

# Fisheye Zone Routing Protocol for Mobile Ad Hoc Networks

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**Abstract**—Zone Routing Protocol provides a flexible solution for discovering and maintaining routes in the MANET. By adopting the idea of Fisheye State Routing in ZRP, a more efficient protocol called *Fisheye Zone Routing Protocol (FZRP)* was proposed in the paper. FZRP provides the advantage of a larger zone with only a little increase of the maintenance overhead. Two levels of routing zone are defined in FZRP: the basic zone and the extended zone. Different updating frequencies of changes of link connectivity are associated with the basic zone and extended zone. Simulation study has shown that FZRP is more efficient than ZRP in terms of route finding cost with only a little increase of the maintenance overhead.

**Keywords**—MANET; Routing; ZRP; Fisheye;

## I. INTRODUCTION

A *mobile ad hoc network* (MANET) [1] is a collection of wireless mobile nodes that cooperatively form an autonomous system that operates without the support of any fixed network infrastructure. MANET has been proposed for a variety of goals such as providing a communication platform in hostile or disaster-stricken areas. Networking mechanisms such as routing protocols for MANETs require high efficiency because of limited resources in a mobile node such as network bandwidth, memory capacity, and battery power. However, the nature of dynamic changing topology in MANETs introduces difficulties in end-to-end route finding. Existing routing schemes for MANET can be classified into three categories according to different design philosophies: (1) *proactive*, (2) *on-demand*, and (3) *hybrid* schemes.

A mobile node in a proactive routing scheme maintains routes to other nodes all the time, which means each node in the MANET needs to record and update timely network information to maintain its routing table. Proactive routing

schemes provide fast route acquisition at the expense of high maintenance overhead of very dynamic network state. *Fisheye State Routing (FSR)* [2], *Optimal Link State Routing (OLSR)* [3] are examples of proactive routing scheme.

Mobile nodes using on-demand routing schemes do not have to maintain all-time routing tables, but performing a route finding process when a route is needed and no available route cached in a mobile node. Comparing with proactive schemes, on-demand routing schemes save the overhead of maintaining the network state all the time at the expense of a longer latency of route acquisition. *Dynamic Source Routing (DSR)* [4] and *Ad Hoc On-Demand Distance Vector (AODV)* routing [5] are well-known examples of on-demand routing scheme.

Hybrid schemes try to find a good compromise between proactive and on-demand schemes. The basic idea behind hybrid schemes is to limit the proactive operation within a small domain to reduce maintenance overhead and use on-demand operation for inter-domain routing. The proactive domain is called *cluster* or *zone* in the literature, and the method of forming clusters in a MANET is called clustering technique. Some clustering techniques [6-13] have been proposed, including *lowest-ID clustering* [6], *highest-connectivity clustering* [7], *weighted clustering* [8], and *Zone Routing Protocol (ZRP)* [10-13].

ZRP provides a flexible solution to the challenge of discovering and maintaining routes in the MANET. As pointed out in [10], the amount of intra-zone control traffic required to maintain a routing zone increases with the size of the routing zone. However, a larger routing zone has the advantage of requiring fewer route request packets in the route acquisition process. A direct and simple question arises: “Is it possible and how to use a larger zone in ZRP while the maintenance cost only increases a little bit?” The answer to the question led to the research of the paper. By adopting the idea of FSR in ZRP, we can enjoy the advantage of a larger zone with only a little

increase of the maintenance cost. The new on-demand protocol is called *Fisheye Zone Routing Protocol (FZRP)* in the paper. As will be shown in the simulation results, FZRP is more flexible and efficient than ZRP.

The remainder of the paper is structured as follows. First of all, we make a brief survey on FSR and ZRP in section II. The proposed FZRP is presented in section III. Simulation environment and results for performance evaluation are presented in section IV. Finally, section V concludes this paper.

## II. RELATED WORK

### A. Fisheye State Routing (FSR)

FSR [2] is a hierarchical proactive routing protocol. It uses the “fisheye” technique proposed by Kleinrock and Stevens [14] 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. In routing, the fisheye approach translates to maintaining accurate distance and path quality information about the immediate neighborhood of a node, with progressively less detail as the distance increases.

