A Survey of Scalable Multicast Routing Protocols For Mobile Ad Hoc Networks

Jyoti.M.Karbhal
Student, ME (Information Technology)
Sinhgad College of Engineering
Pune, India, jyotikarbhal@gmail.com

Kishor B Sadafale
Assistant Professor (Information Technology)
Sinhgad College of Engineering
Pune, India,kishor_sadafale@yahoo.com

***Abstract*—A mobile ad hoc network (MANET) consists of a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration.. Multicast is a efficient method for supporting collaborative applications among a group of mobile users. Group communications are important in Mobile Ad hoc Networks (MANETs).Scalability is important issue in term of group size and network size while designing multicast protocol. In this paper we study multicast protocols which consider scalability aspect and point out the associated advantages and disadvantages.**

Keywords-Mobile ad-hoc network (MANET) , group ,Multicast routing protocol, Scalability, Routing.

I. INTRODUCTION

A mobile ad-hoc network (MANET) is composed of mobile nodes without any infrastructure. In such a network, since nodes are often not within the radio transmission range of each other, each node operates not only as a host, but also as a router, forwarding packets for other mobile nodes. The nodes move freely and independently of one another. Ad hoc networks are mainly used in emergency situations where no infrastructure is available, for eg. military battlefields, disaster mitigation, emergency search, rescue sites, classrooms and conventions, where participants share information dynamically using their mobile devices. These applications lend themselves well to multicast operations. In addition, within a wireless medium, it is even more crucial to reduce the transmission overhead and power consumption. Multicasting can improve the efficiency of the wireless link when sending multiple copies of messages by exploiting the inherent broadcast property of wireless transmission. Basically MANET multicast protocol divided into two main category i) Topology based multicast protocol (stateful)ii) Position based multicast protocol (stateless)

Topology-based multicast protocols for mobile ad-hoc networks can be categorized into two main classes: tree-based and mesh-based protocols. The tree-based approaches build a data dissemination tree that contains exactly one path from a source to each destination. Topological information is used for its construction. The trees can be sub-classified further into source trees and shared trees. E.g MZR [1] and ADMR [2]. In these protocols, each single source builds its own tree to distribute its packets. In contrast to that, a shared tree is one in which each connected node is able to send packets to all other nodes using the same tree. Shared trees are built among others E.g. MAODV [3]. Tree-based approaches often use local repair mechanisms to shield the distribution structure from link failures caused by mobility.

Mesh-based approaches, building meshes of data paths to make the multicast routes more stable against topological changes. This comes at the expense of a higher overhead during data delivery. A mesh can contain multiple possible paths from a source to a destination. E.g ODMRP [4], FGMP [5].

Drawback of Topology-based multicast protocols are generally difficult to scale to a large network size, as the construction and maintenance of the conventional tree or mesh structure involve high control overhead over a dynamic network.

Second category is position based multicast protocol. In location-based multicast routing protocols, Each node determines its own location through the use of the availability of a Global Positioning System (GPS), Bluetooth or other locations systems easily s when required [6]. A location service is used by the sender of a packet to determine the location of the destination. The routing decision at each forwarding node is then based on the location information of its neighbors and the destination nodes.E.g DSM [7], LGT [8].

Drawback of geographic multicast protocols like DSM [7], LGT [8] is these protocol used only for small groups. As these protocol need to put the information of the entire tree or all the destinations into packet headers, which would create a big header overhead when the group size is large, these protocols are not scalable. So more research on scalability aspect is required.

In this paper we study protocols which focus scalability and efficiency of multicast protocols. The remainder of this paper is organized as follows. Section II, III, IV discuss working, advantage and disadvantage of HRPM [9], SPBM [10] and EGMP [11] protocol respectively. Finally, Section V concludes the paper.

II. HIERARCHICAL RENDEZVOUS POINT MULTICAST PROTOCOL (HRPM).

Like stateless or position based protocol HRPM [9] also used location information that is available from the Global Positioning System (GPS) or localization algorithms. But, existing location based multicast protocols are not scalable to large groups. As group size increased, the per-packet encoding overhead, and the centralized group membership and location management become more difficult for large group size. HRPM is designed to overcome these issues. HRPM uses two key concept two support large group sizes 1) hierarchical decomposition of a large group into a hierarchy of recursively organized manageable-sized subgroups and 2) the use of distributed geographic hashing to construct and maintain such a hierarchy.

