Efficient Energy Optimization Protocol for Heterogeneous Wireless Sensor Networks Relying on Node Energy: A Review

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Abstract— **Wireless sensor networks (WSNs) are the technology that is expanding at the fastest rate, and its uses range from monitoring the environment to predicting the flow of traffic to listening in on conversations to research and academic fields. The haphazard placement of sensor nodes in a wireless environment has led to the emergence of security metrics as the most promising challenge that communication wireless networks must face today.**

Stable election protocol, also known as SEP, is an updated version of the Low Energy Adaptive Clustering Hierarchy algorithm. Its purpose is to maximize the life cycle of heterogeneous wireless sensor networks, also known as WSNs (LEACH). On the other hand, the lifetime would be shortened due to the disparity in the amount of energy consumed by cluster heads and nodes. Include node energy in the election of the cluster head to decrease the amount of energy that is consumed by the cluster head. On the other hand, reduce the amount of energy that is consumed by individual nodes in the cluster through the use of indirect transmission by intermediate nodes. SEP is a heterogeneous-aware protocol that extends the time interval before the first node dies (what we call the stability period). This is essential for many applications in which the output from sensor networks needs to be reliable. The SEP is calculated based on the weighted election probability of each node to become the cluster head, which vary according to the amount of energy that each node still possesses. When the LEACH protocol and the SEP protocol were compared to the enhanced Efficient-SEP protocol using the algorithm that was suggested by MATLAB, the results revealed that the enhanced E-SEP protocol works well in balancing the energy consumption to improve the lifetime. This was determined by looking at how well the enhanced E-SEP protocol compared to the other protocols.

Index Terms— Heterogeneous wireless sensor networks, Stable Election Protocol (SEP), Clustring, election probability

I. INTRODUCTION

Wireless sensor networks, often known as WSNs, have recently attracted a lot of attention as a potential new application field for ad hoc networks. WSNs are constructed from a collection of sensor nodes that are characterized by their multifunctionality, low power consumption, and low cost in addition to their capacity for wireless processing and communication. These sensors collaborate to achieve a common objective, such as environmental monitoring, the tracking of targets, and the management of industrial processes [1], and they do so by communicating with one another over a short distance utilizing a wireless medium. The plan is to use a collection of affordable, small fixed sensors to sense the various physical features of the environment, and then to send those findings to a node that will act as a sink [2]. Despite the wide variety of uses for WSNs, their fundamental purpose is to collect data, then process that data, and then transmit the processed data to a particular node (base station or sink). Due to the increasing computing capacity of WSN technology, it is imperative that these sensor nodes be better equipped to handle more complex functions. Challenges pertaining to energy conservation, sensor node coverage, and dependability are tackled during the installation of a base station in a sensor network. In most cases, it is considered that base stations are stationary; however, in certain scenarios, it is expected that base stations are mobile in order to collect data from sensor nodes. The LEACH [3] protocol is a Low-Energy Adaptive Clustering Hierarchy protocol, and it is considered to be an established method in the field of clustered routing protocols. It is clustered based on the signal strength that was received by the node, and the cluster head node is chosen in a random loop so that the energy consumption of the nodes within the network may be maintained at a consistent level. A procedure that is aware of heterogeneity and is called the Stable Election Protocol (SEP) was proposed in [4]. It is calculated using the individual energies of each node, which are then used to weight the election possibilities of each node to become the cluster leader. This method ensures that cluster heads are chosen at random and distributed according on the fraction of energy utilized by each node, so ensuring that the energy from the nodes is used in an even-handed manner.

The SEP [4] algorithm is a form of LEACH-based heterogeneous network clustering routing technique. [LEACH] stands for "Local Extensible Abstract Computing Environment." The SEP algorithm uses an energy heterogeneous approach. This approach involves increasing the likelihood of high-level nodes becoming cluster heads based on the beginning energy of distinct sets of different cluster election probabilities. This ensures that high-level nodes and ordinary nodes pass away at the same time. However, the SEP algorithm still has an unequal distribution of cluster heads, a large number of nodes in the cluster, and does not take into account the residual energy of the nodes. There is much potential in clustering as a method for increasing the lifetime of WSNs. At this time, I would like to investigate a different, more effective technique that is based on the Improved-SEP procedure and other enhancement procedures that are analogous to it.

