Energy Efficient Routing Protocol with Adaptive Fuzzy Threshold Energy for MANETs

P.S.Hiremath, Shrihari M.Joshi
Dept. of PG Studies and Research in Computer Science
Gulbarga University, Gulbarga. India

***Abstract*— Mobile ad-hoc network (MANET) is an infrastructure-less multihop network where each node communicates with other nodes directly or indirectly through intermediate nodes. Thus, all nodes in a MANET basically function as mobile routers participating in some routing protocol required for deciding and maintaining the routes. All these mobile nodes are battery operated. Hence energy conservation is a critical issue in case of MANETs. The lifetime of a MANET depends on lifetime of its mobile nodes. Research is being carried out to conserve energy of mobile nodes at various levels, i.e., at the hardware level, operating system level and application level. Lot of work has been done to improve the energy efficiency of existing routing protocols for MANETs. There is little work done that address the lifetime issue of MANETs. In this paper, we propose a new protocol that conserves energy of mobile nodes and, hence, enhances the lifetime of the MANET. It is an on-demand routing protocol based on adaptive fuzzy threshold energy (AFTE). The experimental results are compared with the Load-Aware Energy Efficient Protocol (LAEE) protocol proposed by the same authors. The results show that AFTE performs better as compared to LAEE. The average network life time is enhanced by 13% considering first node failure, 15% considering 50% node failure and 23% considering 100% node failure as compared to LAEE.**

Keywords-MANET; residual energy; fuzzy Threshold energy

I. INTRODUCTION

The MANETs are infrastructure-less, self-organizing, rapidly deployable wireless networks. They are highly suitable for applications involving special outdoor events, communications in regions with no wireless infrastructure, emergencies, natural disasters, and military operations. Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature. Wireless devices have maximum utility when they can be used "anywhere at any time". Not only are mobile devices getting smaller, cheaper, more convenient, and more powerful, they also run more applications and network services, commonly fueling the explosive growth of mobile computing equipment market. The exploding number of Internet and laptop users is driving this growth further. With this trend, we can expect the total number of mobile Internet users soon to exceed that of the fixed-line Internet users. One of the greatest limitations to that goal, however, is finite power supplies. Since batteries provide limited power, a general constraint of wireless communication is the short continuous operation time of mobile terminals. Since the energy sources have a limited life time, power availability is one of the most important constraints for the operation of the ad-hoc network. There are different processes of power consumption in a mobile node. Communication is one of the main processes of energy consumption. Since the rate of battery performance improvement is rather slow currently, and in the absence of breakthroughs in this field, other measures have to be taken to achieve the goal of more energy efficient performance utilizing the currently available battery resources. Communications in ad-hoc networks are done using the RF transceivers at the source, intermediate and destination nodes to exchange information. The source node sends control and data messages which are received by one or more receiving nodes, depending on the message type. The receiving node could be the intended receiver of a packet, or it could be on the path to the destination (when the destination is not within range from the source) acting as a forwarder of the traffic. In order to address the energy efficiency issues at the communications level within ad hoc networks, it is important to understand the energy model which represents the power consumption behavior in the wireless interfaces of the ad-hoc network nodes. Therefore, power management is one of the most challenging problems in wireless communication, and most of the current research has been aimed at addressing this problem.

