Energy Efficient Route Discovery for Mobile HCI in Ad-Hoc Networks

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Abstract. A mobile ad-hoc network [1] is a set of mobile nodes acting as routers in infrastructureless networking situations. In ad-hoc environments, to extend the lifetime of wireless mobile hosts, energy-efficient ad-hoc routing protocols must be designed. However, in conventional reactive ad-hoc routing, the route discovery operation is triggered whenever a source node has packets to send to a certain destination, but has no route information for the destination. Intermediate nodes, then, repeatedly broadcast the message until it is received by all nodes. This route discovery process could result in excessive drain of limited battery power and increase collisions in wireless transmission. In this paper, we propose an energy efficient route discovery scheme using the K-hop Pre Route Request (PRREQ) message which is only flooded within K hops from the source node. This reduces the number of nodes that participate in the route discovery process. Our empirical performance evaluation, which compares our proposed scheme to the conventional reactive adhoc routing schemes, demonstrates that proposed enhancement reduces energy consumed in the route discovery procedure by about 27% when each node initiates a new route at a rate of 0.05/sec.

Keywords: DSR, AODV, RREQ, RREP.

1 Introduction

In today's increasingly mobile computing world, people wish to be able to access a range of services at any time, at any place. However, the mobile computing environment is characterized by narrow network bandwidth and limited battery power. One of the greatest limitations is the finite power supplies inherent in mobile devices [2]. Accordingly,

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numerous studies have focused on energy efficient wireless communications. Further, it has recently been recognized that networking techniques can also have a strong impact on the energy efficiency of such systems instead of the development of improved battery and low-power electronics [3]. Therefore, limited battery capacity of mobile host is one of the most challenging problems facing effective wireless communications.

An ad-hoc network is a set of wireless mobile hosts with the capability of cooperatively establishing communications independently. In ad-hoc environments, to extend the lifetime of wireless mobile ad-hoc hosts with limited battery capacity, an energy-efficient ad-hoc routing protocol must be designed. Ad-hoc routing protocols can be classified into two main categories, proactive [4-7] and reactive protocols [8-10]. In proactive routing protocols, node periodically exchanges routing information with its neighbors to consistently maintain valid routes on all destinations. Therefore, nodes are able to communicate with each other without the route discovery procedure. However, the exchange of control messages for maintaining all routes can consume large amounts of energy of nodes. In contrast, in reactive routing protocols, the operation of route discovery is triggered whenever a source node has packets and desires to send to a certain destination, but has no route information for the destination. Therefore, in general, reactive routing can be more energy efficient than proactive routing.

However, in traditional reactive routing protocols, when each node initiates a new route to a certain destination, it broadcasts the route request message to all nodes within its radio frequency coverage area. Then, all nodes within the area re-broadcast the message to their neighbor nodes. This process is repeated until the all nodes in a network receive the route request messages. This conventional route discovery scheme could lead to excessive drain of limited battery power of ad-hoc nodes, and increase collisions in wireless transmission. This energy is wasted in the overhead where the source node broadcasts route messages to an entire network, even when neighbor nodes are maintaining the route to the destination in its route cache, or the destination is close to the source node.

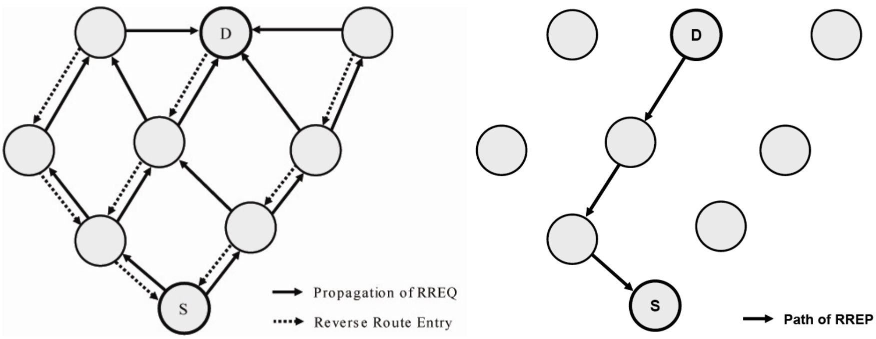
In this paper, an energy efficient route discovery using the K-hop Pre Route Request message which is flooded within K hops from an initiator, is proposed. This scheme reduces the number of broadcasting of route request messages in the route discovery process of reactive routing protocols. We demonstrate that the performance of the proposed scheme compared to the conventional reactive ad-hoc routing, is improved about 27% in terms of energy consumed in the route discovery process, and when each node initiates a new route at a rate of 0.05/sec. As the network traffic is increased, the relative efficiency of the proposed scheme becomes greater.

