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Heteroleach Protocol for Improvement of Stable Operation of Wireless Sensor Networks

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Abstract : *Wireless sensor networks(WSN) are very much sensitive to energy consumption by the sensor nodes. Many protocols have been designed for efficient use of energy of the nodes so that the lifetime of the network can prolong. The sensors consume more energy in communication of sensed information to the base station as compared to actually sensing the physical phenomena and processing it. Therefore selection of proper routing protocol for communication is crucial in sensor networks. Hierarchical and clustered approaches are proven to be more efficient as compared to flat based organization of WSN. LEACH and other variants of dynamic clustering approaches perform well in case of homogeneous network but a lot of overhead energy is used for balanced operation of the network. We propose a smart heterogeneous method in which we do not need to run a setup round after each steady state round. Both the phases need near about same amount of energy. So if we reduce the number of setup operations which causes overhead energy loss, we can perform more steady state operations with the same energy nodes. To achieve this we use heterogeneous nodes. Some of the nodes have higher energy as compared to normal nodes which can serve as cluster heads for longer time without a need of setup operation repeatedly and save energy. A proper selection of a multiplying factor α for energy of high energy, high priority nodes, can prolong the lifetime up to twice as compared to LEACH.*

Keywords: *heterogeneous nodes, multiplying factor α, network lifetime, dynamic clustering, setup phase, steady state phase*

I. Introduction

Wireless sensor networks are used in many applications now days. But they have a very important characteristic that sensor nodes' battery power is limited and they are not easy to recharge. All the sensors have to sense the monitored phenomena and convey the data to the base station. Power requirement is more for communication as compared to sensing or some processing at the node. If all the nodes start sending the data separately to the base station then to much energy will be consumed in communication and node's energy will drain soon. Therefore Heinzelman proposed a beneficial strategy, Low Energy Adaptive Clustering Hierarchy (LEACH), for hierarchical organization of nodes. This protocol is more energy efficient as compared to flat routing. Each round of data transmission consists of two phases namely setup phase and steady state phase. Clusters are formed in the first phase. Cluster head and member nodes are selected and a schedule of data transmission is communicated to all members. Actual data gathering and data transmission to base station is done in second phase. All the nodes are having same initial energy and operation of CH is more energy intensive. So to balance the energy consumption dynamic clustering is used. The setup phase energy is an overhead energy and our analysis proves that this energy is on an average 100% of the energy requirement by steady state phase where actual data transmission to sink takes place. This overhead energy can be reduced if we use a heterogeneous approach. High energy nodes can be deployed to function as CHs so that frequency of setup phase and thereby energy waste in overhead operation is reduced. We propose here a heterogeneous approach in which a predetermined percentage of nodes will have high initial energy as compared to other normal nodes. Overall energy of the network will remain same as that of LEACH. These high energy nodes will have high priority to become the cluster heads in the setup phase. They will function as CHs till their energy do not reach a predetermined threshold E_{min}. Therefore steady state operation can be done for many rounds without a need of setup operation and that overhead energy can be saved. This energy saved will increase the lifetime expectancy of network.

The paper is organized as follows. Section II contains some related work. Section III contains Proposed Heteroleach protocol description; section IV contains the simulation results and discussion. Finally section V contains the conclusion.

II. Related Work

As the WSN consist of large number of energy constrained nodes more energy is drained in transmitting and receiving the data as compared to other processing. Therefore we can use cluster based (Hierarchical) protocols. Cluster based protocols are used widely in wireless sensor networks, mobile ad- hoc networks as well as wireless ad- hoc networks. Several clustering techniques have already been introduced for partitioning nodes in these areas. LEACH is used as a basis for development of these protocols.

2.1 Low-energy adaptive clustering hierarchy(LEACH)

The idea of hierarchical routing approach proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed [2]. All the nodes have equal initial energy E_0 and they are randomly placed in the sensor field.

