

Multiparameter Based Energy Efficient Scheduling For Wireless Sensor Networks

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ABSTRACT: Wireless sensor networks have become increasingly popular due to their wide range of applications. Energy consumption is one of the biggest constraints of the wireless sensor node and this limitation combined with a typical deployment of large number of nodes has added many challenges to the design and management of wireless sensor networks. At high temperature the transmission power and sensitivity will decrease which leads to the degradation of wireless links. To avoid that we have implemented a hybrid routing protocol: Zonal-Stable Election Protocol (Z-SEP) for heterogeneous WSNs. In this protocol, some nodes transmit data directly to base station while some use clustering technique to send data to base station as in SEP. We implemented Z-SEP and compared it with traditional Low Energy Adaptive Clustering Hierarchy (LEACH) and SEP. In addition, that energy can be optimized by scheduling the node to sleep mode and alive mode. Simulation results showed that Z-SEP enhanced the stability period and throughput than existing protocols like LEACH and SEP.

KEYWORDS: Wireless sensor networks, connectivity, energy saving, heterogeneous networks, scheduling.

I. INTRODUCTION

Wireless sensor networks use low power transceivers to enable nodes to communicate at low energy cost. These transceivers are sensitive to temperature variations which affect both their transmission and reception capabilities. The effect of temperature has been validated independently by many researchers in the literature (e.g. [1] [2]), and documented in the data sheets of the low power radios (e.g. [3]). When temperature increases, both transmission power and sensitivity decrease which leads to the degradation of wireless communication links, and thus the overall connectivity of the network. As an example, a network designed to operate under typical conditions, i.e. a temperature of 25°C, will experience connectivity degradation when temperature increases above 25°C. Conversely, when temperature decreases below 25°C, wireless link quality improves, the network becomes over-dimensioned and some nodes can go to deep death mode without affecting the connectivity of the network.

Hierarchical scheduling protocols have been proved more energy efficient routing protocols. Several protocols are designed for homogeneous networks. LEACH [1] is one of the first clustered based routing protocols for homogeneous network. LEACH assigns same probability for all nodes to become cluster head. However, LEACH does not perform well in heterogeneous environment. Heterogeneity of nodes with respect to their energy level has also proved extra lifespan for WSNs. To improve efficiency of WSNs, SEP [2] was proposed. SEP is a two level heterogeneous protocol. SEP assigns different probability (to become cluster head) for nodes on the basis of their energy level. However, SEP does not use extra energy of higher level nodes efficiently. To send messages from nodes to base station we require minimum dissipation of energy. For such purpose a need of better routing protocol arises which should efficiently utilize energy. Classical approaches were insufficient to fulfil this demand. In this paper we have implemented a hybrid approach for transmitting data to base station. Some nodes send their data directly to base station and some uses clustering algorithm for transmitting data to base station. Our hybrid approach enhanced the stability period, network lifetime and also throughput of the network.

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Paper is organized as follows. Section I explains about the Stability and Throughput of the sensor networks, Problem faced by using Traditional algorithm, Section II includes the related work that about the traditional protocol such as LEACH, SEP and also different routing protocol used in WSN, Section III discusses about protocols such as Z-SEP and AR-MAC used for comparison with Traditional Protocols. Section IV shows the comparison of three different protocols for calculating the Stability and Throughput of the network and Packet error rate calculation for AR-MAC and 802.11.4. Section V includes the conclusion of the result.

II. RELATED WORK

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 a times more energy than the others. We refer to these powerful node as *advanced* nodes, and the rest $(1 - m) \times n$ as *normal* nodes. We assume that all nodes are distributed uniformly over the sensor field.

A. Clustering Hierarchy

We consider a sensor network that is hierarchically clustered. The LEACH (Low Energy Adaptive Clustering Hierarchy) protocol [6] maintains such clustering hierarchy. In LEACH, the clusters are re-established in each “round.” New cluster heads are elected in each round and as a result the load is well distributed and balanced among the nodes of the network. Moreover each node transmits to the closest cluster head so as to split the communication cost to the sink (which is tens of times greater than the processing and operation cost

