

Energy Neutral Hierarchical Routing Protocol for Energy Harvesting Wireless Sensor Network

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Abstract: - providing network-wide energy neutral operation for wireless sensor nodes with energy harvesting capabilities is possible if and only if the amount of energy consumed by the nodes is no more than the amount of energy harvested in a certain period of time. In this paper, we propose an Energy Neutral LEACH routing protocol which is an extension to the traditional LEACH protocol that group energy harvesting sensors into a number of clusters that ensures the energy neutral status of all sensors via inter and intra-cluster communications. The main idea of our proposed protocol consists of using Gateway node in each cluster so as to reduce the data transmission ranges of cluster head nodes. Simulation results show that our proposed routing protocol achieves a higher throughput and ensured the energy neutral status of the whole network.

Key-words: - Wireless sensor networks; Clustering; Energy harvesting WSN; Energy neutral LEACH protocol.

1 Introduction

The application of Wireless Sensor Networks (WSNs) in various fields such as industrial control, tactical military applications, environmental and security monitoring, is widely acknowledged [1, 2]. In wireless sensor networks, sensor nodes are often powered by non-rechargeable batteries. As soon as a battery gets exhausted, then the battery lifespan is totally brought to a halt and must be replaced. Despite several research efforts, energy consumption has remained a key challenge during the design of battery-powered WSNs [3]. Energy harvesting is a technique that recently found its way into the networking spheres. It was solely introduced for wireless sensor networks. It provides an additional source of energy that can be collected from environments that include solar and wind energy. According to [4, 5], the technique has the capacity to tremendously extend the span of life of wireless sensor networks. It not only prolongs life span but also enables sensor nodes run continually.

In WSNs, routing is often used to prolong the lifespan of a network, since wireless sensor nodes are power-constrained devices. There is plethora of research done over the past few decades in the area of routing protocol for WSNs and this is due to its present day significant and applications to the field of sensor networks [6]. Given the limitations of resources available to a sensor network, it is not promising to have each node deliver data to the base station. Network scalability has been achieved by way of creating clusters which are composed of grouped sensor nodes. The cluster head (CH) is used to denote the leader of each cluster. The benefits of clustering include route localization, reduction in overhead accruing to topology maintenance, reduction of rate of energy intake, reduced volume of packets to be relayed [7, 8].

This work majorly extends the traditional routing protocol known as “Low-energy adaptive clustering hierarchy” (“LEACH”) to “Energy Neutral LEACH”. Energy neutral “LEACH” attempts to minimize the transfer range of cluster heads (CHs) by introducing a

Gateway Node (GN) to each cluster. The “EN-LEACH” does not only inherit the benefits of “LEACH” but helps to keep all sensors in an energy neutral state and by so doing, the amount of energy taken by all the sensors is less than the amount of energy harvested at a particular time [8]. Overall network throughput in energy collection is improved in wireless sensor networks.

This paper is organized as follows: In Section 2, review of related works is presented, and in Section 3 we provide the proposed system model. Then we explain “Energy Neutral LEACH” in details in Section 4, and in Section 4 we discuss the performance evaluation of EN-LEACH through computer simulations. In Section 5 we provide some further discussion of results and future directions for research.

2 Related Work

According to [13, 14], higher energy nodes can be employed in the processing and transmission of information whereas low energy nodes can be employed in sensing in the proximity of the target in a hierarchical architecture. The implication of this is that making clusters and assigning them to cluster heads to perform special tasks has the potential to improve overall system scalability and energy productivity. In [15], “hierarchical routing” presents a two layers of routing in which one of the layers is applied to the selection of cluster head while the other is applied to routing. A reduction in energy intake by a cluster is better achieved through “hierarchical routing” coupled with the application of data aggregation. Fusion can equally be applied so as reduce the volume of messages delivered to the BS. It is however worthy to note that some of the techniques that fall under this class are not concerned with routing, instead, the boarder on “who and when to send or process or aggregate information. According to [9, 10] and other literature we came across, the “LEACH” protocol still appear to be the most preferred “hierarchical clustering” algorithm used for wireless sensor networks (WSNs) owing to its energy efficiency. The “LEACH” has the capability to select nodes that serve as cluster heads at random, and intermittently switch roles by sharing energy-loads to all the network sensors. The mathematical relation

below gives the probability that any given node is selected to represent a cluster head.

$$P_i(r) \begin{cases} \frac{P}{1 - P \times (r \bmod \frac{1}{P})} & \text{if } i \in G(r) \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where P_i denotes the likelihood that node i can serve as a cluster head, P indicates the node number percentage that can serve as cluster heads in any given round, r indicates the index of the current round under consideration. $G(r)$ represents the node-set that have not served as cluster head in the most recent $r \bmod (1/P)$ round.

