Energy-Aware based Cooperative Multipath Routing Protocols for MANET

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***Abstract*—** The Mobile Ad Hoc Network (MANET) is a group of Wireless Mobile Nodes with restricted Power Supply that can easily form a provisional and dynamic network and it can communicate each other without the support of any established infrastructure. It was noticed that the routing is one of the major challenges in MANET due to the mobility nature. This research work proposed an efficient Power-Load Aware Multipath Routing Protocol (PLA-AOMDV) to address the Link Failure as Power Dissipation happened in a route and link. The PLA-AOMDV is carefully designed and implemented in QualNet 6.1. The simulation results of the proposed model were studied thoroughly in terms of Throughput, Packet Dropping Rate, Routing Overhead, Energy Consumption, End-to-End Delay, Life Time (Dead Nodes Count). From the experimental results, it was established that the proposed Power-Load Aware Multipath Routing Protocol (PLA-AOMDV) is performing. However, this Research Work observed that Link Break Degree and Link Utilization needed to calculate effectively to retain stable route that is selected for communication. To address the identified issue and needs, this work enhanced its previous Model PLA-AOMDV and proposed Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV). It is implemented in QualNet6.1 Simulation Platform and the results were studied in terms of Throughput, Packet Dropping Rate, Energy Consumption, and Network Life Time (Dead Nodes Count). Results established that the proposed ELA-AOMDV Routing Technique is performing well as compared with that of the existing PLA-AOMDV in terms of Throughput, Packet Dropping Rate, Energy Consumption, and Network Life Time (Dead Nodes Count).

Keywords— Energy Consumption, Power Aware, Load Aware, Link Break, Link Utilization, Routing Overhead, Energy Efficient Protocol, Fitness Function, FF-AOMDV, MANET, Multipath Routing, PLA-AOMDV, .

I. INTRODCTION

Mobile Ad Hoc Networks (MANET) is an Autonomous System that consists of collections Mobile Nodes without any support of Infrastructure. The MANETS Routing Protocols proposed for packet transmissions can be classified into Table-Driven and On- Demand Driven based on the working nature and methodologies of route updated. In Table-Driven Routing, it maintain consistent. It will forward the updated routing information to each and every Nodes which are connected to the network. Because of dynamism in routing, low and high quality links, change of radio channels, failure of node and the routes being used for current communication becomes void. Due to this new route need to be discovered which creates delay. To overcome this problem MANET[1,3,4,5] introduce On-Demand Routing which identified Multiple Path between Sender and Receiver at the single route discovery.

From the literature survey, it was noticed that recently, many re- searchers have focused to contribute for the Multipath Routing. It was noticed that a few standard multipath routing protocols namely AODVM[1,32], AOMDV[1,33], SMR [1,34] and MSR[1,35].The major design issue is dynamic energy consumption of multi- path routing. To address the identified and above mentioned is- sues, there were a few Power-Aware and Energy-Efficient Multi- path Routing Protocols were proposed[1,2,3,4,5].

Power-Aware Routing Protocols are dealing with a few smart approaches which reduced the energy consumption of the Sensor Nodes. These schemes were performed by forwarding Packets through various Sensor Nodes those have higher Energy levels. This is one of the best techniques that will maximize network lifetime. From the literature survey, it has been identified that the Power- Aware Node-disjoint Multipath Source Routing (PNDMSR)[1,5] Protocol is proposed with different approach to find the energy aware node-disjoint multipath to destination from source and noted that this model employs relatively less overhead broadcast mechanism for optimizing the noted overhead with the help of different approach and scenario.

From the literature survey, it is noticed by the author that the Multipath routing protocols flood a route request packet to understand more possible routes to the destination which is used to forward packets between Source and Destination. It was understanding that the Multipath routing protocols have a few major challenges and demands such as Path Discovery and Maintenance as well, Disjoint Route, Route Selection, Route Failure, Bandwidth Allocation, Throughput, Power Consumption, End-to-End Delay and etc.

In this research paper, the FF-AOMDV Routing Protocol was enhanced by adding an efficient procedure for Power Aware and Load Aware Routing. That is the proposed Protocol is made to make intelligent decision to discover best optimal paths between source node and required destination node. The achievement of the proposed Protocol is to avoid nodes that have less than 25% of residual energy to participate route discovery processes. This will save Nodes' and Network power as well as long as possible.