Initially each node can become a cluster head with a probability p_{opt} . On average, $n \times p_{\text{opt}}$ nodes must become cluster heads per round per epoch. Nodes that are elected to be cluster heads in the current round can no longer become cluster heads in the same epoch. The non-elected nodes belong to the set G and in order to maintain a steady number of cluster heads per round, the probability of nodes $\in G$ to become a cluster head increases after each round in the same epoch. The decision is made at the beginning of each round by each node $s \in G$ independently choosing a random number in $[0, 1]$. If the random number is less than a threshold $T(s)$ then the node becomes a cluster head in the current round. The threshold is set as:

$$t(n) = \begin{cases} \frac{p}{1 - p \left(r \bmod \frac{1}{p} \right)}, & \text{if } n \in G \\ 0, & \text{if } n \notin G \end{cases} \quad (1)$$

Where r is the current round number. The election probability of nodes $\in G$ to become cluster heads increases in each round in the same epoch and becomes equal to 1 in the last round of the epoch. Note that by round we define a time interval where all clusters members have to transmit to the cluster head once. We show in this paper how the election process of cluster heads should be adapted appropriately to deal with heterogeneous nodes, which means that not all the nodes in the field have the same initial energy.

B. Optimal Clustering

Previous work have studied either by simulation [6, 7] or analytically [2, 3] the optimal probability of a node being elected as a cluster head as a function of spatial density when nodes are uniformly distributed over the sensor field. This clustering is optimal in the sense that energy consumption is well distributed over all sensors and the total energy consumption is minimum. Such optimal clustering highly depends on the energy model we use. For the purpose of this study we use similar energy model and analysis as proposed in [7].

According to the radio energy dissipation model illustrated in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an L -bit message over a distance d , the energy expended by the radio is given by:

$$E_{\text{Tx}}(L, d) = \begin{cases} L \cdot E_{\text{elec}} + L \cdot \epsilon_{\text{fs}} \cdot d^2, & \text{if } d < d_0 \\ L \cdot E_{\text{elec}} + L \cdot \epsilon_{\text{mp}} \cdot d^4, & \text{if } d \geq d_0 \end{cases} \quad (2)$$

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

C. Heterogeneous-Oblivious Protocols

The original version of LEACH does not take into consideration the heterogeneity of nodes in terms of their initial energy, and as a result the consumption of energy resources of the sensor network is not optimized. The reason is that LEACH depends only on the spatial density of the sensor network. Using LEACH in the presence of heterogeneity, and assuming both normal and advanced nodes are uniformly distributed in space, we expect that the first node dies on average in a round that is close to the round where the first node dies in the homogeneous case wherein each node is equipped with the same energy as that of a normal node in the heterogeneous case. Furthermore, we expect the first dead node to be a normal node. We also expect that in the following rounds the probability of a normal node to die is greater than the probability of an advanced node to die. During the last rounds only advanced nodes are alive. Our expectations are confirmed by simulation results in Section 5. We next demonstrate how such heterogeneous-oblivious clustering protocol fails to maintain the stability of the system, especially when nodes are heterogeneous.

i. SEP Protocol

In this section we describe SEP[13], which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α). In order to prolong the stable region, SEP attempts to maintain the constraint of well-balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. Note that the new heterogeneous setting (with advanced and normal nodes) has no effect on the spatial density of the network so the a priori setting of p_{opt} does not change. On the other hand, the total energy of the system changes. Suppose that E_0 is the initial energy of each normal sensor. The energy of each advanced node will be $E_0(1 + \alpha)$. The total energy of the new heterogeneous setting is equal to:

$$n \cdot (1 - m) \cdot E_0 + n \cdot m \cdot E_0 \cdot (1 + \alpha) = n \cdot E_0 \cdot (1 + \alpha \cdot m) \quad (3)$$

So, the total energy of the system is increased by $1 + \alpha \cdot m$ times. The first improvement to the LEACH is to increase the epoch of the sensor network in proportion to the energy increment. In order to optimize the stable region of the system, the new epoch must become equal to $\frac{1}{p_{opt}} \cdot (1 + \alpha \cdot m)$ because the system has $\alpha \cdot m$ times more energy and virtually $\alpha \cdot m$ more nodes (with the same energy as the normal nodes).

ii. Energy Consumption Constraints in the Stable Period

In this section we propose a solution, we call SEP (Stable Election Protocol), which is based on the initial energy of the nodes. This solution is more applicable compared to any solution which assumes that each node knows the total energy of the network in order to adapt its election probability to become a cluster head according to its remaining energy [5]. Our approach is to assign a weight to the optimal probability p_{opt} . This weight must be equal to the initial energy of each node divided by the initial energy of the normal node. Let us define as p_{norm} the weighted election probability for normal nodes and p_{adv} the weighted election probability for the advanced nodes.

