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Link Stability Aware Ad Hoc on Demand Multipath Routing Protocol (LS-AOMDV) for MANETs

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Abstract: *In Mobile ad hoc networks (MANETs) the nodes can join the network and can exit the network at any point of time without any centralized control. Also, these nodes tend to move at random speeds and in random directions. This induces frequent changes in the topology of the network giving rise to frequent link breakages among the nodes. The links which are available atcurrent time may not be available at later stage as the nodes can move out of communication range of each other. Therefore, this broken links problem leads to degraded network performance such as lower packet delivery ratio or lesser value of throughput. This research paper proposes Link Stability Aware Ad Hoc on Demand Multipath Routing Protocol (LS-AOMDV) protocol to solve this issue. The protocol tries to predict the lifetime of the links between the nodes that are moving under random way point mobility model. The lifetime is computed for each epoch of the mobility model. The path having the nodes with higher link lifetime or the nodes with more stable links as well as higher remaining energy is considered as the optimal path. The performance of the proposed protocol was compared against FF-AOMDV protocol in terms of packet delivery ratio, throughput, end to end delay, routing overhead and remaining energy of the network. These parameters have shown better values for the proposed protocol which indicates that the links formed in the network are more stable.*

Keywords: *MANETS, AOMDV, link lifetime, random way point mobility model, packet delivery ratio*

1. Introduction

Wireless networks are a fore most worry in the communications arena in latest ages (G. Varghese 2015). These networks may be applied in numerous are nas of expertise, for example in personal area networks, army, in addition to industrialized setting. Wireless networks have treasured characteristics, for instance stress-free setting up, cost effectiveness, as well asconsistency, leading to their extensive variety of uses (M.R. Zasad et. al 2010).A mobile ad hoc network (MANET) is frequently used to permit communication oncemutual communication structure is inaccessible. This category of network is used in numerous applications for example in army (X. Zhao et. al 2013). Due to its extensive variety of uses, MANETs have been developed as a lively investigations ubject. Network node has binary roles: a router for information packets organized for some different nodes besides creator and end user of data packet flow (S. Choudhary et. al 2015). Regardless of these purposes, the inadequate battery lifetime as well as mobility of the nodes raise two significant tests in MANET investigation.

The wireless topography of MANET may be altered proficiently as well as quickly. The advantage of this network is it may be connected to a comprehensive Internet scale. The nodes in this network has dual purposes: it may be routed by different node plusit may be used as a router for different nodes. Nodes in this network travel arbitrarily and liberally and they may exit as well as enter any period of time. These networks most commonly use random way point mobility model for the nodes. According to this, the nodes move randomly at random speeds and in random directions as well. Due to nodes' moveable behavior, the topography of the network is vigorously altering. This leads to link breakage issues for these networks. A link which is existing at one of time may not be available in next point of time. Therefore, appropriate routing procedure is compulsory for the network to adjust to the variations in topology (A. Zadin et. al 2013).Link stability approximation is an imperative factor in these networks for effective connectivity of the link as well as steady path selection procedure (B. Xu et. al 2014, Q. Song et. al 2012). Numerous parameters can impact the stability of the link in these networks for example communication overhead, remaining energy of intermediate nodes establishing the route throughput as well as latency of the network, and channel exploitation (A. Moussaoui et. al 2015). In order to solve the issues of the link breakage caused by frequent changes in the topology, this paper proposes a modification to the path selection process in Ad hoc On demand Multi path Distance vector routing (AOMDV) protocol. The link stability has been defined in terms of link lifetime which has been predicted for nodes moving according to the random way point mobility model.

2. Related Work

A. Naushad et. al (2019) have worked on estimating the stability of the path for the network where the nodes move randomly under uniform speed. They have modeled link connectivity metrics to predict the stability of the link among the neighbors of the node which are members of the same cluster. They analyze that random movement of the nodes impact expiration time of the link among them, their relative velocity and the connectivity of their link. Furthermore, they also present path distribution analysis which is impact by the throughput and overhead generated when the Hello messages are exchanged among the nodes and the capacity of the link. Their model provides optimal connectivity for the links leading to greater throughput as well as greater energy effectiveness of the network. D. Kang et. al (2018) have designed routing protocol for MANETs to guarantee the reliable packet delivery of the data. It makes use of gradient forwarding that allows the nodes (that receive the data from uplink nodes) to make the routing decision which depends on the gradient of the routing cost. The instant value of signal to noise ratio is employed for the calculation of routing metric. M. Malathi et. al (2018) proposed protocol that is effective in terms of power consumption and is reliable also to forward the data between the source-destination pair. The capability of the channel is measured to decide if the source-destination node would communicate directly or via relay nodes. These relay nodes are chosen based on the quality of the link between them, capacity of the channel as well as remaining battery of the nodes. The link's quality between the nodes is estimated used received strength value. M.L. Bote-Lorenzo et. al (2018) have performed analysis for machine learning techniques to predict the quality of the links in context of the accuracy as well as computational load. Furthermore, a hybrid online technique for the predicting the link quality has also been presented.