The rest of this paper is organized as follows. The section 2 presents traditional reactive routing protocols and policies of the route cache. The proposed energy efficient route discovery scheme is presented in section 3. In section 4, we evaluate the performance of our scheme, compared to conventional reactive routing schemes. Finally we conclude the paper in section 5.

2 Related Work

2.1 Reactive Routing Protocols for Ad-Hoc Networks

AODV. The Ad-hoc On Demand Distance Vector (AODV) routing protocol [10] uses a reactive approach for finding routes. Thus, a route is established for transmitting data, only when it is requested by the source node. When the source node wants to find a path to the destination node, it broadcasts a Route Request (RREQ) message.



(a) Propagation of RREQ (b) Path of a RREP

Fig. 1. Path discovery mechanism of AODV

When an intermediate node receives a RREQ, it either forwards it on, or prepares a Route Reply(RREP) if it has a fresh route to the destination. The freshness of a route at the intermediate node is determined by comparing the destination sequence number in the RREQ. Intermediate nodes ignore the duplicate requests when the RREQ is received multiple times. The intermediate nodes set up a reverse path entry for the source node in its route table. In this way, the node knows where to forward a RREP to the source node, if a RREP is received later.

When the destination node eventually receives the RREQ, it creates a RREP and unicasts it toward the source node. When an intermediate node receives the RREP, it sets up a forward path entry to the destination in its route table. In this way, the forward path from source to destination node is established. Fig. 1 indicates the process of forwarding RREQ and RREP.

DSR. The Dynamic Source Routing (DSR) protocol [8] is based on a reactive approach to find routes by employing source routing. The source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which to forward the packet. Therefore, each data packet carries the complete list of nodes through which the packet will pass, and the route cache maintains the information of routes which has the complete lists of nodes.

In DSR, when a source node sends a packet to destination node, the sender first checks its route cache for a source route to the destination. If a route is found, the sender uses this route to transmit the packet. If no route is found, the sender broadcasts a route request packet to discover a route to the destination node. Each route request packet contains the source address, the destination address, and a route record which contains the address of intermediate nodes that the route request packet has been forwarded. The nodes that receive a route request packet, if it is the target of the Route Discovery, or if it has a route to the target of the request in its own route cache, it returns a Route Reply to the initiator, giving a complete path from the source to destination. Otherwise, the intermediate nodes that receive the route request packet append its address to the route record in the route request packet, and re-broadcast the request. Additionally, when the route request packet has been received multiple times, the intermediate nodes discard the route request packet. The initiator of the route request that receives a route reply according to this process of route discovery, caches the route in its route cache for use in sending subsequent packets to the destination. In DSR, possible optimization such as using non-propagating route request and expanding ring search is presented. However, employing such mechanisms can cause increase of delay of route discovery process.

3 Proposed Scheme

In traditional reactive routing protocols, such as AODV and DSR, source nodes broadcast route request messages for route discovery. Then, all nodes in the ad hoc network participate in the route discovery process re-broadcasting the route request messages. Obviously, overhead is created, consuming energy when route messages are broadcasted to the entire network, even in the case neighbor nodes maintain the route to the destination in their route cache, or the destination is close to the source node. The frequent route discovery process causes not only the delay of route discovery and data transmission time, but also consumes the energy of nodes. In this section, an energy efficient route discovery scheme using the K-hop Pre Route Request (K-hop PRREQ) message is proposed. This reduces the number of broadcasting of route request messages in the route discovery process of reactive routing protocols.