To discover the best route and to selects best path for communication, Research work proposed an efficient Power-Load Aware Multipath Routing Protocol (PLA-AOMDV)[36,37].It addresses Power Dissipation issues that cause link failure.

The rest of this paper is arranged as follows. In the Section 2, the existing Ad-Hoc On demand Multipath Distance Victor with the Fitness Function (FF-AOMDV) and Power-Load Aware Multi- path Routing Protocol (PLA-AOMDV) are described and the features and methodologies also narrated. Section 3 defines the novelty of the Proposed Multipath Routing Protocol, Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV). Results of the proposed model are discussed and analyzed Section 4 and Section 5 delivers the conclusion of this research paper.

II. Recently proposed routing Techniques

In this section, the Ad-Hoc on demand Multipath Distance Victor with the Fitness Function (FF-AOMDV) and our previous Multi- Path Routing Protocol, Power-Load Aware Multipath Routing Protocol (PLA-AOMDV) are discussed[36,37].

A. Ad-Hoc On demand Multipath Distance Victor with the Fitness Function (FF-AOMDV)

Ad-Hoc On-Demand Distance Vector Routing Protocol, popularly known as AODV is one the best Single-Path Routing Protocols and the Ad-Hoc On-Demand Multipath Distance Vector (AOMDV)[1,4,5] Routing Protocol is one the best Multi Protocols. Multipath AOMDV Routing Protocol is used to discover more possible paths with its efficient Path Discovery Process between the source and the destination.

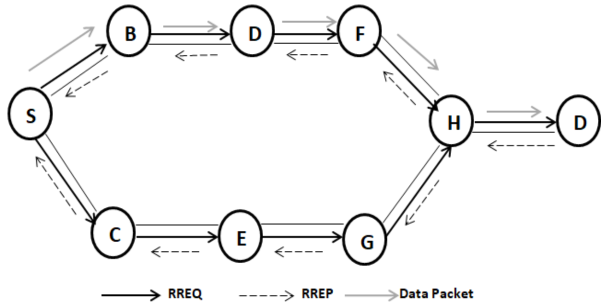

Fig 1: Handling Duplicate Message by FF-AOMDV

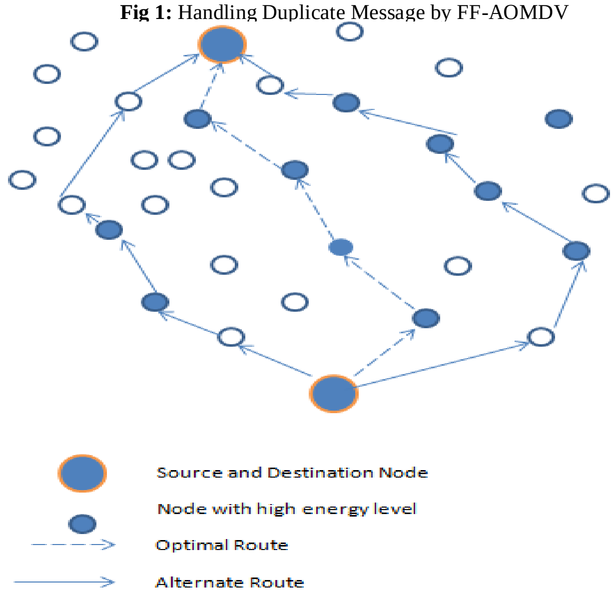

Fig 2: Optimal Route Selection of FF-AOMDV

As shown in the Fig.1, the Node S sends the RREQ to find the best path to its destination. The Node H was receiving the duplicate Propagation of Request (RREQ) message. This Node did not discard the duplicate message though it is duplicated one because the duplicated message was reserved and used for another path. That is without using Propagation of Request (RREQ) message, this protocol can establish a new connection. That is the reason why, it is maintaining multiple copies of Propagation of Request (RREQ) messages to understand all other possible Routes. This is one of the strengths of AOMDV.

