Zone-Based Clustering Protocol for Heterogeneous Wireless Sensor Networks

S Taruna*, Sakshi Shringi**
*(Department of Computer Science, Banasthali University, India)
** (Department of Information Technology, Banasthali University, India)

ABSTRACT

Wireless sensor networks (WSN) consist of hundreds or thousands of sensor nodes each of which is capable of sensing, processing, and transmitting environmental information. While wireless sensor networks (WSN) are increasingly equipped to handle more complex functions, in-network processing still requires the battery powered sensors to judiciously use their constrained energy so as to prolong the effective network life time. There are a few protocols using sensor clusters to coordinate the energy consumption in a WSN. In this paper, we propose a Zone based Heterogeneous Energy Efficient Clustering (ZHEEC) protocol in order to balance the energy consumption among all nodes. In this protocol we have divided the network into various equal size zones. We have implemented ZHEEC protocol in network simulator: MATLAB. Simulation results show that our method outperforms LEACH in terms of network lifetime.

Keywords – *Clustering, Sensor Nodes, Residual Energy, Wireless Sensor Networks, Zones*

I. INTRODUCTION

Wireless Sensor Networks are designed by many small nodes which possess high sensing and wireless communication capabilities. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. The focus, however, has been given to the routing protocols which might differ depending on the application and network architecture [1].

Routing protocols are one of the core technologies in the WSN. Due to its inherent characteristics, routing is full of challenge in WSN [2]. Clustering is a well-know and widely used exploratory data analysis technique, and it is particularly useful for applications that require scalability to hundreds or thousands of nodes [3]. For large-scale networks, node clustering has been proposed for efficient organization of the sensor network topology, and prolonging the network lifetime. Among the sources of energy consumption in a sensor node, wireless data transmission is the most critical.

At present, research on wireless sensor networks has generally assumed that nodes are homogeneous. In reality, homogeneous sensor networks hardly exist. This leads to the research on heterogeneous networks where two or more types of nodes are considered. However, most researchers prevalently assume that nodes are divided into two types with different functionalities, advanced nodes and normal nodes. The powerful nodes have more initial energy and fewer amounts than the normal nodes, and they act as clustering heads as well as relay nodes in heterogeneous networks. Moreover, they all assume the normal nodes have identical length data to transmit to the base station. In [4], we have researched a heterogeneous sensor networks with two different types of nodes that they have same initial energy but different length data to transmit.

In this paper, we have proposed a Zone based Heterogeneous Energy Efficient Clustering (ZHEEC) protocol to balance the energy consumption among all nodes. The WSN is divided into zones of equal size. ZHEEC helps to extend the network lifetime with less consumption of energy in the heterogeneous network. We have performed simulations in MATLAB [5]. Further, the performance analysis of the proposed scheme is compared with benchmark clustering algorithm LEACH [6].

The remaining paper is organized as follows: Section 2 describes the related work, Section 3 gives detail of the proposed ZHEEC protocol, Section 4 evaluates the performance and simulation results and section 5 gives the conclusion.

II. RELATED WORK

The first and most popular energy efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption is LEACH [7]. In LEACH, the clustering task is rotated among the nodes, based on duration. Direct communication is used by each CH to forward the data to the Base Station (BS). It is an application specific data dissemination protocol that uses clusters to prolong the life of the WSN. LEACH is based on an aggregation (or fusion) technique that combines or aggregates the original data into a smaller size of data that carry only meaningful information to all individual sensors. LEACH divides the network into several clusters of sensors, which are constructed by using localized coordination and control not only to reduce the amount of data that are transmitted to the sink, but also to make routing and data dissemination more scalable and robust. Based on LEACH protocol, more clustered protocols have been proposed, like PEGASIS [8], TEEN [9], HEED [10] and BCDCP [11] etc, but they all comes under the homogenous condition.

At present, the research to the heterogeneous networks has brought to the attention, and many literatures have obtained some achievements. In [11], authors proposed a probability approach for real-time sensor network applications to assign and optimize sensor systems using heterogeneous functional units with probabilistic execution time.

In [12], authors examined the impact of heterogeneous device deployment on lifetime sensing coverage and coverage aging process, and found an optimal heterogeneous deployment can achieve lifetime sensing coverage by several times as much as that with homogeneous deployment considering both initial coverage and the duration of sensing operation as well as the optimum number of high-cost devices in the single-hop communication model that maximizes the lifetime sensing coverage information incorporating several factors that affect the initial sensing coverage and the energy consumption of nodes.

In [13], authors analyzed the operation of a clustered sensor network with two types of nodes, the powerful nodes and the normal nodes. The powerful nodes act as clustering-heads and expend energy much faster than the normal nodes within its cluster until the cluster enters a homogeneous state with all nodes having equal energy levels.