Several routing protocols have been proposed based on LEACH. The basis for these propositions stems from ease, scalability, and above all, the ability to create a balance in energy throughput in the whole network. The “Power-Efficient Gathering in Sensor Information System” (PEGASIS) creates several networks of node sensors instead of clusters. Theses sensor nodes are able to deliver packets of information to the BS. This implies that individual sensors can receive and also send data from neighboring nodes. However, the complex nature of the aforementioned algorithm is not appealing to designers and therefore dissuades them from its real use. The “Hybrid Energy-Efficient Distributed Clustering (HEED) presented in [11] builds on the foundation of the “LEACH” algorithm by way of introducing residual energy and sensor node closeness to other nodes in the CH-node selection. It however pays little or no focus to neither sensor node densities nor distribution. The “Threshold sensitive Energy Efficient Protocol” (TEEN) [12], works in a way that is similar to “LEACH”. The difference comes from the fact that sensor nodes do not require data to be delivered. TEEN appear more adapted to sensor networks that are reactive because it has the ability of processing of time-bound critical data.

3 Concept of Clustering

Clustering the wireless network can help decrease the sensor energy consumption, enables in-network data aggregations and improve the network scalability. In this section, we describe the constituent elements

in a cluster, classes and advantages of clusters in WSN.

3.1 Elements in a Cluster

In general, when working with clusters it is possible to identify three main different elements in the WSN: sensor nodes (SNs), base station (BS), cluster heads (CH) and sometimes a gateway node (GN). The SNs are the set of sensors present in the network, arranged to sense the environment and collect the data. The main task of a SN in a sensor field is to detect events, perform quick local data processing, and then transmit the data. But the greatest constraint it has is the power consumption, which usually is caused when the sensor is observing its surroundings, and communicating (sending and receiving) data. The BS is the data processing point for the data received from the sensor nodes, and where the data is accessed by the end-user. It is generally considered fixed and at a far distance from the sensor nodes. The CH acts as a gateway between the SNs and the BS. The function of the cluster head is to perform common functions for all the nodes in the cluster, like aggregating the data before sending it to the BS. In some way, the CH is the sink for the cluster nodes, and the BS is the sink for the cluster heads. The GN acts as a gateway between CHs and the BS.

This structure formed between the sensor nodes, the sink, gateway, and the base station can be replicated as many times as it is needed, creating the different layers of the hierarchical WSN.

3.2 Classes of Clusters

There are many ways to classify the clusters in a wireless sensor network (WSN). Two of the most common classifications are homogeneous or heterogeneous clusters and static or dynamic clusters. The formal classification is based on the characteristics and functionality of the sensors in the cluster. Whereas the later is based on the method used to form the cluster.

In heterogeneous sensor networks, there are generally two types of sensors: (a) sensors with higher processing capabilities and complex hardware, used generally to create some kind of backbone inside the WSN. They are designated as the cluster head nodes, and

therefore have to serve as data collectors and processing centers for data gathered by other sensor nodes, and (b) participating sensors, with lower capabilities than the previous ones, used to actually sense the desired attributes in the field.

In homogeneous networks, all nodes have the same characteristics, hardware and processing capabilities. This is the typical case when the sensors are deployed in battle fields. In this case, every sensor can become a CH. The cluster head role is periodically rotated among the nodes to balance the load, ensure that sensors consume energy more uniformly and try to avoid the black hole problem described before. Static clusters are usually created when the network is formed of heterogeneous nodes and the network designers want to create the clusters around the more powerful nodes.

