Performance Analysis of An Energy Aware Multi-path Routing Algorithm for Mobile Ad Hoc Networks

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Abstract- In this paper we present the performance analysis of an Energy Aware Multi-path Dynamic Source Routing protocol (EA-MPDSR). This protocol is based on the existing on-demand Dynamic Source Routing protocol (DSR). It is energy aware and uses a multi-path technique. EA-MPDSR reduces the energy consumed per received data bytes as well as prolongs the network lifetime which leads to improvement in the performance of the network. The simulation results show the EA-MPDSR protocol performs better than conventional DSR and Maximum of Minimum Energy DSR (MME-DSR) protocols.

I. INTRODUCTION

A collection of wireless nodes that can dynamically be set up anywhere and anytime without using any pre-existing network infrastructure is called mobile ad hoc network (MANET) [1, 2, 3]. It is an independent system in which mobile devices connected by wireless links are free to move randomly. In addition to their normal functionalities, these devices often act as routers too, see Figure 1. These type of networks are useful in any situation where temporary network connectivity is needed, such as in disaster relief, rescue operations, automated battlefields, and many other applications.

One of the most challenging problems in ad hoc networks is to keep the nodes as long as possible. This is due to the fact that the nodes operated using the energy from batteries. A number of studies have been done on different network layers to achieve energy conservation such as MAC layer and application layer [4] or routing/network layer [4, 5].

We implemented one of the energy aware routing protocols that use only one route to deliver the data packets called MME-DSR. The result of simulation shows the EA-MPDSR protocol performs better than conventional DSR and MME-DSR protocols. In particular, it achieves a remarkable improvement over conventional DSR protocol in the energy efficiency by about 12% and improves the packet delivery fraction by about 8%. EA-MPDSR improves the end-to-end delay by about 35% when we have stress network environment (high mobility, high network load). It also reduces routing overhead by up to 17% by reducing the frequency of route discovery operations. It also reduces the total number of packets dropped by up 40% in average. The drawback of our proposed protocol is the average end-to-end delay when the mobility and the network loads are low.

II. ROUTING IN MOBILE AD HOC NETWORKS.

The role of routing is to find, based on a specific metric, the most suitable route to forward data packets in a multi-hop network. The autonomy of the ad hoc nodes prevents the formation of a hierarchical structure, making it difficult to the routing protocol to be scalable. Routing protocols like Routing Information Protocol (RIP) [6], and Open Shortest Path First (OSPF) [7], work correctly on wired networks that have a nearly static topology but these protocols would have convergence problems in MANETs, because of its dynamic topology. Other problems such as the possibility of asymmetric links and the varying connectivity of wireless networks add to the complexity of dealing with such a network. The ad hoc routing protocols are divided into two classes:

- **Table-Driven(Proactive) Protocols:** Each node in the network keeps information about other nodes in the network in a table. Destination Sequence Distance Vector routing protocol (DSDV) [8, 9], Fisheye State Routing (FSR)[10], and the Optimized Link State Routing (OLSR) [11] are some of the popular table-driven protocols for mobile ad-hoc networks.

- **On-Demand (Reactive) Protocols:** In on-demand protocols, if a source node requires a route to the destination for which it does not have route information, it initiates a route discovery process. The source node uses this route for data transmission to the destination node.
Multi-path routing consists of three components: route discovery, route maintenance, and traffic distribution among multiple paths (traffic allocation).

- **Route Discovery**: It finds multiple routes between a source and destination nodes. Multipath routing protocols may be node disjoint (no common nodes), link disjoint (no common links), or non-disjoint routes. Non-disjoint routes may have lower aggregate resources than disjoint routes, because non-disjoint routes share links and/or nodes. Disjoint routes provide higher fault-tolerance.
- **Route Maintenance**: It finds and repairs the broken paths.
- **Traffic Allocation**: The traffic allocation strategy is used to deal with how the data is distributed amongst the paths.

The EA-MPDSR [25] protocol, that we are studying its performance, is based on the on-demand DSR routing protocol. It modifies DSR route discovery mechanism to collect the node-disjoint paths with nodes that contain higher energy. The source then selects two paths based on their length (the shortest) and their energy. The source node distributes the data traffic among these paths according to the minimum energy of their nodes. The higher the energy of the minimum energy node, the higher the traffic load will be sent through that path.

