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Zonal circular LEACH Protocol (ZCLP) for Homogeneous WSN

Deepika Gogia[1], Dr. Kamal Sharma[2], Deepak Kumar[3]

[1]Student, M. Tech, ESEAR, Ambala
[2]Professor, Dept. of ECE, E-Max group of Institutions, Ambala
[3]Assistant Professor, Dept. of ECE, E-Max group of Institutions, Ambala

Abstract— **Wireless sensor networks have recently attracted significant attention for many military and civil applications, such as target tracking, surveillance and security management. Wireless sensors nodes have limited energy resources and are usually deployed in environments where recharging or replacement of the battery is either impossible or too costly. Therefore, energy resources for wireless sensor networks should be managed wisely to extend the lifetime of networks. There are several number of energy efficient protocols which have been used to prolong the network lifetime of the wireless sensor networks. These protocols can further be improved to achieve better results. In this paper, "zonal circular LEACH protocol" for wireless sensor networks is proposed. The fundamental concept of this protocol is that there is a pre-defined zone around the Base Station (located at centre), some nodes are inside the zone and others are outside the zone. Cluster Heads which are outside the zone find the nearest Cluster Head which is inside the zone and send data to it. Then these inside Cluster Heads aggregate the data and send it to the Base Station. The proposed scheme is compared against LEACH protocol. Simulations have been conducted to evaluate these protocols and favorable results are obtained. Our results show that ZCLP improves network lifetime by an order of magnitude compared with LEACH.**

Keywords— **Clustering, network lifetime, LEACH, routing protocols, wireless sensor networks.**

I. Introduction

A wireless sensor network consists of small devices, which collect information by cooperating with each other. These small sensing devices are called nodes [1] which consist of CPU (for data processing), memory (for data storage), battery (for energy) and transceiver (for receiving and sending signals or data from one node to another), as shown in Figure 1. The size of each sensor node varies with applications. For example, in some military or surveillance applications it might be microscopically small.

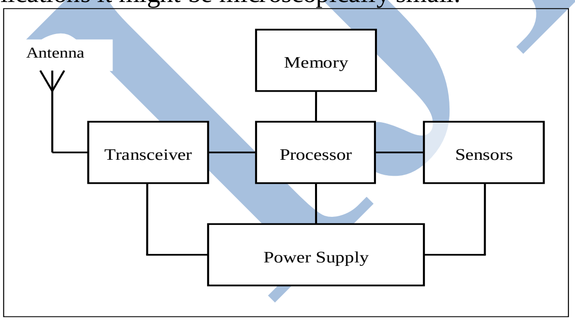


Figure 1. Sensor Node Architecture

Today, wireless sensor networks are widely used in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance. For example, in a military area, we can use wireless sensor networks to monitor an activity. If an event is triggered, these sensor nodes sense it and send the information to the base station (called sink) by communicating with other nodes.

In WSNs the only source of life for the nodes is the battery. Communicating with other nodes or sensing activities consumes a lot of energy in processing the data and transmitting the collected data to the sink. In many cases (e.g. surveillance applications), it is undesirable to replace the batteries that are depleted or drained of energy. This paper, therefore, trying to find power-aware and enhanced system lifetime protocols for wireless sensor networks in order to overcome such energy efficiency problems.

The rest of paper is organized into six sections. Section 2 is about radio propagation model used, Section 3 will discuss about LEACH. Section 4 describes about improved protocol ZCLP. Section 5 includes system design and parameters for LEACH and ZCLP protocol. Section 6 includes simulation results and comparison between LEACH and ZCLP. Section 7 concludes the paper

II. ENERGY DISSIPATION RADIO MODEL

We assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Figure 2. Depending on the distance between the transmitter and receiver, both the free space (d2 power loss) and the multi path fading (d4 power loss) channel models are used. If the distance is less than a threshold crossover distance, the free space model is used; otherwise, the multi path model is used. Thus, to transmit a k-bit message a distance d, the radio expends:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \quad (1)$$
$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{fs} * k * d^{2}, \quad d<do \quad (2)$$
$$E_{Tx}(k,d) = E_{elec} * k + \varepsilon_{mp} * k * d^{4}, \quad d>do \quad (3)$$