In this case, the clusters are formed at the time of network deployment. The attributes of each cluster, such as the size of a cluster, the CH, the number of participating sensors and the area it covers, are static. Static clusters are easy to deploy, but their use is only appropriate for limited scenarios where the sensor field is predetermined, the targets to monitor are not in motion and it is easy to perform maintenance tasks in the network. Dynamic cluster architectures make a better use of the sensors. Sensors do not statically belong to a cluster and may support different clusters at different times. This communication schema is generally used in WSN with homogeneous sensors, but can also be used in heterogeneous WSN. The formation of a cluster can be triggered by using a special message sent to the cluster every certain period of time, or can be triggered by the occurrence of certain events (i.e. the detection of a big change in the monitored attributes). No explicit leader (CH) election is required, and this decreases the number of messages used during the network deployment. However, a CH election method, a cluster formation method and cluster maintenance methods must exist on the network. Dynamic clustering in WSN is also more feasible when monitoring moving targets, due to the possibility of clusters reconfiguration.

3.3 Advantages of Clustering

The cluster-based communication scheme helps solving the previous problems. Once the WSN has been divided into clusters, the communication between nodes can be intra-cluster or inter-cluster. Intra-cluster communication comprises the message exchanges between the participating nodes and the CH. Inter-cluster communications includes the transmission of messages between the CHs or between the CH and the BS. The fact that only the CH is transmitting information out of the cluster helps avoiding collisions between the sensors inside the cluster, because they don't have to share the communication channel with the nodes in other clusters. This also helps saving energy and avoiding the black hole problem. Latency is also reduced. Although the data has to hop from one cluster head to another, it covers larger distances than when the sensor are using a multi-hop communication model as the one used in Hybrid Energy-Efficient Distributed Clustering (HEED) [11]. The cluster based communication model also facilitates the use of data aggregation models. In this case, only the CH performs data aggregation operations, helping the participating nodes inside the cluster to save energy.

3.4 The Clustering Process

During the process of establishing clusters, it is necessary to take into account aspects like: cluster size and form, how to select the cluster head, how to control inter-cluster and intra-cluster collisions, and energy saving issues. The design of the clustering process is one of the more important issues for the correct functioning of the WSN, due to the probed efficiency of using a hierarchical scheme for communications between the network elements.

In all the cluster-based protocols we can identify three main phases during the clustering establishment process: (a) cluster head election, (b) cluster formation (set-up phase), (c) data transmission phase (steady-state phase). Different approaches exist to implement each one of these stages. For example, it is possible to use a fixed distribution of the SN and the CH, or to use a dynamic algorithm for the location of the sensors and the CH election.

4 System Model

4.1 System Architecture

In our architecture, we make the assumption that 300 energy harvesting sensor nodes will be arbitrarily positioned over sensor field area spanning 100 x 100 m. We further separate the whole network is divided into layers and the BS is positioned around (50, 175). Three classes (CH, CN, and GN) of sensor nodes form each cluster. The CH class collects and aggregates information it obtained from the cluster member (CM). The CM class of sensors sense information and relay same to their CH counterpart. What is relayed takes the form of packets of data with a corresponding data rate. The GN class of sensors delivers the data aggregated by the CH class of sensors to the BS. Sensors that are elected as CH or GN node are released from the task of sensing. This in turn minimizes their energy intake. Figs. 1 and 2 present an illustration of Random deployment of sensor and Network Models.

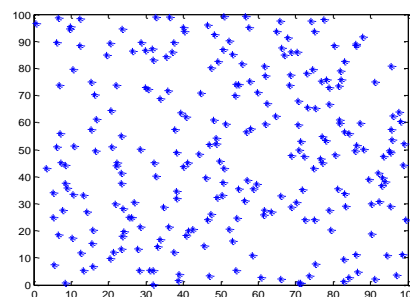


Fig. 1 Random deployment of sensors

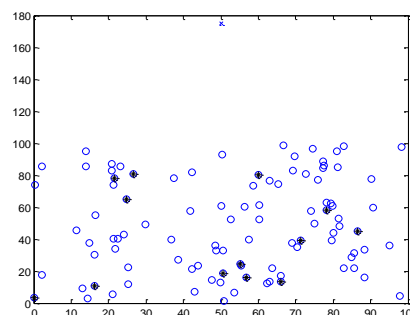


Fig. 2 Network Model

Fig. 3 presents the design that fully describes the operation of EN-LEACH. It is basically separated into slices. Each slice has mainly

two segments which include a set up segment and a steady- state segment. The set-up segment comprised of cluster head selection, gateway selection and cluster formation. It is

further made up of a gateway and cluster selection, and cluster formation algorithms. The EN-LEACH further comprises of three algorithms, which include the cluster