A. Taha et. al (2017) proposed FF_AOMDV to define a fitness function for the selection of optimal paths. The first path is selected based on highest function which uses remaining energy of the nodes as the prime measure of fitness. If this route fails, then second path having minimum value of distance as the fitness value is chosen to resume the data communication. G. Singal et. al (2017) proposed link stability cost function in their study to select the most reliable node to forward the data. Then the nodes having maximum value of cost function are used to formulate the multicast routes between source-destination pairs. W.A. Jabbar wt. al (2017) have focused on the energy conservation of the network as well as countering the effect of topological changes caused due to mobility of the nodes. Relay nodes are chosen considering the residual battery level as well as mobility of the nodes. They propose a selection method for the nodes that computes their inclination to become relay node based on the factors mentioned above and for these nodes, the stability is computed using the multi criteria node rank metric. S.R. Afzal et. al (2017) has proposed estimated directional delivery ratio metric (x-DDR) to predict link quality. This metric helped in improvement of the packet delivery ratio for network when compared against expected transmission count (ETX).M. Baushaba et. al (2017) proposed node stability based routing technique to address the concerns caused by instability of the network. The quality of the link is considered using the interference ratio as well as congestion over the link. The quality of link is further used to compute link stability index to identify the links as acceptable or not acceptable links. This method finally discards the links that are degraded. G. Kok et. al (2016) designed a routing metric to select the stable routes between source-destination pair, the stability of these routes depend upon length of the links and mobility of the nodes in the routing path.

3. Motivation

The better quality of service for any network would mean that the network should have better packet delivery ratio (PDR) and throughput, lesser latency, overhead and energy consumption. These parameters are dependent on the quality of the link formed between the two nodes which are involved in data transmission. In a network with fixed nodes, the link between two nodes remains stable unless one of the two communicating entities dies due to battery drainage. The stable links if having lesser congestion, will allow successful data transmission. Whilst, if the nodes are moving as in the case of mobile ad hoc networks (MANETs), the packets transmitted from one node may not be received properly at the other node. The reason can be related to higher congestion over the established link between them, or the link might be no longer available because the nodes have moved out of communication range. Therefore, to improve the quality of service for MANETs, the stability of the links between the nodes needs to be considered. The constant movement of the nodes leads to frequent topology changes in these networks and become a prime reason for reduced performance of the network. Also, it is seen in the related works that many of the authors have tried to predict the quality of the links or their stability based on various factors including the mobility of the nodes, signal to noise ratio over the link, congestion level, remaining energy of the nodes etc. Apart from this, the prediction of link lifetime for random way point mobility model is rarely seen in this works. Therefore, in this work we define the stability of the link by predicting its lifetime. Also, other modifications have been proposed to ensure better QoS parameters for the network.

4. System Model and Assumptions:

- Nodes move randomly in the network using random way point mobility model.
- Node has bidirectional link with other node if the distance between them is less than communication range, R.
- Nodes are free of any kind of hardware fault.
- Nodes are cooperative in nature.

5.Proposed Modified AOMDV Protocol:

To improve the quality of service for MANETs, we proposed modification to the AOMDV routing protocol. The AOMDV protocol uses the broadcasting of route request packets (RREQ) in the first phase to find multiple routes between two nodes. The FF-AOMDV also follows the first phase laid out by traditional AOMDV. In the modified protocol, the broadcasting is done while considering the congestion occurring at the nodes while they forward the RREQ packet. For this, PDR of the nodes is taken as measure of the congestion and the congested nodes are removed from taking part in broadcasting. Once the initial paths are constructed, the AOMDV would start route reply phase (second phase) by sending route reply packets (RREP) over all the paths to the source node. Again the existing FF-AOMDV follows the same procedure. In the modified version, the paths are prioritized considering the latency of the links constructing the paths. The paths having higher latency have lesser priority and in this phase only higher priority paths are considered for route reply. The last phase is the selection of optimal path from the set of multiple paths via which RREP packet reached the source node. The normal AOMDV considers the hop count as the optimal measure for selecting the path, FF-AOMDV considers the highest energy as the first optimal measure and shortest distance as the second optimal measure. However the modified protocol considers the link stability index to select the optimal path. Once the optimal paths are selected, the data transmission begins from source to destination node.

All the modifications that include the impact of congestion, the significance of prioritizing the paths and choosing the link stability index as optimal measure to select the path have been discussed in the next section.

5.1 Impact of the parameters used for modification of AOMDV:

The nodes in the ad hoc networks use reactive protocols to find route to destination node. For this, they broadcast RREQ packets to their neighboring nodes. In such networks, broadcasting usually creates congestion over the nodes. This happens because a node has multiple neighbors and when RREQ packets are flooded the congestion is bound to occur. When the congestion happens, the packets tend to get dropped from the node's buffer or queue thus leading to drop in PDR. Therefore, as a first modification to the AOMDV, the PDR is used as a measure of congestion. The less value of PDR for any node will indicate congestion over it. Therefore, the congestion nodes are removed or we can say the congested node will not forward the RREQ packet further in the network.

