

PLP – A Packet Loss Prevention Technique for Partitioned MANETs using Location-Based Multicast (LBM) Algorithms

Dr. Asad Hussain, Kashif Zia, Umar Farooq and Sajjad Ahmed

asadhussain@pucit.edu.pk, kashif@pucit.edu.pk, umar@pucit.edu.pk and sajjad@pucit.edu.pk

Punjab University College of Information Technology, University of the Punjab, Lahore Pakistan

Abstract: *Geocasting using Global Position System (GPS) in Mobile Ad hoc Network (MANET) has made location based services feasible. Location dependent services are mostly intended for a group of nodes in a geocasting region. Location based Multicast (LBM) Algorithms have presented multicasting techniques based on a forwarding zone. In this paper, a packet loss prevention technique is presented for partitioned networks between the source node and geocast region (although there exists a path between source and the multicast region); an issue not addressed by LBM Algorithms. It is proved through simulations that this scheme ensures high success rate with minimum possible flooding.*

Keywords: *MANETs, Ad hoc Networks, Geocasting, Multicasting, Location Based Multicast Algorithms*

1. INTRODUCTION

Mobile Ad hoc NETWORK (MANET) comprises of a set of wireless devices that are mobile. Due to their mobility, it is difficult to maintain a fixed infrastructure or centralized administration for managing the network. Further the devices are available with limited bandwidth and have limited battery power, consequently a limited transmission range. Hence, distant nodes have to communicate through multihop paths. Due to lack of fixed infrastructure, each node relay packets of other nodes acting as a router.

There are two basic mechanisms for communication in MANETs:

- **Unicast** MANETs find a routing path from a source node to a destination node. **Reactive** routing mechanisms are invoked on-demand (when a source has a packet to send to the destination). Examples of reactive routing protocols are Dynamic Source Routing (DSR) [1], Zone Routing Protocol (ZRP) [2, 3], and Ad hoc On-demand Distance Vector (AODV) [4]. **Proactive** routing mechanisms are invoked periodically (activating after each specified period of elapsed time). Examples of proactive routing protocols are Destination-Sequenced Distance-Vector (DSDV) [5] and Optimized Link-State Protocol (OLSR) [6].
- Collective communication approach involves more than one destination (**multicasting**). In multicasting, the protocols are either tree based (establish a tree involving

all members of multicast group) or flooding based (distributes multicast messages all around the network). Examples of tree based protocols are Ad hoc Multicast Routing Protocol (AMRoute) [7], Lightweight Adaptive Multicast protocol (LAM) [8] and Ad hoc Multicast Routing protocol (AMRIS) [9]. Whereas flooding based approaches also involve many protocols described in literature [10, 11].

Multicasting, where the same information is sent to more than one destination, have advantage of low communication cost when compared with equivalent multiple unicasts. Communication cost is important in MANETs due to sparse bandwidth of wireless media and power constraints of devices. But multicasting is more challenging in an ad hoc environment when compared with static networks due to rapid topology changes. Tree and mesh (a variant of tree) based approaches for multicasting has a serious problem of frequent tree reconfigurations due to high mobility of the nodes which results in excessive channel overhead. Multicast flooding can be an attractive alternative but it needs serious modifications as unconditional flooding is always undesirable [12]. One attractive option to reduce multicast flooding is to use location information based on Global Position System (GPS) [13], generally termed as **geocasting** [14].

Geocasting is a variant of the conventional multicasting approaches. It supports mechanism to specify hosts as group members within a specified geographical region, i.e., the geocast region. Nodes eligible to receive packets are implicitly specified by a physical region. Membership in a geocast group changes whenever a mobile node moves in or out of the geocast region.

Geocasting routing protocols fall in two basic categories:

- *Data-transmission oriented protocols:* These protocols use flooding or a variant of flooding to forward data from a source node to a destination region. Popular protocols proposed in this category are:
 - Location Based Multicast (LBM) [12]: reduces the forwarding space for geocast packets.
 - Voronoi diagram based geocasting [15]: increases the success rate and decreases the hop count and flooding rate of LBM.

