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A Load Aware Routing Mechanism for Improving Energy Efficiency in Mobile Ad Hoc Networks

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ABSTRACT

Integration of Load Balancing mechanisms into routing protocols has elicited significant interest to alleviate congestion and improve the performance of on-demand routing protocols. For the sustained network functionality, load balancing mechanisms need to compute energy efficient paths with lesser traffic. Further severe degradation of network performance is observed due to intense traffic activity of the neighboring nodes. In this paper, we propose a load balancing mechanism that is also energy efficient by considering potential traffic interference caused to neighboring nodes that influence the load of an existing flow. Our proposed work (ELB-MRP) formulates a combined traffic and energy cost to optimize upon the routing mechanism by encompassing interference caused due to neighbor effect into routing decisions along with energy conservation .Simulation studies show significant improvement in the performance of the network.

General Terms: MANET, On-Demand Routing.

Keywords: , Multipath AODV, Energy aware Routing, Load balancing.

1. INTRODUCTION

Mobile Ad hoc networks (MANET) are self configuring networks that can be set up on the fly to provide tether-less communication. Nodes in this network are resource constrained. Hence routing protocols should perform routing keeping in view their resource limitations.

As against table driven routing protocols used by wired networks , Mobile Ad hoc networks commonly use on-demand routing protocols like AODV[1]and DSR[3]. Frequent mobility of nodes causes changes in the topology of the network. This makes storing routing information in routing tables unusable. So on-demand routing protocols commonly use flooding to learn new routes . All the routing protocols use minimum number of hops as the criteria for route selection .Nodes which are part of shortest path will be burdened when network traffic increases giving rise to congestion. Consequently overburdened nodes start dropping packets. Moreover energy of these nodes, starts decreasing rapidly . Hence such nodes die earlier resulting in network partitioning. So incorporating load awareness into routing protocols is very essential for distributing traffic uniformly over all portions of the network. Incorporating just load awareness proves to be still not sufficient to improve the performance. For instance ,a node may be selected as part of a routing path because of its lower traffic level, but that node may not be having enough energy in it . Therefore very often traffic and battery aware routing metrics are combined. Wireless network medium is shared among nodes participating in a communication. Nodes in this network overhear communication from the nodes that fall in the carrier sense range. So nodes consume energy while being idle, transmitting, receiving and overhearing. Energy spent on overhearing can be overwhelming when a node lies near one or more active flows thus decreasing its lifetime rapidly. Hence it is imperative that a routing protocol does load balancing and energy balancing taking into effect the number of neighbors, their traffic and their energy.

Multipath routing protocols has been studied to improve route resilience and save routing overhead. Compared to single path transmission, multipath routing protocols perform better. We extend Adhoc On demand Multipath AODV (AOMDV) [6] with traffic and energy awareness.

2. REVIEW OF LITERATURE

Studies on load or traffic balancing has attracted significant studies as congestion is alleviated leading to the improvement in end to end delay and throughput . Queue length at the mobile nodes was used as a routing metric to measure traffic around a node instead of the conventional shortest path routing metric. CSLAR[11] makes route selection based on channel contention information ,number of packets in its queue and number of hops along the route. Busy and idle portion of the channel around a mobile node is estimated using NAV obtained from MAC layer. [9] integrates contention degree of the nodes and queue size as another metric for load calculation. .This improves the packet delay. Considering only queue size cannot be the indicator of traffic specially when a node has a busy channel around it. Load Balanced Packet Success Rate (LBPSR) is defined in [2] by using MAC Layer information based on the capacity. Node i ‘s traffic handling capability is the ratio of number of ACK packets received by node i to number of RTS packets transmitted by node i. [14] takes a different approach to monitor current and future congestion status of active routes and distribute traffic evenly on each path. The number of RREP and RERR packets received is used as an indicator of to predict current and future congestion.

