Energy Levels and Optimal Consumption in Heterogeneous Sensor Networks

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ABSTRACT:
In recent years, there has been a growing interest in wireless sensor networks. One of the major issues in wireless sensor network is developing an energy-efficient clustering protocol. The hot point in these algorithms is the cluster head selection. In this paper, we study the impact of heterogeneity of nodes in terms of their energy in wireless sensor networks that are hierarchically clustered. Adapting this approach, we introduce energy efficient to cope with energy heterogeneity among sensor nodes; a modified clustering algorithm is proposed with a three-tier sensor node (SEP-E) setting. Finally, the simulation results for MATLAB demonstrate that our proposed heterogeneous clustering approach is more effective in prolonging the network lifetime compared with LEACH.

KEYWORDS: Wireless sensor network; heterogeneous settings; clustering..

1. INTRODUCTION

A generic wireless sensor network is composed of a large number of sensor nodes scattered in a terrain of interest. Each of them has the capability of collecting data about an ambient condition, i. e., temperature, pressure, humidity, noise, lighting condition etc., and sending data reports to a sink node.(Fig 1)

However, one of the key issues that merit attention is the energy heterogeneity in sensor networks. This occurs when there is energy difference to some threshold between an individual sensor and its neighbors, either caused by the introduction of new sensors of sensor nodes, or by network settings which may be necessary for some applications. An inefficient use of the available energy will lead to poor performance and short life cycle of the network. To this end, energy in these sensors is a scarce resource and must be managed in an efficient manner. We present a modified algorithm for properly distributing sensor energy and ensuring the maximal network life time. Our algorithmic approach operates in a WSN under three-level energy heterogeneity. Simulation results show an improvement in the effective network life time, and increased robustness of performance in the presence of energy heterogeneity. [1]

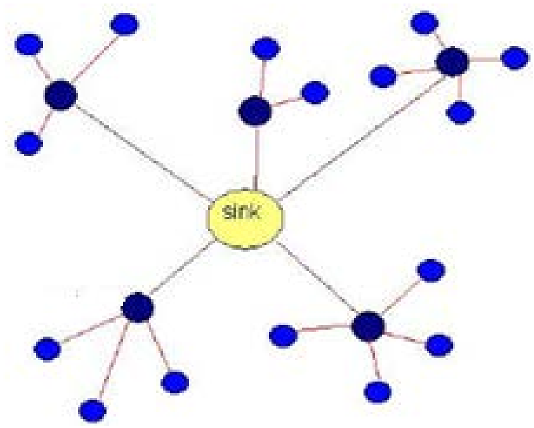

Figure 1: Clustering in Wireless Sensor Networks

The remainder of this paper is organized as follows. We briefly review related work in Section 2. We then discuss our proposed clustering technique in section 3. Our simulation result is presented in section 4. Finally, in section 5, we conclude the paper and highlights future directions for other aspects of improvement in WSN.

2. RELATED WORK

Two important algorithms in sensor networks with the gathering and direction hierarchical data in wireless sensor networks is LEACH and SEP. Most designs are based protocol LEACH hierarchical protocol. We describe the performance characteristics of these two protocols specifying the performance criteria, compare the proposed protocol.

1.1. LEACH

Low-energy adaptive clustering hierarchy (LEACH) is one of the most popular distributed cluster-based routing protocols in wireless sensor networks. LEACH randomly selects a few nodes as cluster heads and rotates this role to balance the energy dissipation of the sensor nodes in the networks. The cluster head nodes fuse and aggregate data arriving from nodes that belong to the respective cluster. And cluster heads send an aggregated data to the sink in order to reduce the amount of data and transmission of the duplicated data. Data collection is centralized to sink and performed periodically. The operation of LEACH is generally separated into two phases, the set-up phase and the steady-state phase. In the set-up phase, cluster heads are selected and clusters are organized. In the steady-state phase, the actual data transmissions to the sink take place. After the steady-state phase, the next round begins.

