Modified Energy Aware Geographic Routing Protocol for Mobile Ad-Hoc Network

Anand Gautam[1], Shiva Prakash[2]
Department of Computer Science & Engineering, Madan Mohan Malaviya Engineering College, Gorakhpur-273010, U. P., INDIA

Abstract: *Mobile ad hoc networks (MANET) are characterized by multi-hop wireless links and resource constrained nodes. One of the major challenge in mobile ad hoc networks (MANETs) is link failures due to mobility as well as nodes energy constraint. The more challenging goal is to provide energy efficient routes in MANET to improve network life time because node have limited lifetime. The Geo-routing has been widely regarded as efficient and scalable. However, it used constant transmission power model for communication and route selection is not based on energy. In this paper we proposed a model of energy aware geographic routing scheme with variant transmission power model. This can improve performance of existing protocol in form of less energy. We explain this concept with help of example that show the improvement of existing EGR.*

Keywords: *Energy efficient, location information, mobile ad hoc network.*

I. INTRODUCTION

A Mobile Ad-hoc network (MANET) is consists of mobile routers connected wirelessly to each other where each node is free to move. This results in a continuously changing topology. Some examples of the possible uses of ad hoc networking include business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield and emergency disaster relief personnel coordinating

In recent years, geographic routing algorithms have been extensively studied due to the popularity and availability of positioning services such as the global positioning system (GPS). Geographic routing is a promising candidate for large-scale wireless ad hoc networks due to its simplicity and scalability and takes advantage of the location information of the nodes are the very valuable for wireless networks. Since geographic routing does not require a route management process, it carries a low overhead compared to other routing schemes, such as proactive, reactive, and hybrid topology based routing protocols. Geographic routing protocols work on the assumption that every node is aware of its own position in the network; via mechanisms like GPS or distributed localization schemes and that the physical topology of the network is a good approximation of the network connectivity. In other words, these routing protocols assume that if two nodes are physically close to each other, they would have radio connectivity between them, which is true in most cases. Hence the protocols use node location information to route packets from source to destination. One big advantage of geographic routing schemes is the fact that there is no need to send out route requests or periodic connectivity updates. This can save a lot of protocol overhead and consequently, energy of the nodes. The most significant difference between MANETs and traditional networks is the energy constraint. Some applications such as environment monitoring need MANETs to run for a long time. Therefore, extending the lifetime of MANETs is important for every MANET routing protocol. However, most geographic routing algorithms take the shortest local path, depleting the energy of nodes on that path easily. The nodes located on the boundaries of holes may suffer from excessive energy consumption since the geographic routing tends to deliver data packets along the whole boundaries by perimeter routing if it needs to bypass the hole.

There should be a mechanism at node for robust communication of high priority messages. This can be achieved by keeping nodes all the time powered up which makes nodes out of energy and degrades network life time. Also, there can be a link or node failure that leads to reconfiguration of the network and re-computation of the routing paths, route selection in each communication pattern results in either message delay by choosing long routes or degrades network lifetime by choosing short routes resulting in depleted batteries. Therefore the solutions for such environments should have a mechanism to provide low latency, reliable and fault tolerant communication, quick reconfiguration and minimum consumption of energy. Routing protocols have a critical role in most of these activities. To measure the suitability and performance of any given protocol, some metrics are required. On the basis of these metrics any protocol can be assessed against its performance [3]. This can save a lot of protocol overhead and consequently, energy of the nodes. The most significant difference between MANETs and traditional networks is the energy constraint. Some applications such as environment monitoring need MANETs to run for a long time.

Therefore, extending the lifetime of MANETs is important for every MANET routing protocol. However, most geographic routing algorithms take the shortest local path, depleting the energy of nodes on that path easily. The nodes located on the boundaries of holes may suffer from excessive energy consumption since the geographic routing tends to deliver data packets along the whole boundaries by perimeter routing if it needs to bypass the hole. This can enlarge the hole because of the excessive energy consumption of the whole boundary nodes. We call this a whole diffusion problem. Many geographic routing protocols assume that the geographic information is accurately available. In fact, all location services update their geographic information periodically. Typically, there can be a time difference between the update of and the demand for this information, which introduces inaccuracy in the geographic information the accuracy of GPS, is limited.

