
Volume 30, Issue 2, 15 January 2007 ISSN 0140-3664
ELSEVIER
computer
communications
Available online at
ScienceDirect
www.sciencedirect.com

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Computer Communications 30 (2007) 261–268
computer communications
www.elsevier.com/locate/comcom

Fisheye zone routing protocol: A multi-level zone routing protocol for mobile ad hoc networks

Chun-Chuan Yang *, Li-Pin Tseng

Multimedia and Communications Laboratory, Department of Computer Science and Information Engineering, National Chi Nan University, Taiwan, ROC

Received 13 September 2005; received in revised form 15 August 2006; accepted 18 August 2006
Available online 12 September 2006

Abstract

Zone Routing Protocol (ZRP) 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

1. 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

* Corresponding author. Tel.: +886 492910960 4827; fax: +886 492915226.
E-mail address: ccyang@csie.ncnu.edu.tw (C.-C. Yang).

0140-3664/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.comcom.2006.08.014

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*) [10–20].

ZRP provides a flexible solution to the challenge of discovering and maintaining routes in the MANET. As pointed out by Hass [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 2. The proposed FZRP is presented in Section 3. Simulation environment and results for performance evaluation are presented in Section 4. Finally, Section 5 concludes this paper.

2. Related work

2.1. Fisheye state routing (FSR)

FSR [2] is a hierarchical proactive routing protocol. It uses the "fisheye" technique proposed by Kleinrock and Stevens [21] 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.

2.2. Zone Routing Protocol (ZRP)

As mentioned in Section 1, ZRP [10] 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.

3. Fisheye Zone Routing Protocol

3.1. 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 Fig. 1,

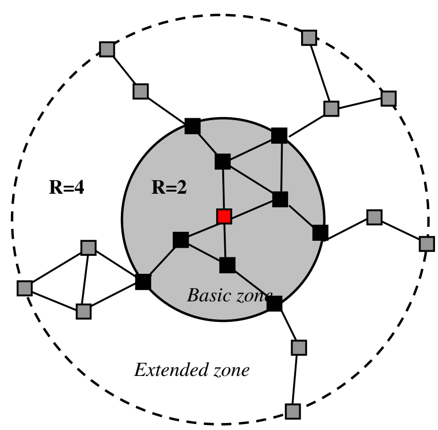

Fig. 1. Two-level routing zone in FZRP.

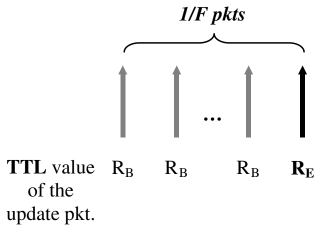

Fig. 2. TTL value in update packets of FZRP.

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*. Fig. 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.

Fig. 2 illustrates the idea of using different updating frequencies for different levels of zone, in which R_B denotes the radius of the basic zone and R_E denotes the radius of the extended zone. 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 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 Fig. 2.

The routing table/information maintained by each node in FZRP thus includes two types of entries: (1) entries for those nodes (hop count $\leqslant R_B$) in the basic zone, and (2) entries for those nodes ($R_B <$ hop count $\leqslant R_E$) 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.

3.2. 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.
(2) In normal cases, the route query packet is forwarded to the peripheral node by bordercasting. However, due to the inaccurate routing information, there are cases that the target peripheral node is actually outside the extended zone such that the TTL value of the route query packet becomes zero before the packet reaches the target peripheral node. In such exceptional case, the final mobile node receiving the query packet substitutes for the target peripheral node and continues forwarding the query.

Inaccuracy of the routing table may result in the failure of route acquisition that is 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.

3.3. 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 Fig. 3-(a). However, as shown in Fig. 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.

