

Using Location Information to Improve Routing in Ad Hoc Networks *

(A brief note)

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Abstract

In ad hoc network environments, any techniques to reduce high routing-related overhead are worth investigating. This brief note explains how to exploit location information to improve ad hoc routing. We also suggest some optimization approaches that can improve the performance of the protocol.

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1 Introduction

Many protocols for routing have been proposed for mobile wireless networks (also known as ad hoc or mobile mesh networks) [5, 6, 8, 9, 11, 12, 14, 16, 18]. As the hosts in such a network are mobile, an inherent drawback of these protocols (more precisely, drawback of the network) is that routing-related overhead tends to be high. Therefore, any techniques to reduce this overhead are worth investigating. In this brief note, we consider how to exploit location information to improve ad hoc routing.

2 Motivation and Related Works

Location information is important in mobile computing environments [17, 19]. While the idea of using location information with routing in ad hoc networks can provide significant gains, e.g. reducing a routing-related overhead, we are not aware of any significant works on this topic. Of course, using location information itself is not necessarily a novel idea, see, for instance, [10]. Dommety and Jain [7] briefly suggest use of location information in ad hoc networks, though they do not present any protocol description or elaborate on exactly how the information may be used.

Utilizing location information with ad hoc routing has a purpose similar to *selective paging scheme* in PCS (Personal Communication Service) networks [1] in that both are trying to reduce the overhead of wireless resources. In selective paging, the network pages a selected subset of the cells close to the last reported location of a mobile host only when the host needs to be located. This allows the location tracking cost to be decreased. We suggest using a similar approach in ad hoc routing.

3 How to use location information ?

With the availability of global positioning system (GPS), it is not unrealistic to expect a mobile host to know its (approximate) location. In this section, we assume that each host

knows its current location precisely (when the location is known only approximately, as would typically be the case, the ideas suggested here can be trivially extended).

To see how location information may be used, let us consider the dynamic source routing (DSR) protocol suggested by Johnson and Maltz[11]. In this protocol, say at time t_1 , when a source node S needs to locate a destination node D, it floods the network with a *route request* for the destination node. (The optimizations proposed in [11] to reduce the message overhead can be used in conjunction with the approach proposed here.) The route request packets are broadcasted into whole networks everytime a path between the source and destination needs to be found.

Now consider the possibility that node S had previously communicated with host D at time t_0 , where $t_0 < t_1$. During this communication, host S learned the current location of host D. Now, when S initiates a search of host D at time t_1 , host S can potentially predict the geographical region or the “expected zone” in which host D must reside – determining the expected zone requires some additional information regarding the host, such as its maximum speed and general direction of movement. Not all pieces of information are necessary, more information results in a smaller expected zone. For instance, as illustrated in Figure 1(a), if S only knows the maximum speed v of host D, then the expected zone will be a circle of radius $v(t_1 - t_0)$ centered around the location of D at time t_0 (recall that S knows this location). On the other hand, if S also knows that D is moving northward, then the expected zone can be reduced to a semi-circle (Figure 1(b)). (In absence of any information regarding D, the expected zone will span the entire network.)

How is S to use this “expected zone”? For instance, the dynamic source routing (DSR) protocol can be improved to reduce the propagation of route request packets. We suggest that, using the “expected zone”, host S determines a “request zone”. If a host outside the request zone receives a *route request*, then it simply discards the route request. Otherwise, the route request is propagated, similar to the original DSR algorithm. Each route request is assumed to include specification of the request zone and the destination identifies.