- GeoGRID [16]: elects a special host in the forwarding space (a grid area) which is responsible for forwarding the geocast packets.
- *Routing-creation oriented protocols*: These protocols manage routes and data. Packets are sent based on already established routes. Popular protocols proposed in this category are:
 - GeoTORA [17]: based on unicast routing protocol Temporary Ordered Routing Protocol (TORA) [18].
 - Meshbased Geocast Routing Protocol [19]: creates redundant routes in the form of a mesh to guarantee packet delivery.

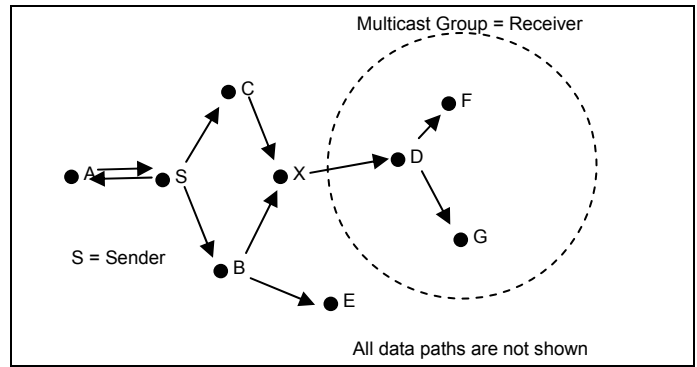


Figure 1 – Unconditional Multicast Flooding

In this paper, we have focused on LBM and proposed a variation in LBM called Packet Loss Prevention (PLP) scheme, for a situation in which the network is partitioned between the source node and geocast region (there is no valid node in forwarding space which would forward the packets, but there exists a path between source and the multicast region). The rest of the paper is organized as follows: Section 2 discusses the LBM Algorithms as presented by their authors [12]. Section 3 presents limitation of LBM that we have tried to address in Section 4. Section 5 provides proofs of our scheme through simulation and evaluation. We have concluded the paper in section 6.

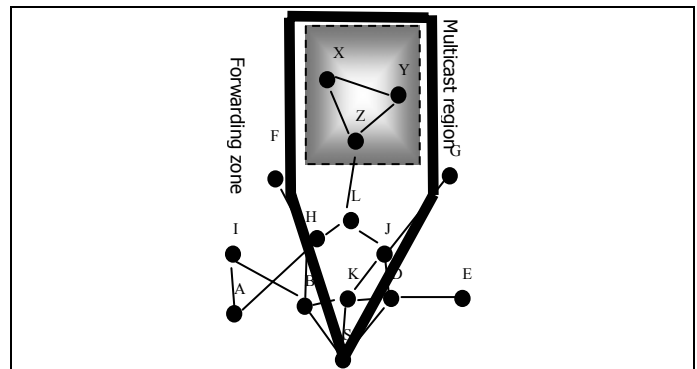


Figure 2 – Multicast Region and Forwarding Zone

2. LOCATION-BASED MULTICASTING

2.1. Multicast Flooding

Figure 1 depicts a simple scenario for unconditional multicast flooding.

If S is the sender and circle shown is the multicasting region, a packet reaching to an arbitrary node Z would be processed as follows: If the packet is not duplicated and location of Z is within the desired multicast region, Z would accept the packet. It would also broadcast the packet for other members of the region. Whereas, if packet is not duplicated, and location of Z is not within the multicast region, Z would broadcast it again.

2.2. Multicast Region and Forwarding Zone

For a packet generated at node S, the multicast region would be the geographic region for which the packet is intended. In Figure 2, node X, Y and Z are within multicast region.

A node forwards the multicast packet only if it belongs to the forwarding zone defined by the current sender. In Figure 2, forwarding zone for data packet sent from S is shown with bold lined region.

2.3. Location based Multicasting

LBM is essentially identical to flooding data packets, with the modification that a node determines whether to forward a geocast packet further via one of two schemes.

2.3.1. 1st Scheme

In the 1st Scheme, the forwarding zone is defined as the smallest rectangle that includes current location of sender S and the multicast region (a closed polygon), such that the sides of the rectangle are parallel to the X (horizontal) and Y (vertical) axes. In Figure 3 example, 'B' will broadcast the data packet while 'A' would not.