Ad-hoc routing protocols are usually classified as being table-driven routing protocols or on-demand routing protocols depending on their response to changes in the topology of a network. Table-driven routing protocols (also called proactive protocols) maintain a continuous view of the full topology of the network in each node, whereas on-demand routing protocols (also called reactive protocols) search for a route between a source and a destination when such a route is needed. Table-driven approaches introduce more overhead as compared to reactive ones. This is because whenever there are changes in the topology of the network, control messages are flooded in order to maintain a full knowledge of the network in each node. Initially, the main criterion in these two classes of protocols was the minimum number of hops. However, the main shortcoming of this criterion in terms of energy utilization is that, the selection of routes in accordance with the min-hop principle does not protect nodes from being overused. These are usually some nodes in the core of the network. When they run out of power, the network becomes partitioned and consequently some sessions are disconnected. In order to alleviate this problem and, also, to achieve energy-efficient consumption, many solutions have been proposed in the literature as extensions of the already existing ad-hoc routing protocols. Since table-driven protocols inherently consume more energy as compared to on-demand ones, most of the proposed protocols involve modifications to the reactive protocols. Therefore most of the energy aware routing algorithms are based on on-demand protocols, namely, AODV and DSR. Instead of searching for the shortest path, as traditionally done, these modified algorithms use energy-sensitive metrics for searching path. In the literature load balancing strategies for ad hoc networks have been explored in the same context as those used for wired networks, i. e, in the prevention and/or alleviation of congestion and fault tolerance. The balanced use of a network's resources leads to more efficient energy utilization, which is essential for ad-hoc networks. Instead of simply establishing correct and efficient routes between pair of nodes, one important goal of a routing protocol is to keep the network functioning as long as possible. The goal of an energy efficient routing algorithm is minimizing mobile nodes' energy consumption not only during active communication but also when they are inactive. Transmission power control and load distribution are the two approaches used to minimize the active communication energy, and sleep/power-down mode is used to minimize energy during inactivity.

II. RELATED WORK

Early work on energy consumption in ad hoc networks was done by Feeney et al [1], in which the various experiments are conducted to determine the energy consumption of a Lucent Wireless waveLan IEEE 802.11 network card. A linear equation to quantify the "per packet energy consumption", is also formulated. In [2], the impact of mobility on energy conservation for mobile ad hoc networks is analyzed. Various mobility models like Random waypoint (RWP), Manhattan Grid Model (MG), Gauss Markov Model (GM), Community Mobility Model (CM) and RPGM have been considered. The energy consumption to receive, transmit and drop the control packets is analyzed and is calculated by mapping it against the mobility speed. In [3], a model for determination of energy consumption in MANETs is proposed. The energy conservation in MAC protocols for mobile ad hoc networks is analyzed in [4]. In [5], the performances of AOMDV, TORA and OLSR protocols for three different energy models are investigated. In [6], an approach for reducing the end-to-end delay and increasing network lifetime in mobile ad-hoc networks has been proposed. It is based on TORA routing protocol. Energy and delay verifications of query packet have been done in each node. A new energy efficient AODV-based node caching routing protocol with adaptive workload balancing (AODV-NC-WLB) has been developed in [7]. In [8], it has been shown that as the network lifetime increases, the percentage energy consumption decreases with increase in the number of hops and attains a minimum at critical hops. After the critical hops, the energy consumption gradually increases due to increase in cumulative energy consumption of the intermediate nodes. In [9], the authors have proposed a Local Energy-Aware Routing protocol which achieves a trade-off between balanced energy consumption and shortest routing delay and at the same time avoids the blocking and route cache problems. In [10], the authors present some improvement suggestion to AODV routing protocol. The proposed protocol, called AODV-UI, improved AODV in gateway interconnection, reverse route and in energy consumption. They also measure performance indicators for some metrics, such as energy, routing overhead, end-to-end delay, and packet delivery ratio. Dynamic transmission power assignment for energy conservation routing (DPAECR) in MANETs has been proposed in [11]. The DPAECR updates the transmission power for every packet transmission. For the purpose of energy conservation, each node can dynamically adjust its transmitting power based on the distance of the receiving nodes. In [12], the authors discuss about various issues in MANETs, energy consumption model, energy aware metrics. In [13], the authors have proposed a new routing protocol, namely, Load-Aware Energy Efficient (LAEE), that conserves energy of mobile nodes and, hence, enhances the lifetime of the MANET. It is an on-demand routing protocol based on load balancing that uses adaptive threshold energy. The experimental results demonstrate the effectiveness of LAEE in comparison with that of the popular on-demand routing protocols namely, DSR and AODV.

III. PROPOSED WORK

The proposed methodology is based on adaptive fuzzy thresholding of residual energy of nodes participating in the route discovery from source to destination.

