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Routing with adaptive path and limited flooding for mobile ad hoc networks

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ABSTRACT

In MANET, each mobile host can freely move around and the network topology is dynamically changing. To send a datagram, a source host broadcasts a route discovery packet to the network. All neighboring nodes receiving this packet will rebroadcast this packet until it reaches the destination. It will have large flooding overhead, poor network performance and undesirable battery power consumption. To improve network performance, we design a novel routing protocol called RAPLF (Routing with Adaptive Path and Limited Flooding) for mobile ad hoc networks. Simulation results show that our protocol has better performance especially in packet delivery rate and flooding overhead when compared to similar protocols.

1. Introduction

Wireless is a new technology that allows users to access information and services regardless of the geographic position. People can utilize and surf the Internet with computers (e.g., laptop, palmtop, smart phone and PDA) whenever and wherever possible. In general, wireless network can be classified into two types: infrastructured network and ad hoc network. Infrastructured network consists of a network with fixed and wired gateways. A mobile host communicates with a bridge in the network (i.e., base station (BS) or access point (AP)) within its communication radius. The mobile host can move geographically while it is communicating. In contrast to infrastructure based network, all mobile hosts can be connected with one another dynamically in an arbitrary manner for an ad hoc network. All mobile hosts behave as routers and take part in the discovery and maintenance of routes to other nodes in the network. An ad hoc network is very useful for emergency search-and-rescue, as well as for meetings or conventions wherein people wish to quickly share information and make data acquisition while in an inhospitable terrain.

An ad hoc network creates many challenging research issues since the plan on how the routing should take place are often unclear. One type of ad hoc network is the mobile ad hoc network (MANET) [1]. A MANET is an autonomous group of mobile users who communicate through relatively bandwidth constrained wireless links. Since the hosts are mobile, the network topology may change rapidly and unpredictably over time.

Routing protocols for ad hoc networks [2–4] can be divided into two categories, namely the table-driven and the on-demand routing, based on when and how the routes are discovered. For the table-driven routing protocols, consistent and up-to-date routing information for all the mobile hosts are maintained at each mobile host. In the case of on-demand routing,

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the routes are created only when desired by a source host. Hence, for the table-driven protocols each mobile host maintains one or more tables containing routing information to every other mobile host in the network. All mobile hosts update these tables in order to maintain a consistent and up-to-date view of the network. When a network topology changes, the mobile hosts propagate the updated messages throughout the network in order to maintain the routing information about the whole network. These routing protocols differ in the method by which the topology change information is distributed across the network and in the number of routing-related tables. Examples of table-driven ad hoc routing protocols are the following: the Destination-Sequenced Distance-Vector (DSDV) [5–7] routing algorithm is based on the classical Bellman-Ford Routing Algorithm with certain improvements; the Wireless Routing Protocol (WRP) [8] is a table-based distance-vector routing protocol wherein each mobile host in the network maintains a distance table, a routing table, a link-cost table and a packet re-transmission list; the Global State Routing (GSR) [9] uses a link state routing but improves it by avoiding the flooding of routing messages; the Fisheye State Routing (FSR) [10,11] is an improvement of the GSR to reduce its update messages.

On-demand routing protocols take a lazy approach to routing. In contrast to the table-driven routing protocols, all up-to-date routes are not maintained at every mobile host. Instead, the routes are created whenever they are required. When a source host wants to send a datagram to a destination, it invokes the route discovery mechanism to find the path. An example is the Ad hoc On-demand Distance Vector Routing (AODV) [12], which is an improvement of the DSDV algorithm. AODV minimizes the number of broadcasts by creating routes on-demand as opposed to the DSDV which maintains a list of all the routes. The Dynamic Source Routing Protocol (DSR) [13] is another on-demand routing protocol. A mobile host maintains the route caches containing the source routes that it is aware of. The mobile host updates the entries in the route cache as soon as it learns about new routes. The Temporally Ordered Routing Algorithm (TORA) [14] is a highly adaptive, efficient and scalable distributed routing algorithm based on the concept of link reversal. TORA is proposed for highly dynamic mobile, multi-hop wireless networks. It is a source-initiated on-demand routing protocol.

