PERFORMANCE EVALUATION OF REALISTIC MANET USING MODIFIED ADAPTIVE POSITION UPDATION IN GEOGRAPHIC ROUTING

Jincy Francis*

Prof. V GOPI ME (Phd)**

Abstract—Now a days, Position based routing is apt for capacious mobile ad-hoc networks. Geographic routing has been widely acclaimed as the most promising draw near to scalable wireless position based routing. In geographic routing, nodes need to keep current positions of their immediate neighbors for making forwarding decisions effectively. Static broadcasting of beacon packets that contain the geographic location coordinates of the nodes is a common technique used by geographic routing protocols to maintain neighbor positions. A beaconing strategy which ignores the node mobility and traffic forwarding patterns in the network is not enchanting from both update cost and routing performance points of view. I put forward a dynamic position updation mechanism known as Modified *A*daptive Position Update (MAPU) strategy .In which the duration of position updation is based on the mobility dynamics of the nodes and the forwarding traffic patterns in the network. M APU is based on three axioms : (i) find out an efficient data forwarding path which contains low mobile nodes , (ii) nodes whose dynamisms are difficult to adumbrate update their location co ordinate more frequently (and vice versa),and (iii) nodes very abreast to data forwarding paths update their positions more frequently (and vice versa). NS2 simulation is used for the theoretical analysis of the geographic routing protocol, Greedy Perimeter Stateless Routing Protocol (GPSR) including MAPU approach. I used to compare the above with periodic beaconing and other recently proposed updating schemes. The

* ME Communication Systems, PSN College of Engineering and Technology, Tirunevelil

** Department of Electronics and Communication, PSN College of Engineering and Technology, Tirunevelil

result shows that MAPU can significantly reduce the update cost and advance the routing performance in terms of packet delivery ratio and average end-to-end delay .Also further researches are mainly related to the evaluation in realistic network scenarios, which account for sparse network , realistic radio propagation, localization error.

Keyword - Wireless communication,. Algorithm/protocol design and analysis,Routing protocols habits, personalization, recommender system, weblog mining, knowledge discovery, topology generation.

.

I. INTRODUCTION

THE infrastructure less nature of the mobile ad-hoc network leads to a suitable position based routing, ie Geographic routing. Geographic routing also called georouting or position-based routing, is a routing protocol that utilize geographical information for data transfer . It is mainly proposed for wireless networks and based on the idea that the source sends a message to the geographic location of the destination instead of using the network address. Geographic routing requires that each node can determine its own location and that the source is aware of the location of the destination. With this information a message can be routed to the destination without knowledge of the network topology or a prior route discovery. Since the forwarding decision is based entirely on local knowledge, it obviates the need to create and maintain routes for each destination. By virtue of these characteristics, position-based routing protocols are highly scalable and particularly robust to frequent changes in the network topology. Furthermore, since the forwarding decision is made *on the fly*, each node always selects the optimal next hop based on the most current topology.

Each packets from the source to the destination are forwarded by intermediate nodes .We know that the main packet forwarding strategies are *unicasting, broadcasting* and *multicasting*. To route a packet from source to destination we need the following information (i) the neighbors position information (ii) position information of destination of the packet .In order to get the position information of a node's neighbors we need to develop a local topology .Each and every node exchanges its own location information (obtained using any localization schemes like GPS).with its neighboring nodes . So that each and every node generate a local map consist of the location information of all neighbors within its vicinity. By using a location service(like the Grid Location System (GLS) [8] or Quorum [9].) we can find location of final destination. But MANET is a dynamic network of autonomous mobile nodes without any fixed infra structure. The dynamic nature of nodes leads to high rate of topology changes and this topology changes occur both rapidly and unexpectedly. So each node updates its position coordinates to all of is neighbors. This location updation packets are usually accredit as *becons.* Normally becon frames is one of the management frames in IEEE 802.11 WLANs. In most of the geographic routing protocols beacon frames are transmitted periodically to announce the presence of a Wireless LAN. These Beacon frames are transmitted by the Access Point (AP) in an infrastructure BSS(basic service set).But in the case of ad hoc (IBSS-Independent basic Service Set) network beacon generation is distributed among the stations.