The existing Distance Vector Protocol, FF-AOMDV, that is Ad- Hoc On demand Multipath Distance Victor with the Fitness Function was proposed by combining the features of Fitness Function and the AOMDV's Protocol as well. But in FF-AOMDV it uses an algorithm which performs Route Selection in different methodology. As discussed before in Fig. 2, when a RREQ is broadcasting and receiving, the Sender Node will use a few information models that facilitate to find the Optimized and shortest route with minimal energy consumption. Whenever the current communication route gets disconnected, the Path Discovery Process will be executed to find alternate path like other multipath routing proto- cols. The prime objective of the model is to find optimal route to achieve and to minimize power consumption and it is called optimal route and it can be calculated as follows[3]

$$Optimal\ Router = \frac{\sum v(n) \in r_{ene}(v(n))}{\sum v \in V_{ene}(v)} \quad (1)$$

The FF-AOMDV was implementing the techniques after selecting the route which will have the highest energy level and that will be the least distance. The shortest path ie shortest route could be calculated as follows

$$Optimal\ Router = \frac{\sum e(n) \in r_{edist}(e(n))}{\sum e \in E} \quad (2)$$

Here the parameter e is representing the links ie edges in the best and optimal route r. The E is representing as the edges of the network.

As shown in the Fig. 2, the Route / Path Selection was initiated with the required parameters by the existing FF-AOMDV and this Fig. 2 clearly helps us to understand the working nature of the Fitness Function. As shown in the Fig. 2, the FF-AOMDV start broadcasting a RREQ for collecting information to decide and select the optimal routes to destination and the Fitness Function is facilitating to find nodes which will possess higher energy level. The best route will specify the route that has the less distance and highest energy level. The discontinuous arrow is clearly used for understanding and specifying the next Priority energy level that is shown in the Figures Fig. 1 and Fig. 2 as well.

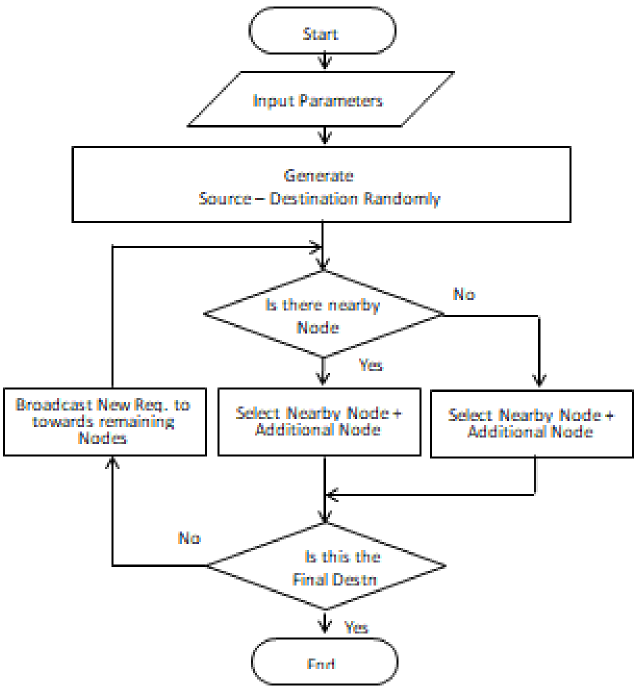

Fig 3: Flowchart of FF-AOMDV (Optimal Route Selection)

The Flowchart which was drawn to demonstrate how this AOMDV is Functioning and it is also used for evaluating the FF- AOMDV. This is one of the Reactive Multi Path Protocol. The Routing Entries in this AOMDV Protocol consists of alternate next-hops loops with the help of Advertised Hop Count to identify maximum possible paths. It consists of two components namely as demonstrated in the Fig. 3.

- Maintaining Multiple **Loop-Free Paths** for Sources and Destinations
  - To Avoid Multiple Broadcast
  - Maintaining Multiple Link Disjoints Paths
  - This is used to identify all possible paths and its counts of Hops. The Advertised Hop Count was used for this purposes
  - It will help Network to select one of the paths to avoid common Nodes that will help to select unique disjoint paths

Even though the FF-AOMDV is finding and selecting best path for communication, it unable to address Power Dissipation. This is the major issue and this is leading to link failure. We know that the Link Failure will minimize the life time of the MANET Sys- tem. To address the above mentioned issue, this Research Paper proposed an efficient Power-Load Aware Multipath Routing Protocol (PLA-AOMDV) which is discussed and described the strengths of the proposed model in the following section.

