GEOGRAPHIC ADAPTIVE ROUTING FOR IMPROVING LINK STABILITY AND ENERGY EFFICIENCY IN MANET

K. Tamilselvi[1], *T. Manigandan*[2]

ABSTRACT

Routing of data packets in Mobile Ad hoc networks requires more power than in other networks. The forwarding of packets in MANET is placed through many intermediate nodes in a multi-hop procedure. The general way is that protocols should also work on optimizing the energy consumption. It leads to the limited use of energy available in wireless nodes of network. The design methodology of routing method and protocols should have the awareness about energy consumption and link life time of the network. The routing protocol should satisfy some Quality of Service constraints and have to reduce the route discovery and route maintenance procedure. Energy saving and path duration and stability can be two contrasting efforts and trying to satisfy both of them can be very difficult. The proposed hybrid approach tries to improve the energy consumption and link stability by using link stability metric, energy aware metric and geographic adaptive fidelity.

Keywords : *Energy aware metric, Geographic Adaptive Fidelity, Link stability metric, MANET, Path stability.*

I. INTRODUCTION

Mobile Ad hoc Networks (MANET) has become an exciting and important technology in recent years because of the rapid proliferation of wireless devices. A mobile ad hoc network consists of mobile nodes that can move freely in an open environment. Communicating nodes in a Mobile Ad hoc Network usually seek the help of other intermediate nodes to establish communication channels [5]. In such an environment Energy is an important resource that needs to be preserved in order to extend the lifetime of the network. MANET has a variety of applications in the field of military and environment monitoring. The interesting application of MANET is routing of packets with less energy consumption and increased link stability. The selection of more stable routes can lead to the selection of shorter routes by considering mobility. This is not always suitable in terms of energy consumption [1]. Sometimes, trying to optimize the energy can lead to the selection of more fragile routes.

Building efficient and scalable protocols [9] is a very challenging task due to the limited resources and the high scale and dynamics. The location information is used to help routing is often proposed as a means to achieve scalability in large mobile ad-hoc networks. These location based routing protocols are also referred to as geographic routing protocols. The sensor nodes are addressed by

---

[1] Assistant Professor, Department of Computer Science and Engineering, P. A. College of Engineering and Technology, Pollachi
E-mail : tamilkrish.cs@gmail.com

[2] Principal, P. A College of Engineering and Technology, Pollachi E-mail : manigandan_t@yahoo.com

means of their locations instead of the information it carries [3]. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths. The state required to be maintained is minimum and their overhead is low in these protocols, and also their fast response to dynamics. The main aim of this work is to propose an optimization routing model within a MANET [4]. The model attempts to minimize simultaneously the energy consumption of the mobile nodes and maximize the link stability of the transmissions, while choosing paths for individual transmissions. The consideration of energy consumption and link stability is motivated by observing that most routing protocols tend to choose shorter routes, in this analysis high efficiency in using wireless bandwidth and increased path stability are ensured. Routes may be affected by higher energy consumption, since higher transmission ranges are selected.

Most of the routing protocols for sensitive networks require location information for sensitive nodes. Location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be calculated in most of the situation. There is no addressing scheme for sensor networks like IP-addresses and are spatially bounded on a region, location information can be used in routing data in an energy efficient way. For additional, if the region to be sensed is known [8], using the location of sensitive nodes, the query can be diffracted only to that particular region it will eliminate the number of transmission significantly. The location of nodes may be available directly by communicating with a satellite [11], using GPS (Global Positioning System) [2], if nodes are equipped with a small low power GPS receiver. These protocols select the next-hop towards the destination based on the known position of the neighbors and the target node. The position of the target node may represent the centroid of a region or the exact position of a specific node. Location oriented routing protocols can reject the communication overhead caused by flooding, but the calculation of the positions of neighbors may result extra overhead. To save energy, some location based schemes demand that nodes should go to sleep if there is no active nodes. More energy savings can be gained by having as many sleeping nodes in the network as possible. The local minimum problem is also common for all decentralized location-based routing protocols: it might happen that all neighbors of an intermediate node are farther from the destination than the node itself. In order to circumvent this problem [12], every protocol uses different routing techniques. The proposed approach uses location based protocol uses link stability metric, Energy aware metric and Geographic Adaptive Fidelity (GAF).

