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A Cluster Based Routing Protocol for Prolonging Network Lifetime in Heterogeneous Wireless Sensor Networks

S Taruna*
Associate Professor, Computer Science Dept.
Banasthali University, India

Sakshi Shringi
Research Scholar, Information Technology Dept.
Banasthali University, India

Abstract— ***Wireless Sensor Networks (WSNs) can provide low cost solutions to various real world problems. WSN consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. To consider energy balancing for nodes is an important factor in wireless sensor networks. Many routing, power management and data dissemination protocols have been specifically designed for WSNs where energy consumption is an essential design issue. Owing to the limited resources available for sensor nodes, designing energy-efficient routing mechanism to prolong the overall network lifetime has become one of the most important technologies in wireless sensor networks (WSNs). The routing protocols for WSN can be classified in three main categories: data centric, hierarchical and location based. In this paper, we have proposed a cluster based routing protocol for heterogeneous WSN in order to minimize the energy consumption and increase the network survivability. As an active branch of routing technology, cluster-based routing protocols have proven to be effective in network topology management, energy minimization, data aggregation and so on. We have performed simulations in MATLAB. The results of proposed protocol are compared with the benchmark protocol LEACH.***

Keywords— Cluster based routing protocol, Wireless Sensor Network, sensor nodes, cluster head and LEACH

I. INTRODUCTION

With the recent developments in wireless networks and multifunctional sensors with digital processing, power supply and communication capabilities, wireless sensor networks are being largely deployed in physical environments for fine-grain monitoring in different classes of applications [1],[2]. There are usually two deployment modes in wireless sensor networks. On the one hand, if the cost of the sensors is high and deployment with a large number of sensors is not feasible, a small number of sensors are deployed in several preselected locations in the area. In this case, the most important issue is *sensor placement* – where to place the sensors in order to fulfil certain performance criteria. On the other hand, if inexpensive sensors with a limited battery life are available, they are usually deployed with high density (up to 20 nodes=m3 [3]). The most important issue in this case is *density control* – how to control the density and relative locations of active sensors at any time so that they properly cover the monitoring area. (Another relevant issue is how to rotate the role of active sensors among all the sensors so as to prolong the network lifetime [4].)

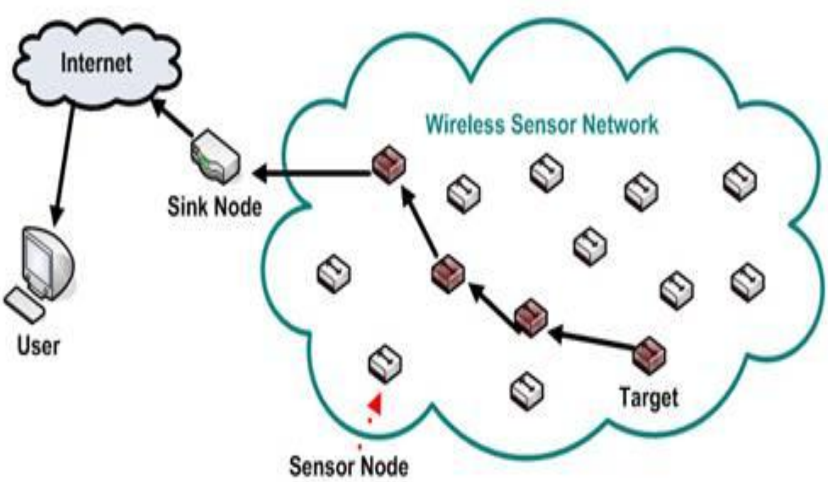

Fig. 1 Architecture of Wireless Sensor Network

At present, research on wireless sensor networks has generally assumed that nodes are homogeneous. In reality, homogeneous sensor networks hardly exist, even homogeneous sensors also have different capabilities like different levels of initial energy, depletion rate, etc. This leads to the research on heterogeneous networks where at 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 [5], 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.