B. Power-Load Aware Multipath Routing Protocol (PLA-AOMDV)

As discussed at the above section, FF-AOMDV discovers and selects best path for communication. However, it unable to ad- dress Power Dissipation causes link failure. To address this major issue this Research work was proposed an efficient Power-Load Aware Multipath Routing Protocol (PLA-AOMDV).

Many Multipath Routing Protocols were designed to select the Paths with relatively less number of Nodes and Hops to frame Shortest Path for possible communication. As it is the repeated process to find shortest path for each and every communication, the battery will be overloaded and Energy of those will be deleted causes Node Failure and Network Partition as well. Thus needed balanced Power-Load distribution is mandatory to maximize network Lifetime.

1. Cost Function, Route Discovery and Route SE lection

The prime objective of PLA-AOMDV is to identify various Optimal Paths with sufficient Power and Bandwidth as well. This procedure does not focus only shortest path. It will find shortest routes at the cost of both Residual Energy and Load of the Node concern as well.

The Power-Load Aware Multipath Routing Protocol (PLA-AOMDV) consists of Composite Power-Aware Routing and Scheduling Procedure to facilitate Power-Load Aware routing to maximize Network Lifetime.

a) Cost Function

The proposed Cost Function is considering both Residual Energy of a Node and incoming Traffic Rate as well. The estimation of Traffic Rate is revealed that it is directly proportional to the effect of Energy Consumption. The cost function is designed to measure the cost of both i. Bottle-necked Intermediate Node Cost ie Path Maximum Cost ($Cost_{Max}$) and ii. Intermediate Nodes Costs of a path ($Cost_{Path}$).

Path Maximum Cost is measured as

$$C(P_i) = \max_{j=1} F(C_j(t)) \qquad (3)$$

Path Total Cost between Intermediate Nodes is measured as

$$C(P_i) = \sum_{j=1}^{m} F(C_j(t)) \qquad (4)$$

The above two Equations is help to measure Energy Costs and Load as well between Source and Destination. Based on the in- puts, the Route will be discovered and selected for communication.

This model is maximizing the performance of a Sensor Networks in terms of Lifetime, Throughput, Delay and Power Consumption. The Nodes will be selected for making route by this proposed model through Scheduler as follows.

Node Selection for Route Discovery

The proposed Power-Load Aware Multipath Routing Protocol (PLA-AOMDV) is managing and nominating Nodes to discover and select optimal routes with the following Energy Level of Nodes.

- If E_{Level} > 60% of Actual Level, Nodes considered as **Nor-mal Status** for path selection
- If E_{Level} ≤ 60 % && E_{Level} > 25 % of Actual Level, Nodes considered as **Warn Status** for path selection
- If E_{Level}≤ 25% of Actual Level, Nodes considered as **Danger Status** and these Nodes will not be considered for Path selection

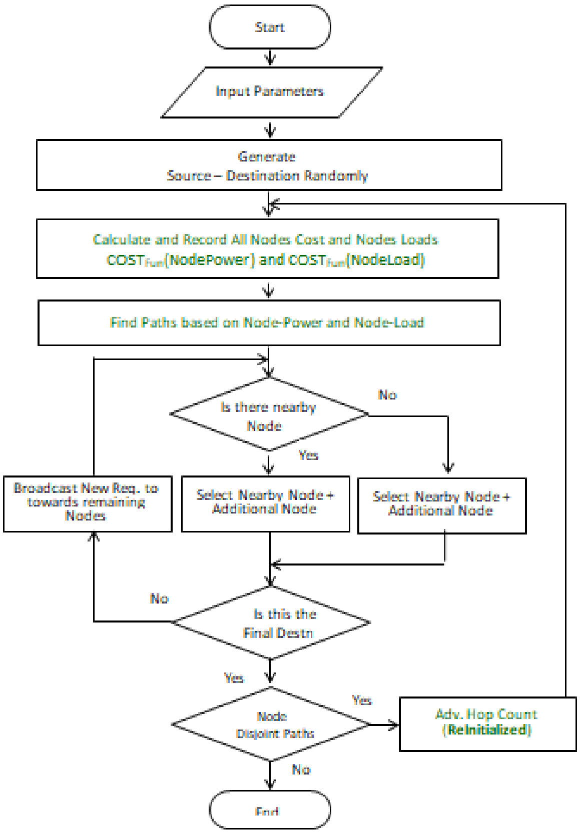

Fig. 4: Flowchart of Proposed PLA-AOMDV (Best Route Selection)

b) Route Discovery and Route Selection

As discussed earlier, a Node if needed to communicate any other Node, it will request Routing Protocol to establish optimal for possible communication, the proposed model will search the setup to find the best possible routes in terms of Nodes' Energy and Load as well which is shown in the Fig.4.