In the current systems the position updates are of static in nature ie becon frame send in periodic intervals, for creating the local topology. But this position updates are costly due to the following reasons. During the becon transmission each and every node consumes energy, increase wireless bandwidth utilization, increase the packet collision ratio at the media access layer. If a becon packet is lost which will affect the local topology accuracy and routing performance. A lost data packet get retransmitted but not a becone packet .The retransmission of data packet increase the jitter. So we need a system which adapts the frequency of becon updation according to the mobility characteristics of node and traffic conditions. Each node have its own mobility characteristics, certain node shows high rate of dynamism (speed/displacement). But few nodes show low mobility. We need to broadcast the updated position of those nodes which shows high mobility characteristics. And periodic broadcasting of those nodes which show low dynamism is not necessary. Another factor of consideration is that a small amount of nodes are involve forwarding a data packet. It's so expensive to update those nodes which are far away from the forwarding path frequently.

In this paper, we propose a neoteric beaconing updation strategy for geographic routing protocols called *Modified Adaptive Position Updates strategy (MAPU).* Which eradicate the main drawbacks of periodic beconing by adjust to a different situation or condition of the network (dynamism of nodes, topology changes etc). this algorithm also helps to find out a forwarding path contain low mobility nodes. For example if we select a set of nodes having high mobility the local topology changes randomly. Also we go for the performance evaluation of the adhoc network , after incorporating the proposed scheme. Comparison of network parameters like becon overhead ,local topology accuracy etc.

MAPU aggregates two algorithms for provoke the beacon update process. They are *Mobility Prediction* algorithm (MP) and *On Demand Learning* algorithm. MP algorithm is a simple movement analysis based algorithm used to estimate when a new becon packet is broadcast. The second one is used to avoid the local topology inaccuracy. A node send it's becon packet whenever its over here a data transmission from its neighboring node. So that the position updation is mainly clouded on the forwarding path .Similarly those nodes far away from the forwarding path need not update it's position information frequently. We presenting two terms used to measure the accuracy of updated topology, *unmapped neighbor ratio* and *fake neighbor ratio*. In the simulation side we evaluate the performance of MAPU based on mobility dynamics and traffic load .Compare the former with the existing beconing scheme like speed based becon and distance based becon[13]. The simulation results show the adaptability nature of the MAPU strategy. Similarly MAPU achieve good performance in terms of average end to end delay ,packet delivery ratio and energy conception.

2 RELATED WORK

Forwarding decision is mainly based on location of both packet destination and node's one hope neighbors. Destination location information obtained and maintained by GLS [8] or Quorum System [9]. In normal case we go for periodic beconing scheme .Where each node broadcast its position to all other nodes with in a fixed time interval known as *becon interval* .If a node doesn't here a becon signal from it's neighbor node for a long time, time out interval, that node considered as an *out dated* node. The neighbor time-out interval often is always multiple of the beacon interval. For a high mobility node, local topology changes unexpectedly .Periodic beconing can cause inaccurate topologies and performance degradation in this type of networks. We found that the outdated entries in the neighbor list is the major source of performance degradation. So to develop a dynamic routing strategy that adapt becon intervals to the traffic load, node mobility and low mobility forwarding path .We discuss these three schemes in the following.

In the distance-based beaconing, a node transmits a beacon when it has moved a distance d. The node eliminates an outdated neighbor if the node does not hear any beacons from the neighbor while the node has moved more than n-times the distance d, or after a total maximum time-out of 5s. This technique therefore is adaptive to the node mobility, e.g. a faster moving node sends beacons more frequently and vice versa. However, this approach has two issues. First, a low mobility node may have many outdated neighbors in its neighbor list since the neighbor time-out interval at the slow node is longer. Another thing is when a high mobility node passes by a slow mobility one, the fast node may not detect the slow node due the infrequent beaconing of the low mobility node, which reduces the perceived network connectivity.

In the speed-based beaconing, the beacon interval is dependent only on the node speed. Each and energy node determines its beacon interval from a fixed predefined range [x, y] with the actual value chosen being inversely proportional to its speed. The neighbor time-out interval of a node is a n^{th} multiple of its beacon frame interval. Each node piggybacks their neighbor time-out interval in the beacons. A receiving node compares the piggybacked time-out interval with its own time-out interval, and selects the smaller time out interval as the time-out interval for this neighbor. In this way, a low mobility node can have small time-out interval for its fast neighbor and therefore eliminate the main problem in the distance-based beaconing. However, the speed-based beaconing still has the problem that a fast node may not detect the slow ones. In reactive beaconing, the beacon generation is accelerated by data packet transmissions. When a node wants to transmit a packet, the node first broadcasts a beacon signal. The neighbors overhearing the packet respond with beacons. Thus, the node built an accurate local topology before the data transmission. However, this process is starts prior to each data transmission, which can lead to a large number of beacon broadcasts, especially when the traffic load in the network is high.

