# Survey On Routing Protocals To Provide Energy Efficiency In WSN

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***Abstract*-The wide utilization of Wireless Sensor Networks (WSNs) is obstructed by the severely limited energy constraints of the individual sensor nodes. This is the reason why a large part of the research in WSNs focuses on the development of energy efficient routing protocols.Hierarchical routing protocols provide energy-efficiency, scalability and reliability for WSN applications. There are several hierarchical routing protocols. However, these proposals have the following drawbacks: ineffective CH selection, low energy- balancing, network lifetime, and scalability. To address the previous issues, proposes an extension of LEACH, called a CLuster-based approach for ENERgy-efficiency in WSNs (CLENER). CLENER combines multiple metrics to solve the above- mentioned drawbacks regarding CH election and cluster formation. Thus, it is possible to balance and reduce the energy consumption between the nodes, while providing data transmission reliability.**

***Keywords*: *Wireless sensor networks, Energy-efficiency, Hierarchical routing protocol***

## I. INTRODUCTION

In a WSN, sensor nodes sense the environment and use their communication components in order to transmit the sensed data over wireless channels to other nodes and to a designated sink point, referred to as the Base Station (BS). BS collects the data transmitted to it in order to act either as a supervisory control processor or as an access point for a human interface or even as a gateway to other networks. Through the collaborative use of a large number of sensor nodes, a WSN is able to perform concurrent data acquisition of existing conditions at various points of interest located over wide areas. Nowadays, WSNs, due to the numerous benefits that their utilization offers, support an ever growing variety of applications, including agriculture, traffic control, environment and habitat monitoring, object tracking, fire detection, surveillance and reconnaissance, home automation, biomedical applications, inventory control, machine failure diagnosis and energy management.

WIRELESS sensor networks (WSNs) have a broad range of applications, such as battlefield surveillance, environmental monitoring, and disaster relief. A sensor network consists of a set of autonomous sensor nodes which spontaneously create imprompt communication links and then, collectively perform tasks without help from any central servers.

Thus, Wireless Sensor Networks (WSNs) have been widely used in surveillance applications such as habitat and weather condition monitoring. These environmental monitoring systems are envisioned to consist of hundreds to thousands of low-cost sensor nodes, which have small on-board memories, limited computing capabilities and restricted power supply. Intra-network communications are accomplished through short range radio transmission. To accommodate sensor failures and ensure coverage, sensor nodes are usually deployed densely in sensing fields. As sensors monitoring common environmental phenomena, such as temperature, in close regions may yield similar readings, known as spatially correlated data, dense deployment will result in collecting a significant amount of redundant data.

A wireless sensor network (WSNs) consists of a large number of wireless sensor nodes that organize themselves into multihop radio networks. Sensor nodes are typically equipped by power-constrained batteries, which are often difficult and expensive to be replaced once the nodes are deployed. Therefore, it is a critical consideration on reducing the power consumption in the network design.

In sensor networks, accurate data extraction is difficult—it is often too costly to obtain all sensor readings, as well as not necessary in the sense that the readings themselves only represent samples of the true state of the world. As such, one technique so-called prediction emerges to exploit the temporal correlation of sensor data. Technology trends in recent years have resulted in sensors' increasing processing power and capacity. A simple approach to developing a predictor in sensor networks is simply to transmit the data from all sensors to the base station (i.e., the sink), which has been realized in many previous studies. Predictor training and prediction operations are carried out by the base station only but not the sensor nodes, despite their increasing computing capacity. This solution while practical has many disadvantages, such as a high energy consumption incurred by transmitting the raw data to the base station, the need for wireless link bandwidth and potential high latency.

One solution is clustering-based localized prediction where a cluster head also a sensor node maintains a set of history data of each sensor node within a cluster. The use of localized prediction techniques is highly energy efficient due to the reduced length of routing path for transmitting sensor data.