Once the paths are created (having lesser congestion), another modification to AOMDV comes in the form of prioritizing the paths considering the latency of the links. The latency of the link is defined in terms of end to end delay of the packets transmitted over the link. The MANETsare also used for applications related to military or defense or healthcare. In such applications, the minimization of delay holds much importance. Therefore, for all the paths created in the first phase, the highest priority is given to the path having least latency. For RREP phase, only those paths are considered that have latency less than average latency obtained for the entire population of paths.

In MANETs, the constant topology changes arising out of movement of the nodes causes many links to stop existing. It is very high possibility that links available during route request or route reply are no longer available at the later stage. Therefore, it becomes very important to consider the stability of the links. We define the stability of the links in terms of lifetime of the links (also termed as link sustenance period in this paper) which is the time during which the two nodes remain in communication range of each other. When the route reply reaches the source node, the links having highest lifetime are considered while selecting the optimal path in the proposed modification.

Therefore, if the least congested nodes are considered in the set of paths from source to destination node and from the set of paths those paths are chosen that have lesser latency and higher link stability, the performance of the network is expected to improve.

5.2Link Stability Aware Ad Hoc on Demand Multipath Routing Protocol (LS-AOMDV)

In this proposed LS-AOMDV protocol, the first phase begins with broadcasting of RREQ packets by the source node to the neighbors in its communication range. This method is similar to almost all of the reactive routing protocols such as AODV, DSR or AOMDV. These protocols however will exploit all the nodes to establish route between a source-destination pair. In the LS-AOMDV, the congested nodes will be removed from the broadcasting process. Each node upon receiving the RREQ packet verifies the destination address from its routing table. If the destination address is not available, the node re-broadcasts the packets further in the network. Before rebroadcasting, it checks the PDR value. If the value is less than 0.90 (i.e. if the node has dropped more than 10 percent of the received RREQ packets), then the node does not forwards the received packet as it indicates the congestion over it. Every node follows the same procedure until the RREQ packet reaches the destination node. This process will therefore, remove the congested nodes from the formulating the possible paths between source-destination pair.

$$PDR = \frac{Nr}{Nr + Nd}\begin{cases} if\ PDR < 0.90; & Drop\ the\ RREQ\ packet \\ \quad else & Rebroadcast\ it \end{cases} \tag{1}$$

Where - Nr is the number of received RREQ packets
Nd is the number of dropped RREQ packets

Furthermore, a field containing value of latency (having initial value of 0) will be added to the RREQ format. When the RREQ packet starts from the source node, the source node will add its origin time to the packet (t_{or}) and broadcast it. The neighbor which receives the packet, will check the time of reception (t_{re}).

$$Latency = t_{re} - t_{or} \tag{2}$$

$$Latency_{path} = \sum_{j=1}^{m-1} (t_{re} - t_{or})_j \tag{3}$$

Where- m is the number of nodes in the path j.

The node will find end to end delay of the packet by subtracting these two values (equation 2) and add it to the value in the field latency and update it. This way when the RREQ packet reaches the destination node over the less-congested nodes, it will have values for end to end delay for every path. The table below show the RREQ packet format for the original and modified version. The field 'Latency' is added as well as 'Time of origin of RREQ packet' is added to the original format so that end to end delay for each path can be computed at the destination node.

Source node address	Source sequence no.	Broadcast Id	Destination node address	Destination sequence no.	Number of hops

Table 5.1: Original RREQ packet format

Source node address	Source sequence no.	Broadcast Id	Destination node address	Destination sequence no.	Number of hops	Latency	Time of origin of RREQ packet (t_{or})

Table 5.2: Modified RREQ packet format

When the destination node receives the RREQ packet from multiple nodes, it back traces all the possible paths to the source node. Then, it extracts the value of latency from the corresponding RREQ packet. The average value of latency for all the paths is computed and the paths having value less than average values are given priority. All the other paths are not considered for route reply phase.

$$Avg.Latency = \frac{\sum_{i=1}^{p} \sum_{j=1}^{m-1} (t_{re} - t_{or})_{j,i}}{p} \tag{4}$$

Where- p is the number of possible paths between source-destination pair

$$\begin{cases} if\ Latency_i < Avg.Latency; & consider\ path\ for\ Route\ reply \\ \qquad else \qquad ; & discard\ the\ path \end{cases}$$

The path with least value is given highest priority as 1.0. The path having next lesser value of latency is prioritized as:

$$Priority\ (\partial_i) = \frac{Latency_{least}}{Latency_i} \tag{5}$$

The destination node now arranges all the paths in the descending order of priorities and forwards the RREP packet to the source node over these paths. The value of priority is included in the RREP packet for the corresponding path. In addition to this, each node will also add the value of residual energy in the RREP packet. This is done to ensure that the path selected in the end is optimal in terms of energy as well.