$$T(s) = \begin{cases} \frac{p_{opt}}{1-p_{opt}*\left(r*\mathrm{mod}\frac{1}{p_{opt}}\right)} & \text{if } s \in G \\ 0 & \text{otherwise} \end{cases}$$

During the set-up phase, when clusters are being created, each node decides whether or not to become a cluster head for the current round. This decision is based on a predetermined fraction of nodes and the threshold T(s). Each node that has elected itself cluster head for the current round broadcasts an advertisement message to the rest of the nodes in the network. All the non-cluster head nodes, after receiving this advertisement message, decide on the cluster to which they will belong for this round. This decision is based on the received signal strength of the advertisement messages. After cluster head receives all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster head creates a TDMA schedule and assigns each node a time slot when it can transmit.

1.2. SEP

SEP, a heterogeneous-aware protocol to prolong the time interval before the death of the first node (we refer to as stability period), which is crucial for many applications where the feedback from the sensor network must be reliable. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. SEP yields longer stability region for higher values of extra energy brought by more powerful nodes. [3]

3. THE PROPOSED PROTOCOL

In SEP, two types of nodes (two tier in-clustering) and two level hierarchies were considered. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. A survey of clustering algorithm was presented in Ref. The even distribution of sensors in clusters is another primary objective of clustering called load balancing that needs to be considered when designing a robust protocol for WSNs. The clustering issue was also discussed in a review on wireless multimedia sensor networks. The contribution of this work is a SEP extension called SEP-E, by considering a three-tier node classification in a two-level hierarchical network. The new node type for the purpose of this study is referred to as “intermediate nodes”, which serves as a bridge between the advanced nodes and the normal nodes. The intermediate nodes can take on the role of information fusion and filtering depending on the application settings, which we intend to study further. Our goal is to achieve a robust self-configured WSN that maximizes its lifetime.

According to the radio energy dissipation model illustrated in Fig. 2, in order to achieve an acceptable. [4]

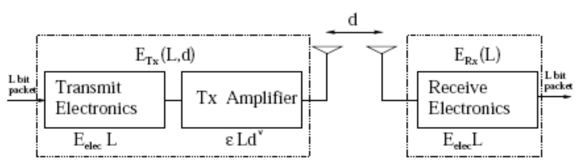

Figure 2 radio energy model

Signal-to-noise ratio (SNR) in transmitting an L bit message over a distance d, energy expanded by the radio is given by:

$$E_{Tx}(l,d) = \begin{cases} L.E_{elec} + L.\epsilon_{fs}.d^2 & if\ d \le d_0 \\ L.E_{elec} + L.\epsilon_{mp}.d^4 & if\ d > d_0 \end{cases} \quad (1)$$

Where the energy is dissipated per bit to run the transmitter or the receiver circuit, and depend on the transmitter amplifier model we use, and d the distance between the sender and the receiver. By equating the two expressions at d=d0, we have $d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$. To receive an L bit message the radio expends

$$E_{rx} = L.E_{elec} \quad (2)$$

Assume an area A = M * M square meters over which n nodes are uniformly distributed. For simplicity, assume the sink is located in the center of the field, and that the distance of any node to the sink or its cluster head is. Thus, the energy dissipated in the cluster head node during a round is given by the following formula:

$$E_{ch} = \left(\frac{n}{k} - 1\right) L.E_{elec} + \frac{n}{k} L.E_{DA} + L.E_{elec} + L.\epsilon_{fs} d_{toBS}^2 \quad (3)$$

The energy dissipated in the non cluster head node during a round is given by the following formula:

$$E_{nonCH} = L.E_{elec} + L.\epsilon_{fs}.d_{toCH}^2 \quad (4)$$

Heterogeneous nodes can provide complex data processing and longer-term storage. Link heterogeneity means that the heterogeneous node has high-bandwidth and long-distance network transceiver than the normal node. Link heterogeneity can provide more reliable data transmission. Energy heterogeneity means that the heterogeneous node is line powered, or its battery is replaceable. Among above three types of resource heterogeneity, the most important heterogeneity is the energy heterogeneity because both computational heterogeneity and link heterogeneity will consume more energy resource. If there is no energy heterogeneity, computational heterogeneity and link heterogeneity will bring negative impact to the whole sensor network, i.e., decreasing the network lifetime. Fig 3 demonstrates the heterogeneous settings we used.