A. Protocol Overview

As we know, per-packet encoding overhead of a stateless location-based multicast protocol grows with the group size. Hence increasing group size limits the usability of position based protocols. The main design goal of HRPM is to limit the per-packet overhead to an application-specified constant (ω) irrespective of the increase in group size. HRPM recursively partitions a large multicast group into manageable sized subgroups so that tree-encoding overhead limits to the application-specified constant (ω). This manageable sized subgroup is formed by dividing the entire MANET region into d2 equal-sized square sub domains called cells, where d is the decomposition index. Such cells form a hierarchy with the root representing the entire region. HRPM introduce two logical entities AP (Access Point) and RP (rendezvous point). Where all members in cell is managed by cell's AP (Access Point) and entire region has an RP. Thus HRPM maintain two level hierarchical and RP is calculated by using concept of concept of geographic hashing [12]. RP and AP is calculated as below.

RP is calculated as H (GID) = {x, y} where x, y ϵ MANET region

Where GID is group identifier and {x, y} a location (x- and y-coordinates) contained in the MANET region

AP is calculated as H(GID, d, myLoc) = {x,y} where x, y ϵ Cell region

Where d is the decomposition index and myLoc is the current location of the node invoking the function, GID is group identifier, {x,y} a location (x- and y-coordinates) contained in the cell region

Since in MANETs, different mobile nodes can become the closest to a fixed location over time, HRPM uses continuous handoff process, which ensures that the data item is always stored on the node that is currently closest to the location. So that all group management message is routed to proper AP and RP. Concept of AP and RP is shown in fig 1.

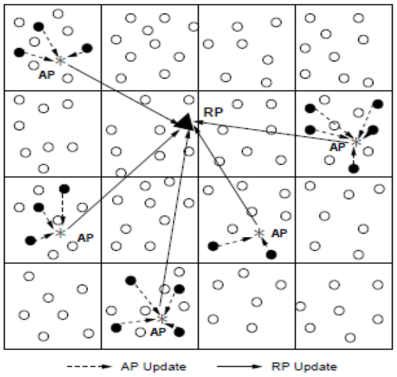

Figure 1.Group management using AP and RP

B. Group management and data delivery

This Section describes how HRPM manages large group and perform data delivery. Here we first discuss group joining and group leaving process. When any node that wants to join a multicast group, it first finds out RP location using above formula. After obtaining the hashed RP location for the group that it wants to join, the node sends a JOIN message that is addressed to this hashed location This JOIN message is routed by geographic forwarding to the node that is currently closest to the hashed location in the network. Here it assumed that all nodes aware of size of the network. After receiving the value of the current decomposition index d of the hierarchy from the RP, the joining node invokes the hash function with d and its current location to compute the hashed location of the AP of its cell. The APs then coordinate with the RP for the group which is shown in fig 1. When any node wants to leave group it send leave message to RP. RP maintain the group information using bit vector of d2 bits. Where each bit representing whether a group member exists in a particular cell or not. Hence in two-level HRPM, RP need to maintain only d2 states. While AP in each cell need to only maintain the addresses and locations of G/d2 nodes on the average, where G is the original size of the multicast group.

When source send a data packet, it first sends an OPEN SESSION message to the RP and receives the membership group vector from the RP. In membership bit vector "1" bit for each cell indicates that cell contain group members. This vector is cached by the source. Whenever there is change in membership bit vector RP updates source by sending the changes.Onces source received group vector from an RP, it build virtual overlay tree source->AP tree The tree is virtual, since the source does not need to know the actual AP node in each cell: it just needs to hash the GID in the AP's cell to put in a virtual vertex in the topology graph. Multicast data packets are first delivered down the Source-> AP tree. When a data packet reaches an AP, the AP performs the following operations:

1. It forwards the data packet on the remainder of the Source-> AP tree below it by reconstructing the remaining tree based on the bitmap that it receives.

