Performance Enhancement in Power aware Ad hoc Routing using Highly Probable Link

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ABSTRACT: *In today's fast-moving world connectivity is the biggest trend to look out for and connecting devices with varying specifications is not a simple task. This becomes more of a problem in an environment where all devices, nodes, are in constant motion and the ability of nodes to retain links with another becomes an important factor. In this paper, not only we try to implement a way to find the path with minimum effect on simultaneous communications, avoiding high power nodes, we also look for the path or link between nodes that can have a high probability of being in use in subsequent transmissions. Our method is to remove any interference during route discovery by finding a route that can be maintained during the entire transmission. Using simulation and by comparing with competing protocols we establish that our method has a notable advantage*

Keywords–*mobile ad hoc networks, link life, power heterogeneity.*

1. INTRODUCTION

Connected devices have become a trend, with every device from in your home to your vehicle forming a highly connected environment. Internet of Things (IoT) [1] is a newly coined term, allowing any device to form a network. The process becomes a bit complex when the nodes are in constant motion called MANETs [2], such a network will have nodes coming in and leaving in a short time. This requires a routing protocol that can find a path from source to destination with links that will exist until at least the final transmission [3] [4].

Another factor that comes into play is the heterogeneity of these nodes [5], as nodes forming these networks can vary in energy levels, total range [6] and more. Here, we focus on the interference a high power node can cause, compared to others and performance advantage of avoiding such nodes. Nodes with larger range are usually high energy and hence energy savings are an added advantage.

The attraction of [1] to consumers can fade away if the communication capability is not stable, i.e., the links among nodes can disappear any time. The work done by [5] Clusters the nodes with higher power as the head, in a very loosely coupled manner, to reduce the negative effect of the heterogeneity. This arrangement uses the high power nodes only when finding the route between two nodes and avoids it during the actual transmission. We propose a new 802.11 MAC protocol which not only considers power heterogeneity, but also considers the probable link duration while finding the final route.

Our paper tries to combine existing work to find out link between nodes that have a higher lifetime [4] with a routing protocol that avoids high power nodes [5]. We propose a routing protocol, power and link aware routing (PLAR), that builds on the work of [5], adding a factor of link duration [3], [4]. According to [7] small lifetime of the links is due to interference which can be solved by [5] and large lifetime determined by mobility whose effect can be reduced by using [4] to calculate link duration.

2. RELATED WORK

Several routing protocols for MANET environment have been developed and more are actively researched making MANET a hot research topic. Much work has been published which tries to find a route with high link stability, but these are limited to homogeneous networks [9] [10]. The protocol [5], which works well for heterogeneous networks doesn't check for link stability.

While [5] can improve link duration by reducing chances of interference, it does not consider link duration [4] in routing. We propose to enhance significantly the link duration by first avoiding links with short lifetimes and second by reduction of interference while data is transmitted.

3. POWER AND LINK-AWARE ROUTING

To improve the performance of routing in heterogeneous nodes we propose a power and link aware routing (PALR). First, let's discuss the topology of the MANET.

3.1 **Partitioning of Nodes into Clusters**

The heterogeneity of nodes makes traditional flat routing not useful and this disadvantage can be overcome by clustering the nodes. Here, we consider a single node having the highest power as the cluster head, which takes care of most routing functions. The overlapped clusters will have both low power nodes and high power nodes, which forms the cluster head.

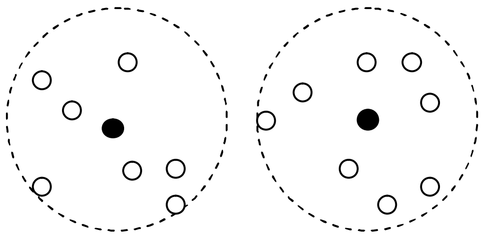

Fig.1. Clustering of nodes

The above figure shows a simple example of clustering where the dark node is the cluster head, which are nodes with the highest power and the rest ordinary nodes. A node that comes under the coverage area of two cluster heads is called a gateway node [8]. Clustering reduces the overhead of routing.

3.1.1 *Topology*

The nodes can be named as B-nodes if it is a high power node and G-nodes if it is an ordinary node in a cluster. The range of the B-nodes, R_B is greater than range of G-nodes R_G. We assume that due to heterogeneity of nodes there may be unidirectional links and we try to remove such links and use only bidirectional links. This will be explained in the next section.