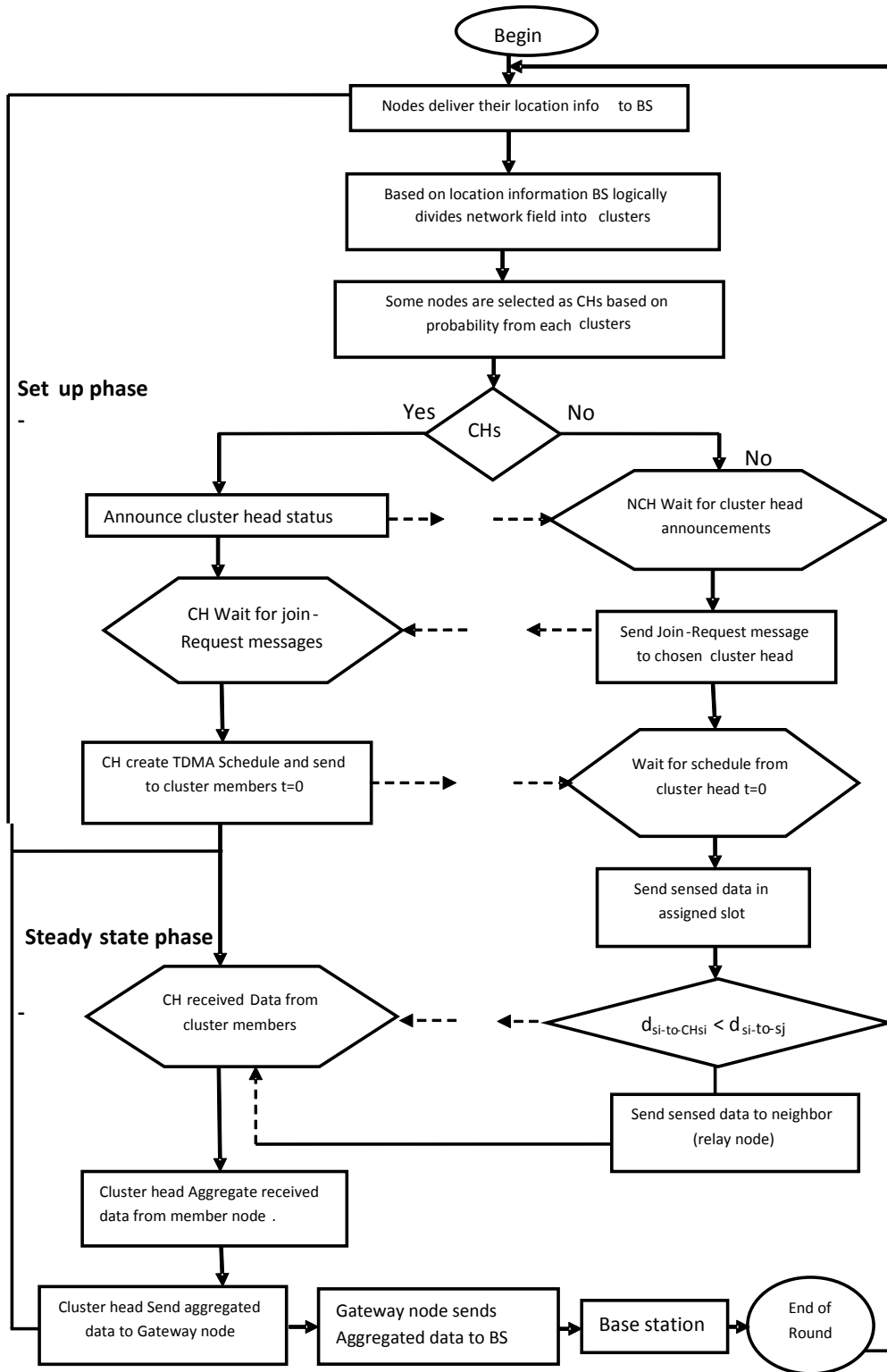


Fig.: EN-LEACH Operation Flow Model

formation algorithm, the gateway and the cluster selection algorithm. Once CHs, GNs, and TDMA cluster schedules are created, data delivery takes place. In our proposed protocol, and in the cluster maintenance segment, two different types of transmissions (intra-cluster and inter-cluster) occur.