The remaining parts of the paper are organized as described below. Following an examination of the relevant literature in Section II, the focus then shifts to a comprehensive discussion of LEACH in Section III. The Section V Efficient SEP Concept was explained in the previous section (IV SEP). The last part of the paper, Section VI, is where it all wraps up.

II. Literature Review

A literary survey involves the examination of historical material and the generation of a combination of new and historical information. As a consequence of this, this section includes a concise explanation of a number of different research studies, in addition to a research paper summary and a research paper synthesis.

The authors Smaragdakis and Smaragdakis [5] are famous for a LEACH variation that they name the Stable Election Protocol (SEP). It is designed to function primarily for dual-level heterogeneous networks that have doublet types of sensors (particularly Advance and normal nodes). When compared to conventional nodes, advance sensors typically have a higher energy retention rate and necessitate more frequent CH rotations. The CHs that have been selected in this instance make reference to the beginning energy of the sensor. The fact that the choice made by the CH is static is the most significant disadvantage. Because of this, advanced nodes that are located a significant distance from the sink expends their energy at a faster rate, and they eventually cease to exist. SEP is useless when applied to a heterogeneous network with multiple layers.

According to Malluh et al. [6,] there has been an improvement made to SEP, additionally, more often than normal sensors, sophisticated nodes are picked to serve as CHs. Additionally taken into consideration is the total number of nodes that are connected to each CH. As a consequence of this, the sensor nodes are able to be dispersed uniformly among all of the CHs. If there is more than one sensor that can be a CH during a particular round, EM-SEP will select the sensor with the highest available energy to serve in that capacity. The stability time of the sensor network is increased thanks to these two components. This tactic's most significant drawback is that it makes no allowance for the cost of maintaining communication between different clusters.

The Stable Election Protocol, also known as SEP, is a heterogeneous-aware protocol that was proposed by Georgious et al. [7] with the intention of extending the stability period and increasing the average throughput. The SEP is calculated using the energy-weighted election probability of the nodes as a function of their residual energy. On the basis of their energy levels, nodes are separated into two distinct categories: ordinary nodes and advanced nodes. The energy that is produced by advanced nodes is greater than that which is produced by regular nodes. Standard nodes have a lower likelihood of becoming cluster heads compared to advanced nodes, which have a larger possibility.

In reference number [7], a heterogeneous aware procedure known as the Stable Election Protocol (SEP) was proposed. It is calculated using the individual energies of each node, which are then used to weight the election possibilities of each node to become the cluster leader. This method ensures that cluster heads are chosen at random and distributed according on the fraction of energy utilized by each node, so ensuring that the energy from the nodes is used in an even-handed manner. The SEP performed an analysis on two different kinds of nodes (two layer in-clustering), as well as two different levels of hierarchies. In a heterogeneous wireless sensor network (WSN), the LEACH [8] protocol, which maintains the Integrity of the Specifications in the same way as a typical clustering approach does, performs very poorly.

The LEACH protocol is the foundation for the SEP protocol [9], which differs from LEACH in that it provides variable electoral cluster head probability for nodes that have varying energy levels and functions more well in a heterogeneous WSN than LEACH does. However, on the one hand, SEP does not adjust the cluster head election probability in real time based on the node's residual energy, which causes some nodes to become cluster heads prematurely, thereby reducing their lifetime; on the other hand, nodes in the cluster transfer information directly to the cluster head, storing a problem that the energy consumption of the edge nodes is far off the mark. In addition to this, the transmission path that connects the cluster head and the base station needs to be optimized.

The paper [10] demonstrates the effectiveness of the SEP protocol in heterogeneous WSN. It also demonstrates the limitations of the unbalanced energy consumption in cluster nodes and the inflexibility of the cluster head election mechanism. Both of these problems can be found in the paper. In the paper [12], greedy routing is used to tackle the problem of the most energy-efficient way for the transmission of information from the cluster head to the base station. This results in a decrease in the amount of energy that is utilized.

III. LEACH Schemes

The Low-Energy Adaptive Clustering Hierarchy [11] is one of the clustering methods that is used for WSN the most frequently. It is a design that has been customized to work with a particular application. Nodes participate in LEACH by forming local clusters, with one node acting as the leader of each cluster and the other nodes participating as member nodes. When the cluster head gets data from all of the member nodes, it processes the data using signal processing tasks (for example, data aggregation) and then transmits the processed data to the remote BS. As a consequence of this, the amount of energy required to maintain a position as a CH node is noticeably higher than that of a member node.