### III. ENERGY AWARE ROUTING IN MOBILE AD HOC NETWORKS.

Wireless mobile devices are useful if they can be used “anywhere and anytime”. But we have a finite power supplies. Therefore, in wireless communication, one of the most challenging problems is power management. Several energy aware routing protocols have been developed [14, 21, 22, 23, 24]. Most of these routing protocols aim to minimize the energy consumed per packet needed to deliver this packet to its destination. Some of the more sophisticated routing algorithms associate a cost with routing through a node with low power reserve. Other routing protocols aim to maximize the network lifetime. All previous protocols use single path to distribute data traffic through network.

The routing protocols, described previously are based on the single path routing between a source and a destination. However, in a reasonably well-connected network, there may exist several paths between a source-destination pair. The concept of multipath routing is to give the source node a choice at any given time of multiple paths to a particular destination by taking advantage of the connectivity redundancy of the underlying network. The multiple paths may be used alternately, namely, traffic taking one path at a time, or they may be used concurrently, namely, traffic flowing through multiple paths simultaneously.

### IV. SIMULATION ENVIRONMENT

A square area (1000m x 1000m) is used to compare the performance of our proposed protocol EA-MPDSR to MME-DSR and conventional DSR protocols. The environment contains 50 wireless nodes forming an ad hoc network, moving randomly in the simulation area. The simulation time is 900 seconds. The energy assigned to each node is uniformly distributed between 1 and 8 Joules. We considered high (speed is 20m/s or 72km/h) low (speed is 1m/s or 3.6km/h) and medium node velocity (speed is 10m/s or 36km/h). We used waypoint mobility to model how nodes move on a terrain. Nodes in the random waypoint regime move according to the following rules: (1) each node picks a destination randomly moves within the simulation area and also picks a speed \( v \) that is uniformly chosen between \((v_{\text{min}})\) and \((v_{\text{max}})\). Each node then moves toward the destination over a straight line with speed \( v \). (2) upon reaching the destination, a node pauses for a given pause-time; (3) the node then picks the next destination and the process re-starts. Typically, the values of \((v_{\text{min}})\), \((v_{\text{max}})\), and pause-time are parameters of the simulation and are selected according to the requirements and operating environment of the application at hand. The movement scenario files, we used for each simulation, were characterized by a pause time. Each node begins the simulation by remaining motionless for a given pause time. It then selects a random destination and proceeds to that destination at chosen speed. Upon reaching the destination, the node again stays stationary for the chosen pause time, selects another destination and moves there as previously described, repeating this behavior for the duration of the simulation. Each simulation ran for 900 seconds of simulated time. We ran our simulations with movement patterns generated for seven

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**TABLE 1: On-demand (reactive) versus table-driven (proactive) protocols**

<table>
<thead>
<tr>
<th></th>
<th>On-demand (reactive)</th>
<th>Table driven (proactive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>overhead</td>
<td>Low</td>
<td>high</td>
</tr>
<tr>
<td>Memory requirement</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Cope with mobility</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Sleep time</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>purpose</td>
<td>Relative high mobility</td>
<td>Low mobility</td>
</tr>
</tbody>
</table>

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different pause times (0, 150, 300, 450, 600, 750 and 900 seconds). A pause time of 0 second corresponds to continuous motion, and a pause time of 900 seconds corresponds to almost no motion. In our simulation we used a set of five movement scenario files with different seeds for each pause time value to improve the accuracy of the results and to smooth out spikes due to extremely favorable or unfavorable movement scenarios.

For the traffic we used constant bit rate (CBR) sources over UDP. We created five different movements scenarios for each run.

Although a lot of benefits have been explored for multipath routing in wired networks, the advantage of multipath routing is not obvious in MANETs because the traffic along different paths may interfere with each other due to the broadcast feature of radio transmission. In order to get the most benefits of multipath routing in MANETs, the following should be considered: how to search for the best multiple paths based on certain criteria? How to select proper multiple paths? And how to use these selected multiple paths to distribute the data?

