Efficient Fisheye State Routing Protocol using Virtual Grid in High-Density Ad-Hoc Networks

Ting-Hung Chiu  
Dept. of Computer Science and Engineering  
Yuan Ze University  
Email: frei@mmlab.cse.yzu.edu.tw

Shyh-In Hwang  
Dept. of Computer Science and Engineering  
Yuan Ze University  
Email: shyhin@cs.yzu.edu.tw

Abstract—Fisheye state routing protocol improves traditional link-state routing in the MANET. By adopting the idea of GRID in FSR, we proposed an efficient GRID-based Fisheye state routing protocol (GFSR). GFSR provides the advantage of less control message exchange and more bandwidth to transmit data. A hierarchical architecture is used in GFSR. A gateway is elected in each grid and is the only node in the grid to exchange control messages and data packets with other grids. Substantial bandwidth can be saved in this way. Simulation shows that GFSR is more efficient than FSR, especially in high-density networks.

Keywords—Mobile Ad hoc Network, GRID, FSR, Link-State Routing

I. INTRODUCTION

An ad hoc network works without infrastructure. Thus, it usually applies to temporary networks or wherever is difficult to build infrastructure. It turns out that a message should be delivered from node to node across a number of hops in an ad hoc network. Therefore, an efficient routing protocol can help message exchanging in an efficient way. There are many protocols designed for different purposes such as shortest path, energy consumption, etc. Existing routing protocols can be classified into categories such as reactive, proactive and hybrid schemes.

The reactive routing protocol is also called the "on-demand" routing protocol. In this class of protocols, a mobile node broadcasts discovery packets when routing is needed and maintains a temporary routing table. Reactive routing protocols can save the message overhead for maintaining routing tables. Ad Hoc On-demand Distance Vector (AODV) [1] and Dynamic Source Routing (DSR) [2] are examples of reactive routing protocols. On the other hand, the proactive routing protocol is called the "table-driven" routing protocol. Mobile nodes need to maintain routing tables by exchanging routing information. To ensure the correctness of routing tables, the mobile nodes exchange the routing information periodically or broadcast the update information when the topology is changed. The advantage of proactive routing is low end-to-end latency, but it generates many update messages in a highly dynamic network environment. A hybrid routing protocol integrates proactive and reactive routing and is a better choice in some cases, such as Zone Routing Protocol (ZRP) [3] and Landmark Routing for Large Ad Hoc Wireless Networks (LANMAR) [4].

Furthermore, recent routing protocols [6][7] take advantage of location information to find the destination. Location information is gathered with global positioning system (GPS) [5] receiver and can be used to limit flooding. Location Aided Routing (LAR) [6] is a well-known routing protocol which uses location information to reduce the search space for discovering the routing path. In GRID [7], location information is used to partition the geographic area of MANET into logic grids and performs routing in a grid-by-grid manner. The GPS-related applications are quickly gaining popularity and bring out many location-related routing schemes.

Link-state routing is one of the most important protocols proposed for traditional wire networks. It periodically broadcasts routing messages to maintain the correct routing table. However, ad hoc networks have different characteristics from traditional wire networks, such as dynamic topologies, multi-hop communication, decentralized operation, constrained bandwidth and energy, etc. Traditional link-state routing may generate too many control messages in a highly mobile environment. To alleviate the problem, in fisheye state routing (FSR) [8], a node exchanges routing information more frequently with its nearer nodes, and less frequently with farther nodes. Although fisheye state routing could reduce control message overhead, the bandwidth usage is still inefficient when the node density is high. By integrating the mechanism of GRID [7] into FSR, only fewer mobile nodes called gateways should be responsible for exchanging update messages and routing. It can reduce message overhead further. In this paper, we proposed a virtual grid-based routing protocol called GFSR to make communication more efficiently under highly-density environment.