Clustering based local prediction in sensor networks faces a couple of new challenges. First, since the cost of training a predictor is nontrivial, they should carefully investigate the trade-off between communication and computation. To support prediction techniques, energy is consumed on communication (e.g., sending and receiving sensor data) and computation (e.g., processing sensor data and calculating a predicted value). Sufficient conditions for the prediction technique are qualitatively derived which reveal that the decision is a function of both the desired error bound and the correlation among the sensor data values. For instance, when the error bound is very tight or the correlation is not significant, a sensor node always has to send its data to the cluster head. The second challenge is due to the characteristics and inherent dynamics of the sensor data. When the data distribution, in particular the data locality, evolves over time, prediction techniques may not work well for a set of less predictable data. Global reclustering is costly if it is initiated periodically.

Routing protocols based on clustering are an alternative to improve energy-efficiency for a set of Internet of Things (IoT) applications and Quality of Service (QoS)[1]. A hierarchical architecture has nodes with different roles or functionalities (heterogeneous nodes can be classified into cluster-head (CH) and non-head nodes).

Where, the nodes inside a cluster communicate with each other (sensor-to-sensor), and mainly with the leader node (cluster-head), responsible for communicating outside the cluster (sensor-to-Base Station (BS)). Moreover, some nodes (CH) can have cameras to retrieve multimedia content [2]. There are many algorithms of CH election, they analyze key features as follows: residual energy, link quality and location . These algorithms require time for cluster formation, generating additional delay and complexity, which are unsuitable for many IoT applications. In this context, the performance of routing protocols affects both the network performance, and the lifetime of the network.In hierarchical architecture, the nodes are divided into clusters and a set of nodes are periodically elected as a leader of each group CH. CHs are used for more complex tasks, such as: the controlling of each cluster, collecting data from non-CHs, data aggregation, and sending the collected data to the BS . For this reason, CHs consume more energy when they are located further away from the BS, which causes communication interference and network partitioning. Thus, it is important to use metrics that can provide an energy-efficient mechanism for CH election and load balance to enable a uniform clustering distribution and homogeneous energy consumption [9]. Furthermore, the cluster formation process can lead unfair energy consumption, if the CHs are only elected on the basis of a single objective metric

In this context, there are several hierarchical routing protocols. However, these proposals have the following drawbacks: low energy- balancing, ineffective CH selection, scalability and network lifetime. To address the above issues, this paper proposes an extension of LEACH, called a CLuster-based approach for ENERgy-efficiency in WSNs (CLENER). CLENER combines multiple metrics to solve the above-mentioned drawbacks regarding CH election and cluster formation. By providing data transmission reliability it is possible to balance and reduce the energy consumption between the nodes, The main contributions of CLENER are as follows: (i) a fair distribution of the network resources between the sensor nodes; (ii) a load balanced cluster formation; (iii) support for resource management. To achieve these aims, CLENER proposes that each node should determine the degree of probability necessary to become a CH, based on the remaining energy and random probability factors. Additionally, the non- CHs choose the CH in accordance with a cost function that is computed through a Takagi-Sugeno fuzzy system (TS) [3].

Simulations were carried out to show the impact and benefits of CLENER for cluster formation and CH election. This paper includes an analysis of energy-efficiency, packet delivery and cluster formation.

## II. Related Work

In [9] Low Energy Adaptive Clustering Hierarchy (LEACH), a hierarchical protocol in which most nodes transmit to cluster heads, is presented. The operation of LEACH consists of two phases:

 The Setup Phase: In the setup phase, the clusters are organized and the cluster heads are selected. In every round, a stochastic algorithm is used by each node to determine whether it will become a cluster head. If a node becomes a cluster head once, it cannot become a cluster head again for $P$ rounds, where $P$ is the desired percentage of cluster heads.

 The Steady State Phase: In the steady state phase, the data is sent to the base station. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

LEACH is a protocol that tends to reduce energy consumption in a WSN. However, LEACH uses single-hop routing in which each sensor node transmits information directly to the cluster-head or the sink. Therefore, it is not recommended for networks that are deployed in large regions LEACH (low-energy adaptive clustering hierarchy) divides the protocol operation into rounds, and each round is subdivided into two phases: setup and steady-state phase. In the setup phase, the nodes create clusters and elect CH. The nodes choose a random number between 0 and 1, and if the number is less than a threshold $T(n)$ (Equation 1), the node becomes the CH for the current round. After the CH election, CHs must create a schedule for the transmission of non-CHs in accordance with a TDMA (Time Division Multiple Access) scheme. On the other hand, non-CH nodes elect the CH on the basis of minimum energy

