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# Improved Stable Election Protocol for Heterogeneous Wireless Sensor Network

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**Abstract:** ***In this paper the impact of heterogeneity of nodes, in terms of their energy, in wireless sensor networks that are studied. In these networks some of the nodes become cluster heads, aggregate the data of their cluster members and transmit it to the sink. It is assume that a percentage of the population of sensor nodes is equipped with additional energy resources—this is a source of heterogeneity which may result from the initial setting or as the operation of the network evolves. Here the sensors are randomly (uniformly) distributed and are not mobile, the coordinates of the sink and the dimensions of the sensor field are known. Classical clustering protocols assume that all the nodes are equipped with the same amount of energy and as a result, they cannot take full advantage of the presence of node heterogeneity. In this paper I-SEP, a new reactive protocol is introduced with three levels of heterogeneity which prolongs 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. By employing simulation ISEP always prolongs the stability period and network lifetime compared to the one obtained using current clustering protocols.***

**Keywords:** Clustering ,Heterogeneous network, Stability Period, Network Lifetime and Throughput

## 1. Introduction

Advancements in technology leading to a move from wired to wireless domain. Wireless Sensor Networks are networks of tiny, battery powered sensor nodes with limited on-board processing, storage and radio capabilities. Nodes sense and send their reports toward a processing center which is called "sink". The design of protocols and applications for such networks has to be energy aware in order to prolong the lifetime of the network, because the replacement of the embedded batteries is a very difficult process once these nodes have been deployed. WSN must operate without human involvement so the main focus is to increase network life in any way and for this purpose many protocols are introduced. Routing protocols can be classified on the basis of their applications into following two categories:

***a. Proactive Routing Protocols**:* Nodes in network provide a continuous report of data, nodes keep on sensing, turn on their transmitters and transmit, so suitable for applications where information on regular basis is required.

***b. Reactive Routing Protocols:*** Nodes sense data continuously however, transmit only at the time when there is a drastic change in sensed value, so, reactive networks are suitable for time critical applications.

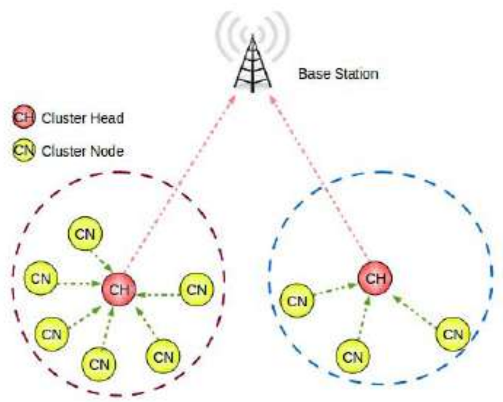



**Figure 1:** Cluster formation of WSN.

## 2. Performance Measures

Here in this paper the measures of evaluating the performance of clustering protocols are as follows .

***Stability Period:*** *It* is the time interval from the start of network operation until the death of the first sensor node. This is also refers to as "stable region."

***Instability Period:*** *It* is the time interval from the death of the first node until the death of the last sensor node.

***Network lifetime:*** *It* is the time interval from the start of operation (of the sensor network) until the death of the last alive node.

***Throughput:*** The measure of total rate of data sent over the network, the rate of data sent from cluster heads to the sink as well as the rate of data sent from the nodes to their cluster heads.

**Epoch:** Number of rounds after which a node becomes eligible for cluster head.

**Data Aggregation:** Data collected in sensors are derived from common phenomena so nodes in a close area usually share similar information. A way to reduce energy consumption is data aggregation. Aggregation consists of suppressing redundancy in different data messages. When the suppression is achieved by some signal processing techniques, this operation is called data fusion.

