Location-Aided Routing (LAR) in mobile ad hoc networks

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A mobile ad hoc network consists of wireless hosts that may move often. Movement of hosts results in a change in routes, requiring some mechanism for determining new routes. Several routing protocols have already been proposed for ad hoc networks. This paper suggests an approach to utilize location information (for instance, obtained using the global positioning system) to improve performance of routing protocols for ad hoc networks. By using location information, the proposed Location-Aided Routing (LAR) protocols limit the search for a new route to a smaller “request zone” of the ad hoc network. This results in a significant reduction in the number of routing messages. We present two algorithms to determine the request zone, and also suggest potential optimizations to our algorithms.

1. Introduction

Mobile ad hoc networks consist of wireless mobile hosts that communicate with each other, in the absence of a fixed infrastructure. Routes between two hosts in a Mobile Ad hoc NETwork (MANET) may consist of hops through other hosts in the network [7]. Host mobility can cause frequent unpredictable topology changes. Therefore, the task of finding and maintaining routes in MANET is nontrivial. Many protocols have been proposed for mobile ad hoc networks, with the goal of achieving efficient routing [6,9,11,13,16,18–20,23,28,30,31,33,35]. These algorithms differ in the approach used for searching a new route and/or modifying a known route, when hosts move.

In this paper, we suggest an approach to decrease overhead of route discovery by utilizing location information for mobile hosts. Such location information may be obtained using the global positioning system (GPS) [10,29]. We demonstrate how location information may be used by means of two Location-Aided Routing (LAR) protocols [19,20,22] for route discovery. The LAR protocols use location information (which may be out of date, by the time it is used) to reduce the search space for a desired route. Limiting the search space results in fewer route discovery messages.

This paper is organized as follows. Section 2 discusses some related work. In section 3, we describe proposed approach for using location information for route discovery in MANET. Performance evaluation of our protocols is presented in section 4, and several optimizations to our basic approach are described in section 5. Finally, section 6 presents conclusions.

2. Related work

Design of routing protocols is a crucial problem in mobile ad hoc networks [5,32], and several routing algorithms have been developed (e.g., [6,9,11,13,16,18–20,23,28,30,31,33,35]). One desirable qualitative property of a routing protocol is that it should adapt to the traffic patterns [7]. Johnson and Maltz [17,18] point out that conventional routing protocols are insufficient for ad hoc networks, since the amount of routing related traffic may waste a large portion of the wireless bandwidth, especially for protocols that use periodic updates of routing tables. They proposed using Dynamic Source Routing (DSR), which is based on on-demand route discovery. A number of protocol optimizations are also proposed to reduce the route discovery overhead. Perkins and Royer [31] present the AODV (Ad hoc On demand Distance Vector routing) protocol that also uses a demand-driven route establishment procedure. TORA (Temporally-Ordered Routing Algorithm) [27,28] is designed to minimize reaction to topological changes by localizing routing-related messages to a small set of nodes near the change. Hass and Pearlman [13] attempt to combine proactive and reactive approaches in the Zone Routing Protocol (ZRP), by initiating route discovery phase on-demand, but limiting the scope of the proactive procedure only to the initiator’s local neighborhood. Recent papers present comparative performance evaluation of several routing protocols [4,8].

The previous MANET routing algorithms do not take into account the physical location of a destination node. In this paper, we propose two algorithms to reduce route discovery overhead using location information. Similar ideas have been applied to develop selective paging for cellular PCS (Personal Communication Service) networks [1]. In selective paging, the system pages a selected subset of cells close to the last reported location of a mobile host. This allows the location tracking cost to be decreased. We propose and evaluate an analogous approach for routing in MANET. In a survey of potential applications of GPS,
Dommety and Jain [10] briefly suggest use of location information in ad hoc networks, though they do not elaborate on how the information may be used. Other researchers have also suggested that location information should be used to improve (qualitatively or quantitatively) performance of a mobile computing system [34,36]. Metricom’s Ricochet is a packet radio system using location information for the routing purpose [24]. The Metricom network infrastructure consists of fixed base stations whose precise location is determined using a GPS receiver at the time of installation. Metricom uses a geographically based routing scheme to deliver packets between base stations. Thus, a packet is forwarded one hop closer to its final destination by comparing the location of packet’s destination with the location of the node currently holding the packet. A routing and addressing method to integrate the concept of physical location (geographic coordinates), into the current design of the Internet, has been investigated in [14,25]. Recently, another routing protocol using location information has been proposed [3]. This protocol, named DREAM, maintains location information of each node in routing tables and sends data messages in a direction computed based on these routing (location) tables. To maintain the location table accurately, each node periodically broadcasts a control packet containing its own coordinates, with the frequency of dissemination computed as a function of the node’s mobility and the distance separating two nodes (called the distance effect). Unlike [3], we suggest using location information for route discovery, not for data delivery.

3. Location-Aided Routing (LAR) protocols

3.1. Route discovery using flooding

In this paper, we explore the possibility of using location information to improve performance of routing protocols for MANET. As an illustration, we show how a route discovery protocol based on flooding can be improved. The route discovery algorithm using flooding is described next (this algorithm is similar to DSR [17,18] and AODV [31]). When a node S needs to find a route to node D, node S broadcasts a route request message to all its neighbors—hereafter, node S will be referred to as the sender and node D as the destination. A node, say X, on receiving a route request message, compares the desired destination with its own identifier. If there is a match, it means that the request is for a route to itself (i.e., node X). Otherwise, node X broadcasts the request to its neighbors— to avoid redundant transmissions of route requests, a node X only broadcasts a particular route request once (repeated reception of a route request is detected using sequence numbers). Figure 1 illustrates this algorithm. In this figure, node S needs to determine a route to node D. Therefore, node S broadcasts a route request to its neighbors. When nodes B and C receive the route request, they forward it to all their neighbors. When node F receives the route request from B, it forwards the request to its neighbors. However, when node F receives the same route request from C, node F simply discards the route request.

As the route request is propagated to various nodes, the path followed by the request is included in the route request packet. Using the above flooding algorithm, provided that the intended destination is reachable from the sender, the destination should eventually receive a route request message. On receiving the route request, the destination responds by sending a route reply message to the sender—the route reply message follows a path that is obtained by reversing the path followed by the route request received by D (the route request message includes the path traversed by the request).

It is possible that the destination will not receive a route request message (for instance, when it is unreachable from the sender, or route requests are lost due to transmission errors). In such cases, the sender needs to be able to reinitiate route discovery. Therefore, when a sender initiates route discovery, it sets a timeout. If during the timeout interval, a route reply is not received, then a new route discovery is initiated (the route request messages for this route discovery will use a different sequence number than the previous route discovery—recall that sequence numbers are useful to detect multiple receptions of the same route request). Timeout may occur if the destination does not receive a route request, or if the route reply message from the destination is lost.

Route discovery is initiated either when the sender S detects that a previously determined route to node D is broken, or if S does not know a route to the destination. In our implementation, we assume that node S can know that the route is broken only if it attempts to use the route. When node S sends a data packet along a particular route, a node along that path returns a route error message, if the next hop on the route is broken. When node S receives the route error message, it initiates route discovery for destination D.

When using the above algorithm, observe that the route request would reach every node that is reachable from node S (potentially, all nodes in the ad hoc network). Using location information, we attempt to reduce the number of nodes to whom route request is propagated.

Dynamic source routing (DSR) [17,18] and ad hoc on-demand distance vector routing (AODV) [31] protocols proposed previously are both based on variations of flooding. DSR and AODV also use some optimizations—several of these optimizations as well as other optimizations sug-