3.1 Basic Mechanism

When the source node initiates a route to the destination node, it broadcasts K-hop PRREQ messages with the Time To Live (TTL) field set at K, while the conventional reactive routing protocols broadcast route request messages to the entire network. The intermediate nodes that receive the K-hop PRREQ, checks its route cache for a route to the destination. If a route is found, the intermediate nodes send back the RREP messages to the initiator of the K-hop PRREQ through the reverse path. If no route is found, the intermediate node re-broadcast K-hop PRREQ messages by decreasing the TTL value. Intermediate nodes discard the K-hop PRREQ when it receives the same K-hop PRREQ multiple times or the TTL value becomes 0.

The initiator that sends the PRREQ message waits a fixed time T, for receiving RREP messages from K-hop neighbor nodes. If the initiator receives several RREP messages in time T, it sends the data packet through the path that has the shortest hop count. If the initiator does not receive RREP messages for the K-hop PRREQ in time T, after sending the PRREQ, it attempts to discover a route to the destination using conventional route discovery protocol in which the source node broadcasts the route request message to the entire network.

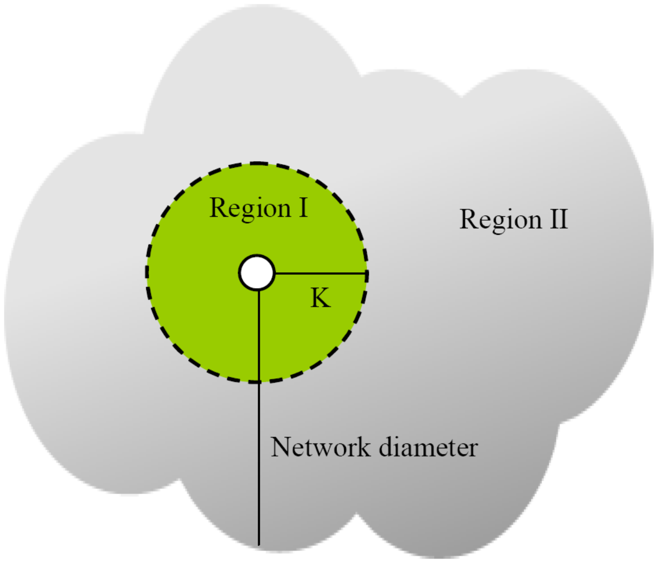


Fig. 2. Flood region of K-hop PRREQ in ad-hoc network

Let us illustrate with the example of Fig. 2. In the case that the source node successfully receive RREP messages for K-hop PRREQ in time T, as the K-hop PRREQ messages are flooded to nodes in the region I of the Fig. 2, the nodes in region II can save energy, which is required for participating in the route discovery process. Additionally, in the case that the hit ratio of the K-hop PRREQ is high, collisions in wireless transmission are decreased. Therefore, using k-hop PRREQ messages reduces not only the energy consuming process of route discovery but also delay of route discovery and data transmission time compared to conventional reactive routing protocols.

However, in the case that the initiator of the K-hop PRREQ does not receive RREP messages in time T, as it has to use the traditional route discovery process, the additional energy is needed to flood the K-hop PRREQ in region I of Fig. 2, compared conventional reactive routing. Moreover, it takes an additional T time to discover a route to a destination node, compared to traditional reactive routing protocols.

3.2 Enhancement

When there are many active routes in the ad-hoc networks, the hit ratio of K-hop PRREQ is increased, thereby raising energy efficiency. However, as mentioned in section 3.1, using the K-hop PRREQ message may cause the nodes consume more energy in some cases. Therefore, it is important to determine whether the initiator should use K-hop PRREQ message. In Fig. 2, let us assume that the nodes are distributed uniformly in an ad-hoc network, and D is the value of the default TTL of conventional reactive routing protocols. Then, when the PRREQ message is hit, the number of nodes that should participate in the broadcasting process of route discovery is proportional to πK^2. In the case that the PRREQ message is not hit, the number of nodes that should flood the route request messages is proportional to $\pi K^2 + \pi D^2$. Similarly, in traditional reactive routing, that does not use K-hop PRREQ messages, the number of nodes that should participate in the route discovery process is proportional to πD^2. In assuming that each node maintains the hit ratio of the K-hop PRREQ in fixed time, the initiator should use K-hop PRREQ messages under the following condition.

