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GFDA: Route Discovery Algorithms for On-demand Mobile Ad Hoc Routing Protocols

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Abstract

Route discovery in many mobile ad hoc protocols is based on flooding. However, flooding suffers from high overhead, which can increase contention and communication delays. In this paper, we propose two new route discovery algorithms that are aimed towards reducing these delays. Both algorithms are suitable for use with ad hoc protocols where nodes periodically broadcast Hello Messages. Using the GloMoSim simulator, the proposed algorithms were evaluated and compared to existing methods. The simulation results show that the proposed approach can reduce routing overhead, number of broken links, average delay, and the number of dropped packets. Small improvements in message delivery ratios are also observed.

Keywords:
Mobile Ad Hoc Networks, AODV, OLSR, DSR, Ad Hoc Routing Protocols.

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1. Introduction

In recent years, the use of mobile devices in various applications has increased. A main reason for this increase has been the progress made in wireless networks research. Mobile ad hoc networks (MANETs) are an important class of wireless networks that allows their nodes to move freely. Nodes in a MANET can exchange data directly if they are within the same radio range, and when they are far apart they exchange data through other nodes. Thus, a node in a MANET acts both as a communication end and a router. Because MANETs have limited radio communication bandwidth and use battery power, their protocols, including the routing protocols, must be efficient in the use of bandwidth and energy. A major way to conserve bandwidth and energy is reducing control overhead [1] [2] [3]. There are two classes of ad hoc routing protocols, the proactive and the on-demand protocols. In the proactive routing protocols, a node typically maintains a local routing table that has an entry for each destination in the network. Route-update messages are propagated periodically throughout the network, so as to update table routing information. This control traffic can cause substantial overhead, increasing network congestion, lowering message throughput and increasing

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battery power consumption. Examples of proactive routing protocols are the Optimized Link State Routing (OLSR) protocol [4] [5] [6] and the Destination-Sequenced Distance-Vector Routing protocol (DSDV) protocol [7] [8] [9]. In contrast, route discovery in on-demand routing protocols is initiated by a source node only when it needs a route to some destination. "Flooding" is used mainly to achieve route discovery. A source node broadcasts a route discovery control message when it needs to, and intermediate nodes that receive such message re-broadcast it. A common restriction to flooding is that a node re-transmits a given route discovery request message only once and duplicates of a route request message are ignored [10]. This type of flooding is used, for example, in Dynamic Source Routing (DSR) protocol [11] [12], Ad Hoc on Demand Distance Vector (AODV) protocol [13] [14] [15], and Zone Routing Protocol (ZRP) [7] [16].

In this paper, we propose a scheme to restrict route discovery flooding in on-demand routing algorithms. To this end, we present two limited-flooding route discovery algorithms. In both algorithms, a node periodically broadcasts a 'Hello Message' that contains a list of its neighbors. Thus, a node periodically receives a list of neighbors for each of its neighbors. The remainder of the paper is organized as follows. In Section 2, we present the proposed route discovery methods. In Section 3, we present and discuss the simulation results. Finally, Section 4 concludes the paper.

2. Proposed Route Discovery Methods

Several MANET protocols have been proposed to the Internet Engineering TaskForce (IETF)-MANET working group. These include Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR), and Topology Broadcast based on Reverse-Path Forwarding (TBRPF) [17] [18]. In this paper, we compare our proposed route discovery schemes to AODV [7], due to its low overhead and maturity [19]. In AODV, a source node initiates route discovery when it needs to communicate with a destination for which it does not have a route. Route discovery is initiated by the source node broadcasting a route request message (RREQ) that contains a request ID. If a node receives a RREQ that it has received previously, it drops the request. Otherwise, it stores the address of the node from which it received the request. In this manner, a reverse route to the source is established. If the RREQ reaches the destination node or a node that has a route to the destination, the node sends a route reply message (RREP) to the source. Intermediate nodes that do not have a path to the destination re-broadcast the request when they receive it for the first time. As the RREP is sent back to the source, each node stores the address of the node that sent the reply. The forward path determined from the source to the destination is used for sending packets to the destination. AODV uses sequence numbers maintained for the different destinations so as to guarantee freshness of routing information. AODV nodes offer connectivity information by broadcasting local Hello messages. If a node has not sent a broadcast within a specified time interval, it broadcasts a Hello message. Thus, a node can have a local table that contains all of its neighbors. Such a table is, for example, available in release 2.02 of GloMoSim [20] [21] [22], which was used here.