The next thing is to choose the optimal path out of various paths for which route reply has been received. For this we need to find the stability of the links constituting the paths. In this paper, we have used Random way point mobility model. This allows the nodes to move randomly in any direction and to any destination in two dimensional space. The direction of the movement is uniformly distributed over the range $(0,2\pi)$ and the speed is in the range of (v_{min}, v_{max}). As per this mobility model, the movement of the node during entire simulation is divided into stochastic length intervals referred to as mobility epochs γ. Within one single mobility epoch, any node will move at constant speed and in constant direction. Whenever the epoch changes, the speed as well as direction of the node changes randomly. Here we assume that the average epoch length of the each node is same.

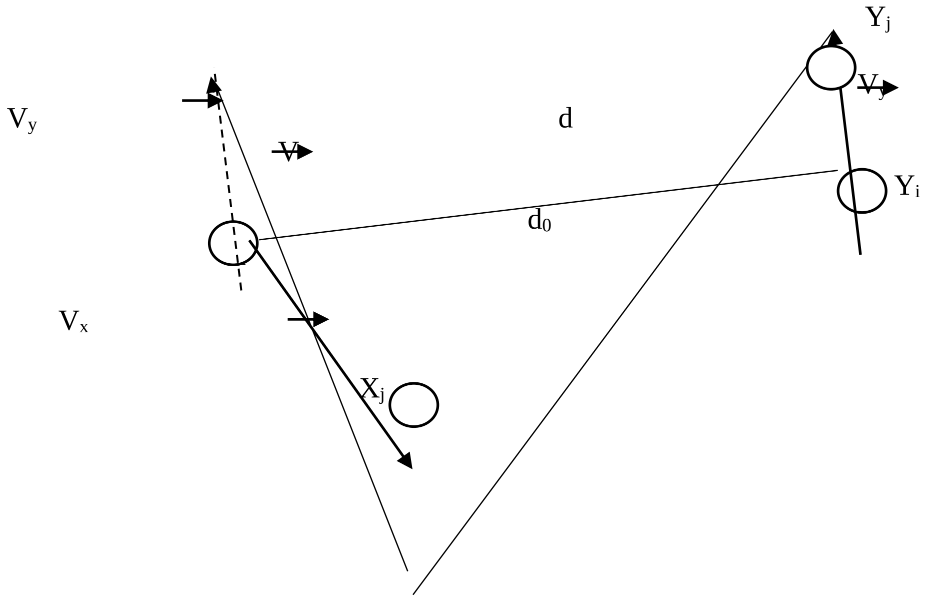

Figure 5.1: Relative movement between two nodes after change of epoch

The above figure shows at the start of the mobility epoch the nodes X and Y are initially separated by a distance ‘d_0’. Their initial position is X_i and Y_i. Once this epoch ends, their direction and speed will change. Let us assume that now their positions are X_j and Y_j such that now the distance between them is ‘d’. V_x and V_y represent their velocity vectors.

The link between these two nodes is said to be stable as long as distance between them at any point of time, $d<R$. The relative velocity between these two nodes will be:

$$\vec{V} = \vec{V_x} - \vec{V_y} \tag{6}$$

If we can find the relative velocity between these two nodes then for an epoch of length γ seconds, we can find the distance covered by these nodes in time γ seconds. If that distance remains less than communication range, then for that epoch the link between the two nodes will remain stable. The magnitude of relative velocity can be found as:

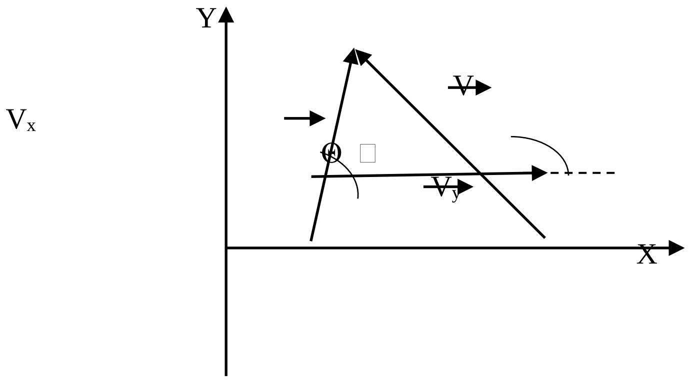

Figure 5.2: Relative velocity between two nodes

This figure shows the angle Θ made between the two velocity vectors and the angle between the relative velocity vector and x axis is □ (which is uniformly distributed in the range (0,2π)).The magnitude of relative velocity can be computed using the cosine rule:

$$V = \sqrt[2]{(V_x{}^2 - 2V_xV_y cos\Theta \,+\, V_y{}^2)} \tag{7}$$

Once the magnitude of relative velocity is available, we can find the relative distance between the two nodes at the end of epoch of length γ seconds.

$$D_{epoch} = V * \gamma \tag{8}$$

Where- D_{epoch} is the distance between the two nodes at end of epoch

The difference between the communication range and D_{epoch} will be the maximum distance these two nodes can cover while travelling at relative velocity of magnitude 'V' while ensuring the availability of the link between them. We term this as link sustenance distance (LSD).

$$LSD = R - D_{epoch} \tag{9}$$

Since these two nodes are moving at relative velocity of magnitude 'V', therefore the link sustenance period (the time during which the link will be available between two nodes) for one single epoch can be derived as:

$$LSP_{link} = \frac{LSD}{V} \tag{10}$$

Where- LSP_{link} is the link sustenance period

For the entire path the bottleneck link will be the one having minimum value of the LSP. It will be considered as the LSP for entire path.

