A Novel Protocol for Energy Efficient Clustering for Heterogeneous Wireless Sensor Networks

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Abstract— The Wireless sensor network (WSN) consisting of a large number of sensors are effective for gathering data in a variety of environments. Sensors are usually randomly deployed where battery replacement or recharge is difficult or even impossible to be performed. In this paper, we first completely analyze the basic distributed clustering routing protocol LEACH (Low Energy Adaptive Clustering Hierarchy). All classical schemes consider that all nodes are deployed with same amount of energy. Here we consider a heterogeneous medium, i.e. each node is provided with varying power levels called Heterogeneous - Hybrid Energy Efficient Distributed Protocol (H-HEED). Heterogeneity can be implemented by various parameters here we consider node energy as the basic parameter. Transmitting data from each node of the sensor field may lead to high power consumption and unreliable network lifetime. In order to avoid this we go for clustering and election of cluster heads. Cluster head alone transmits the aggregate data of the cluster. The formation of the clusters and cluster head selection are done by comparing the residual energy of the individual in every round this improves the lifetime to a considerable level. Also we introduce a node scheduling scheme in HEED. The nodes are classified into ACTIVE and SLEEP nodes. A widely employed energy-saving technique is to place nodes in sleep mode, corresponding to low-power consumption as well as to reduce the operational capabilities. Finally the simulation result demonstrates that proposed work achieves longer lifetime and more effective data packets in comparison with the HEED and LEACH protocol.

Index Terms— Heterogeneity, H-HEED, LEACH, Network Lifetime, Wireless Sensor Network (WSN)

I INTRODUCTION

Wireless Sensor Networks are networks of tiny, battery powered sensor nodes with limited on-board processing, storage and radio capabilities [1]. A node in sensor network consists of CPU for data processing, memory for data storage, battery for energy and transceiver for receiving and sending signals or data one node to another node. Sensor nodes are typically operated by batteries, which are limited in energy capacity, and difficult or even impossible to be replaced or recharged. The sensor nodes are deployed in a sensor field. The deployment of the sensor nodes can be random, regular or mobile sensor nodes can be used. The base station is a master node. Data sensed by the network is routed back to a base station [1,2]. The base station is a larger computer where data from the sensor network will be compiled and processed. The base station may communicate with the remote Controller node via Internet or Satellite Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Power control is needed to efficiently make use of the limited energy resources in order to minimize the energy consumed by the sensor nodes and thus prolong network lifetime [3, 4]. For this purpose, energy efficiency must be considered in every aspect of network design and operation, not only for individual sensor nodes, but also for the communication of the entire network. Energy efficiency and power control are the basic guarantee of the network performance. HEED (Hybrid Energy-Efficient Distributed clustering) [5] that periodically select cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbours or node degree. In all classical methods all nodes are assumed to be homogenous i.e. all sensor nodes are equipped with same initial energy. But, in this paper we study the impact of heterogeneity in terms of node energy. We assume that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network - this is the case of heterogeneous sensor networks. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in terms of node energy. Furthermore, the proposed model enables us to investigate the trade-offs existing between these performance metrics and the sensor dynamics in active/sleep mode. From the energy saving viewpoint, a widely employed technique is to place nodes in a low-power operational mode, the so-called sleep mode. Each sensor is characterized by two operational states: active and sleep. In active state the node is fully working and is able to transmit/receive data, while in sleep state it cannot take part in the network activity; thus, the network topology changes as nodes enter/exit the sleep state. The remainder of the paper is organized as follows. In Section 2, we briefly review related work. Section 3 describes the Network Initialization in the H-HEED protocol. Section 4 describes formation of cluster and cluster head selection H-HEED protocol. Section 5 shows the heterogeneous WSN model of H-HEED. Section 6 shows the implementation of Active and Sleep nodes. Section 7 shows the simulation results by comparing with the preceding methods.