A. Fuzzy Threshold Energy

Let RE_i, i = 1,2, …… , n , be the residual energies of the n neighboring nodes of a transmitter node. Let minRE = min{ RE_i} , maxRE = max { RE_i } and midRE = (minRE + maxRE) / 2. We define the three fuzzy subsets of these nodes with low, medium and high residual energy whose membership functions μ_{low} , μ_{medium} and μ_{high} , respectively, are given below (Fig 1).

$$\mu_{low}(RE_i) = \begin{cases} \dfrac{RE_i - midRE}{\min RE - midRE}, & midRE \le RE_i \le \max RE \\ 0, & \min RE \le RE_i \le midRE \end{cases}$$

$$\mu_{medium}(RE_i) = \begin{cases} \dfrac{RE_i - midRE}{\min RE - midRE}, & midRE \le RE_i \le \max RE \\ \dfrac{RE_i - \max RE}{midRE - \max RE}, & \min RE \le RE_i \le midRE \end{cases}$$

$$\mu_{high}(RE_i) = \begin{cases} 0, & midRE \le RE_i \le \max RE \\ \dfrac{RE_i - midRE}{\max RE - midRE}, & \min RE \le RE_i \le midRE \end{cases}$$

Then, the membership value μ of RE_i for the i^{th} node is given by:

$$\mu_i(RE_i) = \max\left\{\mu_{low}(RE_i), \mu_{medium}(RE_i), \mu_{high}(RE_i)\right\}$$

Let RE_{Th} be the value of RE_i for which the membership value is minimum among neighboring nodes, i.e,

$$\mu_{Th}(RE_{Th}) = \min_{1 \le i \le n}\left\{\mu_i\left(RE_i\right)\right\}$$

If there is a tie, it is broken by selecting the node with min RE among the nodes with the same minimum membership value.

Then, RE_{Th} obtained by this defuzzification process, is used as the threshold energy value, which is transmitted in RREQ packet to the neighboring nodes.

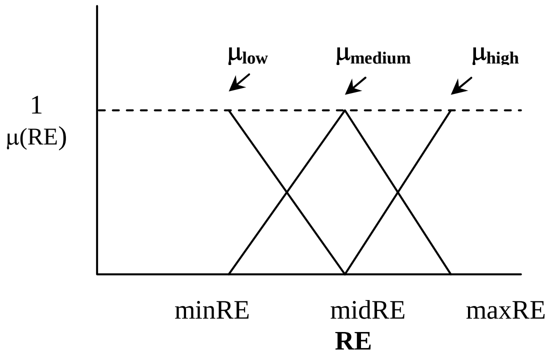


Figure 1.

B. Proposed Protocol based on Adaptive Fuzzy Threshold Energy (AFTE).

The specific goal of the load distribution approach is to balance the energy usage of all mobile nodes by selecting a route with underutilized nodes rather than the shortest route. This may result in longer routes but packets are routed only through energy-rich intermediate nodes. Protocols based on this approach do not necessarily provide the lowest energy route, but prevent certain nodes from being overloaded, and thus, ensure longer network lifetime. The lifetime of MANET is very vital parameter. It is expected that a MANET lasts for a longer duration. To achieve this, we need to ensure that no node is overused during routing process. Hence, the routing load needs to be equally distributed among all the neighboring nodes. Otherwise, it results in early network partitioning. In this paper, a fuzzy based adaptive threshold energy policy is proposed, in which only the nodes with energy above the threshold value can take part in the route discovery process. This method ensures that no node is overused and hence the life time of the MANET gets enhanced. In our proposed protocol, we have different threshold level at different hops. This is because at each hop we have different set of neighbors having different residual energies. The fundamental idea behind the proposed protocol is to apply the remaining battery capacity of each node as a prime metric in the route selection process. The cost of a node i is given by:

$$C_i = 1/ RE_i$$

where RE_i is the residual energy of node i. The cost of a node to forward a packet keeps increasing as its residual energy continues to decrease. The residual energy defines the reluctance or willingness of intermediate nodes to respond to route requests and forward data traffic. When energy RE_i in a node i is lower than a predefined threshold level RE_{Th}, i. e, $RE_i < RE_{Th}$, the node does not forward the route request control message, but simply drops it. Thus, it does not participate in the route selection and forwarding phase. The proposed routing algorithm is, thus, the modified AODV routing protocol incorporating the fuzzy based adaptive energy thresholding during route discovery stage which is given below.

