Energy Efficient Shortest Path Routing Protocol for Wireless Sensor Networks

K S Shivaprakasha, Muralidhar Kulkarni
Centre of Excellence in Wireless Sensor Networks,
National Institute of Technology Karnataka,
Surathkal, Karnataka, INDIA
e-mail: shivu_kssp@rediffmail.com, mkuldce@gmail.com

Abstract: **Wireless Sensor Networks (WSNs) have become one of the emerging trends of the modern communication systems. Routing plays a vital role in the design of a WSNs as normal IP based routing will not suffice. Design issues for a routing protocol involve various key parameters like energy awareness, security, QoS requirement etc. Energy awareness is one of the vital parameters, as the batteries used in sensor nodes cannot be recharged often. Many energy aware protocols were proposed in the literature. In this paper, we propose a new Energy Efficient Shortest Path (EESP) algorithm for WSNs, which manages uniform load distribution amongst the paths so as to improve the network performance as compared to the traditional shortest path routing strategy.**

Keywords: Shortest Path Routing (SP), Energy Efficient Shortest Path (EESP), Dynamic Source Routing (DSR), Energy Aware DSR (EADSR), Adhoc On demand Distance Vector (AODV)

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is a network of large number of sensor nodes deployed either randomly or deterministically over a large geographical area [1, 2, 3]. Nodes of a sensor network are called as motes consist of a sensor, processing unit, transmitter, position finding system and power units. Power units cannot be recharged often and thus the data transmission has to be done with the minimum energy consumption.

Sensors sense a physical entity like temperature, pressure, humidity etc and send the information to the central entity called the base station. The transmission of the data can be via direct transmission, multihop communication or using hierarchical approach [4, 5 6].

WSNs pose many design challenges. One such important design issue is the energy awareness. As the recharging of the batteries of sensor nodes are practically very difficult, the data transmission has to take place using the minimum energy consumption. Thus the routing algorithms used for WSNs also have to consider energy awareness along with the distance parameter. Many routing protocols were proposed in the literature which were proved to be optimal energy efficient algorithms [7, 8]. Shortest path algorithm is one of the most powerful algorithms used for the route computation. Although it discovers an optimal path with respect to the distance metric, it does not considers energy of the intermediate nodes into account [9, 10, 11]. Thus the existing shortest path algorithm can be made energy efficient shortest path by incorporating energy metric along with the distance parameter. In this paper we propose the Energy Efficient Shortest Path (EESP) algorithm which discovers an optimal path of minimum hops with maximum average node energy. The simulation results show that the proposed algorithm enhances the network lifetime by increasing the average lifetime of the nodes in the network.

The rest of the paper is organized as follows: Section II gives an overview of the energy aware routing protocols proposed in the literature. Section III details the proposed EESP algorithm. Section IV discusses the simulation results obtained and the performance comparison of the proposed algorithm with the existing one. Finally Section V gives the concluding remarks of the paper and a scope for the future extension.

II. PREVIOUS WORKS

A lot of work is being carried out in the area of energy aware routing for WSNs. Various parameters were considered to improve the energy efficiency in the network. In this section a brief note on the energy aware protocols proposed in the literature has been given. Heinzelman, et. al. [12] proposed a hierarchical clustering algorithm for homogeneous wireless sensors networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network [12]. PEGASIS [13] is a chain based protocol which avoids cluster formation and uses only one node in a chain to transmit to the BS instead of using multiple nodes.

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) was proposed by Manjeshwar et al. in [14]. TEEN pursues a hierarchical approach along with the use of a data-centric mechanism. TEEN is not good for applications where periodic reports are needed. An improvement over TEEN was proposed in [14] which aim at both capturing periodic data collections and reacting to time-critical events. The architecture is same as in TEEN.

978-0-7695-4587-5/11 $26.00 © 2011 IEEE
DOI 10.1109/CICN.2011.70

An improvement over the existing LEACH algorithm was proposed by Heinzelman, et al. in [15] called LEACH-centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH. O. Younis, et al. proposed HEED (Hybrid Energy-Efficient Distributed clustering), which periodically select cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree [16].