The electronics energy E_{elec} depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, whereas the amplifier energy depends on the distance to the receiver and the acceptable bit-error rate. For the experiments described in this paper, the communication energy parameters are set as:

$$E_{Rx}(k) = E_{Rx\text{-}elec}(k) \qquad (4)$$

$$E_{Rx}(k) = E_{elec} * k \qquad (5)$$

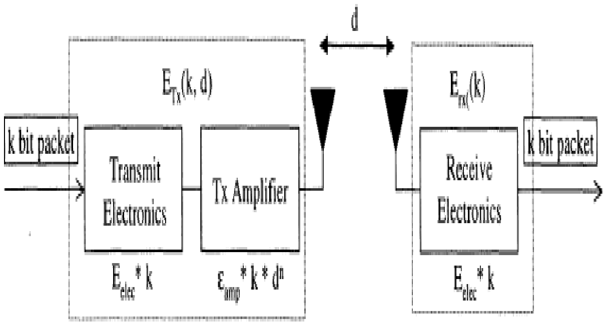


Figure 2 Radio Energy Dissipation Model [3]

III. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network [3] which partitions the nodes into clusters, in each cluster a dedicated node with extra privileges called Cluster Head (CH) as shown in figure 3,CH is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS where these data is needed using CDMA (Code division multiple access). Remaining nodes are cluster members. This protocol is divided into rounds; each round consists of two phases:

In the **Set up phase**, all the sensors within a network group themselves into some cluster regions by communicating with each other through short messages. At a point of time one sensor in the network acts as a cluster head and sends short messages within the network to all the other remaining sensors. The sensors choose to join those groups or regions that are formed by the cluster heads, depending upon the signal strength of the messages sent by the cluster heads. Sensors interested in joining a particular cluster head or region respond back to the cluster heads by sending a response signal indicating their acceptance to join. Thus the set-up phase completes.

$$T(n) = \begin{cases} \dfrac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} & n \epsilon G \end{cases}$$

As soon as a cluster head is selected for a region, all the cluster members of that region send the collected or sensed data to the cluster head. The cluster head transmits this collected data to the base station which completes the second phase, called the **Steady State Phase** [4].

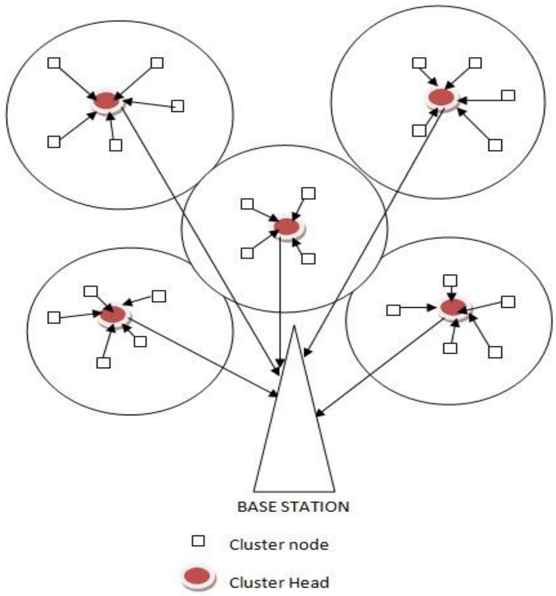


Figure 3: LEACH Protocol Architecture.

Although LEACH protocol acts in a good manner, it suffers from many drawbacks such like;

- CH selection is randomly, that does not take into account energy consumption.
- It can't cover a large area.
- CHs are not uniformly distributed; where CHs can be located at the edges of the cluster.

Since LEACH has many drawbacks, there is a requirement to make this protocol performance better.

IV. ZONAL CIRCULAR LEACH PROTOCOL (ZCLP)

In our improved version of LEACH protocol, we introduced a zonal hierarchy, the Hierarchy contains;

- Cluster Nodes (responsible only for gathering data from environment and send it to the CH),
- Cluster Heads outside zone (the nodes which is located outside from a pre-defined zone to the Base Station),
- Cluster Heads inside zone (the nodes which is located inside a pre-defined zone to the Base Station), as shown in figure 4.

In the LEACH, the CH is always on receiving data from cluster members, CH dies earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing. When the CH die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station. In our protocol, besides transmitting data directly from CH to base station, CH sends data to the other cluster head which is inside a pre-defined zone, so that transmitting energy is less dissipated.