Algorithm: Energy Efficient Routing Protocol with Adaptive Fuzzy Threshold Energy (AFTE)

Step1. Let S be the source node having n neighbors with residual energy levels RE_i, i = 1,..,n. Initialize hopcount = 0.

Step2. For node S, compute initial threshold energy RE_{Th} using the fuzzy mathematical procedure described in Section III (A).

Step3. The node S floods request packet RREQ to all its neighbors after embedding the value RE_{Th} into RREQ, for establishment of path connection to destination node D.

Step4. Each intermediate node, which receives RREQ, checks whether its residual energy is greater than RE_{Th}. If 'yes', go to step 5 else simply drop the RREQ packet.

Step5. Intermediate node responds by sending reply packet RREP if it has a path to destination. Go to step 7.

Step6. Intermediate node forwards RREQ after replacing the embedded RE_{Th} value by the modified threshold value calculated using the procedure given in Section III (A).

Step7. Increment the hopcount by 1.

Step8. Repeat Steps 4 to 7 until packet sent by node S reaches the destination node D. Output the value of the hopcount.

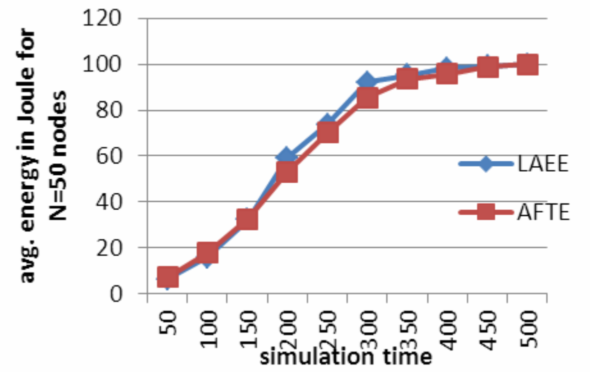
IV. RESULTS AND DISCUSSIONS

The proposed protocol is implemented using NS2 simulator, for different simulation times (50,100,.., 500) and for different number of nodes (50,100,…,300). The other parameters used for simulation are given below in the Table 1.

TABLE 1. SIMULATION PARAMETERS USED

Parameter	**Value**
Simulation Time	500sec,100sec.
Terrain Area	500 X 500 sq. mts
Number of Nodes	50,100,150,200,250,300
Node placement	Random
Propagation Model	RWP
Channel Frequency	2.4 G.Hz.
Routing Protocol	LAEE,AFTE
Transmission Range	250mts
Initial Energy for each node	100 Joules

The simulation results for 50,150 and 250 nodes are shown in the Figs.2–3. The complete simulation results are given in the Table 2.The results are compared with the performance of the Load Aware Energy Efficient Routing Protocol (LAEE). In the Fig.2, it is observed that as the simulation time increases, the average energy consumed by the mobile nodes keeps on increasing.



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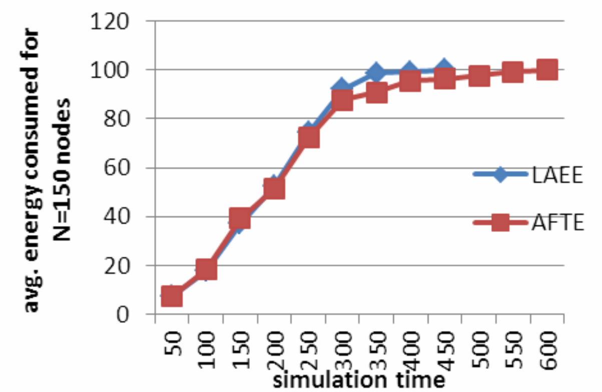