In [14], we have examined a heterogeneous sensor network with two different types of nodes possessing same initial energy but sending different length data packet. We found that conventional routing protocols like LEACH etc. cannot ideally adapt the network model proposed; therefore, we propose a cluster based routing protocol to prolong the network lifetime. The proposed algorithm better balances the energy consumption compared with conventional routing protocols and achieves an obvious improvement on the network lifetime.

III. THE PROPOSED ZONE-BASED HETEROGENEOUS ENERGY EFFICIENT CLUSTERING (ZHEEC) PROTOCOL

In this the WSN is divided into various zones of equal size. Cluster heads for each zone are selected with the help of cluster head selection mechanism. We have made various assumptions to implement ZHEEC protocol.

1. Model Architecture and Basic Assumptions
    - Number of nodes is 500 in the network.
    - The WSN consists of heterogeneous sensor nodes.
    - The BS is located inside WSN.
    - Some sensor nodes have different initial energy.
    - All sensor nodes and BS are stationary after deployment.
    - All nodes can send data to BS.
    - Data compression is done by CH.
    - Data compression energy is different from transmission and reception.
    - In first round, each node has probability *p* of becoming the cluster head.
    - A node, which has become cluster head, shall be eligible to become cluster head after *1-1/p* rounds
    - Energy for transmission and reception is same for all nodes.
    - Energy of transmission depends on the distance (source to destination) and data size.

2. Proposed Algorithm.

We have considered a heterogeneous network with two types of nodes (normal and advanced nodes). Advanced nodes are more powerful and are having higher battery power than the normal nodes. We have assumed the cluster head selection is based on residual energy of node.

The total initial energy for new heterogeneous network is given by the following equation:

$$n.E_0(1\text{-}m) + n.m.\ E_0\ (1+\alpha) = n.E_0(1+m) \qquad (1)$$

Where, n is number of nodes, m is proportion of advanced nodes.

The probabilities of normal and advanced nodes are respectively:

$$p1 = \frac{popt}{(1+m.\alpha)} \qquad (2)$$

$$p2 = \frac{popt}{(1+m.\alpha)}.(1+\alpha) \qquad (3)$$

The threshold value for normal nodes, T (s1) can be calculated by the following equation:

$$T\ (s1) = \begin{cases} \frac{p1}{1-p1(r.mod\ 1/p1)} \cdot \frac{E_{res}}{E_{max}} & \text{if } s1\ \epsilon\ G \\ 0 & \text{Otherwise} \end{cases} \qquad (4)$$

Similarly, threshold for advanced nodes T (s2) is evaluated.

The proposed algorithm works in phases as follows:

- **In the set-up phase:**

1) Network is virtually divided into 9 zones as shown in Fig. 1.

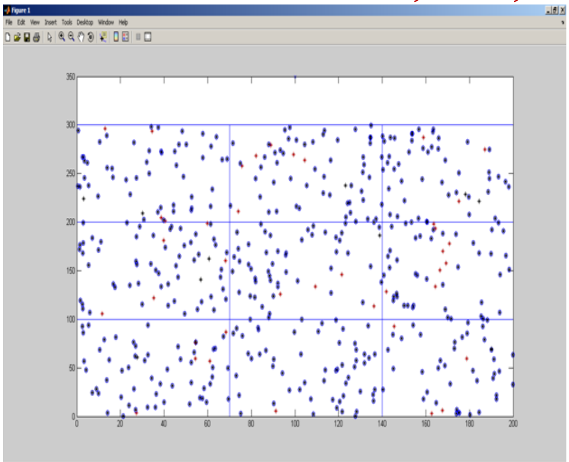

Figure 1: Deployment of heterogeneous WSN

2) Each node generates a random probability (p) at the beginning of round and computes the threshold value (T(n)) with the help of equation (4).
3) In case if p<pt, the node will be selected as a cluster head.
4) Selected CH broadcasts an advertisement message to all neighboring nodes.

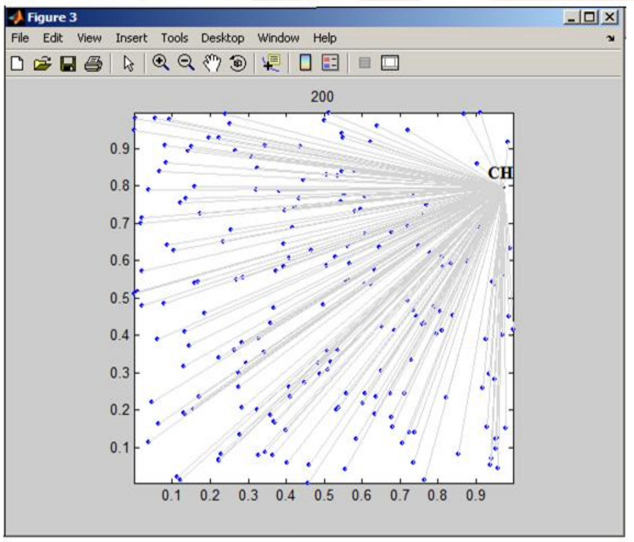

Figure 2: CH sends data to nodes

5) The neighbor nodes collects the advertised messages during a given time interval and send a "join REQ" message to the nearest CH.
6) The CH receives the "join-REQ" messages and builds a cluster member and broadcasts them to all neighboring nodes.
7) The member node receives and save this message for data transfer.