DEEC (Distributed energy efficient Clustering) algorithm in which cluster head is selected on the basis probability of ratio of residual energy and average energy of the network was proposed in [17]. Simulations show that its performance is better than other protocols. In [18] the authors have suggested a mechanism to reduce the size of the routing overhead by replacing the larger routing tables with a field in the preamble. It also accounts for the reduction of the network traffic. The traditional directed diffusion algorithm has been modified to lead Energy Aware Directed Diffusion (EADD) [19] in which the path with more residual energy is selected if more number of nodes in the network have the same data of interest requested by the base station.

Unnecessary route discovery processes can be avoided if the routes computed are stored in the node memory for some duration [20]. This in turn improves the network performance. Also the flooding rate can be adjusted by the source node depending on the loss rate [21]. In the paper [22], the energy awareness is incorporated by reliving the nodes from route computation process and the base station does the job of route discovery depending on the distance. A hierarchical routing protocol has been proposed in [23]. Node with the highest energy is selected as the cluster head. The uniform load distribution is emphasized in paper [24]. TDMA-based MAC protocol, is proposed in [25] where each node selects its slot by gathering the information from its neighbors.

An improvement over traditional DSR has been proposed in [26]. This is done by incorporating an energy function at the time of route discovery. An additional delay is introduced by each of the nodes depending on the available energy enabling the path with larger energy to get selected. An optimal separation between nodes called the characteristic distance has been analyzed in [27]. In [28] the authors have proposed an improvement over distance vector routing called Energy Aware Distance Vector (EADV) where the sink node initiates the route discovery by sending an initial broadcast packet. The intermediate nodes will extract the information and updates the packet.

In [29] an algorithm is developed in which each of the nodes will decide the next hop to which the data has to be forwarded depending on the residual energy of that node. In [30] Energy Efficient AODV was considered as the base paper and some improvements were proposed on the same so as to inculcate optimal load distribution amongst nodes.

III. Energy Efficient Shortest Path Routing Protocol

Shortest Path Routing (SP) algorithm is one of the most powerful and popular algorithms used to find the shortest distance path amongst any two nodes in a network. But this algorithm is not applicable for energy constrained applications as it does not consider any energy parameter for the route discovery. Thus in this paper we propose a slight modification over the Shortest Path algorithm so as to make the computed route energy efficient.

A. Energy Model

The radio model is used as the energy model for the proposed algorithm. The energy required for the transmission of a packet for distance d is given by,

$$E_T(d) = E_{ct} + \varepsilon\, dn \quad (1)$$

Where E_{ct} is the energy consumed by the circuitry at the transmitter

ε is the energy dissipated in the transmitter amplifier

n is a design parameter which can be either 2 or 4.

Also the power consumed in receiving is given by

$$E_R(d) = E_{cr} \quad (2)$$

where E_{cr} is the energy consumed by the circuitry at the receiver

As intermediate nodes need to receive and forward the packets, the energy consumed by them will be the sum of the expressions (1) and (2).

B. Algorithm

The EESP protocol follows the thought of SP. Unlike SP, in EESP route computation is based not only on the distance but also on the residual energy in the nodes. The EESP routing algorithm is as follows:

- The network is initialized. A threshold is set for the network. Threshold is chosen such that it should be small enough that unnecessary route initiations should not take place and large enough that the node should not be denied to initiate its own communication due to the battery extinction.
- Here as the communication is wireless, the distance to all neighbouring nodes from a given node is considered to be 1 indicating the connectivity else it is zero.
- Assign to every node a distance value: set it to zero for the initial node and to infinity for all other nodes.
- Mark all nodes as unvisited. Set initial node as current node.
- For current node, consider all its unvisited neighbours and calculate their tentative distance.
- If this distance is less than the previously recorded distance, overwrite the distance. Also update its distance

value by including the effect of the residual energy level of that node. This can be accomplished by introducing the energy metric at the denominator of the distance parameter.

- The distance parameter will be high for low energy nodes and thus making them less likely to be included in the path.
- A node whose energy level is greater than the threshold and has the least distance value is chosen to be the current node for the next iteration.
- The process continues till the destination node becomes the current node
- The optimal distance will be given by the distance value of the destination node and the corresponding path can be determined by considering the processors of the nodes.

IV. Simulation Results and Analysis

In this section we will discuss the results obtained after simulations for the proposed EESP algorithm. The simulations were carried out for various network scenarios and the results show that the proposed algorithm provides a better network survivability compared to the shortest path algorithm.