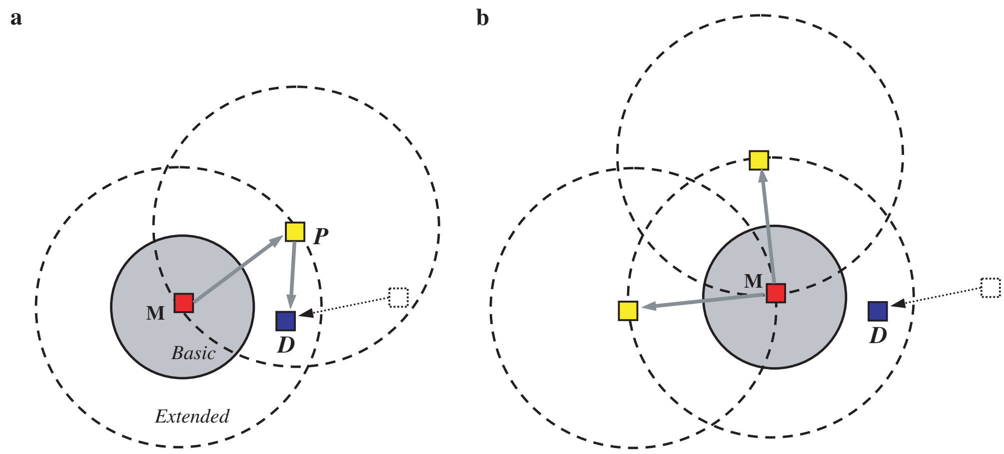

Fig. 3. *D* is in the area of *M*'s extended zone, but not found in the routing table. (a) *D* is found in the routing table of node *P*; (b) *D* is not found in the routing table of *M*'s peripheral nodes (a case of route finding failure).

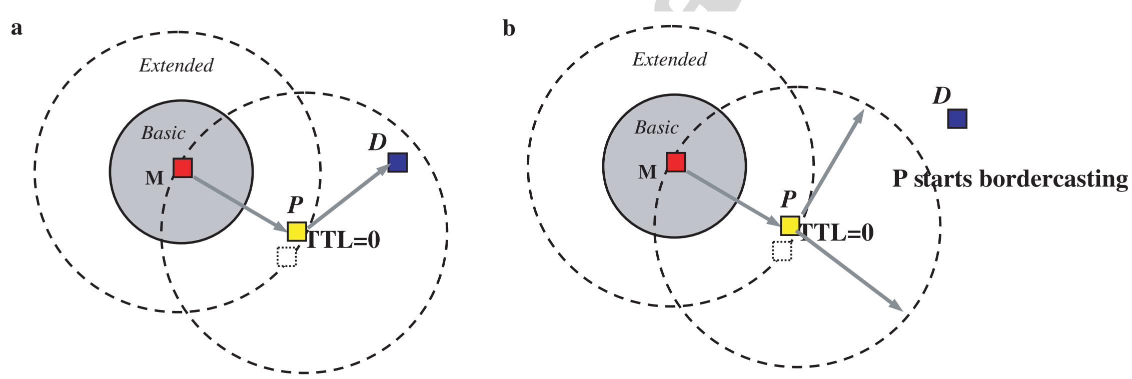

Fig. 4. *D* is not in the area of *M*'s extended zone, but found in the routing table. (a) The query reaches the edge of *M*'s extended zone at node *P*, and *D* is in *P*'s routing table; (b) the query reaches the edge of *M*'s extended zone at node *P*, but *D* is not found in *P*'s routing table. *P* starts bordercasting.

For case (2), since the destination node is found in node *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 Fig. 4-(a). Otherwise, as illustrated in Fig. 4-(b) if the destination node is not found in *P*'s routing table, bordercasting is used for the delivery of the query packet.

3.4. Route maintenance

As in ZRP, upon a change in the network topology, such that a link within an active path is broken, a local path repair procedure is initiated in FZRP. The path repair procedure substitutes a broken link by a mini-path between the ends of the broken link. A path update is then generated and sent to the end points of the path.

3.5. Discussion

Interestingly, Wang and Olariu [20] published a similar idea namely *Two-Zone Hybrid Routing Protocol* (*TZRP*) in the end of 2004, which is pretty close to the publication date of our previous work for FZRP [22]. TZRP is an extension of ZRP that aims to decouple the protocol's ability to adapt to traffic pattern from the ability to adapt to mobility. In TZRP, each node maintains two zones: a *Crisp Zone* for proactive routing and efficient bordercasting, and a *Fuzzy Zone* for heuristic routing using imprecise locality information. The Crisp Zone and the Fuzzy zone in TZRP are similar to the basic zone and the extended zone in FZRP, respectively. Although FZRP and TZRP share a similar idea to some extent, there are some significant differences between them as explained in the following:

(1) The presentation of FZRP in the paper is based on two-zone structure for simplicity, however FZRP is designed to support multi-level extended zone with different updating frequencies for link state update.