4.2 System Energy Intake Model

The energy transmission cost is proportional to distance between the two communicating nodes. Thus, there exists a significant relationship between energy intake and distance of delivery in the process of delivery of data. Given the increased distance of delivery, power transmission dies rapidly. So, in this paper, we first consider the energy intake occasioned by information transmission and also adopt a simplified power model discussed in [8], [9]. The transmission of k -bit data among two nodes given the distance d , the energy intake is calculated thus:

$$E_{Tx}(k, d) = \begin{cases} k \times E_{elec} + E_{amp} \times d^2 & , \text{if } d < d_0 \\ k \times E_{elec} + E_{fs} \times d^4 & , \text{if } d \geq d_0 \end{cases} \quad (3)$$

Where E_{elec} is the base energy required to run the transmitter or receiver electronics; d_0 is the distance threshold. E_{amp} and E_{fs} are the unit energy required for the transmitter amplifier that depends on the distance and the propagation model to approximate the power loss (the free space d^2 or the multipath fading d^4) [10].

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad (4)$$

To receive k -bit data, the radio expends energy

$$E_{Rx}(k) = k \times E_{elec} \quad (5)$$

Therefore, the energy consumption of CH_i for a round is:

$$E_c(CH_i) = \sum_{i=1}^m E_{Rx}(k_i) + E_{DA}(k) + E_{Tx}(k_u, d(CH_i, GN_i)) + E_s + E_i \quad (6)$$

In this equation, m is the number of cluster member nodes of CH_i ; $E_{DA}(k)$ is energy consumption for data aggregation with k bits data. E_s and E_i are the energy consumption in sensing and idle state, respectively and $E_{Tx}(k_u, d(CH_i, GN_i))$ is the energy expend by CH in forwarding the aggregated data to the

GN_i . Where $E_{Tx}(k_j, d(GN_i, BS))$; is the energy is expended by GN in forwarding the CH aggregated data to BS. The energy consumption of a cluster member node j in cluster i^{th} for a round is [10]:

$$E_c(j) = E_{Tx}(k_j, d(j, CH_i)) + E_{Rx}(k_i) + E_s \quad (2)$$

5 Energy Neutral LEACH

This part of the paper extends the famous LEACH protocol to the “energy neutral LEACH” protocol. The work of EN-LEACH is separated into segments, and each segment comprises of two major phases which are namely: the setup and stable state phases as shown in (Fig.4).

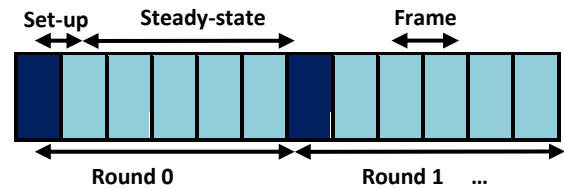


Fig.4 Time line showing EN-LEACH

5.1 Set up phase

The cluster head and gateway selections together with cluster formation make up the set-up phase. Also included are the gateway and cluster selection algorithms and the cluster creation algorithm this is shown in Fig. 5.

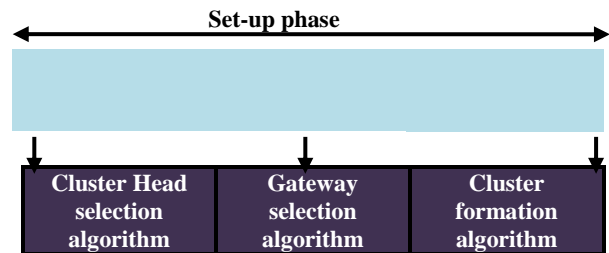


Fig. 5 Time line showing set-up phase

5.1.1 Cluster Head Selection

The design of LEACH is better suited to WSNs that run on battery power. The scheme used for cluster heads selection in a way turns the nodes into cluster heads thereby bringing about an even energy intake among nodes. Nodes with high energy collection rate are

expected to have higher likelihood to be selected as cluster heads. It is also expected that no time limit is placed on a node to become the cluster head. In “Energy Harvesting Wireless Sensor Networks (EH-WSNs)”, energy is unlimited and the energy harvesting rates tend to vary between nodes. The energy collected by any sensor node cannot withstand the heavy energy intake of a CH in practice. According to [9], [10], one option to salvaging this situation is the application of a cluster head rotation scheme as is applied to the conventional clustering algorithms.