In most cases location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated. Consequently, we should define the packet destination as an area rather than a point. In this paper we will present Modified Energy- Aware Geographic Routing (MEGR) Protocol, novel geographic routing algorithm combining local position information and balancing node energy consumption. It forecasts the destination node's movement to ensure packet delivery and to prolong the network lifetime. We also use various model for providing energy efficient path.

The remaining part of this paper is organized as follows: In section II we will discuss the literature review of energy aware geographic routing and we will discuss the problem statement with help of example in section III. We will propose a model with help of example in section IV and finally we conclude the paper and give future scope in section V.

II. LITERATURE REVIEW

In case of location-aware routing mechanisms, the nodes are often aware of their exact physical locations in the three-dimensional world. This capability might be introduced in the nodes using Global Positioning System (GPS) or with any other geometric methods. Based on these concepts, several geocast and location-aware routing protocols have already been proposed. The major feature of these routing protocols is that, when a node knows about the location of a particular destination, it can direct the packets toward that particular direction from its current position, without using any route discovery mechanism. Recently, some of the researchers proposed some location-aware protocols that are based on these sorts of idea. Some of the examples of them are Geographic Distance Routing (GEDIR)[18], Location-Aided Routing (LAR)[2], Greedy Perimeter Stateless Routing (GPSR)[3], Geo-GRID[20], Geographical Routing Algorithm (GRA)[21], etc. Other than these, there are a number of multicast routing protocols for MANET. Some of the mentionable multicast routing protocols are: Location-Based Multicast Protocol (LBM)[22], Multicast Core Extraction Distributed Ad hoc Routing (MCEDAR)[23], Ad hoc Multicast Routing protocol utilizing Increasing id-numberS (AMRIS)[24], Associativity- Based Ad hoc Multicast (ABAM)[25], Multicast Ad hoc On- Demand Distance-Vector (MAODV) routing [26],Differential Destination Multicast (DDM)[27],On-Demand Multicast Routing Protocol (ODMRP)[28], Adaptive Demand-driven Multicast Routing (ADMR) protocol [29], Ad hoc Multicast Routing protocol (AMRoute)[30], Dynamic Core-based Multicast routing Protocol (DCMP)[31], Preferred Link-Based Multicast protocol (PLBM)[32],etc. Some of these multicast protocols use location information and some are based on other routing protocols or developed just as the extension of another unicast routing protocol. For example, MAODV is the multicast-supporting version of AODV.

Early research of geographic routing includes DREAM [1] and LAR [2] that proposed cons trained flooding. The *expected zone* is defined by predicting the boundary of the destination node's movement. In both protocols, prediction is made based on the time difference between sending data and the location information's update, as well as the destination node's speed. We adopt this approach in our routing protocol and describe it in the fourth section. In the LAR protocol, before the transmission of a data packet, the source node finds a route by flooding routing packets in its *request zone*. In the DREAM protocol, however, according to the location information, the data packet is flooded in a restricted directional range without sending a routing packet. Although this kind of forwarding effectively guarantees delivery, its energy use is notably high, especially in large-scale networks. Recently, *Local maxima* in geographic routing have received much attention. Many routing protocols for planar network graphs are presented for solving this problem, such as GFG [3], GPSR [4], GOAFR+ [5] and CLDP [6].

In the following, we review the shared characteristics of these geographic routing algorithms. Geographic routing schemes use greedy routing where possible. In greedy routing, packets are stamped with the position of their destination; and a node forwards a packet to a neighbor that is geographically closer to the destination. Local maximum may exist where no neighbor is closer to the destination. In such cases, greedy forwarding fails, and making progress toward the destination requires another strategy. In particular, the packet needs only to find its way to a node closer to the destination than the local maximum; at that point, greedy routing may once again make progress.