Studies on energy conservation for routing protocols has also been taken up .[5] Path cost metrics routing defines a cost metric using queue length, hop count and energy cost of the link from previous hop to the current node to avoid nodes having hotspot . In a wireless network, nodes contend for the shared channel causing channel contention. This gives rise to access delay and collision at MAC layer EMRP (Energy Aware Multipath Routing

Protocol [7] suggests assigning a weight to each route by collecting status information like distance between a node and its next hop, number of retransmission attempts , current length of the queue and remaining energy at each node during Route Reply phase .Packets are then distributed according to inverse weighted assignment .MEER (Multipath Energy Efficient Routing Protocol)[13] extends Split Multipath Routing protocol, to provide energy efficiency. Route Discovery phase is enhanced to collect information about a node that has minimum energy and then calculates average energy of a routing path .Route selection phase selects a path which has highest minimum energy .In case of tie ,MEER selects a path with highest average power or a path with shortest number of hops.

All the above studies solve the problem of load balancing and energy conservation independently. But we can see that if energy conservation is not considered load or traffic balancing alone cannot improve the performance .[10] proposes Lifetime–aware Leisure Degree Adaptive Routing (I-LDAR) uses a heuristic route selection mechanism in order to efficiently control the congestion by balancing the traffic load and prolonging the network lifetime. It defines the transmission condition of a node based on the node's transmission rate, reception rate , remaining energy and energy drain rate. [4] proposes a load balancing technique with node caching enhancement to learn about nodes recently involved in data packet forwarding. Although this study highlights the potential energy savings achieved by adopting a load aware mechanism into routing decisions , it lacks explicit energy aware mechanisms that is necessary for further prolonging the network lifetime. PTPSR (Power and traffic balance awareness path selection routing scheme) [12] incorporates traffic factor ,energy factor and minimum number of hops into multipath AODV routing protocol without considering the impact of interference caused due to the neighboring nodes for Load Balancing. Our protocol suggests a combined Load Balancing scheme that attains traffic and energy balancing mechanism that can significantly improve the performance of a routing protocol.
In section 2, we review related prior work. In section 3, detailed protocol is described. Simulation results are presented in section 4 ,while conclusions are offered in section 5.

3. PROTOCOL DESCRIPTION

3.1 Motivation

Load balancing mechanisms have the advantage of balancing network traffic evenly in all parts of the network and minimize congestion. Battery aware routing metrics are combined with load to further improve network lifetime. But most existing battery aware routing schemes consider the energy consumed at the nodes in a routing path .Because of the wireless nature of MANETs ,communication between any two nodes affect all other nodes that are also in the carrier sense range. Thus nodes loose a significant portion of their energy if it has more active neighbors. If a node that is part of a routing path has more active neighbors, then considerable portion of its energy starts declining rapidly due to overhearing. Energy spent on overhearing is equal to energy spent on receiving .The total energy spent at a node i with N neighbors can be given by

$$E(i)= E_{tx}(i) + E_{rx}(i) + E_{o}(i) *N \qquad (1)$$

Where E_{tx} ,E_{rx} ,E_{o} denotes energy spent on transmission ,receiving and overhearing respectively and N is the number of neighboring nodes. (1) implies that, as number of neighbors increase, energy expenditure due to overhearing increases.

This work intends to take into account, this energy decline due to more number of active neighbors and thereby enhance upon load and energy balancing. Our protocol Energy & Load Balancing Multipath Routing Protocol (ELB-MRP) measures the traffic and remaining energy of a node and then measures the traffic and remaining energy of its 1 hop neighbors. We believe that this can give a measure of energy spent on overhearing as it is directly proportional to the number of neighbors and the amount of neighbor activity. Neighbor activity is measured by noting the level of contention observed at the neighboring nodes. Increased level of channel contention indicates a busy neighbor . Later a heuristic cost function is defined using the above parameters.

3.2 Path Selection

Like most of the existing load balancing techniques , our protocol uses contention window size and queue size [9] to assess the load at a node and its 1-hop neighbors. Remaining energy is also noted. We assume that any node *(i)* is capable of measuring its contention window size, queue size and remaining energy at any time. Let the ratio of initial energy to remaining energy be denoted as Energy Factor (EF), and ratio of initial queue size to remaining queue size be denoted as Queue Factor (QF) and size of the contention window averaged over a period of t seconds be denoted as ACW . Let N be the number of neighbors of node *(i)* Now the cost can be expressed as :

$$C(i) = f\ (ACW , EF ,QF , N) \qquad (2)$$

The last parameter in the cost function ,N is included to take into account neighbor activity and the potential energy loss due to collisions. Each node other than the source and destination node collects information about the size of the contention window (CW), energy factor (EF) and queue factor(QF) of itself and its 1 hop neighbors. Traffic is measured by averaging the size of contention window (ACW) and queue length as in [9]. Cost *C(i)* due to node *(i)* is then found by taking the product of ACW, EF, QF. Cost due to the node's 1-hop neighbors is calculated in the same way.