The request zone, at the minimum, must include the expected zone. However, typi-

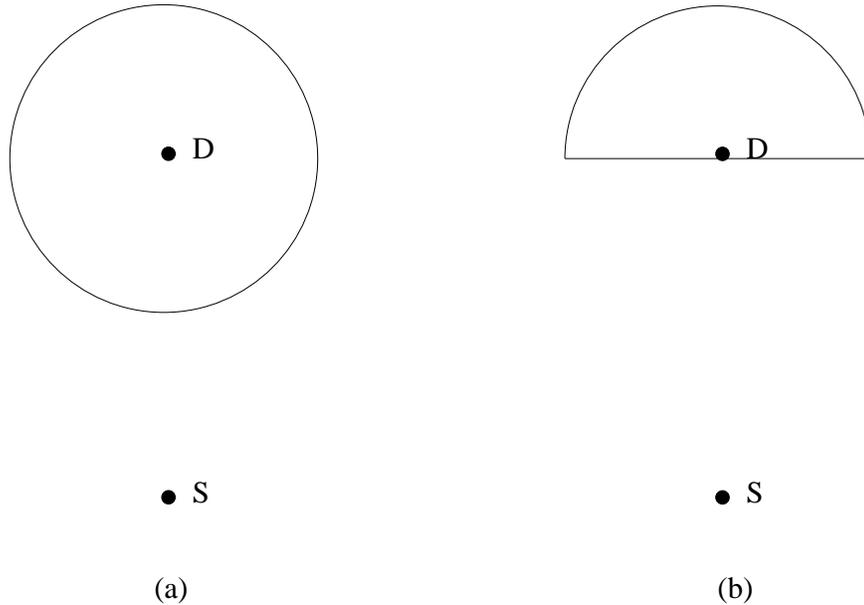


Figure 1: Examples of *expected zone*

cally, the request zone must also include additional region around the request zone. There are two reasons behind this, as follows:

- Consider Figure 1(a). As the expected zone (circular) does not include host S, a path from host S to host D must include hosts outside the expected zone. Therefore, additional region must be included in the request zone, so that S and D both belong to the request zone.
- Consider Figure 2(a). This figure shows a request zone, that includes the expected zone of Figure 1(a). Is this an adequate request zone? Perhaps not. In the example in Figure 1(b), all paths from S to D include hosts that are outside the request zone. Thus, there is no guarantee that a path can be found consisting only of the hosts in a chosen request zone. Therefore, if a route is not discovered within a suitable “time-out” period, the protocol should allow S to initiate a new route request with an expanded request zone (perhaps to include the entire network). In this event, however, the latency in determining the route to D will be longer (as two rounds of route request propagation will be needed).

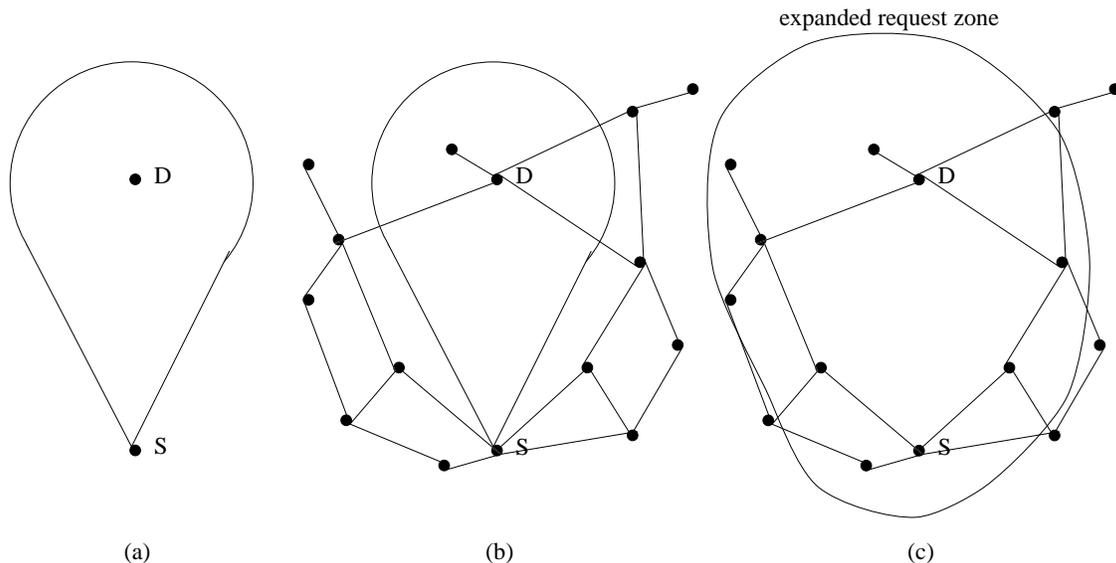


Figure 2: Request zone

Note that probability of finding a path can be increased by increasing the size of the request zone (for instance, see Figure 2(c)). However, route discovery overhead also increases with the size of the request zone. Thus, there exists a trade-off between latency of route determination and the message overhead.

