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# PALBMRP: Power Aware Load Balancing Multipath Routing Protocol for MANET

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**ABSTRACT**

**A set of mobile hosts or nodes that form a dynamic topology which is ad hoc in nature is called MANET. There are several challenges while designing a routing protocol for MANET due to the limited energy, less processing capability, fewer resources and dynamic environmental changes. Most of the existing energy efficient protocols focuses on choosing a route or path through the nodes with maximum residual energy and distribute a network traffic blindly among generated paths. Network congestion caused due to traffic and node packet carrying capability based on its remaining energy are not considered which leads to increasing number of dead nodes and result in more energy depletion. Hence we have proposed a Power Aware Load Balancing Multipath Routing Protocol (PALBMRP) which selects an optimal energy efficient route based on multiple parameters i.e. residual energy, delay, congestion and hop count and perform load balancing by considering nodes minimal residual energy to transmit packets according to its capacity. The simulation shows the proposed protocol reduced overall energy consumption up to 9%, increased packet delivery ratio up to 12%, and reduced end to end delay up to 3%, compared to AOMDV and LBMMRE-AOMDV [1].**

**Keywords** –AOMDV, Load Balancing, MANET, Multipath Routing.

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## 1. INTRODUCTION

Mobile Ad-hoc Network is a set of mobile nodes in which mobile nodes establishes communication with each other in a multi-hop fashion. MANET does not rely on fixed infrastructure like a base station. Each node is free to travel in any direction and act as a router so that it can transmit as well as receive the packets from other nodes at the same time. Due to nodes movement and transmission power, ad hoc network follows dynamic topology. Designing a routing protocol for such type of network has multiple challenges as the wireless medium has a number of limitations like low bandwidth, noise in a signal, limited battery power capacity of the nodes, and interference. One of the key challenge in MANET due to these constraints is to design an energy efficient routing protocol.

MANET routing protocols are categorized into three different parts: proactive routing, reactive routing, and hybrid routing protocols. Protocols in proactive routing periodically maintain the route information about the other nodes in a network into their routing table. Due to an advance availability of the routes, immediate packet transmission can be done in such type of protocols. Reactive routing protocols will not maintain any prior information about routes and will collect when a request occurs. These type of protocols reduces routing table maintenance cost and network traffic as it avoids periodic flooding of control packets. Hybrid protocols are the combination of proactive and reactive routing protocols which takes combines featuresavailable in both the protocols to provide better performance.

Thus, we have proposed a Power Aware Load Balancing Multipath Routing Protocol (PALBMRP) in which we have considered multiple parameters like residual energy, delay, hop count and congestion to select the energy efficient and congestion free paths as well as load balancing to efficiently distribute the network load among selected paths. In PALBMRP, due to energy efficient route selection, congestion free path finding and uniform distribution of load based on the capacity of the path makes the proposed solution perform better than the existing approach. Our simulation results show that PALBMRP has improved the overall network lifetime and packet delivery ratio and reduced an end to end delay.

Rest of the paper is organized as follows: Section 2 presents Proposed Protocol in terms of algorithm and flowcharts, Section 3 summarizes the working example of proposed protocol, Section 4 describes our Performance Evaluation. Simulation observation and result analysis have been carried out in Section 5. At last, we are concluding our work.

## 2. POWER AWARE LOAD BALANCING MULTIPATH ROUTING PROTOCOL (PALBMRP)

In this section, we discuss the Power Aware Load Balancing Multipath Routing Protocol (PALBMRP) with the help of flowchart, algorithm, and example. As per the analysis of existing protocols, most of the protocols are considering one or two of the parameters (residual energy, hop count, delay, and congestion) as part of route discovery to find the best route. This sometimes may result in longer routes, the route with congestion, the route

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with less residual energy etc. Different load balancing techniques have been proposed in several types of research in which total residual energy while route selection and minimal residual energy while load distribution is not considered. So based on these observations we have proposed Power Aware Load Balanced Multipath Routing Protocol which selects the path by considering multiple parameters and efficiently distribute the data packet between generated paths. The basic purpose of proposed system is to improve overall network lifetime and packet delivery ratio and reduce the network delay.

