An Improved Location-Aided Routing Protocol for Mobile Ad Hoc Networks with Greedy Approach

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Abstract: - A mobile ad hoc network (MANET) is a dynamically reconfigurable wireless network that does not have a fixed infrastructure. Due to the high mobility of nodes, the network topology of MANETs always changes. This makes it more difficult to find the routes that message packets use when they are routed. In this paper, we propose an efficient greedy location-aided routing (GLAR) scheme to improve the efficiency of location-aided routing (LAR) scheme for MANETs. In this scheme, we first decide a baseline, which is the line between the source node and the destination node, for route discovery. The request packet is broadcasted in a request zone based on the baseline to determine the next broadcasting node. The neighboring node with the shortest distance to the baseline is chosen as the next broadcasting node. We also propose a partial reconstruction process that maintains a routing path. When a node on a routing path finds that a link is broken, the node starts the process of routing maintenance. Simulation results show that the proposed GLAR can reduce the control overhead and increase the route lifetime than LAR.

Key-Words: - Expected zone, Global positioning system, Location-aided routing, Mobile ad hoc networks, Request zone.

1 Introduction

A mobile ad hoc network (MANET) is a dynamically reconfigurable wireless network that does not have a fixed infrastructure [14]. Host mobility can cause unpredictable network topology changes. Therefore, the task of finding and maintaining routes in MANETs is very important. Many routing protocols have been proposed for MANETs to achieve efficient routing [1, 3, 4, 5, 6, 7, 8, 11, 13, 15, 20, 24].

In general, the routing protocols of MANETs can be divided into two classes: table-driven routing protocols and on-demand routing protocols. In table-driven routing protocols [8, 16, 17, 18, 21, 22, 25, 26], every node continuously maintains the complete routing information of a network. When a node needs to forward a packet, a route is readily available. The most popular table-driven protocols are DSDV [22] and OLSR [8]. In on-demand routing protocols [3, 9, 19, 23, 27], mobile nodes maintain path information for destinations only when they need to contact the source node or relay

packets. The source node will issue a search packet and transmit the packet using the flooding technique to look for the destination node. The most popular on-demand protocols are AODV [23] and DSR [9]. Hybrid routing protocols [6, 7, 20] are a combination of table-driven and on-demand routing strategies. The most popular hybrid protocol is ZRP [7].

Recently, many routing protocols in MANETs use the global positioning system (GPS) [2, 10, 12] for assistance. The coordinates of each node can be known by using GPS. Furthermore, the route process can be completed discovery bv mathematically calculation to determine the routing path. Thus, the routing protocols can reduce the overhead amount effectively. There are many applicable GPS routing protocols [1, 11, 13, 15], such as zone-based hierarchical link state (ZHLS) 15], hierarchical cellular-based management for mobile nodes in wireless ad hoc networks [1], location-aided routing (LAR) [11], and full location-aware routing protocol (GRID) [13]. ZHLS [15] divides a MANET geographic area into several zones. Through a GPS receiver, each mobile node knows its current position and thus its zone ID. LAR [11] uses selective flooding to exploit location information when searching for a route.

In this paper, we propose a routing scheme that uses the global positioning system (GPS) to improve the efficiency of location-aided routing. In this scheme, we first decide a baseline, which is the line between the source node and the destination node, for route discovery. The request packet is broadcasted in a request zone based on the baseline to determine the next broadcasting node. The neighboring node with the shortest distance to the baseline is chosen as the next broadcasting node.

The rest of this paper is organized as follows. Section 2 presents the preliminaries of this work. The proposed scheme is developed in Section 3. Simulation results are given in Section 4. Finally, concluding remarks are made in Section 5.

2 Preliminaries

In this section, we first introduce the expected zone and the request zone. Then we describe the technology used in the global positioning system (GPS). Finally, we present the location-aided routing (LAR) protocol [11].

2.1 Expected Zone and Request Zone

We assume that a source node *S* needs to find a route to destination node *D*. We also assume that node *S* knows the position of node *D* at location *P* at time t_0 and that the current time is t_1 . If node *S* knows the velocity of node *D*, then the extent that node *D* moves about can be anticipated by the formula $v(t_1 - t_0)$. Example of an expected zone is shown in Fig. 1.