II. RELATED WORK

The description of some works related to the link stability, energy metrics and the respective routing protocols is given in this section.

A. DSR (Dynamic Source Routing)

The unique feature of DSR [2] is routing of source, data packets handle information about the route from the source to the target in the header of the packet. As a result, middle nodes do not need to store up-to-date routing information in their succeeding tables. This eliminates the need for beacon control neighbor detection packets that are used in the stability-oriented routing protocols. Route discovery is from the concept of the broadcast query-reply cycle. A source node is interested to send a data packet to a destination d, broadcasts a Route-Request (RREQ) packet into the whole network. The RREQ packet obtaining a node contains the list of intermediate nodes through it has propagated from the source node [3].

After receiving the first RREQ packet, the target node waits for a time period of short for any more RREQ packets, then selects a path with the minimum hop count and sends a Route-Reply Packet (RREP) along the chosen path. If any RREQ is obtained along a path whose hop count is lower than the one on RREP will be send, another RREP would be sent on the recent minimum hop path discovered. In order to minimize the route acquisition delay, DSR lets middle nodes to promiscuously listen to the channel, store the learnt routes (from the RREQ and data packets) in a route cache and use these cached route information to send the RREP back to the source. We do not use this feature as promiscuous listening dominates the energy consumed at each node and DSR could still effectively function without caring and route caching. Networks of high node mobility, cached routes are more likely to become stale, by the time it is used.

B. ABR (Associativity-Based Routing)

ABR [4] classifies a link as stable or unstable based on link age. Each node determines the age of a link with its neighbors based on the number of beacons periodically received from that neighbor. If the number of beacons received from a neighbor is greater than an associativity threshold, A_{thresh}, the link with the neighbor is considered stable; otherwise the link is deemed to be unstable. The value of A_{thresh} between two nodes is 2rtx/v, v is the relative velocity between the two nodes and *rtx* is the transmission range of a node.

Route discovery in ABR is accomplished using a broadcast query-reply cycle. Each intermediate node forwards the first received RREQ packet to its neighbors after affixing its node id, the beacon count and the association stability for the link to the node from it received the RREQ packet. After receiving the first RREQ packet, the destination waits for a fixed time period to receive multiple RREQs through different paths. The destination selects the path that has the maximum proportion of stable links and sends a RREP packet along the reverse direction of the selected route. Each intermediate node through the RREP packet is forwarded marks the route as valid and stores the next hop information in its local routing table.

C. MDR (Minimum Drain Rate)

Energy saving mechanisms based only on metrics related to the remaining energy cannot be used to establish the best route between source and target nodes. If a node is interested to allow all route requests only because it currently has enough residual battery capacity, much traffic load will be selected through that node [1]. In this sense, the actual drain rate of energy consumption of the node will tend to be large, resulting in a huge reduction of battery energy. As a consequence, it could evaluate the node energy supply very quickly, causing the node soon to halt. This problem is resolved through other metrics, depends on the traffic load characteristics, and could be employed. The techniques to measure accurately traffic load at nodes should be devised. The Minimum Drain Rate will be considered.

III. LINK STABILITY AND ENERGY AWARE ROUTING

A. Link-Stability Aware Metric

Link stability metric rather than path stability metric is considered. This belongs to the protocol scalability properties that we tried to offer to the routing scheme. A node with the best tradeoff between link stability and energy consumption is adopted through a local forwarding criterion. Before explaining the method used to calculate the link stability and energy aware metrics, the definition is provided as follows:

Definition 1. A link between two nodes i and j with transmission range R is established at time instant t_{in} when the distance between both nodes is such that $d(i,j) < R$.

Definition 2. A link between two nodes i and j with transmission range R is broken at instant time t_{fin} when the distance between both nodes verify the condition $d(i,j) > R$.