(2) Link state update in TZRP is timer-based in which a longer timer is associated with the Fuzzy Zone. Link state update in FZRP is on-demand which means mobile nodes send out link state update only when there is a change in the network topology.
(3) Bordercasting in TZRP is performed in the range of the Crisp Zone, while FZRP performs bordercasting in the range of the extended zone. Extended zone-based bordercasting in FZRP can save more control overhead for route acquisition, but it also requires some modification in the bordercasting mechanism as presented in Sections 3.2 and 3.3.

4. Performance evaluation

4.1. Simulation environment and performance criteria

Simulation study was conducted to compare the performance of FZRP with original ZRP. We developed a custom program in C++ language for the simulation study. The MANET in the simulation consists of 100 mobile nodes, whose initial positions are chosen from a uniform random distribution over an area of 2000 m by 2000 m. 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 and 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 250 m, which means a communication link exists between two mobiles nodes whose distance are less than 250 m.

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 extended zone-based route finding in FZRP.

4.2. Performance comparison

We compare the performance of FZRP with corresponding schemes of ZRP. More specifically, FZRP with 2-hop basic zone and 4-hop extended zone with reduction factor $F = 1/4$ is compared with 2-hop ZRP and 4-hop ZRP. As shown in Fig. 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 Fig. 6. The route finding cost of FZRP with

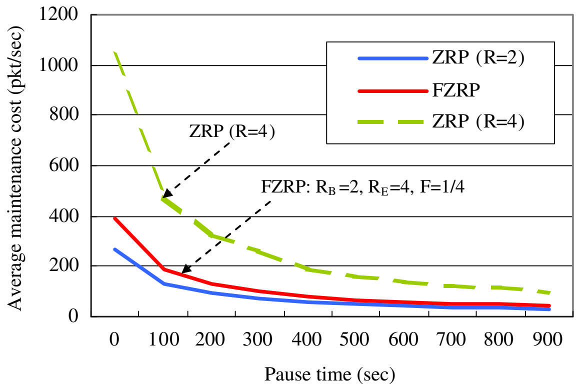

Fig. 5. Average maintenance overhead.

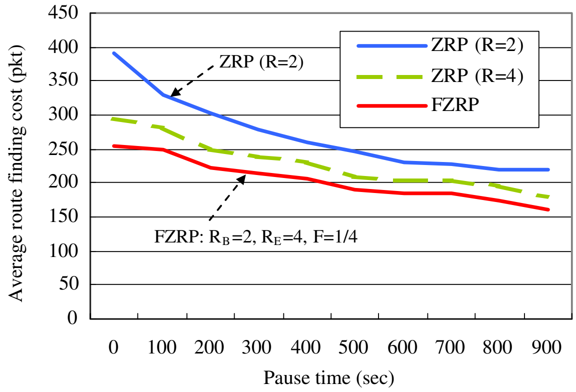

Fig. 6. Average route finding cost.

$R_B = 2$, $R_E = 4$, $F = 1/4$ is smaller than that of ZRP with 2-hop radius since a larger zone (extended zone) can effectively reduce the cost of bordercasting. Fig. 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 both ZRP and FZRP to improve the efficiency of bordercasting. We explain this more in the following.

According to more simulation results, 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 nodes in FZRP routing table is the same as in ZRP. The investigation result is reasonable since incorrectness of the entries in FZRP routing table comes from two cases: (1) missed entries that should be included in the routing table, and (2) wrong entries that should not be included in the routing table. The equal probability of the two cases in the simulation due to the random waypoint mobility model makes the average number of entries in FZRP routing table equate the number of entries in ZRP routing table.

Although FZRP and ZRP have the same number of entries in the routing table, the major difference is entries

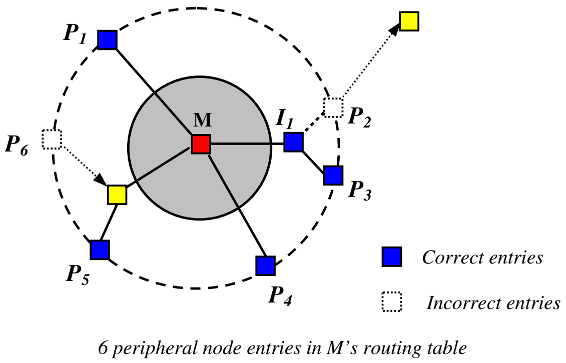

Fig. 7. Reduction of the bordercasting cost due to inaccuracy of the routing table.