The rest of this paper is organized as follows: First of all, we make a brief survey on GRID and FSR in section II. In section III, we describe how GFSR works. Section IV presents the performance evaluation and section V concludes the paper.
II. RELATED WORK

A. GRID: A Fully Location-Aware Routing Protocol for Mobile Ad hoc Networks (GRID)

GRID is a two-level hierarchical reactive routing protocols. The main idea of GRID is that a geographic area is partitioned into several logic grids and the gateway election is held in each grid. A number of mobile nodes may exist in each grid. However, when gateway election has finished, a single mobile node called gateway in each grid will take responsibility for route discovery and forwarding messages. Its advantage is that significantly less routing cost is incurred in GRID than in other reactive routing protocols. Only gateways will relay messages for the route discovery. If a gateway node crashes or leaves the network, a new gateway election will be held and a newly elected gateway will take over. Although GRID needs some messages to keep correctness of grid operations, it still brings the advantages of less control message overhead and more stable routing path.

B. Fisheye State Routing (FSR)

FSR[8] is similar to Link State (LS) routing. A topology table is maintained at each node. The main difference is the method of updating the routing table. Link state routing broadcasts the update messages to the whole network, while in FSR, the routing information is disseminated. The control messages can be reduced by adopting different periods for exchanging update messages. Fisheye state routing protocol uses the “fisheye” technique proposed by by Kleinrock and Stevens [9] to reduce the size of information required to represent graphical data. The eye of a fish captures with high detail the pixels near the focal point. The detail decreases as the distance from the focal point increases. Based on this idea, mobile nodes exchange update messages more frequently with nearer mobile nodes, and less frequently with farther nodes. The accuracy of the nodes information depends on how far a node is. The node information is more accurate if it is nearer, while the node information becomes less accurate if it is farther. In other words, path information appears to have progressively less detail as the distance increases. However, the imprecise route path will be corrected by each forwarding node on the route path. The route becomes progressively more accurate as the packet gets closer to destination. Therefore, FSR can reduce control overhead but does not seriously compromise the routing accuracy.

III. GRID BASED FISHEYE STATE ROUTING PROTOCOL

A. Basic idea

GRID-Based Fisheye State Routing (GFSR) Protocol is an extension to Fisheye State Routing. By adopting the idea of GRID into Fisheye State Routing, fewer forwarding nodes can lower the cost of control messages and can save bandwidth for data transmission. This makes transmission more efficiently, especially in high-density networks. In high-density networks, many collisions may occur. When there are more nodes existent in the radio transmission range, more interference will occur. If the number of forwarding nodes in a certain square can be reduced, less interference and collisions occur and more bandwidth can be saved.

B. GRID architecture

We assume that each node in ad hoc networks has installed a GPS[5] receiver. Through GPS devices, nodes can easily derive their location information. The geographic area of an ad hoc network is partitioned into two dimensional virtual grids and each grid has its unique coordinate number (x,y). As illustrated in Fig. 1, each node can calculate in which grid it currently dwells based on the physical location information derived from GPS.

Initially, a gateway election is held in each grid, where a gateway is the node responsible for maintaining the routing table in its grid, and for exchanging routing information using fisheye state routing scheme. The node nearest to the physical center of a grid is a good candidate as a gateway. The grid length in GRID architecture can be set in a such way that the transmission range of each gateway can effectively cover its eight neighbor grids. Therefore, any mobile node knows the gateways of its eight neighbor grids. As illustrated in Fig. 2, the black-dotted nodes denote gateways and the large gray circle represents the transmission range of node B.
C. Information update scheme

According to FSR, a parameter SCOPE is used to define the set of nodes that can be reached within a given number of hops. The routing update interval is divided into two parts named intra update interval and inter update interval. If the distance of hops is greater than SCOPE, the inter update interval is used. Otherwise, the intra update interval is used. The inter update interval is longer than the intra update interval. In other words, the update frequency of the intra scope is higher than that of the inter scope. A gateway sends inter update messages to its neighbor nodes based on the inter update interval. Inter update messages contain updates from nodes whose distance is greater than SCOPE. The similar procedure is performed based on the intra update interval. While the update messages are received and processed by all neighbor nodes in FSR, in our protocol, the update messages will be only processed by its neighbor gateways, which are its eight neighbor gateways in most cases. For example, assume that there are fifty nodes in a square. Therefore, all of the fifty nodes need to exchange routing information in this square in FSR. However, there are only eight gateways responsible for exchanging routing information in our method. Hence, the collision problem is more serious in FSR. The bandwidth is also consumed much more to update the routing information in FSR. When data packets are to be transmitted, they need to compete with the routing control messages. The problem becomes more serious especially in high-density networks. However, in our method, messages can be reduced significantly by employing fewer forwarding nodes using virtual grid scheme.

