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Energy Efficient Routing Over Mobile Adhoc Networks

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ABSTRACT—

Most wireless ad-hoc networks consist of mobile devices which operate on batteries. Power consumption in this type of network is important. To maximize the lifetime of an ad-hoc network, it is essential to prolong each individual node (mobile) life through minimizing the total transmission energy consumption for each communication request. Therefore, an efficient routing protocol must satisfy the energy consumption rate at each node is evenly distributed and at the same time the total transmission energy for each request is minimized. The proposed PEER scheme developed energy efficient routing algorithms which find routing paths whenever necessary based on the energy consumption, and the hop count. By selecting the minimum energy path it minimize the total transmission energy consumption, therefore prolong the life of the entire network. Another issue in mobile ad-hoc network is it maintenance. By using Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) mechanism and adding time to live metrics in the route request packets, energy consumption of unwanted packets and the maintenance overhead issues are reduced. Compared with a previously known result, this PEER scheme have less energy and Maintenance overhead and can be implemented in a distributed environment. For an adhoc network equipped with different types of battery mobile nodes,a new poweraware routing protocol is proposed, and the algorithm can also be implemented in distributed manner.

Index Terms—Energy Efficient Routing, Overhead, MAC, PEER

I. INTRODUCTION

A mobile ad-hoc network (MANET) is a self-configuring infrastructure less network of mobile devices connected by wireless. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each node must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. In past years the effort is made in increasing the processing capacity and memory space of computing devices but the battery techniques lags far behind. Therefore it is critical to derive schemes for energy conservation to increase the device and network operation time.In wireless networks the transmitted signals are propagated at the rate of $1/d^n$, where d is the distance between a source and destination and n is the path loss exponent with the value between 2 and 6 depending on the working environment. While using the maximum transmission power all time, with power control scheme, a sender can adjust the transmission power based on the d value. Now day's energy is the one of the most important source for any communication we have to conserve energy in these types network, because the devices are mobile battery operated computing devices. Many energy efficient routing protocols have been proposed. Generally these protocols can be classified into two types: They are *Minimum energy routing protocol* and *Maximum network life time routing protocols.* The first type protocols look for the most energy efficient path, where as the second type try to balance the remaining battery-power at each node while looking for the energy-efficient path. At the same time *Minimum energy routing schemes* are also an important part in most of the *Maximum network life time routing protocols such as CMMBCR.* In this paper we will focus on developing and increasing the efficiency of minimum energy routing protocols. Minimum Energy routing protocols can be further classified into three types based on the link cost: *Minimum Total Transmission Power* (MTTP), *Minimum Total Transceiving Power* (MTTCP), and *Minimum Total Reliable Transmission Power* (MTRTP).However MTTP and MTTCP protocols did not consider the energy consumption due to data packet retransmission from one node to another node. Instead MTRTP protocol take into account the energy consumption of packet retransmission. In existing minimum energy routing protocols, signaling packets are often transmitted at the maximum power to reduce the hidden terminal problems. The signaling packet that experiences more collision for example, RTS and CTS packet in 802.11, would consume significant amount of power. Without taking into account the energy used for signaling, the path discovered would consume much more energy than a path selected based on a more accurate energy consumption model. In most of the existing work focused only on the development of new link cost metric. If the new link cost metric is derived, the traditional shortest path routing protocols such as *Dynamic Source Routing* (DSR) and *Ad-Hoc On Demand Distance Vector* (AODV) protocols are modified to search for the minimum cost path. In this paper, we first provide a detailed discussion on the problems in traditional energy-efficient routing protocols.We then derive a new link cost model to account energy consumption due to signaling packets at MAC layer,and provide the schemes for estimating the parameters required for calculating the link cost. Based on the new energy consumption model, we propose a Progressive Energy-Efficient Routing (PEER) protocol for more timely path setup, and for efficient path maintenance. PEER searches for the more energy-efficient path progressively and maintains the route continuously Particularly, a path closest to the most energy efficient path is established between the source and the destination quickly, and then the transmission path adapts whenever necessary with little overhead to ensure more energy-efficient transmissions all the time. Our performance evaluation demonstrates that, as compared to normal minimum energy protocols, PEER could significantly reduce routing overhead and path setup delay, and consume much less energy in both static and mobile scenarios. The rest of the paper is organized as follows: Section 2 describes the observation and motivation for this paper. In Section 3, The detailed PEER protocol is described. In Section 4 Performance evaluation is conducted. In Section 5 concludes the work.