2.3.2. 2nd Scheme

In 2nd scheme, the forwarding region is not explicitly defined by sender (as it was in 1st scheme). In this scheme node S includes three pieces of information with its multicast packet:

- The multicast region specifications.
- The location of geometric center of the multicast region (X_c, Y_c) and distance of any node (say Z) from (X_c, Y_c) can be represented by $DIST_z$.
- The coordinates of sender (X_s, Y_s).

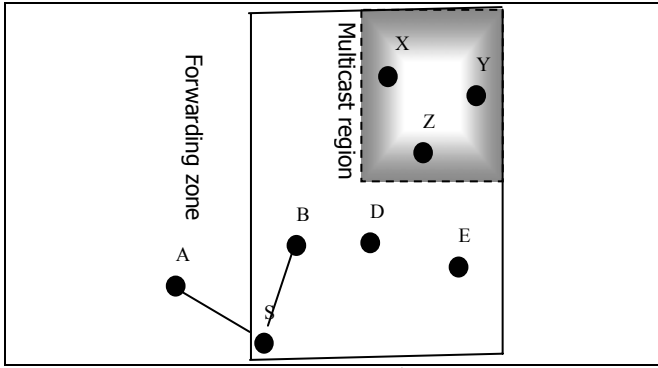


Figure 3 – LBM 1st Scheme

When a node I receives the multicast packet from node S, I calculates its distance from location X_c, Y_c , denoted as $DIST_i$, and:

- For some parameter δ , if $DIST_s + \delta \geq DIST_i$ then node I forwards the packet to its neighbors. But before forwarding the multicast packet, node I replaces the (X_s, Y_s) coordinates received in the multicast packet by its own coordinates (X_i, Y_i) .
- Else $DIST_s + \delta < DIST_i$; In this case, node I sees whether or not sender S is within the multicast region. If S is in the multicast region, then node I forwards the packet to its neighbors. Otherwise, it discards the packet.

When some node J receives the multicast data packet (originated by sender S) from node I, it applies a criteria similar to above

- Thus, node J forwards a multicast packet delivered by I (originated by S), if J is “at most δ farther” from (X_s, Y_s) than node I.
- Node J also forwards the packet in the case when node I is in the multicast region, even if J is not closer to (X_s, Y_s) than I.

Figure 4 shows a scheme implementing scheme 2.

When comparing the two schemes, 2nd scheme seems to be better than the 1st, as it is following geometrically optimized path towards multicast destination.

3. LBM LIMITATIONS

In both schemes, if there is no node lying on an optimal location within the forwarding zone, the network can be considered as partitioned and the packet delivery would be halted even without letting any of the senders in hierarchy know. This situation can cause data critical applications to suffer packet loss.

Suppose S floods a packet; two neighbors A and B are in transmission range of S, so they receive packet containing

coordinates of center of multicast region and S. If both A and B are located farther away from the multicast region as compared to S, they will discard the packet while S does not know its packet has been discarded.

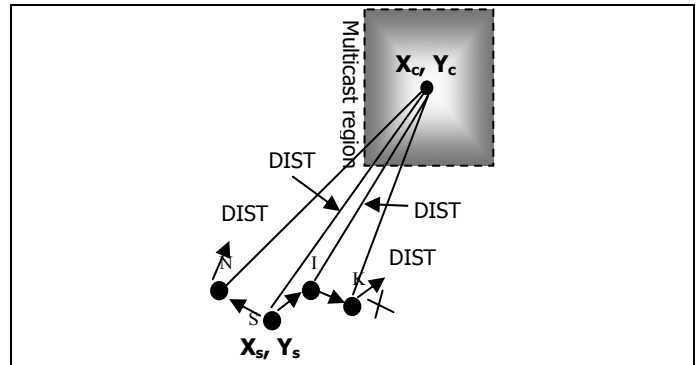


Figure 4 – LBM 2nd Scheme

4. PACKET LOSS PREVENTION SCHEME

The key point here is that A and B (or any of the node) should not discard the packet straight away. A scheme which implements an Advanced one-hop response can provide the solution.