2. It constructs an AP -> Member overlay tree to distribute this packet to the members of the group (the data packet has a

destination group ID) in its cell by using the member locations that it stores. This operation is shown in Fig 2

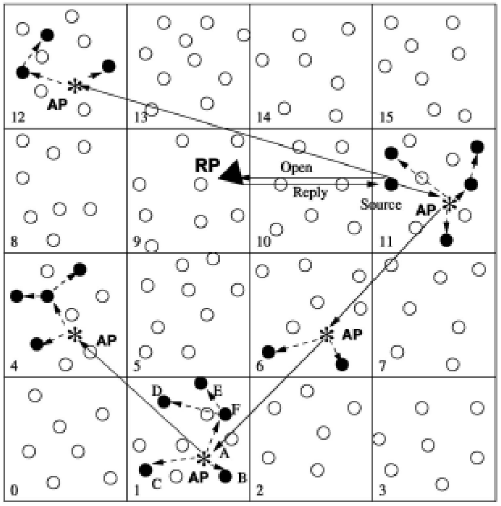

Figure 2. Data delivery in HRPM

C. *Discussion Of Protocol*

As HRPM protocol, uses two key concepts: distributed mobile geographic hashing and hierarchical decomposition of large multicast groups, HRPM improve the scalability of location-based multicast. HRPM also reduces per packet overhead and cost associated with maintaining a distributed state at any particular mobile nodes.

Beside these advantages here we discuss some points which may affect the performance of HRPM 1) In HRPM nodes need to hash RP, and for calculating RP it assumes that every node knows network size which is very difficult for dynamic network . 2) There is some additional challenges due to mobility of the nodes. It causes frequent RP handoff. 3) Increase mobility also increases the chance of RP search inconsistency and failure. 4) When any node want to join group it first send join request to RP, which will increase joining delay.

III. SCALABLE POSITION BASED MULTICAST PROTOCOL (SPBM)

A. *Protocol Overview*

Scalable Position-Based Multicast (SPBM)[10] protocol uses the geographic position of nodes to support large group size .SPBM forward the data packet with a very low overhead .SPBM is robust to changes in the topology of the network. To achieve this SPBM uses the concept of quad tree where entire network is subdivided into a quad-tree with a predefined maximum level of aggregation L. Single squares are identified by their concatenated level-n to level-1 square number as shown in Fig 3.

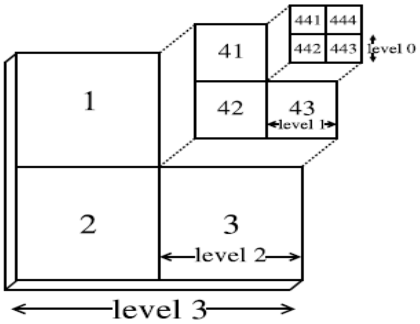

Figure 3. Network represented by Quad Tree (L=3)

B. *Group management and data delivery Acronyms*

The SPBM is designed to provide each node in the ad-hoc network with an aggregated view of the position of group members. For this purpose, each node maintains a global member table containing entries for the three neighboring squares for each level from level 0 up to level ((L-1) . In addition each node has a local member table for nodes located in the same level-0 square. Global and local member table of a node located in square 442 is as shown below.

TABLE I Global member table

Square	Group
1	00011100
2	01000100
3	10100010
41	01010000
42	00010101
43	00100100
441	00000100
443	00010000
444	00100100

TABLE II Local Member table

Node	Group
14	00000001
23	01000100
51	00000100

Each entry in the global member table consists of the square's identifier and the aggregated membership information (bit vector)of all nodes contained in that square. Each entry in the local membership table consists of a node ID and the membership information (bit vector) of that node. In bit vector each bit represents one multicast group.1 A bit set to 1 indicates group membership. Table 1 shows an example for a node located in square "442" with a membership vector length of 8. In this example the first entry of the global member table can be interpreted as follows: there is at least one multicast receiver for groups 3, 4 and 5 located in the level-2 square "1". The first entry of the local member table contains the information that node 14 is in the same level- 0 square as the node maintaining the table and that 14 is member of group 7.

Any updation of group membership is done by simple mechanism in SPBM. A node stores the membership information for all nodes in its level-0 square. SPBM periodically select one node in each level-0 square. This node compute aggregated group membership information by using bitwise OR operation. OR operation performed on membership vectors

of the nodes located in the level-0 square. The selected node floods the level- 1 square with an update message that includes the ID of the selected node, a membership vector describing the aggregated group membership information, the identifier of the destination square that is to be flooded, and a sequence number so as to enable duplicate message detection. Thus, a total of four update messages will be flooded in each level-1 square: one from each level-0 square. Selected nodes aggregate their level-0 membership information and flood them in an update packet within the level-1 square. The same mechanism is used to aggregate the membership information from an arbitrary level-κ square and flood it in the area of a level (κ+1).