The MAPU strategy discussed in this paper dynamically adjusts the beacon update intervals based on the mobility dynamics of the nodes , forwarding patterns in the network and local topology. The beacons transmitted by each nodes contain their current position and speed. Nodes compute their positions periodically by employing linear kinematic equations based on the parameters declare in the last announced beacon. If the predicted location is different from the actual location, a new beacon is broadcast to inform the neighbors about new changes in the node's mobility characteristics. Also, an accurate representation of the local topology is particularly desired at those nodes that are indented for forwarding packets. Hence, MAPU used to increase the frequency of beacon updates at those nodes that overhear data packet transmissions.

3 MODIFIED ADAPTIVE POSITION UPDATE (MAPU)

The main assumptions made in our work: (1) all nodes should aware of their own position and velocity, (2) all links in the network are bi-directional, (3) beacon updates include the current location and velocity of the nodes, and (4) data packets should piggyback position and velocity updates and all one-hop neighbors overhear the data packets while operate in the promiscuous mode. During initialization, each node broadcasts a beacon frame informing its neighbors about its presence and its current location and velocity. In most geographic routing protocols such as GPSR, each node broadcasts its current location information periodically. The position information received from neighboring beacons is saved at each node. Based on these position updates received from its neighbors, each node continuously updates its own local topology, which is represented as a new neighbor list. Only those nodes from the new neighbor list are considered as the only possible candidates for data forwarding. Thus, the beacon signal plays an important part in maintaining an accurate maintence of the local topology. Instead of periodic beaconing, MAPU adapts the beacon update intervals to the mobility dynamics of the nodes , the amount of data being forwarded in the neighborhood of the nodes and low mobility forwarding path. MAPU employs two mutually exclusive beacon accelerating rules, which are discussed in the following.

3.1 Mobility Prediction (MP) Rule

This rule adapts the beacon updation rate to the frequency with which the nodes change the characteristics that govern their motion (velocity and heading). The mobility characteristics are included in the beacons broadcast to a node’s neighbors. The neighbors can then trace the node’s motion using simple linear motion (kinematic) equations. Nodes that frequently change their motion need to update their neighbors frequently, since their locations are changing dynamically. On the other hand, nodes which move slowly do not need to send frequent updates. A periodic beacon update policy cannot satisfy both these requirements at the same time, since a small update interval will be wasteful for low mobility nodes, whereas a larger update interval will lead to inaccurate location information for the highly mobility nodes.

In MP scheme, upon receiving a beacon update from a node n, each of its neighbors records node n's current position and velocity and periodically trace node n's location using a simple prediction algorithm based on linear kinematics (discussed below). Based on this position estimate the neighbors can check whether node n is still within their transmission range or not and update their neighbor list accordingly. The aim of this scheme is

to send the next beacon update from node n when the error between the predicted location in the neighbors of n and node n's actual location is greater than an acceptable threshold value. We use a location prediction scheme based on the theory of motion to estimate a node's current location. We assume that the nodes are located in a two-dimensional coordinate system with the location indicated by the x and y coordinates. However, this scheme can be easily mapped to a three dimensional coordinate system. Table 1 illustrates the tearms used in the rest of this session.

Common Notations for Mobility Prediction

Variables	Definition
(X_l^n, Y_l^n)	The Co-ordinate of node n at time T_l(included in the previous becon)
(Xp^n, Yp^n)	The predicted position of node n at the current time
(V_x^n, V_y^n)	The velocity of node n along the direction of the x and y axes at time Tl (included in the previous becon)
T_l	The time of the last beacon broadcast
T_C	The current time