Virtually there are $n \times (1 + \alpha \cdot m)$ nodes with energy equal to the initial energy of a normal node. In order to maintain the minimum energy consumption in each round within an epoch, the average number of cluster heads per round per epoch must be constant and equal to $n \times p_{opt}$. In the heterogeneous scenario the average number of cluster heads per round per epoch is equal to $n \cdot (1 + \alpha \cdot m) \times p_{norm}$ (because each virtual node has the initial energy of a normal node). The weighed probabilities for normal and advanced nodes are, respectively:

$$p_{norm} = \frac{p_{opt}}{1 + \alpha \cdot m} \quad (4)$$

$$p_{adv} = \frac{p_{opt}}{1 + \alpha \cdot m} \times (1 + \alpha) \quad (5)$$

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We replace p_{opt} by the weighted probabilities to obtain the threshold that is used to elect the cluster head in each round. We define as $T(S_{norm})$ the threshold for normal nodes and $T(S_{adv})$ the threshold for advanced nodes Thus, for normal nodes, we have

$$T(S_{norm}) = \begin{cases} \frac{p_{norm}}{1 - p_{norm} \cdot (r \bmod \frac{1}{p_{norm}})}, & \text{if } s_{norm} \in G^r \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

Where r is the current round. G^r is the set of nodes that have not become cluster heads within the last $\frac{1}{p_{norm}}$ rounds of the epoch, and is the threshold applied to a population of $n \cdot (1 - m)$ (normal) nodes. This guarantees that each normal node will become a cluster head exactly once every

$\frac{1}{p_{opt}} \cdot (1 + \alpha \cdot m)$ Rounds per epoch, and that the average number of cluster heads per round per epoch is equal to $n \cdot (1 - m) \times p_{norm}$. similarly, for advanced nodes, we have:

$$T(S_{adv}) = \begin{cases} \frac{p_{adv}}{1 - p_{adv} \cdot (r \bmod \frac{1}{p_{adv}})}, & \text{if } s_{adv} \in G^r \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

Where G is the set of nodes that have not become cluster heads Within the last $\frac{1}{p_{adv}}$ rounds of the epoch, and $T(S_{adv})$ is the threshold applied to a population of $n \cdot m$ (advanced) nodes. This guarantee that each advanced node will become a cluster heads exactly once every $\frac{1}{p_{opt}} \cdot \frac{1 + \alpha \cdot m}{1 + \alpha}$ round. Let us define this period as sub-epoch. It is clear that each epoch

(let us refer to this epoch as “heterogeneous epoch” in our heterogeneous setting) has $1 + \alpha$ sub-epochs and as a result, each advanced node becomes a cluster head exactly $1 + \alpha$ times within a heterogeneous epoch. The average number of cluster heads per round per heterogeneous epoch (and sub-epoch) is equal to $n \cdot m \times p_{adv}$.

The average number of cluster heads per round per heterogeneous epoch is equal to the average number of cluster heads that are normal nodes per round per heterogeneous epoch plus the average number of cluster heads that are advanced nodes per round per sub-epoch. This average number is given by:

$$n \cdot (1 - m) \times p_{norm} + n \cdot m \times p_{adv} = n \times p_{opt} \quad (8)$$

Which is the desired number of cluster heads per round per epoch.

III. IMPLEMENTED ARCHITECTURE

A. Z-SEP Protocol

Zonal-Stable Election Protocol (Z-SEP) for heterogeneous WSNs. In this protocol, some nodes transmit data directly to base station while some use clustering technique to send data to base station as in SEP. We implemented Z-SEP and compared it with traditional Low Energy adaptive clustering hierarchy (LEACH) and SEP. Simulation results showed that Z-SEP enhanced the stability period and throughput than existing protocols like LEACH and SEP.Z-SEP uses two techniques to transmit data to base station. They are direct communication and Transmission via Cluster head[16].

i. Direct Communication

Nodes in Zone 0 send their data directly to base station. Normal nodes sense environment gathers data of interest and send it data directly to base station.

ii. Transmission via Cluster head

Nodes in Head zone 1 and Head zone 2 transmit data to base station through clustering algorithm. Cluster head is selected among nodes in Head zone 1 and Head zone 2. Cluster head collect data from member nodes, aggregate it and transmit it to base station. Cluster head selection is most important. Advance nodes are deployed randomly in Head zone 1 and Head zone 2. Cluster is formed only in advance nodes. Assume an optimal number of clusters k_{opt} and n is the number of advance nodes. According to SEP optimal probability of cluster head is

$$p_{opt} = \frac{k_{opt}}{n} \quad (9)$$

Every node decides whether to become cluster head in current round or not. A random number between 0 and 1 is generated for node. If this random number is less than or equal threshold $T(n)$ for node then it is selected as cluster head. Threshold $T(n)$ is given by