The main constraint in designing a routing protocol in WSNs is limited power of sensor nodes that mandates the design of energy-efficient communication protocol. There are many protocols proposed for other wireless networks like mobile or ad-hoc. How-ever, these protocols cannot be used directly due to resource constraints of sensor nodes like limited battery power, computational speed, and human interface of node device and density of nodes in network. Clustering techniques in wireless sensor networks aims at gathering data among groups of nodes, which elect leaders among themselves. The leader or cluster-heads has the role of aggregating the data and reporting the refined data to the BS. The advantages of this scheme is that it reduces energy usage of each node and communication cost. One of the earliest work proposing this approach in WSNs is [6] LEACH (Low Energy Adaptive Clustering Hierarchy). Recently, there have been lots of other clustering techniques which are mostly variants of LEACH protocol with slight improvement and different application scenarios. In this paper, we have proposed a cluster based routing protocol for prolonging the network lifetime in heterogeneous WSN.

The remainder of the paper is organized as follows: Section 2 describes the related work. In section 3 we discuss the proposed clustering protocol. Section 4 gives details of simulation setup and performance evaluation. Finally section 5 gives the conclusion of our work.

II. RELATED WORK

LEACH [7] is the first and most popular energy efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption. 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. PROPOSED CLUSTER-BASED ROUTING PROTOCOL

In this Scheme, we describe a cluster based routing protocol based upon the LEACH algorithm, which considers residual energy of sensor nodes to avoid unbalanced energy consumption of the sensor node and to extend the overall network lifetime without performance degradation. To increase the lifetime of network, the proposed algorithm uses a probability function. Equation (1) shows computation of the threshold value for a cluster head selection.

$$T(n) = 1\begin{cases} \frac{P_t \, . \, E_{res}}{P_t (r \bmod 1)} \_ \; E_{max} & \text{if } n \in G \\ 0, & \end{cases} \qquad (1)$$

Otherwise

Where,

P_t: the desired percentage of cluster heads,

r: current round number

G: the set of nodes that have not been cluster-heads in the last 1/ P_t rounds,

E_{res} : current residual energy of node

E_{max} : maximum residual energy of entire network

A. Assumptions

For implementing the proposed protocol we have made following assumptions.

- Number of nodes in the network are 500.
- Nodes are uniformly distributed in the network.
- Base Station (BS) is fixed and located outside the deployment area.
- All nodes can send data to the BS.
- BS has information about location of each node.
- Data compression is done by Cluster Head.
- Data compression energy is different from the energy of reception and transmission.
- In first round, each node has the 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
- All nodes in the network are having different energy at starting point.
- Energy for transmission and reception is same for all nodes.
- Energy of transmission depends on the distance (source to destination) and data size.

B. Proposed Algorithm

The proposed algorithm works in round. Each round has three phases: (1) a set-up phase, (2) a steady state phase, and (3) a pre-setup phase.

The algorithm works as follows:

- *In the set-up phase*: Each node generates a random probability (p) at the beginning of a new round and computes the threshold value (T(n)) with the use of equation (1). If r=1 (i.e. the first round), let E_{max} of all nodes be 1. In case of P < P_t, the node is selected as a cluster head. A selected cluster head broadcasts an advertisement message over neighbor nodes. The neighbor nodes collect advertised message during a given time interval and then send a "join REQ" message to the nearest cluster head. The cluster head receives the "join-REQ" message and builds a cluster member list schedule. The member node receives and save the message for data transfer.

- *In the steady-state phase*: After the cluster selection process completes, each member sends data and its residual energy information to the cluster head. Cluster head maintains the received information of member nodes.

- *In the pre-setup phase*: Before the last frame of a round completes, the cluster head sends the maximum residual energy value of nodes, belonging to its own cluster, to the BS. BS collects all the values, finds maximum residual energy value (E_{max}) of the network, and sends E_{max} back to cluster heads. The cluster head broadcasts E_{max} over cluster nodes. Each node save the value of E_{max} for the next computation of T (n) and the current round is terminated.