For multicast data forwarding the nodes use the information stored in their member tables. In addition each node maintain neighbor table which consists nodes in its transmission range. The forwarding decision is based on information about neighboring nodes. SPBM design two basic steps for multicast forward 1) As an input, the algorithm requires the current node n, the packet p and the list of neighbors N of n. The packet includes a list of-destinations field which is initially set to one entry that comprises the whole network and a group address field indicating the group the packet is sent to. Once the algorithm is invoked, it first checks whether the current node n is a member of the multicast group the packet is sent to. If this is the case, then the packet is delivered.2) In the next step the algorithm looks at each entry in the list-of-destinations field of the packet: if the global or the local membership tables contain a de-aggregation of the entry, then the entry is subdivided into those squares of the next lower level that include members for the group the packet is transmitted to. At level-0 a de-aggregation is performed by replacing the square with the IDs of the nodes that are group members.

Fig. 4 shows an example of the forwarding procedure. 3 Node A wants to send a packet to the group in which nodes C, E and F are members. Thus A's member table contains the information that there is at least one receiver in square "4". It sends the packet in this direction and node B is the first node located in the level-2 square "4". Consequently, it has the information that there are nodes subscribed to the group in the level-1 squares "43" and "44". It therefore updates the information in the packet header accordingly. Node C is the first forwarding node in square "43". Besides delivering the packet, it checks its member table and recognizes that it does not need to forward the packet to any additional receivers in square "43". In square "44", node D replaces square "44" in the packet header by the level-0 squares "441" and "444". After receiving the packet, nodes E and F replace their square by potential additional destination nodes in this square. If there were any, the packets would now directly be sent to the receivers since the radio ranges of E and F cover the complete squares "441" and "444", respectively.

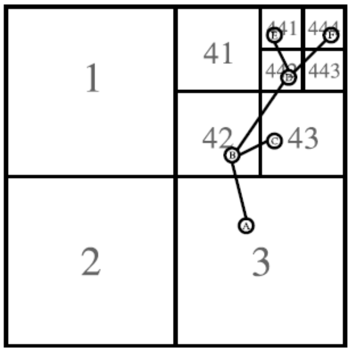

Figure 4. Forwarding on quad tree

C. Discussion Of Protocol

As SPBM uses quad tree concept and bit vector to store group membership information, it reduces the membership management overhead. SPBM support large group through this hierarchical approach to position-based multicast.

Beside these advantages here we discuss some points which may affect the performance of SPBM. 1) To update group membership at each level, every square needs to periodically flood its membership into its upper level square. So when the network size increases due to membership flooding significant control overhead will be generated. 2) In SPBM any membership change of a node may need to go through L levels to make it known to the whole network. This leads to a long multicast group joining time.

IV. EFFICIENT GEOGRAPHIC MULTICAST PROTOCOL (EGMP).

A. Protocol Overview

The main goal of EGMP [11]is to support scalable and reliable membership management and multicast data delivery. In EGMP, it assume every node is aware of its own position through some positioning system e.g., GPS or other localization schemes. EGMP uses two key concepts: 1) Use Two tier virtual zone based structure 2) Construct zone based bidirectional multicast tree.

In two tier virtual zone based structure at the lower layer, in reference to a predetermined virtual origin, the nodes in the network self organize themselves into a set of zones and a leader is elected in a zone to manage the local group membership. EGMP choose zone size in such a way that in zone structures nodes from the same zone are within each other's transmission range and are aware of each other's location which is shown in fig 5. At the upper layer, the zone leader act as a representative for its zone. Zone leader responsible for join or leave a multicast group as required. In EGMP instead of connecting each group member directly to the tree, tree is formed in granularity of zone. EGMP construct bidirectional tree in which multicast packets can flow not only from an upstream node/zone down to its downstream nodes/zones, but also from a downstream node/zone up to its upstream node/zone.

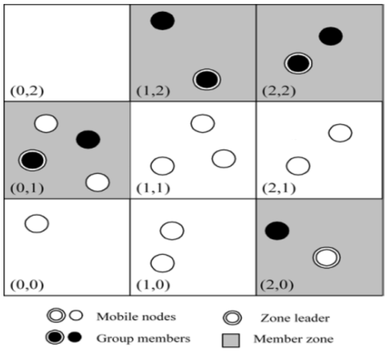

Figure 5. Two tier virtual zone architecture

B. *Group management and data delivery*

Here we discuss how EGMP maintain a group and construct zone based multicast tree. To maintain group each Multicast group member maintain membership table which consists 1.