## 3. Related work and Motivation

Classical approaches like Direct Transmission and Minimum Transmission Energy do not guarantee well balanced distribution of the energy load among nodes of the sensor network. Using Direct Transmission (DT), sensor nodes transmit directly to the sink, as a result nodes that are far away from the sink would die first. On the other hand, using Minimum Transmission Energy (MTE), data is routed over minimum-cost routes, where cost reflects the transmission power expended. Under MTE, nodes that are near the sink act as relays with higher probability than nodes that are far from the sink. Thus nodes near the sink tend to die fast. Under both DT and MTE, a part of the field will not be monitored for a significant part of the lifetime of the network, and as a result the sensing process of the field will be biased. A solution proposed in [4], called LEACH, guarantees that the energy load is well distributed by dynamically created clusters, using cluster heads dynamically elected according to a priori optimal probability. Cluster heads aggregate reports from their cluster members before forwarding them to the sink. By rotating the cluster-head role uniformly among all nodes, each node tends to expend the same energy over time. LEACH-type schemes are obtained assuming that the nodes of the sensor network are equipped with the same amount of energy—this is the case of *homogeneous* sensor networks. In this paper the impact of heterogeneity in terms of node energy is taken.

### A. Low Energy Adaptive Clustering Hierarchy (LEACH)

Heinzelman, et. al. [2] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead. During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs as follows. A sensor node chooses a random number, r, between 0 and 1. If this random number is less than a threshold value, T(n), the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G. It is given by:

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \quad if\ n \in G$$

Where G is the set of nodes that are involved the CH election.

### B. Stable Election Protocol (SEP)

As described in [4], heterogeneity is introduced in SEP protocol, which is based on two levels of heterogeneity. A fraction $m$ of total $n$ nodes is provided with an additional energy factor $\alpha$, which are called advanced nodes. So, probabilities of normal nodes and advanced nodes to become CHs are $pnrm = popt /1+m.\alpha$ and $padv = popt.(1+\alpha)/1+m.\alpha$ respectively, where $popt$ is the optimal probability of each node to become CH. CHs election in SEP is done randomly on the basis of probability of each type of node as in LEACH. Nodes sense data and transmit it to associated CH which convey it to BS. By increasing $m$ or $padv$, we can further improve our system. So, SEP results in increased stability period and network life due to advance nodes however two levels heterogeneity also caused increased throughput. In SEP normal nodes and advance nodes are deployed randomly. If majority of normal nodes are deployed far away from base station it consumes more energy while transmitting data which results in the shortening of stability period and decrease in throughput.

### C. Z-SEP Protocol

Z-SEP uses two techniques to transmit data to base station. Techniques are:

a. Direct communication.

b. Transmission via Cluster head.

**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.

**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. As shown in Fig.1 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 *Kopt* and *n* is the number of advance nodes. According to SEP optimal probability of cluster head is

$$Popt = \frac{Kopt}{n}$$

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

$$T(n) = \begin{cases} \dfrac{Popt}{1 - Popt\left(r \times mod \dfrac{1}{Popt}\right)} & if\ n \in G \\ 0 & otherwise \end{cases}$$

Where G is the set of nodes which have not been cluster heads in the last 1/Popt rounds. Probability for advance nodes to become cluster head is proposed in [2] which is

$$Padv = \frac{Popt}{1 + (\alpha.m)} \times (1 + \alpha)$$

accordingly the threshold for advance nodes is

$$T(adv) = \begin{cases} \frac{Padv}{1 - Padv\left(r \times \bmod \frac{1}{Padv}\right)} & \text{if } adv \in G' \\ 0 & \text{otherwise} \end{cases}$$

G' is the set of advance nodes that have not been cluster head in the last 1/ Padv rounds .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.

## 4. Proposed ISEP Protocol

In this section we describe our new protocol ISEP (Improved Stable Election Protocol) which has two main features: "It is reactive routing protocol", as transmission consumes more energy than sensing and it is done only when a specific threshold is reached and "Three levels of heterogeneity" .To describe whole protocol clearly we particularly discuss about energy model and how optimal number of clusters can be computed. For three levels of heterogeneity, nodes with different energy levels are:
1) Normal Nodes
2) Intermediate Nodes
3) Advance Nodes