5.1.2 Cluster Formation

On the initial deployment, the base station (BS) delivers a layer-one signal using minimal energy level. Nodes listening on this broadcast message reset their layer to 1. Subsequently, the base station upturns its energy power to achieve the next layer in order to deliver a layer-two signal. In this case, all nodes listening on the new broadcast message but were unable to set the previous layer are able to set their layer to 2. This process proceeds accordingly pending when the BS delivers matching messages to all layers respectively. After dividing the network into layers and picking the CH, individual nodes can choose any cluster of interest and relay such interest to the CH. It then becomes a member of cluster. In choosing the cluster, nodes have to pay attention to proximity with the CH. In order to avoid collision individual nodes have to relay the information to the CH via “Carrier Sense Multiple Access (CSMA) MAC” protocol. Each CH obtains all the communications from the sensor nodes that wish to be contained in the cluster, and given their volume, generates a “time division multiple access (TDMA)” schedule of equivalent size. This takes place after several time intervals. The subsequent step is to relay to each one of its cluster node when it will again deliver information according to the TDMA schedule which is disseminated across to the nodes in the cluster.

Table 1: Algorithm for setup phase

1. for each (node j)
2. j selects random number y between 0 and 1.
3. If ($y < T(j)$)
4. j becomes CH.
5. j broadcasts an advertising message for its CH status then .
6. CH waits for join-request
7. Else
8. j becomes a NCH node then .
9. NCH chooses the CH, this selection is based on RSS of Advertise.
10. NCH send join request to CH and become a member of its Cluster.
11. End if .
12. for each (CH)
13. CH creates TDMA schedule for NCH.
14. Each NCH communicates to the CH in its time slot.
15. End for
16. End for

5.1.3 Gateway Selection

Controlling the rate of data delivery is an attempt to keep the volume of transmissions at a minimum thereby saving more energy. The distance of each cluster may be quite long in which some CHs dies while trying to exchange messages directly with the BS. In order to resolve this situation, individual CH utilizes several transitional nodes along the path towards the BS to relay CH data. The role of BS is to identify all GNs in each cluster. The *id* and the corresponding locations of gateway nodes together with the chosen CH are transmitted by the BS. There are predefined total number of nodes which are allocated to be GNs and CH. Given that the *id* and the locations of gateway nodes are transmitted, individual CH have to select the nearest as the middle node and notifies it. The gateway nodes play the role of linking the CH to the BS. They also control delivery of packets received from the CH to the BS. This means that the CH can conserve energy during the course of data delivery.

5.2 Steady State Phase

Immediately following the formation of CHs, GNs cluster, and TDMA-based schedules, delivery of data commences. The cluster head that are not nodes obtains the sensor data and delivers same the cluster head within their

apportioned time slices. The radio within the cluster head node has to be on in order to receive the data from the nodes that are in the cluster. The amount of information transmitted by a sensor determines its energy intake. It is therefore worthy of mentioning that in order to energy neutral operation must be taking into consideration in the design of routing protocols. In our proposed protocol, two kinds of message exchanges occur in the cluster maintenance segment. They are namely: “intra-cluster” communication and “inter-cluster” communication.

5.2.1 Intra-Cluster Communication

For each cluster, the data generated by sensor node is delivered to the CH. These packets of data are sent to the neighboring node having the shortest distance from CH. The following node relays towards the CH in a similar way. Intra-cluster communication is performed by means of “TDMA” technique. In this time interval, CH allocates time slices to the node in the cluster. Algorithm listing 2 presents the Intra-cluster communication execution process.

Table 2: Algorithm for Intra-cluster communication

1. for each (Cluster)
2. for each Non-Cluster head S_i and S_j
3. for each Cluster Head (CH)
4. S_i wishes to send its sensed data to CH
5. if ($d_{S_i-to-CH_{S_i}} < d_{S_i-to-S_j}$)
6. S_i transmits data to CH
7. Else
8. S_i transmits data to S_j (S_j is a Relay node)
9. S_j transmits data to CH
10. End if
11. End for
12. End for
13. End for.

In the intra-cluster algorithm above; $d_{S_i-to-CH_{S_i}}$ represent the distance between sensor node S_i and cluster head CH_{S_i} , $d_{S_i-to-S_j}$ is the distance between sensor node S_i and its neighbor S_j .