It is not enough to select the node-disjoint paths and distribute the data load among these paths. There are some other factors that may affect the performance of the network such as the length of the paths, the number of paths selected, and the correlation between the selected paths. If two node disjoint paths have different length, this will cause out of order problem (packets arrive out of order) in the destination node. It also affects the performance of the network. In [46], it is concluded that when the number of paths used in a multipath algorithm exceeds three, the overheads increase significantly. The correlation between paths also affect the end to end delay of the network because the increasing of traffic interference [15]. In our case, we observe from simulation results that the number of node-disjoint paths is often not exceeding two paths due to the number of nodes in our simulation study. In dense environments where the number of nodes is high (greater than 50), the chance to find more node-disjoint paths increases. For all previous reasons, we limit the number of the selected paths to two.

V. ROUTING METRICS

The following metrics are used to compare the protocol EA-MPDSR protocol to the conventional DSR protocol:

- **Energy Efficiency (EE):** Total data received measured in Bytes/Joule at the end of simulation.
  \[ EE = \frac{\text{Total received data (Bytes)}}{\text{Total consumed energy (Joules)}} \]

- **Packet Delivery Fraction (PDF):** the ratio of the number of packets generated by sources to the number of packets received by the destinations. This metric reflects the throughput a network can support. One of our goals is to design an energy-efficiency network protocol which can improve energy consumption without a significant loss of capacity. Thus, this metric is useful to measure any degradation in the network throughput.

\[ PDF = \frac{\text{number of packets received}}{\text{number of packets sent}} \times 100 \]

- **Average End-to-End Delay of data packets:** the delay of data propagation and transfer, and the delays caused by buffering, queuing and retransmitting data packets. The delay of each packet is computed as: (the time of received data packets – the time of sent this data packet). The average end to end delay is then computed as:

\[ \text{Average delay} = \frac{\text{Total Delay of each data packets}}{\text{total data packets received}} \]

- **Normalized Routing Load (NRL):** The metric is also called routing overhead; it is equal to the number of routing packets transmitted per data packet delivered at the destination. Each hop-wise transmission of a routing packet is counted as one transmission.

\[ \text{NRL} = \frac{\text{number of routing packets}}{\text{number of received packets}} \]

- **Total number of dropped packets:** The total packets dropped during simulation time. It includes all types of dropped packets such as TOUT which means time out (i.e. packet has expired), and NRTE which means no route is available.

VI. PERFORMANCE EVALUATION

We compared the performance of our proposed protocol EA-MPDSR, conventional DSR protocol, and MME-DSR protocol. The results show that our proposed protocol EA-MPDSR outperforms the MME-DSR protocol in EE, PDF, NRL, and Total packets dropped. MME-DSR outperforms EA-MPDSR in average end to end delay.

We use two sets of experiments to study the comparison. The first set of experiments, shown in Figure 2, uses high mobility (high speed 20m/s and pause time 0) as a function of network load (1, 5, 10, 15, and 20 connections). The second set, shown in Figure 3, uses high network load (20 connections) and pause time 0 as a function of speed (1, 5, 10, 15 and 20 m/s). We choose the highest mobility and highest network load in these two experiments to make the situation fairly challenging for the routing protocols.

VII. CONCLUSION

In this paper we designed an energy aware multipath routing protocol based on the conventional DSR protocol. We compared this protocol to DSR and MME-DSR. The metrics considered for the comparison are energy efficiency, packet delivery fraction (PDF), average end-to-end delay, normalized routing load (NRL), and number of dropped packets during simulation time. The simulation results show that the proposed protocol performs better than these two protocols for most of these metrics.
Fig. 2. EA-MPDSR compared to MME-DSR and DSR protocols for different speeds.

Fig. 3. EA-MPDSR compared to MME-DSR and DSR protocols for different network load.
EA-MPDSR protocol outperforms the conventional DSR and MME-DSR for all situations, with widening performance gaps with increasing stress (e.g. more load, higher mobility). In low network stress (low mobility, less load) EA-MPDSR still performs better except the average end to end delay metric due to correlation between nodes. In all cases, MME-DSR has the shortest delay than both EA-MPDSR and conventional DSR protocols. EA-MPDSR has shorter delay than conventional DSR in high network stress only.

REFERENCES


