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Comparison and Performance Analysis on Clustering Scheme

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Abstract— In wireless sensor network, clustering is one of the major concerns. Effective clustering helps to increase the network stability and achieve network lifespan. Heterogeneous protocols consider two or more energy level of nodes. By analyzing such protocols, the overall network lifetime is enhanced to a greater extent. Nodes are equipped with the ability to aggregate, transmit and receive data messages which requires great energy. Simulation results shows that four level and three level nodes achieve better stability of the network. In this paper we propose and evaluate a scheme for heterogeneous wireless sensor network to balance the number of nodes in each cluster and hence make it a Balanced Cluster. The network will have some randomly deployed nodes, all belonging to some cluster. The count of nodes in each cluster will be definite in each round and therefore achieves greater stability for heterogeneous environment.

Keywords-*wireless sensor networks,homogenous networks,initial energy,residual energy.*

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I. Introduction

The Wireless Sensor Network consists of nodes from a few to more than hundreds or thousands. Every node is connected to one or more sensors. Each node has typically several parts: a microcontroller, an electronic circuit for interfacing with the sensors ,a radio transceiver with an internal antenna or connection to an external antenna, and an energy source, usually a battery or an embedded form of energy harvesting. The sensing electronics part measure surrounding conditions related to the environment surrounding the sensor and converts them into an electric signal. Processing such a signal reveals some characteristics about objects located and/or events happening in the proximity of the sensor [1]. A large number of these accessible sensors can be grouped to form a network in many applications that require unattended operations.

One important aspect in WSN's is that it should be very well integrated into their environment. A visionary perception is that they should become 'smart dust'; nodes should be spread around an environment in large amounts [5]. This puts some restrictions on nodes cost and size. It also implies that nodes can be scattered into an environment and would made to work rapidly. This can be achieved by making WSN's easily applicable to a variety of events [2].

Researchers usually assume that the nodes in wireless sensor networks are homogeneous, but in reality, homogeneous sensor networks are rare in existence. This is because homogeneous sensors have different potential like depletion rate, different levels of initial energy, etc. A Network in which nodes are at different initial energy level is termed as heterogeneous network. Many researchers have proposed various clustering algorithms for homogeneous wireless sensor networks such as LEACH [3], PEGASIS [4], and TEEN [6]. These algorithms have not performed adequately in heterogeneous environment. Nodes with less energy will perish faster than the high energy nodes. This is so because these homogenous clustering based algorithms are inefficient to treat every node in terms of energy level. In heterogeneous WSNs, each node to be deployed has different initial energy level. Heterogeneity in wireless sensor network could be the outcome of regeneration of WSN in order to prolong the network lifetime. Stable Election Protocol (SEP) [7], Distributed Energy Efficient Clustering (DEEC) [8], Developed DEEC (DDEEC) [9], Enhanced DEEC (EDEEC) [10] are protocols for heterogeneous WSNs.

Moreover, the differences between homogeneous networks and heterogeneous networks can be summarized in the following figure.
for math, etc.

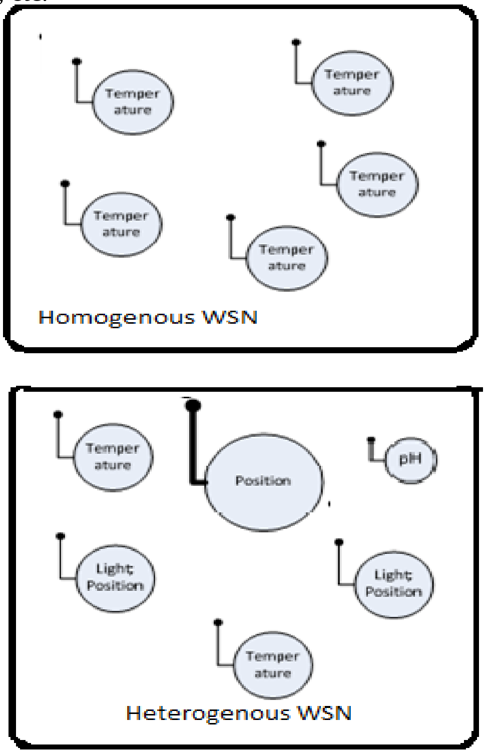

Figure 1. Example of a Wireless Sensor Networks

II. Related Work

Various WSN applications demand only a composite value to be reported to the monitoring authority. A wireless sensor network can be categorized as homogeneous network and heterogeneous network. All the nodes of homogenous network are identical in terms of initial energy, hardware complexity, battery consumption etc.