5.2.2 Inter-Cluster Communication

In [9, 10], LEACH expects cluster members to exchange messages using the single hub with CH class of sensors. The CHs then assemble the information obtained from cluster members for onward direct delivery to the BS. But during the inter-cluster communication in EN-LEACH (see Fig. 6), individual CH gets packets of data from with its cluster members. The acceptance of all data is followed is followed by the aggregation of the data by individual CH. This results in a single composite message. The aggregated message is then delivered to its gateway node and yet again the data is delivered to the BS through the multi-hub path the gateways are utilized in this process. That is, cluster Heads-Gateway nodes-cluster heads...repeatedly until it reaches the BS. During this process, the other nodes are kept asleep to save energy (see algorithm listing 3).

Table 3 Algorithm for Inter-cluster communication

1. for each (Layer i)
2. for each Cluster Head (CH_i)
3. for each Gateway node (GN_i)
4. CH_i received data from Non-cluster head
5. CH_i aggregate the received data
6. if ($i == 1$)
7. CH_i transmits aggregated data to GN_i , then
8. GN_i transmits aggregated data to BS
9. Else
10. CH_i broadcast data to the next Layer CH
11. End if
12. End for
13. End for
14. End for.

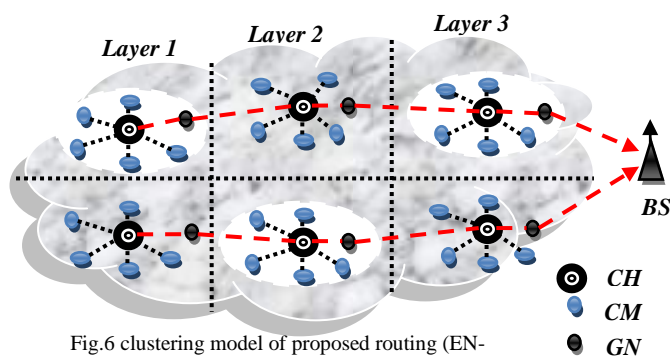


Fig.6 clustering model of proposed routing (EN-LEACH) protocol

6 Outcome of Simulation Experiments

In this section, we report the outcome of simulating the performance of the “Energy Neutral LEACH” (EN-LEACH) algorithms with respect to energy intake by cluster heads, coupled with the throughput of the network. MATLAB is used for this simulation. The results obtained are given by Figs 6, 7 and 8 respectively. The parameters used in the experiments are also given in Table 4.

Table 4 Simulation Parameters

Parameters	Values
Network field	100m x 100 m
BS Location	(50, 175)
E_{elec}	50nJ/bit
E_{fs}	10pJ/bit/m ²
E_{amp}	0.0013 pj/bit/m ⁴
E_D	5nJ/bit/signal
d_o	87m
E_{bgt}	54joule
Packet size (K)	4000bits
Number of node	300

6.1 Energy Objectivity Test

Usually, simulation experiments can be undertaken to possibly test energy neutrality with respect to any neutral-hierarchical energy protocol that is being proposed and even the “LEACH” protocol. The duration of any cluster failure is used to measure energy neutrality of the network. Cluster failure is mainly as a result of CH failure. In LEACH protocol, Cluster heads directly communicates with BS. The consequence of this direct communication is unfair energy intake between cluster heads. Cluster heads that appear far distant from the BS attract huge energy load as a result of long distances in communication links. Consequent upon this, they die early hence cluster failure. Fig. 7 indicates that the “EN-LEACH” is able to maintain energy neutrality in the network. It achieves this with an insignificant duration of

failure in clusters. The implication of this is that packets of data can be delivered to the BS non-stop. It is worth to note that this is possible because EN-LEACH uses gateways as intermediate node between cluster head to balance the energy intake.