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$$T(s) = \begin{cases} \frac{p_{adv}}{1 - p_{adv} \left(r \bmod \frac{1}{p_{adv}} \right)}, & \text{if } s \in G \\ 0, & \text{otherwise} \end{cases} \quad (10)$$

Where G is the set of nodes which have not been cluster heads in the last $\frac{1}{p_{adv}}$ rounds. Probability for advance nodes to become cluster head is proposed in [2] which is

$$p_{adv} = \frac{p_{adv}}{1 + \alpha} \times (1 + \alpha) \quad (11)$$

Once the cluster head is selected then the cluster head broadcasts an advertisement message to the nodes. The nodes receive the message and decide to which cluster head it will belong for the current round. This phase is called as cluster formation phase. On the basis of received signal strength, nodes respond to cluster head and become member of cluster head. Cluster head then assign a TDMA schedule for the nodes during which nodes can send data to cluster head. After the clusters formation, every node data and sends it to the cluster head in the time slot allocated by the cluster head to the node. When data is received from nodes, Cluster head then aggregates this data and send it to the base station this phase is called as *transmission phase*. The reason why normal nodes (deployed in Zone 0) do not form cluster is because energy of normal node is less than advance node, and cluster head consumes more energy than cluster members in receiving data from cluster members.

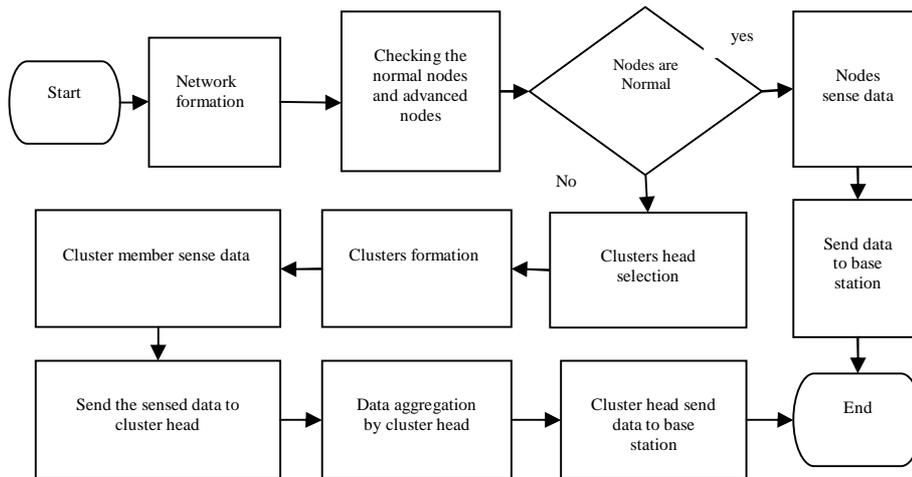


Fig 1: Flow chart of Z-SEP

IV. SIMULATION RESULTS

We compare the results of our protocol with SEP and LEACH. We have introduced heterogeneity in LEACH, with the same setting as in our proposed protocol, so as to access the performance of all the protocol in presence of heterogeneity.

Our goals in conducting simulation are

- To examine the stability period of LEACH, SEP and Z-SEP.
- We also examine the throughput of LEACH, SEP and Z-SEP.

SEP has weighted probability for selection of cluster head for both normal nodes and advance nodes. Z-SEP performs better than LEACH and SEP, because nodes in Zone 0 (normal nodes) communicates directly to base station while nodes in head zone 1 and head zone 2 communicates via cluster head to base station, As in clustering technique, cluster head consumes energy in the form of data aggregation and also by receiving data from nodes in the cluster. So this

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energy is conserved in normal nodes as they do not have to aggregate data and receive data from other nodes, so energy is not dissipated as that of cluster head, resulting the increase of stability period.

