An Energy Efficiency Routing Protocol for Improving Lifetime of Wide Area Wireless Sensor Networks: A Review

Nilesh Kumar[#1], Mamta Katiyar[*2]

Department of Electronics and Communication Engineering, Maharishi markandeshwar University, Mullana, Ambala, Haryana*

[1]*Master of Technology final year student*

Abstract— **The key challenge in wireless sensor network protocol designs is to provide energy efficient communication, as most of the nodes in sensor networks have limited battery power and it is not feasible to recharge or replace the batteries. There are so many levels of power consumption in sensor networks like as: idle listening, retransmissions resulting from collisions, control packet overhead, unnecessarily high transmitting power and sub-optimal utilization of the available resources. By definition, sensor nodes are deployed in an ad hoc fashion, with individual nodes remaining largely inactive for long periods of time. In order to minimize power consumed during idle listening, some nodes, which can be considered redundant, can be put to sleep. Therefore, the energy of the nodes and the network needs to be conserved. The idea is sensor nodes dynamically create on-off schedules such that the nodes will be awake only when they are needed. This also limits the collisions; therefore, the energy consumed during retransmissions can be saved. Although, it seems best way to limit consumed energy and the main consideration should be energy efficiency, the other Quality of Service (QoS) issues have to be considered. The key design considerations for duty cycle control protocol design are scheduling and routing. The research through this paper will be focused on routing protocol for modern high speed integrated wireless sensor networks [3,4].**

Keywords— **Wireless sensor network, Routing protocol, energy efficient. Life time.**

I.   Introduction

Over the recent years, the continued advances in micro-sensor technology have resulted in the development of small, low cost and low power sensing devices with computational "sensing" and communication capabilities. These advances make economically possible the deployment of large numbers of nodes to form a wireless sensor network (WSN) that can monitor a one or more parameters. Because of these advancements, modern WSNs offer significant advantages, such as these are easier, faster and cheaper to deploy than wired networks; and have a large coverage area and longer

range. Another feature of these networks is that these are mostly unattended to, and can be self-configuring or self-organizing. In terms of construction, a typical wireless sensor network may comprise of hundreds or thousands of nodes that can be densely deployed in a large geographical area. These

sensors measure ambient conditions/desired parameters in the environment surrounding them and then transform these data into electric signals which can be processed to reveal some characteristics about phenomena located in the area around these sensors [1]. Therefore, one can get the information about the area which is far away from them. Wireless sensor networks is build up of products integrating sensors, embedded techniques and distributed information processing, and communication techniques. An example of wireless sensor network is shown in Figure 1 and the functional component of a typical wireless sensor of WSN is given in Figure 2.
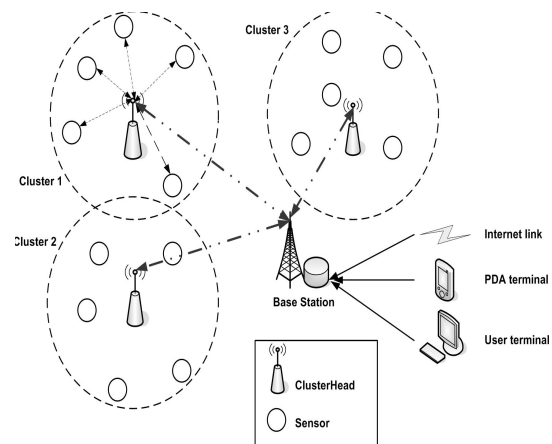

Figure 1: wireless sensor network architecture [1].

As shown in Figure 2, in a typical wireless sensor system, the transducer unit senses and gives the electrical analog signal, A/D convertor converts the sensed analog signal to digital signal, control unit receives digital input from the sensing unit and perform protocol operation, the radio unit transmits the packet over wireless link and the battery is the power source of the entire device [1]. The control unit can function at micro-watts, while the radio transmissions typically require energy in milli-watts to even watts depending upon the transmission power.
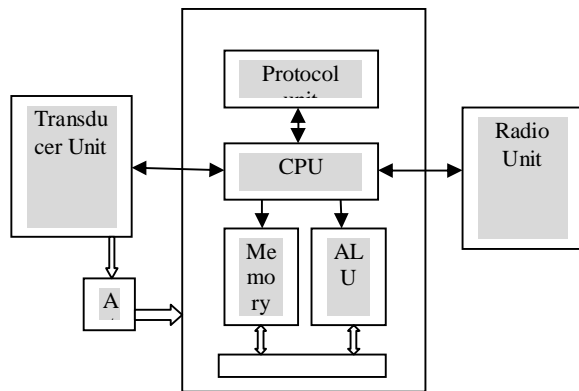
Figure 2: Functional components of a typical wireless sensor network [1].