Fig. 1. Example of an expected zone.

We also assume that node S needs to determine a route to node D. S utilizes broadcasts to deliver packets. The request zone should embrace the expected zone. When S is not embraced in an expected zone of D, S needs to deliver packets to D by way of a path that involves many other nodes. Furthermore, these nodes are not in the expected zone, either. Therefore, the request zone must embrace additional ranges. As shown in Fig. 2(a), we give an example of request zone. We suppose that the expected zone does not include the source node, a path from the source node to the destination node must include nodes outside the expected zone. Fig. 2(b) shows a request zone that the source node cannot transmit data to the destination node. The probability of finding a path can be increased by increasing the size of the initial request zone. However, route discovery overhead also increases with the size of the request zone. A larger request zone is shown in Fig. 2(c).



Fig. 2. Examples of request zone. (a) A request zone. (b) A request zone that the source node cannot transmit data to the destination node. (c) A larger request zone.

2.2 Global Positioning System (GPS)

Here, we briefly review some ways to identify the location of a device. The easiest way is perhaps through the global positioning system (GPS), which is a worldwide, satellite-based, radio navigation system [22, 23]. The system consists of 24 satellites in six orbital planes operating in a circular 10900 nautical mile (20200 km) orbit at an inclination angle of 55 degrees with at 12-hour periods. Operating on the L-band frequencies (1575.42 MHz and 1226.6MHz), GPS can be used anywhere near the surface of the Earth. Satellites on the sky transmit navigation messages containing their orbital elements, clocks, and statuses, which can be used by a GPS receiver to determine its position and thus, roaming velocity. Three satellites are necessary to determine the receiver's longitude and latitude, and four the receiver's altitude. More satellites can increase the accuracy of the readings of the position of a receiver, with an error which is typically in the range of a few tens of meters. To improve accuracy, assistance from ground stations can be applied. Such systems, called differential GPS (DGPS), can reduce the error to less than a few meters [25].

2.3 Location-Aided Routing (LAR)

In this section, we introduce the location-aided routing (LAR) protocol [11]. As shown in Fig. 3, LAR uses a request zone that is a rectangle. Suppose that the source node $S(x_s, y_s)$ knows the location of node $D(x_d, y_d)$ at time t_0 . At time t_1 , the source node S initiates a new route in order to discover the destination.

Furthermore, we assume that if *S* knows the velocity of *D*, node *S* can point to an expected zone at time t_1 . Then the radius of the expected zone is $r = v(t_1 - t_0)$ and the center is located at *D* (x_d , y_d).

The LAR scheme determines a request zone. This request zone contains the source node S and the expected zone. The sides of the rectangle are parallel to the x-axis and the y-axis. The source node S depends on the expected zone to determine the four corners of the request zone. Node S includes their coordinates with the route request message transmitted when the route discovery is initiated. When a node receives a route request, it discards the request if the node is not within the request zone. For instance, if node I receives the route request from another node, node I forwards the request to its neighbors because it is located in the request zone. However, when node J receives the route request, node J discards the request, as node J is not within the request zone.





3 Greedy Location-Aided Routing (GLAR)

In this section, we propose a routing scheme to improve the efficiency of location-aided routing (LAR). In the proposed scheme, the request packet can be broadcasted in a request zone based on the baseline that is the line between the source node and the destination node. The baseline is used to determine the next broadcasting node. The next broadcasting node will be chosen as close as possible to the line of sight. An example of a baseline is shown in Fig. 4.

We assume that the source node is $S(x_s, y_s)$ and that the destination node is $D(x_d, y_d)$. Based on the LAR scheme, we assume that we already know the coordinates of D. Then we can determine the baseline by using the following equation.

$$(x_d - x_s)(y - y_s) - (y_d - y_s)(x - x_s) = 0 \qquad .$$
(1)



Fig. 4. An example of a baseline.