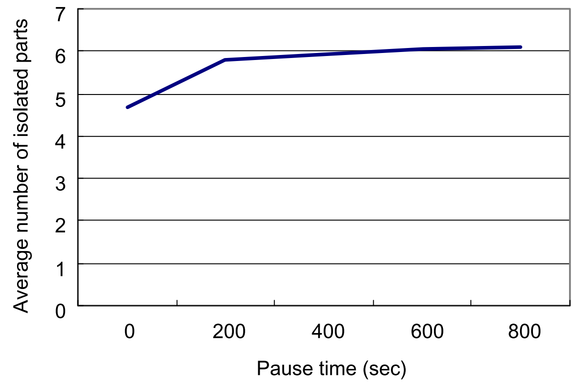

Fig. 8. Average number of isolated parts.

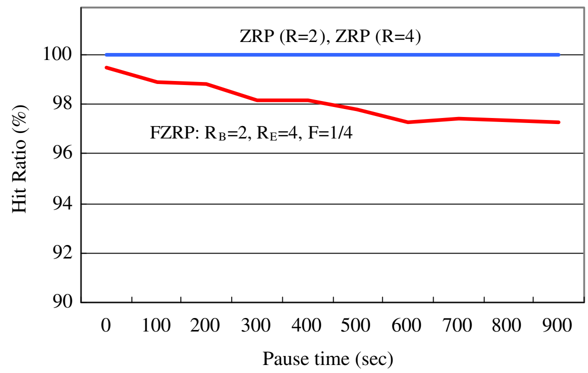

Fig. 9. Hit ratio of FZRP (extended zone).

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 Fig. 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 Fig. 7, only four out of the six peripheral nodes in the routing table re-bordercast, resulting in reduction of average bordercasting cost.

Moreover, Fig. 6 also shows that the average route finding cost (for both ZRP and FZRP) decreases as the pause time increases. The reason behind the phenomenon is the increase of the pause time results in more isolated parts among mobile nodes as displayed in Fig. 8. More isolated parts imply a smaller network size for route finding and the average route finding cost is thus reduced.

Lastly, the performance of FZRP depends on the hit ratio of the extended zone-based route finding. The hit ratio in the simulation is calculated only for the case that the receiver node is reachable from the sender node. Thus, the hit ratio (success rate of route finding) of ZRP is always 100%. Hit ratios 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 Fig. 9. As shown in the figure, the hit ratio is always higher than 96%, which demonstrates the efficiency and feasibility of FZRP. Note that the hit ratio of FZRP (extended zone) decreases as the pause time increases. The reason is: the increase of the pause time results in fewer link updates, which lengthens the lifetime of incorrect routing entries in the extended zone and thus reduces the hit ratio of FZRP.

4.3. Impact of *F* and R_E

Reducing the value of *F* can reduce the maintenance overhead in FZRP, but the hit ratio of FZRP extended zone decreases as *F* decreases as shown in Fig. 10. From the aspect of route finding efficiency, it is better to choose a value of *F* that makes the hit ratio of extended zone close to 100%. Hence, $F = 1/4$ is a good choice in our simulation.

In order to investigate more about the impact of R_E on the performance of FZRP, we calculate the maintenance overhead as well as the route finding cost for different values of R_E. Fig. 11 shows the maintenance overhead of FZRP under different values of R_E and pause time. Fig. 12 shows the route finding cost of FZRP under different values of R_E. Note that we set $R_B = 2$ and $F = 1/4$ in the two figures. Considering both Figs. 11 and 12, we have the following observation:

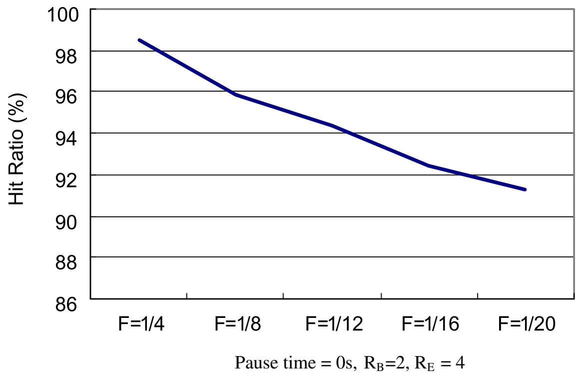

Fig. 10. Hit ratio of FZRP (extended zone).