G – Group Id 2.Root-ZId-root zone ID 3.isAcked-flag indicating that whether node is on corresponding multicast tree. And zone leader maintain Multicast table which consists 1.Group ID 2. Root-Zone ID 3.Upstream Zone-ID 4.Downstream Zone ID 5.Downstream node list.

When any source node want to send multicast data, it first initiate multicast session by flooding the message New-Session (G, ZoneID) where ZoneID is the ID of zone where source s is located. Same zone ID is used as initial root-zone ID for group G.

When any node want to join a multicast group and node is not a zone leader, then it send join request to zone leader. Zone leader send JOIN_REQ message to root zone. JOIN_REQ(M,POSM,G,{Mold}) where M –Address of node,POSM- Position of node,G-GroupID,Mold –Address of old group leader.

If JOIN_REQ Message is received from member M of same zone the leader add M to the downstream node list. And if the JOIN_REQ is from another zone it compare zone depth of requesting zone and that of its own zone . If its zone depth is smaller it will add requesting zone to its downstream zone list. Otherwise simply continue to forwarding JOIN request. Zone depth of zone can be calculated as, for a zone with ID (a, b), its depth is

Depth =max(|a0- a|,|b0- b|) where (a0, b0) is the root-zone ID.When new node or zone is added to downstream list leader will check root zone ID and upstream zone ID .With the knowledge of root zone, if its upstream zone ID is unset leader will send JOIN_REQ message to root zone. Otherwise the leader will send back JOIN_REPLY message to the source of JOIN _REQ message. If the leader of requesting zone receive JOIN_REPLY message it will set its upstream zone ID as ID of the zone where JOIN_REPLY message is send & then send JOIN_REPLY message to unacknowledged downstream node and zones. If it is node ,it set isAck flag in membership table and joining procedure is completed. Fig 6 shows zone structure and multicast session example and table 2and 3 shows multicast table and membership table.

When member M want to leave G it sends a LEAVE (M,G) message to its zone leader. On receiving a leave message leader removes source of leave message from its downstream node list or zone list. This is called as explicit leave. Leader can remove node from its downstream if it does not receive any BEACON message from node exceeding predefine time interval this is called as implicit leave.

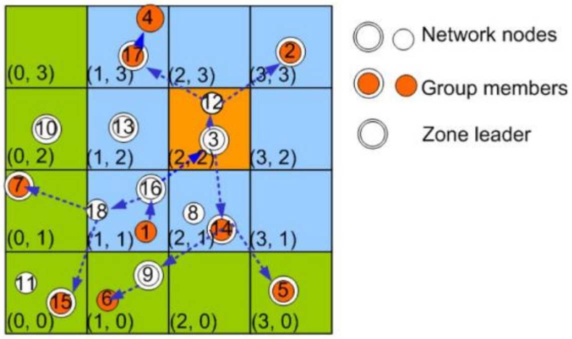

Figure 6. Zone structure and multicast session example

TABLE III Multicast Table of Node 16

Group ID	G
Root zoneID	(2,2)
Upstream Zone ID	(2,2)
Downstream zone list	(0,1),(0,0)
Downstream Member list	1

TABLE IV Member table for node 1

Group ID	G
Root zoneID	(2,2)
IsAcked	0

In EGMP only zone leader maintain the multicast table, and the member zones normally cannot be reached within one hop from the source. When a node N has a multicast packet to forward to a list of destinations (D1;D2;D3; . . .), it decides the next hop node toward each destination (for a zone, its centre is used) using the geographic forwarding strategy. After deciding the next hop nodes, N inserts the list of next hop nodes and the destinations associated with each next hop node in the packet header. An example list is (N1: D1; D3; N2: D2; . . .), where N1 is the next hop node for the destinations D1 and D3, and N2 is the next hop node for D2. Then, N broadcasts the packet. Upon receiving the packet, a neighbor node will keep the packet if it is one of the next hop nodes or destinations, and drop the packet otherwise. When the node is associated with some downstream destinations, it will continue forwarding packets similarly as done by node N.

C. *Discussion Of Protocol*

EGMP uses two tier virtual zone concepts and bidirectional tree concept which reduces the group management overhead and support the large network size. As in EGMP nodes need to send group joining and leaving message to only zone leader, there is group joining delay.

Beside these advantages here we discuss some points which may affect the performance of EGMP 1) As EGMP support zone structure, zoning can complicate the scaling processing if there is sudden increase in the number of nodes, so there will be a disconnection in the tree, leads to the packet loss, significantly in short period of time.