Note that if the graph is not planar, face routing may fail. Wireless networks connectivity graphs typically contain many crossing edges. A method for obtaining a planar sub graph of a wireless network graph is thus needed. Greedy routing operates on the full network graph, but to work correctly, face routing must operate on a planar sub graph of the full network graph. Geographic routing algorithms planarize graphs using two planar graph constructs that meet that requirement: the Relative Neighborhood Graph (RNG) and the Gabriel Graph (GG). The RNG and GG give rules for how to connect vertices placed in a plane with edges based purely on the positions of each vertex's single-hop neighbors. Up to the present, literature, such as GOAFR+, CLDP and LCR [15], has focused on methods of deleting these crossing links.

However, there are several drawbacks to pure geographic routing. In certain circumstances, one cannot guarantee delivery by greedy routing, for example, when there is the rapid movement of nodes. Because of this, the location information of a destination node is rather inaccurate. Secondly, greedy routing is a single-path transmission process which means once the process drops a data packet the whole routing fails. Thirdly, there have been several schemes to overcome the *Local maxima*.

All the schemes can be classified into two categories: perimeter routing [5, 6] and the back pressure rule [7, 8]. In perimeter routing the system tends to route data packets along the boundaries of holes, but the perimeter routing cannot avoid the excessive energy consumption and data congestion in these nodes. Using the back pressure rule, the system returns the data packets to the upstream node in an attempt to find another route to the destination. This rule may generate an additional routing overhead.

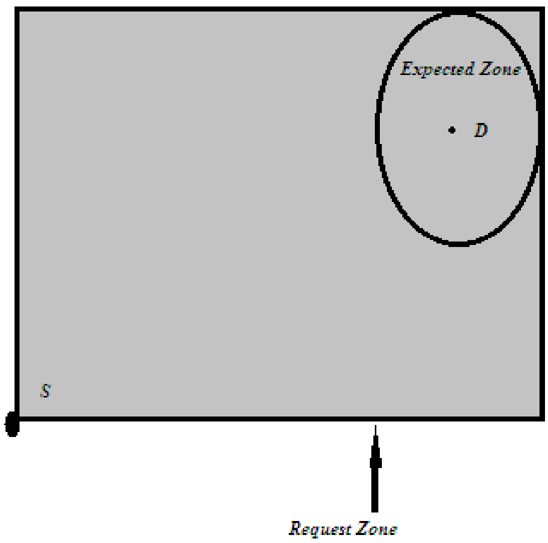
Mobile networks use a power-aware routing protocol in [17]. However, to save energy as much as possible, its iterative relay process will result in unacceptable end-to-end delay. Due to the non-linear attenuation of wireless signals, it is possible that one hop consumes more energy than multiple hops. Yet it can be impractical to change from one hop to several, following the mechanism in [17]. The end-to-end delay may increase significantly, especially in a high-density network.

III. PROBLEM STATEMENT

In recent years various works has been done in the field of energy aware geographic routing but a lot of work has to be done in the near future by overcoming the problems still lies in the geographic routing protocol so that we can be able to sends the packet from source to destination without fear of loss of packets, higher packet delivery ratio, low energy consumption etc. But when we talk about the Energy Aware Geographic Routing there are still a lot of problem are there which is discussed below:

3.1 Need of EGR: As we know that in EGR, to make routing decision it uses local position information and residual energy and also uses prediction of range of a destination's movement. EGR uses the concept of Location aided routing (LAR) and Distance effect algorithm for mobility (DREAM).

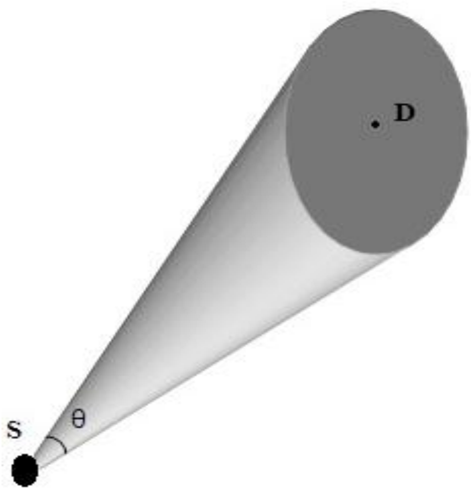
In LAR protocol, before the transmission of a data packet, a source node finds a route by flooding routing packets in its request zone.