A problem with the route discovery methods of current on-demand routing protocols, such as DSR and AODV, is that they use flooding. Nodes re-broadcast route request messages that they receive, however they limit the number of these messages only by not re-transmitting route request messages received more than once. To reduce this route discovery overhead further, we propose two techniques that are based on constrained flooding. Our goal is reducing the number of route request broadcasts by giving preference to successively propagating a route request via neighboring nodes that have the largest number of neighbors.

2.1. Greedy Flooding via Dense Areas (GFDA)

The basic idea of GFDA is to determine, at each step, a routing set that includes a number of neighboring nodes that have the largest number of neighbors. It is assumed that a node maintains a neighbors-table, and that the table entry for a neighboring node contains a list of the neighboring node's neighbors and their number. Also, the table contains the time at which a node became neighbor and the degree of the neighbor node. The degree of a node is the number of its neighbors (i.e., if the node x has 12 neighbors then the degree of x = 12). When two or more neighbors have the same degree, the newest among them is selected for membership in the routing set.

Each node builds its neighbors-table using information contained in periodic Hello Messages and other broadcasts from neighbors. A neighbor's table entry contains the neighbor's network address, degree, timestamp, and a list of its neighbors. Once a source node requires a route to a destination, a route request message that contains the routing set is broadcast. If a receiving node is in the routing set received with a route request, it computes the next routing set and re-broadcasts the request, together with this next routing set. Otherwise, the receiving node ignores the request. The GFDA algorithm is:

1. Start with an empty routing set, (RS = Ø).
2. From the set of immediate (1-hop) neighbors, select up to three neighbors that have the largest degrees. If two or more of these neighbors have the same degree, choose the most recent one first.
3. Using the neighbors-table, compute the number of 2-hop neighbors (N2), that are not covered by the 1-hop neighbors in RS.
4. If N2 is greater than a predefined threshold value, add up to two 1-hop neighbors that satisfy the conditions: a) the selected nodes are not in RS, and b) The selected nodes cover the largest number of 2-hop neighbors.

The predefined threshold value was determined by trying N2=5, N2=7, N2=8 and N2=9, where the best coverage was obtained for N2=8.

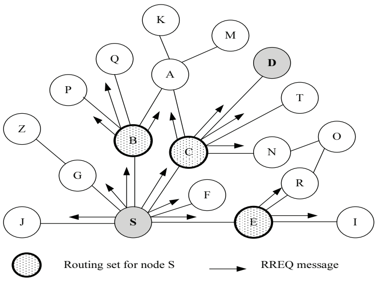


Fig. 1. GFDA example Route Request (RREQ) from source (S) to destination (D).

The example in Figure 1 shows a RREQ from the node S to the node D. Node S broadcasts the RREQ message to the neighbor nodes (J, G, B, C, F, and E) and the RREQ includes the routing set for node S (shown shaded). Each neighbor node checks if it is in the routing set. The routing set members broadcast the message to their neighbors which are 2-hop neighbors of S. The remaining nodes discard the message (see Table 1 and Table 2).

Table 1. The degree of the nodes

Neighbor	B	C	F	E	G	J
Degree	4	5	1	3	2	1

Table 2. Selecting the routing set for the node S

Node	1 Hop Neighbors	2 Hop Neighbors	RS
S	J,G,B,C,F,E	Z,P,Q,A,D,T,N,R,I	B,C,E

2.2. *Greedy Flooding via Dense Areas using Flooding (GFDAF)*

A problem with GFDA is that a destination may not be reached after all. The routing sets selected may not lead to the destination of the route discovery operation. To address this problem, GFDAF attempts flooding if the GFDA route discovery operation times out. That is, if the source for the route discovery operation does not receive a reply within a specified timeout period. The details of GFDAF algorithm are the same as GFDA with one added step. The added step is: *Broadcast the RREQ message from all nodes, as in flooding and ignoring the routing set.* Below is the algorithm of our technique.