Lets S broadcast a packet before transmitting the actual packet called Adv-Inq (Advanced Inquiry). A and B receive Adv-Inq packet containing coordinates of center of multicast region and S. A and B both calculate their distances for multicast region and compare it with S’s respective distance. There is another packet called Inq-Res (Inquiry Response), possibly consisting of only a flag. If A or B return Inq-Res with flag set to ‘Yes’, then there is no problem (unless the topology is instantly changed), S will transmit immediately. If they return ‘No’, S waits for a while (the ideal time can be calculated with evaluation) and retry using Adv-Inq packet again (hoping for a positive topology change).

S can retry for n (can be any integer decided keeping in mind the trade-off between delay in retries and unconditional broadcasting) times after that S can decide to broadcast the packet throughout the network unconditionally. It can be implemented by keeping a broadcast flag in actual packet, which would be ‘Up’ in only this situation.

5. SIMULATION AND EVALUATION

Simulation was performed in OPNET 8.0 [20]. The test bed used was NIST AODV model [21], which was modified to implement LBM and PLP schemes. All nodes are set to be mobile and they were deployed with in the area of 1000*500 meters. Transmission range of each node was set to 200 meters. Positions of the nodes in OPNET were considered to be the GPS coordinates. For simplicity node 17 transmits

data as shown in Figure 5. The multicast destination geographic region was considered to be 0-200 meters on x-axis and 0-100 meters on y-axis. The multicast region of the network contains only one node i.e. node 0. Other nodes only forward the information towards the destination.

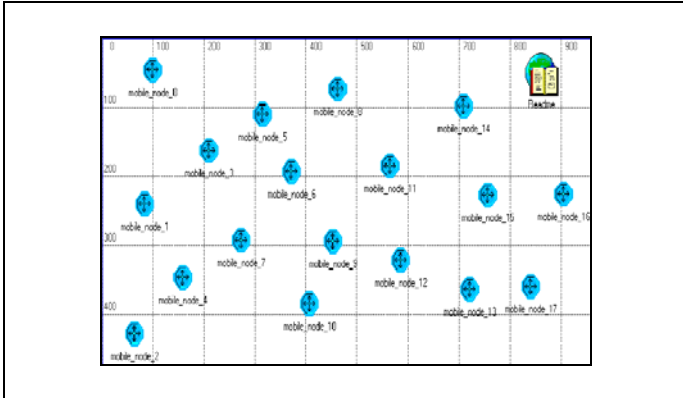


Figure 5 – Scenario 1 (Network having no partition)

Figure 5 shows a scenario in which there is no partitioning of the network. In case of LBM, majority of the packets reached to the destination, while others were in the nodes' buffers waiting for their turn to be transmitted. In the second scenario shown in Figure 6, the network is partitioned due to the movement of certain nodes. This resulted in zero packets reaching the destination node. All packets are stored in buffers.

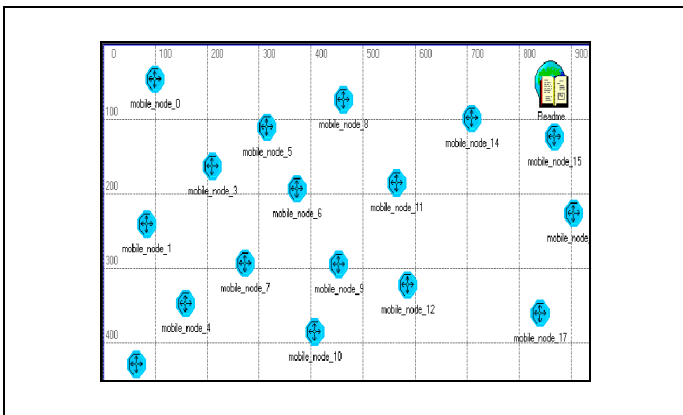


Figure 6 – Scenario 2 (Partitioned Network)

Two new packets; Adv-Inq and Inq-Res were introduced. Whenever a data packet reached a node (including source) the current packet was buffered if the packet was not duplicated and an Adv-Inq packet was generated containing the following four fields: Current node (Source) Address, Coordinate X of the Source, Coordinate Y of the Source and Sequence number of the current data packet. This Adv-Inq reaches at all nodes at distance of one hop. At each node the two distances (distance of current node from destination

region and distance of source node from destination region) is calculated as:

$$\text{Sqrt}(Y_1 + X_1) < \text{Sqrt}(Y_2 + X_2) \text{ --- (1)}$$

where

$Y_1 = (\text{y position of current node} - \text{mid point of y coordinate of multicast region})^2$