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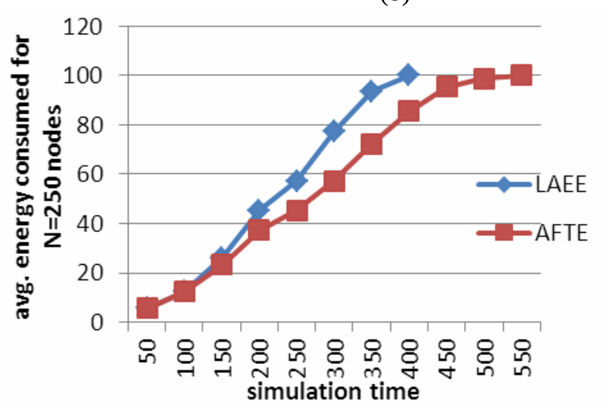

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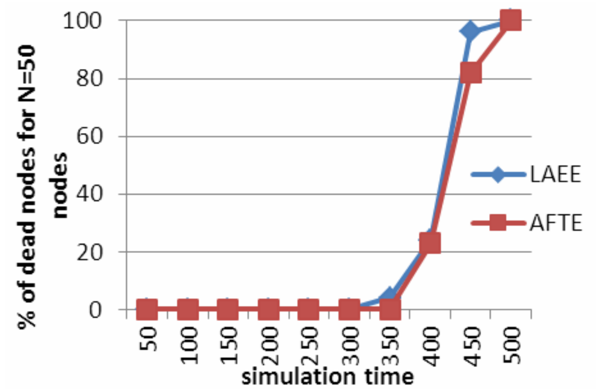
Figure.2. The average energy consumed vs. simulation time

The proposed routing algorithm AFTE consumes lesser energy as compared to LAEE routing algorithm. All the nodes drain off their residual energy by 450 sec. for LAEE protocol, for 50 and 150 nodes and at 400 sec. for 250 nodes, whereas for the proposed AFTE algorithm it occurs at 500 sec. for 50 ,at 600 sec. for 150 nodes and at 550 sec. for 250 nodes.

The Fig.3 shows the percentage of dead nodes as the simulation time varies from 50 to 500sec.in steps of 50 sec. When the nodes lose all their residual energy, they can be declared as dead nodes. The network life time depends on the lifetime of the nodes. Network partitioning is usually defined [12] according to the following criteria:

- The time until the first node burns out its entire battery budget.
- The time until a certain portion of the nodes fails.
- The time until the network partitioning occurs.



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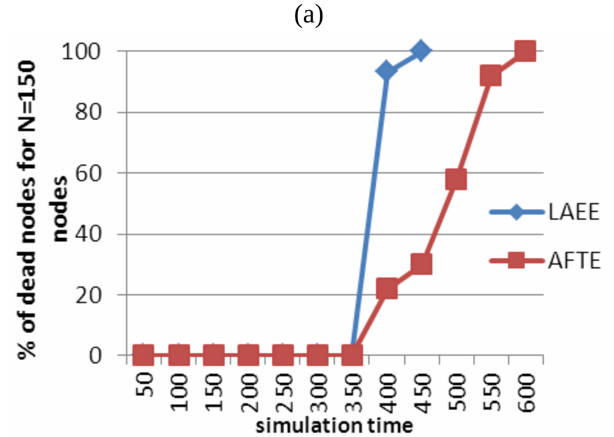

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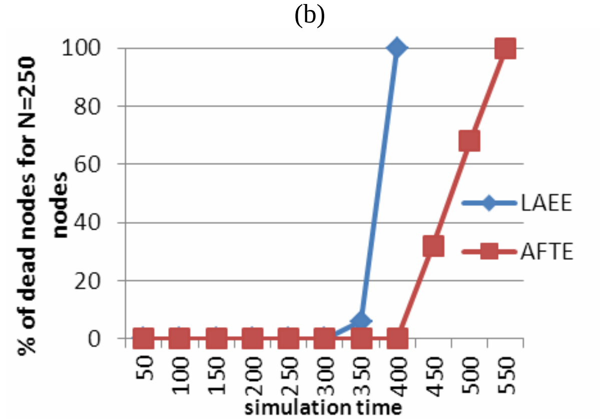