IV. SIMULATION SETUP AND PERFORMANCE EVALUATION

A. Energy model for communication

We have used the first order radio model in this study [15]. The two parameters used in this model are, E_{elec} and $\in_{amp}$. E_{elec} denotes the energy dissipations per bit by the transmitter or receiver circuits and is set to 50nJ/bit. $\in_{amp}$ denotes the energy dissipations per bit by the transmitter amplifier and is set to 0.1 nJ/bit/m^{β}.

The energy consumption for transmitting/receiving H-bit data message for a given distance d is formulated by:

$$E_{Tx}(d,H) = k\,(E_{elec} + \in_{amp} d^{\beta}) \qquad (2)$$
$$E_{Rx}(d,H) = HE_{elec}$$

where E_{Tx} is the energy consumption for transmitting data E_{Rx} denotes the energy dissipation by receiving data, and β is the pass loss exponent. The pass loss exponent α is set to 2 for the transmission from each node, and β is set to 2.5 for the transmission from a cluster head to BS.

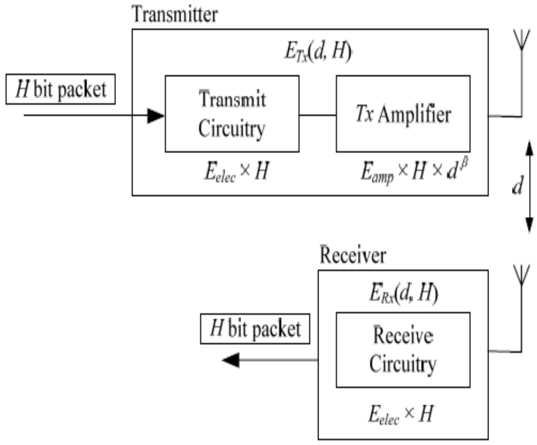

Fig. 2 Energy consumption model

B. Simulation Parameters

Table 1 shows the parameters we have used for implementing the proposed algorithm. Figure 3 shows the deployment of nodes in heterogeneous WSN.

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	50m * 50m
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

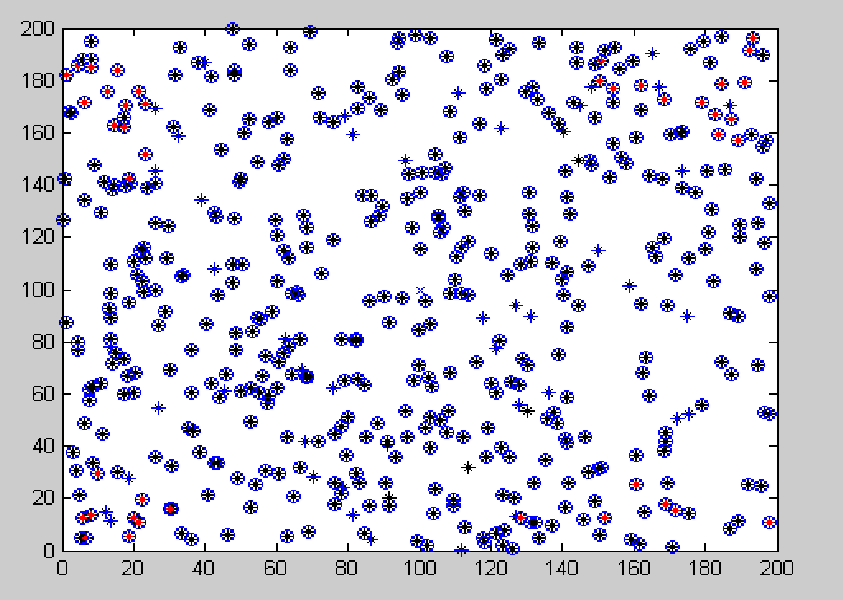

Fig. 3 Heterogeneous Wireless Sensor network

C. Simulation Results

1) *Network Lifetime (First node dead):* Since dead nodes are the reason for short network lifetime, we observe the result of first node dead. The base station position is at the centre with 4000 packet size. Data values are shown in Table 2 and figure 4 concludes that in the proposed algorithm, first node dies later in the network.