FSR is functionally similar to Link State (LS) Routing in that it maintains a topology map at each node. The key difference is the way in which routing information is disseminated. The reduction of routing update overhead in FSR is obtained by using different exchange periods for different entries in routing table. More precisely, entries corresponding to nodes within the smaller scope are propagated to the neighbors with the highest frequency. FSR produces timely updates from near stations, but creates large latencies from stations afar. However, the imprecise knowledge of the best path to a distant destination is compensated by the fact that the route becomes progressively more accurate as the packet gets closer to destination.

### B. Zone Routing Protocol (ZRP)

As mentioned in section I, ZRP [10-13] is a hybrid proactive/on-demand routing scheme. Each node maintains a current view of a surrounding region that is referred to as a *routing zone*. The most distant (in hops) nodes of each routing zone are referred to as the routing zone’s *peripheral nodes*, and lie at a distance (in hops) called the *routing zone radius*. Note that every node maintains its own routing zone, so that routing zones of neighboring nodes overlap. In order to maintain timely topological information for a routing zone, each node must be notified about the changes of neighbor connectivity within its routing zone.

To find an end-to-end route, a source node sends out a route query packet and waits for the reply from the destination. Knowledge of routing zone topology can be used to direct route queries from a node to its peripheral nodes, rather than just simply flooding queries from a node to all its neighbors. This kind of packet delivery mechanism is called *bordercasting*. By bordercasting queries to peripheral nodes, redundant querying within a routing zone can be avoided.

The radius of routing zones affects the performance of ZRP. Simulation studies [11, 12] showed that the overhead of finding an end-to-end route decreases as the routing zone radius increases. However, the amount of intra-zone control traffic required to maintain a routing zone increases with the radius of the routing zone.

## III. FISHEYE ZONE ROUTING PROTOCOL

### A. Basic idea and Zone maintenance

*Fisheye Zone Routing Protocol (FZRP)* is an extension of *Zone Routing Protocol (ZRP)* adopting the concept of *Fisheye State Routing (FSR)*. The idea of fisheye leads to a multi-level routing zone structure in FZRP, in which different link state update rates are associated with different levels. In this paper, we discuss the case of two-level routing zone for simplification. As illustrated in Figure 1, two-level routing zone in FZRP is defined. The inner level of the routing zone is called the *basic zone*. The outer extension of the basic zone is called the *extended zone*. Figure 1 shows the case of a basic zone with 2-hop radius and an extended zone with 4-hop radius.

Different updating frequencies of changes of link connectivity are associated with the basic zone and extended zone. Maintenance of the basic zone is the same as in ZRP, in which each node transmits timely updates of link state to all the nodes in the basic zone. In order to reduce the maintenance overhead of the extended zone, a *reduction factor*  $F$  ( $0 < F < 1$ , e.g.  $F = 1/4$ ) is defined in FZRP to reduce the frequency of transmitting updates in the extended zone such that the updating frequency for the extended zone is  $F$  of the basic zone.

Figure 2 illustrates the idea of using different updating frequencies for different levels of zone. We define the radius of the basic zone is  $R_B$  and the radius of the extended zone is  $R_E$  in Figure 2. As in ZRP, the *TTL (Time-to-Live)* field in update packets is used to limit the spreading of the packets. On detecting a change of link connectivity, a mobile node broadcasts an update packet with a proper TTL value. The value of TTL is usually set to  $R_B$  to cover the basic zone. Reduction of the updating frequency for the extended zone by

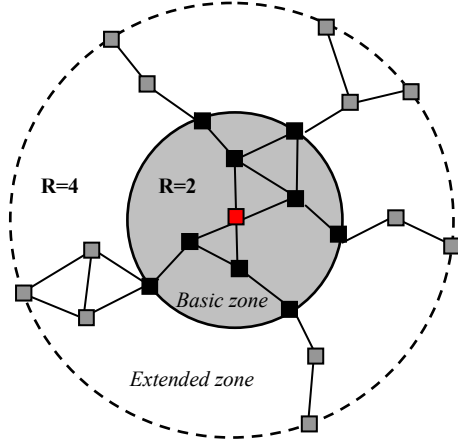


Figure 1. Two-level routing zone in FZRP

the reduction factor  $F$  means that the TTL value in one update packet out of  $1/F$  update packets should be set to  $R_E$  as shown in Figure 2.