II. OBSERVATIONAND MOTIVATION

There are many existing routing protocols for wireless ad-hoc networks. In general, these protocols can be categorized as table-driven, on-demand, and hybrid. In table-driven routing protocols, all nodes need to advertise the routing information periodically to keep an up-to-date view of the network topology. Different from table-driven routing protocols, on-demand routing protocols create a transmission path only when required by the source node. Hybrid protocols combine both approaches. For example, in Zone Routing Protocol (ZRP), table-driven routing scheme is used for intra zone routing and on-demand routing scheme is used for inter zone routing. Most of energy-efficient schemes proposed in the literature modified on-demand routing protocols such as AODV [5] or DSR [6] to build energy efficient path since the routing overhead is very high in table-driven routing protocols [2]. In on-demand routing protocols such as AODV, a node will start a route discovery process if it needs to find a path to a destination. It broadcasts the route request packet and waits for the reply from the destination. The neighboring nodes that receive such route request packet will rebroadcast it, and so on. To reduce the routing overhead, the intermediate nodes will only rebroadcast the first received route request packet and discard the following duplicate ones. In addition, the destination node only replies to the first route request packet. Route discovery in energy-efficient routing protocols is however quite different. The intermediate nodes could not simply discard the duplicate route request packets now as such packets may come from more energy-efficient paths. That is, the intermediate nodes need to process and rebroadcast the duplicate route request packets if they come from a more energy-efficient path. Therefore, the nodes may need to broadcast the same route request packet many times. Higher routing overhead causes several issues. The first one is higher energy consumption. As the path discovery packets are very important, they have to be transmitted at the maximum power level. Therefore, even though the size of routing packets is small, the energy consumption for one route discovery packet is comparable to one data packet. The second one is longer route setup delay as 1.

III. PEER PROTOCOL

As discussed in Section 2, the existing minimum energy based routing schemes often introduce big overhead during path discovery and the path setup time is very long. Therefore, a good strategy is to find a path close to the minimum energy one quickly and then use a maintenance scheme to adjust the path for further energy reduction. Taking this into consideration, PEER searches for the energy-efficient path quickly during route discovery process, and maintains the route actively so that it can respond to topology and channel changes quickly. In the following, we show how PEER achieves both goals.

3.1 Route Discovery Process

In this section, we introduce the route discovery strategy of PEER. The quickest way to find a path between two nodes would be through a shortest path routing scheme. However, there may exist a few shortest (smallest number of hops) paths between the source node and destination node.

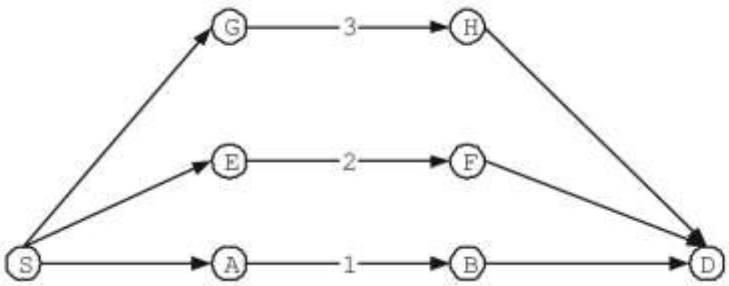


Fig. 1. Three routes between node S &D.

For example, in Fig. 1, assuming all the intermediate nodes (A, B,E, F, G, H) are the neighboring nodes of both S and D while S and D are beyond transmission range, then there are six shortest (2 hops) paths (SAD, SBD, SED, SFD, SGD, SHD). Among all the shortest paths, it is better to pick the most energy-efficient one (we call it minimum energy shortest path).Denote the set of paths between the source and the destination by L, the number of hops for path l by Nl, and the energy consumption for link i in path l by El,i, then the set of shortest paths Ls would be Ls

$Ls =¼ \arg\min(N_l), l \in L.$

The set of minimum energy shortest paths Lms would be

$L_{ms} =¼ \arg\min(\sum E_{l,i}), l \in L_s$

Even though there may be more than one minimum energy shortest path in L_{ms}, the routing protocol can pick a unique one by some criterion, such as route request packet arriving time. Based on the previous definition, the basic searching