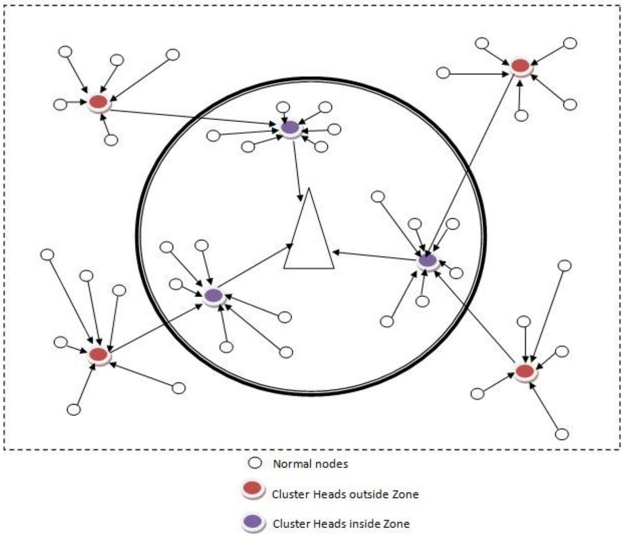


Figure 4 Zona Circular LEACH Protocol Architecture

V. SYSTEM DESIGN

To validate the performance of ZCLP protocol, we simulate LEACH and ZCLP protocol and utilize a network with 100 nodes randomly deployed between (x=0, y=0) and (x=100, y=100) and base station at (50,50). Zone around base station for ZCLP protocol is set to 30m. The bandwidth of channel is set to 1 Mb/s; each data message is 500 bytes long. The initial power of all nodes is considered to be 0.5J. Characteristics of the test network is shown in Table 1 and Parameters values are shown in Table 2.

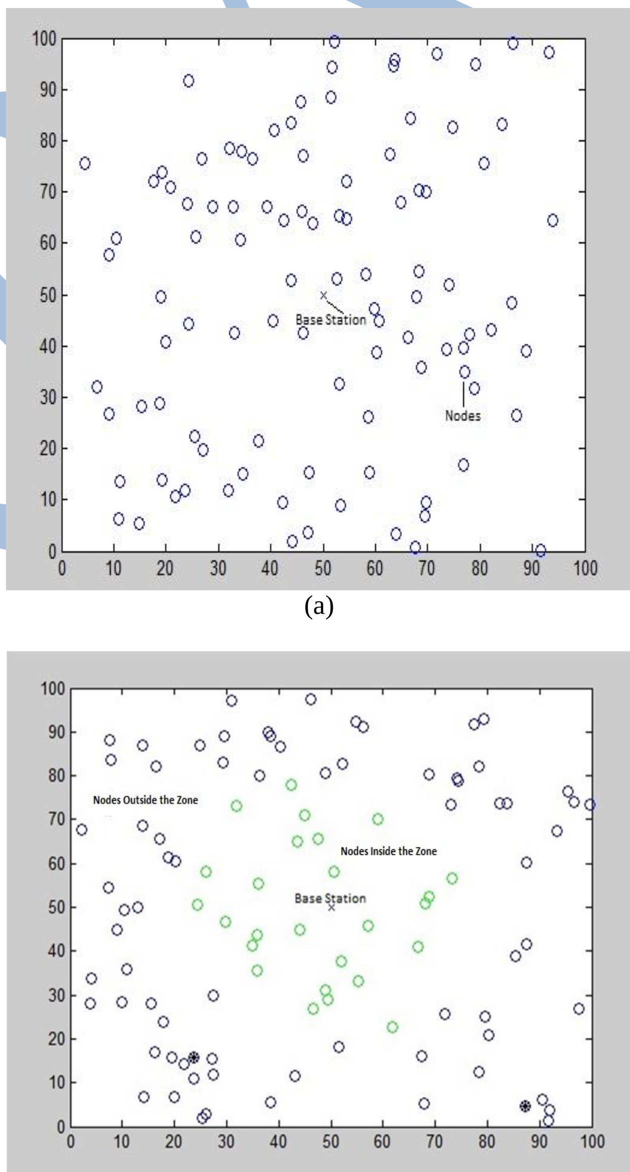
Table 1 Characteristics of the Test Network

PARAMETERS	
Number of Nodes	100
Network Size	100m*100m
Base Station Location	(50,50)
Radio Propagation Speed	$3*10^8$ m/s
Processing Delay	50 µs
Initial Energy of node	0.5J