It shown and discussed in the Section 3.1, the Cost Function for measuring Nodes Residual Energy $COST_{FUN}$(Node Power) and Nodes Load $COST_{FUN}$(NodeLoad) will be executed to discover route which is shown in the Fig. 4.

1) Route Discovery Process

The Format and Structure of Route Request Packet (RREQ) is modified with the Control Packets such as Route Request Packet (RREQ) , Route Error (RERR), Route Request Table (RRT) and Route Reply Packet (RREP).

The Procedure of Route Discovery will be executed by broadcasting Route Request Packet (RREQ) on the created Sensor Network.

This Route Request Packet (RREQ) message will be received by neighbour Nodes and these Nodes will broadcast again and again till the required destination Node is receiving the message. Once the destination Node receives Route Request Packet (RREQ), it will reply to Source by broadcasting Route Reply Packet (RREP). When source Nodes receives Route Reply Pack- et (RREP), the Route Discovery Process certainly stopped and the communication Packets will forward to its destination.

III. *Proposed Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV)*

This research work enhanced its previous Multi-Path Routing Protocol, Power-Load Aware Multipath Routing Protocol (PLA- AOMDV) by modifying the Route Selection Process by considering Energy Consumption by routes, Residual Energy of Nodes and Link usage and Link Break Degree. That is it proposed an efficient Route Selection Scheme to maximize Energy Efficiency and Load Balancing of the entire Network.

This proposed Routing Technique ELA-AOMDV will retain all features of our previous Multi-Path Routing Technique PLA- AOMDV. The Route Selection Criteria of PLA-AOMDV is redefined with the following Intelligent Route Selection Criteria that is proposed for Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV)

A.Route Selection Criteria

For obtaining the best possible route with the coefficient Q that used for measuring highest route performance, the Route Selection Process is considering the various parameters such as Energy Harvest Degree (Hi), Energy Harvest Contribution (Ki), Energy Conversion Efficiency (Ce), Battery Capacity (Ca), Real-Time Residual Energy Degree (Ei), Energy Accumulation Rate (Ri), Link Break Degree (Li) Energy Drain Rate Coefficient (Ai), and Link Break Probability (Pi)

The Energy Harvest Degree is calculated as follows:

$$Hi = Ce\ (-e\ \frac{-ki}{n} + 1)$$

The energy node i with the constant value n is related to Energy Conservation Efficiency Ce and Harvest Contribution Ki, where the Ki is used to determine the by Battery Capacity Cai the harvest node I with the constant value n is related to Energy Conservation Efficiency Ce and Harvest Contribution Ki where the Ki is used to determine the by Battery Capacity Cai the accumulation rate Ri

$$Ki = \frac{R_i}{C_{ai}}$$

For each device, the battery capacity is fixed but the energy accumulation rate R_i different based on energy source.

***1.**Real time Residual Energy Degree*

$$E_i = (-R^{\ -E^{r(1+H_e/e_1}} + 1)^{n2}$$

E^r represents the real-time residual energy of node i and $E^r \geq 0$.

Hi is the energy harvest degree. n1 and n2 are the constant values. Ei will be in the range of [0,1].

Energy Drain Rate Coefficient : It can be used to reflect the energy consuming rate of one node.

If one node has high residual energy, but its life time could not be long because of its high energy consuming rate.

To describe the energy drain rate coefficient to describe the property where Ei is called real-time residual energy and Ri is the energy drain rate Rthr is a scenario-selectable parameters.

The energy drain rate coefficient ai used for selecting the final route to exclude the node with high energy drain rate.

$$ai = \begin{cases} 1, & \frac{R_i}{E_i} < R_{thr} \\ 0.1, & \frac{R_i}{E_i} \geq R_{thr} \end{cases}$$

$$R_i = \frac{1}{N-1} \sum_{k=i-N+1}^{i} R_k(t)$$

The above mentioned Route Selection Process is implemented as shown in the Fig. 5.