$$C(i) = ACW * EF * QF \qquad (3)$$

If a node I has neighbors j and k then cumulative cost CC(i) can be given as

$$CC(i) = C(i) + (C(j) + C(k)) \qquad (4)$$

3.3 Route Discovery

AOMDV's Route discovery procedure is modified to associate a cost for each routing path. Route Discovery is initiated by ELB-MRP when the source node has no route in its cache. RREQ packets are flooded in all directions. When intermediate nodes receive the RREQ packets ,it checks if it is a duplicate. If it is not a duplicate the intermediate node processes them. RREQ packet is modified to collect traffic and energy status of each intermediate node. Hello packet carries the node id , ACW, EF and QF values. As the Hello packets are exchanged periodically they propagate the current condition of network without any additional communication overhead .Using the neighbor information from the Hello packet the intermediate node computes the cumulative cost as in (4) and adds it to a field in the RREQ header. When RREQ reaches the destination it will have the cumulative cost for the whole path. Destination waits as in AOMDV to receive further RREQs . Destination then selects two paths with minimum cost, of which one path would be used for ongoing data transmission and the other would be used as a back up path.

3.4 Route Maintenenance

When an active route fails due to mobility ,RERR packet is generated by the node that experiences link failure. Source node on receiving a RERR packet selects an alternate path which is already found during earlier route discovery.

4. PERFORMANCE EVALUATION

In this section, benefits of ELB-MRP is shown by comparing the simulation results with AOMDV. Analysis of the protocol is done by studying the efficiency of routing metrics like throughput, packet delivery ratio and end to end delay. Energy efficiency of our protocol is evaluated using energy metrics average energy consumed variance and network lifetime.

4.1 Energy Model

Energy model considered here is the updated model [15] supported by ns2. It includes four states: idle, sleep, receiving (RX) and transmitting (TX). Every node starts with an initial energy level and consumes energy as it transmits ,receives data and while being in sleep and idle state. Nodes update their energy level when transmission is initiated. When energy level in a node becomes zero, the node does not accept or send any packet.

4.2 Simulation Scenario

This protocol is simulated using ns2[8] which supports complete physical, data link and MAC layer models for simulating wireless ad hoc networks. We simulated a network of mobile nodes placed randomly in an area of 1500 x 300 square meters, with 50 mobile nodes. A source and a destination is selected randomly. Free space propagation model is assumed as the channel model. Each node is assumed to have a constant transmission range of 250 meters as defined in ns2 and a channel capacity of 2Mbps. Medium access control protocol used is IEEE 802.11 distributed coordination function (DCF). Traffic generator tool cbrgen is used to generate CBR traffic. Source destination pairs are spread randomly over the network. Mobility pattern of the mobile nodes is generated using Random waypoint model . A mobile selects another node in the network and constantly moves towards it at a given velocity. Once it reaches there, it waits for some pause time and selects another node and again starts moving. By observing the performance of the network under mobility we can test the stability of the design in real time scenario. Speed of a mobile node is assigned a value between 0 to 20 meters/sec.

4.3 Results –Routing Metrics

Working of ELB-MRP protocol is compared with the normal AOMDV. Performance metrics analyzed are packet delivery ratio, throughput, and end to end delay. These parameters are determined for different pause times. To study the effect of increasing network load ,these parameters are again examined by varying the number of connections. Packet delivery ratio is the ratio of total number of packets that have successfully reached the destination to the total number of packets generated by various CBR sources.Packet Delivery Ratio is better as shown in Figure 1. ELB-MRP can take into account increasing traffic level at the nodes due to increasing number of connections. Similarly by varying the mobility of the nodes , Packet Delivery Ratio of ELB-MRP is compared against AOMDV which does not adopt any load and energy balancing. Figure 7 shows improved packet delivery ratio attained by ELB-MRP. Throughput is again studied by varying the load and mobility as these parameters can clearly indicate the advantage of our protocol. Throughput achieved is again remarkable for ELB-MRP than AOMDV as seen in Figure 2 and 8. This can be attributed to the fact ,that there will lesser packet drops as traffic will be uniformly spread in all parts of the network. End to end delay is the next parameter studied. There is again considerable improvement shown by ELB-MRP because it avoids paths that are less congested and hence suffer less queueing delay. Number of route breaks experienced would also be less as paths avoids high traffic nodes . Figure 3 and 9 shows end to end delay observed .