Definition 3. A link age a between two nodes i and j is the duration $a(i,j) = a_{i,j} = t_{fin} - t_{in}$.

The expected residual lifetime $R_{i,j}(a_{i,j})$ [5] of a link (i,j) of age a_{ij} is determined from the collected statistical data as follows in the equation(1):

$$R_{i,j}(a_{i,j}) = \frac{\sum a = ai,j\,.\ a.\ d[a]}{\sum a = ai,j.\ d[a]} - a_{i,j} \text{ for all } (i,j) \in A \qquad (1)$$

Stability of the link (i,j) for all (i,j) A, at time t, has been represented by the coefficient $S_{i,j}(t)$ is defined as follows in the equation (2) :

$$S_{i,j} = \frac{d^{avg}}{R_{i,j}(ai,j).\ K} \text{ for all } (i,j) \in A \qquad (2)$$

B. Energy-Aware Metric

It is assumed that each node does not enter in standby mode and each node can overhear the packet inside its transmission range and it is not addressed to itself. [6] Energy needed to transmit a packet p from node i is defined as in the equation (3):

$$E_{tx}(p,i) = I.\ v.\ t_b \text{ Joules} \qquad (3)$$

Here I is the current (in Ampere), v the voltage (in Volt), and tb the time taken to transmit the packet p (in seconds). Energy E (p, i) spent to transmit a packet from node i to node j is defined as in the equation (4):

$$E(p,i) = E_{tx}(p,i) + E_{rx}(p,j) \qquad (4)$$

Power used to transmit at a given instant of time t is defined as in the equation (5):

$$P_{i,j}(t) = c_{i,j}.\ \ f_{i,j} \qquad (5)$$

Power consumption cost per bit associated with the link (i,j) is defined as in the equation(6):

$$c_{i,j} = b.\ \beta.\ d_{i,j}^{\,n} \qquad (6)$$

C. Forwarding Strategy

The data forwarding strategy of LAER is based on a greedy technique like as GPSR. The resulting one will be differently by GPSR, the next node selection tries to reduce the joint energy stability metric [8]. LAER packet forwarding presents high scalability property because that the neighborhood and destination knowledge are necessary for the greedy technique. The utility of energy-stability-based greedy forwarding is offered through the capability to weight the stability and the energy consumption on the basis of the interest of the application layer as shown in the Fig 1.

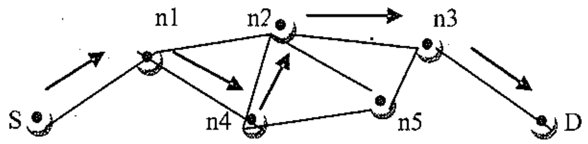

Figure 1 : LAER greedy based on the joint metric

IV. GEOGRAPHIC ADAPTIVE ROUTING

The proposed approach uses the method of location based routing named Geographic adaptive fidelity in order to improve the efficiency of link stability and energy consumption. The proposed method uses geographic adaptive fidelity together with existing LAER greedy forwarding method. Geographic routing provides a way to deliver a packet to a destination location, based on local information and without the need for any extra infrastructure that makes geographic routing the main basic component for geographic protocols.

A. Geographic Adaptive Fidelity

Geographic Adaptive Fidelity or GAF is an energy aware location-based routing algorithm designed primarily for mobile ad hoc networks, but is used in sensor networks as well [7]. This protocol aims at optimizing the performance of wireless sensor networks by identifying equivalent nodes with respect to forwarding packets. The GAF protocol, each node uses location information based on GPS to associate itself with a virtual grid so that the entire area is divided into several square regions, and the node with the large residual energy within each grid becomes the master of the grid. Two nodes are considered to be equivalent that maintains the same set of neighbor nodes and so it can belong to the same communication path. Starting and target in the application are excluded from this characterization.