4 Optimizations

4.1 Adaptation of Request Zone

Accuracy of a request zone (i.e., probability of finding a destination in the request zone) can be improved by adapting the request zone, initially determined by the source node S, with up-to-date location information for host D, which can be acquired at some intermediate nodes. Let us consider the case that node S starts search of a destination node D within a request zone Z at time t_1 , which is based on location information about D learned by S at time t_0 (Figure 3(a)). Let us assume that the *route request* includes a timestamp equal to t_0 because the location of node D at time t_0 is used to determine the request zone. Optionally, location of node S and the time when the request is originated may also be included. Now

suppose that some intermediate node I within Z receives the route request at time t_2 , where $t_1 < t_2$. Since I is located closer than S to D, more recent location information for D may be known by the node I (as compared to node S) and the expected zone based on that information may be different from previous request zone Z, as shown in Figure 3(b). The request zone initially determined at a source node may be adapted at an intermediate node. As illustrated in Figure 3(c), the adaptation is achieved by requiring node I to modify the request zone and the timestamp before forwarding the route request.

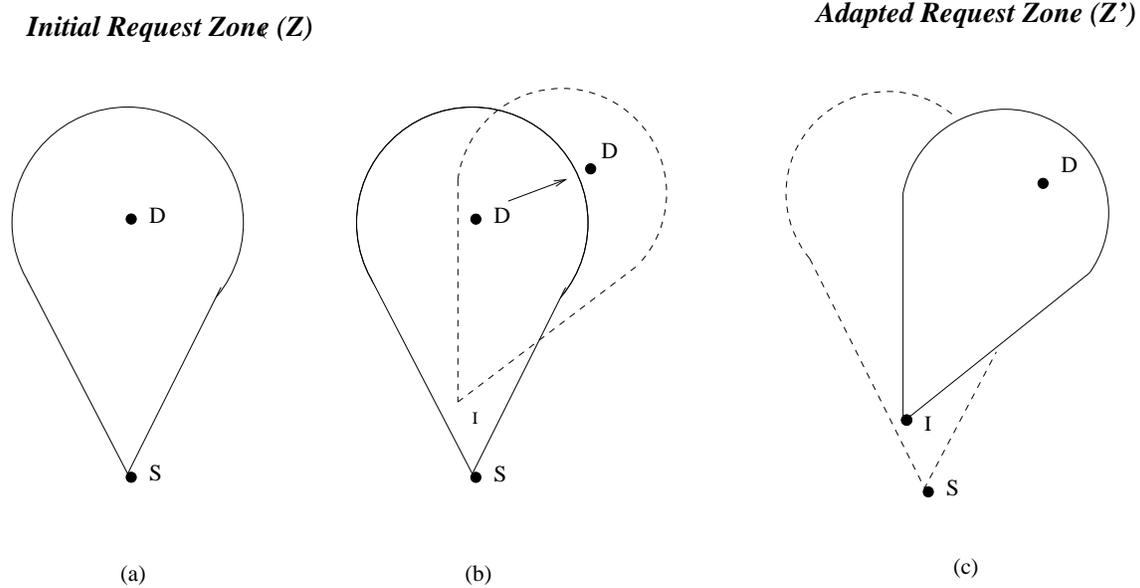


Figure 3: Adaptation Process of Request Zone

4.2 Propagation of Location Information

Initially, in ad hoc network environments, any node may not know the physical location (either current or old) of other hosts. However, as time progress, each node can get location information for many hosts either as a result of its own route discovery or as a result of message forwarding for another node's route discovery. That is, if all intermediate nodes (say, I) as well as a destination D put their location information on a *route reply packet* for a source S, the source S may be able to get information for all nodes on the route to D. Of course, any intermediate nodes I on a route also can know where the destination D is,

even without its own route discovery for D. If the source includes its location information in a *route request packet* for initially searching for D, this process lets D know about where source S resides. In general, location information may be propagated by piggybacking it on any message.

Local Search to Reduce Size of Request Zone

In DSR protocol, any intermediate node I detecting routing errors informs the source node S by generating *route error packet*. See Figure 4(a). Then, S initiates a “route discovery” again through the global search procedure to find a new path for a destination D whose location may be changed. This event causes significant control traffic, especially if topological change in an ad hoc networks is quite often. As we have already seen, if we use location information, this heavy control traffic can be somewhat reduced by limiting propagation of route request packets to the requested zone determined by the source at time t_i . However, since a *route error packet* has to reach by the source, there is still long delay to find a new route. Figure 4(c) shows how this scheme may be improved to reduce the size of request zone as well as latency of route re-determination for node D. This is possible by allowing any intermediate node I detecting route error (say, at time t_1) to initiate a route discovery toward a request zone based on its own location information of D at time t_0 , where $t_0 < t_1$. This may result in a smaller request zone (than at node S with a timestamp equal to t_2 , where $t_1 < t_2$, as shown in Figure 4(b)) because node I may be closer D than S. The time of finding a new path for D also can be reduced due to smaller request zone to be searched.