4.3 Results –Energy Metrics

Energy efficiency of ELB-MRP is evaluated using following metrics by varying node mobility and network load.

1. Average Energy Consumption at a node: It is defined as the ratio of total energy consumed in the network to total number of nodes in the network. This metric can determine the energy consumed at each node.

2. Network Lifetime : is one of the important metrics to evaluate the energy efficiency of a routing protocol with respect to operational lifetime of a network. We define this as the time when any node first runs out of energy. A node with less than 25% of the initial energy is considered dead.

3. Variance of Remaining power levels : This metric indicates fair distribution of the energy among all the nodes. The computed value reflects whether the routing scheme has penalized any number of nodes. A smaller variance value close to 0 indicates fair energy usage by all the nodes.

The energy consumed by the nodes in our proposed protocol is considerably less. This reflects that ELB-MRP is able to find paths , that brings down energy consumption due to overhearing and energy consumed due to retransmissions occurring because of congestion. Figure 5 and Figure 11 shows this. Node lifetime is another parameter studied by varying the mobility and load. ELB-MRP enhances the lifetime of the node. Our enhancement considers paths with nodes with minimum interference. Figure 4 and Figure 10 shows this. Node life constantly keeps improving. A major factor that contributes to increased node lifetime is lessoning number of packet drops and retransmissions due to collisions. Energy is not wasted in our protocol as it chooses paths with minimum traffic at the neighboring nodes .

Energy Variance parameter shows how fairly energy is distributed among all the nodes. A value close to zero indicates this. Our protocol achieves fair amount of energy distribution without overloading any particular node. Figure 6 and Figure 12 shows variance of energy levels observed for increasing number of connections and mobility. Energy distribution in ELB-MRP achieved when compared to AOMDV is better for increasing number of connections, which shows that our protocol performs well under increasing network load. ELB-MRP maintains better variance values than AOMDV under different mobility values although initially it is high during high mobility.

5. CONCLUSION

We have presented a Enhanced Multipath protocol that performs load and energy balancing ELB-MRP . This protocol guarantees hotspot mitigation and network survivability. ELB-MRP suggests a combined cost metric that collectively characterizes not only the load and energy consumption experienced at a node but also due to a node's 1 hop neighbors. Incorporating the load and energy status of 1 hop neighbors is adopted to refine upon the measurement of energy consumption taking place at a node. Energy consumption study analysis conducted here also shows how a node looses its significant portion of its energy due to overhearing in addition to the energy consumed while transmitting, receiving and in idle state. Selection of less congested and energy efficient paths ensures better throughput and less end to end delay with minimized energy consumption.