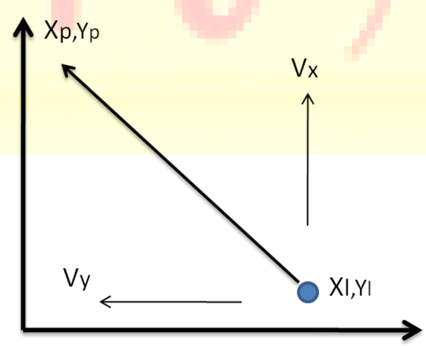

Figure 3.1 an example of mobility prediction

As shown in Fig. 1, given the position of node n and its velocity along the x and y axes at time Tl, its neighbors can estimate the current position of n, by using the given equations:

$$X_p^i = X_l^i + (T_c - T_l) * V_x^i$$
$$Y_p^i = Y_l^i + (T_c - T_l) * V_y^i$$

Node n uses the prediction scheme to keep track of its predicted location among its neighbors. Let (Xa, Ya), denote the actual location of node n, obtained via GPS or other localization techniques. Node n then computes the deviation D^n_{devi} as follows:

$$D_{devi}^i = \sqrt{(X_a^i - X_p^i)^2 + (Y_a^i - Y_p^i)^2}$$

If the deviation is greater than a certain threshold value, know as the *Allowable Error Range (AER)*, it acts as a trigger for node n to broadcast its current location and velocity as a new beacon.The MP rule, thus, tries to maximize the effective duration of each and every beacon, by broadcasting a beacon only when the predicted location information based on the previous beacon becomes inaccurate. This extends the effective duration of the beacon for nodes with less mobility, thus limiting the number of beacons. Further, highly mobile nodes can broadcast frequent beacons to assure that their neighbors are aware of the rapidly changing topology.

3.2 On-Demand Learning (ODL) Rule

The MP rule solely, may not be sufficient for maintaining an accurate local topology and increasing in performance. Consider the example illustrated in Fig. 2, where node A moves from P1 to P2 at a constant speed. Now, assume that node A has sent a beacon packet while at P1. Consider if node B did not receive this packet, it is unaware of the existence of node A. Further, assume that the *Allowable Error Range (AER)*, is sufficiently large such that when node A moves from P1 to P2 the MP rule is never initiated. However, as seen in Fig. 2 node A is within the transmission range of B for a significant portion of its motion. Even then, neither node A nor node B will be aware of each other. Now, in situations where any one of these nodes are transmitting data packets, this is perfectly fine since they are not within communicating range once A reaches

P2. However, if either A or B was transmitting data packets, then their local topology will not be updated and they will not consider each other while selecting the next hop node. In some extreme condition, assuming no other nodes were in the vicinity, the data packets would not be transmitted at all.

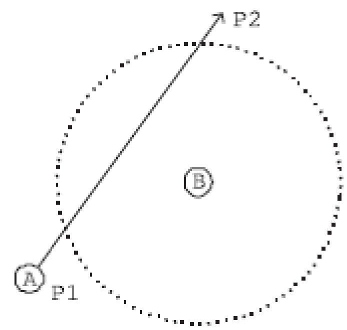

Fig. 2. An example illustrating a disadvantage of the MP rule

Hence, it is necessary to develop a mechanism, which will maintain a more accurate local topology in those regions of the network where major data forwarding activities are on-going. This is what the *On- Demand Learning (ODL)* rule aims to achieve. As the name indicates, a node broadcasts beacons *on-demand*, i.e. in response to data packet forwarding activities that occur in the vicinity of that node. According to this rule, whenever a node overhears a data packet transmission from a *new* neighbor, it broadcasts a beacon packet as a response. By a *new* neighbor, here we imply a neighbor who is not contained

in the neighbor list of this node. In normal case, a node waits for a small random time interval before responding with the beacon to avoid collisions with other beacons. We already assumed that the position updates are piggybacked on the data packets and that all nodes operate in the promiscuous mode, which allows them to overhear all data packets transmitted in their vicinity during that time.

In addition, if the data packet contains the actual position information of the final destination, any node that overhears a data packet also checks its current location and checks if the destination is within its transmission range. If so, the destination node is added to the list of existing neighboring nodes, only if it is a new entry. No beacons need to be transmitted in this case. We refer to the neighbor list developed at a node by virtue of the starting phase and the MP rule as the *basic* list. This list is mainly updated in response to the mobility characteristics of the node and its neighbors. The ODL rule allows active nodes that are involved in data forwarding todevelope their local topology beyond this basic set. In other words, an *accurate* neighbor list is maintained at the nodes located in the regions of high traffic load. Thus the rich list is maintained only at the active nodes(nodes involving in the forwarding data) and is built reactively in response to the network traffic. All inactive nodes simply maintain the primary neighbor list. By maintaining a rich neighbor list along the forwarding path, ODL assures that in situations where the nodes involved in data forwarding are highly dynamic, alternate routes can be easily established without causing additional delays.