### 2.1 Working of PALBMRP

PALBMRP protocol uses multipath transmission capability of MANET to carry out data transmission. A node wants to send a data packet to the destination, discovers multiple link disjoint paths using route discovery process. During route discovery, source node generates a Route Request (RREQ) packet and insert a timestamp, minimal residual energy, delay and total residual energy information with it. RREQ packet travels through multiple neighbor node where each intermediate node updates this information with its own. Finally, destination node computes the route cost for each received route request and assigns a priority. The route priority for each request is updated to the source node through Route Reply (RREP) packet. During data transmission, source node selects the path with higher priority, computes its capacity and transmit the data packet according to its packet carrying capacity.

### 2.2 Packet Formats

RREQ Packet: Source node floods RREQ in the network when no route information is available for selected destination. RREQ packet has ID, source, and destination sequence number, source, and destination IP addresses, and hop count. PALBMRP introduces four additional fields as part of route request packet that is: minimal residual energy, time stamp, total residual energy and total delay. Each intermediate node, re-compute the values for received fields and rebroadcast it to next node until it reaches to the destination.

<table>
<tr><td>Packet Type</td><td colspan="2">Broadcast ID</td><td>Hop Count</td></tr>
<tr><td colspan="4">Source IP Address</td></tr>
<tr><td colspan="4">Destination IP Address</td></tr>
<tr><td colspan="2">Source Sequence</td><td colspan="2">Destination Sequence</td></tr>
<tr><td colspan="2">Time Stamp</td><td colspan="2">Total Delay</td></tr>
<tr><td colspan="2">Minimal Residual Energy</td><td colspan="2">Total Residual Energy</td></tr>
</table>

**Figure 1. RREQ Packet Format**

RREP Packet: Destination node will originate the Route Reply Packet(RREP) packet. RREP packet contains ID, source and destination sequence number, source and destination IP addresses and reverses path list. We have introduced additional fields that are: priority, total residual energy, minimal residual energy and total delay which travel as part of route reply and required for the source node while data transmission.

<table>
<tr><td>Packet Type</td><td colspan="2">RREP ID</td><td>Hop Count</td></tr>
<tr><td colspan="4">Source IP Address</td></tr>
<tr><td colspan="4">Destination IP Address</td></tr>
<tr><td colspan="2">Source Sequence</td><td colspan="2">Destination Sequence</td></tr>
<tr><td colspan="2">Priority</td><td colspan="2">Total Delay</td></tr>
<tr><td colspan="2">Minimal Residual Energy</td><td colspan="2">Total Residual Energy</td></tr>
</table>

**Figure 2. RREP Packet Format**

### 2.3 Energy Efficient Route Discovery

When any mobile host or node wants to transmit data to another mobile node it will check the routing table to find if it has any route entry to the destination in its routing table. If not, it will initiate route discovery process. A source node creates route request (RREQ) packet, initializes the fields with the default values and starts broadcasting it to all of its neighbor nodes. The RREQ packet format is described in table 1 which shows extra fields required to select energy efficient route. Proposed protocol considers multiple parameters while selecting an optimal route between source to destination.

When a packet reaches to any intermediate node, it will check if it is been already received by checking its routing table. If yes, it will discard the packet to generate disjoint paths. Disjoints path is one in which no common link is shared in between the source and destination. Each node will compute and update congestion status, minimal residual energy, delay and total residual energy values based on values received from route request(RREQ) packet. Intermediate node checks its current congestion level with the threshold value and if it is greater than the threshold, it will simply discard the RREQ to form a congestion free paths. Fig. 3 shows the flow chart of route discovery process.