TABLE 2
NETWORK LIFETIME (FIRST NODE DEAD)

Simulation Run	**Round Number when first node dies**	
	LEACH	**Proposed Algorithm**
1	967	1030
2	985	1042
3	980	1049
4	974	1064
5	968	1051
6	968	1030
7	977	1054
8	986	1031
9	965	1042
10	983	1058

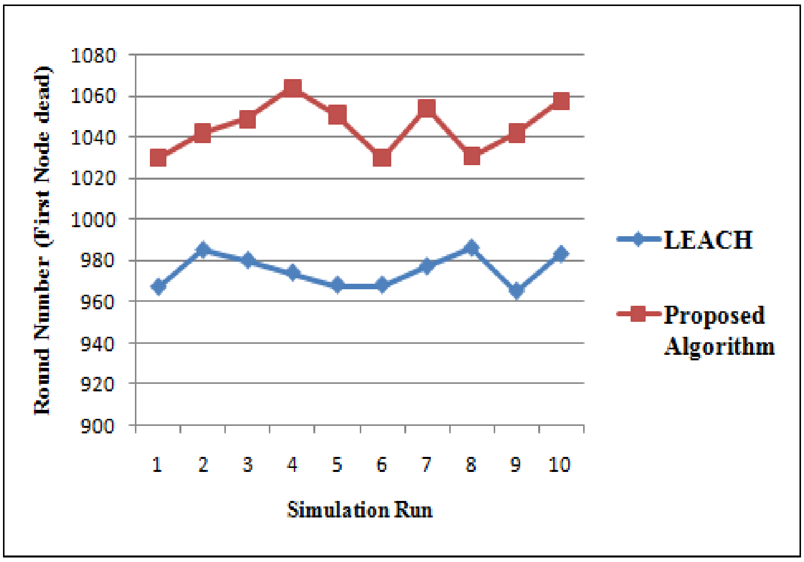

Fig. 4 Network Lifetime (First Node Dead)

2) *Network Lifetime (Last node dead):* When 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 position is at the centre with 4000 packet size. Data values are shown in Table 3 and figure 5 concludes that in the proposed algorithm, first node dies later in the network.

TABLE 3
NETWORK LIFETIME (LAST NODE DEAD)

Simulation Run	**Round number when last node dies**	
	LEACH	**Proposed Algorithm**
1	2220	2247
2	2304	2540
3	2261	2464
4	2405	2601
5	2322	2542
6	2131	2614
7	2227	2493
8	2133	2532
9	2365	2497
10	2210	2603

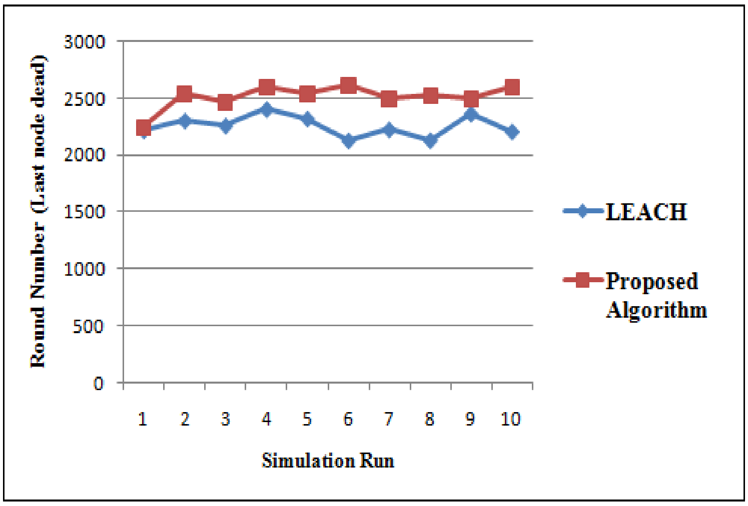

Fig. 5 Network Lifetime (Last Node Dead)

3) *Network Lifetime with varying message size*: We simulated the proposed method with different message size to observe the lifetime of network. The base station position is (50, 50). The results are shown in Table 4.