➢ **In the steady-state phase:**

1) After the completion of cluster selection process, each member sends its data and residual energy to the CH.
2) The CH maintains residual energy information of all the member nodes.

➢ **In the Pre-setup phase:**

1) The CH sends BS the maximum residual energy value of nodes belonging to its own cluster when the last frame of the round completes.
2) BS finds the maximum residual energy value, E_{max} of the network and sends back this value to CH.
3) The CH broadcasts value of E_{max} to all cluster nodes.
4) Each node save the value E_{max} for the next computation of T(n) and the current round is terminated.

IV. PERFORMED EVALUATIONS AND RESULTS

The performance analysis of ZHEEC protocol is evaluated with MATLAB. The protocol is then compared to the heterogeneous LEACH algorithm, in which cluster selection is done by randomly.

1. Energy Consumption Model

We assume a simple model [15] 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. For the experiments described here only the free space channel model is used. Thus, to transmit an *l*-bit message a distance *d*, the radio expends energy:

$$E_{Tx}\ (l, d) = (\ l\ E_{elec}\ + l\ E_{fs}\ d2\ ) \qquad (5)$$

To receive this message, the radio expends energy:

$$E_{Rx}\ (l) = lE_{elec} \qquad (6)$$

2. Simulation Parameters

Table 1: Simulation Parameters

Parameters	Values
Network size	200m * 200m
Number of Nodes	500
Node distribution	Nodes are uniformly distributed
Initial Energy	0.5 J
Data Packet size	4000bits
BS position	100m * 100m
Eelec	50nJ/bit
$E_{Tx} = E_{Rx}$	50nJ/bit
$\in_{fs}$	10 pJ/bits/m^2
$\in_{amp}$	0.0013 pJ/bit/m^4
EDA	5 nJ/bit
α	1
p	0.5

3. Simulation Results

3.1 Network Lifetime: When any node in the network is dead, it is no longer the part of that network. This implies that if a dead node occurs in early rounds of algorithm, it will affect the network. This may also lead towards the early dead of all the nodes in the network. In this simulation we have observed the first dead node by keeping the base station position at (100,200) with 4000 packet size. Table 2 shows the values and Fig. 3 concludes that ZHEEC is better compared to LEACH protocol.

Table 2: Network Lifetime (First Node Dead)

Simulation Run	Round Number when fist node is dead	
	LEACH	ZHEEC
1	437	632
2	500	660
3	461	637
4	554	720
5	475	674
6	452	635
7	466	711
8	531	696
9	520	694
10	447	740

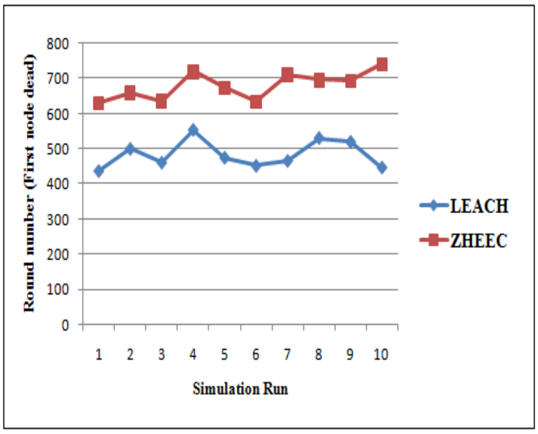

Figure 3: Network Lifetime (First Node Dead) v/s Simulation Runs

3.2 Network Lifetime with last node dead: In this we have observed the round number in which all nodes in the network are dead. If all nodes are dead in the network, the lifespan of a network is over. Less the round number, lesser is the lifetime of network. The base station is positioned at centre with 4000 packet size. Table 3 and Fig. 4 shows the dead nodes with number of rounds.