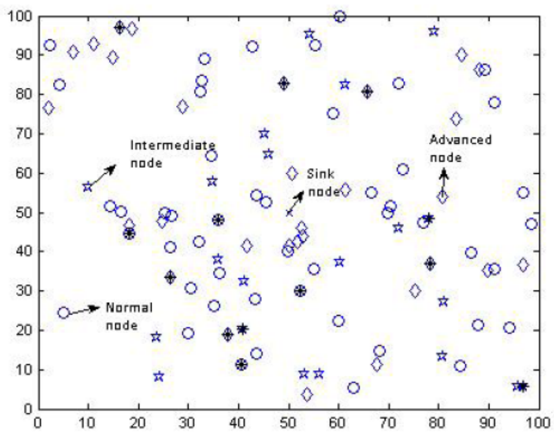

Figure 3: Wireless Sensor Network in clusters.

The total initial energy of the system is increased by the introduction of intermediate nodes:

$$n.(1 - m - b).E_0 + n.m.E_0.(1 + \alpha) + n.b.E_0.(1 + y) = n.E_0.(1 + \alpha.m + by) \quad (5)$$

Where n is the number of nodes, m is the proportion of advanced nodes to the total number of nodes n and b is the proportion of intermediate nodes. So, the total energy of the system is increased by a factor of $(1 + am + by)$.

1. The advanced nodes must be cluster head exactly $1 + a$ times every $\frac{1}{P_{opt}}(1 + am + by)$
2. The Intermediate nodes must be cluster head exactly $1 + b$ times every $\frac{1}{P_{opt}}(1 + am + by)$
3. Every normal nodes must also become cluster head once every $\frac{1}{P_{opt}}(1 + am + by)$

The weighed probabilities for normal, advanced and super nodes are, respectively:

$$P_{nrm} = \frac{P_{opt}}{1 + a * m + by} \quad (6)$$

$$P_{int} = \frac{P_{opt} * (1 + y)}{1 + a * m + b * y}$$

$$P_{adv} = \frac{P_{opt} * (1 + a)}{1 + a * m + b * y}$$

The threshold $T(sn)$, $T(si)$, $T(sa)$ for normal, intermediate and advanced respectively becomes:

$$T(sn) = \begin{cases} \dfrac{P_{nrm}}{1 - P_{nrm}\left(r * mod\ \dfrac{1}{P_{nrm}}\right)} & if\ \ s\epsilon G \\ 0 & otherwise \end{cases} \quad (7)$$

$$T(si) = \begin{cases} \dfrac{P_{int}}{1 - P_{int}\left(r * mod\ \dfrac{1}{P_{int}}\right)} & if\ \ s\epsilon G \\ 0 & otherwise \end{cases}$$

$$T(sa) = \begin{cases} \dfrac{P_{adv}}{1 - P_{adv}\left(r * mod\ \dfrac{1}{P_{adv}}\right)} & if\ \ s\epsilon G \\ 0 & otherwise \end{cases}$$

4. SIMULATION

We used a 100m × 100m region of 100 sensor nodes scattered randomly. MATLAB is used to implement the simulation. To have a fair comparison with LEACH, we introduced advanced and intermediate nodes with different energy levels as in our SEP-E protocol. Likewise, to have a fair comparison with SEP, we introduced additional energy so that the total initial energy of the network system becomes same as in SEP-E and LEACH in three node settings. The notion is for us to be able to assess the performance of these protocols in the presence of heterogeneity. Specifically, we have the following settings: Let 20% and 40% of the nodes be advanced nodes and intermediate nodes with additional energy levels: **a**= **2** and **y** = **1** respectively .Other parameters used in our simulation is shown in table 1.