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Figure.3. The percentage of dead nodes vs. simulation time

Considering the first node failure, it can be seen that in case of LAEE protocol, the network partitioning occurs between 300 to 350sec. for 50 and 250 nodes and between 350 to 400 sec. for 200 nodes. For the proposed AFTE protocol, it occurs between 350 to 400 sec. for 50 and 150 nodes and between 400 to 450 sec. for 250 nodes. It can also be seen that the residual energy of all the nodes becomes zero at simulation time t=500, at t=450 and at t=400 correspondingly for n= 50, n=150 and n=250 for the LAEE protocol. For AFTE protocol it occurs at t-500, at t=600 and at t=550 sec. Further the nodes lose all their residual energy (thus become dead) rapidly in case of LAEE protocol as compared to the gradual decrease of energy in case of AFTE protocol. Hence, the AFTE protocol is able to provide more lifetime for the network. The results of simulation for all nodes ranging from 50 to 300 in steps of 50 is given in the Table 2. From the Table 2, we observe that, for a smaller number of nodes (50), considering the network partitioning due to a single node failure, AFTE protocol is more efficient as it provides 10.6% more lifetime as compared to LAEE. For medium density of nodes (100-150 nodes) , considering network partitioning due to 50% node failure, AFTE is more advantageous as it achieves 12 to 14% more lifetime as compared to LAEE. When 100% node failure is considered, AFTE achieves 20 to 33% extra lifetime than LAEE. For more denser networks (200-300 nodes), AFTE is advantageous under all circumstances. Considering network partitioning due to single nodes failure, AFTE achieves 13 to 31% more lifetime as compared to LAEE. Similarly, considering network partitioning due to failure of 50% node failure, it provides 13 to 26% more lifetime. Finally, considering 100% nodes failure, AFTE performs well as it gives an additional life time of 22 to 37% as compared to LAEE protocol.

TABLE 2. PERFORMANCE COMPARISON OF LAEE AND A FTE ROUTING PROTOCOLS FOR DIFFERENT NODE DENSITIES.

No. of Nodes	*Time when first node's residual energy becomes zero*		*Time when 50% of nodes' residual energy becomes zero*		*Time when 100% of nodes' residual energy becomes zero*	
	LAEE	*AFTE*	*LAEE*	*AFTE*	*LAEE*	*AFTE*
50	320	354	423	426	500	500
100	362	364	425	476	500	600
150	360	364	422	482	450	600
200	362	410	392	490	450	550
250	308	405	383	476	400	550
300	260	308	372	422	400	500

V. CONCLUSION

In this paper, a novel routing algorithm based on adaptive fuzzy threshold energy is proposed. In the proposed protocol, the energy of a mobile node is conserved by employing threshold energy for each node which is always a function of the residual energy of neighbors of that node. The average network lifetime is enhanced by 13% considering first node failure, 15% considering 50% node failure and 23% considering 100% node failure. The simulation experiments have been conducted using NS2 simulator. The experimental results show that the proposed algorithm AFTE performs better as compared to the LAEE protocol.

REFERENCES

[1] Laura Marie Feeney and Martin Nilsson,"Investigating the Energy Consumption of a Wireless Network Interface in an ad hoc Netwroking Environment" ,Technical report T99:11, SICS..

[2] Preetha Prabhakaran and Ravi Sankar, "Impact of Realistic Mobility Models on Wireless Networks Performance", IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, Montreal, 19-21 June 2006, pp 329-334.

[3] Laura, Marie,Feeny "An Energy Consumption Model for Performance Analysis of Routing Protocols for Mobile Ad Hoc Networks", Mobile Networks and Applications 6, 239–249, 2001

[4] S. Singh and C.S. Raghavendra, "PAMAS – power aware multi-access protocol with signalling for ad hoc networks, Computer Communication ACM SIGCOMM Computer Communication Review Volume 28 Issue 3, July 1998 .