$$\pi K^2 p + (\pi K^2 + \pi D^2)(1 - p) < \pi D^2 \tag{1}$$

That is,

$$\frac{K^2}{D^2} < p \tag{2}$$

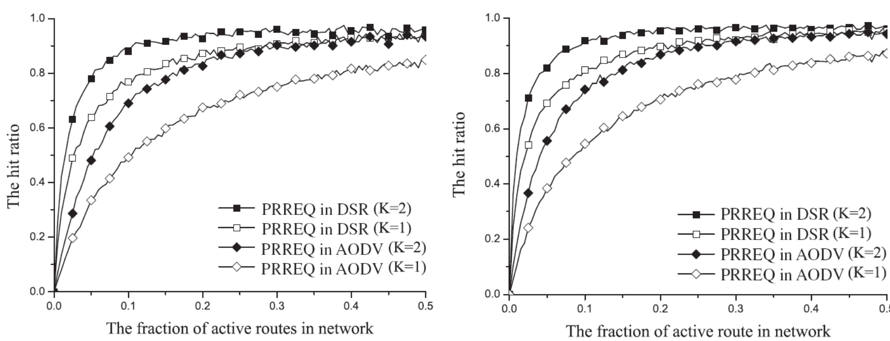
As mentioned in section 3.1, the efficiency of the proposed scheme relies heavily on the hit ratio of K-hop PRREQ messages. [11] has presented an analysis of the effects of different design choices in caching strategies for reactive routing protocols in wireless ad hoc networks. As the proposed scheme uses route cache of neighbors within K hops, the hit ratio of K-hop PRREQ messages depends on caching strategy (i.e., choices of cache structure and cache replacement strategies based on the cache capacity and cache timeout) in each nodes. In our scheme, the proper caching strategy for the different network environments is applicable for enhancing the performance. In the environments that network traffic is concentrated on several nodes, for a example, caching policy that maintains the route which has been referenced from itself or neighbors frequently in certain time can improve the hit ratio of K-hop PRREQ compared to the policy which discard the route entries simply depending on the time when the route is obtained.

4 Performance Evaluation

To evaluate the efficiency of proposed scheme, we demonstrate the hit ratio of K-hop PRREQ and the number of nodes which participate in the route discovery process according to the fraction of active routes in network. In addition, we presented the result of energy consumed in the route discovery process as the number of flooding of route request messages. The proposed scheme is applied in AODV and DSR and implemented in C. 100 different networks are generated for 50 and 100 nodes, which are placed randomly with a density of 0.003 nodes/m^2. The transmission radius is set to 30m.

Random networks are the accepted model for explaining different kinds of networks. There are many algorithms and programs, however, the speed is usually the main goal, not the statistical properties. In the last decade the problem was researched by Waxman [12], Doar [13], Toh [14], Calvert et al. [15], and Kumar et al. [16]. They developed fast algorithms to generate random graphs with different properties, similar to real communication networks. However, none of them discussed the stochastic properties of generated random graphs. Rodionov and Choo [17] have formulated two major demands to the generators of random graph: attainability of all graphs with required properties and the uniformity of their distribution. If the second demand is sometimes difficult to prove theoretically, it is possible to check the distribution statistically. The random graph is similar to that used in real networks. The random networks used in this paper are generated by modifying Rodionov and Choo's mechanism to include the properties of ad-hoc networks.