5 Using Location Information in Other protocols

The location information may be useful for other routing protocols also, particularly those having the characteristics of on-demand route discovery or flooding.

For instance, location information may be easily combined with the zone routing protocol (ZRP) [9]. ZRP is a hybrid reactive/proactive routing protocol in that each node always knows about locally who are its neighbor nodes by using proactive protocols (such as,

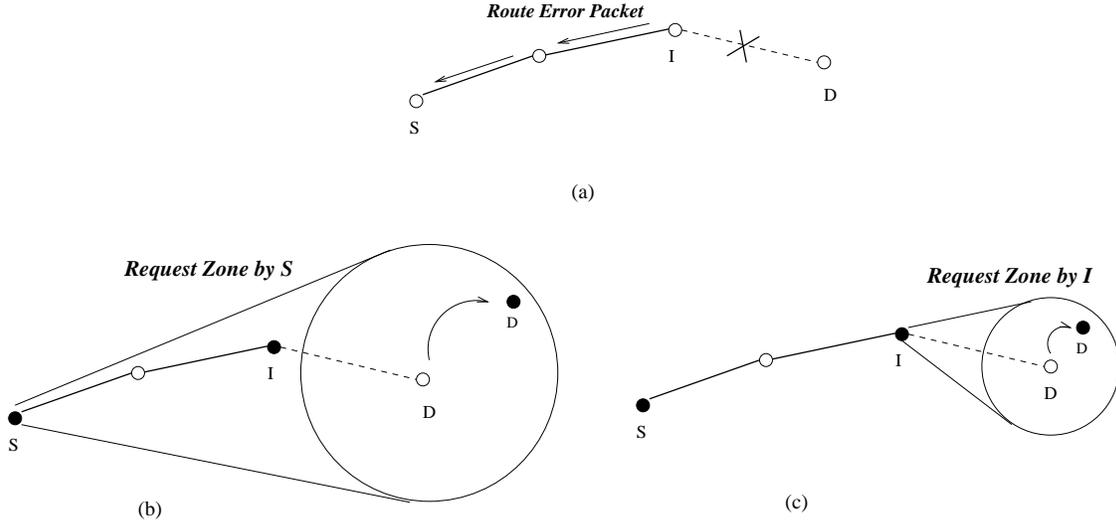


Figure 4: One example of propagating location information

the family of distance vector or shortest path first protocols [13, 15]), whereas global search using reactive protocols (also called on-demand [11, 14]) is done for non-neighbor nodes that are far from each other. If a node has location information about non-neighbor nodes requiring global search, that information can be useful for reducing the search overhead.

In ZRP, an area of the neighborhood for each node is called as “routing zone” of it. A “zone radius” which is some predefined number of hops is used to discriminate whether two nodes belong to the same routing zone or not. Clearly, the performance of the ZRP is dependent on the value of the zone radius. As authors pointed out in their report, this value should be larger in more stationary networks or very active networks with frequent query requests and, in highly mobile or low-active networks, the zone radius should be smaller. However, since each node has a different pattern of mobility in ad hoc networks, fixed and predefined hop counts seems not be good as the zone radius value. This is because, even though nodes are close enough with small number of hops, they do not always have to keep routing information for another if the frequency of communication with each other is relatively rare. Therefore, we can think of using location information to decide the zone radius value so that a routing zone may have different value of routing radius according to location information.

6 Performance Evaluation

In order to ensure our proposed scheme meets with expected intuitive results and to compare the relative performance of it, it will be evaluated using simulations. In the simulation using an event-driven network simulator, MaRS (Maryland Routing Simulator) [2, 3, 4], we will compare our proposed routing scheme utilizing location information with DSR. In particular, we expect to show that proposed protocol improves the efficacy of routing especially in case that the average mobility of the network is not too high.

7 Summary

This brief note describes how location information may be used to reduce the overall routing cost in ad hoc network. To explain how location information can be used, we consider the dynamic source routing (DSR) protocol suggested by Johnson and Maltz. DSR protocol can be improved by limiting propagation of *route request packets* to a “request zone” determined by the source which has ever communicated with a destination and might know about where it seemed to reside.

We also suggest some optimization approaches that can improve the performance of the protocol. We are continuing to study how location information can be used in other proposed routing protocols for ad hoc networks (such as TORA[14]). Finally, we are presently writing a simulation to evaluate our protocol.

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