International Journal of Engineering Technology and Applied Science
Vol. 1 Issue 1
February 2015

Energy Consumption and Performance based Analysis of LEACH-DSR Protocol in MANET

Sujeet Singh[1], Aishwary Agarwal[2]
sujeet.baghel@gmail.com[1], aishwary.agrawal4@gmail.com[2]

Abstract—Energy is one of the important issue in MANET then efficient routing is necessary to utilizes full energy consumption and enhance the network performance. LEACH is energy based protocol work on the cluster base mechanism to utilize the energy consumption. In this paper we analyses the performance of LEACH protocol with reactive on demand DSR protocol to efficiently utilizes the energy constraint in network. Here proposed scheme are not compare with any previous existing scheme. The performance of proposed LEACH-DSR protocol is analysis on the basis of performance matrices. Residual energy based energy utilization and analyze the life of node in a given simulation time. In this work, we use DSR as the underlying routing protocol and focus on residual energy level as performance metric, which has been used for routing decisions in energy-efficient routing protocol proposals. In addition the performances of TCP congestion window are also analyze. Our experiments show that nodes have at best imprecise state information, especially under high traffic rates.

***Index Terms*— Energy, LEACH-DSR, MANET, Network performance, TCP, Analysis.**

INTRODUCTION

All Mobile Ad hoc Networks (MANET) consist of wireless nodes that form a communications network among themselves without a fixed infrastructure [1]. MANET is frequently used in special situations such as in emergency operations such as natural or manmade disasters, rescue activities, battle fields or seminar halls particularly in areas where there is no fixed infrastructure or such infrastructure has been destroyed [2]. Topology changes in MANET usually occur due to the mobility of a participating node or breakdown of a node due to loss of energy in that node [3]. These dynamic conditions disrupt the smooth communication between needs in the network. Conceptually, in MANET, a node may either function as an end node or as a router forwarding data packets between end nodes [4]. An effective routing mechanism is required to maintain acceptable service quality during communication between nodes [5]. Hence the fitness of the node in terms of available energy in the node becomes an important issue during the selection of an intermediate node in order to maintain stable transfer of data between nodes. Maintaining an optimized lifetime of a routing path in a network is a very challenging task because the power or energy of the nodes depends on the size, model, property, and capacity of the battery [3]. Energy in batteries continuously deplete due to node activities such as transmission, reception and overhearing [6]. Depletion of energy in nodes especially the intermediate ones disrupt communication and results in changes to the network topology. However disruption can be minimized through an efficient selection of intermediate nodes. Such selection criteria must be the first step in any route selection process in order to maintain a stable routing of data between the end nodes.

The node selection process has been included in many routing algorithms and techniques [4]. Hence these algorithms and techniques have considered the service quality an important factor. But these algorithms and techniques suffer from certain shortcomings especially during the route discovery process. These techniques do not consider the available energy of a node as a parameter, so they may select a node with low energy level as an intermediate node. Selection of a node with low energy level reduces the stability of the communication path as that node may run out of energy causing the breakdown of the communication channel. In this paper the authors propose a probability based node selection scheme where the available energy level of a node is an important parameter.

Nodes consume energy while transmitting beacon signals to neighboring nodes for the purpose of detecting their existence or transmitting data to another node [4].When an intermediate node has been selected as a router, it consumes more energy than an idle node as it is actively involved in communication.

Thus, the nodes' residual energy is important in determining the path to successfully completing data transfer without interruption. Hence a routing protocol that considers the nodes residual energy will perform better than the protocols that do not.

This paper is organized as follows: in section II we present a brief description of LEACH and Section 3 of DSR protocol, section 4 includes a Literature survey and proposed work description are explained in section 5. Section 6 gives the overview of Simulation Environment and finally, section 7 provides concluding remarks and future work

LEACH

The Low-energy adaptive clustering hierarchy (LEACH) [7,8] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes. All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The nodes die randomly and dynamic clustering increases lifetime of the system. LEACH is completely distributed and requires no global knowledge of network. However, LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. Moreover, the idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc.