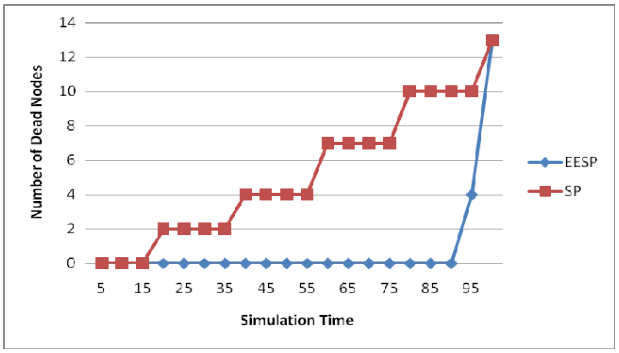

Figure 1 Average Number of dead Nodes for a Network of size 10

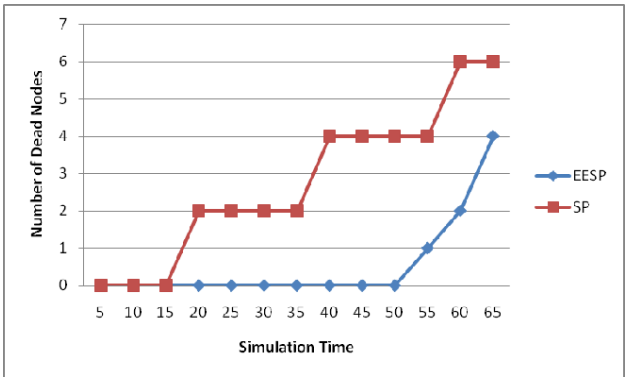

Figure 2 Average Number of dead Nodes for a Network of size 15

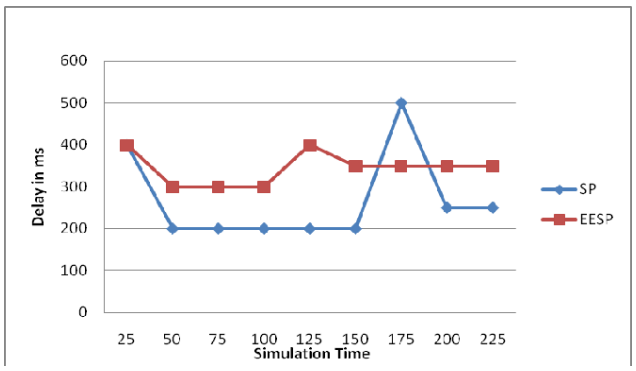

Figure 3 Delay incurred as a function of simulation time

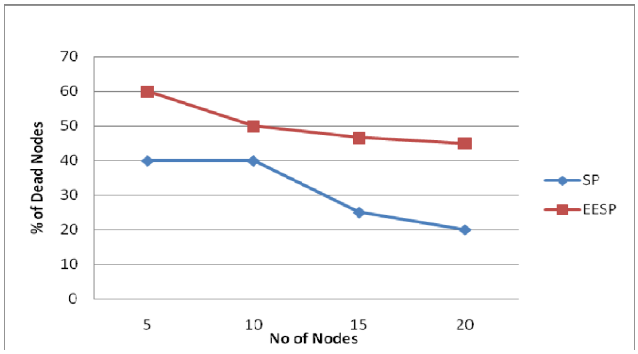

Figure 4 % of Dead Nodes as a function of Network Size

The figures 1and 2 show the plots of number of dead nodes as a function of simulation time for a network of size 10 and 15 respectively. It is clear from the graphs that nodes die early in the Shortest Path algortihm than in EESP. In other words the average lifetime of nodes is improved in the proposed algorithm which in turn increases the network lifetime. This is because the path includes nodes with battery level above threshold leading to the uniform load distribution in the network.

Figure 3 gives a plot of the average delay incurred for communication as a function of simulation time for a network of 15 nodes. It can be seen from the plot that the delay incurred in EESP algorithm would be higher than that of the SP algorithm. This is due to the fact that EESP selects the path with more residual energy rather than the shortest. Also there will be frequent route discoveries in EESP which will add to the delay. Whereas in SP although the average delay is very less, there will be a significant increase in the delay towards the data loss due to link failures which may also lead to network partitioning. Thus in EESP the delay is almost consistent compared to that of SP algorithm.