A. LEACH

Heinzelman, et. al. [3] for homogeneous wireless sensor networks introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is one of the most acceptably recognized cluster-based protocols, in which node clusters are formed on the basis of received signal strength. This algorithm performs a random selection of cluster heads among few sensor nodes that were deployed in the sensing region. The process of communication in sensor networks starts with the nodes sensing the region and transmits its sensed data to their respective CH and each cluster head transmit the data of its cluster directly to the sink. The roles of cluster heads are randomly rotated so as to balance the energy load among the nodes in the network [1] and hence network prolongitivity is achieved.

LEACH protocol is separated into two main phases named Setup phase and steady phase. In setup phase cluster heads are elected

One major limitation associated with LEACH protocol is that it is not applicable to networks deployed in vast region. It also assumes that nodes deployed closer to each other have similar data to send. It is difficult to predict how the predefined numbers of cluster heads are going to be distributed in the network.

B. PEGASIS

An improved algorithm, in which each sensor node communicates only with its closest neighbor node, is a chain based optimal protocol called PEGASIS (Power-Efficient Gathering in Sensor Information Systems). The core idea in PEGASIS is to generate a chain among the sensor nodes in which every node can receive and transmit the data to its nearest neighboring node. Aggregated data moves from one node to another, get integrated and hence a designated node transmits to the base station. In PEGASIS average energy drained is reduced by nodes taking turns and transmitting data to the BS. PEGASIS avoids cluster formation, as in the case of LEACH, and uses only one node in a chain to transmit the data to the base station. In order to discover the closest node, each node uses its signal strength to measure the distance from all the adjacent nodes and then acclimatizes the signal strength so that at one time only one node can be heard. The key idea in PEGASIS is to build a chain of nodes that are closest to each other and make a path to the base station. The performance of the PEGASIS protocol shows that the network lifetime is achieved twice as compared to LEACH protocol. Such potential gain is attained by avoiding the idea of dynamic cluster formation as in the case of LEACH.

One major limitation associated with PEGASIS protocol is that it requires dynamic topology adjustment since a sensor node needs to know about the energy level of its entire neighboring node so as to know where to route the data. Such topology management can present remarkable overhead, especially for highly utilized networks.

Many scientists have made certain comparison between different homogeneous networks topologies. Stephanie Lindsey in his paper[11] presented that PEGASIS performs better than LEACH by about 100 to 300% when 1%, 20%, 50% , and 100% of nodes die for different network sizes and topologies.

C. DEEC

For heterogeneous wireless sensor network, Li Qing [12] in his paper discussed that DEEC achieves longer lifetime and effective messages than present important clustering protocols in heterogeneous environments. He proposed a new distributed energy-efficient clustering protocol for heterogeneous wireless sensor networks, called as DEEC. DEEC contributes in strengthening the stability period and network lifetime, by heterogeneous clustering algorithms. DEEC algorithm distributes different epoch of any of the cluster-head to each node by determining their initial and residual energy. A particular algorithm is used in DEEC to evaluate the network lifetime, thus eliminating the need of routing protocol. (r) denotes average energy of network during round r *which* can be given as in [12]:

$$\overline{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \qquad (1)$$

Probability for CH selection in DEEC is given as in [12]:

$$p_i = p_{opt}\left[1 - \frac{\overline{E}(r) - E_i(r)}{\overline{E}(r)}\right] = p_{opt}\frac{E_i(r)}{\overline{E}(r)} \qquad (2)$$

This ensures that the total average number of cluster heads in each round is given by:

$$\sum_{i=1}^{N} p_i = \sum_{i=1}^{N} p_{opt}\frac{E_i(r)}{\overline{E}(r)} = Np_{opt} \qquad (3)$$

Where p_i is the probability of every node to become a cluster head. If G is the set of nodes eligible to become CH at round r and if node becomes CH in recent rounds then it belongs to G. During each round every node selects a random number between 0 and 1. If this number is less than threshold value, it is eligible to become a CH otherwise not

$$T(s_i) = \begin{cases} \dfrac{p_i}{1 - p_i\left(r \bmod \dfrac{1}{p_i}\right)} & if\ s \in G \\ 0 & otherwise \end{cases}$$

In DEEC we estimate average energy (r) of the network for any round r as in [12]:

$$E(r) = \frac{1}{N}E_{total}\left(1 - \frac{r}{R}\right) \qquad (5)$$

R implies total rounds for the network lifetime and is estimated as follows:

$$R = \frac{E_{total}}{E_{round}} \qquad (6)$$

E_{total} is total energy of the network where E_{round} is energy expenditure during each round.

