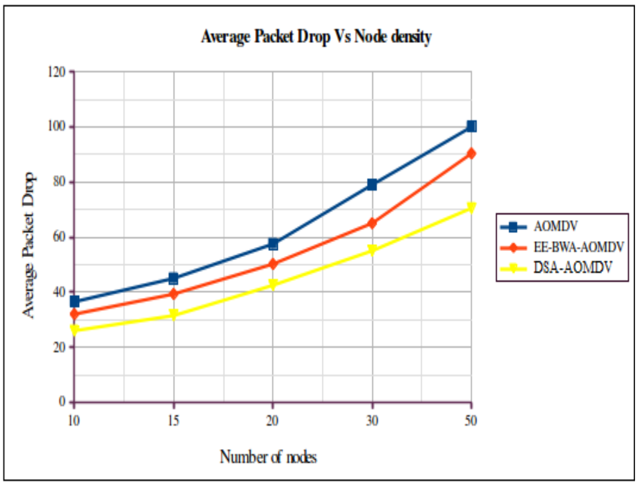

Figure 6. Average Packet drop Vs Node density

Changing the network size have its own impact on packet drop performance, and its showing that increased network size resulted into increased rate of packet drop. But still DSA-AOMDV has minimum rate of packet drop in comparison which is due to the consideration of energy factor and amount of time that it takes for a packet to deliver packet i.e. the PTT which if large might result in packet to be dropped.

C. End to End delay performance metric

End to End delay is the time interval between two nodes: sending and receiving node. This delay might occur during packet processing or queuing. A routing path with no or minimum average End-to-End delay is considered to be the best one. In application areas that we are developing for, delay metrics must be too small (or no if possible).

So our proposed approach do consider this issue, taking into account combined metrics that affect delay(such as packet travel time, and node energy factor in addition to hop count), results in minimum end-to-end delay than those preexisting EE-BWA-AOMDV and AOMDV protocols.

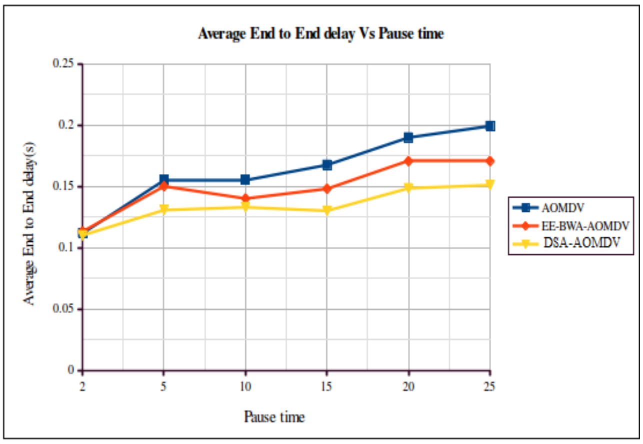

Figure 7. End to End delay Vs Pause time

Figure 8 illustrates the comparison of average end-to-end delay for DSA-AOMDV, EE-BWA-AOMDV and AOMDV different node densities.

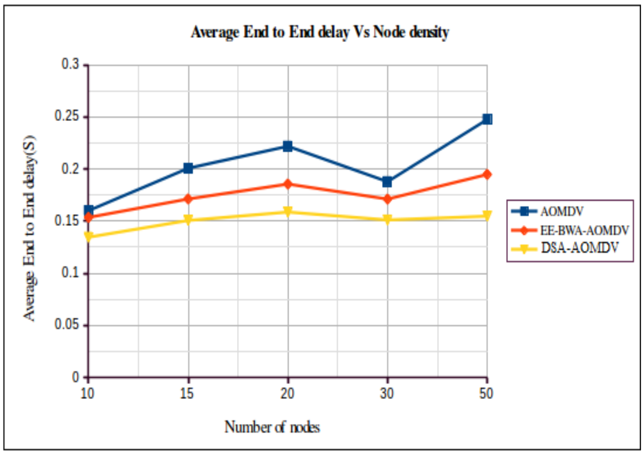

Figure 8. End to End delay Vs Node density

With an increase in the network size as in Figure 8, the number of nodes that needs to communicate also increases. The high delay experienced by EE-BW-AOMDV and AOMDV is due to the fact that they used to send packets over the high energy, maximum bandwidth and shortest path, which might be through a path that requires more time to deliver data packet from certain source node to sink node. Thus, their combined results in a high delay that decreases network performance.

D. Packet Delivery ratio performance metric

The proposed path selection mechanism has high success rate when we compare with that of the EE-BWA-AOMDV and the hop count based path selection mechanism (AOMDV). This average packet delivery rate comparison is shown in Figure 9 with varying the pause time (2, 5, 10, 15, 20, 25).