$$LSP_{path} = \min\,(LSP_{link}) \tag{11}$$

The optimal path for transmission of the data will be the one having maximum value of LSP. Furthermore, the path having maximum value of LSP also needs to the resourceful in terms of residual energy of the intermediate nodes. Therefore, the fitness function of the path is computed as:

$$f(p) = LSP_{path} * \frac{\sum_{i=1}^{m} R.E._{i}}{\sum_{i=1}^{m} I.E._{i}} \tag{12}$$

Where- $R.E_i$ is the residual energy of the i^{th} node in the path
$I.E_i$ is the initial energy of the node 'i'

The source node will choose two paths, one path will be used to transfer the data to the destination node and other can be stored in the source node's cache memory for later use (in case the first path is no longer available). The first path will be the one having maximum value of LSP and second path will be the one having second maximum value of LSP.

However, it is also possible that the data transfer interval (time for which the source node has to send data to the destination node) is more than single epoch length. In such a case, the value of LSP computed for single epoch cannot be reciprocated to other epochs to predict the LSP since the speed and direction changes every epoch. In such a case, at the start of the epoch, the LSP of the paths will be recomputed to check the optimality of the selected path.

5.3 Algorithm

```
Suppose 'N' is the total number of nodes in the network
Source node broadcasts a packet in the communication range.
while (Destination not found), do
Neighboring node (the node that received the RREQ packet) checks the PDR
if PDR >0.90
    compute latency and update it in RREQ packet
    forward the RREQ further to the neighbors
else
    Drop the RREQ packet
End if
End while
Compute all the paths to the source node
Compute average latency of the paths
If latency of the path < average latency
    Add residual energy value in the RREP packet and send to the source node
Else
    Discard the path
End if
Compute Link sustenance period for all the paths in single epoch
if Fitness function == maximum
    Path is optimal
else
    Path is not optimal
End if
Forward data to the destination over optimal path
Update LSD value every epoch to ensure optimality of each path
```

6. Results and Discussion

Both the protocols, existing FF-AOMDV as well as proposed LS-AOMDV, were implemented in network simulator 2.35 in the unix environment. The various simulation parameters that were used to model the network for the simulation are described in the next section.

6.1 Simulation Model and Parameters

This work was focused on solving the link breakage issues for MANETs. The prime reason attributed to the link breakage is the movement of the nodes out of the communication range which normally occurs due to varying speeds. Therefore, the performance of FF-AOMDV as well as proposed LS-AOMDV was analyzed under varying mobility of the nodes. For the simulation scenario, the parameters given in the following table were used:

Parameter	**Value**
Channel	Wireless
Mac	802.11
Antenna	Omni Directional
Number of nodes	50
Node speed	2.5, 5, 7.5, 10 (m/s)
Size of the queue	50
Network Area	1500 * 1500 m^2
Routing Protocols	FF-AOMDV, LS-AOMDV
Mobility Model	Random Way Point
Packet Size	512 bytes
Transmission Range	250 meters
Traffic Type	CBR
Initial Energy	100 Joules
Transmission Power consumption	0.02 Joules
Receiving Power consumption	0.01 Joules
Sleep Power	0.001

Table 6.1: Simulation Parameters

A simulation for 50 nodes were conducted. These nodes were randomly deployed in the network area of 1500 * 1500 sq. meters where these nodes follow random mobility model to move at random destinations and at random speeds. To communicate with other nodes, the traffic agent Constant Bit Rate (CBR) was used and these nodes were supplied initially with energy of 100 Joules.

6.2 Performance Parameters

To evaluate the performance of the network, following parameters were considered:

- Packet Delivery Ratio: This metric tells the percentage of the sent packets from one node that were successfully received at the other node in the network. This parameters holds importance because we are analyzing the solution to the link breakage between the nodes and whenever the link breaks the packets get dropped from the network. Therefore, analysis of this parameter will reflect the effectiveness of the proposed method in solving the link breakage issue. Mathematically this can be represented as:

$$PDR = \frac{Number\ of\ received\ Packets}{Number\ of\ sent\ packets} \tag{13}$$

- End to end delay: This is the time taken by the packets to travel over a link between two nodes. Apart from this, the other delays can be processing delay, queueing delay etc. Mathematically it can be computed as:

$$E2E\ Delay = Time\ of\ packets\ reception - Time\ of\ packet\ sending \qquad (14)$$

- Remaining energy: This reflects the lifetime of the network. The energy of any node is mainly consumed in transmitting the packet and receiving the packet. The higher value of remaining energy indicates better network lifetime.

$$Remaining\ energy = Initial\ Energy - Energy\ consumed \qquad (15)$$

- Routing Overhead: This is another important parameter to analyze in this study. It reflects the number of routing packets that needs to be sent to receive data packets in the network. This factor is closely linked to link breakages in a way that if the links are breaking frequently in the network, more routing packets are required to be sent to maintain them. Therefore, a higher value of overhead may indicate more routing packets are sent to maintain the links between the nodes and a low value represents healthy links in the network. Mathematically, it can be computed as:

$$Routing\ overhead = \frac{Number\ of\ routing\ packets\ sent}{Number\ of\ data\ packets\ received} \qquad (16)$$