Advance nodes having energy greater than all other nodes, intermediate nodes with energy in between normal and advance nodes while remaining nodes are normal nodes. Intermediate nodes can be chosen by using $b$, a fraction of nodes which are intermediate nodes and using the relation that energy of normal nodes is $\mu$ times more than that of normal nodes. In SEP energy for normal nodes is $Eo$, for advance nodes it is $EADV = Eo(1+\alpha)$ and energy for intermediate nodes can be computed as $EINT = Eo(1 + \mu)$, where $\mu = \alpha/2$ .So total energy of normal nodes, advance nodes and for intermediate nodes will be, $n.b(1 + \alpha)$, $nEo.(1 - m - bn)$,and $n.m.Eo.(1 + \alpha)$ respectively. So, the total Energy of all the nodes will be, $nEo.(1-m-bn) + n.m.Eo.(1 + \alpha) + n.b.(1 + \mu) = n.Eo(1 + m\alpha + b\mu)$. Where, $n$ is number of nodes $m$ is proportion of advanced nodes to total number of nodes $n$ with energy more than rest of nodes and $b$ is proportion of intermediate nodes. The optimal probability of nodes, which are divided on the basis of energy, to be elected as a CH can be calculated by using following formulas:

$$p_{nrm} = \frac{p_{opt}}{1 + m.\alpha + b.\mu}$$

$$p_{int} = \frac{p_{opt}.(1 + \mu)}{1 + m.\alpha + b.\mu}$$

$$p_{adv} = \frac{p_{opt}.(1 + \alpha)}{1 + m.\alpha + b.\mu}$$

Now to ensure that CH selection is done in the same way as we have assumed, we have taken another parameter into consideration, which is threshold level. Each node generates randomly a number inclusive of 0 and 1, if generated value is less than threshold then this node becomes CH [1], [12]. For all these type of nodes we have different formulas for the calculation of threshold depending on their probabilities, which are given below:

$$T_{nrm} = \begin{cases} \frac{p_{nrm}}{1 - p_{nrm}[r.mod\frac{1}{p_{nrm}}]} & \text{if } n_{nrm} \epsilon G' \\ 0 & \text{otherwise} \end{cases}$$

$$T_{int} = \begin{cases} \frac{p_{int}}{1 - p_{int}[r.mod\frac{1}{p_{int}}]} & \text{if } n_{int} \epsilon G'' \\ 0 & \text{otherwise} \end{cases}$$

$$T_{adv} = \begin{cases} \frac{p_{adj}}{1 - p_{adv}[r.mod\frac{1}{p_{adv}}]} & \text{if } n_{adv} \epsilon G''' \\ 0 & \text{otherwise} \end{cases}$$

$G'$, $G''$ and $G'''$ are the set of normal nodes, intermediate nodes and set of advanced nodes that has not become CHs in the past respectively

The CH broadcasts the following parameters

- **Report Time (TR):** Time period during which reports are being sent by each node successively
- **Attributes (A):** The physical parameters about which information is being sent.
- **Hard Threshold (HT):** An absolute value of sensed attribute beyond which node will transmit data to CH. As if sensed value becomes equal to or greater than this threshold value, node turns on its transmitter and sends that information to CH.
- **Soft Threshold (ST):** The smallest sensed value at which the nodes switch on their transmitters and transmit. All nodes keep on sensing environment continuously. As parameters from attribute set reaches hard threshold value, transmitter is turned on and data is transmitted to CH, however this is for the first time when this condition is met. This sensed value is stored in an internal variable in the node, called Sensed Value (SV). Then for second time and the other, nodes will transmit data if and only if sensed value is greater than hard threshold value or if difference between currently sensed value and the value stored in SV variable is equal to or greater than soft threshold. So, by keeping these both thresholds in consideration, number of data transmissions can be reduced, as transmission will only take place when sensed value reaches hard threshold. And further transmissions are lessened by soft threshold, as it will

eliminate transmissions when there is a small change in value, even smaller than interest. Some of important features are described below:

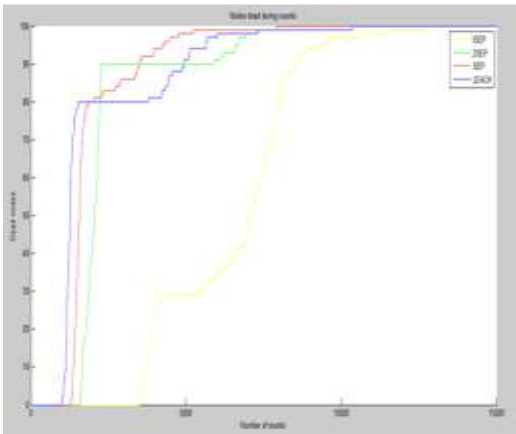
1) Time critical data reaches the user almost instantaneously.
2) Nodes keep on sensing continuously but transmission is not done frequently, so energy consumption is much more less than that of proactive networks.
3) At time of cluster change, values of soft threshold, TR and A are transmitted afresh and so, user can decide how often to sense and what parameters to be sensed according to the criticality of sensed attribute and application.
4) The user can change the attributes depending on requirement, as attributes are broadcasted at the cluster change time