Figure 4 gives a plot of the percentage number of dead nodes as a funtion of the number of nodes. It can be concluded from the graph that the EESP algorithm outperforms the traditional SP algorithm with respect to the network survivability.

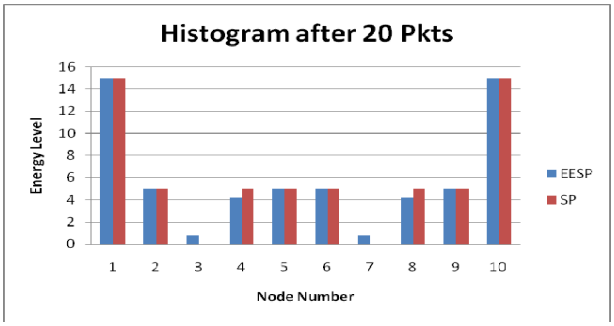

Figure 5 Energy Histogram after the Transmission of 20 Packets

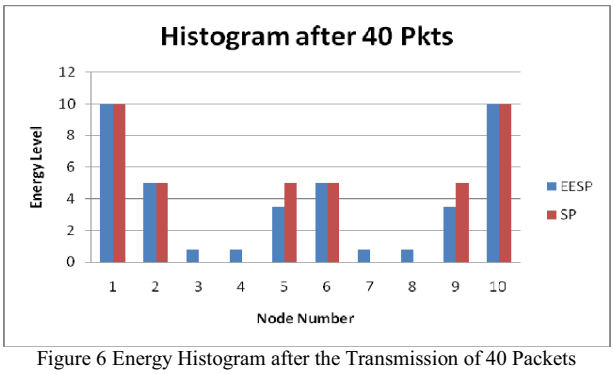

Figure 6 Energy Histogram after the Transmission of 40 Packets

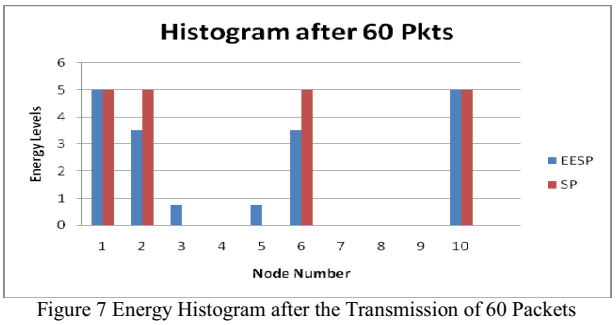

Figure 7 Energy Histogram after the Transmission of 60 Packets

Figures 5, 6 and 7 give the Energy Histogram in the network of size 10. From the plots it is evident that the drain of the battery is almost uniform in EESP and is better for the network performance.

Similar comparisons of histograms for the network size of 15 are depicted in the following plots. Figures 8, 9 and 10 give the histogram for the network with 15 nodes.