ISSN: 2278-0181

communication. Thus, LEACH cannot provide reliability, energy-efficiency or a fair distribution of resources.

$$T(n) = \begin{cases} \frac{P}{1-P(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Power-Efficient GAthering in Sensor Information Systems (PEGASIS) is an energy efficient protocol [10], which provides improvements over LEACH. In PEGASIS, each node communicates only with a nearby neighbor in order to exchange data. It takes turns in order to transmit the information to the base station, thus reducing the amount of energy spent per round. The nodes are organized in such a way as to form a chain, which can either be formed by the sensor nodes themselves using a greedy algorithm starting from a certain node, or the BS can compute this chain and broadcast it to all the sensor nodes.

In LEACH, a node becomes a cluster-head using a stochastic mechanism. This is prone to producing unbalanced energy level reserves in nodes and, thus, to increasing the total energy dissipated in the network. In PEGASIS, the cluster head selection does not take into consideration neither the residual energy of the nodes nor the location of the base station. PEGASIS has better performance compared to LEACH [11], but the nodes are grouped into chains that cause redundant data transmissions.

Threshold Sensitive Energy Efficient (TEEN) is a hierarchical protocol designed for sudden changes in the sensed environment [12]. The response of the network in time-critical applications is extremely important, obliging the network to operate in a reactive mode. The sensor network architecture in TEEN is based on hierarchical grouping. The nodes close to upper level clusters are used to transfer data from other nodes that are further away, a process that goes on the next level cluster until the sink is reached. The main advantage of TEEN is that it works well in conditions where sudden changes in the sensed attributes occur. On the other hand, in large area networks and when the number of layers in the hierarchy is small, TEEN tends to consume considerable amounts of energy, because of long distance transmissions. Moreover, when the number of layers increases, the transmissions become shorter and there exists a considerable overhead in the setup phase, as well as the operation of the network.

The Shortest Hop Routing Tree protocol (SHORT) [13] efficiently collects useful data from a remote wireless sensor network to the base station and provides energy efficiency. This protocol selects the node with the largest value of residual energy as the leader. The Extending Lifetime of Cluster Head (ELCH) routing protocol [14] has self-configuration and hierarchal routing properties. It elects cluster heads based on the votes that it collects from the network nodes. The Energy Efficient Cluster Formation Protocol (EECFP) [15] elects the nodes with the higher energy as cluster heads and rotates them in each round to provide a balance of energy consumption and to minimize the energy spend for cluster formation.

In [16], a centralized routing protocol, called Base-Station Controlled Dynamic Clustering Protocol (BCDCP), which distributes the energy dissipation evenly among all the sensor nodes to improve the network lifetime, and its average energy savings are presented. The base station receives the residual energy of each node, and then, it computes the average energy level of all the nodes. Then, it elects as candidate cluster heads a number of nodes, which have a higher residual energy than this value. This protocol provides a balanced energy consumption. However, the selection of the node with the highest energy as a cluster head at a round may cause the other nodes to spend more energy to send data to this node. The selection of a node that allows the other nodes in the cluster to spend less energy is a better solution.

A novel energy efficient routing protocol, named ECHERP, is presented. ECHERP selects cluster heads in the network using a model, as most of the previously proposed protocols. However, the main difference with other protocols is that this one uses a more efficient mechanism to select a node as the cluster head. This is performed by considering the current and the estimated future residual energy of the nodes, along with the number of rounds that they can be cluster heads, in order to maximize the network lifetime. ECHERP models the network and the energy spent by the nodes as a linear system and, using the Gaussian elimination algorithm, selects the cluster heads of the network.