(a)The model of LAR

But LAR fails when there is a large scale network and also uses high energy.

To solve out this problem the DREAM routing protocol comes into existance. In DREAM protocol, according to the location information the data packet is flooded in a restricted directional range without sending a routing packet.



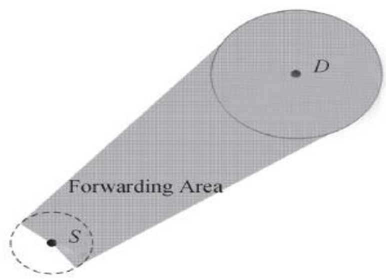
(b)The model of DREAM

In DREAM, if source is quite far away from destination, the angle θ will be too small for source to find the next hop.

3.2 Need of MEGR: To remove the problem of DREAM EGR comes into existence which works as follows:

(a) Dissemination of location and energy information: EGR assume the existence of a mechanism such as GPS system that allows each node to be aware of its location and residual energy.

(b) Forwarding Data packets: To remove the problem of DREAM it uses the concept of tangent lines between two circle, first circle is centered on source node whose radius is the transmission distance of source node and other one is destinations expected zone.



(c) The model of EGR

In EGR it uses a mechanism for choosing the next hop in the flooding area and uses a single path before destination expected zone.

If node i is located in forwarding area the i chooses the next hop from it neighbor nodes given by:

NEXTHOP=k $e^{k}_{remain} = \max\{e^{j}_{remain}\}, j \in N_i$

It means i chooses the next hop k with the most residual energy from all its neighbors nodes whose position are closer to destination than i.

If node i is in expected zone it directly relay the packet to the destination.

The main problem with EGR that it uses the constant power model means it always sends the packet to the node which has maximum energy which will leads to the depleting of energy very fast as well as it also suffers from taking decision of route request and gives a single path.

IV. PROPOSED MODEL

To make energy efficient routing protocol than EGR we modified the Energy Aware Geographic Routing (EGR) [1] protocol to solve out the problem lies in the EGR we proposed a new routing protocol named Modified Energy Aware Geographic Routing Protocol (MEGR) in which we use the variant power model as well as we use the decision of route request will be taken at destination for choosing the best path through which we can increase the network lifetime.

In MEGR, a source node that requires sending a packet to destination acquires the address of the destination. After preparing the packet by adding appropriate information in the header, we calculate the distance from each of its neighbors to the destination and also calculate the minimum energy required for sending a packet. We choose the path that requires minimum energy. But also in route request phase we find the paths which have highest energy by comparing available residual energy and minimum energy required. If the available energy is less than the minimum energy required we append the residual energy of that node the move to the next node. In this way after reaching the destination we wait for Δt time which is less than the TTL. After that time we find the total route request packet reach at the destination. The destination will choose the path for route reply that has highest energy.

The distance between two points on the earth surface can be calculated by using its latitude and longitude coordinates. Hence in our approach we will divide the network into x-axis and y-axis. The parameter used to calculate the distances are defined below:-

DISTANE = Distance in meters between first and second point.

$DISTANCE_x$ = x-axis distance between the first and second point.

$DISTANCE_y$ = y-axis distance between the first and second point.

X_1 = x-axis of the first point in degrees.
Y_1 = y-axis of the first point in degrees.
X_2 = x-axis of the second point in degrees.
Y_2 = y-axis of the second point in degrees.

$DISTANCE_x = x_2 - x_1$
$DISTANCE_y = y_2 - y_1$

$$DISTANCE = \sqrt{(DISTANCE_x)^2 + (DISTANCE_y)^2}$$

After calculating the distance, for given threshold energy E_{th}, The minimum transmit energy E_{min} can be calculated by giving formula:

$$E_{min} = \frac{E_{th} * D^n}{K}$$

Where D is the distance between two nodes,
n is the path loss exponent whose value is lies between 2-4,
K is a constant. Here, K= 2.8 x 10^{-10} *μJ/(byte-m^4)*
E_{th} in the LAN 802.11 is 3.652 x 10^{-10} mW.