Table 3: Network Lifetime (All Nodes Dead)

Simulation Run	Round Number when all nodes are dead	
	LEACH	ZHEEC
1	1810	2312
2	2142	2454
3	1985	2220
4	1865	2531
5	2135	2652
6	1852	2431
7	1863	2562
8	1921	2320
9	21 02	2421
10	1820	2465

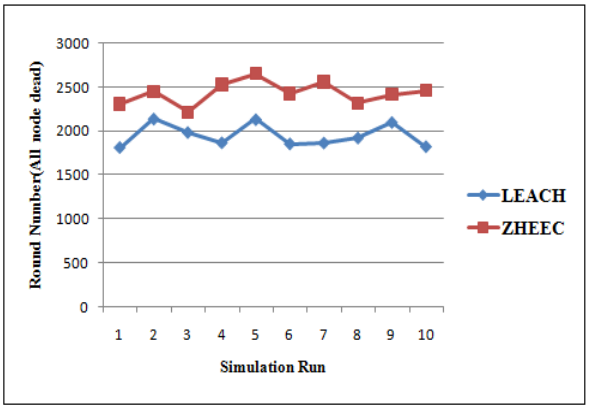

Figure 4: Network Lifetime (All Nodes Dead) v/s Simulation Runs

3.3 Network Lifetime (First Node Dead) with varying packet size: Even on varying the packet size the network lifetime for the proposed ZHEEC protocol remains better than that of LEACH. Table 4 and Fig. 5 Shows the comparative results.

Table 4: Network Lifetime (First Node Dead) with Varying Packet Size

Packet Size	Round Number when first node dies	
	LEACH	ZHEEC
12000	321	412
10000	346	452
8000	472	613
6000	541	625
4000	611	750
2000	725	910

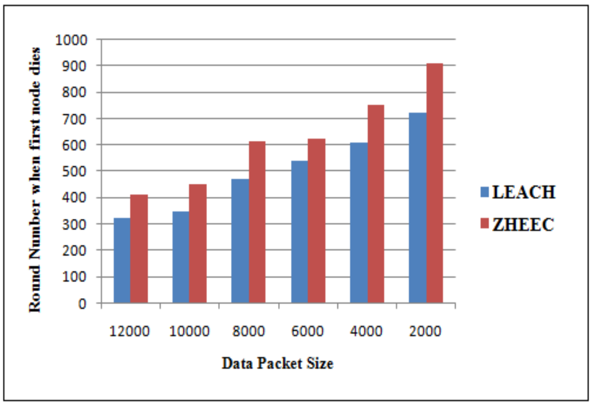

Figure 5: Network Lifetime (First Node Dead) with Varying Packet Size

3.4 Residual Energy of the Network: We simulated the proposed protocol to get the value of residual energy left for the network at different rounds. Table 5 and Fig. 6 shows the results.

Table 5: Residual Energy in Joules for different rounds

Round Number	Residual Energy	
	LEACH	ZHEEC
500	23.595	35.567
1000	15.097	26.120
1500	6.2684	17.475
2000	3.1902	9.4093
2500	2.5828	5.8712
3000	0.5632	4.0321

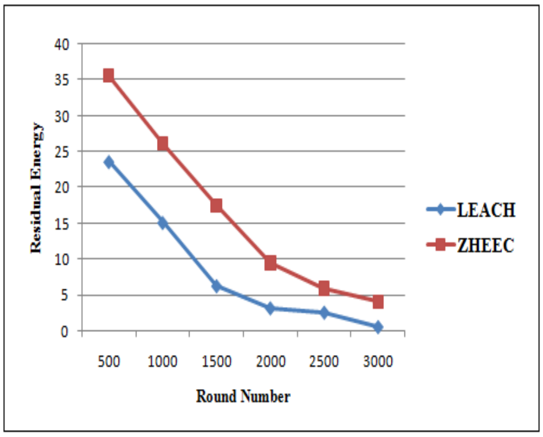

Figure 6: Residual Energy v/s Round Number

V. CONCLUSION

In this paper, we have proposed a Zone-Based Heterogeneous Energy Efficient Clustering (ZHEEC) protocol. It is a cluster based routing protocol that considers energy of nodes to extend the network lifetime. We have compared the results of proposed ZHEEC protocol with heterogeneous LEACH in aspects of network lifetime. The results show that our protocol clearly makes the network lifetime much longer without other critical overhead and performance degradation.

In future we can easily extend our analysis to scenarios in which unreliable nodes are deployed randomly or along grid points. We can also compare our protocol with other protocols such as HEED, PEGASIS and TEEN.

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Authors

S.Taruna is an active researcher in the field of communication and mobile network, currently working as Associate Professor in Department of Computer Science at Banasthali University (Rajasthan), India. She has done M.Sc from Rajasthan University and PhD in Computer Science from Banasthali University (Rajasthan), India. She has presented many papers in National and International Conferences, published 7 papers in various journals and reviewer of various journals and conferences.

Sakshi Shringi received B.TECH degree in Information Technology from Rajasthan Technical University, Kota in 2011. She is pursuing her M.TECH degree in Information Technology from Banasthali University (Rajasthan). She has presented many papers in National and International Conferences, published 4 papers in various journals. Her research interest includes computer network, wireless sensor and ad-hoc networks and virtualization.