Nodes use their GPS-indicated location to associate itself with a point in the virtual region. Inside each grid, nodes Collapse with each other to play different roles. The nodes will elect one sensor node to stay awake for a certain period of time and then it go to sleep[13]. This node is responsible for monitoring and reporting data to the sink on behalf of the nodes in the zone and is known as the master node. Other nodes in the same grid can be regarded as redundant with respect to forwarding packets, and thus it can be safely put to sleep without sacrificing the routing fidelity.

The slave nodes switch between off and listening with the guarantee that one master node in each grid will stay awake to route packets. The nodes 2, 3 and 4 in the virtual grid B in Figure 2 are equivalent in the sense that one of them can forward packets between nodes 1 and 5 while the other two can sleep to conserve energy. Geographic Adaptive Fidelity conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. The node uses its Global Positioning System-indicated location to associate itself with a point in the virtual grid. It is shown in the Fig 2.

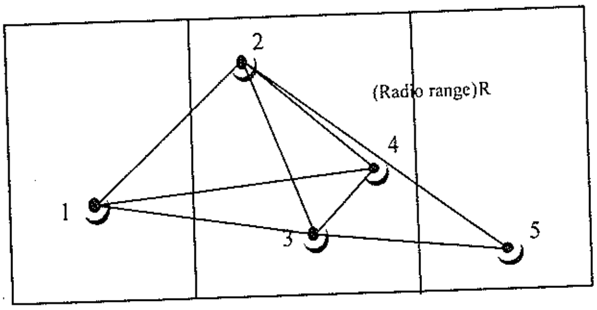

Figure 2 : Virtual grid structure in the GAF protocol

The region size *r* can be easily derived from the relationship between *r* and the radio range R given by the formula [9] as defined in the equation (7):

$$r \leq R/\sqrt{5} \quad (7)$$

There are three states defined in GAF as shown as follows. These states are predicted, for measuring the neighbors in the grid, active repeating participation in routing and sleep the radio is turned off. The handling of the mobility, each node in the grid estimates it's leaving time of grid and sends this to its neighbors [10]. The sleeping neighbors adjust their sleeping time accordingly in order to keep the routing fidelity. The leaving time of the active node exits, sleeping nodes will be active and one of them becomes active. The state transitions in GAF are depicted as follows:

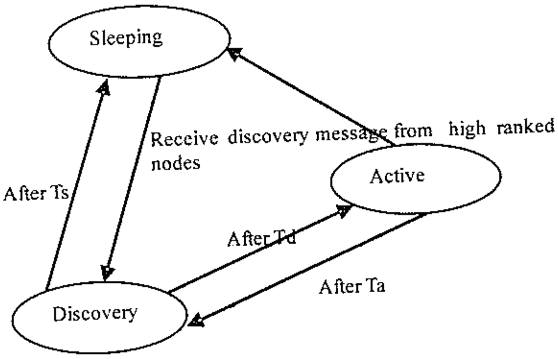

Figure 3 : State transitions in GAF

B. Master Election Rule

Master election rule in GAF is as follows. The initial process is that a node is in the discovery state and exchanges discovery messages including grid IDs to find other nodes within the same region. A node becomes a ruler if it does not hear any other discovery message for a predefined duration Td. There is more than one node is in the predictable state, one with the largest expected lifetime becomes a master. The master node remains active to handle routing for Ta as shown in the Fig 3.

After Ta, the node changes its state to discovery to give an opportunity to other nodes within the same grid to become a master. The scenarios with high mobility, sleeping nodes should wake up earlier to take over the role of a master node, the sleeping time Ts is calculated based on the estimated time the nodes stays within the grid[14]. The node will sleep for how long is application dependent and the related parameters are tuned accordingly during the routing process.

C. Forwarding the Packets towards the Target Region

The receiving of a packet is defined as a node checks its neighbors to see if there is one neighbor that will be closer to the target region than itself. There is more than one, the nearest neighbor to the target region is selected as the next hop. There are all further than the node itself, this means there is a hole. The traditional case is that one of the neighbors is picked to forward the packet based on the learning of cost function [16]. This choice can then be considered according to the convergence of the learned cost during the delivery of packets.