II. Organization of this paper

The research reported in this paper is focused on developing a routing algorithm for improving wide area wireless sensor networks.

III. Components of wireless sensor node

The key components of wireless sensor node are:

- A/D converter: It is used for converting the analog signal into digital signal. It takes an analog signal from sensor and converts it into digital signal and relay to microcontroller for further processing.

- Sensors: WSN consists of large number of sensor nodes where each node contains more than one sensor at the same time depending upon the application. There are different types of sensors like acoustic sensor, resonant temperature sensor, magnetic field sensor etc. Basically sensor is device that sense physical phenomenon such as pressure, motion, speed etc and transform it into analog signal and the same signal are processed by analog to digital converter. Sensor may be directional or Omni-directional and may be active or passive.

- Processing unit: The processing unit, usually a low speed CPU with small storage capabilities, performs tasks like routing and processing of sensed data etc. The choice of processing unit also determines, to a great deal, both the energy consumption as well as the computational capability of a sensor node. In order to provide the

flexibility for CPU implementation, large number of microcontroller, microprocessor and FPGAs (field programmable gate arrays) are available.

- Microcontroller: It is general purpose processor used for processing. It not only consists of memory and processor but also non-volatile memory and interfaces. It helps to reduce the requirement of wiring, extra hardware, circuit board space and energy. For saving of power, microcontroller should have three states-active, sleeps and idle.

- Operating system: WSN uses less complex operating system as compared to general purpose operating system in the sense that it uses few thousands of lines for coding the system; whereas, general-purpose consist of millions of lines of codes. Some WSN node operating systems are Tiny OS, Contiki, MANTIS, BTnut and SOS etc.

- Memory: RAM is used as an internal memory for storing information in microcontroller. Size of memory can affect consumption of power and cost.

- Communication: The transmission between sensor nodes is wireless and can be implemented by radio, infrared or other optical media. Much of the current hardware for sensor nodes is based on radio link communication.

IV. Low Energy Adaptive Clustering Hierarchy Protocol (LEACH):

Low Energy Adaptive Clustering Hierarchy (LEACH) is a TDMA-based MAC protocol which is integrated with clustering and a simple routing protocol in wireless sensor networks [11]. LEACH is a distributed clustering protocol which utilizes randomized rotation of local CHs to evenly distribute energy utilization between the nodes of WSNs. The goal of LEACH is to provide data aggregation for sensor

networks while providing energy efficient communication that does not predictably deplete some nodes more than others.
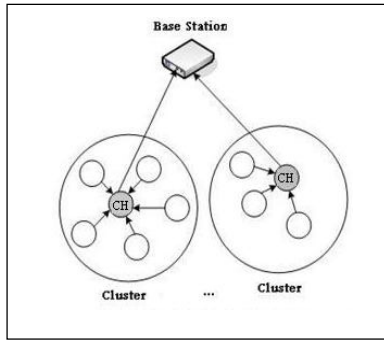

Figure 3: LEACH protocol [12].

According to the Figure 3, the LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station. Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy [11, 12].The principle of LEACH protocols is shown in Figure 4.
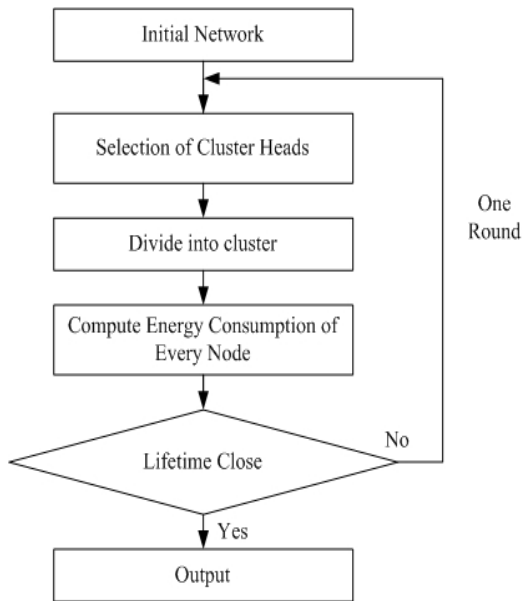