The routing table/information maintained by each node in FZRP thus includes two types of entries: (1) entries for those nodes (hop count  $\leq R_B$ ) in the basic zone, and (2) entries for those nodes ( $R_B < \text{hop count} \leq R_E$ ) in the extended zone. Routing entries for those nodes in the extended zone are not always accurate because of reduction of the updating frequency. Inaccuracy of the entries for the nodes in the extended zone makes the route finding mechanism of FZRP different from that of ZRP. Route finding in FZRP is explained in the following section.

### B. Route acquisition

As in ZRP, a source mobile node in FZRP sends out a route finding request. Intermediate nodes in the MANET forward (bordercast) the route request to other nodes until the destination node is reached. When receiving the route request, the destination node sends a reply back to the source node and an end-to-end route is established.

In FZRP, each intermediate node bordercasts the route query to the peripheral nodes of its extended zone (hop count  $= R_E$ ). Due to the inaccuracy of the extended zone entries in the routing table, bordercasting used in ZRP needs to be modified in order to support FZRP as explained in the following.

(1) Bordercasting is performed when the destination node of the route query is not found in the routing table. Each node on the path of bordercasting must also check whether the destination node is within its zone (including basic and extended zone). If so, the bordercasting process stops, and the route query is forwarded to the destination node directly.

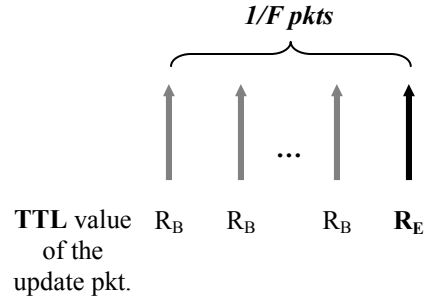


Figure 2. TTL value in update packets of FZRP

(2) There are cases that the TTL value of a bordercast packet becomes zero before the packet reaches the peripheral node. In such cases, the final mobile node receiving the query packet substitutes the peripheral node and continues bordercasting.

Inaccuracy of the routing table may result in the failure of route acquisition that based on bordercasting to the peripheral nodes in the extended zone. Thus, if the route reply is not received within a proper time, the source node starts another route finding process that based on the basic zone only.

### C. Impact of uncertainty

In this section, we discuss the impact of inaccurate routing entries on route finding in FZRP. For a mobile node  $M$  (either a source node or an intermediate node) dealing with a route query, there are two cases that its routing table does not reflect the real situation: (1) the destination node is in the area of its extended zone, but not found in the routing table, or (2) the destination node is outside the extended zone, but found in the routing table.

For case (1), since the destination node is not found in the routing table, the mobile node  $M$  bordercasts the query to its peripheral nodes. Each en route node of bordercasting checks whether the destination node is in within its zone (basic or extended). If so, the query is directly forwarded to the destination node as illustrated in Figure 3-(a). However, as shown in Figure 3-(b), if the destination node is not detected by any of the peripheral nodes (or en route nodes), this extended zone-based route finding process fails. In this case, the timer for the reply at the source node will eventually expire, and the source node starts another route finding process that is based on the basic zone.

