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Energy Efficient Heterogenous Clustered WSNs

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ABSTRACT: Wireless sensor networks (WSNs) play an important role in modern day communication, by employing low cost sensor devices for measuring various physical and environmental parameters. Power supplies in the sensor networks are usually non-replaceable. Therefore energy efficiency is critical for effective operation of WSNs. Clustering based routing protocols are more energy efficient than other protocols. This paper proposes an energy efficient heterogeneous clustering based algorithm. Proposed approach gives priority to the residual energy of node for becoming cluster head and will try to bring down the cluster head variations in the optimal range. It will also attempt to control the inherent randomness of the cluster head selection algorithm by using MAC layer information. The MATLAB simulation results and analysis show that the proposed approach could achieve better performance in terms of network lifetime, energy efficiency and quality of communication.

KEYWORDS: Clustering, Energy Efficiency, Routing Protocol, Wireless Sensor Networks.

I. INTRODUCTION

Wireless sensor network consists of large number of micro sensor nodes which are deployed in region of interest. Nodes in such networks organize themselves as wireless communication network system [1-2]. These are generally applied in physical environments for monitoring data especially in special and severe conditions which are inaccessible for humans [3]. Deployment of micro-sensor nodes is easy but their limited amount of energy restricts their application and development [4-5]. There are lot of studies on energy efficiency and network lifetime of wireless sensor network. A lot of research has been done on routing algorithms, energy efficient network topology, protocol design and many more for making WSN energy efficient [7-8]. Among them, the hierarchical clustering routing algorithms has better energy efficiency and adaptability in comparison to planar routing algorithms [9]. Clustering algorithms [10] distributes the nodes into different clusters, each cluster has its own cluster head, and rest of the nodes send the collected information to their respective cluster head. It is the responsibility of cluster head to forward data and perform data integration. Cluster heads are the main key of clustering algorithms; research on forming high quality cluster with help of different option on cluster head to reduce energy consumption is of great significance [11].

II. RELATED WORK

In past decade cluster based routing protocol has attracted lot of attention from researcher's academicians and industry in comparison to other routing protocol such as data centric, location based QoS aware protocols. LEACH [12] is a benchmark clustering routing protocol which uses cluster heads to complete a lot of data aggregation and to act as relay

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for transferring messages to the base-station. However, there are limitations in LEACH. It suffers from cluster head variability problem and unbalanced energy consumption issue. LEACH-TL [13] balance the energy consumption among sensors by creating two level, i.e. primary cluster head and secondary cluster heads. Multihop-LEACH, known as M-LEACH protocol changes the mode of communication from single to multihop communication across sink and CH. In 2013, Javaid et al. [14] introduced EDDEEC, a routing protocol based upon heterogeneous clustering for Wireless Sensor Networks. The main idea was on dynamic change in Cluster head election probability the algorithm shows improvement in stability period, network lifespan in heterogeneous conditions as compared to Distributive Energy-Efficient Clustering (DEEC) [15]. All of the above discussed protocol enhances the energy efficiency and the lifespan of the network by distributing network energy consumption uniformly. However authors did not try to solve main problem which is cluster head variability; the randomness in cluster head election. This paper proposes a clustering based heterogeneous algorithm EEHC (Energy Efficient Heterogeneous Clustering). This work mainly focuses on reducing the energy consumption and reducing the randomness present in cluster head selection by using MAC layer information. It also gives priority to higher energy node in the cluster head selection.

III. SYSTEM DESIGN AND ASSUMPTIONS

The proposed routing protocol employs two models, namely the Radio energy model and the Network Model.

3.1.1. RADIO MODEL

The first order radio model [16] has been used for the energy consumption analysis. Energy consumed in transmitting l -bit data at distance d is given as:

$$E_{Tx}(k, d) = \begin{cases} kE_{elec} + E_{\epsilon_{fs}}d^2, & d < d_c \\ kE_{elec} + E_{\epsilon_{two_ray}}d^4, & d \geq d_c \end{cases} \quad (1)$$

where d_c is the cross-over distance, ϵ_{fs} and ϵ_{two_ray} are the amplification factor for free-space and two-ray ground model respectively. E_{elec} is energy dissipated due to electronic circuitry, which depends upon the coding, modulation, filtering and spreading of the signal. Energy consumed in receiving the l -bit message is: $E_{Rx} = l * E_{elec}$.

3.1.2. NETWORK MODEL

The network is modelled as a square field of uniformly distributed heterogeneous N random nodes. These sensor nodes continuously monitor the region of interest. Some assumptions are made which are as follows:

- BS is located within the sensor field and nodes can communicate with the BS directly.
- WSN comprises of heterogeneous nodes which have the separate levels of nodal energy.
- Nodes are stationary, location unaware.
- For saving energy, the node's transceivers can go into sleep mode.
- Links are symmetric, i.e., equal amount of energy is dissipated in the communication on either side.
- Each node can aggregate the data and the energy consumed in aggregation.