3.1 Route Discovery

The route discovery process is initiated whenever a source node needs to communicate with another node for which it has no routing information in its table. Every node maintains two separate counters: a node sequence number and a broadcast ID. The source node initiates route discovery by broadcasting a route request (RREQ) packet to its neighbors. The RREQ packet format is shown in Fig. 5.

1	Туре	Reserved	Hop Count
2	Broadcast ID		
3	Destination ID		
4	Destination sequence number		
5	Source ID		
6	Source sequence number		
7	Request zone		
8	Source location information		
9	Destination location information		

Fig. 5. RREQ packet format.

The pair <Source ID, Broadcast ID> uniquely identifies a RREQ. The broadcast ID is incremented whenever the source node issues a new RREQ. When an intermediate node receives a RREQ, if it has already received a RREQ with the same broadcast ID and source address, it discards the redundant RREQ and does not rebroadcast it.

Eventually, if possible, a RREQ will arrive at a node (possibly the destination itself) that possesses a current route to the destination. If an intermediate node has a route entry for the desired destination in its table, it determines whether the route is current by comparing the destination sequence number recorded in its table to the destination sequence number in the RREQ. If the RREQ's sequence number for the destination is greater than that recorded in the intermediate node, the intermediate node will not use the recorded route to respond to the RREO. Instead, the intermediate node rebroadcasts the RREQ. The intermediate node can reply only when it has a route with a sequence number that is greater than or equal to that contained in the RREQ. If it does have a current route to the destination, and if the RREQ has not been processed previously, the node then unicasts a route reply (RREP) packet back to its neighbor from which it received the RREQ. The RREP packet is shown in Fig. 6.

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1	Туре	Reserved	Hop Count	
2	Destination ID			
3	Destination sequence number			
4	Source ID			
5	Source sequence number			

Fig. 6. RREP packet format.

In the following, we introduce two parameters of the GLAR, *DIST* and *VDIST*. An example of *DIST* and *VDIST* is shown in Fig. 7.

 $DIST_A$: The distance between the source node and node *A*.

 $VDIST_A$: The distance from node A to the baseline.



The route discovery process is described as below. First, the source node broadcasts the RREQ packet. After the neighboring nodes receive the RREQ packet, the neighboring nodes will decide whether they are in the request zone and reply with a route request revise (RREQ_R) packet to the transmitting node. The RREQ_R packet format is shown in Fig. 8. The transmitting node will compare the *VDIST* of all neighboring nodes. Then the transmitting node to be the node with the shortest distance to the baseline. Furthermore, the *DIST* of each candidate node for the next broadcasting node is larger than that of the current broadcasting node. This guarantees that the node chosen as the next broadcasting node will always be far from the source node.

1	Туре	Reserved
2		VDIST
3		DIST
4		My ID

Fig. 8. RREQ_R packet format.

As shown in Fig. 7, when node *A* receives the RREQ from source node *S*, node *A* will calculate the distance between the source node and itself, denoted as $DIST_A$. Moreover, node *A* will calculate the distance from the node to the baseline, denoted as $VDIST_A$. We assume that the baseline is ax+by+c=0. Then $VDIST_A$ can be obtained from the following equation:

$$VDIST_{A} = \left| \frac{ax_{A} + by_{A} + c}{\sqrt{a^{2} + b^{2}}} \right|$$
(2)

The detailed route discovery process is shown in Algorithm 1 and the steps of route discovery are described below.

- Step 1: First, source node *S* broadcasts a RREQ packet to its neighboring nodes. When a node receives the RREQ packet, the node will decide whether they are in the request zone and reply with the RREQ_R packet to the transmitting node. The source node *S* will compare *DIST* and *VDIST* of all neighboring nodes. Then the neighboring node which is the nearest to the baseline will be chosen as the next broadcasting node.
- Step 2: We assume that node *N* has been chosen to be the next broadcasting node. Node *N* keeps broadcasting the RREQ packet to its neighboring nodes. Suppose that the neighboring nodes are node *A* and node *B*. Node *N* will compare the *DIST* of node *N* (*DIST_N*) with the *DIST* of node *A* (*DIST_A*) and with the *DIST* of node *B* (*DIST_A*), respectively. We assume that the *DIST* of node *A* and node *B* are greater than that of node *N*. In addition, if the *VDIST* of node *A*