For case (2), since the destination node is found in node

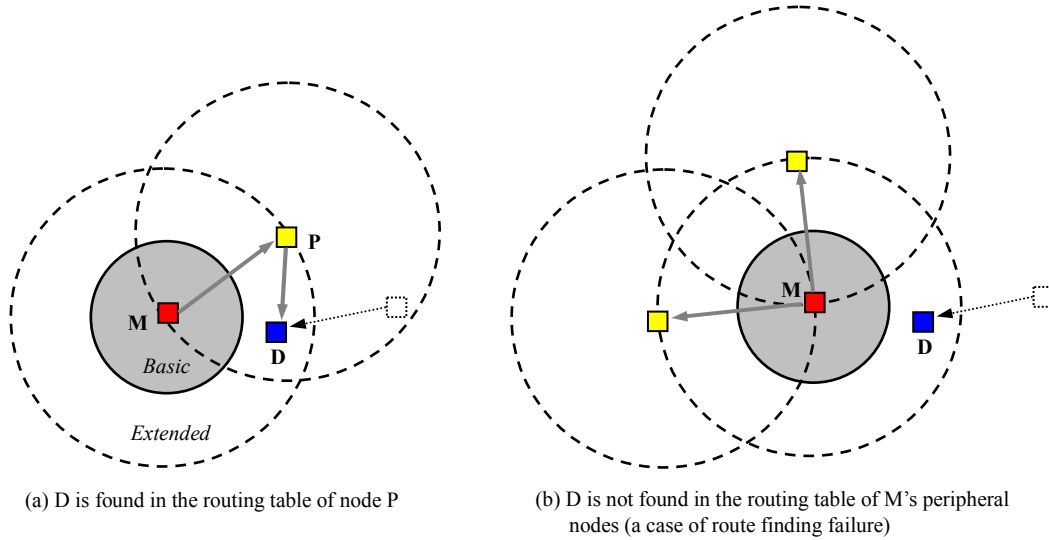


Figure 3. D is in the area of M's extended zone, but not found in the routing table

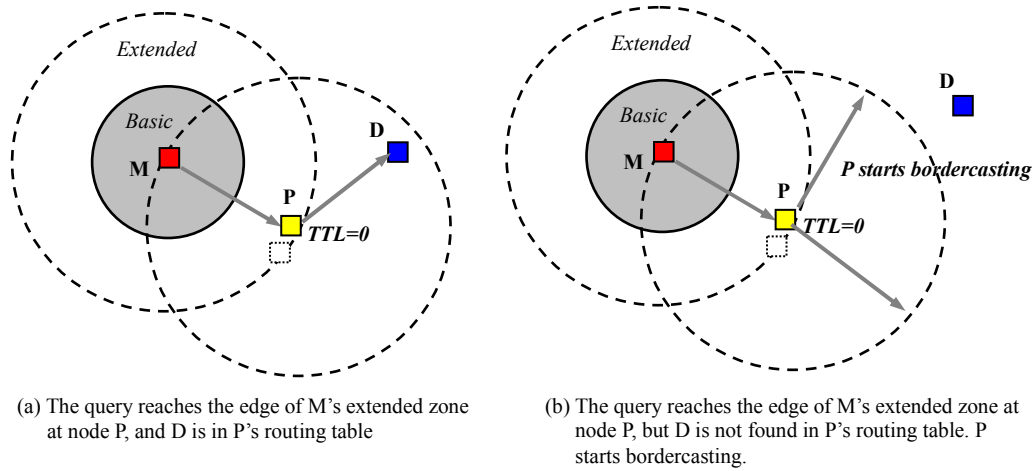


Figure 4. D is not in the area of M's extended zone, but found in the routing table

M's routing table, the query packet is forwarded directly to the destination node. The query packet will finally reach the edge of node M's extended zone (and its TTL becomes 0) at some peripheral node (e.g. node P) instead of the destination node. If the destination node is in P's routing table, node P continues to forward the query packet to the destination node as displayed in Figure 4-(a). Otherwise, as illustrated in Figure 4-(b) if the destination node is not found in P's routing table, bordercasting is used for the delivery of the query packet.

#### IV. PERFORMANCE EVALUATION

Simulation study was conducted to compare the performance of FZRP with original ZRP. The MANET in the simulation consists of 100 mobile nodes, whose initial positions are chosen from a uniform random distribution over

an area of 2000m by 2000m. The *random waypoint* model is adopted as the mobility model for each mobile node, in which a mobile node starts its journey from its initial position to a random destination with a randomly chosen speed (uniformly distributed between 0 ~ 20 m/s). Once the destination is reached, another random destination is targeted after a pause. We vary the pause time, which affects the relative speeds of the mobile nodes. Simulations are run for 5000 simulated seconds. The transmission radius of each mobile node is 250m, which means a communication link exists between two mobile nodes whose distance is less than 250m.