II RELATED WORKS

W. R. Heinzelman, A. P. Chandrakasan and H. Balakrishnan [6] proposed Low Energy Adaptive Clustering Hierarchy (LEACH) protocol in 2000. It is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal

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strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes. All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold

$$T(n) = \begin{cases} \frac{p}{(1-p*(r \bmod 1/p)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where p is the desired percentage of cluster heads (e.g. 0.05), r is = the current round, and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

In 2005, M. Ye, C. Li, G. Chen and J. Wu [7] proposed Energy Efficient Clustering Scheme (EECS) protocol. It is novel clustering scheme for periodical data gathering applications for wireless sensor networks. It elects cluster heads with more residual energy through local radio communication. In the cluster head election phase, a constant number of candidate nodes are elected and compete for cluster heads according to the node residual energy. The competition process is localized and without iteration. The method also produces a near uniform distribution of cluster heads. Further in the cluster formation phase, a novel approach is introduced to balance the load among cluster heads. But on the other hand, it increases the requirement of global knowledge about the distances between the cluster-heads and the base station.

In 2006, Q. Li, Z. Qingxin and W. Mingwen [8] proposed Distributed Energy Efficient Clustering Protocol (DEEC) protocol. This protocol is a cluster based scheme for multi level and two level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are selected using the probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster-heads for nodes are different according to their initial and residual energy. The nodes with high initial and residual energy have more chances of the becoming cluster heads compared to nodes with low energy.

O. Younis and S. Fahmy proposed [9] Hybrid Energy Efficient Distributed clustering Protocol (HEED) protocol in 2004. It extends the basic scheme of LEACH by using residual energy as primary parameter and network topology features (e.g. node degree, distances to neighbours) are only used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to achieve power balancing. The clustering process is divided into a number of iterations, and in each iterations, nodes which are not covered by any cluster head double their probability of becoming a cluster head. Since these energy-efficient clustering protocols enable every node to independently and probabilistically decide on its role in the clustered network, they cannot guarantee optimal elected set of cluster heads.

III Network Initialization

The network includes some of the initial setting of energy parameters and the initialization of the sensor nodes. So it is necessary to generate a random distribution of these nodes in the L * L m2 of the region. Random 100- node topology for a 100 * 100 m2. Sink is located at (50, 50). Fig. 1 demonstrates the wireless sensor network initialization.

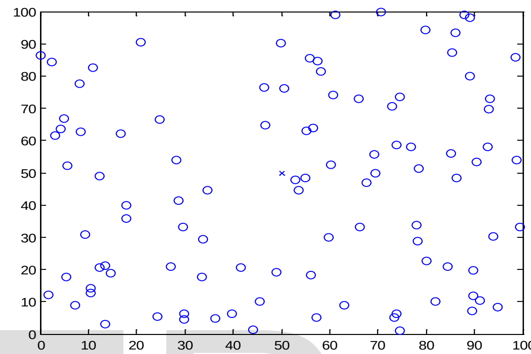

Fig. 1. Random deployment of nodes

IV CLUSTER AND CLUSTER HEAD FORMATION

Sensor node are densely deployed in wireless sensor network that means physical environment would produce very similar data in close by sensor node and transmitting such type of data is more or less redundant. So all these facts encourage using some kind of grouping of sensor nodes such that group of sensor node can be combined or compress data together and transmit only compact data. This can reduce localized traffic in individual group and also reduce global data .this grouping process of sensor nodes in a densely deployed large scale sensor node is known as clustering. The way of combing data and compress data belonging to a single cluster called data aggregation. Issues of clustering in wireless sensor network: (a) how many sensor nodes should be taken in a single cluster Selection procedure of cluster head in an individual cluster. (b) Heterogeneity in a network, it means user can put some power full nodes, in term of energy in the network which can behave like cluster head and simple node in a cluster work as a cluster member only. Many protocol and algorithm have been proposed which deal with each individual issue. Following assumptions are made regarding the network model is:

1. Nodes in the network are quasi-stationary.
2. Nodes locations are unaware i.e. it is not equipped by the GPS capable antenna.