Figure 4: Flowchart of LEACH protocol [11]

V.   Overview of routing techniques:

Routing technique determine the specific choice of route. Most routing technique for WSN depends on location information of sensor nodes for estimation of distance between two specific nodes to deduce energy consumption. For example, to sense a known region, through the use of location sensor, a specified query can be sent to that known region and this will significantly reduce transmitted data compare to a broadcast request being sent to the entire network.sensor protocol for information via negotiation [13,14]. The idea behind this approach is using a meta-data or high level descriptors. There are three types of messages, ADV, REQ, and DATA. As shown in Figure 5,
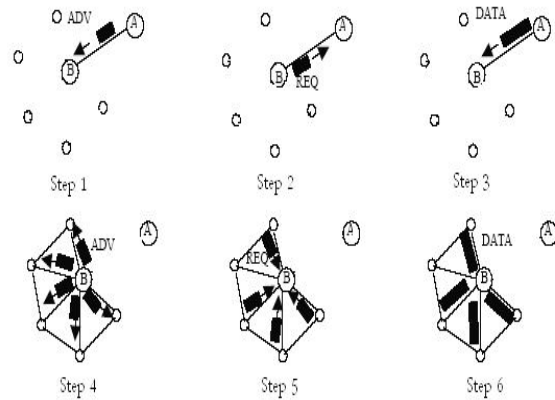

Figure 5: The Sensor Protocol for Information via Negotiation Protocol [8].

In other words, the location-based protocol utilizes the position information to relay the data to the desired regions rather than the whole network. An example of a protocol that uses this technology is MECN (minimum energy communication network). Hierarchical routing in WSN involves the arrangement of clusters in form of hierarchy when sending information from the sensor nodes to the base station. Hierarchical routing efficiently reduces energy consumption by employing multi-hop communication for a specific cluster and thus performing aggregation of data and fusion in a way that decreases the number of data carried across the network to the sink.

VI. Literature review:

A review of key related research papers is given below.

Pantazis et. al. [1] in 2013 mentioned that the distributed nature and dynamic topology of Wireless Sensor Networks introduces very special requirements in routing protocols that should be met. In this research, energy efficient routing protocols are classified into four main schemes: Network Structure, Communication Model, Topology Based and Reliable Routing. The routing protocols belonging to the first category can be further classified as flat or hierarchical. The routing protocols belonging to the second category can be further classified as Query-based or Coherent and non-coherent-based or Negotiation-based. The routing protocols belonging to the third category can be further classified as Location-based or Mobile Agent-based. The routing protocols belonging to the fourth category can be further classified as QoS-based or Multipath-based. Then, an analytical survey on energy efficient routing protocols for WSNs is provided.

Karakus et. al. [2] in 2013 mentioned that improving the lifetime of wireless sensor networks is directly related to the energy efficiency of computation and communication operations in the sensor nodes. Compressive sensing (CS) theory suggests a new way of sensing the signal with a much lower number of linear measurements as compared to the conventional case provided that the underlying signal is sparse. This result has implications on WSN energy efficiency and prolonging network lifetime. In this paper, the effects of acquiring, processing, and communicating CS-based measurements on WSN lifetime are analyzed in comparison to conventional approaches. Energy dissipation models for both CS and conventional approaches are built and used to construct a mixed integer programming framework that jointly captures the energy costs for computation and communication for both CS and conventional approaches.

Anitha et. al. [3] in 2013 mentioned that energy efficient cluster head selection algorithm in mobile wireless sensor networks. According to authors, in Wireless sensor networks, existing energy efficient routing algorithms assumed that the sensor nodes are stationary. Some of the applications in WSN must combine with both mobile sensor nodes and fixed sensor nodes in the same networks. When mobility is functioned there should be performance degradation. Because these nodes are equipped with a lesser amount of memory, restricted battery power, little computation capability, and small range of communication. So there is a need for energy efficient routing protocol to forward the incoming packet. In this paper, authors proposed Energy Efficient Cluster Head Selection Protocol in Mobile Wireless Sensor Network (EECHS-MWSN). The cluster-head nodes are selected from the residual energy, lowest mobility factor and density of the node.