**Algorithm 1: Algorithm for Optimal Route Selection**

**Input:**Source node (s) has data packet for destination node (d)

**Output:**One or more RREP packet with reverse route information including priority for each path

**Begin**:

Initialization: Timestamp- time packet originated at node, $E_{min}$- minimal residual energy of node, $E_{total}$- total residual energy of node, $D_{total}$- total delay of packet reaching destination

**if***source-node* **then**

  Generate RREQ packet and initialize the values

**else if** *intermediate-node*}{

  Compute minimal residual energy at node n(i), $E_{min}$=min[Ecurrent, Emin]

  Compute total residual energy at n(i)

  $E_{total} = [E_{total} + E_{min}]$

  Compute delay including queuing delay

  $D_{total} = [D_{total} + Timestamp + Queuing\ Delay]$

  Compute the current congestion level of node

  $Congestion = [Queue_{current} / Queue_{total}]$

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**if** congestion > 0.8 **then**
discard RREQ packet
**else**
Create the RREQ and put the computed values and broadcast
**end**
**else**
Compute the route cost for each received RREQ. HC is total hop counts
$RC_{i,j} = [E_{total} / (D_{total} * HC)]$
Assign a priority based on route cost value
Add a priority inside RREP and send
**end**

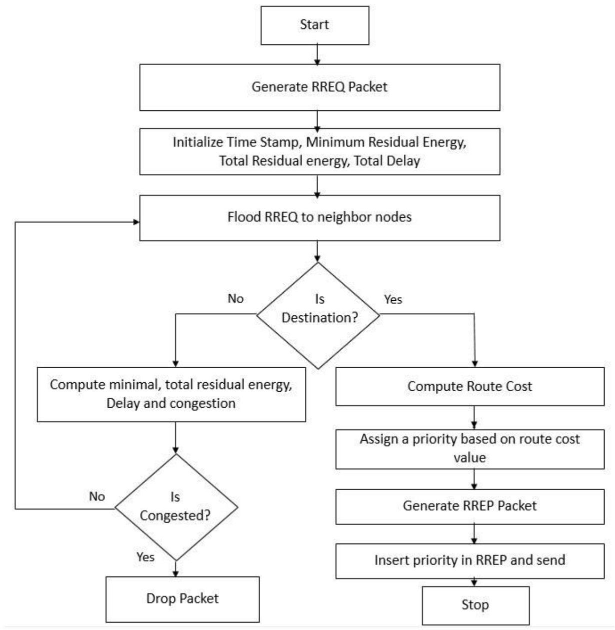


**Figure 3. Route Request Reply Traversal Flow Chart**

2.4 Load Distribution

The proposed system effectively distribute network load among generated link disjoint paths by keeping minimal residual energy into consideration. Load balancing provides better fault tolerance capability in case of link failure and guarantees data transmission to the destination. Proposed protocol uses priority-based route selection that means a route which is energy efficient, less congested and shorter will be used first and assigns a load to each route based on route capacity while data transmission hence no single path will be overloaded. Assigning a load by considering minimal nodal residual energy helps to avoid the dead nodes and improves packet delivery ratio. Before data transmission, for each route, its maximum and actual data handling capability are calculated and traffic is split accordingly among generated paths. The Minimal nodal residual energy of route is used as a major parameter during calculating route capacity. To calculate maximum packet transmission of a route is computed as[1]. Fig. 4 shows the flowchart of load balancing algorithm.

**Algorithm 2: Algorithm for Load Balancing**

**Input:**Source node (s) send n number of data packets to destination node (d)
**Output:**Total number of data packets reaches to destination
**Begin**:
Initialization: DP- number of data packets, $P_{max}$- maximum number of packets, $P_{act}$- actual number of packets
Compute total number of DP to be transmitted
Selects a path having higher priority
Compute $P_{max}$ packet capacity of the path. alpha is computed as[1]
$P_{max} = [E_{min} / alpha) – 1]$
Compute $P_{act}$ capacity of the path, K is total disjoint paths
$P_{act} = [E_{min} * DP / sum(E_{min(K)})]$
Selects $min(P_{max}, P_{act})$ number of packet to send and transmit
Repeat step 2 until all packets are transmitted