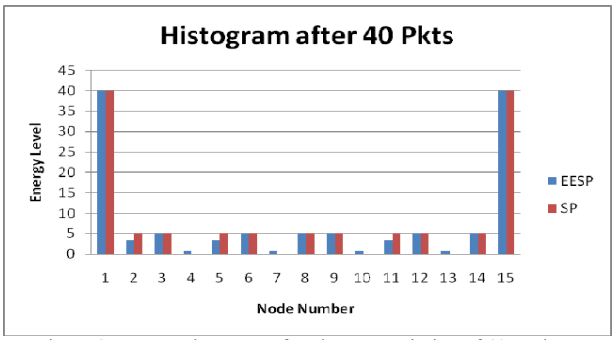

Figure 8 Energy Histogram after the Transmission of 40 Packets

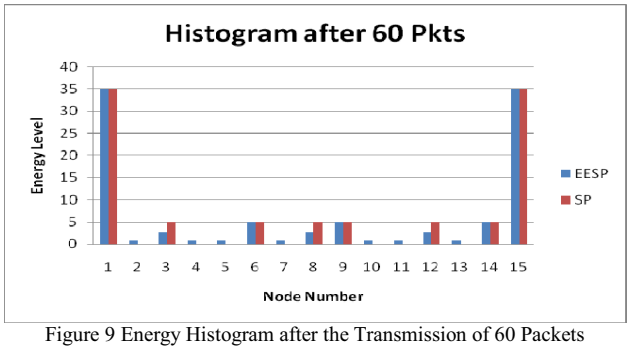

Figure 9 Energy Histogram after the Transmission of 60 Packets

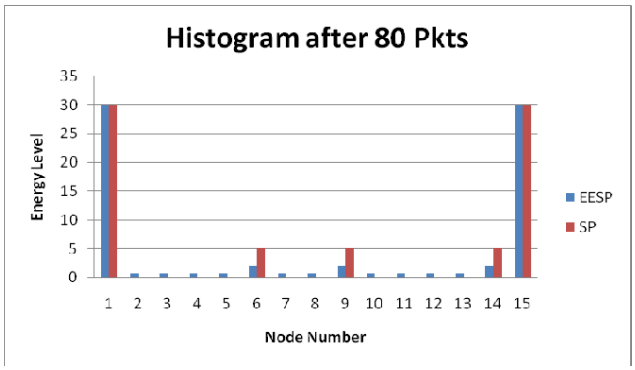

Figure 10 Energy Histogram after the Transmission of 80 Packets

It is again confirming the better performance of the proposed protocol over the existing shortest path algorithm with reference to the network survivability.

V. Conclusion and Future Scope

Routing is one of the most crucial research challenges in WSNs. A novel energy efficient routing algorithm is considered in this paper which is an improvement over the existing shortest path algorithm. Here the energy awareness is introduced by incorporating energy metric at the time of route computation. Simulation results show that the average lifetime nodes in the network have been improved considerably in the proposed algorithm. Thus the overall lifetime of the network is increased.

The paper assumes the network to be homogeneous. As a part of our future extension the algorithm can be modified for heterogeneous environments.

References

[1] David Culler, Deborah Estrin, Mani Srivastava, "Overview of Sensor Networks", IEEE Computer Society, August 2004

[2] M.K.Jeya Kumar, "Evaluation of Energy-Aware QoS Routing Protocol for Ad Hoc Wireless Sensor Networks", International Journal of Electrical, Computer, and Systems Engineering 4:3 2010

[3] Curt Schurgers, Mani B. Srivastava, "Energy Efficient Routing in Wireless Sensor Networks" [www.citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.11]

[4] Sinem Coleri Ergen and Pravin Varaiya, "On Multi-Hop Routing for Energy Efficiency", IEEE Communications Letters, Vol. 9, No. 10, October 2005