Table 1: Parameter settings

Parameters	
ε_{fs}	10 nj/bit/m^2
ε_{mp}	0.0013 nj/bit/m^4
p_{leach}	0.08
E_{DA}	5 nj/bit/signal

The simulation results are as follows:

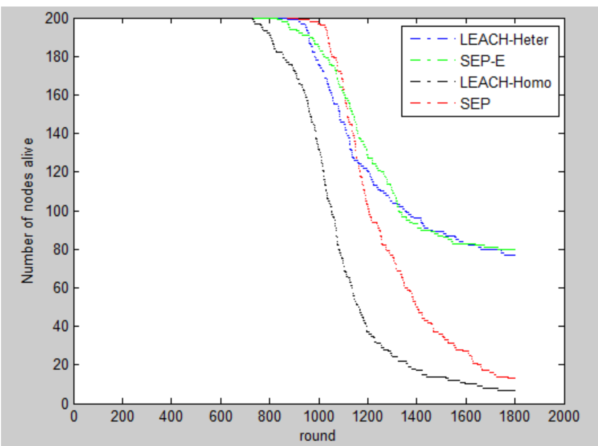

Figure 4: The performance of *SEP(m=0.2,a=1)، ,SEP-E(m=0.2,b=0.4,a=2.y=1) (Hetergeneity , m=0.2,b=0.4,a=2.y=1) LEACH و LEACH (Homogeneity ,m=0,b=0,a=0,y=0)* in the presence of high energy heterogeneity

In Fig. 4, a detailed view of the behavior of LEACH and SEP-E is illustrated, for heterogeneity parameters. Fig. 3 shows the number of alive nodes. The number of nodes die in LEACH is more than SEP-E 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.

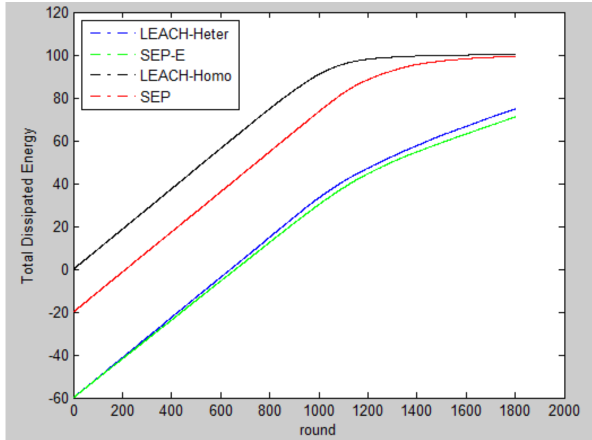

Figure 5: Shows the rate of energy dissipation of SEP-E and LEACH nodes *SEP(m=0.2,a=1)، ,SEP-E(m=0.2,b=0.4,a=2.y=1) (Hetergeneity,m=0.2,b=0.4,a=2.y=1) LEACH و LEACH (Homogeneity,m=0,b=0,a=0,y=0)*

The rate of energy dissipation for all the nodes in SEP-E is much better than in LEACH (heterogeneity) (see Figure 5). This means SEP-E achieves better utilization of the extra energy introduced into the system compared with LEACH, which is the intended objective for our protocol design.

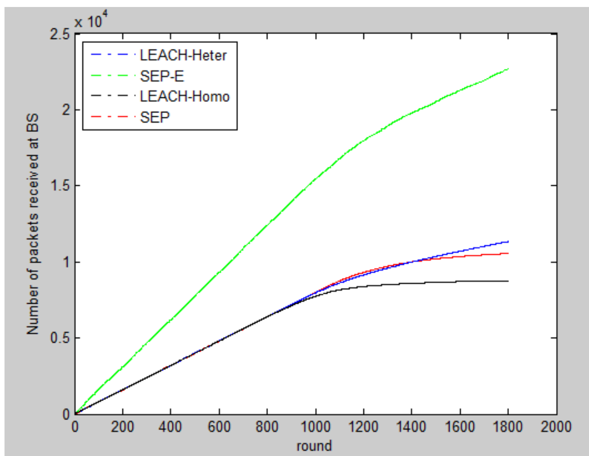

Figure 6: Comparison between LEACH and SEP-E in the presence of heterogeneity *SEP(m=0.2,a=1)، ,SEP-E(m=0.2,b=0.4,a=2.y=1) (Hetergeneity ,m=0.2,b=0.4,a=2.y=1) LEACH و LEACH (Homogeneity ,m=0,b=0,a=0,y=0)*