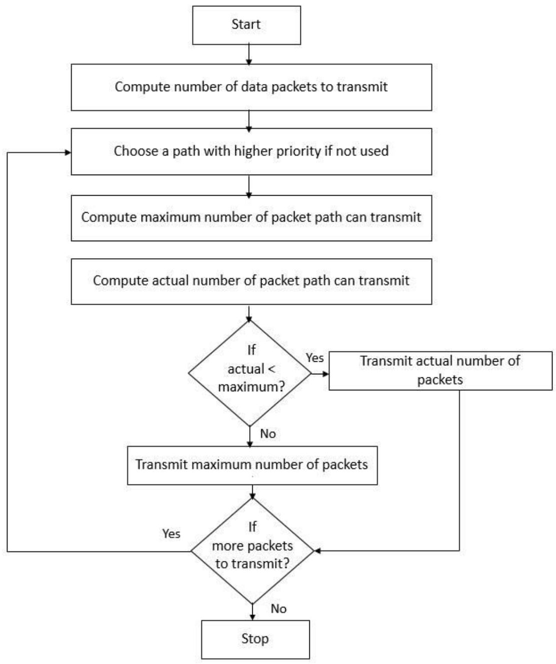


**Figure 4. Load Balancing Flow Chart**

## 3. WORKING EXAMPLE OF PALBMRP

Let's assume a network in which MANET has formed a topology shown in fig.5. Node S and D are source and destination respectively, N1, N2... N8 represents the intermediate nodes. Route discovery is started by source node S. Consider $E_{total}$ is total residual energy of the path, $E_{min}$ is minimum residual energy of the node in path, $P_{hops}$ is number of hops, $P_{RC}$ is route cost of the path, $P_{Priority}$ is priority of the path.
Route discovery is started by node S by broadcasting the route request(RREQ) in the network. Route request packet initializes timestamp, total residual energy, minimum residual energy and delay values. All neighbor of S, N1, N3, N5 will receive the RREQ and extract. Each node will first check whether arrived packet is duplicate and discard if true. A node computes its current congestion level and if it is greater than the threshold value(we are assuming it as

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0.8), it will discard the RREQ packet to make congestion free paths. Here in our case node N4 is congested and hence will not participate in any of the paths. Further, each node evaluates total residual energy, minimal energy, congestion, and delay to include it inside RREQ and rebroadcast the packet to all its neighbors. The Same process will get repeated unless the packet reaches to destination node D.

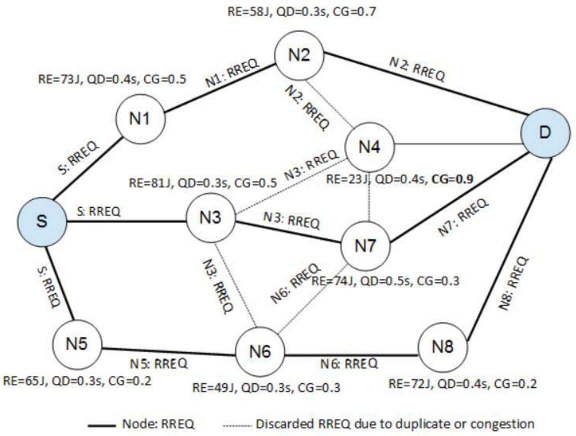


**Figure 5. PALBMRP Route Discovery Process**

As per the topology is shown in Fig.5, assume that D receives three route request from different link disjoint paths. Nodes S-N1-N2-D represent the path 1, S-N3-N7-D represent path 2 and S-N5-N6-N8-D represent the path 3. Node D compute the route cost value for each received RREQ packet according to the equation specified in the algorithm. Below Table 1 shows the computation done by destination node D.

| Path | $D_{total}$ | $E_{total}$ | $E_{min}$ | $P_{hops}$ | $P_{RC}$ | $P_{priority}$ |
|---|---|---|---|---|---|---|
| P1 | 0.7 | 131 | 58 | 3 | 62.38 | 2 |
| P2 | 0.8 | 155 | 74 | 3 | 64.58 | 1 |
| P3 | 1.0 | 186 | 49 | 4 | 46.5 | 3 |

**Table1. Route Cost Computation**

Based on generated route cost, destination node decides the priority for each path. While assigning priority, destination checks whether two path has same route cost and assigns based on delay if found. That means a route which has less delay value will get higher priority than other. According to table Path 1 has route cost 62.38, Path 2 has 64.58 and Path 3 has route cost value 45.5. So Path 2, Path 1, Path 3 will get assigned a priority 1, 2, 3 respectively.