V. CONCLUSION

Multicast routing is an essential component of communication protocols in mobile ad hoc networks. The survey tries to review multicast protocols which focus scalability aspect only and reveal the characteristics and trade-offs. All protocols use hierarchical approach to support scalability. Whatever the drawbacks of HRPM and SPBM are tried to minimize in EGMP but still there is increasing demand and a big challenge to design more scalable and reliable multicast protocol over a dynamic ad hoc network (MANET).With scalability aspect we have to consider other aspect also like QoS guarantees, security, and so on. The subject of our future investigations will be to improve the quality and efficiency of scalable multicast protocol.

REFERENCES

[1] S. Basagni, I. Chlamtac, and V.R. Syrotiuk, “Location Aware, Dependable Multicast for Mobile Ad Hoc Networks,” Computer Networks, vol. 36, nos. 5-6, pp. 659-670, Aug. 2001.

[2] K. Chen and K. Nahrstedt, “Effective Location-Guided Tree Construction Algorithms for Small Group Multicast in MANET,”Proc. IEEE INFOCOM, pp. 1180-1189, 2002.

[3] S.M. Das, H. Pucha, and Y.C. Hu, “Distributed Hashing for Scalable Multicast in Wireless Ad Hoc Network,” IEEE Trans. Parallel and Distributed Systems, vol. 19, no. 3, pp. 347-362, Mar. 2008.

[4] M. Transier, H. Fubler, J. Widmer, M. Mauve, and W. Effelsberg, “A Hierarchical Approach to Position-Based Multicast for Mobile Ad-Hoc Networks,” Wireless Networks, vol. 13, no. 4, pp. 447-460, Aug. 2007.

[5] X. Xiang, Member, IEEE, X. Wang, Member, IEEE, and Y. Yang,” Efficient and Scalable Multicasting over mobile Ad Hoc Networks”, IEEE Trans. MOBILE COMPUT.ING, VOL. 10, NO. 5, APRIL 2011

[6] S. Ratnasamy, B. Karp, L. Yin, F. Yu, D. Estrin, R. Govindan, and S. Shenker, “GHT: A Geographic Hash Table for Data-Centric Storage in Sensornets,” Proc. First ACM Workshop Wireless Sensor Networks and Applications (WSNA ’02), Sept. 2002.

[7] S. Basagni, I. Chlamtac, and V.R. Syrotiuk, “Location Aware, Dependable Multicast for Mobile Ad Hoc Networks,” Computer Networks, vol. 36, nos. 5-6, pp. 659-670, Aug. 2001.

[8] K. Chen and K. Nahrstedt, “Effective Location-Guided Tree Construction Algorithms for Small Group Multicast in MANET,”Proc. IEEE INFOCOM, pp. 1180-1189, 2002.

[9] S.M. Das, H. Pucha, and Y.C. Hu, “Distributed Hashing for Scalable Multicast in Wireless Ad Hoc Network,” IEEE Trans. Parallel and Distributed Systems, vol. 19, no. 3, pp. 347-362, Mar. 2008.

[10] M. Transier, H. Fubler, J. Widmer, M. Mauve, and W. Effelsberg, “A Hierarchical Approach to Position-Based Multicast for Mobile Ad-Hoc Networks,” Wireless Networks, vol. 13, no. 4, pp. 447-460, Aug. 2007.

[11] X. Xiang, Member, IEEE, X. Wang, Member, IEEE, and Y. Yang,” Efficient and Scalable Multicasting over mobile Ad Hoc Networks”, IEEE Trans. MOBILE COMPUT.ING, VOL. 10, NO. 5, APRIL 2011

[12] S. Ratnasamy, B. Karp, L. Yin, F. Yu, D. Estrin, R. Govindan, and S. Shenker, “GHT: A Geographic Hash Table for Data-Centric Storage in Sensornets,” Proc. First ACM Workshop Wireless Sensor Networks and Applications (WSNA ’02), Sept. 2002.

AUTHORS PROFILE

Ms. Jyoti M Karbhal received her B.E degree from Sinhgad college of Engineering, Pune University, doing her Post-Graduation in from Sinhgad college of Engineering ,Pune University, India. Her research interest is in the area of Wireless Adhoc Networks, Mobile Communication.

Mr. Kishor B. Sadafale has received his M.E degree in computer engineering from Pune University,India. He is currently an Assistant Professor with the Department of Information Technology,Sinhgad College Of Engineering, Pune University. His research areas include Database management system & networking. He has published over 6 National and international conference papers.