$X_1 = (\text{x position of current node} - \text{mid point of x coordinate of multicast region})^2$

$Y_2 = (\text{y position of source node} - \text{mid point of y coordinate of multicast region})^2$

$X_2 = (\text{x position of source node} - \text{mid point of x coordinate of multicast region})^2$

If the condition in equation (1) is true, it means that current node is closer to the multicast region as compared to the source node. In this case the current node would generate an Inq-Rep packet containing the following fields: Current node (Source) Address, distance of the node to the destination as calculated above, destination for the packet (source address copied from Inquiry packet) and Sequence number of the current data packet copied from Adv-Inq. If the condition in equation (1) is false, the node would discard the inquiry packet.

When copies of this Inq-Rep packet reaches all neighbors, only the node which sent the Inquiry originally would entertain the reply due to destination field in Inquiry Reply. If this packet is not duplicated (assuming first Inquiry reply reached to be optimal), current node would de-queue the data packet in its buffer and would transmit it for the destination copied from the Source field of the inquiry reply packet.

In LBM the number of data packets forwarded is 23952, including the generated at source which are 1498 and forwarded at intermediate nodes which are 22454. In PLP, the number 22454 has decreased to 2075 including the packets generated at source which are 1498. This decrement is due to selective flooding. The 7522 packets out of 9597 are Adv-Inq and Inq-Rep packets. The size of two packets (Adv-Inq and Inq-Rep) is 40 bits. The payload is 172 bits. The Figures 7 and 8 show that PLP performs better than LBM in terms of load generated (bits/sec) and end-to-end delay in the network respectively.

In case of LBM, the load generated on the network was total of 23952 data packets as described earlier. We can calculate the total load by multiplying 23952 by 172 which comes out to be 4119744 bits. But 23952 data packets is not the only traffic generated. There is also control traffic generated at MAC layer consisting of RTS, CTS and ACK frames. When accumulated for all 18 nodes, this traffic turned out to be 219554 bits. Load is also constituted of the packets reached at the destination (destination node process them) which are 4426 packets. Multiplying it with 172 we get a load of 761272. Adding 4119744, 219554 and 761272 we get a total

load of 5100570 bits. So the statistics of the graph of figure 7 indicating a total load of 5213552 bits is very close to our calculation. Taking final average of it comes out to be 51619 bits/sec.

Table 1. Comparison between Simple LBM and LBM with two extra inquiry packets

Packet Type	Number of Packets
PLP	
Inquiries	3342
Inquiry Replies	4180
Data Packets Forwarded	2075
Total	9597
Packets Transmitted	1463
Packets Reached at destination	195
LBM	
Data Packets Forwarded	23952
Packets Transmitted	1498
Packets Reached at destination	4426

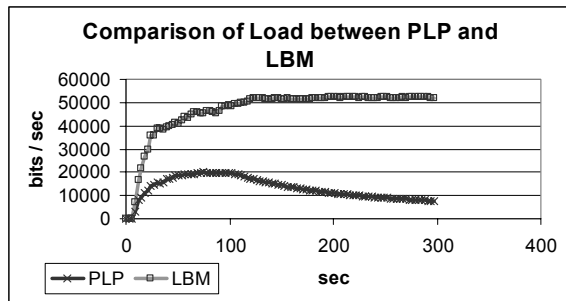


Figure 7. Load generated by LBM and PLP.

In case of PLP, the load primarily consists of three kinds of packets i.e. Inquiries (3342), Inquiry-Replies (4180) and data (2075). The total load is calculated as follows:

$$\text{Adv-Inq} = 3342 * 40 = 133680$$

$$\text{Inq-Res} = 4180 * 40 = 167200$$

$$\text{Data} = 2075 * 172 = 356900$$

the total comes out to be 657780 bits. When accumulated for all 18 nodes, the control traffic turned out to be 77426 bits. Load contributed by the packets reached at the destination is $195 * 172 = 33540$ bits. Adding 657780, 77426 and 33540 we get a total load of 768746 bits. So the statistics of the graph of figure 7 indicating a total load of 766465 bits is very close to our calculation. Taking final average of it comes out to be 7588 bits/sec.