It includes two operations performed in each round of working, namely setup and steady state operation. Clusters of nodes are formed in setup phase where, a predetermined fraction of nodes, *P*, elect themselves as CHs as follows. A sensor node chooses a random number, *r*, between 0 and 1. If this random number is less than a threshold value, *T(n)*, the node becomes a cluster head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by *G*. It is given by

$T(n) = P/(1-P(r \bmod (1/P)), \quad \text{if } n \in G$

Where, G is the set of nodes that are involved in the CH election. Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster-heads. CHs create and broadcast a TDMA schedule for the member nodes for data transmission so that collisions are avoided.

During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads. The cluster head node receives all the data, aggregates it before sending it to the base-station and transmits this data to base station. This data compaction will reduce the communication energy needed during transmission.

In the next round again the setup and steady state operations are repeated.

2.2 Stable Election Protocol (SEP*)*

This protocol uses a selected percentages (m) of nodes as advanced nodes which have more initial energy (by a factor α) as compared to the normal nodes. Normal nodes have initial energy E_0 and advanced nodes have initial energy $E_0 * (1 + \alpha)$. The system has $\alpha.m$ times more total energy as compared to scenario of LEACH. Weighed probabilities for normal and advanced nodes are used which is represented by P_{norm} and P_{adv} respectively. They are given by:

$P_{norm}=P/(1 + \alpha.m)$

$P_{adv} = P. (1 + \alpha) /(1 + \alpha.m)$

The thresholds of cluster head selection for these nodes is given by $T_{norm}(n)$ and $T_{adv}(n)$:

$T_{norm} (n) = P_{norm} /(1- P_{norm} (r \bmod (1/ P_{norm})), \quad \text{if } n \in G'$

$T_{adv} (n) = P_{adv} /(1- P_{adv} (r \bmod (1/ P_{adv})), \quad \text{if } n \in G''$

Where, G' is set of normal nodes and G'' is set of advanced nodes.

Thus probability of advanced nodes to become a cluster head is increased and duration of epoch is also increased which increases the stability region of the network. But the overhead energy is still consumed similar to that of the LEACH protocol. Therefore we propose another approach of network operation in which the nodes will be arranged according to decreasing order of their energy and the nodes with the higher energy are given a chance to become a CH. The next section gives the details of this approach.

III. Proposed Heteroleach Protocol

We consider total no of nodes to be same as LEACH. *m* percent of nodes are advanced nodes and *(1-m)* percent of nodes are normal nodes. Advanced nodes have *(1+ α)* times more energy than normal nodes. Normal nodes have initial energy E_0. The nodes are placed randomly in the sensing area away from base station therefore the energy consumption is also unequal for different nodes in different rounds. So we are arranging the nodes in descending order of their energy and allowing the top *P* percent of nodes to become the cluster heads.

That is first i number of nodes will have more energy than other nodes k for all k > i. A set of p number of these nodes will be selected as cluster heads (CH). It can be given as follows.

$$max_pE = \bigcup_{i=1}^{p} \{n_i \mid E_i > E_k \text{ for all } k>i \}$$

$$CH =\{n_i \mid n_i \in max_pE \}$$

We have selected the probability of CHs to be 5%. After selection of CHs, the other nodes will join the nearest CH as its member node. CH determines the TDMA schedule for the member nodes and broadcasts it to them so that member nodes will be active during their slot and remain in sleep mode for rest of the time. This will save some energy of the nodes. With this the setup round will be completed and the steady state operation may start. All the CHs have high energy as compared to normal nodes therefore they can continue as CHs for longer time. We consider an energy threshold E_{min} and the CHs will function as CHs for next rounds till the energy of these node do not reach below this E_{min}. So more number of steady state rounds can be performed with a single setup operation. From the previous paper we can find that the energy needed in the setup operation is nearly equal to steady state operation. So if j number of steady state rounds are performed before any CH's energy goes below E_{min}, we can save j* (setup energy per round). Whenever one of the CH's energy goes below E_{min}, a setup phase is executed and the CH, who's energy is depleted below E_{min} will be further treated as normal node instead of advanced node. This node can contribute as a normal node in further rounds. With this arrangement we can prolong the duration of first node dead to a larger extent and get a wider stable region for the network operation.