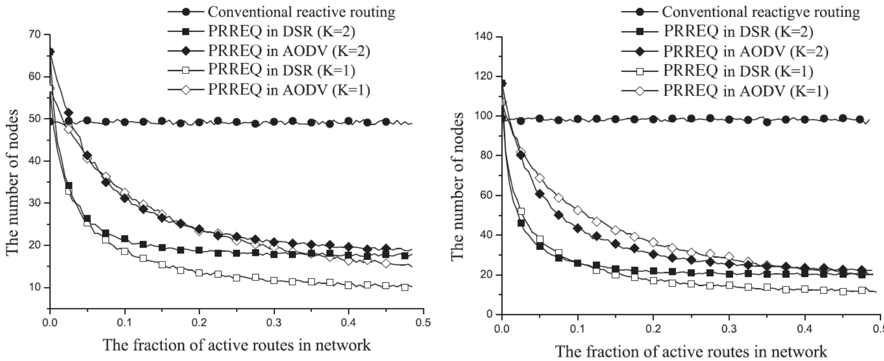
Fig. 3 shows the results for the variation of hit ratio of K-hop PRREQ messages according to increasing the number of active routes in the network. In AODV, intermediate nodes do not maintain the complete list of nodes in the route cache. However, as DSR uses the source routing technique, the hit ratio of K-hop PPREQ in the proposed scheme applied in DSR is higher than that applied in AODV. In the certain range, when the value of K is 2, the hit ratio is much higher than when the value of K is 1. However, when the number of active route in the network is small or very large, the gap is relatively small.



(a) Network with 50 nodes (b) network with 100 nodes

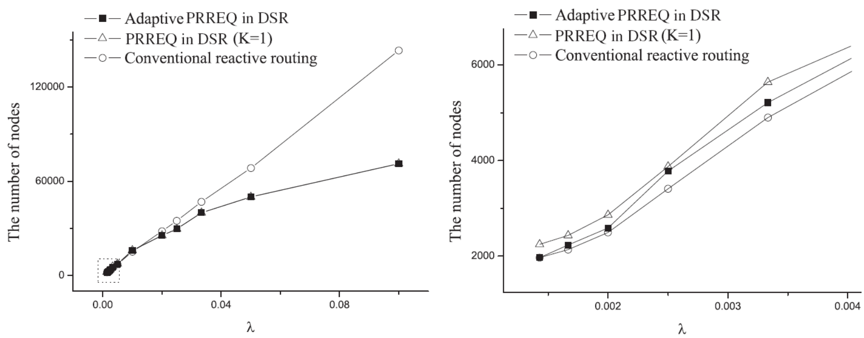
Fig. 3. The hit ratio of K-hop PRREQ according to the fraction of active routes in network

Fig. 4 presents the number of nodes that participate in the flooding of route request message when a node attempts to initiate a new route to the destination. When the number of active route is very small, using the K-hop PREEQ message is not efficient, considering the energy consumption of nodes in network. Using the 2-hop PRREQ message is more efficient than the 1-hop RREQ message only for a certain range.



(a) Network with 50 nodes (b) network with 100 nodes

Fig. 4. The number of nodes which participate in the route discovery process according to the fraction of active in network



(a) The number of flooding of route request at (0.01, 0.1) (b) The number of flooding of route request at (0.01, 0.035)

Fig. 5. The number of flooding of route request messages in the network within 600 sec according to variation of route initiating rate at each node

Fig. 5 shows the number of flooding of route request messages in the network, over a period of 600 seconds. Each node initiate a new route at a rate of λ. It is assumed that event interval follows an exponential distribution. Fig. 5(b) represents the dotted rectangle area of Fig. 5(a). When network traffic is very low, the proposed scheme is inefficient compared with traditional reactive routing. The adaptive scheme described in section 3.2 is able to improve the efficiency of the proposed scheme using K-hop RREQ messages in fixed way. The simulation results represented in Fig. 5(a) demonstrate that the energy consumed in the route discovery process is reduced approximately 27% compared to conventional reactive routing when the each node initiate a new route at a rate of 0.05/sec. In addition, the network traffic is higher; and the efficiency of the proposed scheme is significantly increased.

5 Conclusion

In this paper, we have proposed an energy efficient route discovery scheme. In traditional reactive routing protocols, the route request messages are flooded to all nodes in the network when a source node initiates new route. This route discovery process causes an increase of energy consumption, as well as a delay in route discovery and data transmission.

The proposed scheme uses K-hop PRREQ message, which is only flooded within K hop neighbors from the source node, thereby reducing the number of nodes that participate in the route discovery process. Performance evaluation demonstrates the efficiency of the proposed scheme compared to that of conventional reactive routing protocols.

Acknowledgments

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