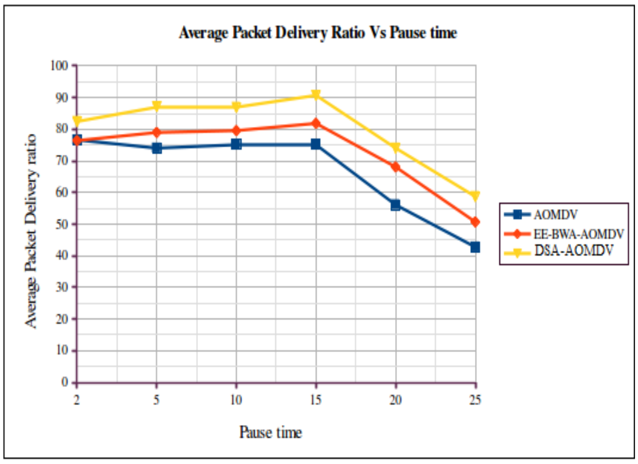

Figure 9.Average Packet delivery ratio Vs Pause time

As shown in Figure 9, even-though the Packet delivery ratio is about to decrease in all routing schemes(DSA-AOMDV, EE-BWA-AOMDV and AOMDV protocols) with increasing the simulation time of the network, but its better with EP-AOMDV in that it has more guarantee in the network throughput which directly results in the maximum packet delivery.

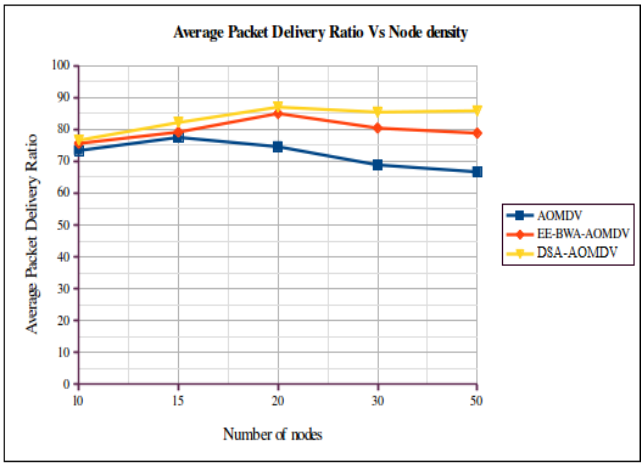

Figure 10. Average Packet delivery ratio Vs Node density

As in Figure 10, compared with EE-BWA-AOMDV and AOMDV with an increase in the network size, our proposed DSA-AOMDV has high packet delivery ratio due to an optimal path selection technique used and has minimal probability of packet to be dropped before reaching particular destination. Since we consider combined metrics, the established links between the nodes have a lower delay and thus it is less probable that the packet will get dropped.

E. Energy consumption as a performance metric

Energy Consumption is the amount of energy consumed throughout the network during communication. The proposed path selection mechanism has minimal energy consumption when we compare with that of the EE-BWA-AOMDV and the hop count based path selection mechanism (AOMDV).

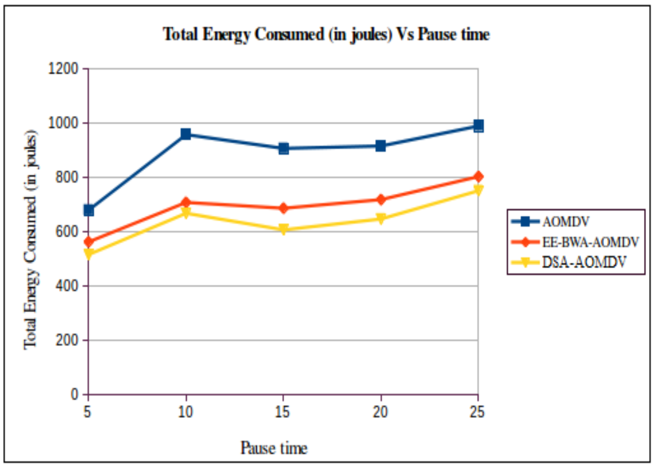

Figure 11. Average Energy consumed Vs Pause time

The comparison is shown in Figure. 11 with varying the pause time (5, 10, 15, 20, 25). From the comparison, we can easily understand that our approach results in minimal energy consumption almost at all the simulation times. Of course, both EE-BWA-AOMDV and DSA-AOMDV approaches have improved the energy consumption than AOMDV.

V. CONCLUSION AND FUTURE SCOPE

In this paper, the on demand multipath protocol for Delay-sensitive application of MANET, called DSA-AOMDV has been proposed by modifying AOMDV through by considering the packet travel time and the nodes energy factor. The protocol identifies the weight of path for every individual path and the minimum remaining energy of node for path selection. Node energy value, Minimum remaining energy of node is calculated to prevent path failure because of drain, which results in packet drop. The weight of path factor which is the combined sum of packet travel time and hop count is then used so as to reduce delay formed in this application.

Our scheme has shown an improved performance in terms of packet drop, PDR, throughput and end-to-end delay metrics. We compared our scheme with AOMDV and EE-BW-AOMDV protocols.

As a future work, an encryption algorithm for secure data communication should be integrated to enhance the performance of MANET in delay sensitive application.

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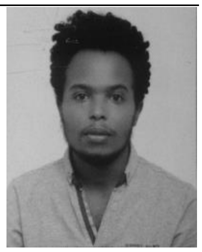
Authors Profile



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