D. Forwarding the Packets within the Region

The packet has reached the region means, it can be diffused in that region by either recursive geographic forwarding or restricted flooding. Restricted flooding is good that the sensors are not densely deployed. In high density networks, recursive geographic flooding is more energy efficient than restricted flooding. In that case, the region is divided into four sub regions and four copies of the packet are created [15]. This splitting and forwarding process continues until the regions with one node are left as shown in the Fig 4.

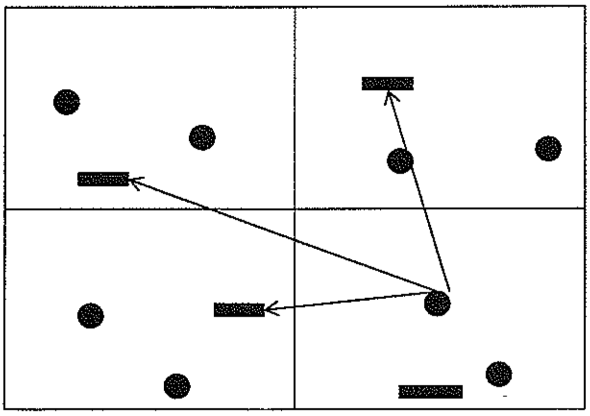

Figure 4 : Recursive Geographic Forwarding

V. RESULTS AND DISCUSSIONS

The simulations have been assessed in order to test the energy consumption by type, the energy-aware willingness mechanism and the impact of different energy-aware metrics on the protocol performance. The evaluation of the proposed protocol, the ns-2 network simulator was used. Between mobile hosts there are 8 and 16 CBR/UDP sources generating 8 packets/s with a packet size will be 512 bytes. The lifetime of each simulation is 700 seconds. The extract average values, the simulated each scenario five times.

A. Data Packet Delivery Ratio

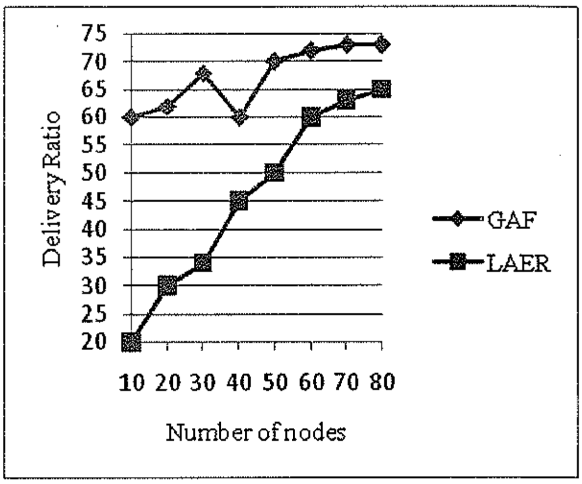

Figure 5 : Number of Nodes Vs Delivery Ratio

It is the number of packets received at destination on data packets sent by source. GPSR, E-GPSR, PERRA, and LAER present similar performance the traffic load is not heavy with percentage value about 99 percent for very low mobility. The improvement in the packet delivery ratio is defined in the figure 5.

B. Variance Energy

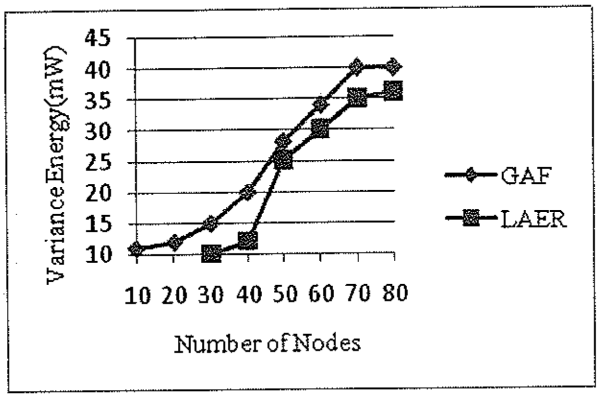

Figure 6 : Number of Nodes Vs Variance Energy

This parameter is considered to evaluate the distribution of energy among nodes. The greater is the dispersion around the average residual node energy, the higher is the unfairness in the node usage and in the energy dissipation among nodes. The variance of node residual energy is defined in the figure 6.