Hence in this way we can modify the EGR now we can explain our model by taking the appropriate example.

4.1 Example:

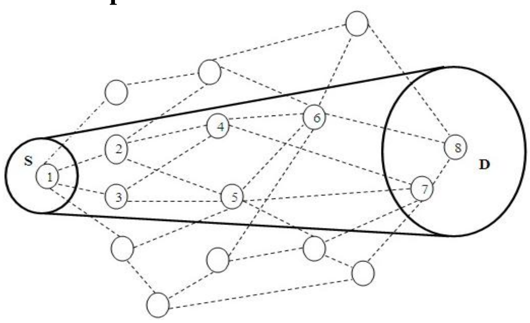


Fig 4.1

Node number	Location of nodes	Residual Energy(*Joule*)
1	-5,0	500
2	-3,2	300
3	-3,-2	100
4	0,2	400
5	0,-2	600
6	3,2	500
7	5,-2	300
8	6,3	200

By using the concept of the EGR we find the path 1-2-5-6-8 which is explained below:

In EGR, we choose the next hop which is having the maximum energy.
So.
Source (1) has two neighbors 2, 3
Residual energy of 2=300J
Residual energy of 3=100J
Therefore, Source (1) will choose next hop 2
Hence distance between node 1 and 2

D(1, 2) = 2.82 m

Now, the minimum transmit energy

$E_{min}(1, 2)$ = 82.483 Joule

Again, Node 2 has two neighbors 4, 5
Residual energy of 4=400J
Residual energy of 5=600J
Therefore, node 2 will choose next hop 5
Hence distance between node 2 and 5

D (2, 5) = 4 m

Now, the minimum transmit energy

$E_{min}(2, 5)$ = 333.89 Joule

Again, Node 5has two neighbors 6, 7

Residual energy of 6=500J
Residual energy of 7=300J
Therefore, node 5 will choose next hop 6
Hence distance between node 5 and 6

D (5, 6) = 5 m

Now, the minimum transmit energy

E_{min}(5, 6) = 815.714 Joule

Now at last node 6 has only one neighbor 8
Hence distance between node 6 and 8

D (6, 8) = 3.16 m

So the minimum energy

E_{min}(6, 8) = 130.42 Joule

Therefore,
Total energy required in EGR= 82.483+333.89 +815.714+130.42=1357.507 Joule

In MEGR

For Source node 1: we calculate the distance between 1 and 2 as well as 1 and 3.

Distance (1,2) = 2.82 m
Distance (1,3) = 2.82 m

Now we will calculate the minimum energy required for both the paths

E_{min}(1,2) = 82.483 J
E_{min}(1,3) = 82.483 J

In this case we choose the next hop 2 because it has total energy 300 Joule which has greater that node 3.

Now for node 2: We calculate the distance between 2 and 4 as well as 2 and 5.

Distance (2,4) = 3 m
Distance (2,5) = 4 m

Now we will calculate the minimum energy required for both the paths

E_{min}(2,4) = 105.847 J
E_{min}(2,5) = 333.89 J

In this case we choose the next hop 4 because it requires only 105.847 joule energy for transmitting the packet while its residual energy is 400 joule.

Now for node 4: We calculate the distance between 4 and 6 as well as 4 and 7.

Distance (4, 6) = 3 m
Distance (4, 7) = 6.40 m

Now we will calculate the minimum energy required for both the paths

E_{min}(4,6) = 105.847 J
E_{min}(4,7) = 2188.228 J

In this case we choose the next hop 6 because it requires only 105.847 joule energy for transmitting the packet while its residual energy is 500 joule.

Now for node 6: We calculate the distance between 6 and 8.

Distance (6, 8) = 3.16 m

Now we will calculate the minimum energy required for the path

E_{min}(6,8) = 130.42 J

In this case we can reach the destination the destination reply on this path which we have followed shown below:-
1-2-4-6-8

4.2 Analysis of the MEGR: When we compare the MEGR with EGR then we can see that Total energy required for sending a packet from source to destination is very less in MEGR.

Total energy required in EGR: 82.483 + 333.89 + 810.714 + 130.42 = 1357.454 Joule.