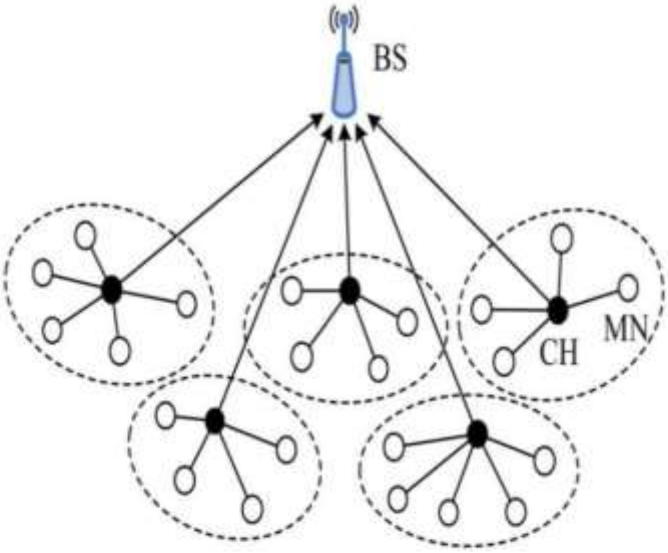

Figure 1: LEACH System

The primary objective of LEACH is to apply rotation in order to choose sensor nodes as cluster heads. As a consequence of this, the energy load associated with serving as a cluster head is distributed uniformly among all of the nodes. The operation of LEACH is divided into different rounds. In each round, there is a set-up phase that comes before the steady state phase. During the phase known as "setup," clusters are organized, and during the phase known as "steady-state," data is transmitted to the BS. In the beginning, CH is selected on the basis of the signal energy of the nodes [13].

The nodes in the CH hierarchy that have the highest energy are selected. Each sensor node n generates a random number between 0 and 1 and then evaluates that number in relation to a threshold T that has been previously established (n). In that round, the sensor node will become CH if random T(n) is true; otherwise, it will remain a member node. Where P is the desired proportion of CHs, r is the current round, and G is the set of nodes that have not been elected as CHs in the past 1/ P rounds, G represents the set of nodes. LEACH is a mechanism that is entirely decentralized and does not call for any global knowledge regarding the network. Not only can LEACH guarantee that every node in the network has the same probability as CH, but it can also make sure that the energy consumption of the network nodes is about equivalent. The LEACH display process is illustrated here in Figure 2, which may be found below.

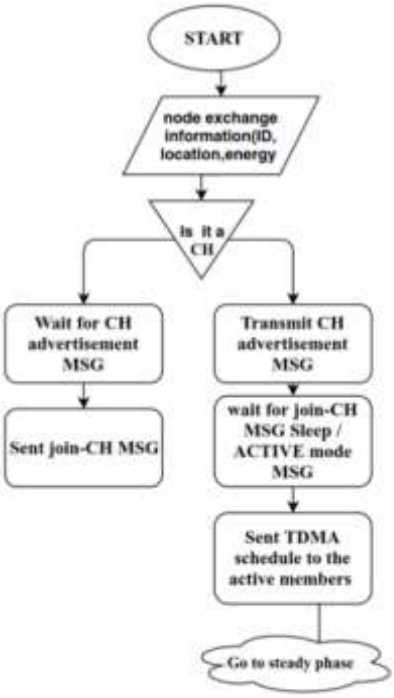

Figure 2: LEACH Protocol Process

IV. Analysis of SEP Algorithm

The SEP [12] method is a conventional heterogeneous network clustering routing approach that was proposed by G. Maragdakis. This agreement is constructed using the second energy heterogeneous network and the LEACH protocol. The initial energy isomorphism of this element is also included in the construction of this agreement. On the basis of their varied qualities, the network is divided into ordinary nodes and high-level nodes, and each type of node possesses a unique cluster election probability. The cluster election probability of high-level nodes is greater than that of ordinary nodes. In order to ensure that high-level nodes and normal nodes pass away at approximately the same time, thereby extending the stable cycle of the network.