The negative aspect of introduction of Inquiry and Inquiry reply packets seems to be the decrease in throughput. It is

due to the extra processing involved in each node before data transmission. This factor has affected the throughput of PLP as shown in Figure 9.

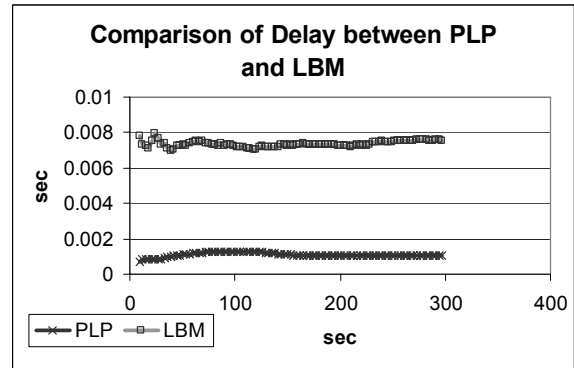


Figure 8. Delays of LBM and PLP

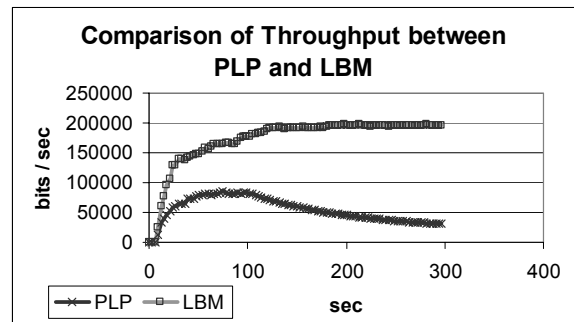


Figure 9 Throughput of LBM and PLP.

In case of LBM, the throughput was of 89728 data packets. Calculating it for total number of bits; it comes out to be $(89728 * 172)$ 15433216 bits. Total control bits come out to be 787427. The important factor here is the dropped bits which has affected the calculations. In PLP there was no packet drop. But in LBM there is packet drop. It is due to the overflow of buffer and the failure of all retransmissions until retry limit. The bits dropped reported are 4027051. Adding all these figures the total throughput in bits comes out to be 20247694. The total bits presented by the statistics of the Figure 9 were 19530795. Taking average of it comes out to be 195307 bits/sec.

In case of PLP, the total packets received were 35810 (Requests = 10394, Replies = 16524, Data = 8874). After calculating total bits generated for each kind of packets, it turned out to be 2603048 bits. Total control bits come out to be 329723. Adding both these figures the total throughput in bits comes out to be 2932771 as there is no packet drop. Statistics of Figure 9 presented a total of 3053957 bits. Taking average it settled down as 30539 bits/sec.

Partitioned network can be defined as an occasional location of nodes managed in a way that there is no optimal node available for data forwarding, but still there is a path (non-

optimal) available from source to the destination region. This situation was implemented as follows: Node X after sending an Adv-Inq packets waits for a reply for a specified time. If no reply is received, X generates Inquiry packet again hoping for topology change. After three attempts X modifies all the packets present in its buffer enabling a flag in data packet, and then broadcast packets.

Each node receiving any of these packets, reads the packet. If its broadcasting bit is 'on', it broadcasts the packets unconditionally. The results were taken for a situation in which the network was partitioned right at the start i.e. at node 17. These results are presented in Table 2:

In this case no packet was forwarded by LBM, while PLP ensured to exploit the existing path and transmitted the data packets.

Table 2. Comparison between Simple LBM and LBM with two extra inquiry packets in Partitioned Network

Packet Type	Number of Packets
PLP	
Inquiries	1116
Inquiry Replies	0
Data Packets Forwarded	15557
Total	16673
Packets Transmitted	1487
Packets Reached at destination	160
LBM	
Data Packets Forwarded	0
Packets Transmitted	1420
Packets Reached at destination	0

6. CONCLUSIONS

A novel scheme called PLP has been presented. This scheme prevents the packet loss in mobile peer to peer networks by using inquiry packets. The simulation results have shown that PLP improves the performance of the network by reducing the packet losses. Due to the mobility of the nodes the packets in LBM schemes would be blocked at the point of partitioning. The packets would keep on accumulating in a single node at one end of partition.