is smaller than that of node B, the neighboring node A will perform the succeeding actions. This ensures that the RREQ packet will proceed further away from source node S. In addition, If node Nhas a route entry for the desired destination in its table, it determines whether the route is current by comparing the destination sequence number recorded in its table to the destination sequence number in the RREQ. If the RREQ's sequence number for the destination is greater than that recorded in node N, node N will not use the recorded route to respond to the RREQ. Instead, node N rebroadcasts the RREQ. If the above-mentioned conditions are all met, repeat Step 2. When the destination node Dreceives a RREQ packet, destination node D sends a RREP packet to the source node S along the decided path.

Algorithm 1: Route Discovery Process

Suppose *n* is the total number of mobile nodes and N is the set of mobile nodes, $N = \{N_1, N_2, N_3, ..., N_n\}$. Assume that the source node N_i wants to find a path to the destination node N_j , and node N_t received the routing information, where $1 \le i, j, t \le n$ and $i \ne j$.

if (node N_t is in the request region) {

if (node N_t is the destination node N_i)

- {
 - (1) Node N_t sends a RREP packet on reverse path.
 - (2) Each node receives the RREP packet to write the entry into the current routing table.
 - (3) Node N_i starts to send data.

}

else {

- (1) Node N_t forwards a RREQ_R packet to the transmitting node.
- (2) The transmitting node compares the *DIST* of all neighboring nodes.
- if (there is one or more neighboring nodes whose *DIST* are larger than the *DIST* of the transmitting node)

{

(1) The transmitting node compares the *VDIST* of all neighboring nodes and chooses the node with minimum *VDIST* value.

(2) Node N_t with minimum *VDIST* value performs the broadcasting actions.

} else

Node N_t performs the broadcasting actions.

```
}
}
```

else

Node N_t discards the RREQ packet.

Let us consider an example, as shown in Fig. 9(a). Node *S* broadcasts a RREQ packet to its neighboring nodes, and it is observed that the

neighboring nodes of *S*, such as nodes *A*, *B*, *C*, and *E*, are all in the request zone. When the four nodes receive the RREQ packet, the four nodes will reply with a RREQ_R packet to the transmitting node.

The transmitting node will compare the *VDIST* of all neighboring nodes. Suppose that node *A* is found to be the nearest node to the baseline *SD*. Then node *A* will continue broadcasting the RREQ packet. As shown in Fig. 9(b), to meet the requirements of route discovery, node *A* will keep broadcasting the RREQ packet and find the node that is nearest to the baseline.



Fig. 9. Route discovery of GLAR scheme. (a) Step 1. (b) Step 2.

3.2 Route Maintenance

Because of the high mobility of nodes, links between nodes are likely to break. Thus, we need to maintain the routing path. Route maintenance is usually classified into full reconstruction and partial reconstruction. In full reconstruction, a node will break the path when it does not receive a RREP packet. In this case, the node sends a route error (RERR) packet to the source node. When the source node receives the packet, it will reconstruct a new path to the destination node. Full reconstruction requires more control overhead to rebuild a routing path. In partial reconstruction, a node will break the path when it does not receive a RREP packet. In this case, the node will find a replacement route, making it unnecessary for it to send anything back to the source node. Because the replacement node is closer to the destination node than the original source node, routing overhead can be reduced. Therefore, partial reconstruction spends less on overhead than full reconstruction.

In this paper, we also propose a partial reconstruction method to maintain a routing path. When a node finds that a path is broken, the node starts the process of routing maintenance. It will directly broadcast a RREQ packet. There is no need to return to the source node for rebroadcast.

The detailed route maintenance process is shown in Algorithm 2 and the steps of the route maintenance are described below.

Step 1: We assume that node N is chosen to be the transmitting node. When node N finds out that a link is broken, node N will send a RERR packet.

Step2: Node *N* restarts the route discovery process and rebuilds a backup path. If it does not find a replacement node, node *N* sends a RERR packet to the source node and restarts the route discovery process.