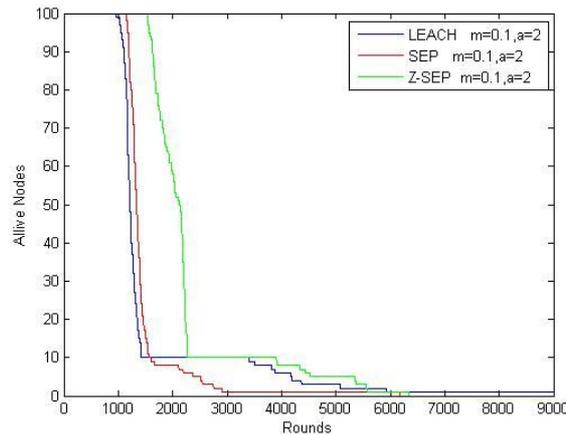


Fig 2: Alive nodes in LEACH, SEP and Z-SEP

In Figure.3, we can see that network lifetime is also increased because of the advance node. Advance nodes have α time more energy than normal nodes so advance nodes die later than normal nodes. So this increases the instability period. In Figure.4, shows the number of alive nodes against rounds. Figure.4 clearly shows that our protocol is enhanced from SEP and LEACH in terms of stability SEP has weighted probability for selection of cluster head for both normal nodes and advanced nodes In Fig.5, we can see that throughput of Z-SEP is far better than LEACH and SEP because every normal directly send data to base station. throughput of LEACH and SEP is less than Z-SEP because only cluster head send data to base station Fig.3 and Fig.4 shows result for the case when $m=0.1$ and $\alpha=1$. This means that there are 20 advance nodes out of total nodes which are 100. According to our proposed protocol 10 advance nodes will be deployed randomly

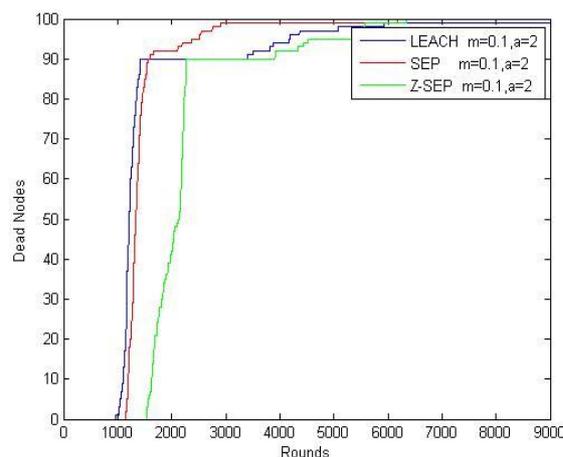


Fig 3: Dead nodes in LEACH, SEP and Z-SEP

Fig.2 shows the number of alive nodes against rounds. Fig.2 clearly shows that our protocol is enhanced from SEP and LEACH in terms of stability. As LEACH is very sensitive to heterogeneity so nodes die at a faster rate. SEP performs better than LEACH in two level heterogeneity, because SEP has weighted probability for selection of clusters.

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The reason behind is that normal nodes have same amount of energy, they consume same amount of energy and they die almost at the same time as before, however network lifetime is increased because of the extra energy of advance nodes. Stability period of LEACH is decreased because LEACH is very sensitive to heterogeneity. LEACH does not have weighted probability as in SEP for even distribution of extra energy. In LEACH every node has equal chance to become cluster head so normal nodes die sooner than advance nodes. Fig. 5 shows the throughput of LEACH, SEP and Z-SEP. Throughput of Z-SEP is greater than LEACH and SEP although energy of advance node has been increased.

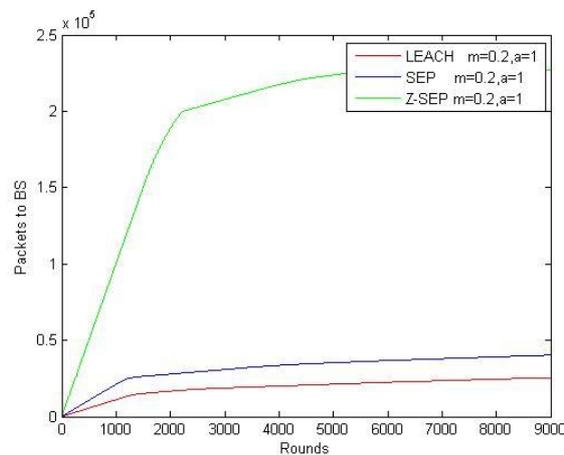


Fig 4: Throughput of LEACH, SEP and Z-SEP

V. CONCLUSION

In this paper, we proposed Z-SEP for heterogeneous environment: two level heterogeneity. Normal nodes are to reduce the energy consumption and they transmit data directly to base station. Half of advanced nodes are uses clustering technique to transmit data to base station. Results have shown that the stability period is increased approximately 50%, by just altering the deployment of the different type of nodes in different zones according to their energy requirement. Throughput of Z-SEP is also increased compared with LEACH and SEP.

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