3.2 **Removing Unidirectional Links**

One drawback of heterogeneity of MANETs is that unidirectional links may exist between two neighboring nodes (B-node or G-node). Let's see, in detail below

3.2.1 *Discovery of Bidirectional Links*

Bidirectional links are discovered by sending a neighbor discovery packet (BND) by a node to all its neighbors. This packet is used by nodes to create a bidirectional neighbor table BN.

3.2.1.1 *Steps to discover Bidirectional links*

Step 1: Each node sends BND packet to all its neighboring nodes in a single hop.

Step 2: Wait for time T_{BND} and collect all BND packets from neighbor nodes. Use these packets to create an aware node (AN) table.

$$AN = N^B_{R_B}(g_i) \cap N^G_{R_G}(g_i)$$

Step 3: Next, again send the BND table to all neighboring nodes, now with node's AN table as well.

Step 4: The nodes check whether its own information is present in the BND packet from neighbor node. If yes the node is added to the BN table.

3.3 **Steps to Build the Cluster**

As seen in 3.1 the nodes are partitioned into clusters. Let's discuss in detail the steps for building a cluster. The basic step is building a local aware topology table (LAT).

Step 1: G-nodes send G-node initialization packets (GI) to all B-nodes in its AN table. The packet will have the information on its Bidirectional links.

Step 2: Each B-node once receiving the GI packets will add the BN to LAT. The B-node then sends B-node initialization (BI) packets to all G-nodes in its coverage area.

Step 3: Once G-node receives the BI packet, it updates the LAT table.

Step 4: A G-node declares it as a member to cluster head by sending cluster member, register (CMR) packet to cluster head.

Step 5: Cluster head replies with a cluster head declare (CHD) packet and updates it LAT. Cluster head maintains the LAT for each member G-node.

3.3.1 *Cluster Head selection*

Each G-node, G_i selects the B-node which has the shortest distance (by any shortest path algorithms) to node G_i Using LAT table G-nodes can easily find out the B-node nearest to it.

3.3.2 *Maintenance*

Due to the mobile nature of the MANET the LAT table needs to be updated. Let's see how,

- If a node doesn't get a BND packet for time T_j then the link is removed from LAT table.
- If a node gets a BND packet from a neighbor node not in the LAT, it is added to LAT.

If the node is a G-node then

- The G-node finds the new cluster head and sends CMR packets to both new and old cluster head.

If the node is a B-node then

- B-node updates its LAT, BN, and AN tables.
- The B-node sends B-node update packet, BNU within one hop in the network to update LAT of other nodes.

3.4 **Calculating Link Duration for Bidirectional Links**

When BND packets are shared, the link duration for bidirectional links will be calculated and added to the packet. Let's see, in brief the theory behind it,

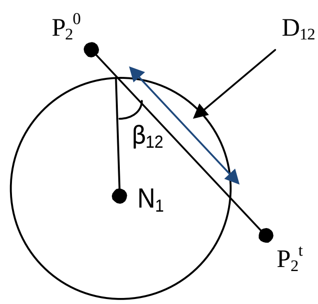

Fig.2. Relative motion of N_2 with respect to N_1

Let N_1 and N_2 be two nodes that travel in such a way that their transmission ranges overlap for a time T_d, also called link duration. For our calculation we consider the movement of N_2 with respect to N_1.

In Fig.2 P_2^0, P_2^t are the positions of the node N2 at time zero and t respectively. The angle β_{12} in the figure is the angle between the relative velocity of a node to transmission range. D_{12} is the distance where link between two nodes will be active.

Fig.3 shows the angle made between velocities of two nodes and is used to calculate effective velocity. The equation for effective velocity is given by the equation (1),

$$V_{ij} = \sqrt{V_i^2 + V_j^2 - 2V_iV_j \cos\alpha_{ij}} \qquad (1)$$

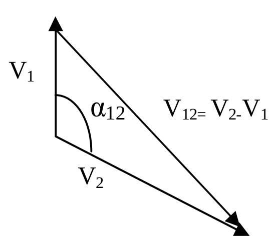

Fig.3. Relative velocity of N_1 with respect to N_2

We can calculate the effective distance D_{ij} using the equation,

$$D_{ij} = 2\gamma\cos(\beta_{ij}) \qquad (2)$$

From (1) and (2) we can calculate the link duration T_{ij},

$$T_{ij} = \frac{D_{ij}}{V_{ij}} \qquad (3)$$

Now let's see how link duration is added to LAT table and how each node calculates the link duration. The BND packet, when it returns from a neighbor node will have a table called duration table, DT, containing the values of the position, velocity of a node and its angle with respect to a common horizontal axis.