Algorithm 2: Route Maintenance Process

Suppose *n* is the total number of mobile nodes and *N* is the set of mobile nodes, $N = \{N_1, N_2, N_3, ..., N_n\}$. Assume that the source node is N_i and the destination node is N_j , and node N_t receives the routing information, where $1 \le i, j, t \le n$ and $i \ne j$.

if (node N_t can not transmit data to the next node in the selected path)

{

(1) Node N_t sends the RERR packet.

(2) Node N_i receives the RERR packet.

(3) Node N_i stops sending the data.

(4) Node N_t restarts the route discovery process.

} else

Node N_t continues to send the data.

As an example shown in Fig. 10, we assume the link between node A and node I was broken. When node A finds that the connection between node I and itself was broken, node A will start to rebroadcast the requirements of the RREQ packet. It does not reply to the source node S for rebroadcasting. Node A finds the replacement node H for broadcasting. Thus, the overhead and the number of packets in the routing process can be efficiently reduced.



Fig. 10. Route maintenance process of the GLAR scheme.

4 Simulation Results

In this section, we will compare the performance of the proposed GLAR with that of LAR using the results from our simulations. We first made some assumptions on the parameters of the system architecture in the simulations. The simulation modeled a network in a 600 m \times 600 m area with 30 mobile nodes. The speed of each mobile node was assumed to be 20-80 km/h. The radio transmission range was assumed to be 100 m. The random waypoint mobility model [9] was employed in our simulations. Each node randomly selects a position and moves toward that location with a speed between the minimum and the maximum speed. Once it arrives at that position, it stays for a predefined time. After that time, it re-selects a new position and repeats the process. The simulations have been run for 600 s.

The simulations evaluated the control overhead, the routing lifetime, and the packet delivery ratio with different number of mobile nodes and mobility speeds. The control overhead is the ratio of control packets generated to the total data packets generated by the source. The control packets include RREQ, RREP, and RERR packets. The route lifetime is the average time per connection. The packet delivery ratio is the ratio of the number of data packets received by the destination to the number of data packets transmitted by the corresponding source.

Fig. 11 shows the control overhead of GLAR and LAR with different speeds. The control overhead of GLAR is lower than that of LAR. The reason is the same as that given above. In general, both the control overhead of GLAR and LAR increased when the speed increased. The reason is that when the speed of the mobile nodes was faster, there was more of a chance that the related routes would break. In addition, the number of rebroadcasts would increase. Therefore, the control overhead was higher.

Fig. 12 shows the route lifetime of GLAR and LAR with different speeds. Both the route lifetime of GLAR and LAR decreased when the speed increased. The reason is that when the speed of the mobile nodes was faster, there was more of a chance that the related routes would break.

Fig. 13 shows the packet delivery rate of GLAR and LAR with different speeds. The packet delivery rate of LAR was larger than that of GLAR when the number of mobile nodes increased. The reason is the same as that given above. In general, both the packet delivery rate of GLAR and LAR decreased when the speed increased. The reason is that when the speed of the mobile nodes was faster, there was more of a chance that the related routes would break.



Fig. 11. Control overhead vs. mobility speed of mobile nodes.



Fig. 12. Routing lifetime vs. mobility speed of mobile nodes.



Fig. 13. Packet delivery rate vs. mobility speed of mobile nodes.

5 Conclusions

In this paper, we proposed an efficient greedy location-aided routing (GLAR) scheme that improves the efficiency of location-aided routing (LAR). In this scheme, we first decide a baseline, which is the line between the source node and the destination node, for route discovery. The request packet is broadcasted in a request zone based on the baseline to determine the next broadcasting node. The neighboring node with the shortest distance to the baseline is chosen as the next broadcasting node.

We compare the performance of GLAR and LAR. In our simulations, we conducted the control overhead, the routing lifetime, and the packet delivery rate with different mobility speeds. Simulation results show that the proposed GLAR can reduce the control overhead and increase the route lifetime than LAR.

Acknowledgments

This work was supported by the National Science Council of Republic of China under grant NSC-97-2221-E-239-024.

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