On-demand routing protocols have two drawbacks. First of all, when performing route discoveries, flooding of route request packets consumes too much of the bandwidth. Secondly, when a route is established, it is never modified unless it is broken. As a result, an inferior route might be used due to the node's mobility. In the present paper, we propose a routing protocol with an adaptive routing path and limited flooding. This protocol is called RAPLF (Routing with Adaptive Path and Limited Flooding). RAPLF limits the flooding by selecting some nodes to do the broadcast. As soon as the routing path is constructed, RAPLF monitors it constantly in order to detect any possible route improvement in the number of hops. Simulation results showed that our proposed protocol can increase the packet delivery rate and decrease the number of control packets when compared to other routing protocols.

Previously, MPR (Multi-Point Relaying) [15–23] techniques have been proposed to reduce the control packets. A technique for improving the routing path was proposed in [24,25] and is called the Self-Healing and Optimizing Routing Technique (SHORT). To utilize the concepts of MPR and SHORT, we proposed the RAPLF routing protocol for mobile ad hoc networks. RAPLF not only reduces flooding in ad hoc networks but automatically tries to keep the shortest path in order to improve network performance. The new protocol can reduce flooding packets and shorten the path length. Simulation results showed that our proposed protocol has a higher packet delivery rate and lower control packets.

The remainder of the present paper is organized as follows: Section 2 discusses the related protocols. Section 3 presents our proposed protocol starting with the search for a route discovery and all the way to route optimization. Section 4 describes the assumptions for the simulation, the simulation environment, and the simulation results. The last section presents the conclusions of the study.

2. Related works

2.1. Ad hoc on-demand distance vector routing (AODV)

Ad Hoc On-Demand Distance Vector Routing (AODV) was proposed by Perkins and Belding-Royer [12] in 1999. AODV is a real on-demand protocol wherein no routes are discovered or maintained until they are needed. The routing table for AODV contains the next-hop routing information. AODV uses the idea of a route-sequence to guarantee that the mobile hosts are not presented with stale routes. Sequence numbers can be thought of as a "virtual time" wherein the higher numbered sequences occurred at a latter time as compared to the lower numbered sequences. Sequences are maintained on a per destination host basis, so that the only useful comparison of sequence numbers is between those whose corresponding paths have the same destination host. The destination host in the route contains the authoritative sequence number for the route as time progresses, while the network topology changes as the sequence number goes higher.

If a source host does not have a path to a destination when it wants to send a datagram to that destination, it broadcasts a route request (RREQ) packet starting from a small Time-To-Live (TTL) value for the RREQ, and increases it if the destination is not found. Any mobile host that receives the RREQ packet updates its next-hop table entries with respect to the source host. AODV uses the RREQ ID and source address to ensure that the RREQ packet is unique and that all the routes are loop-free. When a mobile host receives the RREQ packet and has a route to the destination with a higher sequence number as compared to the one specified in the RREQ packet or the destination host itself, it sends back a route replay (RREP) packet to the source host. If a mobile host receives extra RREQ packets containing the same broadcast ID and source address, these packets are dropped. When receiving the RREP packet, each intermediate mobile host along the RREP routes updates or inserts its routing table entries with respect to the destination host.

2.2. Multi-point relaying (MPR)

The concept of multi-point relaying is to reduce the number of redundant re-transmissions when forwarding a broadcast message in the network. The MPR [17,19,20] mechanism restricts the set of mobile hosts which need to re-transmit a route request packet. The size of this subset depends on the topology of the network. Multi-Point Relaying sets (MPR-sets) are selected mobile hosts which forward broadcast messages during the flooding process. In this process, the MPR tries to minimize the flooding traffic and each mobile host can build a minimum spanning tree consisting of all the neighboring nodes. This technique substantially reduces the message overhead as compared to a classical flooding mechanism wherein every mobile host re-transmits each message when it receives the first copy of the message.

In multi-point relaying, a mobile host is selected by its one-hop neighbor, node v_M, to re-transmit all the broadcast messages it receives from v_M, provided that the message is not a duplicate and the lifetime field of the message is greater than one. Each mobile host in the network selects a set of nodes in its one-hop neighborhood which can re-transmit its messages. This set of selected neighbor nodes is called the MPR-set of that mobile host. If the neighbors of the mobile host are not part of its MPR set, they can receive and process broadcast messages but cannot re-transmit broadcast messages received from the mobile host.