Table 2 Radio Parameters Values

Description	**Parameter**	**Value**
Crossover distance	d_0	86.6m
Radio Electronics Energy	E_{elec}	50nJ/bit
Energy for Beam Forming	E_{DA}	5nJ/bit
Radio Amplifier Energy	E_{fs} E_{mp}	10pJ/bit /m^2 0.0013/ bit/m^4
Antenna Gain Factor	G_t, G_r	1
Antenna height above the ground	h_t, h_r	1.5m
Bit Rate	R_b	1Mb ps

Sensor network models of 100 nodes for both the LEACH and ZCLP is shown in figure 5. Base station is located at centre. Zone around base station for ZCLP is set to 30m, the nodes which are shown by green colour in fig 5(b) is inside the zone.



(a)

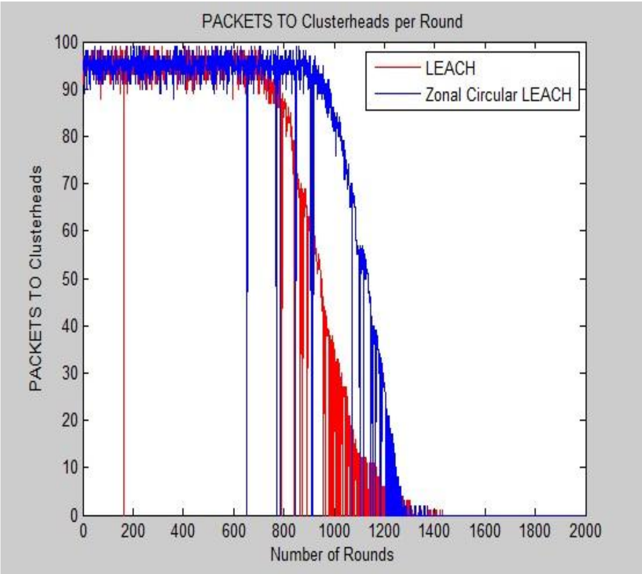
(b)

Figure 5: Sensor Network Models (a) LEACH (b) ZCLP

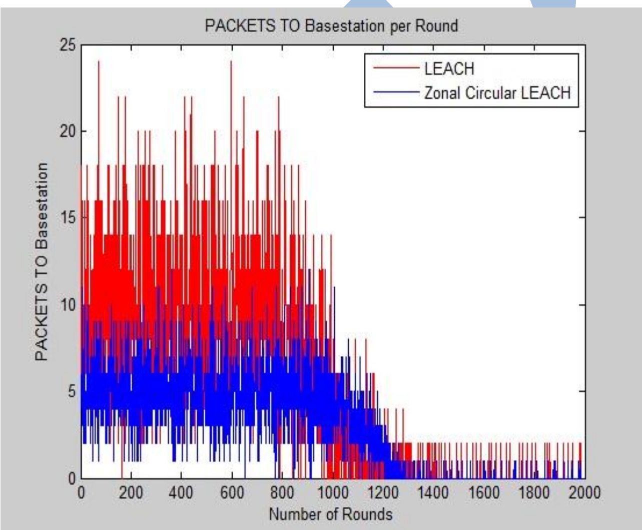
VI. Simulation Results: Comparison between ZCLP & LEACH

A. Throughput

Throughput is represented in terms of packets sent from nodes to cluster head and from cluster heads to base station. As the network operation progresses further, nodes start dying. With decreasing nodes, packets transmission from nodes to base station also decreases.



(a)

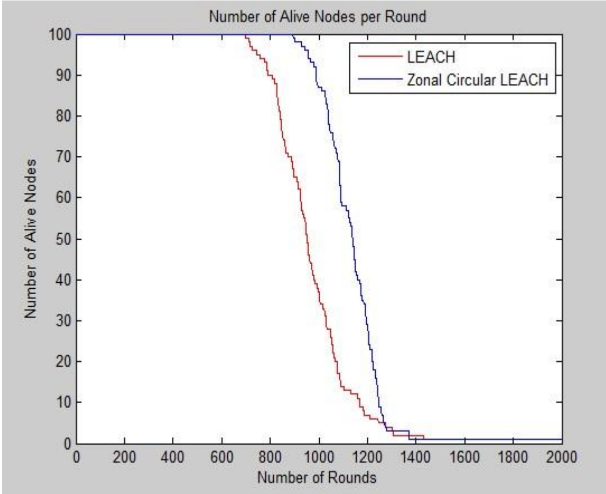


(b)