A recent protocol architecture that optimizes the energy efficiency in networks is Low Energy Adaptive Clustering Hierarchy (LEACH) [7]. LEACH considers communications between nodes randomly distributed in a fixed square area, and an external receiver. It includes distributed cluster formation technique, which enables self-organization of large numbers of nodes, algorithms for adapting clusters and rotating cluster head positions to evenly distribute the energy load among all nodes. In this paper we represent the analysis of LEACH-DSR, starting from the basic idea of LEACH. We propose a new routing strategy, denoted as LEACH-DSR the main characteristics of our performance analysis are:

- We characterize in a better way the transceiver than how it was done in [7, 8] with data taken from [9].
- We consider a decentralized algorithm of cluster for-mation, in which nodes only know their own position and the position of the final receiver, and not the po-sition of all nodes.
- With our model, the optimal number of cluster heads depends also on the energy dissipated for broadcast packets.

DESCRIPTION ABOUT DSR PROTOCOL

The DSR protocol [10] is composed of two mechanisms that work together to allow the discovery and maintenance of source routes in the ad hoc network:

- **Route Discovery** is the mechanism by which a node **S** wishing to send a packet to a destination node **D** ob-tains a source route to **D**. Route Discovery is used only when **S** attempts to send a packet to **D** and does not already know a route to **D**.
- **Route Maintenance** is the mechanism by which node **S** is able to detect, while using a source route to **D**, if the network topology has changed such that it can no longer use its route to **D** because a link along the route no longer works. When Route Maintenance in-dicates a source route is broken, **S** can attempt to use any other route it happens to know to **D**, or can in-voke Route Discovery again to find a new route. Route Maintenance is used only when **S** is actually sending packets to **D**.

Route Discovery and Route Maintenance each operate entirely *on demand*. In particular, unlike other protocols, DSR requires *no* periodic packets of *any kind* at *any level* within the network. For example, DSR does not use any periodic routing advertisement, link status sensing, or neighbor detection packets, and does not rely on these functions from any underlying protocols in the network. This entirely on-demand behavior and lack of periodic activity allows the number of overhead packets caused by DSR to scale all the way down to *zero*, when all nodes are approximately stationary with respect to each other and all routes needed for current communication have already been discovered. As nodes begin to move more or as communication patterns change, the routing packet overhead of DSR *automatically* scales to only that needed to track the routes currently in use. In response to a single Route Discovery (as well as through routing information from other packets overheard), a node may learn and cache multiple routes to any destination. This allows the reaction to routing changes to be much more rapid, since a node with multiple routes to a destination can try another cached route if the one it has been using should fail. This caching of multiple routes also avoids the overhead of needing to perform a new Route Discovery each time a route in use breaks. The operation of Route Discovery and Route Maintenance in DSR are designed to allow uni-directional links and asymmetric routes to be easily supported it is possible that a link between two nodes may not work equally well in both directions, due to differing antenna or propagation patterns or sources of interference. DSR allows such uni-directional links to be used when necessary, improving overall performance and network connectivity in the system. DSR also supports internetworking between different types of wireless networks, allowing a source route to be composed of hops over a combination of any types of networks available [Broch 1999b]. For example, some nodes in the ad hoc network may have only short-range radios, while other nodes have both short -range and long- range radios; the combi-nation of these nodes together can be considered by DSR as a single ad hoc network. In addition, the routing of DSR has been integrated into standard Internet routing, where a “gate-way” node connected to the Internet also participates in the ad hoc network routing protocols; and has been integrated into Mobile IP routing, where such a gateway node also serves the role of a Mobile IP foreign agent [Johnson 1995, Perkins 1996].

RELATED WORK

We discuss the research most relevant to this paper. We first describe work related to network organization followed by a summary of energy-efficient wireless network protocols.

Sridharan et al **[**11**]** proposed ELQR as an energy aware link quality estimator, which takes into account the residual energy as one of the factor before selecting the route. In CTP the node with better link quality is selected as parent most of the time and is the one which is involved in most of the communication, which drains out such good link quality nodes and results in network disconnection. In order to avoid this problem, a routing protocol is proposed to balance the traffic load among the possible routes. This is done by having residual energy as a decision factor in the routing tables and this information is exchanged between the neighboring nodes.

TOSSIM [12]which is a simulator for Tiny OS networks and showed increased network lifetime comparing to CTP. But the PRR (Packet Reception Rate) is less as compared to CTP as it takes longer to converge when there is a route change. This work also dealt with testing CTP only in static scenarios.