Algorithm 1 Route Discovery Alogorithm

```
INPUT: Source node, destination node.
OUTPUT: A route from the source node to the destination node.
Set Routing set (RS)= $\emptyset$.
for each neighbor do
    Calculate the degree of the source node neighbors (1-hop).
end for
Add three neighbors that have the highest degree.
if two nodes have the same degree then
    select the most recent one.
end if
Compute the (2-hop) neighbors (N2) are not covered by RS.
if N2 $\geq \beta$ then
    Add add two neighbors to RS that cover the largest number of N2.
end if
Broadcast the route request through the RS
```

3. Simulation Model and Results

There are many simulators for ad hoc networks such as NS2, OPNET and GloMoSim. We use GloMoSim [2], as it provides flexibility in determining the simulation environment. Our chosen simulation environment is stated in Table 3.

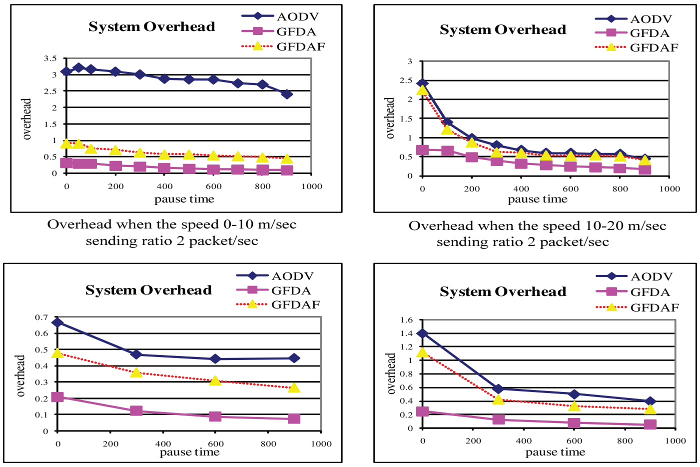
Table 3. Simulation environment

Factor	Value
Area	600 meters × 2200 meters
Number of nodes	100
Number of sources	20
Simulation time	900sec
Packet sending ratio	2 packets/sec and 4 packets/sec
Movement speed	0-10 m/s and 10-20m/s
Radio frequency	250 meters
Pause time	0-100-200-...-900s

The simulation results show substantial performance improvement. The proposed algorithms reduce the overhead, the number of broken links, the average delay, the number of dropped packets number, and battery usage. Also, they increase the delivery ratio for moderate movement [20].

Overhead

The simulations show good improvement in the amount of overhead associated with the GFDA and GFDAF protocols in comparison to AODV, as can be seen in Figure 2. The figure shows that the overhead for AODV is very high and GFDA decreases the overhead by more than 75%. The main reason for the lower overhead in GFDA is that not all the nodes rebroadcast the message, causing the number of the control messages to be reduced. Note that the overhead is calculated by dividing the number of control messages by the number of all messages. In addition, the graphs show that GFDAF overhead is fairly low, compared to AODV, but higher than GFDA. This result comes from the additional time in using flooding in case that GFDA could not reach the distention.



Overhead when the speed 0-10 m/sec
sending ratio 2 packet/sec

Overhead when the speed 10-20 m/sec
sending ratio 2 packet/sec

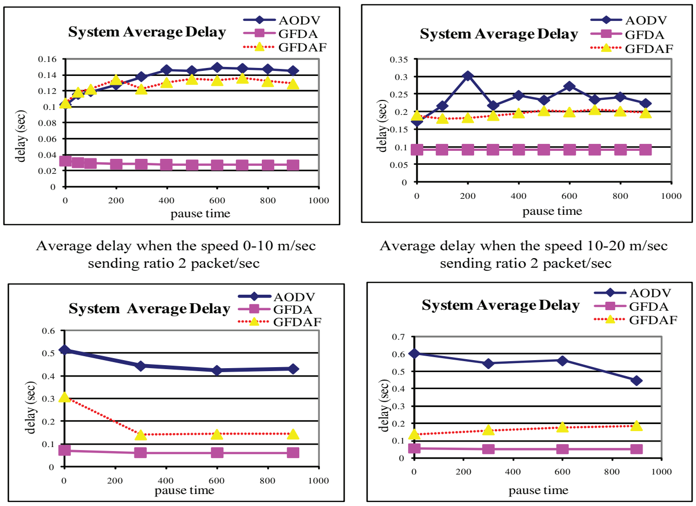
Overhead when the speed 0-10 m/sec
sending ratio 4 packet/sec