In ECHERP, the BS is assumed to have unlimited energy residues and communication power. It is also assumed that the BS is located at a fixed position, either inside or away from the sensor field. The longer the distance between the BS and the center of the sensor field, the higher the energy expenditure for every node transmitting to the BS. All the network nodes, which are assumed to be located within the sensor field, are dynamically grouped into clusters. One of the nodes within every cluster is elected to be the cluster head of this cluster. Therefore, the number of cluster heads is equal to the number of clusters. The cluster heads, which are located close enough to the network base station, are referred to as the first level cluster heads. These cluster heads are capable of direct transmission to the base station with reasonable energy expenditure. The cluster heads that are located at remote distant from the base station are considered as second, third, etc.. level cluster heads. These cluster heads transmit data to the upper level cluster heads. Moreover, in order to achieve balanced energy consumption and extend the network's lifetime, the election of the cluster heads is performed in turns.

All the aforementioned protocols try to minimize the energy consumption using different algorithms. These algorithms offer a good solution, since they select the node with the higher residual energy in the cluster as the cluster head for the next round. However, this does not assure the maximum prolongation of the overall network lifetime. Therefore, if the node with the highest residual energy is a node located at the side of the cluster, this can lead other nodes to spend considerable amounts of energy to reach that node, which cannot be energy efficient for the entire network. This is the reason we propose a protocol that elects as cluster

ISSN: 2278-0181

heads nodes that minimize the total energy consumption in a cluster.

## III. CLUSTER-BASED APPROACH FOR ENERGY-EFFICIENCY IN THE WSN (CLENER)

CLENER was developed for application where there are sensor nodes periodically collecting scalar data and send them to BS for further analysis. The physical scalar sensor measurements are processed by means of existing models or methods, with the aim of predicting the occurrence of events, such as flooding, fire or intruders. CLENER considers a network with the following characteristics:

• The sensor nodes fixed, are energy-constrained and they have the same capability;
• The BS has not subject to energy restrictions and is located inside the sensing field;
• There is no batteries recharge after node deployment;
• The sensor nodes can transmit with enough power to reach the BS; • Each sensor node can change its transmission power level dynamically.

This general scenario may be used for various applications ranging from civilian and military areas. For example, monitoring in rainforest area to measure environmental factors, such as: temperature, humidity, and wind speed. These information can be used to predict event occurrence.

### A. *CH election*

As mentioned earlier, in hierarchical architectures, the nodes are divided into clusters and a set of nodes is periodically elected as a CH. CHs are used for more complex tasks, such as: the management of each cluster, collecting data from non-CHs, data aggregation, and sending the collected data to the In this context, it is important to use multiple metrics for CH election to provide an energy-efficient and load balance model. Furthermore, the cluster formation process can lead to poor energy use, if the CHs that are elected are only based on a single metric. In this context, CLENER proposes an equation, which is used by nodes to enable them to become a CH.

During the initialization of the network, BS broadcasts a *startup message*, which enables the node to compute the distance to BS. The distance is computed by means of Received Signal Strength Indicator (RSSI) [4]. Following this, the nodes are able to adjust the transmission power according to distance, which reduces the energy consumption since higher transmission power consumes more energy
BS.
After adjusting the transmission power, each node generates a random number (μ), which ranges from 0 to 1. Then, the node decides to become a CH by comparing $\mu$ with the *T(n)*, which is computed by means of Equation 2. If $\mu$ is less than *T(n)*, the node becomes a CH for the current round.

$$T(n) = \eta \frac{P}{1-P(r \bmod \frac{1}{P})} + \alpha(1 - e^{\frac{-RE^2}{2\sigma_{RE}^2}}) \qquad (2)$$

Where $\eta$ and $\alpha$ are weights to give importance, the sum is exactly 1. The Residual Energy is denoted as *RE*, and $\sigma_{re}$ means the energy variance, which is used to produce better CH candidates. Equation 2 uses a gauss function, due to the fact that has better result in terms of energy efficiency and representation in the context of an imprecise environment.

The node that becomes CH broadcasts a *ch message*, which contains the value of its remaining energy. Then, CH waits for a *join message* from the non-CH nodes. However, if the CHs do not receive a *join message*, this CH should not become CH. Algorithm 1 describes the steps for CH election and cluster formation.

The proposed CLENER algorithm has a computational complexity of *O(n)*. Additionally, the communication complexity can be analyzed as follows: the most expensive communications are the reception of *ch* and *join messages* from non-CH and CH respectively. In the worst case, *n* non-CHs receive a *ch message* from all CHs a with a complexity *O(log n)*.