## 5. Simulation and Discussions

For performance evaluation we used MATLAB .Our goals in doing simulations was to compare performance of ISEP with SEP, ZSEP and LEACH protocols on the basis of energy dissipation and longevity of network. A network consisting of 100 nodes, placed randomly in a region of MxM and a BS located in the center is considered. We performed simulations for different values of $\alpha$ and $m$ while keeping $b$ constant that is 0.3. For the first case $\alpha$ = 1,m = 0.1 , for second case $\alpha$ = 3 and $m$ = 0.2. This is done to observe change in network's stability, life and throughput relative to increase in number of advance nodes and their energies. Since $popt$ = 0.1, is the optimal probability of CHs.

**Table 1:** Parameters Settings

| Parameters | Value |
| --- | --- |
| $E_{elect}$ | 50nJ/bit |
| $E_{DA}$ | 5nJ/bit/message |
| $\epsilon_{fs}$ | 10pJ/bit/$m^2$ |
| $\epsilon_{mp}$ | 0.0013pJ/bit/$m^4$ |
| $E_o$ | 0.5J |
| $K$ | 4000 |
| $P_{opt}$ | 0.1 |
| $n$ | 100 |
| $\alpha$ | 1 |
| $m$ | 0.1 |



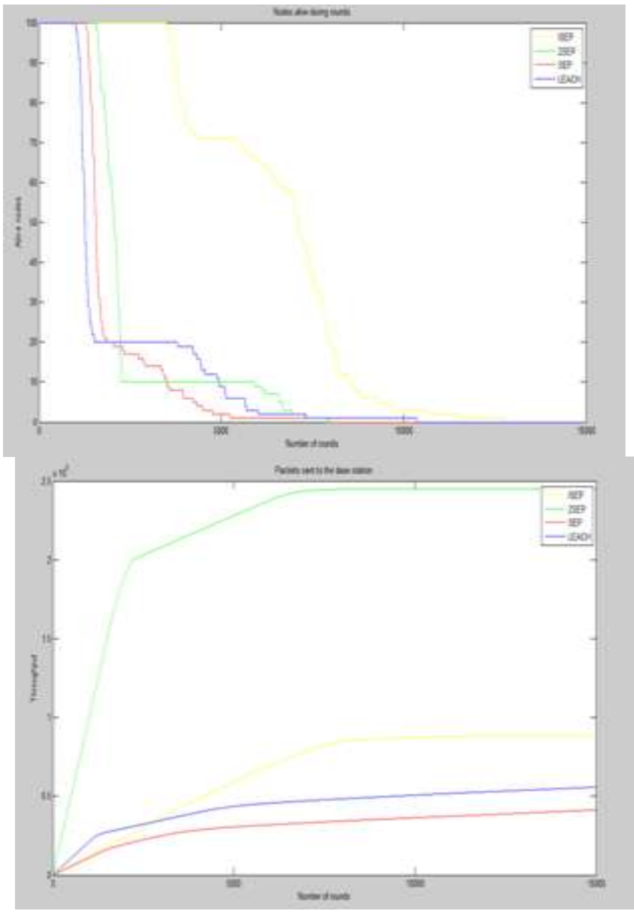
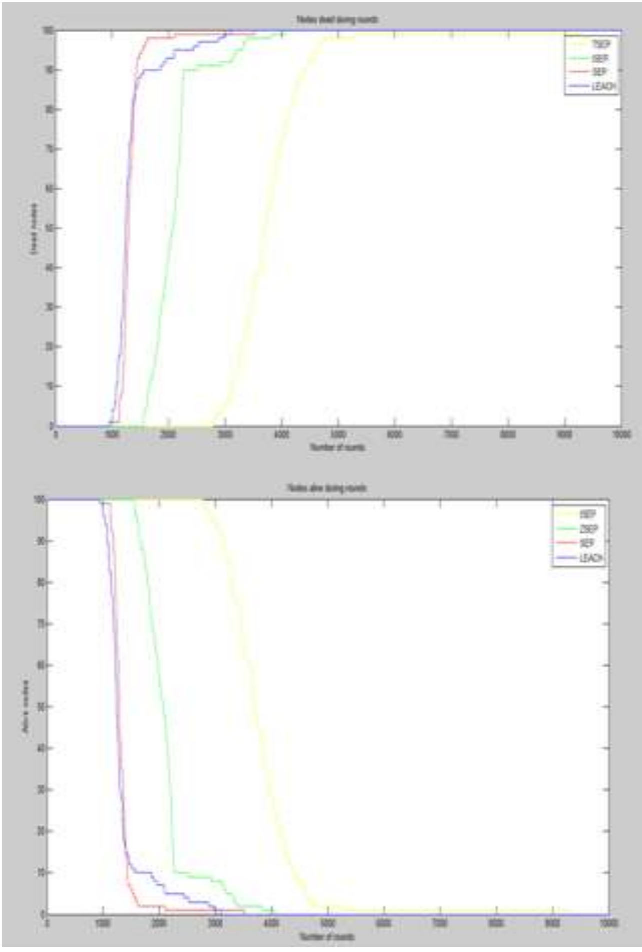