Common nodes and advanced nodes are the two categories of energy nodes that are included in the SEP routing protocol, which is a two-level initial energy heterogeneous WSN cluster protocol. The primary concept behind the SEP protocol is to first determine the cluster head election probability of individual nodes depending on the amount of energy they started with, and then to change the cluster head nodes in a manner that is random each round. Because of this, all of the sensor nodes are able to share the load on the network, which helps to reduce the amount of power that is lost while also extending the lifetime of the network.

A. Cluster Establishment Stage

It is presumed that there are initially n nodes, which are then categorized as either common or advanced nodes depending on their level of complexity. Within the network of nodes, the optimal cluster head ratio is denoted by P_{otp}. E_0 represents the starting energy level of the common node. The energy of the advanced node is (1+α) times that of the common node, which is one and a half times (1+α) E_0.

Since the overall node fraction of the advanced node is m, the following expression can be used to calculate the total energy of the entire heterogeneous WSN: [9]

$$n(1-m) E_0 + nm (1+\alpha) E_0 = n(1+m\alpha) E_0 \qquad (1)$$

As a result of their responsibility for coordinating activities taking place across clusters and transmitting data to base stations, cluster leaders have a higher energy demand than other members of the network. As a consequence of this, the relevant cluster head is rotated continuously; this maintains the consistent level of energy consumption required by the SEP protocol. Each node makes its own determination, based on the computing likelihood, as to whether or not it has a chance of being a cluster head in the current wheel. Every sensor node will select a value at random from the range [0 1] and then compare that value to the T(i) threshold. If the value is lower than T(i), then the node has a chance of being elected as the cluster head; otherwise, it will not be.

The SEP algorithm, which is a technique for the random selection of cluster heads, continues to make use of the LEACH algorithm. The signal strength that is received from the cluster head node through the non-cluster head node is evaluated by the mechanism that controls clustering to determine whether or not the node should join the cluster. As a consequence of this, the cluster head is not dispersed in an even manner, and the number of nodes that make up the cluster is determined by chance as a result of the clustering mechanism.

After the network has been operating for some time, the residual energy of the high-level node may differ from that of the ordinary node, but the probability of becoming the cluster head is still higher than that of the ordinary node. The election probability in the SEP algorithm is only related to the node's initial energy, not its residual energy. This shortens the amount of time the network will be able to survive overall by hastening the death of some advanced nodes. When the SEP algorithm is used in single-hop transmission mode, nodes that are located a significant distance from the cluster head nodes are required to expend a significant amount of energy in order to carry out long-distance information transmission. This results in the premature death of network nodes and a reduction in the life cycle of the network.

B. Transmission Stage

After the cluster has been constructed, the nodes that make up the cluster will communicate with the nodes that serve as the cluster head within the allotted time period in order to finish the transfer of the data that was gathered in the relevant region. The cluster head sends the Time Division Multiple Address (TDMA) scheduling table, which defines the allocation time slot. During the non-transmission slot, the cluster nodes are in the dormancy state, which is one way that the SEP protocol saves energy. After the data have been received, the cluster head will converge on them, compress them with their own data, and then transfer them to the sink node.

V. Improved Efficient-SEP Protocol

In regard to the shortcomings of SEP that were discussed before, we offer the nodes' residual energy so that they can take part in the edge calculation in order to change the chance of becoming cluster heads of nodes within a given amount of time. In order for the cluster nodes to be able to transfer the apparent data, the interlude nodes in the cluster are further displayed.

A. Energy Consumption Model

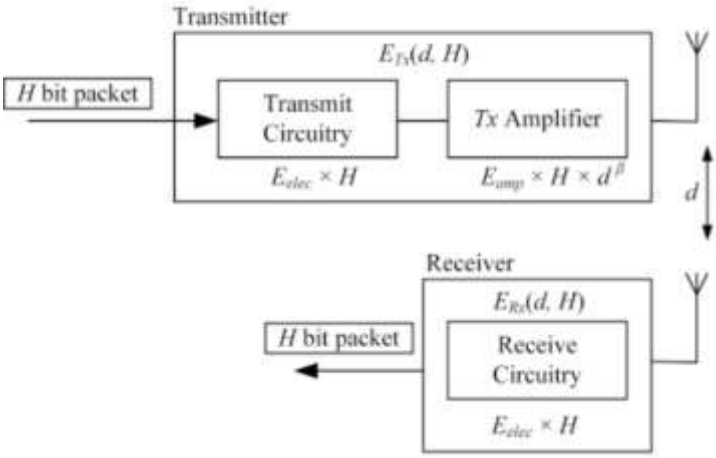

Figure3: Energy Consumption Model

For the record, the amount of energy used to accept or send k bits of data when a distance of d is specified is provided here [14]. Supplicant time

$$E_T(k,d) = \begin{cases} E_{elec}\,k + E_{fs}\,kd^2 & d < d_0 \\ E_{elec}\,k + E_{mp}\,kd^4 & d > d_0 \end{cases} \qquad (2)$$