Stefanos et. al. [4] in 2013 mentioned that the wide utilization of Wireless Sensor Networks is obstructed by the severely limited energy constraints of the individual sensor nodes. This is the reason why a large part of the research in WSNs focuses on the development of energy efficient routing protocols. In this paper, a new protocol called Equalized Cluster Head Election Routing Protocol (ECHERP), which pursues energy conservation through balanced clustering, is proposed. ECHERP models the network as a linear system and, using the Gaussian elimination algorithm, calculates the combinations of nodes that can be chosen as cluster heads in order to extend the network lifetime. The performance evaluation of ECHERP is carried out through simulation tests, which evince the effectiveness of this protocol in terms of network energy efficiency when compared against other well-known protocols.

Sharma et. al. [5] in 2011 mentioned that the wireless sensor networks consist of small, autonomous devices with wireless networking capabilities. In order to further increase the applicability in real world applications, minimizing energy consumption is one of the most critical issues. Therefore, accurate energy model is required for the evaluation of wireless sensor networks. Many factors can influence the energy consumption in wireless sensor networks. A lot of research is being done in this area.

Kansal et. al. [6] in 2010 used the existing protocol, techniques and concepts from traditional wireless network, such as cellular network, mobile ad-hoc network, wireless local area network and Bluetooth, are applicable and still used in wireless sensor network, but there are also many fundamental differences which lead to the need of new protocols and techniques. Analysis of various Routing protocols via simulation suitable for WSN. The design of routing protocols for WSN's must consider the power and resource limitation of the network nodes, the time varying quality of wireless channels and possibility of packet loss and delay.

Dwivedi et. al. [7] in 2010 classified the routing mechanisms or protocols for Wireless Sensor Networks are challenging due to the some inherent characteristics (energy efficiency and awareness, connection maintenance, minimum resource usage limitation, low latency, load balancing in terms of energy used by sensor nodes, etc.) that distinguish this network from the other wireless networks such as mobile ad hoc networks, cellular networks, and wireless mesh networks. Due to these unique inherent characteristics, it is a challenging task to select or propose a new algorithm for a specific WSN application.

Zhang et. al. [8] in 2008 investigated adding security to cluster-based routing protocols for wireless sensor networks which consisted of sensor nodes with severely limited resources, and propose a security solution for LEACH, a protocol in which the clusters are formed dynamically and periodically.

Yin Bolian et. al. [9] in 2007 analyzed the optimal transmission range problem for energy consumption in clustered wireless sensor networks and established an energy consumption model based on the assumptions of uniform deployment and uniform traffic. The accuracy of the model is verified by simulations under various network configurations. The model provides an insight into the energy consumption behavior in clustered wireless sensor networks. The optimal transmission range in a clustered wireless sensor networks is a function of the traffic load and the node density, but the traffic load has a much greater impact on the optimal transmission range than the node density

Jemal et. al. [10] in 2007 focuses on the problem of maximizing sensor network lifetime using grid-based sensor networks with emphases on sensor node sleep scheduling problem. It is assumed that the sensors have the capability of buffering sensed data and there exists a mobile base station which is a single mobile data collector such as an unmanned aerial vehicle (UAV) that flies around the field being monitored, visits the area periodically, and collects the data buffered from the nodes in the area

Zheng J. [11] in 2006 defined the characteristics of the physical and MAC layers for Low-Rate Wireless Personal Area Networks (LR-WPAN). The advantages of an LR-WPAN are ease of installation, reliable data transfer, short-range operation, extremely low cost, use of unlicensed radio bands (ISM band), flexible and extendable networks, integrated intelligence for network set-up and message routing, and a reasonable battery life, while maintaining a simple and flexible protocol stack.

VII.   Work Methodology

TABLE: 1

Steps	Description
I	Implement a WSN in Matlab.
II	Compute its lifetime and cluster head selection in various conditions.
III	Implement routing protocol to increase lifetime of WSN and investigate its shortcomings in selecting Cluster Heads.
IV	Develop an algorithm to do adaptive selection of Cluster Heads in routing protocol under different conditions.
V	Develop an algorithm to investigate its efficiency in various conditions.
VI	Develop an algorithm to investigate its effect on bandwidth.

VIII.   Conclusions:

Over the last decade, wireless sensor networks have become very popular. This is because of their low cost, less power requirement, performance and high potential application areas. Although a significant work has been done in relation with wireless sensor networks; yet, there are many challenges in WSN to be addressed. For example, increasing the lifetime of wireless sensor networks is a critical issue because of the limited energy resources. Therefore, this paper focuses on developing an algorithm for increasing the lifetime of the wireless sensor network. More specifically, it focuses on LEACH protocol as its basis. It is because, the cluster head generation algorithm with the original LEACH clustering protocol can cause unbalanced distribution of cluster heads, which often leads to redundant cluster heads in a small region and thus cause the significant loss of energy. To solve this problem, an algorithm for the cluster head selection is proposed in this paper. To solve this problem, an algorithm for the cluster head selection is proposed in this paper.