### B. *Cluster Formation*

During this sub-phase, non-CHs select the best CH by considering a multiple metrics, i.e. residual energy and a distance from non-CH to CH. Then, non-CHs compute a probability value to each CH candidate using TS. The non-CH chooses the CH with a higher probability value and sends a *join message* to CH.
The use of fuzzy logic is appropriate, whenever it is not possible to employ a mathematical model for the system. Additionally, fuzzy can reduce the complexity of the model, computational effort and memory [5]. In this context, TS is able to provide higher computational efficiency and better Gain-scheduling controllers than Mamdani fuzzy system, which is expected for resource constrained WSN [6].

TS receive context information from nodes as input and converts into fuzzy linguistic variable input. The defuzzifier process produce a crip output from the fuzzy set and rules that is the output of the inference engine. TS is formed of four modules: rules, inference engine, fuzzifier and defuzzifier. The architecture of the fuzzy system used is shown in Figure 1.

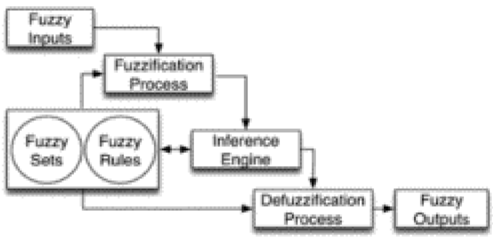


Fig 1: Fuzzy Diagram

ISSN: 2278-0181

**Algorithm 1** CLENER

```
StartUp
if BS then
    Broadcast startupMessage( ID )
end if
On receiving a startupMessage
μ ← rand(0, 1)
probability ← Equation 2
if μ < probability then
    beCandidate ← TRUE
end if
if beCandidate = TRUE then
    Broadcast chMessage( ID,residualEnergy )
end if
On receiving a chMessage
if !beCandidate then
    c.rssi ← estimateDistance( chMessage )
    c.residualEnergy ← chMessage.residualEnergy
    c.id ← chMessage.id
    ADD c to candidateClusterHead set S
end if
Join a Cluster Head Candidate
if !beCandidate then
    CH = fuzzySystem( S,residualEnergy,RSSI )
    Broadcast joinMessage( CH[0].ID,id )
end if
```

## IV. PERFORMANCE EVALUATION

Simulation experiments were conducted to analyze the performance of CLENER in WSNs by using the Castalia Framework [7]. Castalia is a widely used network simulator for WSNs based on OMNET++. The simulations were carried out and repeated 30 times with different number of seeds. The data analyzes use the 10 percentiles, in order to provide a confidence interval of 95%. The performance of CLENER was compared with LEACH.

We evaluate CLENER under characteristics of rainforest areas, which have various effects on wireless communications, such as attenuation, scattering, and absorption. In this context, Tewari et al. [8] propose a propagation model that is based on an empirical model and consider the natural features of the forest region1. Thus, by using this propagation model, it is possible to evaluate CLENER in real-life conditions and improve the accuracy of the results.

In the hierarchical architecture, CHs are responsible for more complex tasks, e.g. they receive the collected data sent by non-CHS, aggregate the non-CHs packets into a single packet, and send it to the BS. At the same time, non-CHs can turn off the radio after transmitting their packets, reducing energy consumption and avoiding communication conflicts.

In resuming, the routing protocols must have the best number of cluster per round, i.e. a number near to the selected probability, which defines the best number of the cluster so that it can reduce energy consumption, interference and the problem of disconnection. Table 3 shows the average and standard deviation of clusters in each round.

When the results are analyzed, it can be concluded that in general CLENER has a better number of clusters per round, i.e. a value near to 5, which is the defined probability (see Table 1). This is due to the fact that CLENER proposes the residual energy as the principal variable in the CH election. In this way, it can establish the correct numbers of CH per round with regard to all the nodes that are alive.

The worst performance of LEACH can be explained by the fact that it only uses a probabilistic equation without considering residual energy, or the relative positions of each non-CH, which can improve the accuracy of the cluster formation.