In [13] the authors propose a new architecture for better handling mobility in wireless sensor networks. They propose a hierarchical network architecture having a low level sensing layer with mobile sensor nodes and a high level routing layer with fixed routing nodes. The nodes in the sensing layer are mobile and they send their sensed data to the static routing nodes in the routing layer which are at a one hop distance from them. The static routing nodes then further process and forward the data to the sink. This is a good solution for such a scenario where we can have fixed nodes at the side with enough processing, storage and communication capabilities and the mobile nodes are only one hop distance away from these fixed nodes.

Many researchers have proposed to use the wireless ad hoc network protocols to be used in wireless sensor networks. Some of them are proactive like Destination Sequenced Distance Vector (DSDV) **[**14**]** and designed for static networks. Some are reactive like Dynamic Source Routing [15] and Ad hoc On Demand Distance Vector (AODV) **[**16**]**.

As mentioned in the previous section these protocols are not designed for low power, battery enabled sensor nodes. In [17] authors performed the simulation study on AODV’s performance in wireless sensor networks and it is shown that it gives around 70% delivery ratio in a static scenario. As they used 802.11 as the MAC layer It would be interested and more relevant to investigate AODV’s performance using 802.15.4 MAC in a mobile wireless sensor network application.

Hierarchical routing schemes **[**18**]** have also been tested to prove that they cannot support mobility in wireless sensor network applications. The flat based multihop routing techniques for wireless sensor networks **[**19**]** also lack the capability to support mobility. The frequent link breakages due to node movements cannot be handled fast enough by their routing mechanism to provide reliable performance.

LEACH-Mobile **[**22**]** protocol supports mobility in wireless sensor networks and is better than LEACH protocol. In LEACH-Mobile each sensor uses a two way communication mechanism to become part of a cluster. The cluster head sends a message to the sensor nodes in its cluster and if it does not hear from a sensor node it is assumed to have moved out of the cluster. When a node does not hear from the cluster head, it tries to connect to other clusters. This protocol also suffers from high packet losses and energy consumption because of its cluster membership mechanism.

In [6], a self organizing, scalable, distributed TDMA based sensor network architecture has been presented. The nodes autonomously organize themselves into an unexciting non-hierarchical network, without any information about timing, number of nodes and topology. Sensor information network architecture (SINA) was proposed in [23] based on hierarchical clustering. Sensor nodes autonomously form groups called clusters, where the clustering is based on power level and proximity. LEACH (Low-Energy Adaptive Clustering Hierarchy) [21] is an information gathering protocol for wireless sensor networks using hierarchical clustering architecture with two tiers. Here, sensor nodes which are close to each other group into a cluster and the nodes in the cluster send their data to a local *cluster-head* which forwards the fused data to the BS. LEACH takes advantage of data fusion [24] to reduce the amount of raw data necessary to be transmitted to the BS. Data fusion is extremely useful when coherent data sources are involved. However when uncorrelated data is being transmitted by sensor nodes, data fusion cannot be applied in which case packet delays can be very high due to increased network loads.

Power management is a challenging problem in wireless sensor networks, since the network operates on battery power and the lifetime is limited by the capacity of its energy source. For increasing longevity of such network and thus increasing their usefulness, it is imperative that we determine ways of either increasing battery power or alternative tether- less sources of energy that nodes in a wireless network can use [25]. Recently, there has been much work on power efficient protocols for wireless networks which include power-aware routing, power-efficient MAC protocol and transmission power control [26].

Some research attention has been devoted to design energy efficient routing protocols for ad hoc wireless networks, in which optimal routes are chosen based on the energy at each node along the route [27]. Routes that are longer but use nodes with more energy than the nodes along the shorter routes are favored. In [27], five different metrics were defined and a shortest-cost routing protocol with respect to these five energy efficiency metrics was proposed.

Other work on power-aware routing for ad hoc networks can be found in [26, 28]. The proposed work is different from past research in that it provides a generalized framework for energy efficient routing protocols, while past protocols typically tend to focus on either MAC or routing protocols.