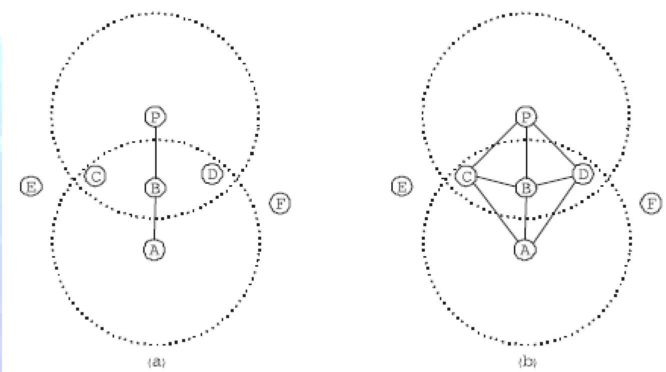

Fig. 3. An example illustrating the on demand learning rule

Fig. 3(a) illustrates the network topology before node A starts sending data to node P. The solid lines in the figure denote that both ends of the link are known each other. The initial possible routing path from A to P is AB- P. Consider when source A sends a data packets to B, both C and D receive the data packet from A. As A is a new neighbor of node C and D, according to the ODL rule, both C and D will send back beacon packet to A. As a result, the new links AC and AD will be discovered. Later based on the location of the destination and their current locations C and D discover that the destination P is within their one-hop neighborhood. Similarly when B forwards the data packet to P, the new links BC and BD are discovered. Fig. 3(b) shows the rich local topology along the routing path from A to P. Note that, though E and F receive the beacons from C and D, respectively, none of them respond back with a beacon packet. Since E and F do not lie on the forwarding path. So ODL aims at improving the accuracy of topology along the forwarding path from the source to the destination, for each traffic flow within the network.

4 ANALYSIS OF MODIFIED ADAPTIVE POSITION UPDATE

In this section, we analyze the performance of the proposed beaconing strategy, MAPU. We focus on two performance measures: (i) update cost of each node and (ii) local topology accuracy. The former is measured as the total number of beacon packets transmitted in the network. The latter is collectively measured by the following two metrics:

•*unmapped neighbor ratio*: This is defined as the ratio of the new neighbors a node is not aware of, but that are within the transmission range of the node to the total number of neighbors.

• *Fake neighbor Ratio*: This is defined as the ratio of those neighbors that are in the neighbor list of a node, but have already moved out of the node's transmission range to the total number of neighbors.

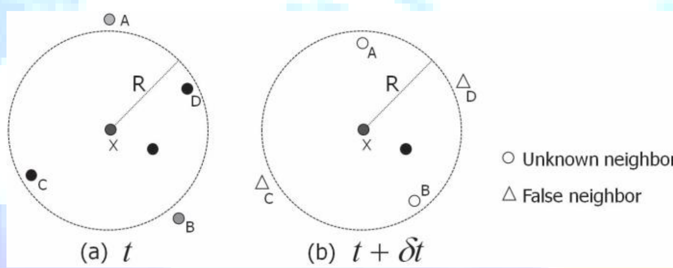

Fig. 4. Example illustrating un mapped and fake neighbors

The unmapped neighbors of a node are the new neighbors that have moved in to the radio range of this node but have not yet been discovered and are hence absent from the node's neighbor table. Consider the example in Fig. 4, which illustrates the local topology of a node X at two different time instants. We can see that nodes A and B, are not within the radio range R of node X at time t. However, in the next time instant (i.e. after a certain period δt), both these nodes have moved into the radio range of node X. If these two nodes do not transmit any beacons, then node X will be unaware of their existence. Hence, nodes A and B are examples of unmapped neighbors.

On the other hand, fake neighbors of a node are the neighbors that exist in the node's neighbor table but have actually moved out from the node's radio range (i.e., these nodes are no longer reachable). Consider the same example in Fig. 4. Nodes C and D are the neighbors of node X at time t. However, both these nodes have moved out of the transmission range of node X in the next time instant δt. But, node X would still list both nodes in its neighbor table. Consequently, nodes C and D are examples of fake neighbors.