- Throughput: It is defined as amount of data received at the destination node per unit of time. Its units are Kilo Bits per second. This again reflects the quality of the links in the optimal path selected for data transmission between the source-destination pair. A network with better links will have higher network throughput as well.

$$Throughput = \frac{Number\ of\ data\ packets\ received * size\ of\ packet * 8}{Time * 1000} \qquad (17)$$

The figure 6.1 shows the values obtained for end to end delay when the speed is varied from 2.5 m/s to 10 m/s. the blue line shows the delay for the existing FF-AOMDV protocol and the orange line shows the delay for proposed LS-AOMDV protocol. At 2.5 m/s the value of end to end delay for FF-AOMDV was 0.0063 seconds which eventually increased to 0.0672 seconds when the speed of the nodes was 10 m/s. On the other hand, the proposed LS-AOMDV protocol had value of end to end delay at 0.0051 seconds when the speed was 2.5 m/s and it increased to 0.033 seconds when the nodes were moving at 10 m/s. This shows that with the increase in the speed of the nodes, the link quality deteriorates and the end to end delay increases for both the protocols. However the proposed protocol shows less end to end delay which reflects that the links made using the proposed protocol were more optimal and better as equated to existing FF-AOMDV.

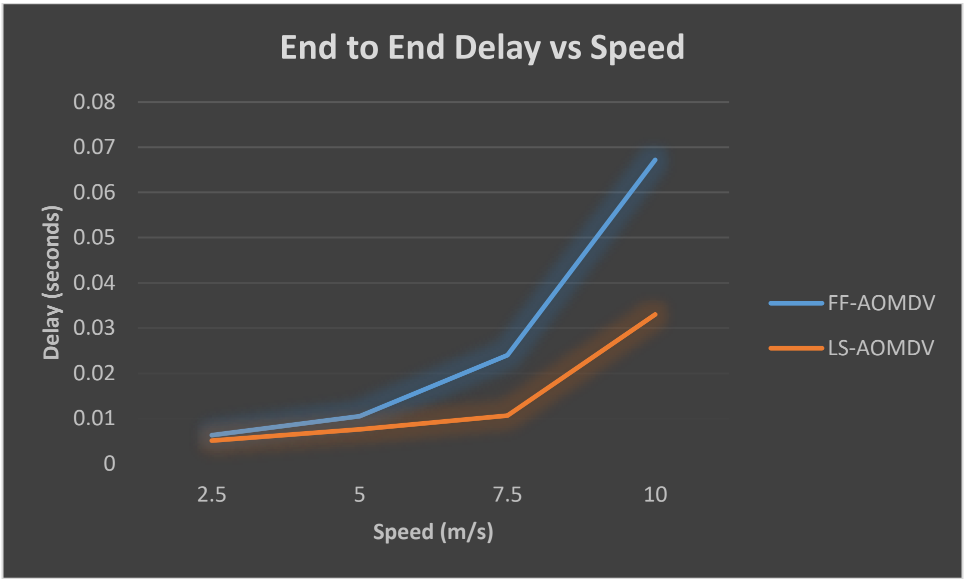

Figure 6.1: End to End Delay Vs Speed

The figure 6.2 shows the variation of the remaining energy of the network against different values of the speed. It can be observed from the above graph that the both the protocols consumed almost similar amount of energy. The energy remaining in the network for the existing FF-AOMDV varied from 82.23 Joules to 85.20 Joules and for the proposed LS-AOMDV, the remaining energy varied from 81.8 to 84.67 Joules. The energy consumption is similar for both the scenarios since both of them focus on selecting the path that is having nodes with higher remaining energy.