PROPOSED WORK

After In this paper, we will propose the energy based analysis of the with DSR protocol to solve the problem of existence of the large clusters in the sensor networks. Here we will introduce an LEACH-DSR which is a modified version of the well known LEACH protocol. LEACH-DSR proposes vital solutions to some shortcomings of the pure LEACH. Clusters in LEACH and LEACH-DSR may be very small or very large in size. Due to the large transmission distance energy can be loss very high of clusters. In the proposed concept, cluster head selection and cluster formation is done in same manner as LEACH and LEACH-DSR. In the proposed concept LEACH-DSR is generally divided into two phases, the group phase and the transmission phase. In the group phase, cluster heads (CH) are selected and clusters are organized. In the transmission phase, the actual data transmissions to the sink take place. In the proposed LEACH-DSR concept, here we will select some node as cluster head (CH) from cluster node. Selection of cluster head will we depend on equal energy between nodes. After a period of time this process will repeat to find new cluster head (CH) node in the network. In the LEACH-DSR concept we will increasing the selection of the cluster head during setup phase by equal energy between cluster nodes which intends to become a CH to prolong the network lifetime. Another thing which will trying to reduce the power consumption between clusters by using enhanced technique and finally we will try to balance of load in routing protocol which will attempts to balance the load over CHs evenly by permitting the CH to discover the optimal route to the base station (BS) with minimum cost and then sends the useful data to the base station (BS) through many other CHs instead of direct sending to the BS. LEACH-DSR is expected to perform well especially when the mobility is very high and will prolong the overall network lifetime through load balancing. In proposed work the routing with DSR of LEACH only show the performance combination of these two protocols by that the behavior of DSR are also analysis with energy factor.

SIMULATION ENVIRONMENT AND RESULTS

Network simulator 2 is the result of an on- going effort of research and development that is administrated by researchers at Berkeley. It is a discrete event simulator targeted at networking research. The simulator is written in C++ and a script language called OTcl2. Ns use an OTcl interpreter towards the user. This means that the user writes an OTcl script that defines the network (number of nodes, links), the traffic in the network (sources, destinations, type of traffic) and which protocols it will use. This script is then used by ns during the simulations. The result of the simulations is an output trace file that can be used to do data processing (calculate delay, throughput etc) and to visualize the simulation with a program called

A. Simulation Parameter

We get Simulator Parameter like Number of nodes, Dimension, Routing protocol, traffic etc. are shown in table 1

Table 1 Simulation parameter

Simulation Parameter	Value
Number of nodes	40
Dimension of simulated area	800×800
Routing Protocol	DSR
Simulation time (seconds)	100
Energy Aware	LEACH
Transport Layer	TCP
Traffic type	CBR
Packet size (bytes)	1000
Initial Energy (in Joule)	Random
Number of traffic connections	10
Maximum Speed (m/s)	Random

B. Performance Evaluation

There are following different performance metrics have showed the results on the basis of following:

- **Packet delivery ratio:** ratio of the data packets received at the destination nodes to the packets that were sent by the sources.
- **Routing load:** number of routing packets transmitted per data packet delivered at the destination.
- **End to End delay:** Time taken to deliver number of data packets in between sender and receiver.
- **Packet loss:** Number packets are dropped in network delivered to destination by sender.