**Figure 2:** Simulations for Number of Dead nodes , Number of Alive nodes and Throughput when m=0.2 and a=3.



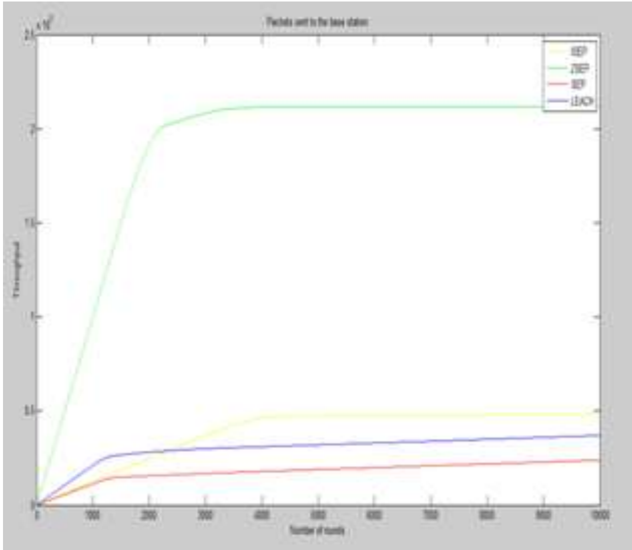


**Figure 3:** Simulations for Number of Dead nodes, Number of Alive nodes and Throughput when m=0.1 and a=1.

Fig.2 and Fig.3 show comparison of protocols LEACH, SEP, ZSEP and ISEP regarding alive and dead nodes, relative to number of rounds It is observed that in ISEP, stability period is greater than all other protocols discussed. As it is threshold based protocol and here transmission is done at only some certain conditions. Nodes keep on sensing and so energy consumption is less than other protocols resulting in increased stability period and network life. The newly proposed protocol ISEP also being threshold based protocol with an additional feature of three levels of heterogeneity results in increased stability period ,Throughput and network life even greater than that of ZSEP.

By performing simulations in MATLAB ,it is observed that:

a) ISEP has enhanced stability period than all other protocols. This is shown in Fig.2, Fig.3 . The network life for ISEP was increased as compared to others.
b) Increase and decrease in number of alive and dead nodes respectively.
c) *C.* Increased throughput due to three level heterogeneity and decrease in throughput due to threshold sensitivity as can be observed in Fig.2, Fig.3.

## 6. Conclusions

In this paper ISEP, reactive routing protocol is proposed where nodes with three different levels of energies. CHs selection is threshold based, due to three levels of heterogeneity and being reactive routing network protocol, it causes increase in stability period and network life. In comparison with ZSEP, L SEP and LEACH it can be concluded that ISEP protocol will perform well in small as well as large sized networks.

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