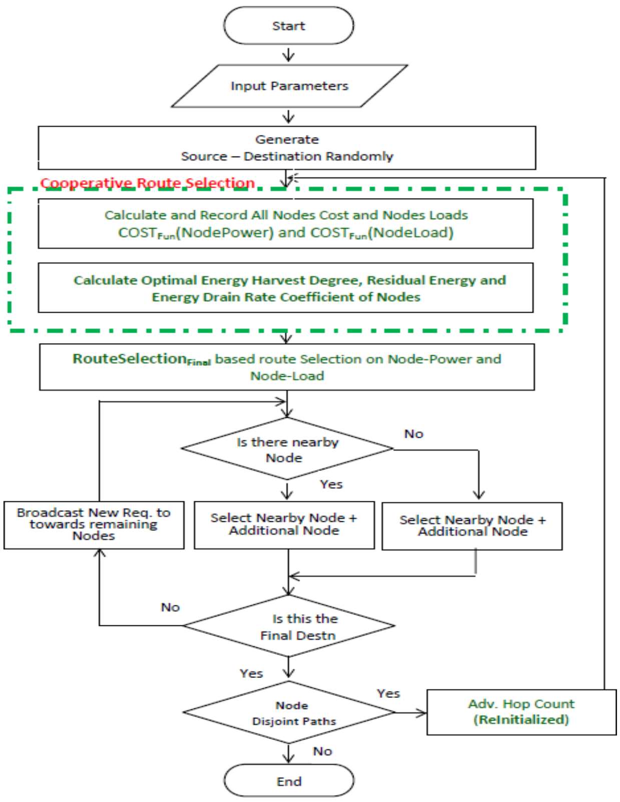

Fig. 5: Flowchart of Proposed ELA-AOMDV (Intelligent Route Selection)

IV. Result and Discussion

The performance efficiency of the proposed Routing Protocol, Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV) is carried out.

It is studied the Energy Efficiency of the proposed Model with Low Load and Heavy Load as well. Simulations are conducted in QualNet 6.1 and integrated with VC++ tool for creating APP (batch file) for the proposed ELA-AOMDV.

The experimental setup considered all its previous model, PLA-AODMV as follows.

The required APP was developed to construct topology and define the network parameters, such as Number of Nodes, Traffic Source, Node Speed, Queue Size, PLA-AOMDV APP Batch Code and many other parameters.

The Simulation Area 500 X 500 m^2 is created with 75 Nodes. The different Packet Rates like 512 KBPS and 1024 MBPS are as- signed with Static as well Dynamic Networks.

It is also specified the Transmission range 250 m, Transmitted signal power 0.38 W, Initial energy of Node 200 J, Transmitting Power 1.4 W and Receiving power 1.0 W. We used our Queue Management Scheme called Fuzzy DSRED.

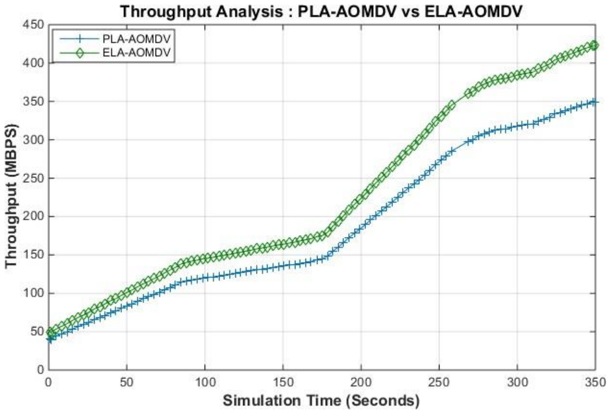

Fig. 6: Throughput Analysis of the proposed ELA-AOMDV

The Protocols CBR, TCP and UDP are used to analysis the pro- posed Protocol. To study the proposed Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV) thoroughly, the Packet Rate and Packet Size is changed when repeating experiments.

The proposed model is implemented in QualNet 6.1 and studied thoroughly. The experimental results were shown from the Figures Fig. 6 to Fig. 9.