Note that, the existence of both unmapped and fake neighbors have a negative impact on the performance of the geographic routing protocol. Unmapped neighbors are ignored by a node when it makes the forwarding decision. When one of the unmapped neighbors is located closer to the destination than the chosen next-hop node. If a fake neighbor is chosen as the next hop node, the transmitting node will repeatedly retransmit the packet without any success, before realizing that the chosen node is unreachable .Eventually, an alternate node would be chosen, but the retransmission attempts waste of bandwidth and increase the end to end delay. For mathematical tractability, we make the following simplifying assumptions:

• Nodes move according to a Random Direction Mobility (RDM) model, a popular model used in the analysis and simulations of wireless ad-hoc networks. This mobility model maintains a uniform distribution of nodes in the target region of the network over the entire time interval under consideration [21].

• Each node has maintained the same radio range R, and the radio coverage of each node is a circular area of radius R.

• The network is sufficiently dense such that the greedy forwarding always succeeds in finding a next hop node

• Both the data packet arrival rate at the source nodes and the intermediate forwarding nodes is constant.

4.1Node Selection

Each node exchanges its own location information for localization with its neighboring nodes using dynamic position updating procedure. This allows each node to build a local map of the nodes within its vicinity, often referred to as the local topology. In Mobile Ad-hoc Networks if forwarding nodes have high mobility, may chances to make local topology inaccuracy. so we enhance this project with low mobility based forwarding node selection, improve routing performance more than APU. In which while we are sending a data packet, it must be go through those nodes which have low mobility characteristics. We compare each nods previous position details and its topology changes, and gets an idea that whether the node is highly mobile or not. If the node shows low mobility characteristics then we select the node for forwarding the data packet.

4.2 Analyzing the Network Parameters

Impact of node density ,becon over head ,packet delivery ratio, node speed, energy conception ,average end to end delay on the performance of beaconing schemes using MAPU is simulated under the routing protocol dynamic source routing(DSR). We compare the result with the existing APU scheme.

5 CONCLUSIONS

In this paper, we have identified the need to adapt the beacon update policy employed in geographic routing protocols to the node mobility dynamics, the traffic load and low mobility path. We proposed the *Modified Adaptive Position Update (MAPU)* strategy to address these problems. The MAPU scheme employs two mutually exclusive rules. The MP rule uses mobility prediction to estimate the accuracy of the location estimate and adapts the beacon update interval accordingly, instead of using static periodic beaconing. The ODL rule allows nodes along the data forwarding path to maintain an accurate view of the local topology by exchanging beacons in response to data packets that are overheard from new neighbors in its visinty. We mathematically analyzed the beacon overhead and local topology accuracy of MAPU and validated the analytical model with the simulation results. We have embedded MAPU within DSR and have compared it with other related beaconing strategies using extensive NS-2 simulations for varying node speeds and traffic load. Our results indicate that the MAPU strategy generates less or similar amount of beacon overhead as other beaconing schemes but achieve better packet delivery ratio, average end-to-end delay and energy consumption.

REFERENCES

[1] J. Hightower and G. Borriello. ”Location Systems for Ubiquitous Computing”, in IEEE Computer, vol. 34, no. 8, pp. 57-66, August 2001.

[2] B. Karp and H. T. Kung. ”GPSR: Greedy Perimeter Stateless Routing forWireless Networks”, in Proceedings of ACM Mobicom 2000, pp. 243-254, Boston, MA, USA, August 2000,

[3] L. Blazevic, S. Giordano, J-Y. LeBoudec. ”A Location Based Routing Method for Mobile Ad Hoc Networks”, in IEEE Transaction on Mobile Computing, Vol. 3 No. 4, December 2004.

[4] Y. Ko and N. H. Vaidya. ”Location-Aided Routing (LAR) in Mobile Ad Hoc Networks”, in ACM/BaltzerWireless Networks, vol. 6, no. 4, pp. 307-321, September 2002.

[5] T. Camp, J. Boleng, B. Williams, L. Wilcox and W. Navidi. ”Performance Comparison of Two Location Based Routing Protocols for Ad Hoc Networks”. In Proceedings of IEEE Infocom, pp. 1678- 1687, NY, USAL, June 2002.