TABLE 4
NETWORK LIFETIME WITH VARYING MESSAGE SIZE

Packet Size	**Round Number**	
	LEACH	**Proposed Algorithm**
12000	321	350
10000	346	372
8000	472	515
6000	541	567
4000	611	650
2000	725	810

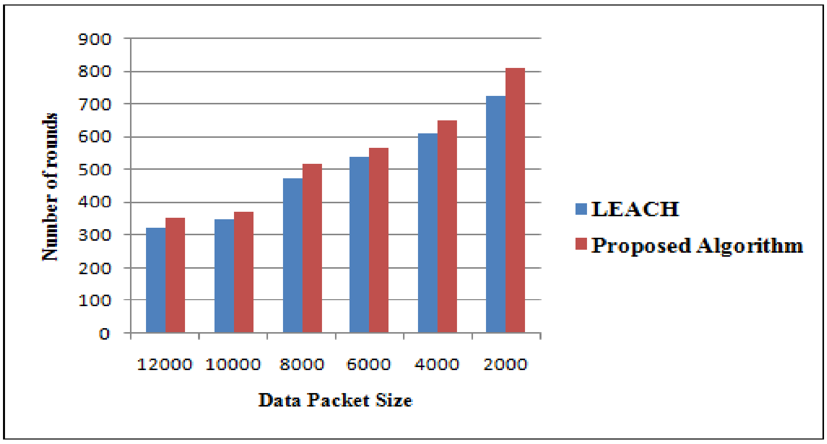

Fig. 6 Network lifetime with varying message size

4) *Network Lifetime with varying Base Station position*: In this simulation we have observed the network lifetime by varying the location of Base Station (Sink). Table 5 shows the value of Base Station position.

TABLE 5
NETWORK LIFETIME WITH VARYING BASE STATION POSITION

Location of BS	**Round Number**	
	LEACH	**Proposed Algorithm**
50,50	980	1082
50,75	930	1049
50,100	910	1021
50,125	840	1001
50,150	721	902

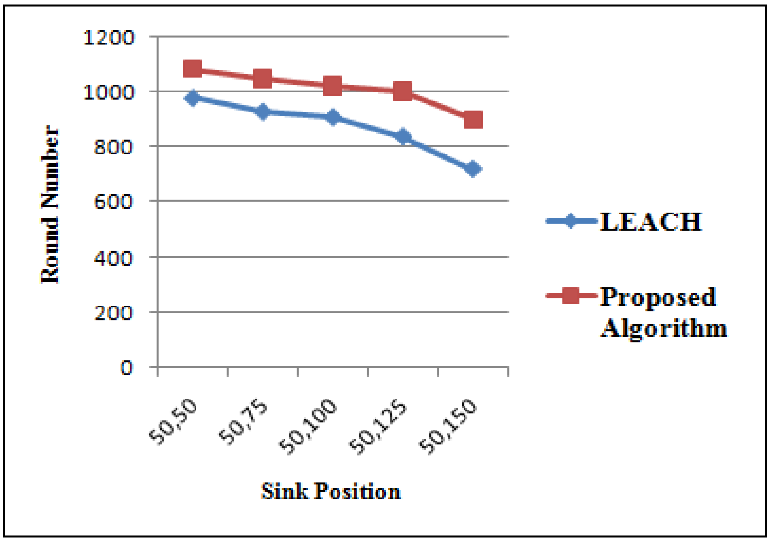

Fig. 7 Network Lifetime with varying Base Station (Sink) position

V. Conclusions

In this paper, we have implemented the cluster based routing protocol which considers residual energy of nodes to extend the network lifetime. We have compared the heterogeneous LEACH protocol with our proposed cluster based routing protocol under same simulation conditions and values. We have considered various parameters such as packet size and Base Station position. The simulation results show that the proposed algorithm is able to prolong the network lifetime as compared to LEACH.

In future we can extend our work by dividing the network into various zones. We can evaluate the cost of network and compare our protocol with various other benchmark protocols.

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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 networks, wireless sensor and ad-hoc networks and virtualization.