C. NAM Visualization of Nodes

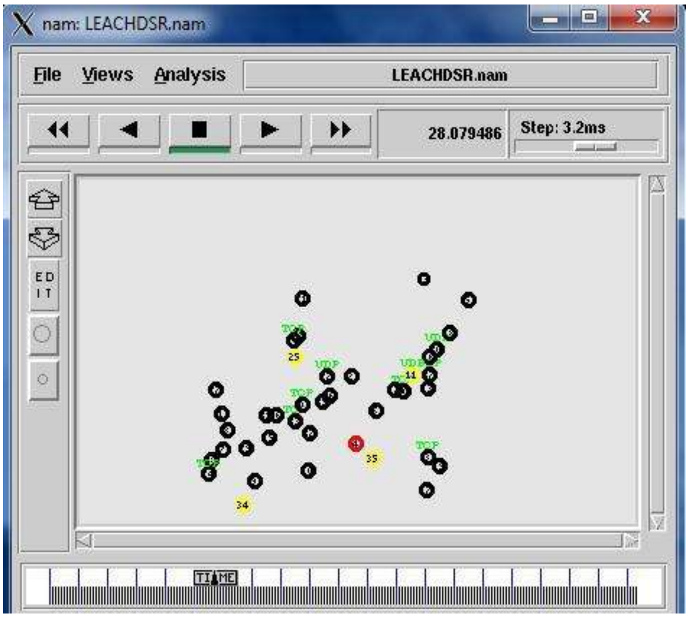


Figure 1: Network Animator scenario

D. Analysis on the basis of Remaining and Residual energy

Residual and remaining energy analyses are shown in Table 1.Here we clearly visualized the remaining amount of each node and observe the utilization of energy in the foam of residual energy. The Node 5 has remaining and residual energy are highest it means that there is no proper utilization of energy of this node, because this node is not completely involve in routing procedure and one of the main important factor is the remaining energy of this node is also maximum it means their energy is not wasted due to any reason. After that the node 9 has highest remaining energy and residual energy. Now Node 0 and Node1 has minimum residual energy it means their energy utilization is more but node 4 has slightly poor of energy utilization. Node 6, Node 7 and Node 8 are intermediate node by7 that has remaining energy is negligible and their residual energy cost is more. Rest of the nodes have proper energy utilization.

Table 3 Energy Analysis

Node No	Energy Remain	Residual Energy
0	2.04	6.32
1	2.63	3.72
2	0.02	20.62
3	0.28	18.28
4	1.57	8.94
5	10.77	38.59
6	0.01	20.64
7	0.02	20.57
8	0.02	20.61
9	9.65	25.94
10	0.13	19.56

E. Died Node Analysis

In this graph the x-axis is represents time and the y-axis are represents first number of nodes and second is died node time in given simulation time and parameters. Here died analysis represents the time at that the node has been lost their functional capability i.e. called node energy.

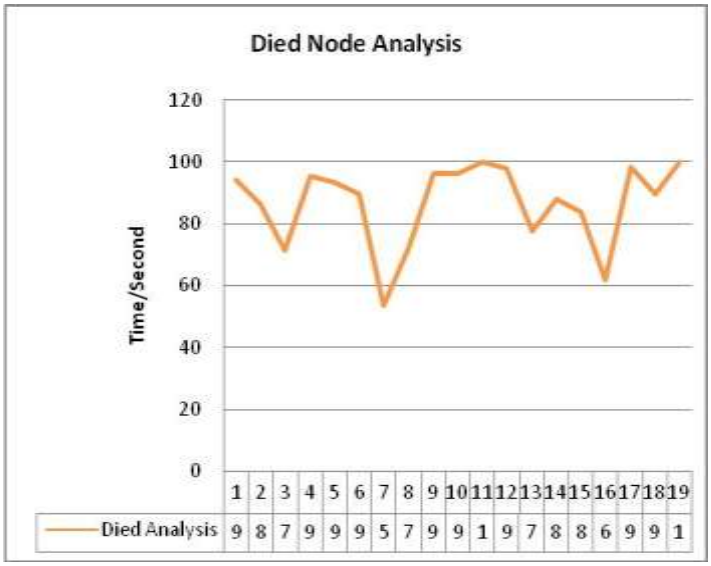
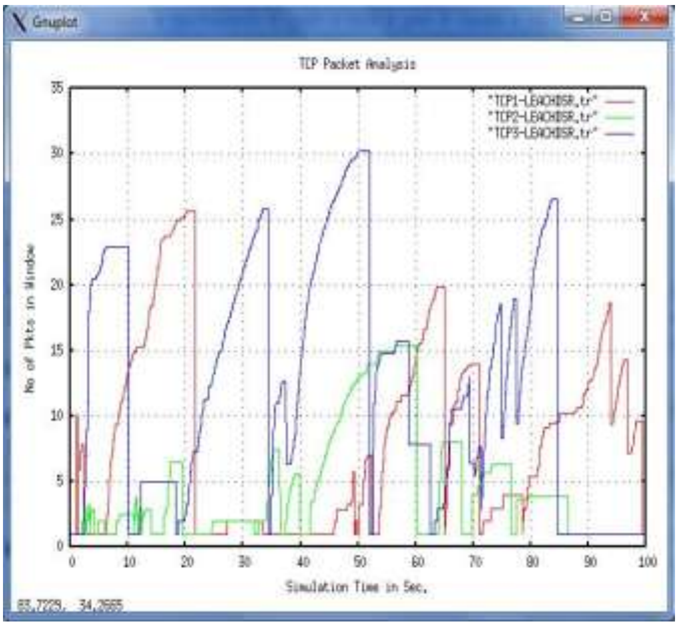