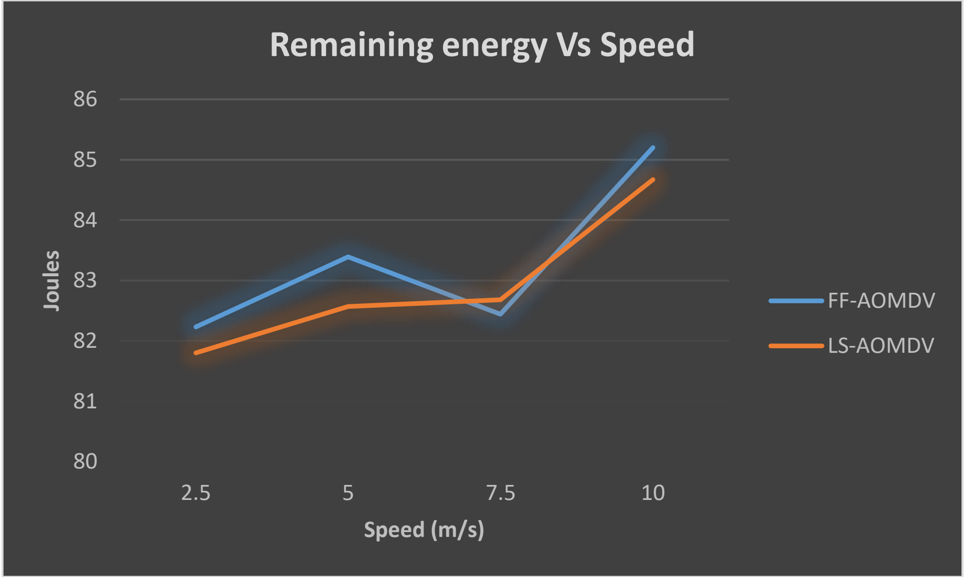

Figure 6.2: Remaining energy Vs Speed

The figure 6.3 shows the values obtained for the routing overhead for both the protocols. The value of routing overhead when the nodes were moving at 2.5 m/s for the existing FF-AOMDV protocol was 0.401 and the same value for the proposed LS-AOMDV protocol was 0.376. The value of routing overhead increased with the increase in the speed of the nodes. This reflects that when the speed of the nodes increased, more routing packets were required in the network. This increase in the number of required routing packets for maintaining the unstable links formed in the network. At the highest speed of 10 m/s, the value of routing overhead was 0.5 for the existing LS-AOMDV and 0.48 for the proposed protocol. The lesser value of routing overhead for the proposed scheme shows that lesser route maintenance is required as lesser links break away in the selected optimal path. When the stable links are selected in the optimal path, the need for rediscovering the routes in case of route failure becomes less which reduces the routing overhead of the network as well.

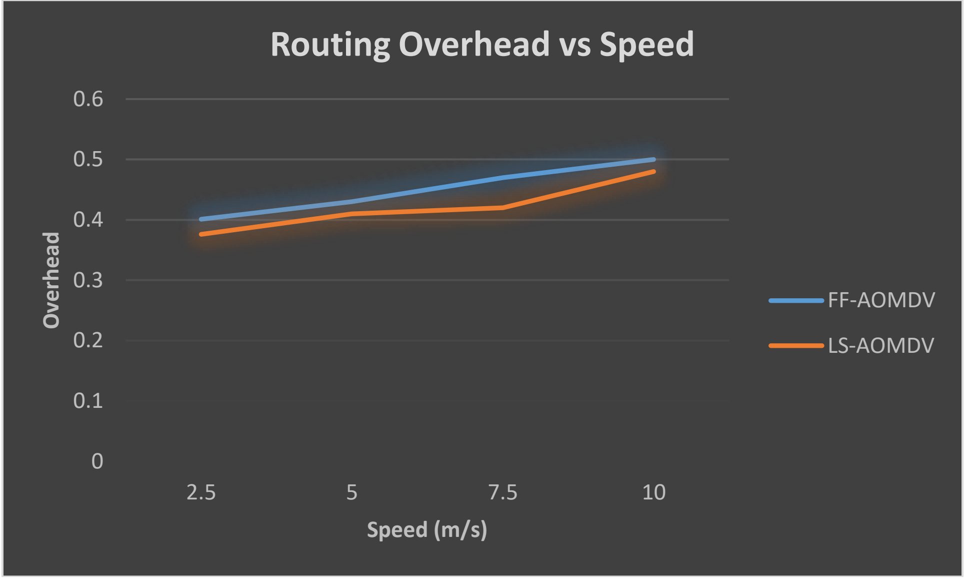

Figure 6.3: Routing Overhead Vs Speed

The figure 6.4 shows the variation of the packet delivery ratio for both the protocols. The value of packet delivery ratio for the existing protocol, FF-AOMDV varies from 0.97 to 0.89 with the increase in the speed of the nodes. The same value for the proposed LS-AOMDV protocol varied from 0.98 to 0.93. The increase in the speed of the nodes leads to unstable links which causes packets getting dropped in the network. This is the main reason that with the increase in the speed of the nodes, the value of packet delivery ratio decreases. However, the proposed protocol have shown better values than the existing protocol. The proposed protocol takes care of the congested links during the route discovery phase also. Furthermore, the links having the better predicted lifetime are considered in selecting the optimal path for data transmission. This leads to higher values of packet delivery ratio for the proposed LS-AOMDV protocol. The existing FF-AOMDV protocol on the other hand, selects the optimal path in terms of higher remaining energy as well as lesser distance. Such a path may have the nodes moving at higher speeds which leads to unstable routes even if optimal in terms of energy and distance.