The values V_{ij} and D_{ij} can be easily calculated using (1) and (2) and the link duration is calculated using (3). When a node receives the BND packet, values corresponding to each node (having a bidirectional link) will be entered into the LAT table and forwarded to the cluster head.

3.5. **Power and Link aware routing**

Let's discuss how we find the best route with minimum interference and minimal chance of failure during transmission.

First, we discuss how a route is found between two nodes that want to communicate.

- If the route has already been used in previous communications, then it will be available in route cache and no need for route discovery.
- If the destination node D is in LAT table, the route can be directly obtained from the table. The B-nodes will be avoided in the discovered route.
- If the destination node D is not in the LAT table the source node S sends Route Request Packet (RREQ). And, the destination node D sends back the route response packet (RREP).

3.5.1 *Steps in Route Discovery*

Step 1: If the RREQ packet is a duplicate packet, it is avoided. Else proceed to step 2.

Step 2: If the destination node, n_i is available in route cache or LAT table, then the path is discovered, else proceed to step 3.

Step 3: If the node is a B-node, then the sequence of nodes discovered is appended and broadcast continuously.

Step 4: If the node is a G-node and in its next hop cluster head is present, it forwards the packet to the cluster head. The cluster head replaces B-nodes present in the discovered route with an alternate route avoiding B-nodes. Also, the G-nodes are replaced to improve the average Link duration.

Step 5: Next head broadcasts the packet to Gateway nodes that are under transmission ranges of other nodes.

Step 6: If G-node, except gateway node, receives a RREQ packet from the cluster head it discards the packet.

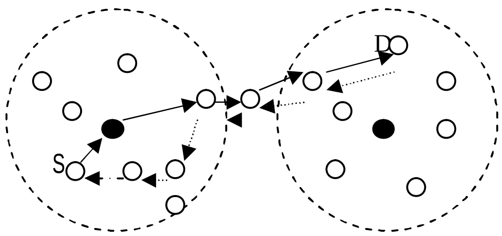

Fig.4. Route discovery

The destination node D replies with a RREP packet containing the discovered route and transmitted back to the source node S. The final route will not have any B-nodes and will have the maximum average link duration.

The discovered paths with the B-node will be replaced by a slightly longer G-node only path. Avoiding unidirectional links have a higher benefit in overall throughput. Also, the links between the two nodes will be selected such that, maintenance will be minimized during transmission.

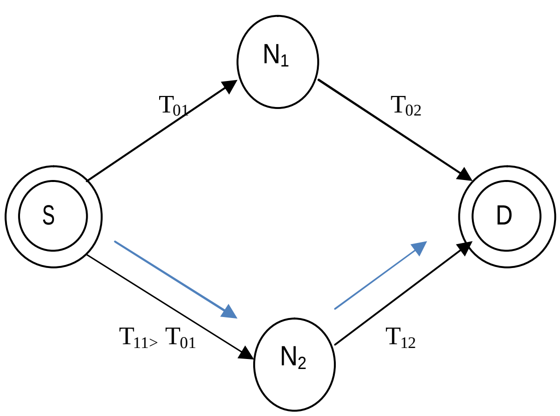

Fig.5. Routes are selected using link duration

The above figure shows the selection of routes based on the link duration. Here the path via N_2 is selected as link duration $T_{11>}T_{01}$ and hence less chance for maintenance. This information about link duration is available from the LAT table. The discovery procedure is repeated until a path is found or the timer expires.

Now let's summarize the route discovery procedure explained above. First, the B-nodes are used to increase the coverage area and hence make the route discovery faster. Second, using LAT table the transmission is more streamlined, i.e., the redundant transmission is reduced and hence the route discovery is faster. The link duration is considered and hence the chance of calling the maintenance protocol is reduced. Finally, as B-nodes are avoided, the impact of high power nodes are limited and overall bandwidth of the network is increased.

3.5.2 *Route Maintenance*

If a node along the discovered route detects a link failure, the node sends a route error packet, RERR in the direction of the source node. All the nodes receiving the packet, removes the link from the local cache. Also, the source node starts a new route discovery procedure.

The probability of route maintenance is reduced in our paper, as the links are selected in such a way that, a final route having a higher average link duration will be selected. This will in turn reduce the chance of link failing during route discovery or even at the time of actual transmission, improving the reliability.

4. PERFORMANCE EVALUATION

4.1 **Evaluation Environment**

We use the Network Simulator version 2 or NS2 for simulating the ad hoc environment. We try to analyze the improvement of PALR with respect to a common protocol. The bandwidth of low power node is 1Mbps and of high power node is 2Mbps. The range of low power node, R_G is 200m and high power node will have higher value.