[5] C Siva Ram Murthy and B S Manoj, "Adhoc Wireless Networks-Architectures and Protocols", Pearson education, 2004
[6] Andrew S Tanenbaum, "Computer Networks", 4e,Pearson Education,2003
[7] Behrouz A Fouruuzan, "Data Communications and Networking", 3e, McGrawHill Publication, 2004
[8] Rajashree.V.Biradar, V.C .Patil, S. R. Sawant, R. R. Mudholkar, "Classification and Comparison of Routing Protocols in Wireless Sensor Networks", Special Issue on Ubiquitous Computing Security Systems, UbiCC Journal – Volume 4
[9] A. K. Dwivedi, Sunita Kushwaha, O. P. Vyas, "Performance of Routing Protocols for Mobile Adhoc and Wireless Sensor Networks: A Comparative Study", International Journal of Recent Trends in Engineering, ACEEE, Vol 2, No. 4, November 2009
[10] Kemal Akkaya , Mohamed Younis, "A Survey on Routing Protocols for Wireless Sensor Networks", Elsevier, Ad Hoc Networks 3 (2005) 325–349
[11] Chiara Buratti, Andrea Conti, Davide Dardari and Roberto Verdone, "An Overview on Wireless Sensor Networks Technology and Evolution", Sensors 2009, 9, 6869-6896, [www.mdpi.com/journal/sensors]
[12] W. Heinzelman, J. Kulik, and H. Balakrishnan: "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks", Proc. 5th ACM/IEEE Mobicom, Seattle, WA, pp. 174–85 (Aug. 1999).
[13] S. Lindsey and C. S. Raghavendra, "PEGASIS: Power Efficient Gathering in Sensor Informatio Systems", in the Proceedings of the IEEE Aerospace Conference, Big Sky, Montana, March 2002
[14] A. Manjeshwar and D. P. Agarwal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks", Parallel and Distributed Processing Symposium, Proceedings International, IPDPS 2002, pp. 195-202.
[15] W.R. Heinemann, A.P. Chandrakasan, H. Balakrishnan, "An Application Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Transactions on Wireless Communications 1 (4) (2002) 660–670.
[16] Ossama Younis and Sonia Fahmy, "HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks", IEEE Transactions on Mobile Computing, Vol. 3, No. 4, October-December 2004
[17] L. Qing, Q. Zhu, M. Wang, "Design of a Distributed Energy Efficient Clustering Algorithm for Heterogeneous Wireless Sensor Networks", Elsevier, Computer Communications 29, pp 2230- 2237, 2006.
[18] Jaejoon Cho, Sungho Kim, Heungwoo Nam, Sunshin An, "An Energy-Efficient Mechanism using CLMAC Protocol for Wireless Sensor Networks", Third International Conference on Networking and Services(ICNS'07), IEEE, 2007
[19] Jisul Choe, Keecheon Kim, "EADD: Energy Aware Directed Diffusion for Wireless Sensor Networks", International Symposium on Parallel and Distributed Processing with Applications, IEEE Computer Society, 2008
[20] Raminder P. Mann, Kamesh R. Namuduri, Ravi Pendse, "Energy-Aware Routing Protocol for Ad HocWireless Sensor Networks", EURASIP Journal on Wireless Communications and Networking 2005:5, 635–644
[21] Basavaraj S.Mathapati, Dr.V.D.Mytri and Dr.Siddarama R. Patil, "An Adaptive Energy Efficient Reliable Routing Protocol for Wireless Sensor Networks", ACEEE International Journal on Network Security, Vol 1, No. 1, Jan 2010
[22] Jin Wang, Jinsung Cho and Sungyoung Lee, "A Hop-based Energy Aware Routing Algorithm for Wireless Sensor Networks" [www.uclab.khu.ac.kr/resources/publication/C_161.pdf]
[23] Backhyun Kim, and Iksoo Kim, "Energy Aware Routing Protocol in Wireless Sensor Networks", IJCSNS International Journal of Computer Science and Network Security, Vol.6 No.1, January 2006
[24] Vamsi Paruchuri, Arjan Durresi, Leonard Barolli, "Energy Aware Routing Protocol for Heterogeneous Wireless Sensor Networks", Proceedings of the 16th International Workshop on Database and Expert Systems Applications (DEXA'05), IEEE Computer Society, 2005
[25] Rozeha A. Rashid, Wan Mohd Ariff Ehsan W. Embong, Azami Zaharim and Norsheila Fisal, "Development of Energy Aware TDMA-Based MAC Protocol for Wireless Sensor Network System", European Journal of Scientific Research, ISSN 1450-216X Vol.30 No.4 (2009), pp.571-578
[26] K S Shivaprakasha, Muralidhar Kulkarni, ""Improved Network Survivability using Energy Aware DSR for Wireless Sensor Networks", Proceedings of IETE Conference on RF and Wireless, 8th and 9th Oct 2010, IETE Centre, Bengaluru.
[27] Marco Zimmerling, Waltenegus Dargie and Johnathan M. Reason, "Energy-Efficient Routing in Linear Wireless Sensor Networks", IEEE International Conference on Mobile Adhoc and Sensor Systems, 2007
[28] S. Mahlknecht, S. A. Madani and M. Roetzer, "Energy Aware Distance Vector Routing Scheme for Data Centric Low Power Wireless Sensor Networks", IEEE International Conference on Industrial Informatics, 2006
[29] R Vidhyapriya, Dr P T Vanathi, "Energy Aware Routing for Wireless Sensor Networks", International Conference on Signal Processing, Communications and Networking, ICSCN 2007.
[30] K.S. Shivaprakasha, Muralidhar Kulkarni, Pravin Kumar and Santosh Kumar Singh, "Optimal Path Energy Efficient Routing Algorithm for Wireless Sensor Networks", CiiT International Journal of Networking and Communication Engineering, February 2011 Issue, ISSN 0974 – 9713