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3. Nodes have similar processing and communication capabilities and equal significance.
4. Nodes are left unattended after deployment

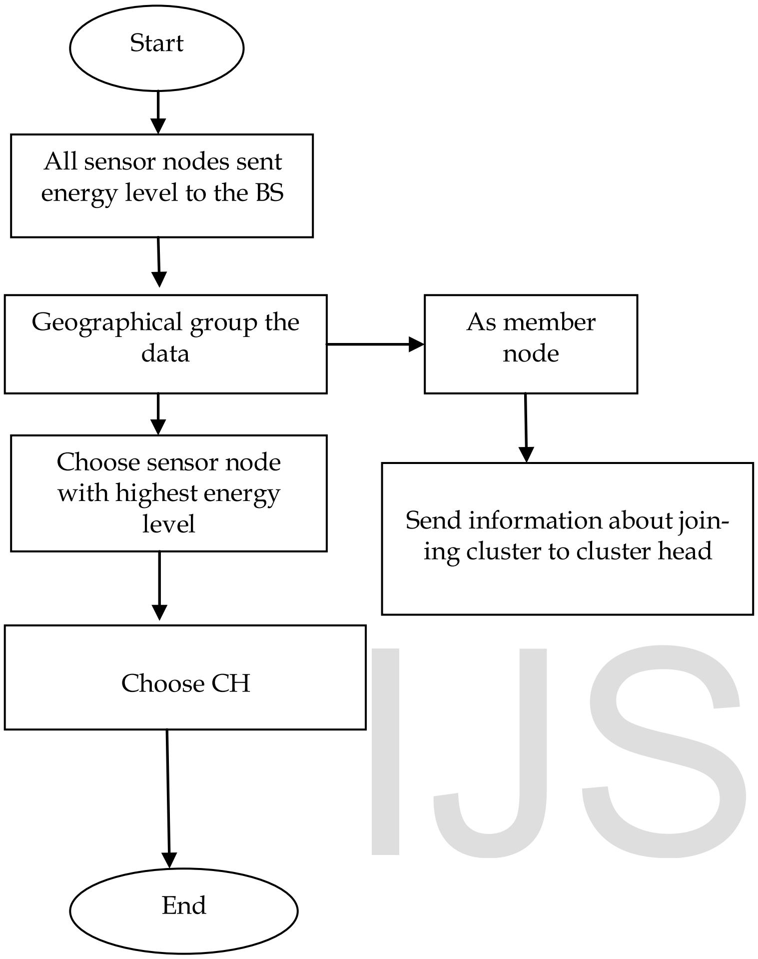

Fig. 2. Cluster head selection process

The secondary clustering parameter, intra-cluster communication cost, is a function of (i) cluster properties, such as cluster size, and (ii) whether or not variable power levels are permissible for intra-cluster communication. If the power level used for intracluster communication is fixed for all nodes, then the cost can be proportional to (i) , if the requirement is to distribute load among cluster heads, or (ii) , if the requirement is to create dense clusters. This means that a node joins the cluster head with minimum degree to distribute cluster head load or joins the one with maximum degree to create dense clusters. Each node performs neighbour discovery, and broadcasts its cost to the detected neighbours. Each node sets its probability of becoming a cluster head, CH_{prob}, as follows:

$$CH\_prob = \max(C\_prob * (E\_residual/E\_\max), P\_\min) \quad (2)$$

V HETEROGENOUS WSN MODEL

In this section we describe our model of a wireless sensor network with nodes heterogeneous in their initial amount of energy. We particularly present the setting, the energy model, and how the optimal number of clusters can be computed. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. We refer to these powerful nodes as advanced nodes, and the rest (1-m)*n as normal nodes. We assume that all nodes are distributed uniformly over the sensor field.