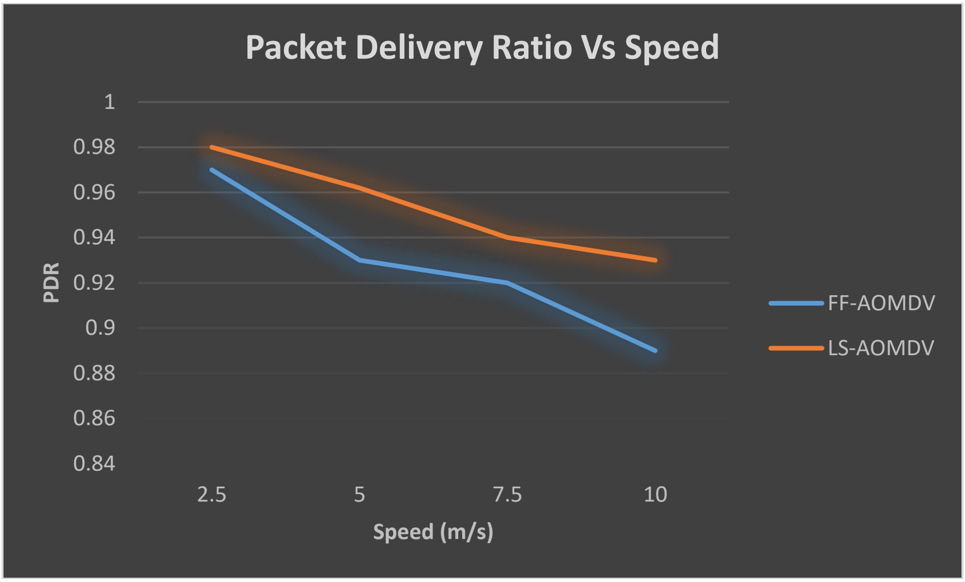

Figure 6.4: Packet Delivery Ratio Vs Speed

The figure 6.5 shows the variation of the throughput of the network for both the protocols. The value of throughput obtained for the proposed protocol varied from 1372 Kbps to 1200 Kbps while for the existing protocol, this value varied from 1261 Kbps to 1032 Kbps. The packet delivery ratio as seen in figure 6.4, decreased for both the protocols with the increase in the speed of the nodes. This also lead to decrease in the value of throughput as well as the speed of the nodes increased since lesser packets get successful delivered at the destination node. The maximum value of the throughput was obtained when the nodes were moving at least speed of 2.5 m/s and the minimum value was seen at higher speeds. This truly reflects the instability of the links at higher speeds. However, the proposed protocol outperforms the existing protocol since the links selected are those which have higher link lifetime or higher link stability.

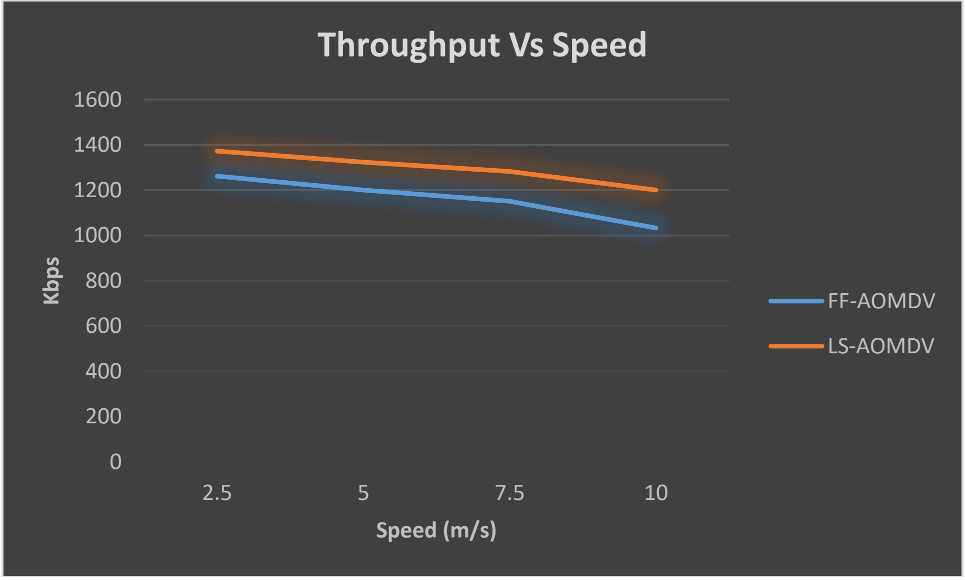

Figure 6.5: Throughput Vs Speed

7. Conclusion

This research work was focused on solving the issues related to the link breakages in the MANETs. This paper proposed LS-AOMDV which selected the optimal path having the links with higher lifetime or having the more stable links. For this, the link lifetime was predicted for the nodes moving under the random way point mobility model. The performance of the proposed protocol as well as existing protocol was analyzed under different mobility values of the nodes. The factors used to assess the network's performance were packet delivery ratio, throughput, end to end delay, routing overhead and remaining energy of the network. These parameters showed better values for the LS-AOMDV as equated to existing FF-AOMDV. This reflects that the selection of the optimal path by predicting the link lifetime has resulted in more stable as well as better quality links for the proposed protocol. Hence, it can be concluded that proposed protocol has outperformed the existing protocol.

In future, the link lifetime prediction method used in this paper can be applied for other routing scheme as well. Also, the effectiveness of this proposed routing protocol can be analyzed against other bio-inspired routing schemes such as ant colony optimization, firefly optimization etc. This work does not considers the security of the network, therefore the proposed protocol can be analyzed under different attacks that happen in MANETs and then a security scheme can be incorporated in this protocol to make it more secure.

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