IX.   REFERENCES :

1) Pantazis, N. A., Nikolidakis, S. A. and Vergados, D. D. "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey", Communications Surveys & Tutorials, IEEE, Vol. 15, Issue. 2, pp. 551 – 591, 2013.

2) Karakus, C., Gurbuz, A. C. and Tavli, B., "Analysis of Energy Efficiency of Compressive Sensing in Wireless Sensor Networks", Sensors Journal, IEEE, Vol. 13, Issue. 5, May 2013, pp. 1999 – 2008, 2013.

3) Anitha, R. U., Kamalakkannan, P., Dharam V., Agarwal S. K. and Imam S. A., "Traffic based energy consumption analysis and improve the lifetime and performance of MAC protocols in ad hoc wireless sensor networks", 2013 International Conference on Computer Communication and Informatics (ICCCI), 4-6 Jan. 2013, Coimbatore, pp. 1 – 5, 2013.

4) Stefanos A. Nikolidakis, Dionisis Kandris, Dimitrios D. Vergados and Christos Douligeris, "Energy Efficient Routing in Wireless Sensor Networks Through Balanced Clustering", Algorithms 2013, Vol. 6(1), pp. 29-42.

5) Amit Sharma, Kshitij Shinghal, Neelam Srivastava and Raghuvir Singh, "Energy Management for Wireless Sensor Network Nodes", International Journal of Advances in Engineering & Technology, Vol. 1, Mar 2011.

6) Parul Kansal, Deepali Kansal and Arun Balodi, "Compression of Various Routing Protocol in Wireless Sensor Network", International Journal of Computer Applications (0975 – 8887), Vol. 5(11), August 2010.

7) A. K. Dwivedi and O. P. Vyas, "Network Layer Protocols for Wireless Sensor Networks Existing Classifications and Design Challenges", International Journal of Computer Applications (0975 – 8887) Vol. 8 (12), October 2010.

8) Kun Zhang and Cong Wang, "A Secure Routing Protocol for Cluster-Based Wireless Sensor Networks Using Group Key Management," IEEE Xplore, Vol. 37, pp. 178-185, Jan 2008.

9) Bolian Yin, Hongchi Shi, and Yi Shang, "Analysis of Energy Consumption in Clustered Wireless Sensor Networks" IEEE Transactions on Mobile Computing, Vol. 3, pp. 272–285, July 2007.

10) J. H. Abawajy, S. Nahavandi and F. Al-Neyadi, "Sensor Node Activity Scheduling Approach," in IEEE International Conference on Multimedia and Ubiquitous Engineering (MUE'07), 2007.

11) Ioan Raicu,"Routing Algorithms for Wireless Sensor Networks", IEEE Wireless Communications, Vol.46, pp.110-119, Sept.2002.

12) Naveen Kumar and Mrs. Jasbir Kaur, "Improved LEACH Protocol for Wireless Sensor Networks", in IEEE Aerospace Conference, March 2002.

13) M. Ibrahim Channa and Irum Memon, "Real Time Traffic Support in Wireless Sensor Networks" IEEE Comm. Magazine, pp.119-133, June 2001.

14) Kay Romer and Friedemann Mattern, Eth Zurich,"The design space of wireless sensor network", CACM, vol. 43, pp. 74–82, Mar. 2000.

15) Zhao Yulan and Jiang Chunfeng, "Research about Improvement of LEACH Protocol: an Energy Efficient Protocol for Wireless Sensor Network", Application Research of Computers, Vol.2, pp: 209-211, Jan. 2005.

16) R. Jurdak, P. Baldi and C. V. Loopes, "Energy-Aware Adaptive Low Power Listening for Sensor Networks," In proceedings of the Second International Workshop on Networked Sensing Systems, San Diego, CA June 2005.

17) J. Greunen, D. Petrovic, A. Bonivento, J. Rabaey, K. Ramchandran, A. Sangiovanni-Vincentelli, "Adaptive Sleep Discipline for Energy Conservation and Robustness in Dense Sensor Networks", IEEE.