2 level H-HEED:

In 2-level H-HEED protocol, two types of sensor nodes, i.e., the advanced nodes and normal nodes are used. Let us assume there are 'N' numbers of sensor nodes deployed in a field. E_0 is the initial energy of the normal nodes, and m is the fraction of the advanced nodes, which own a times more energy than the normal ones. Thus there are m * N advanced nodes equipped with initial energy of $E_o * (1 + a)$ and (1-m)*E_0 normal nodes equipped with initial energy of E_0. The total initial energy of the network is given by:

$$\begin{aligned} E_{total} &= N * (1 - m) * E_0 + N * m * E_0(1 + a) \\ &= N * E_0 * (1 + am) \end{aligned} \quad (3)$$

3-level H-HEED:

There are three types of sensor nodes, i.e. the super nodes, advanced nodes and the normal nodes. Let m be the fraction of the total number of nodes N, and m_0 is the percentage of the total number of nodes N * m which are equipped with β times more energy than the normal nodes, called as the super nodes, the number is N * m *m_0. The rest N * m * (1-m_0) nodes are having a times more energy than the normal nodes, being called as advanced nodes and the remaining N * (1- m) nodes are the normal nodes. E_0 is the initial energy of the normal nodes. The energy of the each super node is $E_o(1 + \beta)$ and the energy of each advanced node is $E_0(1 + a)$
The total energy of the network is given by:

$$E_{total} = N * (1 - m) * E_0 + N * m * (1 - m_0) * E_0(1 + a) + N * m * m_0 * E_0(1 + \beta) \quad (4)$$

$$E_{total} = N * E_0(1 + m * (a + m_0 * \beta)) \quad (5)$$

So, the total energy of the network is increased by the factor of $1 + m * (a + m_0 * \beta)$

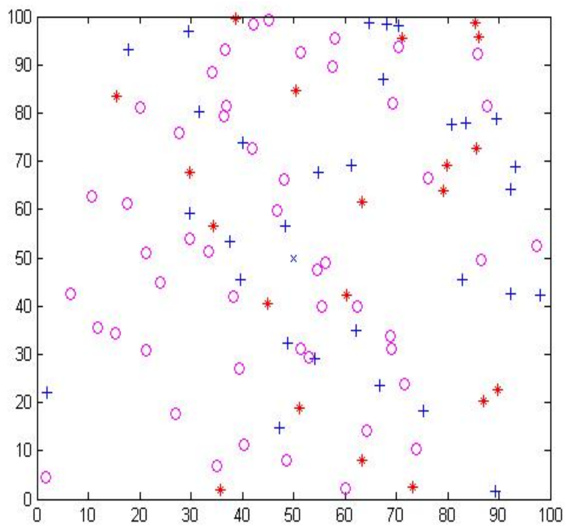

Fig. 3. Deployment of 3 level H- HEED

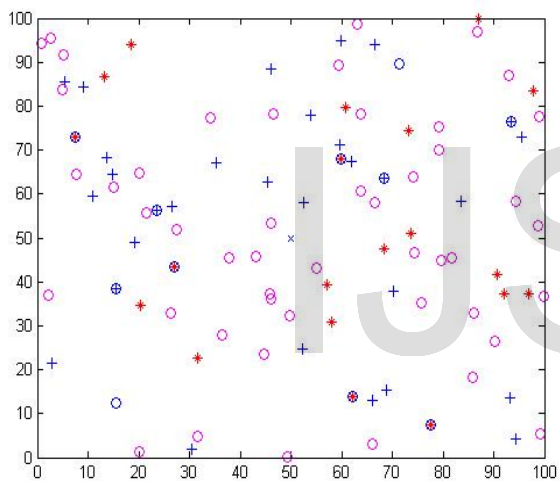

Fig. 4. Cluster head selection in 3 levels H-HEED

+ = Advanced node
O = Normal node
* = Super node
⊙ = Cluster head

VI ACTIVE AND SLEEP NODES

In this node scheduling the total available residual energy is equally distributed and the cluster head also elected as per the residual energy comparison. Only thing is whenever the node is under sleep mode in each cluster it consumes very small energy. Here the total rounds are increased by doing both changing of sleeping and active modes and the available energy is distributed in a balanced manner. By properly doing the node scheduling in each cluster with proper time interval, the total energy consumed is low and the total lifetime of the wireless sensor network is increased near to 50%, when compared with the normal LEACH.

VII SIMULATION RESULTS

The simulation is done in MATLAB. Let us assume the heterogeneous sensor network with 100 sensor nodes are randomly distributed in the 100m*100m area. The base station is located at the centre (50, 50). We have set the minimum probability for becoming a cluster head (p_{min}) to 0.0001 and initially the cluster head probability for all the nodes is 0.05. The parameters used in our simulation are listed in the Table 1.