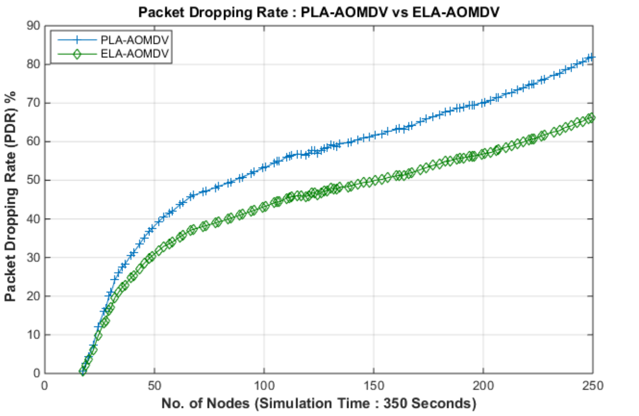

Fig. 7: Packet Dropping Rate Analysis of the proposed ELA-AOMDV

As shown in the Fig. 6, it is clearly noticed that the proposed Routing Protocol ELA-AOMDV is outperforming our previous Routing Protocol PLA-AOMDV in term of Throughput. This is happened because the proposed model achieves high Fairness and it considerably reduced Link Failure which helps for more Throughput. Thus, the proposed Multipath Routing Protocol achieves better Packet Dropping Rate also which is shown in the Fig.7.

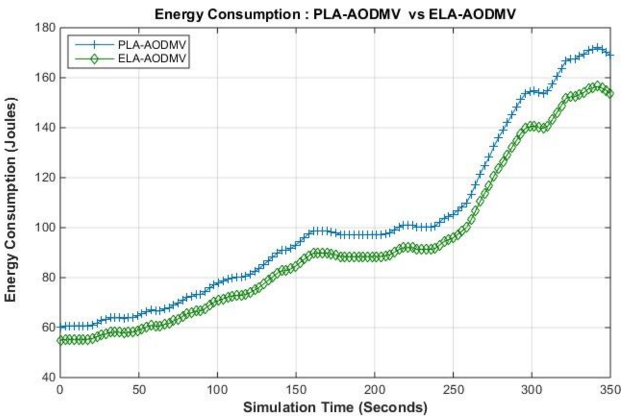

Fig. 8: Energy Consumption Analysis of the proposed ELA-AOMDV

As shown in the Fig. 8, the proposed Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV) performs better than that of our previous Routing Protocol PLA-AOMDV in term of Energy Consumption.

Since the proposed Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV) has less retransmission due to better Dropping Rate and less Partitioning, it consumes relatively less energy for Transmission and Computation which will maximize the Network Lifetime very steadily.

That is it achieves better fairness. It reduces the Number of Dead Nodes which is shown in the Fig. 9.

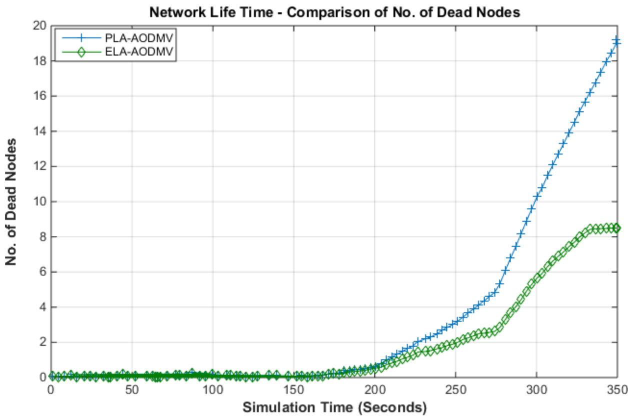

Fig. 9: No. of Dead Node Analysis of the proposed ELA-AOMDV

E. Conclusion

This research work is proposed an efficient energy-Load Aware Multipath Routing Protocol (ELA-AOMDV) to address the Power Dissipation issue which is leading to link failure. This work de- signed and implemented the ELA-AOMDV in QualNet 6.1 and results were studied thoroughly in terms of Throughput, Packet Dropping Rate, Energy Consumption, and Network Life Time (Dead Nodes Count).

From the experimental results, it was established that the proposed Energy-Load Aware Multipath Routing Protocol (ELA-AOMDV) is outperforming the existing our previous Routing Protocol PLA-AOMDV in terms of Throughput, Packet Dropping Rate, Energy Consumption, and Network Life Time (Dead Nodes Count).

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