3.1 Simulation parameters

MATLAB Tool is used for development of the program. The scenario considered is same as that of the LEACH and SEP protocols. Just the initial energy of nodes is changed. For studying the effect of location of base station on performance, we can change the position of the base station. Also we can change the advanced node energy factor α, E_{min} and E_0 for further analysis of working. Total initial energy of network is kept same as that of LEACH scenario. The radio characteristics are considered same as proposed by Heinzelman. The general parameters for simulation and study purpose are as mentioned in Table 1.

Table 1: Parameters for Simulation

Parameters	Value
Network size	100m x 100m
Sink coordinates	x = 50; y = 175
E_{elec}	50 nJ/bit
E_{fs}	100 pJ/bit/m2
E_{mp}	0.0013 pJ/bit/m4
Number of nodes	100
$E_{aggregation}$	5 nJ/bit/signal
Packet size	500 bytes
Advanced node energy factor α	9
Initial energy of normal nodes E_0	0.6 J/node
Initial energy of advanced nodes	(1+ α). E_0 J/node
E_{min}	0.3J
Broadcast range	50 m

Energy dissipation by the nodes while performing different operations are as follows:
Two models for the radio hardware energy dissipation are considered: free space and multipath fading where the transmitter consumes energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. Both the free space (d^2 power loss) and the multipath fading (d^4 power loss) channel models are used in this paper, depending on the distance between the transmitter and receiver. If the distance is less than a threshold d_0, the free space model is used; otherwise, the multipath model is used.
Thus, to transmit a k bit message a distance d, the radio expends [3]:

$E_{Tx}(k,d) = k\, E_{ele} + k\, \varepsilon_{fs}\, d^2, \quad if\ d < d0$

$E_{Tx}(k,d) = k\, E_{ele} + k\, \varepsilon_{mp}\, d^4, \quad if\ d < d0$ ……….. (1)

To receive this message, the radio expends:

$E_{Rx}(k) = k\, E_{ele}$ …………. (2)

Where, E_{elec} is the electronics energy; ε_{fs} and ε_{mp} are the amplifier energy of the free space model and the multipath model.

3.2 Hetero Leach operation

The operation of the network starts with plotting of the nodes in the sensor field in a random way. Out of *n* (100) number of total nodes *m(10%)* percent of the nodes are randomly selected as advanced nodes and denoted as '+' symbol in the plot. Rest of the nodes is normal nodes denoted by 'O' symbol. The sink node is denoted by 'X' symbol and has deterministic position *(50, 50)* in the scenario given in fig 1(a).

In the first setup round top *p(5%)* percent of nodes are selected as CHs and marked as '*'in the figure. According to our criteria these CHs can serve as CHs for 889 numbers of steady state rounds without a need of another setup round. Fig 1(a) shows 1st setup phase and Fig 1(b) shows the next setup phase after 889 rounds. In this round one of the CH's energy goes below E_{min} therefore converted to normal node, 'O' (CH node at position

(62, 30)) and serves as normal node further. Thus dynamic cluster updating is done whenever any existing CH loses its energy beyond a certain limit.