Accepting time

$$E_R(k) = E_{R-elec}(k) = E_{elec}\,k \quad (3)$$

$E_{elec}$is energy dissipated of the transmission a unit of data; $E_{fs}$and $E_{mp}$is energy dissipated for gain magnifying; d_0 is threshold distance.

B. Cluster Head Election Method

Simply taking into account the initial energy consumption won't be enough to solve the problem of imbalanced energy use, according to SEP. In order to construct the WSN life cycle, the residual energy of the nodes must be added to the estimation of the cluster head election perspective. In order to balance the distribution of energy consumption among the nodes and improve the life cycle, the node that has the lowest amount of residual energy has a lesser likelihood of becoming the clusterhead.
E_r is the residual energy of the node, Es denotes the overall residual energy, and E_c denotes the energy reference factor.

$$E_c = e^{-(E_r - \frac{E_S}{n})} \qquad (4)$$

In reference to the original technique for selecting the SEP cluster head, the node residual energy is integrated as the energy reference factor E_c. The initial energy for normal nodes is denoted by Eo, and the initial energy for advanced nodes is denoted by Ea, $Eadv = 1+\alpha Eo$.
Consider the case of the intermediate nodes, $E_{int} = 1+\mu\ Eo$.
Lets we have: $\mu = \alpha/2$
The value of our probability setting, $popt$, has not changed. The addition of advanced and intermediate nodes, on the other hand, causes a rise in the system's total initial energy, which is a negative result:

$$n\cdot E_o(1-m-b) + n\cdot m\cdot E_o 1+\alpha + n\cdot b\cdot(1+\mu) = n\cdot E_o(1+m\cdot\alpha+b\cdot\mu) \qquad (5)$$

Where n represents the total number of nodes, m represents the percentage of advanced nodes relative to the total number of nodes, and b represents the percentage of intermediate nodes in the network. It is required that the new epoch of the system be equal to $Popt\cdot(1+m\cdot\alpha+b\cdot\mu)$, which results in an increase in the overall energy of the network by a fraction of $(1+m\cdot\alpha+b\cdot\mu)$. Ec is the energy reference factor that is derived from equation no. 4, and if P_{nrm}, P_{int} and P_{adv} are the probabilities of becoming normal, intermediate, and advanced nodes, respectively, then Ec is the value that is used. Because of this, we have:

$$P_{nrm} = P_{opt}/(1+m\cdot\alpha+b\cdot\mu)*E_c \qquad (6)$$
$$P_{int} = (P_{opt})\times(1+\mu)/(1+m\cdot\alpha+b\cdot\mu)*E_c \qquad (7)$$
$$P_{adv} = (P_{opt})\times(1+\alpha)/(1+m\cdot\alpha+b\cdot\mu)*E_c \qquad (8)$$

In order to ensure that the sensor nodes must take on the role of cluster leaders, as was stated earlier, we need to specify a new threshold for the election procedures and refer back to the equation that was previously used (5). The thresholds (n_{nrm}),(n_{int}), $T(n_{adv})$ for normal, intermediate, and advanced users, respectively, are redefined as follows:

$$T(n_{nrm}) = \begin{cases} \frac{P_{nrm}}{1-P_{nrm}[r \times mod(1/P_{nrm})]} & if\ n_{nrm} \in G' \\ 0 & otherwise \end{cases} \qquad (9)$$

The fact that we have $n\times 1-m-b$in normal nodes, as stated above, demonstrates that our assumption (1) is accurate.
The same logic applies to the intermediate and advanced nodes, where G' refers to the set of normal nodes that have not become cluster heads in the $1/P_{nrm}$ rounds that have passed since the previous one,

$$T(n_{int}) = \begin{cases} \frac{P_{int}}{1-P_{int}[r \times mod(1/P_{int})]} & if\ n_{int} \in G'' \\ 0 & otherwise \end{cases} \quad (10)$$