Total energy required in MEGR: 82.483 + 105.847 + 105.847 + 130.42 = 424.651 Joule.

Hence in MEGR we can reduce the energy consumption more than three times than EGR.

4.3 Algorithm for MEGR:

(a) Route Request

Step1: Initialize network (Source, Destination)
Step2: For every node of the network
Step3: Find LOC(N_x, N_y) // Find location of all nodes where N is the set of nodes defined in the network.
Step4: Find neighbors (S, D) // Detect neighbors of the node and add it to the LET.
Step5: Calculate Distance (n, d) // Calculate distance of all neighbors node.
Step6: Calculate minimum transmit energy (E_{min})
Step7: If ($E_{min} > E_{residual}$)
Add $E_{residual}$ of the neighbor node that have high residual energy.
Else
Route request is send at the next hop.
Step8: When route request is reach at the destination
Wait Δt time where (Δt < TTL).
Step9: Choose the best path
Step10: End

V. CONCLUSION AND FUTURE SCOPE

As per literature review we come to know that as route selection is not based on energy efficiency in and use constant power model for packet transmission. Our proposed solution for theses existing problem in EGR can be improved. In this we presented Modified Energy Aware Geographic Routing protocol which gives better results to minimize energy consumption and Delay time and extends network lifetime. We will present simulation of our proposed Modified EGR protocol in our future work. It can be improved to find accurate information for faulty location of Geographical based information.

REFERENCES

[1] Gang Wang and Guodong Wang, An Energy Aware Geographic Routing Protocol for Mobile Ad Hoc Networks, *Int J Software informatics*, Vol. 4, No. 2, June 2010, pp. 183-196.

[2] Adel Gaafar A. Elrahim and et al., An Energy Aware WSN Geographic Routing Protocol, *Universal Journal of Computer Science and Engineering Technology, 1(2), 105-111, Nov. 2010.*

[3] S.Corson and J. Macker, "Routing Protocol Performance Issues and Evaluation Considerations," Naval Research Laboratory, Jan.1999.

[4] B. Karp and H. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," in the Proceedings of the 6th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM), pp.243-254, Boston, August 2000.

[5] Ko Y, aidya NHV. Location-aided routing (LAR) in mobile ad hoc networks. Proc. The ACM/IEEE International Conference on Mobile Computing and Networking, 1998. 66{75.

[6] Ma XL, Sun MT, Zhao G, *et al.* An efficient path pruning algorithm for geographical routing in wireless networks. IEEE Trans. Vehicuar Technology, 2008, 57(4): 2474{2488}.

[7] Kim Y J, Govindan R, Karp B, *et al*. Geographic routing made practical. Proc. the 2nd Symposium on Networked Systems Design and Implementation, 2005. 217{230.

[8] Watanabe M, Higaki H. No-Beacon GEDIR: Location-Based Ad-Hoc Routing with Less Communication Overhead. Proc. the International Conference on Information Technology, 2007.

[9] Singh S, Woo M, Raghavendra CS. Power-Aware routing in mobile ad hoc networks. Proc. the ACM/IEEE International Conference on Mobile Computing and Networking, Oct. 1998.

[10] Basagni S, Chlamtac I, Syrotiuk VR. A distance routing e®ect algorithm for mobility (DREAM). Proc. the ACM/IEEE International Conference on Mobile Computing and Networking, 1998.

[11] Kuhn F, Wattenhofer R, Zhang Y, *et al*. Geometric ad-hoc routing: Of theory and practice Proc. the 22nd ACM Symposium on Principles of Distributed Computing, 2003. 63-72.

[12] Zeng K, Ren K, Lou W, *et al*. Energy Aware Geographic Routing in Lossy Wireless Sensor Networks with Environmental Energy Supply. Proc. the 3rd International Conference on Quality of Service in Heterogeneous Wired/Wireless Networks, Waterloo, Canada, Aug. 2006.

[13] Stojmenovic I. A scalable quorum based location update scheme for routing in ad hoc wireless networks. Technical Report TR-99-09, SITE, University of Ottawa, Sep. 1999.