Criteria for performance evaluation and comparison include: (1) *maintenance overhead* (number of maintenance packets per second), (2) *route finding cost* (number of route request packets generated per route), and (3) *Hit ratio* of the

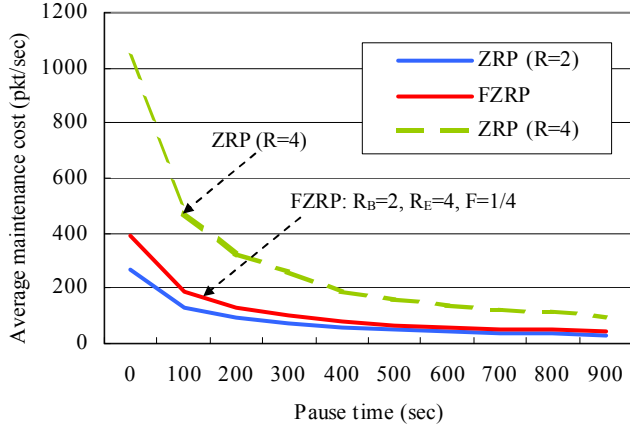


Figure 5. Average maintenance overhead

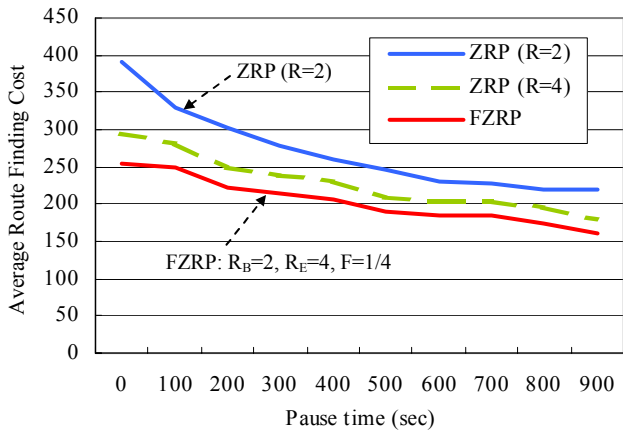


Figure 6. Average route finding cost

extended zone-based route finding in FZRP.

As shown in Figure 5, the maintenance overhead of FZRP with  $R_B=2$ ,  $R_E=4$ ,  $F=1/4$  is much smaller than that of ZRP with 4-hop radius ( $R=4$ ). Moreover, as the pause time increases (low mobility), the maintenance overhead of FZRP is getting close to the overhead of ZRP with 2-hop radius ( $R=2$ ). As we expected, FZRP only increases a little bit of the maintenance overhead for the extended zone.

The average route finding costs for FZRP and ZRP are displayed in Figure 6. The route finding cost of FZRP with  $R_B=2$ ,  $R_E=4$ ,  $F=1/4$  is smaller than that of ZRP with 2-hop radius since a larger zone (extended zone) can effectively reduce the cost of bordercasting. Figure 6 also shows an interesting result that the route finding cost of FZRP is even slightly lower than that of ZRP with 4-hop radius. Further experiments have demonstrated that the reason behind the result is due to (1) inaccuracy of the routing table and (2) the technique called *early termination (ET)* adopted by FZRP to improve the efficiency of bordercasting. We explain them more in the following.