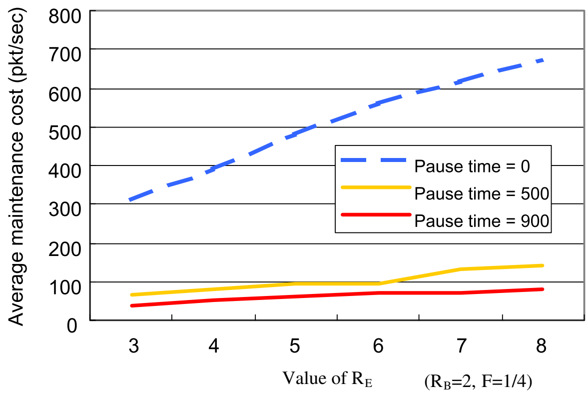

Fig. 11. Average maintenance overhead.

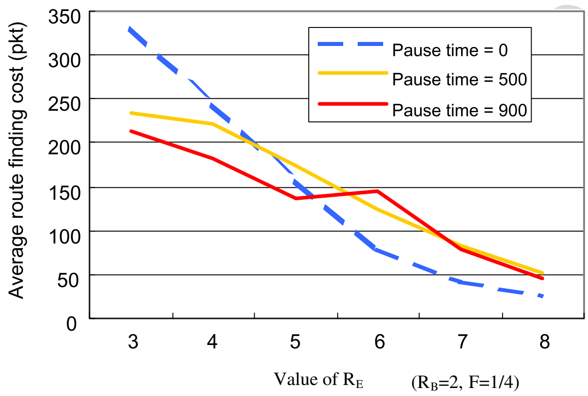

Fig. 12. Average route finding cost.

(1) The pause time does not affect the route finding cost as much as its impact on the maintenance cost (the difference among the three curves of different pause times in Fig. 12 is not significant).
(2) In Fig. 12, for the case of 900 s pause time, the average route finding cost for $R_E = 6$ is slightly higher than that of $R_E = 5$. The reason for the phenomenon is because the lower hit ratio for $R_E = 6$ (comparing with $R_E = 5$) results in more failures in extended zone-based route finding and triggers extra basic zone-based route finding. Extra basic zone-based route finding for $R_E = 6$ creates more cost than the gain of a larger extended zone. Similarly, the impact of extended zone hit ratio and the zone size on the route finding cost results in the complicated relation among the curves of different pause times in Fig. 12.
(3) A large size for the extended zone (e.g., $R_E = 8$) can significantly reduce the route finding cost. Moreover, a large value of R_E does not increase the maintenance overhead significantly for a large pause time (e.g., pause time = 900 s).

Therefore, the selection of R_E depends on the mobility level of the mobile nodes in the MANET. For the network with high mobility nodes (e.g., pause time = 0s), a smaller value of R_E (e.g., 4) should be chosen to reduce the maintenance overhead. On the other hand, for low mobility case (e.g., pause time = 900 s), a larger value of R_E (e.g., 8) can significantly reduce the route finding cost with only a little increase of maintenance overhead. If the mobility information for mobile users in a MANET cannot be obtained beforehand or the mobility level for mobile users in the network is quite different and the whole network cannot be identified as a low- or high-mobility case, then ($R_B = 2$, $R_E = 4$, $F = 1/4$) is a good choice for FZRP in general.

5. 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.

Acknowledgment

This work was supported in part by the National Science Council, Taiwan, R.O.C., under grant NSC93-2219-E-260-004. Part of the research in the paper has been published in proceedings of IEEE Consumer Communications and Networking Conference (CCNC), January 2005.

References

[1] S. Corson, J. Macker, Mobile Ad hoc Networking (MANET): routing protocol performance issues and evaluation considerations, RFC 2501, 1999.
[2] G. Pei, M. Gerla, T.-W. Chen, Fisheye state routing: a routing scheme for ad hoc wireless networks, in: Proceedings, IEEE International Conference on Communications (ICC), 2000, pp. 70–74.