Destination node D creates a route reply (RREP) packet, insert a priority value in a packet and send in reverse path of generated link disjoint path. Figure6 shows the route reply packet traversal from the destination node to the source node. Each intermediate node updates the priority value in its routing table and forward it to next node.

Source node S upon receiving multiple route reply (RREP) through multiple paths update its routing table and

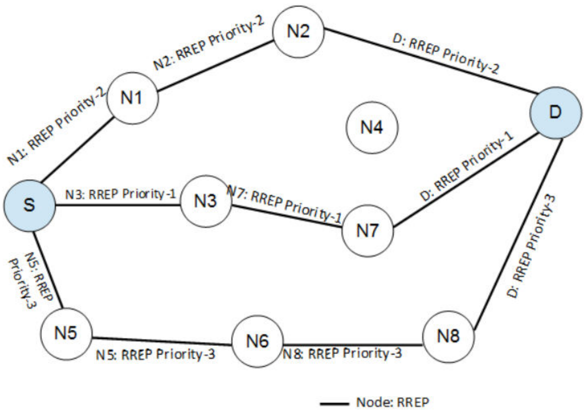


**Figure 6. PALBMRP Route Reply Process**

insert a priority against each path. Suppose source S has 10 packets to transmit to destination D. First it will choose the path with higher priority from routing table computes the path capacity i.e. maximum and actual number of packets path is able to carry according to algorithm 2 and repeat the process for the remaining path as well until all packets are get transmitted. Imagine Path 2, Path 1 and Path 3 can transmit (12, 4), (9, 3) and (6, 3) respectively then it transmit the packet as below:

- 4 packets are sent through the Path 2
- 3 packets are sent through the Path 1
- 3 packets are sent through the Path 3

## 4. EXPERIMENTAL EVALUATION USING NETWORK SIMULATOR

Simulation has been done using network simulator (NS-3.20) in the area of 1500m * 1500m. Simulation setup is described in this section. We have compared PALBMRP with the existing protocols AOMDV and LBMMRE-AOMDV[1]. We have considered following parameters for evaluation: number of nodes, transmission range, queue length and node speed. Average energy consumption, packet delivery ratio and average end to end delay performance metrics are used for evaluation. A different number of nodes are placed at a different time with an initial energy of 100J to observe the result. The network is analyzed by introducing traffic and sending different data packets of size 512 and 1024 bytes. Below table represents additional parameters used during simulation.

| Parameters | Values |
|---|---|
| Simulator | NS-3.20 |
| Simulation Area | 1500m * 1500m |
| Routing protocols | AOMDV, LBMMRE-AOMDV, PALBMRP |
| Number of nodes | 20, 30, 40, 50 |
| Traffic Type | CBR |
| Simulation time (s) | 30, 60, 120, 300, 600 |
| Initial node energy (J) | 100 |
| Data payload | 512, 1024 bytes |
| Mobility Model | Random Waypoint |
| Maximum speed | 10 m/s |

**Table2. Simulation Parameters**

## 5. Experimental Results And Analysis

By using all the parameters discussed in earlier section we have simulated the proposed protocol.

### 5.1 Average Energy Consumption

Measured in terms of average amount of energy consumed by all mobile nodes in the network. Fig.7 shows the overall energy consumption of all protocols with a different number of mobile nodes. Energy consumption of proposed PALBMRP is less as compared to existing protocols AOMDV and LBMMRE-AOMDV[1]. This is due to total energy considered by proposed protocol during route selection and minimal energy during data transmission.