C. Average Link Stability

This parameter is adopted rather than path stability because for protocols such as GPSR, E-GPSR, and LAER the path stability cannot be considered due to the absence of a path establishment phase. The improvements in the average link stability are defined as follows in the figure 7:

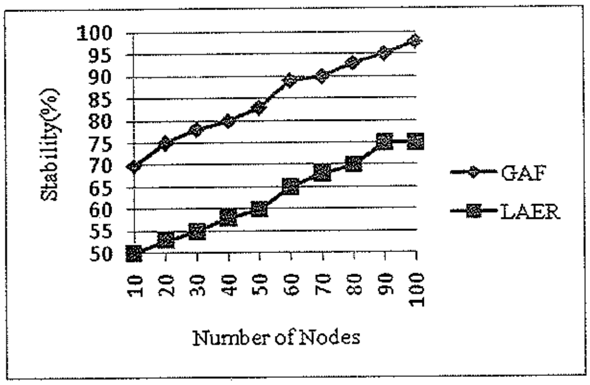

Figure 7 : Number of Nodes Vs Stability

D. Average Residual Energy

It can be useful to evaluate the remaining energy in order to have an idea of the network lifetime. The average energy consumption for decreasing nodes speed and different stability weight values are shown in the figure 8:

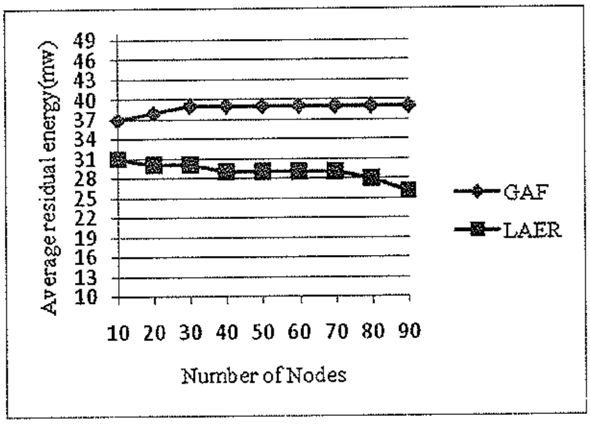

Figure 8 : Number of Nodes Vs Residual Energy

VI. CONCLUSION

The proposed hybrid routing for improving link stability and energy efficiency in MANET uses the link stability metric, energy aware metric and geographic adaptive fidelity. It is based on the local topology knowledge and it makes use of a greedy technique based on a joint metric and a modified perimeter forwarding strategy for the recovery from local maximum. The proposed method shares the good characteristic of Ellipsoid protocol such as simplicity and ability to operate in a three dimensional space. The proposed algorithm has been tested by simulation and the results compared with other protocols. The simulation experiment shows that the proposed protocol preformed better than Greedy Perimeter Stateless Routing and Ellipsoid in most of the tested scenarios. About a 3% better than Greedy Perimeter Stateless

Routing for different pause time, in the 50 nodes configuration. The proposed method is 3.5% better than Ellipsoid protocol on the same configuration. This improvement is a consequence of the prediction influence in the forward decision process.

REFERENCES

[1] Floriano De Rango, Francesca Guerriero and Peppino Fazio, *"Link-Stability and Energy Aware Routing Protocol in Distributed Wireless Networks"*, VOL. 23, NO. 4, APRIL 2012.

[2] S. Roychowdhury and Chiranjib Patra, *"Geographic Adaptive Fidelity and Geographic Energy Aware Routing in Ad Hoc Routing"*, August 2010.

[3] G. Lim, K. Shin, S. Lee, H. Yoon, and J. Soo Ma, *"Link Stability and Route Lifetime in Ad-Hoc Wireless Networks"*, Proc. Int'l Conf. Parallel Processing Workshops (ICPPW '02), p. 116, 2002.