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IV. ALGORITHM DESIGN

For effective clustering, the number of cluster heads should lie in the optimal range. Let optimal number of cluster heads are k , then the average number of nodes per cluster will be N/K . For single TDMA frame energy consumed by a cluster is calculated below:

$$E_{\text{CLUSTER}} = E_{\text{CH}} + N/K * E_{\text{NON-CH}} \quad (2)$$

where, E_{CH} , energy dissipated by the cluster head and $E_{\text{non_CH}}$, energy consumed by the cluster member.

$$\begin{aligned} E_{\text{CH}} &= lE_{\text{elec}}N/K + lE_{\text{DA}}N/K + l\epsilon_{\text{two-ray}}d_{\text{toBS}}^2 \\ E_{\text{NON-CH}} &= lE_{\text{elec}} + l\epsilon_{\text{fs}}d_{\text{toCH}}^2 \end{aligned} \quad (4)$$

Total energy consumed in a frame is given as:

$$E_{\text{total}} = kE_{\text{cluster}} \quad (5)$$

Optimal cluster heads, k , can be found by differentiating E_{total} with respect to k and equating it to 0.

$$K = \frac{\sqrt{N} \sqrt{\epsilon_{\text{fs}}}}{\sqrt{2\pi} \sqrt{\epsilon_{\text{two-ray}}}} \frac{M}{d^2} \quad (6)$$

4.1. OPERATION

Similar to LEACH, EEHC protocol works in rounds. Each round is divided into setup phase and steady state phase.

4.1.1. SETUP PHASE

The setup phase consists of cluster head election process and cluster configuration process.

• Cluster Head Election

The rotating epoch for every single node is unique. Initially every single nodes decides whether to become a cluster-head or not for the current round. This decision is made by generating a random number between (0-1), if the generated number is less than the threshold $Th(s_a)$ it will participate in CH. election process otherwise not. The threshold function is set as:

$$Th(s_a) = \begin{cases} \frac{P(i)}{1 - P(i) \left(r * \text{mod} \left(\frac{1}{P(i)} \right) \right)}, & \text{if } s_a \in G \\ 0, & \text{otherwise} \end{cases}$$

Here r represents the current round count, G represents sensor nodes group that had not been chosen as CHs in previous rounds with respect to the given threshold function. $P(i)$ function based on type of node namely normal and advanced node is defined as:

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$$P(i) = \begin{cases} \frac{P}{(1 + a * m)} & \text{for normal nodes} \\ \frac{P(1 + a)}{(1 + a * m)} & \text{for advanced nodes} \end{cases}$$

where 'a' is energy factor of advanced nodes and m is fraction of advanced nodes among normal nodes. After passing through the threshold function nodes select a random time in the interval (0- total_advtime), where total_advtime is time required for cluster head advertisement reception and transmission[12].

After selection of random time it is divided by the residual of the node, so that higher energy may get selected. At the same time nodes check the number of advertisement heard, if they are less than optimum count, the nodes declare itself as cluster head otherwise as normal node.

- Cluster Configuration

After the election, cluster head inform other non-cluster head nodes by sending the advertisement message using CSMA MAC protocol. After receiving message from the nodes that would like to be the member of cluster, cluster head creates a TDMA schedule. This schedule is transmitted to the member nodes informing each node when it can transmit.

4.1.2. STEADY STATE PHASE

In steady-state phase transmission of data take place. Nodes send data to their respective cluster heads according to their allotted transmission time. This transmission uses minimum amount of energy as cluster heads were selected based on energy required for transmission. During this phase cluster head keep their receiver On, for collecting the data from member nodes. While member nodes can keep their radio Off until their transmission time come, thus minimizing energy dissipation. After receiving all the data from nodes, cluster head performs signal processing functions to compress the data into single composite signal. This composite signal is then send to the base station.

V. EXPERIMENTAL RESULTS

5.1. NETWORK LIFETIME

This parameter gives the measure that how long a network region can be monitored. Figure 1 and 2 shows EEHC has greater life time in comparison of LEACH, and Heterogeneous LEACH protocol. The first node of EEHC is dead after 1806 number of rounds whereas first node of LEACH and Heterogeneous LEACH is dead after 1613,1772 number of rounds respectively. The last node of EEHC, LEACH and Heterogeneous LEACH is dead after 13010, 3254, 3947 number of rounds respectively. Thus EEHC shows significant improvement in overall network lifetime.