Each mobile host selects its MPR set from among its one-hop neighbors. This set is selected in such a way that it covers (in terms of radio range) strictly all two-hop nodes. The MPR-set of the mobile host is an arbitrary subset of the one-hop neighborhood of the mobile host which satisfies the following condition: every mobile host in the strictly two-hop neighborhood of the mobile host must have a link to the MPR-set. The smaller the MPR-set is, the lesser the control of traffic overhead resulting from the routing protocol. Each mobile host maintains the information about the set of neighbors that are selected as its MPR. A mobile host obtains this information from the periodic hello messages received from the neighbors.

An example is shown in Fig. 1a of a mobile host which broadcasts a hello message and includes a neighbor node list. If node ***S*** is a source host after the exchange of hello messages, then it would find that the mobile hosts ***a***, ***b***, ***c*** and ***f*** are in the one-hop region of source host ***S***, and that the mobile hosts ***d*** and ***e*** are in the two-hop region. In this case, the mobile hosts ***a***, ***c*** and ***f*** are in the one-hop region and can also transmit to the two-hop region's nodes. But mobile host ***a*** can transmit to mobile hosts ***c*** and ***d***, mobile host ***c*** can transmit to mobile hosts ***a***, ***d***, ***e*** and ***f***, and mobile host ***f*** can transmit to mobile hosts ***c***, ***d*** and ***e***. Hence, the source host ***S*** can select mobile host ***c*** to act as the MPR-set as shown in Fig. 1b.

2.3. Self-healing and optimizing routing techniques for mobile ad hoc networks (SHORT)

SHORT [24,25] improves routing optimality by monitoring routing paths continuously and gradually redirects the route towards what is currently better. SHORT optimizes the route since routing optimality affects the ad hoc network performance and energy consumption especially when the loading is high. When using the SHORT, all the neighboring nodes monitor the whole route and try to optimize it. It tries to determine a short-cut on the route and updates the route accordingly. Thus, SHORT enhances performance in terms of bandwidth and latency with some additional cost in route monitoring.

SHORT is a general technique which should work with any underlying routing protocol. It can monitor the built route, try to identify the short-cut on the route, and update the topology. In order to monitor the built route, each packet needs to carry a "hop-count (*hop_cnt*)" field in its header. The *hop_cnt* field is initialized to zero at the source host and gets an increment of one at every hop that the packet takes. For every packet, the destination address (*dst_addr*), source address (*src_addr*), and the *hop_cnt* can be obtained from the packet header. This information is maintained as an array which is referred to as the hop-compared cache. The format of each entry in the cache is <*src_addr*, *dst_addr*, *hop_cnt*, *neig_addr*>, where *neig_addr* is the neighbor's address from which the packet was broadcasted. Each of the elements of the cache has an expiration period beyond which they are invalidated. If the cache becomes full with valid entries, the new entries can replace the older entries.

Fig. 2a shows an original path from source to destination. But in the case of the ad hoc network, all mobile hosts are always moving, so that the path becomes more like the one shown in Fig. 2b. In Fig. 2b, the source host ***S*** needs to forward a

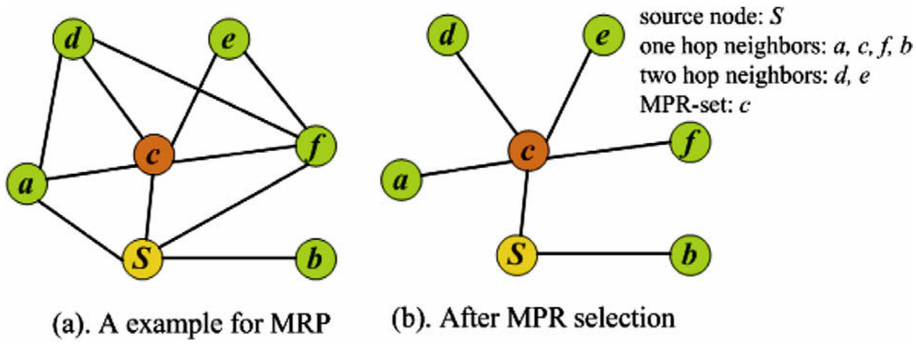

Fig. 1. MPR selection.