[4] N. Meghanathan, *"Stability-Energy Consumption Tradeoff among Mobile Ad Hoc Network Routing Protocols"*, Proc. Third Int'l Conf. Wireless and Mobile Comm. (ICWMC '07), Mar. 2007.

[5] N. Meghanathan and A. Farago, *"Looking at Protocol Efficiency from a New Angle: Stability-Delay Analysis"*, Proc. Second Int'l Conf. Mobile Computing and Networking, pp. 51-55, 2004.

[6] F. De Rango, M. Fotino, and S. Marano, *"EE-OLSR: Energy Efficient OLSR Routing Protocol for Mobile Ad-Hoc Networks"*, Proc. IEEE Military Comm. Conf. (Milcom '08), pp. 1-7, Nov. 2008.

[7] Y. Xu, J. Heidemann, D. Estrin, *"Geography-informed Energy Conservation for Ad-hoc Routing"*, In Proceedings of the Seventh Annual ACM/IEEE International Conference on Mobile Computing and Networking 2001, pp. 70-84.

[8] B. Karp and H.T. Kung, *"Greedy Perimeter Stateless Routing for Wireless Networks"*, Proc. ACM/IEEE MobiCom '00, pp. 243-254, Aug. 2000.

[9] L. Subramanian and R. H. Katz, *"An Architecture for Building Self Configurable Systems,"* in the Proceedings of IEEE/ACM Workshop on Mobile Ad Hoc Networking and Computing, Boston, MA, August 2000.

[10] V. Rodoplu and T.H. Ming, *"Minimum energy mobile wireless networks,"* IEEE Journal of Selected Areas in Communications, Vol. 17, No. 8, pp. 1333-1344, 1999.

[11] C. Taddia, A. Giovanardi, G. Mazzini, and M. Zorzi, *"EnergyEfficient Unicast Routing Protocols over 802.11b"*, Proc. IEEE Global Telecomm. Conf. (GLOBECOM '05), pp. 555-560, Nov/Dec. 2005.

[12] M. Gerharz, C. de Waal, P. Martini, and P. James, *"Strategies for Finding Stable Paths in Mobile Wireless Ad Hoc Networks,"* Proc. IEEE 28th Ann. Conf. Local Computer Networks (LCN '03), pp. 130-139, 2003.

[13] K. Yamazaki and K. Sezaki, *"A Proposal of Geographic Routing Protocols for Location-Aware Services,"* Electronics and Communications in Japan, vol. 87, no. 4, pp. 26-34, 2003.

[14] W. Creixell and K. Sezaki, *"Routing Protocol for Ad Hoc Mobile Networks Using Mobility Prediction,"* Int'l J. Ad Hoc and Ubiquitous Computing, vol. 2, pp. 149-156, 2007.

[15] Zoe Abrams, Ashish Goel and Serge Plotkin, *"Set K Cover Algorithms for Energy Efficient Monitoring in Wireless Sensor Networks"*, 2004.

[16] Fucai Yu, Guangmin Hu and Haojun Huang, *"Energy-aware Geographic Routing in Wireless Sensor Networks with Anchor Nodes"*, Vol 26, Issue 1, September 2011.

AUTHOR'S BIOGRAPHY

Dr. T.Manigandan is a principal at P.A college of Engineering and Technology. He received B.E degree in Electronics and communication Engineering from Bharathiar university, M.E in control systems from Bharathiar university and Ph.D. in Electrical Engineering from Anna university Chennai. Since 1988 he has been with the faculty of Electrical Engineering. His research interest includes Control Systems, Image Processing and Computer Networks. He has published more than 100 papers in these areas.

Ms. K. Tamilselvi is an Assistant Professor in the Department of Computer Science and Engineering at P. A. College of Engineering and Technology, Pollachi, Coimbatore. She received her B.E Degree in CSE from Anna University, Trichy and M.E. degree in CSE from Anna University, Chennai. Her research interest includes Mobile Ad-hoc Networks.