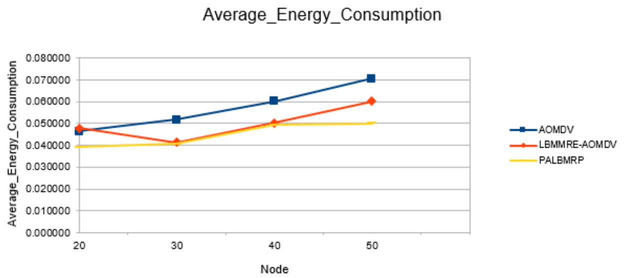


**Figure 7. Average Energy Consumption**

### 5.2 Packet Delivery Ratio

It is measured in terms of a total number of destination nodes received the packet and an actual number of sent packet by the source node. Fig.8 shows the packet delivery ratio of the PALBMRP, AOMDV, and LBMMRE-AOMDV with respect to a number of nodes. With less number of nodes, all protocol performs nearby similar because network density is low. As nodes increases packet delivery ratio of all protocol decreases as the network becomes slightly loaded so packet delivery ratio decreases. PALBMRP chooses the route based on route cost which includes hop count and delay hence improves the packet delivery ratio compared to other protocols.

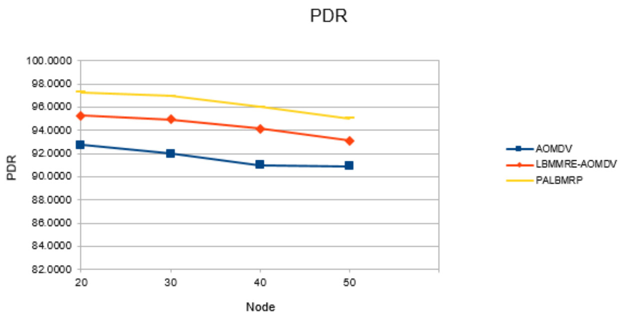


**Figure 8. Packet Delivery Ratio**

### 5.3 End To End Delay

The average time is taken by a packet to be transmitted from source node to destination node. Fig.9 shows end to end delay of proposed protocol compared to existing approaches. It shows end to end delay of LBMMRE is very high compared to AOMDV and PALBMRP. This is because it mainly focuses on the maximum number of packet delivery irrespective of the delay hence increased in dead nodes which increase delay too. PALBMRP selects a congestion free path and considers delay and hop count while selecting route causes reducing end to end delay.

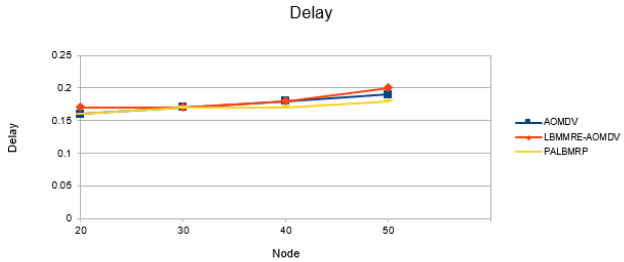


**Figure 9. End to End Delay**

## 6. Conclusion

Various energy efficient routing protocols are designed for mobile ad hoc network to improve the overall lifetime of a network by choosing the nodes with maximum residual energy. Network traffic which causes congestion and results in fast depletion of energy is not taking into consideration while selecting the route. We have proposed an energy efficient routing protocol for mobile ad hoc network in this paper called PALBMRP. Two approaches energy efficient route selection and effective load distribution are combined in proposed protocol. Paths are selected by considering several parameters i.e. residual energy, hop count, delay, and congestion which helps in minimizing overall network energy consumption by selecting congestion free and energy efficient paths. Network load is effectively distributed causes improve in packet delivery ratio. Simulation results show that PALBMRP performs better compared to existing protocols and reduces 9% of overall energy consumption, increased 12% of packet delivery ratio and reduces end to end delay up to 3%. Additional MAC layer energy consumption can be taken into consideration in the future to further improvement in energy efficiency.

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