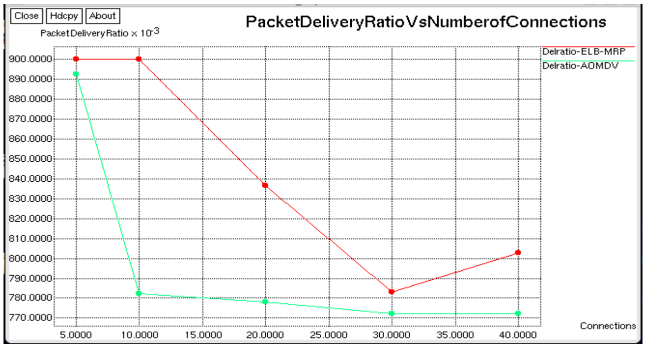

Figure 1 Packet Delivery Ratio for different connections

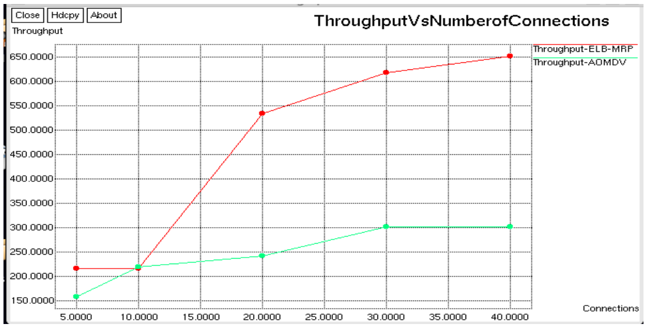

Figure 2 Network Throughput for different connections

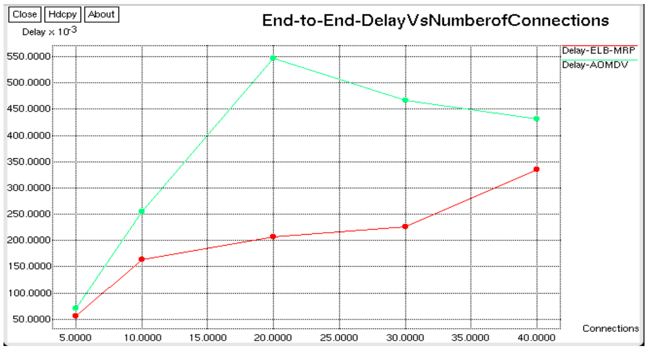

Figure 3 Latency for different connections

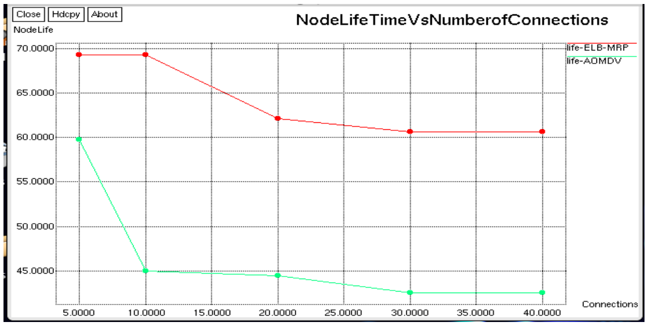

Figure 4 Node Life Time for different connections

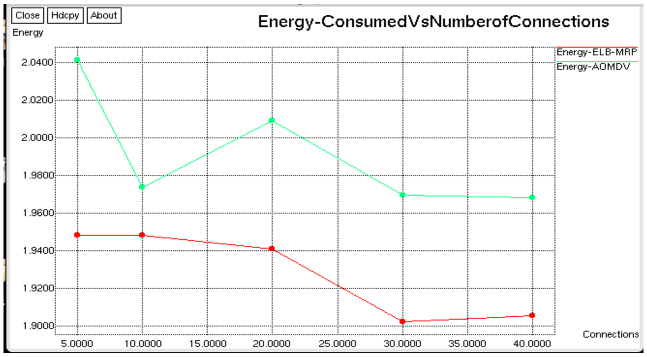

Figure 5 Energy consumption for different connections

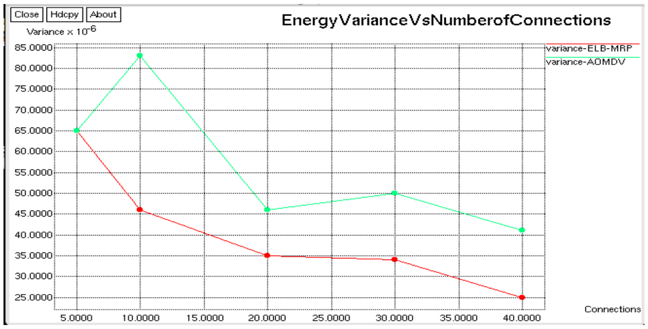

Figure 6 Energy variance for different connections

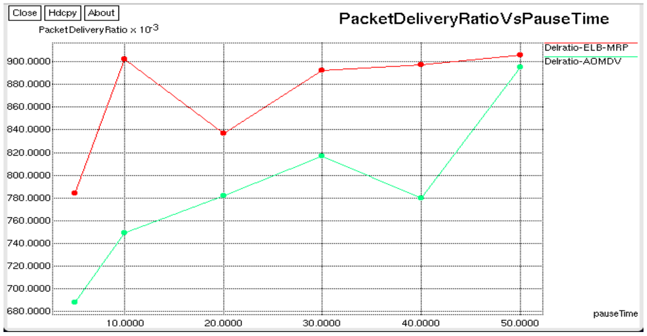