Overhead when the speed 10-20 m/sec
sending ratio 4 packet/sec

Fig. 2. System overhead in relation to time

Average Delay

The average delay of GFDA in comparison with other protocols is shown in Figure 3. The graphs show that the average delay of packets is slightly better for GFDAF than for AODV, with GFDA having a huge advantage over the others because it does not have any sort of flooding. We can see that when the speed or sending ratio are changed, GFDA behaves the same in terms of producing the lowest average delays. This is because the neighbors table and routing set get updated.



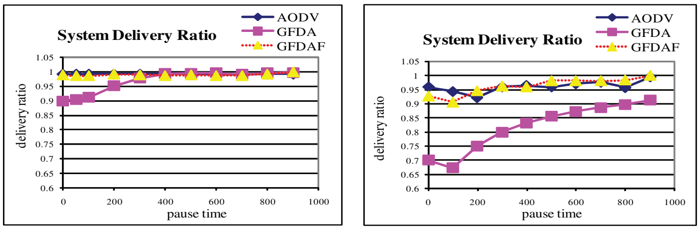
Average delay when the speed 0-10 m/sec
sending ratio 2 packet/sec

Average delay when the speed 10-20 m/sec
sending ratio 2 packet/sec

Average delay when the speed 0-10 m/sec
sending ratio 4 packet/sec

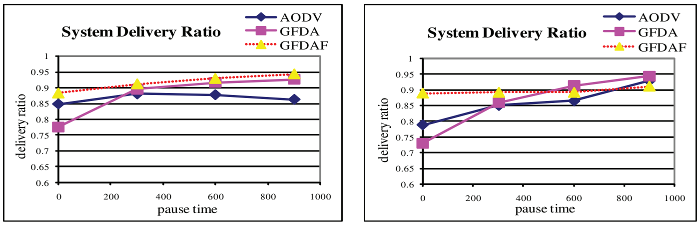
Average delay when the speed 10-20 m/sec
sending ratio 4 packet/sec

Fig. 3. Average system delay in relation to time



Delivery ratio when the speed 0-10 m/sec
sending ratio 2 packet/sec

Delivery ratio when the speed 10-20 m/sec
sending ratio 2 packet/sec



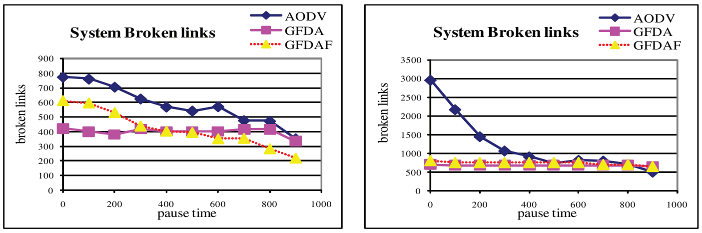
Delivery ratio when the speed 0-10 m/sec
sending ratio 4 packet/sec

Delivery ratio when the speed 10-20 m/sec
sending ratio 4 packet/sec

Fig. 4. System delivery ratio in relation to time

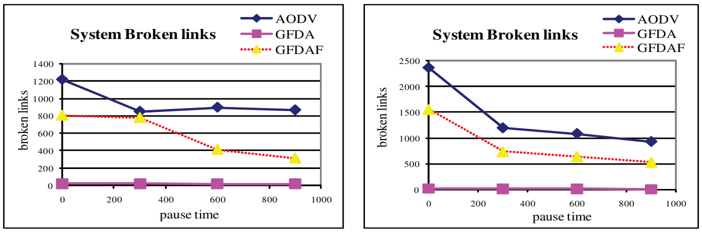
Delivery ratio

The next comparison is for the delivery ratio (Figure 4), which is defined as the number of received packets divided by the number of packets sent. The graph shows the GFDAF protocol to have the highest delivery ratio. This is because GFDA sometimes cannot reach the destination, which means a decrease in the delivery ratio.