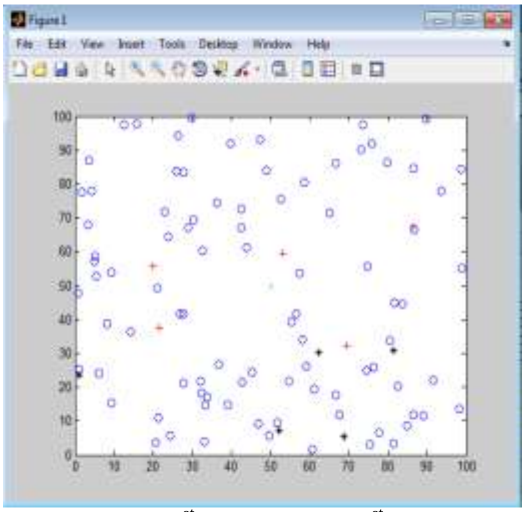

Fig 1(a): 1st setup phase in 1st round

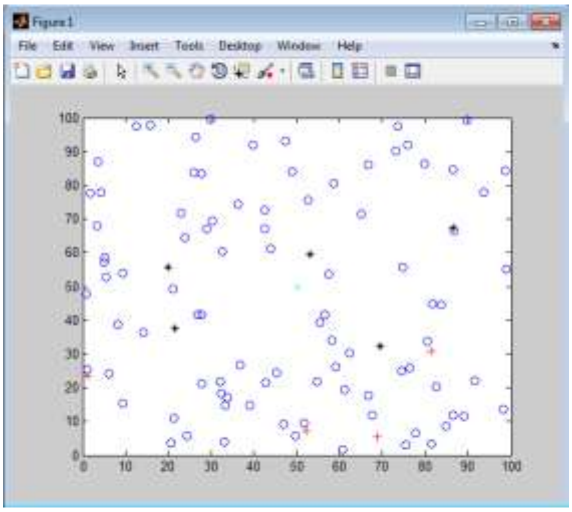

Fig 1(b): Next setup phase after 889 rounds

IV. Results

We executed all the three protocols many times with the same number of nodes n (100), in the similar sensing area (100m X 100m) and same sink position (50, 50). Initial energy of nodes for Heteroleach is as given in table 1, whereas, in LEACH all nodes have same initial energy of 1.08J. In case of SEP normal nodes have 0.8J of energy and advanced nodes have energy with factor $\alpha = 4.5$ that is 3.6J. All protocols have same total initial energy of network as 108J. Five execution results are considered here and the round number for first node dead is listed in the Table No. 2 given below.

Table 2. First node dead

Protocol / Round No.	LEACH	SEP	HETEROLEACH
1	941	1094	2256
2	974	1040	2052
3	899	1094	2150
4	953	1116	2059
5	936	1131	2081
Average	**940**	**1095**	**2120**

The average results given shows that the stable region of operation in Heteroleach is near about twice with respect to LEACH and SEP protocols. Number of nodes alive per round out of 2500 rounds is plotted in figure 2. Nodes start dying after 1000 to 1200 number of rounds in case of LEACH and SEP protocol whereas in HETEROLEACH (HLEACH) it starts dying after 2100 to 2200 rounds.

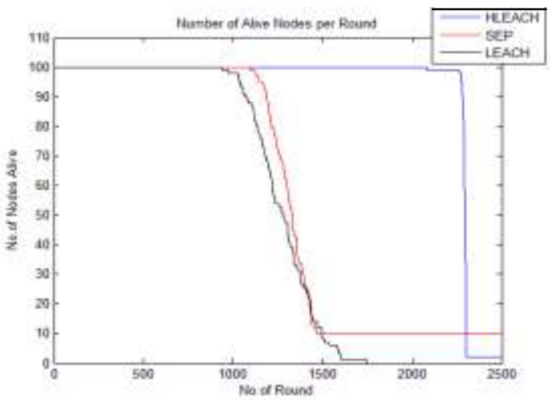

Fig. 2: Number of Alive nodes per Round

V. Conclusion

In operation of WSN the energy constrained nodes need more amount of energy during communication of sensed data to sink node. As compared to flat routing, hierarchical approach performs well because number of communications to long distance sink is reduced. A lot of protocols have been designed to govern their operations where LEACH has been referred as base protocol. Dynamic leader updating is the key idea of these approaches. The operation of the network takes place in two phases, setup and steady state phase. Setup phase is an overhead operation for balancing the working of the network. We considered energy consumption in these phases and proposed Heteroleach approach in which minimum energy waste is incurred during setup phase. We assign some nodes higher initial energy so that they work as leaders for longer time without a need of running setup phase again and they work till some threshold energy remains with them. Our approach is performing well and different simulations show that lifetime expectancy of the network is on an average 80% more as compared to LEACH protocol and SEP protocol. The time of first node death is also prolonged to above 2000 rounds which is less than 1000 in LEACH and near to 1000 in case of SEP protocol considered.

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