Figure 7 Packet Delivery Ratio for different Pause Times

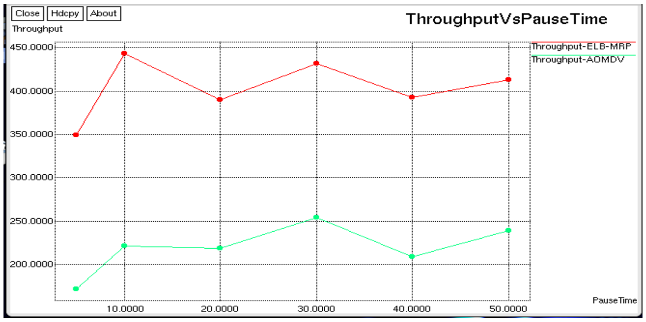

Figure 8 Network Throughput for different Pause Times

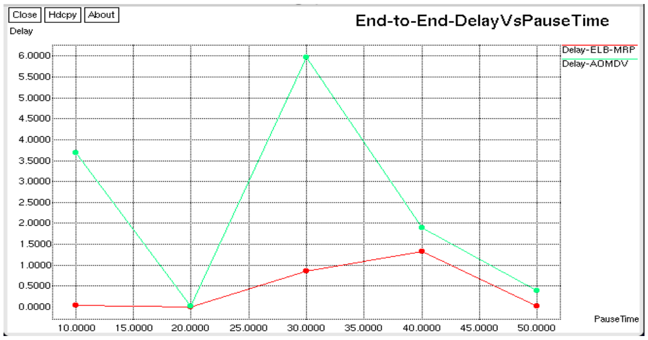

Figure 9 Latency for different Pause Times

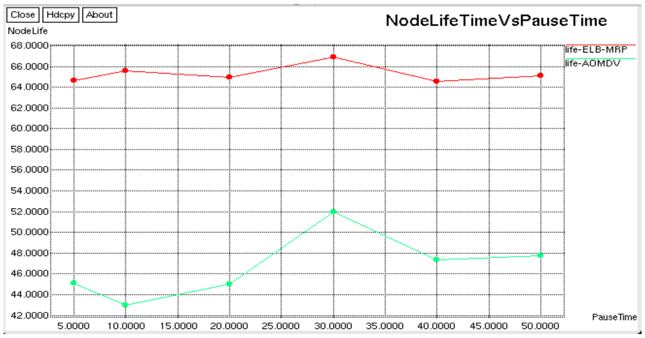

Figure 10 Node Life Time for different Pause Times

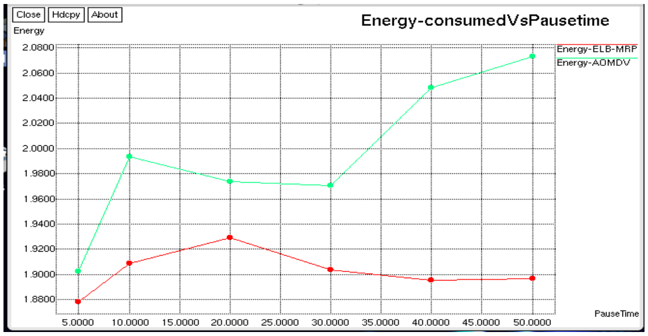

Figure 11 Energy consumption for different Pause Times

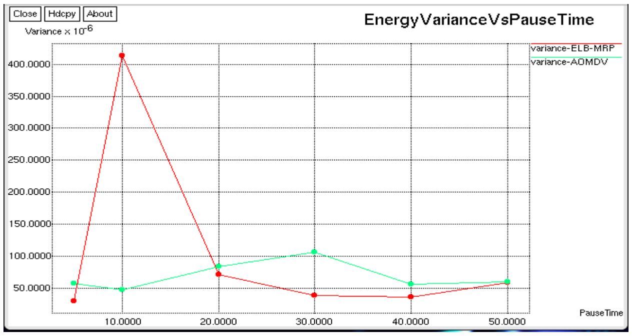

Figure 12 Energy variance for different Pause Times

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