[3] A. Laouiti, L. Viennot, T. Clausen Optimized link state routing protocol, Internet Draft, draft-ietf-manet-olsr-04.txt, 2001.
[4] D.B. Johnson, D.A. Maltz, Y.-C. Hu, J.G. Jetcheva, The dynamic source routing protocol for mobile ad hoc networks, Internet Draft, draft-ietf-manet-dsr-05.txt, 2001.
[5] C.E. Perkins, E.M. Royer, S.R. Das, Ad hoc On-Demand Distance Vector (AODV) routing, Internet Draft, draft-ietf-manet-aodv-08.txt, 2001.
[6] C.R. Lin, M. Gerla, Adaptive clustering for mobile wireless networks, IEEE Journal on Selected Areas in Communications 15 (7) (1997) 1265–1275.
[7] M. Gerla, Jack Tzu-Chieh Tsai, Multicluster, mobile, multimedia radio network, Wireless Networks 1 (3) (1995) 255–265.
[8] M. Chatterjee, S.K. Sas, D. Turgut, An on-demand weighted clustering algorithm (WCA) for ad hoc networks, in: Proceedings of the IEEE Global Telecommunications Conference (GLOBECOM), 2000, pp. 1697–1701.
[9] S. Basagni, D. Turgut, S.K. Das, Mobility-adaptive protocols for managing large ad hoc network, in: Proceedings of the IEEE International Conference on Communications (ICC), 2001, pp. 1539–1543.
[10] Z.J. Hass, A new routing protocol for the reconfigurable wireless networks, in: Proceedings, IEEE 6th International Conference on Universal Personal Communications, 1997, pp. 562–566.
[11] Z.J. Hass, M.R. Pearlman, The performance of a new routing protocol for the reconfigurable wireless networks, in: Proceedings, IEEE International Conference on Communications (ICC), 1998, pp. 156–160.
[12] M.R. Pearlman, Z.J. Hass, Determining the optimal configuration for the zone routing protocol, IEEE Journal on Selected Areas in Communications 17 (8) (1999) 1395–1414.
[13] Z.J. Hass, M.R. Pearlman, The performance of query control schemes for the zone routing protocol, IEEE/ACM Transactions on Networking 9 (2001) 427–438.
[14] Xiaofeng Zhang, L. Jacob, Adapting zone routing protocol for heterogeneous scenarios in ad hoc networks, in: Proceedings, International Conference on Parallel Processing, 6–9 October 2003, pp. 341–348.
[15] R. Beraldi, R. Baldoni, A caching scheme for routing in mobile ad hoc networks and its application to ZRP, IEEE Transactions on Computers 52 (8) (2003) 1051–1062.
[16] P. Samar, M.R. Pearlman, Z.J. Haas, Independent zone routing: an adaptive hybrid routing framework for ad hoc wireless networks, IEEE/ACM Transactions on Networking 12 (4) (2004) 595–608.
[17] X. Zhang, L. Jacob, Multicast zone routing protocol in mobile ad hoc wireless networks, in: Proceedings, 28th Annual IEEE International Conference on Local Computer Networks (LCN), 2003, pp. 150–159.
[18] X. Zhang, L. Jacob, Adapting zone routing protocol for heterogeneous scenarios in ad hoc networks, in: Proceedings, International Conference on Parallel Processing, 2003, pp. 341–348.
[19] R. Kapoor, M. Gerla, A zone routing protocol for Bluetooth scatternets, in: Proceedings, IEEE Wireless Communications and Networking Conference (WCNC), 2003, pp. 1459–1464.
[20] L. Wang, S. Olariu, A two-zone hybrid routing protocol for mobile ad hoc networks, IEEE Transactions on Parallel and Distributed Systems 15 (12) (2004) 1105–1116.
[21] L. Kleinrock, K. Stevens, Fisheye: a lenslike computer display transformation, Technical report, UCLA, Computer Science Department, 1971.
[22] C.-C. Yang, L.-P. Tseng, Fisheye zone routing protocol for mobile ad hoc networks, in: Proceedings, IEEE Consumer Communications and Networking Conference (CCNC), January 2005.

Chun-Chuan Yang received his B.S. degree in computer and information science from National Chiao-Tung University, Taiwan, in 1990 and Ph.D. degree in computer science from National Taiwan University in 1996. He joined the Department of Computer Science and Information Engineering, National Chi-Nan University (NCNU), Puli, Taiwan, as an Assistant Professor in 1998. Since August 2003, he has been an Associate Professor. His research area of interests includes multimedia network protocols, multimedia synchronization control, and multimedia applications.

Li-Pin Tseng received his B.S. degree in information engineering and computer science from Feng Chia University, Taiwan, in 2001. He received his master degree in computer science and information engineering from National Chi Nan University, Taiwan, in 2003. His research interest is wireless computer networking.