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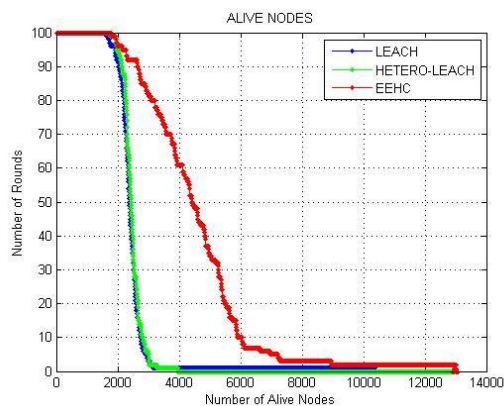


Figure 1. Number of Alive Nodes

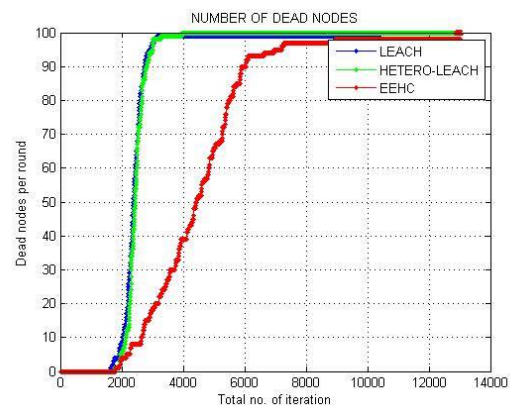


Figure 2. Number of Dead Nodes

5.2. RESIDUAL ENERGY

Figure 3 shows residual energy comparison of EEHC, LEACH and Heterogeneous LEACH. Total energy of network approaches to zero in EEHC after 8000 rounds and become completely zero at 13010th round, while in LEACH and 2300 rounds, and become zero at 3254th round and in Heterogeneous LEACH network energy start approaching zero after 3000 approx and become zero at 3947th round. Thus EEHC shows significant reduction in energy consumption per round in comparison to LEACH and Heterogeneous LEACH. The reason behind this is balanced energy consumption and presence of advance node in EEHC.

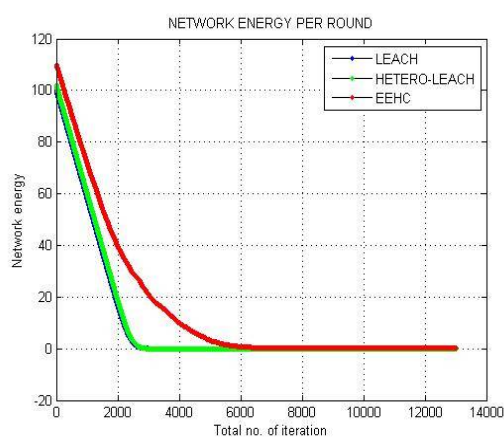


Figure 3. Residual Network Energy Per Round

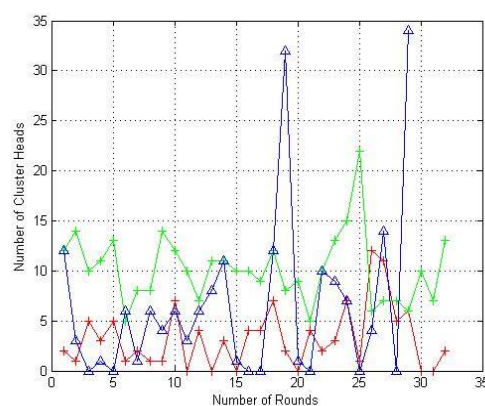


Figure 4. Variation in Cluster heads per round

5.3. NUMBER OF CLUSTER HEADS

Cluster head count greatly impacts the energy efficiency of network. Figure 4 shows comparison of cluster head count of LEACH indicated by green, Heterogeneous LEACH indicated by blue and EEHC indicated by red. From figure it can be seen that fluctuations in proposed EEHC is less in compared to LEACH and Heterogeneous LEACH. This is

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because in case of our proposed EEHC protocol first the residual energy of node is checked, then number of cluster head advertisement are checked, if the value of advertisements received by the node is less than optimal count then the node become cluster head otherwise declare itself as normal node.

VI. CONCLUSION

Sensors are required to transmit data and control packets to the base station. All of these operations involve power consumption which leads reduction in network overall lifetime. The control over unnecessary data transfer by using proper protocol can save the energy. In this paper we proposed a heterogeneous aware wireless sensor network routing protocol which attempts to reduce the randomness present in clustering algorithms. It also makes the cluster head count stable which affect the network lifetime greatly. If cluster head count is large than more amount of aggregation energy will be consumed. If this value is less, it affects the communication cost for cluster members. The proposed EEHC protocol reduces the inherent randomness present in cluster head election process by using MAC layer information. It also gives importance to residual energy of nodes while electing the cluster heads. In our proposed approach, the stability period, first node dead, last node dead, number of cluster head count and network lifetime have been improved. Simulation results have show that there is significant amount of improvement in all these parameters in comparison to LEACH and heterogeneous LEACH protocol.

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