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D. EDEEC

In recent years many routing protocols on clustering scheme have been proposed based on the concept of heterogeneity. EDEEC was proposed for three types of sensor nodes in order to achieve network stability and prolonging the lifetime of the network. EDEEC is the enhancement of DEEC protocol with the addition of another node , that is super node. Simulation results show that EDEEC performs better than DEEC with effective messages and more stability of network. The probability for three types of nodes with different p_{opt} values is given by EDEEC is given below:

$$p_i = \begin{cases} \dfrac{p_{opt} E_i(r)}{(1+m(a+m_0 b)\bar{E}(r))} & \text{if } s_i \text{ is the normal node} \\ \dfrac{p_{opt}(1+a) E_i(r)}{(1+m(a+m_0 b)\bar{E}(r))} & \text{if } s_i \text{ is the advanced node} \\ \dfrac{p_{opt}(1+b) E_i(r)}{(1+m(a+m_0 b)\bar{E}(r))} & s_i \text{ is the super node} \end{cases}$$

E. EDDEEC

In EDDEEC, the concept used is of three levels heterogeneity only but with some amendments. Aim of this expression given by EDEEC is to scatter the consumed energy over network efficiently in order to increase network lifetime. However, after some rounds, few advanced and super nodes have equal residual energy level same as normal nodes due to frequent CH selection. Though EDEEC continues to punish super and advance nodes. and DEEC continues to punish only advance nodes. So to elude the unbalancing in three-level heterogeneous network model and to protect super and advance nodes from being over penalized, EDDEEC was proposed with changes in function for calculating probabilities of normal, advance and super nodes. These changes are based on absolute residual energy level Tabsolute, which is the value in which advance and super nodes have same energy level as that of normal nodes. The idea specifies that under Tabsolute all normal, advance and super nodes have same probability for CH selection. Our proposed probabilities for CH selection in EDDEEC are given as follows:

$$p_i = \begin{cases} \dfrac{p_{opt} E_i(r)}{(1+m(a+m_0 b))\overline{E}(r)} & \text{for } N_{ml} \text{ nodes} \\ & \text{if } E_i(r) > T_{absolute} \\ \dfrac{p_{opt}(1+a) E_i(r)}{(1+m(a+m_0 b))\overline{E}(r)} & \text{for Adv nodes} \\ & \text{if } E_i(r) > T_{absolute} \\ \dfrac{p_{opt}(1+b) E_i(r)}{(1+m(a+m_0 b))\overline{E}(r)} & \text{for Sup Node} \\ & \text{if } E_i(r) > T_{absolute} \\ c\,\dfrac{p_{opt}(1+b) E_i(r)}{(1+m(a+m_0 b))\overline{E}(r)} & \text{for } N_{ml}, \text{Adv, Sup nodes} \\ & \text{if } E_i(r) \le T_{absolute} \end{cases}$$

Tabsolute is the absolute residual energy level whose value is given as *Tabsolute* = $zE0$ (9) where, $z \in (0, 1)$. If $z = 0$ then we have traditional EDEEC.

III. SIMULATION AND RESULT

In this section we compare and evaluate the performance for LEACH DEEC, EDEEC and EDDEEC protocol using MATLAB. We consider a wireless sensor network containing of N = 100 nodes that are randomly deployed inside $100m \times 100m$ field. For this situation, we are considering base station is placed at center of network field. We observe performance of LEACH DEEC, EDEEC and EDDEEC for homogenous and multi-level heterogeneous WSNs. We take the parameters; $m = 0.8$, $m0 = 0.6$, $a = 2$, $b = 3.5$ *and* $u = 2.5$, containing 50 normal nodes having $E0$ energy, 35 advanced nodes having 1.5 times more energy than normal nodes, 12 super nodes containing 2 times more energy than normal nodes and 3 ultra-super nodes containing 2.5 times more energy than normal nodes.

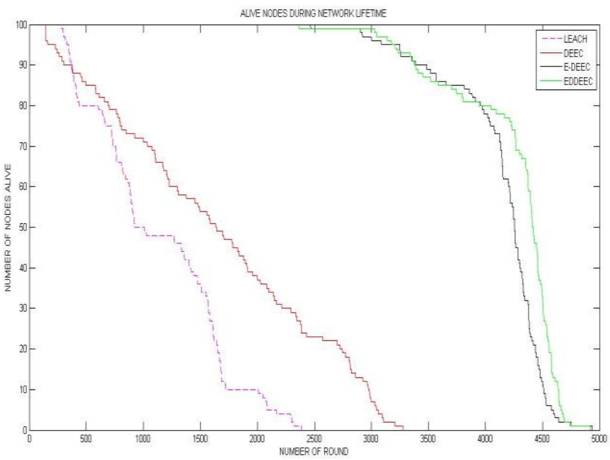

Figure 2. Comparison graph

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