Algorithm would be: 1) search for all shortest (fewest hops) paths; 2) pick the minimum energy path(s) among the shortest paths in (1). To implement this algorithm, the route request packet should carry two pieces of information: one is the hop count; the other is the energy consumption. The source node first broadcasts the route request packet with both hop count and energy consumption set to 0. Once an intermediate node receives a route request packet, it first updates the hop count (increased by 1) and energy consumption (increased by the energy consumption between the sender and itself) information in the route request packet. Then, it will rebroadcast such packet only if one of the following conditions holds: 1.The node hasn't received such a packet before or the packet comes from a shorter (smaller number of hops) path. 2. The packet comes from a path with the same number of hops as the best path so far, but the energy consumption is lower. The first condition ensures that the shortest path is selected, while the second condition selects the minimum energy path from all the shortest ones. This algorithm, however, has similar path selection issues as other energy-efficient routing protocols. That is, the destination node may receive many route request packets from different possible minimum energy shortest paths, but it could not tell which one is the best until it receives all possible packets. As the destination node has no knowledge on the number of route request packets it will receive, it may not be able to make the decision even if it has three routes between node S and D.already received all the route request packets. For example, assuming all six shortest paths (SAD, SBD, SED, SFD, SGD, and SHD) in Fig. 1 have the same energy consumption and the destination D has received all of them, D may still not be able to select the best one as it does not know when the best time to make the decision is. There are several ways to deal with this issue at the destination node. One option is that the destination sets up a timer after receiving a route request packet. If it receives another route request before the timer goes off, it will reset the timer. Otherwise, it will select the best path found before the timer goes off and reply the source with a route reply packet. We use this approach one as it can adapt to the number of arriving route request packets. If there are only very few route request packets arriving at the destination, the destination can send back route reply packet quickly to reduce the route setup time. On the other hand, it can wait for a period of time for the route request packet from a more energy-efficient path to arrive if there are more route request packets arriving at the destination and there is no significant time difference between two consecutive request packets.

3.2 Route Maintenance

The route obtained in path discovery phase is suboptimal and may still lead to a higher end-to-end energy consumption than that of the minimum energy path. In addition, the network environment can change dramatically due to node movements and dynamic channel conditions, and the previous energy-efficient route may no longer be efficient as time goes on. Therefore, the route maintenance phase is very critical for energy-efficient routing protocols. As extra signaling messages will consume more energy, the route maintenance scheme of PEER will not use additional periodic messages. Instead, an observing node will passively monitor data packets exchanged in its neighborhood and collaborate with its neighbors to look for a more energy-efficient path. As described , each node can estimate the necessary transmission power and the link cost to a neighboring node once it receives RTS, CTS, or broadcast packet from this node. In PEER, each forwarding node will insert the link cost into the IP header of the packet targeted for its next-hop receiver as an IP option, and every node will monitor the data packets exchanged in its neighborhood to intercept the corresponding link costs and use these link costs to estimate the cost of a path segment. For each data packet transmitted, received, or overheard by a node, it will record the following information into a link cost table:

TABLE 1

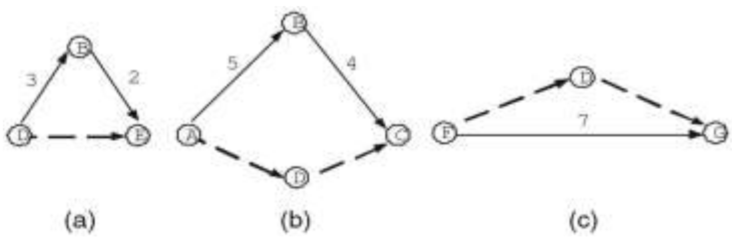
Link Energy Table Recorded by Node D

(a)	(b)	(c)	(d)	(e)	(f)	(g)
A	B	5	S1	D1	1	1
B	C	4	S1	D1	1	1
D	B	3	S2	D2	3	3
F	G	7	S3	D3	5	4
B	E	2	S2	D2	3	5

(a) sender, (b) receiver, (c) link cost between the sender and the receiver, (d) source, (e) destination, (f) IP header ID, and (g) the current time.

Among these parameters, (a) and (b) can be obtained from the MAC header, while (c)-(g) can be obtained from the IP header. The information for a link will be kept only for a short time for accurate information and reducing storage overhead. In this we additionally added time to live metrics. From the link cost table, a node can know how a packet passes through its neighborhood and the total link cost for that. Based on the information recorded in its link cost table, a node can help reduce the cost of a local path segment and hence the cost of the end-to-end path between a source and a destination with the use of the following three operations:

Remove, Replace, and Insert.



1. Remove: If X finds that the link cost between X and B is smaller than the cost of the two-hop path segment, it will update its routing table by setting the next hop for the destination Z to B. If X finds that the link cost between X and B is smaller than the cost of the two-hop path segment, it will update its routing table by setting the next hop for the destination Z to B.