[6] D. Johnson, Y. Hu and D. Maltz, “The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4”, RFC4728, February 2007.

[7] C. Perkins, E. Belding-Royer and S. Das. ”Ad hoc On-Demand DistanceVector (AODV) Routing”. RFC3561, July 2003.

[8] J. Li, J. Jannotti, D. S. J. D. Couto, D. R. Karger, and R. Morris. ”A Scalable Location Service for Geographic Ad Hoc Routing”, in Proceedings of ACM Mobicom 2000, pp. 120-130. Boston, MA, August 2000.

[9] Z. J. Haas and B. Liang, ”Ad Hoc Mobility Management with Uniform Quorum Systems”. IEEE/ACM Transactions on Networking, vol. 7, no. 2, pp. 228-240, April 1999.

[10] A. Rao, S. Ratnasamy, C. Papadimitriou, S. Shenker and I. Stoica. “Geographic routing without location information”, in Proceedings of ACM Mobicom 2003, pp. 96-108. San Diego, CA, USA, September 2003.

[11] S. Lee, B. Bhattacharjee and S. Banerjee. “Efficient geographic routing in multihop wireless networks”, in Proceedings of ACM MobiHoc, pp. 230-241, Urbana-Champaign, IL, USA, May 2005.

[12] Q. Chen, S. S. Kanhere, M. Hassan and K. C. Lan. ”Adaptive Position Update in Geographic Routing”, in Proceedings of the International Conference on Communications (ICC 2006), pp. 4046- 4051, Istanbul, Turkey, June 2006.

[13] M. Heissenbuttel, T. Braun, M. Walchli and T. Bernoulli. “Evaluating of the limitations and alternatives in beaconing”, in Ad Hoc Networks, vol. 5, no. 5, pp. 558-578, 2007.

[14] Y. Kim, R. Govindan, B. Karp and S. Shenker. “Geographic routing made practical”, in Proceedings of the 2nd Conference on Symposium on Networked Systems Design and Implementation, pp. 217-230, Berkeley, CA, USA, May 2005.

[15] F. Kuhn, R. Wattenhofer and A. Zollinger. “Worst-Case optimal and average-case efficient geometric ad-hoc routing”’, in Proceedings of the ACM MobiHoc 2003, pp 267-278. Annapolis, Maryland, USA, June 2003.

[16] B. Blum, T. He, S. Son, and J. Stankovic. "IGF: A state-free robust communication protocol for wireless sensor networks". Tech. Rep., Department of Computer Science, University of Virginia, USA, 2003.

[17] M. Zorzi and R. Rao. "Geographic random forwarding (GeRaF) for ad hoc and sensor networks: energy and latency performance", in IEEE Transactions on Mobile Computing, vol. 2, no. 4, pp. 349- 365, 2003.

[18] M. Heissenbuttel, T. Braun, T. Bernoulli et al. "BLR: Beacon-Less Routing Algorithm for Mobile Ad-Hoc Networks", in Computer Communications, vol,27, pp. 1076-1086, July 2004.

[19] P. Casari, M. Nati, C. Petrioli and M.Zorzi. "Efficient Non Planar Routing around Dead Ends in Sparse Topologies using Random Forwarding", in Proceedings of IEEE ICC, pp. 3122-3129. Scotland,
UK, June 2007.

[20] S. Basagni, M. Nati, C. Petrioli and R. Petroccia "ROME: routing over mobile elements in WSNs", in Proceedings of the 28th IEEE conference on Global telecommunications (GLOBECOM), pp. 5221–5227. Honolulu, Hawaii, USA, December, 2009.

[21] P. Nain, D. Towsley, B. Liu and Z. Liu. "Properties of random direction models", in Proceeding of IEEE Infocom 2005, pp. 1897- 1907, Miami, FL, USA, March, 2005.

[22] C. Bettstetter, H. Hartenstein and X. Prez-Cos. "Stochastic Properties of the Random Waypoint Mobility Model", in Wireless Networks, vol. 10, no. 5, pp. 555-567, September 2004.

[23] Q. Chen and S. S. Kanhere and M. Hassan. "Mobility and
Traffic Adaptive Position Update for Geographic Routing". CSE, UNSW, Sydney, Australia. UNSW-CSE-TR-1002, 2010.
Available:ftp://ftp.cse.unsw.edu.au/pub/doc/papers/UNSW/1002.pdf