EECHS employs a correct variable but at the wrong time. During a CH election in EECHS, each node has a different view of its parameters, which have different values. Hence, each node has different ways of making a decision, and at different stages the network will have smaller or larger clusters. In view of this, it may not be a satisfactory method for CH election.

*TABLE I.* NUMBER OF CLUSTERS

| Protocol | Cluster/Round(average) | Standard deviation |
|---|---|---|
| LEACH | 6.3 | 2.045 |
| EECHS | 8.1 | 2.652 |
| CLENER | 5.8 | 1.577 |

Table 2 shows the numbers of non-CHs obtained in each cluster per round. CLENER has a low average and standard deviation for the number of non-CHs. This is due to the use of the fuzzy system, which makes it possible to indicate the most eligible CHs for each non-CH during the cluster formation, where there was efficient energy consumption. On the other hand, LEACH and EECHS obtained a higher standard deviation, because these proposals do not improve the fast convergence response with regard to energy. Since the proposal has a low variance with regard to numbers of clusters and non-CHs, it can be inferred that CLENER provides a better cluster formation regardless of distance. Thus, CLENER has a better system of clusterization than LEACH and EECHS.

*TABLE II.* NON-CHS PER CLUSTER

| Protocol | Number of non CH(average) | Standard deviation |
|---|---|---|
| LEACH | 21.23 | 11.737 |
| EECHS | 19.34 | 12.745 |
| CLENER | 20.77 | 7.709 |

The network lifetime was measured as the period of time until the point where 10% of the nodes had run out of energy. The results show that LEACH protocol consumed their energy at a faster rate than CLENER. CLENER increases the network lifetime in all cases, especially after the first nodes consume the energy resource. This is due to the fact that CLENER always

ISSN: 2278-0181

creates the expected number of clusters. Additionally, the cluster formation takes account of fuzzy system residual energy and distance to CH, which balances the energy consumption.

However, LEACH does not consider an important variable that is needed to provide energy-efficiency, i.e. residual energy, and thus reduces the network lifetime. It can be assumed that the network lifetime is the time until the point when 1%, 50% and 100% of the nodes run out of energy, as shown in Figure 2. This is useful to evaluate the capability of the routing protocols to dynamically adapt to the new topologies that are caused by the death of the nodes. CLENER increases the network lifetime in all cases, especially after the first nodes consume the energy resource.

Additionally, the cluster formation takes account of fuzzy system residual energy and distance to CH, which balances the energy consumption. However, LEACH does not consider an important variable that is needed to provide energy-efficiency, i.e. residual energy, and thus reduces the network lifetime.

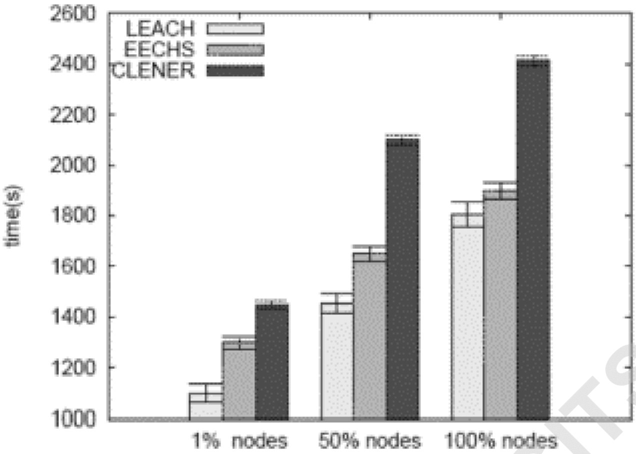


*Fig 2: Network Lifetime*



## CONCLUSION

This paper presented CLENER, a CLuster-based approach for Energy-efficiency for WSNs. CLENER proposes two sub-phases for the setup phase, namely CH election and cluster formation. In the former of the CH, each node determines a new probability function to become a CH, based on its remaining energy and a stochastic equation. The cluster formation, the non-CHs select the most reliable CH based on residual energy, and the distance between them. This information is used as input to TS, which seeks to overcome any uncertainties and thus be able to estimate the correct CH. Simulations were carried out to show the impact and benefits of CLENER in terms network lifetime and PDR. We found that CLENER increases the network lifetime in 18% compared to LEACH and EECHS.

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