REFERENCES

[1] Johnson, D. B., Maltz, D. A.: Dynamic Source Routing in Ad-Hoc Wireless Networking, Mobile Computing, T. Imielinski and H. Korth, Eds. Norwell, MA: Kluwer, 1996, pp. 153-181

[2] Z. J. Haas, "A new routing protocol for the reconfigurable wireless networks," in Proceedings of IEEE International Conference on Universal Personal Communications (ICUPC '97), 1997, pp. 562-566.

[3] Z. J. Haas, M. R. Pearlman, and P. Samar, "The zone routing protocol (ZRP) for ad hoc networks," Draft-ietf-manet-zone-zrp-04.txt, Internet-Draft, IETF, 2002.

[4] Perkins, C. E., Royer, E. M.: Ad-hoc On-Demand Distance Vector Routing, February 1999, Proc. 2nd IEEE Workshop on Mobile Computer Systems and Applications, pp. 90-100

[5] Perkins, C. E., Bhagwat, P.: Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers, October 1994, Computer Communications, pp. 234-244

[6] Clausen, T., Jacquet, P., Laouiti, A., Minet, P., Muhlethaler, P., Qayyum, A., Viennot, L.: "Optimized Link State Routing Protocol", September 2001, IETF Internet Draft, draft-ietfmanet-olsr-06.txt

[7] Bommaiah, McAuley, Talpade, and Liu. AMRoute: Adhoc multicast routing protocol (Internet-Draft), August 1998.

[8] L. Ji and M. S. Corson. LAM: Lightweight adaptive multicast protocol (Internet-Draft), August 1998.

[9] C.Wu, Y. Tay, and C.-K. Toh. Ad hoc multicast routing protocol utilizing increasing id-numbers (AMRIS) functional specification (Internet-Draft), November 1998.

[10] Mohapatra, P. Chao Gui Jian Li: Group communications in mobile ad hoc networks, Feb 2004, Computer, pp. 52-59.

[11] Yu-Chee Tseng, Shih-Lin Wu, Wen-Hwa Liao, Chih-Min Chao: Location Awareness in Ad Hoc Wireless Mobile Networks, June 2001, Computer, pp. 46-52

[12] Y.-B. Ko and N. H. Vaidya. Geocasting in mobile ad hoc networks: Location-based multicast algorithms. Technical Report TR-98-018, Texas A&M University, September 1998

[13] Ahmed El Rabbany, "Introduction to GPS the Global Positioning System", 2002

[14] X. Jiang and T. Camp, A Review of Geocasting Protocols for a Mobile Ad Hoc Network, Proceedings of the Grace Hopper Celebration (GHC '02), 2002

[15] Ivan Stojmenovic, Anand Prakash Ruhil, D.K. Lobiyal. Voronoi diagram and convex hull based geocasting and routing in wireless networks. Eighth IEEE International Symposium on Computers and Communications 2003

[16] W.-H. Liao, Y.-C. Tseng, and J.-P. Sheu. Grid: A fully location-aware routing protocol for mobile ad hoc networks. Telecommunication Systems, 18(1):37-60, 2001.

[17] Y. Ko and N. H. Vaidya. GeoTORA: A protocol for geocasting in mobile ad hoc networks. In 8th International Conference on Network Protocols (ICNP), November 2000.

[18] V. Park and S. Corson. Temporally-ordered routing algorithm (TORA) version 1 functional specification. Internet Draft: draft-ietf-manet-tora-spec-04.txt, July 2001.

[19] J. Boleng, T. Camp, and V. Tolety. Mesh-based geocast routing protocols in an ad hoc network. In Proceedings of the International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing (IPDPS 2001), pages 184-193, April 2001.

[20] <http://www.opnet.com>

[21] http://www.antd.nist.gov/wctg/manet/prd_aodvfiles.html