Figure 1: Died node analysis

F. TCP Performance of LEACH-DSR Protocol.

This graph represents the performance of LEACHDSR protocol on the basis of TCP (Transmission control protocol) packets. The working of transmission control protocol is first establish the connection in between source and destination then if the destination confirm the request of sender after that sender will start data delivery. Here we clearly see that there are three TCP connections are created and the size of TCP window are random that has seen in the foam of graph variations. The TCP3 connection has delivered highest number of packets as compare to connection TCP1 and TCP2.



G. Over all summery of LEACH-DSR Protocol

The total summery of LEACH-DSR protocol is shown in table 3. This summery is very important to analyse the performance protocol if it updated or it will be compare to other protocol.

Table 3.Overall Summery of LEACH-DSR

Parameter	Value
SEND	3500
RECV	3391
ROUTINGPKTS	1563
PDF	96.89
NRL	0.46
Average e-e delay(ms)	615.0

CONCLUSION

The significant observations of present analysis are to make proposed LEACH-DSR protocol efficient. Simulation results agree with expected results based on theoretical analysis. As expected, reactive routing protocol DSR performance is the best considering its ability with LEACH to maintain connec-tion by periodic exchange of information, which is required for TCP, based traffic. The performance of proposed LEACH-DSR protocol are gives excellent results in given simulation parameters. The packet delivery fraction and normal routing are represents the performance of proposed protocol. The de-lays are also not poor but try to reduce more of it. For the fu-ture work, this area will investigate with location based routing because location based routing protocol minimizes the flooding of packets and also compare the performance of proposed scheme with other energy based routing protocols.

REFERENCES

[1] Perkins C.E., Ad Hoc Networking. Addison-Wesley, New York, 2001.

[2] Latiff N, and Fisal L,A., "Routing protocols in wireless mobile ad hoc network - A Review," in Conference on Asia-Pacific Communications, (APCC2003), pp. 600-606, 2004.

[3] Zhao W., and Ammar, M.E.Z, "The energy-limited capacity of wireless networks," in IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks, (IEEE SECON2004), pp. 279-288, 2005.

[4] Shakkeera, "Optimal path selection technique for flooding in link state routing protocol using forwarding mechanisms in MANET," in International Conference on

Communication and Computational Intelligence, (INCOCCI2010), Erode, India, pp. 318-323, 2011.

[5] El-Gamal A., Uysal-Bi C., Nair, and B. Prabhakar B., "Energy-efficient scheduling of packet transmissions over wireless networks," in INFOCOM 2002. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies, pp. 1773-1782, 2002.

[6] Kumar D., and Kumar V., "EAAC: Energy-awareadmission control scheme for ad hoc network," World Academy of science, Engineering andTechnology, vol. 51, pp. 934 - 942, 2009.

[7] Wendi B. Heinzelman, Anantha P. Chandrakasan, and Hari Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Trans. on Wireless Comm., Vol. 1, No. 4, Oct. 2002.

[8] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient routing protocols for wireless microsensor networks", in Proc. 33rd Hawaii Int. Conf. System Sciences (HICSS), Maui, HI, Jan. 2000.

[9] Priscilla Chen, Bob O'Dea, Ed Callaway Motorola Labs, "Energy Efficient System Design with Optimum Transmission Range for Wireless Ad Hoc Networks", IEEE International Conference on Comm. (ICC 2002), Vol. 2, pp. 945-952, 28 April -2 May 2002. (references)

[10] Josh Broch, David B. Johnson, and David A. Maltz, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks", Internet-Draft, draft-ietf-manet-dsr-03.txt, October 1999. Earlier revisions published in June 1999, December 1998, and March 1998.