TABLE 1
SIMULATION PARAMETERS

Parameters	Values
Sink	At (50,50)
Threshold distance, d_0	70 m
Cluster radius	25 m
Energy consumed in the electronics circuit to transmit or receive the signal, E_{elec}	50 nJ/bit
Energy consumed by the amplifier to transmit at a short distance, E_{fs}	10 pJ/bit/m2
Energy consumed by the amplifier to transmit at longer distance, E_{amp}	0.0013 pJ/bit/m4
Data Aggregation Energy, EDA	5 nJ/bit/signal
Message Size	4000 bits
Initial Energy, E_0	0.5 J

In the analysis, we use the same energy model as proposed in [6]. In the process of transmitting an l-bit message over a distance d, the energy expended by the radio is given by:

$$E_{TX(l,d)} = E_{TX-elec}(l) + E_{TX-amp}(l,d)$$
$$= f(x) = \begin{cases} lE_{elec+}lE_{fs}d^2 \\ lE_{elec+}lE_{fs}d^4 \end{cases} \quad (6)$$

And to receive the message, the radio expends:

$$E_{RX}(l) = E_{RX-elec}(l)$$
$$= lE_{elec} \quad (7)$$

There are other factors like noise, physical obstacles or collision may affect the received power are ignored. We have introduced the advanced nodes to the HEED protocol, so as to assess the performance of HEED protocol in the presence of heterogeneity. Let us consider the case for 2-level H-HEED, 30% of the nodes are advanced nodes (m=0.3) and equipped with 150% more energy than normal nodes (a=1.5). For 3-level H-HEED, 30% of the nodes are advanced nodes and 20% of the nodes are super nodes are equipped with 150% and 300% more energy than the normal nodes (a=1.5 and b=3, m=0.5 and m0=0.4). For multilevel H-HEED, each node in the sensor network is randomly assigned different energy between a closed set [0.5, 2].

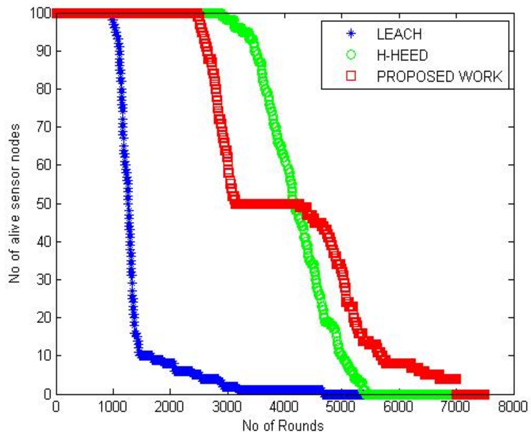

Fig. 5. Simulated output

In Fig. 5, a detailed view of the behaviour of HEED and H-HEED protocol is illustrated; it shows the number of alive nodes per round. The number of nodes die in HEED is more than H-HEED over the same number of rounds. The number of normal nodes dies very fast and as a result the sensing field becomes sparse very fast. On the other hand, advanced nodes and super nodes die in a very slow fashion. But in multi-level H-HEED, all the sensor nodes are having different energy as a result nodes will die randomly. In this we can say that multi-level H-HEED prolongs lifetime and shows better performance than other level of H-HEED and HEED protocol. Figure 5 represents the total remaining energy of the network in each round. In this both HEED and H-HEED, the energy depletes very fast at constant rate. We can conclude that both 3-level H-HEED and multi-level H-HEED is more energy efficient.

VIII CONCLUSIONS

In this paper, H-HEED protocol is proposed along with active and sleep node implementation for heterogeneous wireless sensor network. In this, we introduced different level of heterogeneity: 2-level and 3-level in terms of the node energy. We have evaluated the performance of the proposed H-HEED with HEED protocol using MATLAB 7.10. It is observed that there is significant improvement in the lifetime in case of H-HEED protocol in comparison with HEED protocol because the number of rounds is maximum with H-HEED.

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