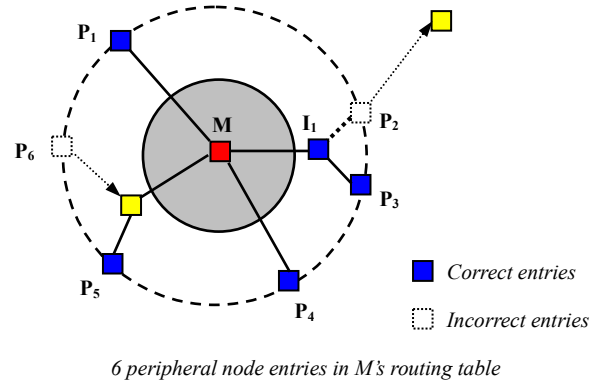


Figure 7. Reduction of the bordercasting cost due to inaccuracy of the routing table

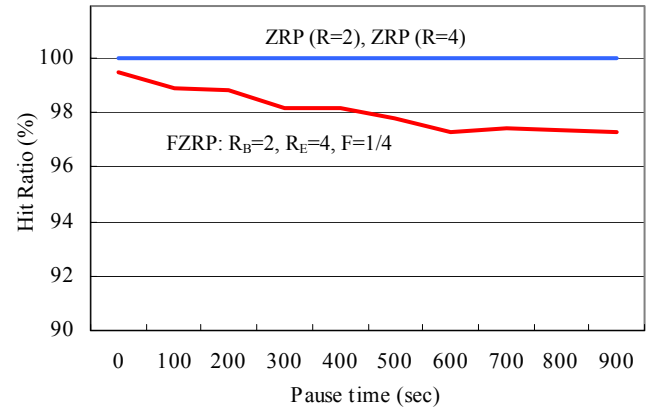


Figure 8. Hit ratio of FZRP (extended zone)

We have found that the average number of routing table entries in FZRP is pretty close to that in ZRP with 4-hop radius, and the average number of peripheral node in FZRP routing table is the same as in ZRP. The major difference is entries in FZRP do not always reflect the real situation. Moreover, FZRP also adopts the approach of *early termination* proposed in ZRP [12]. In a nutshell, ET is the ability for a mobile node to terminate a query because a different packet of the same query was previously detected. Using ET in bordercasting together with inaccurate peripheral node entries sometimes reduces the bordercasting cost. We use an example to illustrate the idea.

Considering the case in Figure 7, in which there are six peripheral nodes in node  $M$ 's routing table and entries for nodes  $P_2$  and  $P_6$  are incorrect. Node  $M$  should bordercast six query packets to each of the six peripheral nodes and the peripheral nodes continue bordercasting. Since node  $P_2$  is outside the extended zone, the query packet with recipient node  $P_2$  cannot reach  $P_2$  but stops at the edge of the extended zone, i.e. node  $P_3$  in the figure. Thus, node  $P_3$  will receive two

query packets but only bordercast once. Another example for incorrect entries is node  $P_6$ , who moved and now becomes an intermediate node on the bordercast path from  $M$  to  $P_5$ . In such case, only  $P_5$  or  $P_6$  continues bordercasting because of early termination. The node winning the chance to re-bordercast is the one who receives its bordercast query first. Therefore, for the example in Figure 7, only four out of the six peripheral nodes in the routing table re-bordercast, resulting in reduction of average bordercasting cost.

The performance of FZRP also depends on the hit ratio of extended zone-based route finding. Hit ratios (success rates) of extended zone-based route finding in FZRP with  $R_B=2$ ,  $R_E=4$ ,  $F=1/4$  under different values of pause time are displayed in Figure 8. As shown in the figure, the hit ratio is always higher than 96%, which demonstrates the efficiency and feasibility of FZRP.

## V. CONCLUSION

In this paper, an efficient clustering and routing protocol that combining Zone Routing Protocol with the idea of Fisheye State Routing was proposed. The protocol was called *Fisheye Zone Routing Protocol (FZRP)*, in which two levels of routing zone, the basic zone and the extended zone, are defined. Each mobile node in FZRP maintains timely routing/topological information in its basic zone. In order to reduce the maintenance overhead introduced by the extended zone, updating frequency for the extended zone is properly reduced. Reduction of the updating frequency for the extended zone results in inaccuracy of the routing table, so the mechanism of bordercasting has been modified as presented in the paper. Simulation study has shown that FZRP is more efficient than ZRP in route finding with only a little increase of the maintenance overhead.

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