[14] Stojmenovic I. Home agent based location update and destination search schemes in ad hoc wireless networks. Technical Report TR-99-10, SITE, University of Ottawa, Sep. 1999.

[15] Li J, Jannotti J, Douglas S J De Couto, *et al*. A scalable location service for geographic ad hoc routing. Proc. the 6th Annual International Conference on Mobile Computing and Networking, Aug. 2000. 120-130.

[16] Kuruvila J, Nayak A, Stojmenovic I. Progress and location based localized power aware routing for ad hoc and sensor wireless networks. International Journal of Distributed Sensor Networks, 2006, 2(2): 147-159.

[17] Kim YJ, Govindan R, Karp B, *et al.* Lazy Cross-Link Removal for Geographic Routing. Proc. the ACM Conference on Embedded Networked Sensor Systems, Nov. 2006. 112-124.

[18] Liao W-H, Tseng Y-C, Lo K-L, Sheu J-P (2000) GeoGRID: A Geocasting Protocol for Mobile Ad Hoc Networks based on GRID. Journal of Internet Technology, Volume 1, Issue 2:23–32

[19] Jain R, Puri A, Sengupta R (2001) Geographical Routing Using Partial Information for Wireless Ad Hoc Networks. IEEE Personal Communications, Volume 8, Issue 1:48–57

[20] Ko Y-B, Vaidya NH (1998) Location-based multicast in mobile ad hoc networks. Technical Report TR98-018, Texas A&M University

[21] Sinha P, Sivakumar R, Bharghavan V (1999) MCEDAR: Multicast Core-Extraction Distributed Ad Hoc Routing. Proceedings of IEEE WCNC, Volume 3:1313–1317

[22] Wu CW Tay TC (1999) AMRIS: A Multicast Protocol for Ad Hoc Wireless Networks. IEEE MILCOM 1999, Volume 1:25–29,

[23] Toh C-K, Guichal G, Bunchua S (2000) ABAM: On-Demand Associativity-Based Multicast Routing for Ad Hoc Mobile Networks. Proceedings of IEEE VTS-Fall VTC 2000, Volume 3:987–993

[24] Royer EM, Perkins CE (2000) Multicast Ad Hoc On-Demand Distance Vector (MAODV) Routing. IETF Draft, draft-ietf-manet-maodv-00, 15 July, 2000, available at http://tools.ietf.org/html/draft-ietf-manet-maodv- Accessed 21 February 2008

[25] Ji L, Corson MS (2001) Differential DestinationMulticast-A MANETMulticast Routing Protocol for Small Groups. Proceedings of IEEE INFOCOM 2001, Volume 2:1192–1201

[26] Lee S, Su W, Gerla M (2002) On-Demand Multicast Routing Protocol in Multihop Wireless Mobile Networks. ACM/Kluwer Mobile Networks and Applications (MONET), volume 7, Issue 6:441–453

[27] Jetcheva JG, Johnson DB (2001) Adaptive Demand-Driven Multicast Routing in Multi-Hop Wireless Ad Hoc Networks. Proceedings of ACM MobiHoc 2001:33–44

[28] Xie J, Talpade RR, Mcauley A, Liu M (2002) AMRoute: Ad Hoc Multicast Routing Protocol. Mobile Networks and Applications, Volume 7, Issue 6:429–439.

[29] Das SK, Manoj BS, Murthy CSR (2002) A Dynamic Core Based Multicast Routing Protocol for Ad Hoc Wireless Networks. Proceedings of ACM MobiHoc 2002:24–35

[30] Sisodia RS, Karthigeyan I, Manoj BS, Murthy CSR (2003) A Preferred Link Based Multicast Protocol for Wireless Mobile Ad Hoc Networks. Proceedings of IEEE ICC 2003, Volume 3:2213–2217.

[31] Song J-H, Wong VWS, Leung VCM (2007) Secure position-based routing protocol for mobile ad hoc networks. Ad Hoc Networks, Volume 5, Issue 1:76–86.

[32] Reddy LR, Raghavan SV (2007) SMORT: Scalable multipath ondemand routing for mobile ad hoc networks. Ad Hoc Networks, Volume 5, Issue 2:162