We have $n\times b$ intermediate nodes and b intermediate nodes total, with G'' being the set of intermediate nodes that have not become cluster heads in the most recent $1/P_{int}$ round r of computations.

$$T(n_{adv}) = \begin{cases} \frac{P_{adv}}{1-P_{adv}[r \times mod(1/P_{adv})]} & if\ n_{adv} \in G''' \\ 0 & otherwise \end{cases} \quad (11)$$

We have $n\times m$ advanced nodes, and the set of advanced nodes denoted by G''' is the set of nodes that have not become cluster heads in the most recent $1/P_{adv}$ round r.
The following equations can be used to calculate the average total number of cluster heads produced in each round:

$$n\cdot(1-m-b) \times P_{nrm} + n\cdot b \times P_{int} + n\cdot m \times P_{adv} = n \times P_{op} \quad (12)$$

In comparison to the initial option for LEACH, this results in the same amount of cluster heads being produced. On the other hand, because of the heterogeneous energy configuration, the dissipation of energy is better managed.

C. Intermediate Node Mechanism

The SEP protocol does not optimize the data transmission that occurs between the members of the cluster; rather, the information is transferred straight from the member nodes of the cluster to the heads of the cluster. Therefore, it will require a greater expenditure of energy to convey information and will drastically reduce the lifetime of the network for the edge nodes that are located a significant distance from the cluster head. Therefore, in this scenario, linking the intermediate nodes will unquestionably improve the negative effects of the edge nodes and maintain equilibrium in the amount of energy consumed by each node [15].

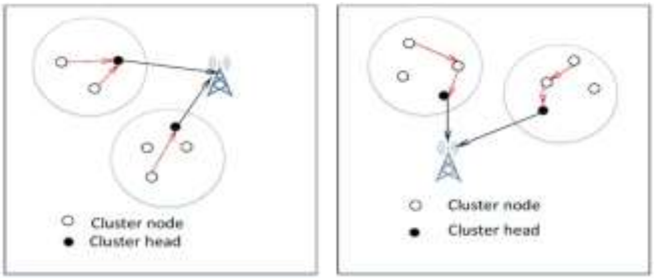

Figure 4: Direct compares indirect transmission

The principle of the intermediate node mechanism is that the nodes in the cluster use the intermediate nodes to transmit the information indirectly so as to reduce their energy consumption and prolong their life [16]. After cluster structure is formed, the cluster node i computes the energy consumed E_1 that transmits information indirectly through other nodes in this cluster. We select the node with the smallest E_1 as the Intermediate node of node i. Compare E_1 with E_i which the energy consumption of direct transmission. If $E_1<E_i$, the node i transmits indirectly through the intermediate nodes; otherwise, the node transmits directly.Figure 4 is the comparison between direct transmission and indirect transmission in a cluster. Part (a) shows the direct transmission in a cluster and part (b) shows the indirect transmission in a cluster.

The nodes in the cluster use the intermediate nodes to transport the information indirectly so that they can lower the amount of energy they use and increase the amount of time they have to live. This is the rationale behind the mechanism known as the intermediate node. After the structure of the cluster has been constructed, the node I of the cluster will compute the amount of energy, E_1, that was used to transfer information indirectly through the other nodes in this cluster. As the Intermediate node of node I we choose the node that has the E_1 value that is the least. When comparing E_1 and E_i, keep in mind that the former has a lower energy usage than the latter. If E_1 is greater than E_i, the node I will transfer information indirectly via the nodes in between; otherwise, it will transmit information directly [17]. The comparison between direct transmission and indirect transmission in a cluster is shown in Figure 4. The direct transmission in a cluster is demonstrated in part (a), while the indirect transmission in a cluster is demonstrated in part (b).

VI. CONCLUSION

In this study, the Stable Election Protocol, sometimes known as SEP, is analyzed and discussed. The starting energy of a SEP sensor node in a heterogeneous two-level hierarchical network is compared to the starting energy of other nodes, and the node with the highest starting energy elects itself as the cluster leader. The SEP is dynamic in the sense that it does not presuppose a prior distribution of the various levels of energy that are contained inside the sensor nodes. In addition, our Efficient SEP analysis is not simply asymptotic; this means that it works just as well with tiny networks as it does with huge networks. Last but not least, the SEP is scalable because it does not require exact information of the position of each node in the field.

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