Broken links when the speed 0-10 m/sec
sending ratio 2 packet/sec

Broken links when the speed 10-20 m/sec
sending ratio 2 packet/sec



Broken links when the speed 0-10 m/sec
sending ratio 4 packet/sec

Broken links when the speed 10-20 m/sec
sending ratio 4 packet/sec

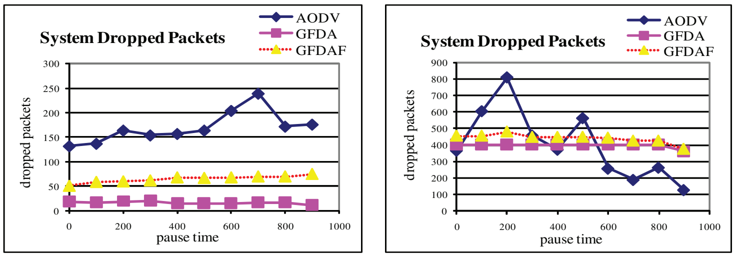
Fig. 5. System broken links in relation to time

Broken links

The simulation results for broken links (source to destination channel) are shown in Figure 5. We can see that GFDAF is very stable for sustaining a connection. It outperforms AODV. When we increase the sending ratio, the links become stable and the number of broken links is close to zero. Also, every time we update the routing set, we notice that there are some nodes disappeared from the network. However, in GFDA we update the routing set, so when the system needs to send a message through the network the nodes should be available.

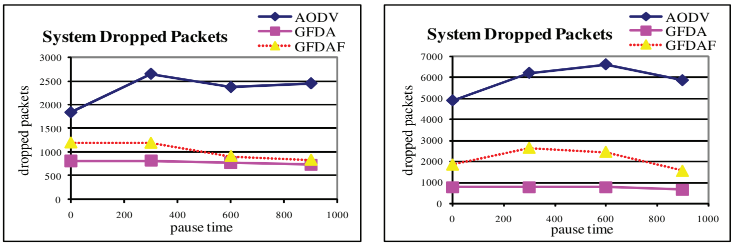
Dropped packets

The results for dropped packets (see Figure 6) show that GFDAF is pretty consistent as to the amount of dropped packets throughout the duration of the simulation time, while the AODV protocol drops the least number of packets, but it has very high fluctuations compared with the other two protocols.



Dropped packets when the speed 0-10 m/sec
sending ratio 2 packet/sec

Dropped packets when the speed 10-20 m/sec
sending ratio 2 packet/sec



Dropped packets when the speed 0-10 m/sec
sending ratio 4 packet/sec

Dropped packets when the speed 10-20 m/sec
sending ratio 4 packet/sec

Fig. 6. Dropped packets in relation to time

4. Conclusion

MANET nodes can search for routes to target nodes that are out of their range by flooding the network with broadcast messages. Alternatively, routing tables can be periodically updated in table-driven routing policies. Within these classes of ad hoc routing approaches lie different sorts of problems, which make them inefficient and leave room for improvement. The problems range from excessive flooding overhead to frequent routing table updates. Both increase network congestion and energy consumption. The challenge is laid forth by these problems to find better algorithms to address the discussed inadequacies which arise with ad hoc routing protocols. We proposed a solution for addressing these problems in this paper.

Our proposed algorithms (GFDAF and GFDA) find connections that have a low number of broken links, high delivery ratio, and a consistent and low number of dropped packets. Moreover, GFDA exhibits excellent packet delay values while GFDAF has adequate ones. In addition, in our algorithms we reduce the network overhead by reducing the number of control messages in the network. GFDAF has the ability to always reach its destination which is not always the case for GFDA. In essence and based on the results of extensive simulation results, the GFDA protocol and its extension GFDAF are advantageous, as compared with existing protocols considered in this paper.

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