D. Routing scheme

Using the routing information which is exchanged periodically, each gateway maintains a routing table as in Fig. 3. When a node needs to transmit data, it checks whether it is a gateway or not. If it is a gateway, it transmits data to next hop by checking its routing table. If it is a non-gateway node, it just sends data to its gateway, and then the gateway will take over to forward the message to next hop. The gateways along the routing path will check the destination and determine who the next hop should be. When a packet approaches nearer to its destination, the routing information stored in the gateways becomes progressively more accurate. Packets finally arrive at the grid of destination node. If destination is a gateway, the packet is received by that gateway. Otherwise, the gateway forwards the packet to the destination node in its grid.

Fig. 3. Each gateway maintain its own routing table.

IV. Performance Evaluation

The proposed GFSR protocol is implemented using GloMoSim[10] simulator. The performance is measured according to (a) control message overhead, (b) path length, and (c) delivery ratio. The result of control message overhead is shown in Fig. 5. In this experiment, the network consists of 100, 200, 300 and 400 nodes roaming randomly in a 1000 x 1000 meter square. The radio transmission range is 250 meters. The random waypoint model was used. The node moving speed ranges from 0 to 50 km/hr. Since all nodes are required to exchange routing information in FSR, the control overhead grows rapidly with the number of nodes in the network.

A. Control message overhead

In GFSR, the control overhead can be reduced substantially. If there are n grids, there are at most n nodes need to exchange routing information. The control messages are exchanged periodically. Therefore, in Fig.5, control message overhead only grows slowly. Note that the message overhead still increases with the number of nodes. The reason is that there are messages used to maintain the grid architecture. More nodes need more maintenance messages. The category of control message overhead is illustrated in Fig. 6.
B. Path length

As illustrated in Fig. 7, grid-based architecture such as GFSR induces longer route path. The original route discovery method using broadcasting can find a best route path. However, in grid-based architecture, the routing path is constructed from gateway to gateway. Those gateways may not be the best next hop. Hence, it sometimes leads to a longer path. Besides, non-gateway nodes should transmit data packets to its gateway and should receive data packets from its gateway. This is another reason causing longer path. In this experiment, we use different square sizes for simulation to measure the effect of longer path. One- or two-hop length may be increased for different square sizes. Generally, the increased length does not grow significantly with the square size.

C. Delivery ratio

The final experiment consists of a 1000 x 1000 meter square. The node mobility is lowered and ranges from 0 to 10 km/hr. In the fixed square area, the number of nodes increases from 50, 75, 100, 125, 150, 175 to 200. The density of network increases with the number of nodes accordingly. The result of delivery ratio is illustrated in Fig. 8. In FSR, all nodes should exchange routing information in different density environments. When density grows, bandwidth is used to exchange more and more routing packets. At the same time, GFSR has a fixed number of gateways in the square. Hence, control messages were restricted to a limited extent. The bandwidth can be saved to transmit data packets. Therefore, when the density of networks increases, delivery ratio of FSR becomes lower and lower. On the contrary, the delivery ratio keeps high when using GFSR scheme. Thus, the bandwidth can still be efficiently utilized when network becomes highly crowded.

V. CONCLUSION

In this paper, we proposed a new routing scheme called GFSR. At the cost of a little longer routing path, GFSR provides a highly efficient solution with lower control message overhead and fewer routing nodes which are responsible for exchanging routing information. In high-density environments, our method exhibits low interference and fewer collisions and it leads to more efficient communication among mobile nodes.

REFERENCES