2. Replace: If X finds the total cost for the path segment A→X→C is smaller than that of the two-hop path segment A→B→C, X will update its routing table by setting its next hop for the destination Z to C. If X finds the total cost for the path segment A→X→C is smaller than that of the two-hop path segment A→ B→C, X will update its routing table by setting its next hop for the destination Z to C. In addition, it will request A to set its next hop for the destination Z to X.

3. Insert: Assume there is a one-hop path segment A→B on the path to destination Z in node X's link cost table and the total cost of the path segment is T. If X finds the total cost of the path segment is A →X → B smaller than that of the one-hop path segment, it will update its routing table by setting its next hop for the destination Z to B. In addition, X will request A to set its next hop for the destination Z to X. In the proposed maintenance scheme, a monitoring node only needs to send out control messages in Replace and Insert operations to facilitate path change. As the control messages are only sent out when a better path is detected, so the maintenance overhead is very low. The control message includes: operation type, requester ID, destination, next hop on the old path segment, the total cost for the new path segment. Within these three operations, Insert may be more easily requested than the other two since it only needs to check one-hop transmission. In PEER, each node receiving Remove or Insert requests will wait for some time before making the decision. If it receives an Insert request and also an operation request of Replace or Remove, it will take the other operation. If it has both Remove and Replace operation requests, it will select the one which allows for a higher percentage of energy saving. For the same example, node A receives the Insert (by node D), Remove (by node C), and Replace requests, it will only perform Remove and Replace operations. As taking path segment AFC will save more energy than taking path segment AC ($\overline{PT\ (A, F)}$ +$\overline{PT\ (F,C)}$ < $\overline{PT\ (A,C)}$), it selects the Replace operation.

IV. PERFORMANCE EVALUATION

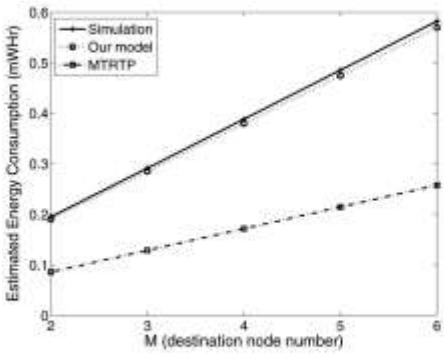
We have simulated PEER, minimum energy protocol MTRTP, as well as normal AODV protocols in Glomosim.number of nodes.

TABLE 2

Default Setup Parameters

Parameter	Value	Parameter	Value
No. of. nodes	60	Packet size(bytes)	512
Connection arrival rate	30	Connection duration(min)	6
Max speed(m/s)	10	Min speed(m/s)	0.5

The application protocol is Constant Bit Rate (CBR) and the source and destination pairs are randomly selected. The mobility follows modified random waypoint model [18] with 30-second pause time. For each CBR session, 50 packets are sent per second. The path loss and collision rate are estimated using method in [06]. The remembering rate, which is called filter memory in [09], is set to 0.99. A simulation result was gained by averaging over 20 runs with different seeds. Some other default setup parameters are in Table 2. We assume that there is no power saving mode for the nodes, and accordingly, a node will spend energy in monitoring the channel even if it doesn't receive a packet. A node also consumes energy when overhearing packet transmissions. Therefore, the receiving power cannot be actively controlled. In the simulations, we thus ignore the receiving power and focus only on the comparison of transmission power. We first evaluate the accuracy of the proposed cost model, we then study the performance of route discovery for each protocol, and finally we consider energy consumption as well as RTS retransmissions in both static and mobile environment.



V. CONCLUSIONS

From the literature survey of various papers in energy efficient routing of wireless mobile ad-hoc network had identified overheads in the route discover and route maintenance. The improvement in energy efficiency is achieved by considering the energy consumption of both data and signaling packets and also by selecting the minimum energy path based on the hop count. Then for maintenance issues collision or any link breakage problems are easily identified and solved based on the Carrier Sensing Multiple Accesses with Collision Avoidance mechanism and by using Time to Live metrics the energy consumption of unwanted packets are also reduced. There by the peer routing scheme can be more energy efficient than the existing routing schemes. The problem can be overcome by proposed technique PEER ROUTING SCHEME. For an adhoc network equipped with different types of battery mobile nodes ,this power –aware routing protocol is proposed, and the algorithm can also be implemented in distributed manner.

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