[11] K. Pavai, D. Sridharan, S.A.V. Satya Murty A. Sivagami, "Energy and Link Quality Based Routing for Data Gathering Tree in Wireless Sensor Networks Under TINYOS - 2.X," International Journal of Wireless & Mobile Networks, vol. 2, no. 2, pp. 47-60, 2010.

[12] N. Lee, M. Welsh, and D. Culler P. Levis, "TOSSIM: accurate and scalable simulation of entire TinyOS applications," in Proceedings of the 1st international conference on Embedded networked sensor systems, New York, 2003, pp. 126-137.

[13] Xuhui Chen and Peiqiang Yu, "Research on hierarchical mobile wireless sensor network architecture with mobile sensor nodes," in Biomedical Engineering and Informatics (BMEI), 2010 3rd International Conference, Yantai, China, 2010.

[14] Charles E. and Bhagwat, Pravin Perkins, "Highly dynamic Destination-Sequenced Distance-Vector routing (DSDV) for mobile computers," in Proceedings of the conference on Communications architectures, protocols and applications, London, UK, 1994, pp. 234-244.

[15] D.B. Johnson, D.A. Maltz, "Dynamic Source Routing in Ad Hoc Wireless Networks," in Mobile Computing, 1996, pp. 153-181.

[16] E. B. Royer, and S. Das C. E. Perkins. (2003) Ad hoc On-demand Distance Vector (AODV) Routing, IETF RFC3561. [Online].http://www3.ietf.org/proceedings/05mar/RFCs/rfc3561

[17] Khan, Rizwan Ahmed and Khan, Shoab A., "Performance evaluation of AODV and DSR for wireless sensor networks," in Proceedings of the 10th WSEAS international conference on Communications, Athens, 2006, pp. 268 273.

[18] J.J., Hosseinzadeh, M.,Alguliev, R.M Lotf, "Hierarchical routing in wireless sensor networks: a survey," in Computer Engineering and Technology (ICCET), 2010 2nd International Conference, Chengdu, 2010, pp. V3-650 - V3-654.

[19] S. R. Sawant, R. R. Mudholkar, V.C.Patil Rajashree.V.Biradar, "Multihop Routing In Self-Organizing Wireless Sensor," IJCSI International Journal of Computer Science, vol. 8, no. 1, 2011.

[20] G., V Paul, M.V.,P Jacob, K. S Kumar, "Mobility Metric based LEACH-Mobile Protocol," in Advanced Computing and Communications, 2008. ADCOM 2008. 16th International Conference, 2009.

[21] W. Heinzelman, .Application-speci_c protocol architectures for wireless networks,. PhD Thesis, Massachusetts Institute of Technology, June 2000.

[22] K.Sohrabi, J. Gao, V. Ailawadhi, and G. Pottie, .A Self Organizing Wireless Sensor Network.. presented at 37th Allerton Conferenceon Communication, Control, and Computing, Sep 1999.

[23] C. Srisathapornphat, C. Jaikaeo, and C.-C. Shen, .Sensor Information Networking Architecture,. in International Workshops on Parallel Processing, pp. 23.30, 2000.

[24] R. Brooks and S. Iyengar, Multi-Sensor Fusion: Fundamentals and Applications with Software. Upper Saddle River, NJ: Prentice Hall PTR,, 1998.

[25] R. Wattenhofer, L. Li, P. Bahl, and Y. M. Wang, .Distributed Topology Control for Power Ef_cient Operation in Multihop WirelessAd Hoc Networks ,. in Proc. IEEE INFOCOM, (Anchorage, Alaska), pp. 1388 . 1397, Apr. 2001.

[26] S. Lindsey, K. M. Sivalingam, and C. S. Raghavendra, .Power-aware routing and MAC protocols for wireless and mobile networks,.in Wiley Handbook on Wireless Networks and Mobile Computing (I. Stojmenovic, ed.), ch. 19, pp. 407.423, John Wiley & Sons, 2002.

[27] S. Singh, M. Woo and C. Raghavendra, .Power-Aware Routing in Mobile Ad Hoc Networks,. in Proc. of ACM/IEEE Mobicom'98,(Dallas, TX), 1998.

[28] I. Stojmenovic and X. Lin, .Power-Aware Localized Routing in Wireless Networks,. in Proc. of the 14th International Parallel and Distributed Processing Symposium (IPDPS'00), 2000.