[5] Gowrishankar.S, T.G.Basavaraju, Subir Kumar Sarkar ,"Simulation Based Overhead Analysis of AOMDV, TORA and OLSR in MANET Using Various Energy Models" ,World Congress on Engineering and Computer Science 2010 Vol I WCECS 2010, October 20-22, 2010, San Francisco, USA.

[6] R. Asokan and A. M. Natarajan, "An Approach for Reducing the End-to-end Delay and Increasing Network Lifetime in Mobile Adhoc Networks", International Journal of Information Technology Volume 4 Number 2, 2008.M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[7] Sunsook Jung, NisarHundewale, Alex Zelikovsky, "Energy Efficiency of Load Balancing in MANET Routing Protocols", Proc. of International Workshop on Self-Assembling Wireless Networks (SAWN 2005), pp 476-483

[8] S M Lambor, S M Joshi, "Performance Analysis of Network Lifetime and Energy Consumption in a Multi-Hop Wireless Sensor Network", 2nd International Conference and workshop on Emerging Trends in Technology (ICWET) 2011 Proceedings published by International Journal of Computer Applications (IJCA).

[9] Kyungtae Woo and Chansu Yu, Hee Yong Youn, Ben Lee, "Non-Blocking, Localized Routing Algorithm for Balanced Energy Consumption in Mobile Ad Hoc Networks", Proceedings of the Ninth International Symposium in Modeling, Analysis and Simulation of Computer and Telecommunication Systems, IEEE Computer Society, Washington DC, 2001.

[10] AbdusySyarif, RiriFitri Sari, "Performance Analysis of AODV-UI Routing Protocol With Energy Consumption Improvement Under Mobility Models in Hybrid Ad hoc Network", International Journal on Computer Science and Engineering (IJCSE), Vol. 3 No. 7 July 2011.

[11] U.Raghavendra, S.Vasundra, "Dynamic Transmission Power Assignment for Energy Conservation Routing in MANETs", International Journal of Smart Sensors and Ad Hoc Networks (IJSSAN), 2011.

[12] Marco Fotino and Floriano De Rango. "Energy Issues and Energy Aware Routing in Wireless Ad Hoc Networks", Mobile Ad-Hoc Networks: Protocol Design, Prof. Xin Wang (Ed.), ISBN: 978-953-307-402-3, InTech, 2011.

[13] P.S.Hiremath, S.M.Joshi, "Load-Aware Energy Efficient Routing Protocol with Adaptive Threshold Energy for MANETs",(nternational Journal for Advanced Research in Computer Science (IJARCS) , (in press).

AUTHORS PROFILE

Dr. P.S. Hiremath, Professor, Department of P. G. Studies and Research in Computer Science, Gulbarga University, Gulbarga, Karnataka, India. He has obtained M.Sc. degree in 1973 and Ph.D. degree in 1978 in Applied Mathematics from Karnatak University, Dharwad. He had been in the Faculty of Mathematics and Computer Science of various Institutions in India, namely, National Institute of Technology, Surathkal (1977-79), Coimbatore Institute of Technology, Coimbatore (1979-80), National Institute of Technology, Tiruchinapalli (1980-86), Karnatak University, Dharwad (1986-1993) and has been presently working as Professor of Computer Science in Gulbarga University, Gulbarga (1993 onwards). His research areas of interest are Computational Fluid Dynamics, Optimization Techniques, Image Processing and Pattern Recognition, and Computer Networks. He has published 140 research papers in peer reviewed International Journals and Proceedings of Conferences.

Mr. Shrihari M.Joshi, Associate Prof., Department of Computer Science and Engg., SDM College of Engineering & Technology, Dharwad, Karnataka, India. .He is having 21 years of teaching experience. He has published 7 research papers in the proceedings of the conferences. His areas of interest are Computer Networks, Network Security and Mobile Adhoc Networks.