In simulations we use a constant bit rate (CBR) setting and the movement of nodes will be determined by random way point. The path will be found to source and destination nodes dynamically.

4.2 **Evaluation Parameters**

The parameters evaluated include packet received, packet loss ratio and residual energy for a better understanding of the proposed protocol.

Number of packets received will give us an understanding of the loss of packets due to interference. As high power nodes are avoided the chance for interference decreases. Packet loss ratio is equally important as we can evaluate how the addition of link duration parameter to routing improved the protocol. The residual energy comparison gives us a better understanding energy efficiency of the protocol.

4.3 **Evaluation Criteria**

The performance of the proposed PALAR protocol will be compared in a NS2 environment with the AODV protocol for each parameter explained in section 4.2. The B-nodes will form the backbone of the network as the cluster heads. The outcome of 10 runs for about 650ms will be used to give a final graphical comparison of protocols with the help of XGRAPH.

4.4 **Evaluation Results**

The results for PALAR will be shown below graphically for each parameter with respect to AODV protocol.

4.4.1 *Packet Received*

In the simulation 20 nodes, including high power and low power nodes, send packets at a constant bit rate of 10 packets per second. Maximum velocity V_{max} is set to 0 so that all nodes are static. We randomly select a source node and destination node. The red line represents PALR and green AODV.

The figure below shows the performance compared with AODV protocol. From below graph we see that while packet received increases for both protocols initially, PALAR has a higher rate of nearly 450 packets received.

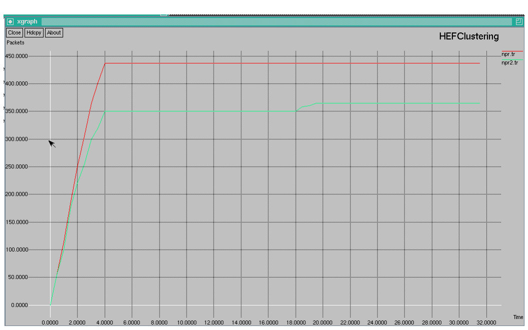

Fig.6. Packet received comparison.

4.4.2 *Packet Loss ratio*

The packet loss ratio shows the reliability of the protocol, i.e. if a greater number of packets reach the destination it reduces the traffic due to retransmission.

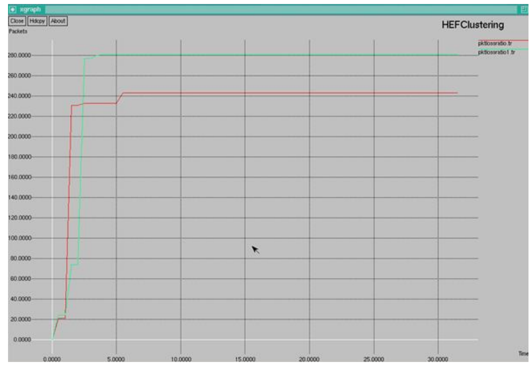

Fig.7. Packet loss ratio

The graph shows a reduction in packet loss by about 40 packets, thereby showing an improvement.

4.4.3 *Residual Energy*

The residual energy graph gives us a clear understanding of the energy level individual nodes, thereby the effect of protocols on the node's power levels.

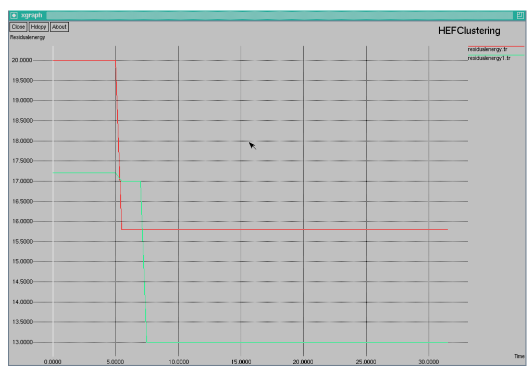

Fig.8. Residual energy

The energy levels have a significant gain due to the efficient routing methodology. The levels drop less compared with AODV and the nodes can communicate for longer duration. This is an enhancement due to the intelligent routing, reducing interference and faster route discovery with less chance of a failure.

5. CONCLUSION

The paper introduced a protocol PALAR, for reliable communication among devices. The routing procedure avoids high power nodes while transmitting packets to reduce interference. Selecting links with the highest duration while routing, reduces chance of failure and improves throughput. We have demonstrated the improvement by using an environment simulated by NS2. The comparison graphs with AODV confirm the improvements of the protocol.

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