In Fig. 6 we see the number of data packets (messages) received from cluster heads at the BS during the lifetime of the network. It shows that the stable region of SEP-E is extended compared to that of LEACH. Moreover, the unstable region of SEP-E is shorter than that of LEACH.

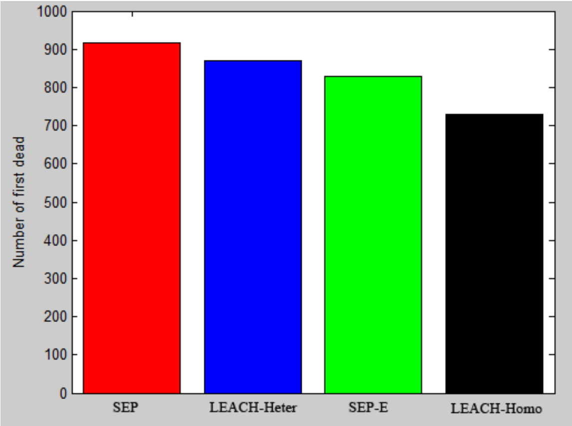

Figure 7: Comparing the first dead node in the protocol *SEP(m=0.2,a=1)، ,SEP-E(m=0.2,b=0.4,a=2.y=1) (Hetergeneity,m=0.2,b=0.4,a=2.y=1) LEACH و LEACH (Homogeneity,m=0,b=0,a=0,y=0)*

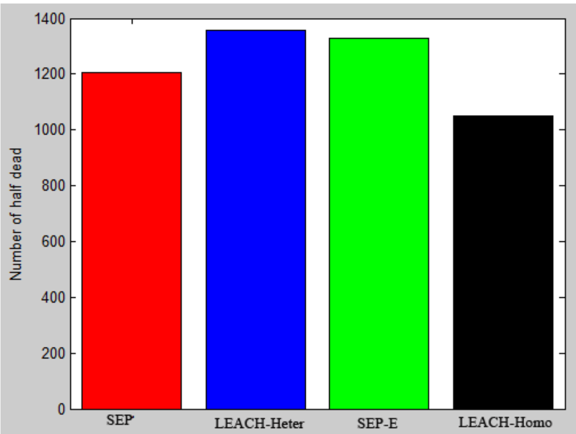

Figure 8: Half of the nodes alive protocol *SEP(m=0.2,a=1)، ,SEP-E(m=0.2,b=0.4,a=2.y=1) (Hetergeneity,m=0.2,b=0.4,a=2.y=1) LEACH و LEACH (Homogeneity,m=0,b=0,a=0,y=0)*

Figure 7 and 8 shows that SAP - E to reduce (FND) In Figure 10, the proposed protocol (HNA) significant improvement over the homogeneous SEP and LEACH, in LEACH heterogeneous while this criterion is nearly equal SEP-E.

5. CONCLUSION

The wireless sensor networks have been envisioned to help in numerous monitoring applications. Energy efficient routing is paramount to extend the stability and lifetime of the system. In this paper, we have proposed an energy efficient heterogeneous clustered scheme for wireless sensor networks. The energy efficiency and ease of deployment make SEP-E a desirable and robust protocol for wireless sensor networks. In order to improve the lifetime and performance of the network system, this paper reports on the weighted probability of the election of cluster heads. Simulations results show that SEP-E has extended the lifetime of the network by 10% as compared with LEACH in the presence of same setting of powerful nodes in a network. Hence, the performance of the proposed system is better in terms of reliability and lifetime. Although we compared SEP-E with LEACH, there are many clustering algorithms that we have to compare and there are many factors that can affect the network lifetime.

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