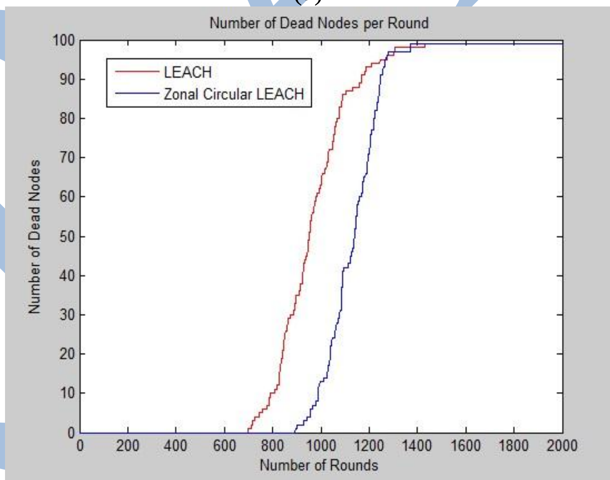
Figure 6 Throughput (a) Packets to cluster heads v/s no. of round (b) Packets to Base station v/s no. of round

B. Network Lifetime

The lifetime of ZCLP and LEACH protocol is compared in Figure 6 (a) and 6 (b) on the basis of number of alive nodes per round and number of dead nodes per round respectively. From the figures it can be seen that the lifetime of network is prolonged for a time. The main energy saving of protocol is due to reduction in the distance between the cluster heads and base station and thus reducing the transmission energy. This results in a substantial reduction of the overall energy dissipation of the system. Hence, higher energy efficiency of the protocol is achieved.



(a)



(b)

Figure 7 Lifetime Comparison (a) Number of alive nodes per round (b) Number of dead nodes per round

C. Lifetime Improvement

From the simulation result shown above, an improvement table is drawn in table number 4 in which lifetime improvement percentage is shown on the basis of first node dead, half nodes alive and all nodes dead. Based on the observations of the table an improvement graph is shown in figure 8 which shows that there is an overall improvement in network lifetime when ZCLP is compared with LEACH.

Table 4: Improvement Table

NODES STATUS	LEACH	ZCLP	Lifetime Improvement
First Node dead	648	918	41.66%
Half nodes alive	945	1233	30.47%
All nodes dead	1272	1530	20.28%

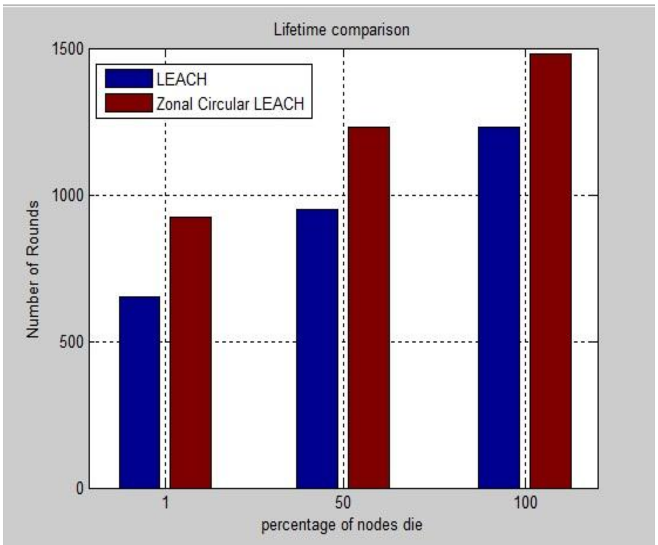


Figure 8: Improvement graph

VII. CONCLUSIONS

In this paper we considered a well known protocol for wireless sensor networks called LEACH protocol which is the first and the most important protocol in wireless sensor network which uses cluster based broadcasting technique. Followed by a new version of LEACH protocol called Zonal Circular LEACH Protocol (ZCLP). From the simulation results, we can draw following conclusions.

In Leach Protocol

- First Node dies approximately at 648th round
- All Nodes dies approximately at 1272th round

But in ZCLP

- First node dies approximately at 948th round
- All nodes dies approximately at 1530th round

Hence ZCLP outperforms LEACH Protocol as expected and network lifetime is improved.

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