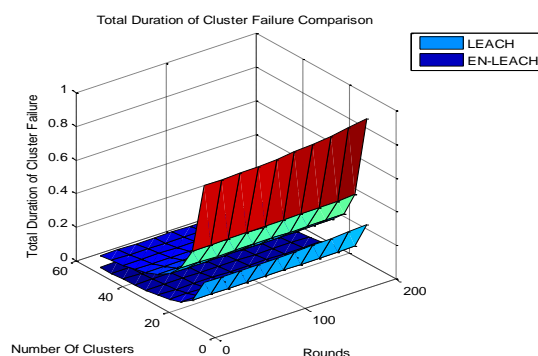


Fig.7 Total Duration of Cluster Failure Comparison

6.2 Energy Consumption of CH Review

In Fig. 4, we show the outcome of “EN-LEACH” in comparison with the more typical “LEACH” protocol. The comparison is on the basis of energy intake per cluster head. The application of gateway nodes in the delivery of data via heads of clusters to sink coupled with energy intake in the entire network is far lessened. This so happens because energy that could have been lost is conserved by the cluster heads for use by the BS. As the graph indicates, it is obvious EN-LEACH is better able to attain double energy conservation which is not the case with LEACH protocol. The illustration in Fig. 8 indicates energy intake by cluster head in terms of cluster number and round totals. As one will expect, energy intake is less if cluster number is high. The total energy intake by cluster heads for each round in EN-LEACH with respect to the increase in the volume of clusters is far less than that found in the LEACH. This is so because cluster heads within the LEACH protocol has the capacity to deliver data straight to the BS. This is addition to the fact that energy intake becomes greater. Therefore, the energy consumption is much higher. In the case of energy neutral LEACH; gateway nodes

obtain data to from the cluster heads thereafter deliver same to the BS. This arrangement significantly conserves more energy.

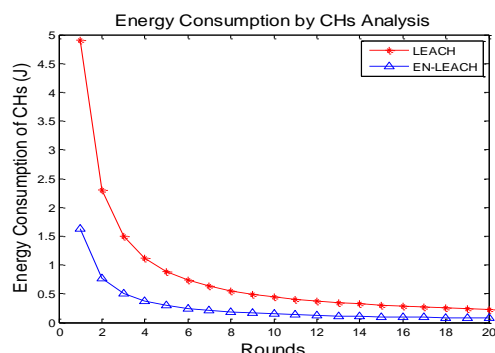


Fig. 8: Energy Consumption by CHs

6.3 Throughput

Throughput is used to specify the rate of transfer of data packets from individual sensor nodes to the designated base station. In Fig. 9 we present a differentiation with respect to the volume of data packets obtained from BS over a given number of segments. The findings from the simulation experiment indicate the throughput for LEACH was far too low unlike the case with EN-LEACH. Base stations however, in our proposed situation do better in obtaining data packets. As shown in Fig. 8, throughput of EN-LEACH appears five times better than LEACH. A substantial change in throughput based on our proposal with LEACH owes it to the almost round-the-clock full coverage provided entirely to the network. In the case of simulation experiments, sensor nodes are allocated minimal amount of energy for the start. In any event CH classes of sensor nodes are out of power, it is deemed that death has taken place hence delivery of data ends

automatically.

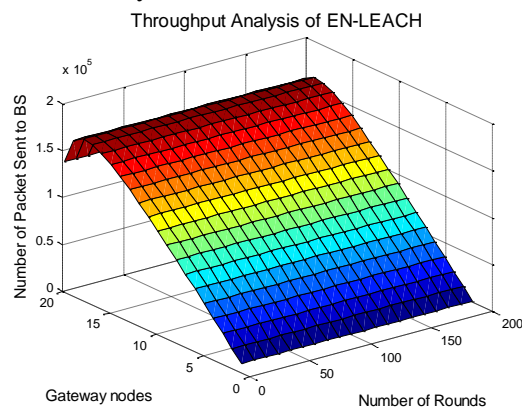


Fig.9 Throughput analysis of EN-LEACH

From the simulation results obtained, the following observations are made:

- i. When gateway nodes together with cluster heads are used, excessive energy requirements are kept very minimal throughout the entire network.
- ii. Energy Neutral LEACH is able to attain double energy requirement reservation unlike the LEACH protocol.
- iii. EN-LEACH outwits LEACH owing to a balance in energy emissions from each network node. Energy neutral state is therefore maintained.
- iv. Emission of energy is kept at a balance between non-cluster head nodes and CH nodes in the EN-LEACH unlike the case with LEACH protocol.
- v. The demise of any cluster head is usually caused by high energy intake; however, balancing this high-intake remedies this situation and further helps to curb the occurrence of an unstable situation that could be caused by a failure of any cluster head. Overall, energy neutrality is maintained throughout the network.

7 Conclusions

Implementing routing in sensor networks comes with a great challenge. This is owing to their peculiar characteristics which to a large extent differentiates them from other conventional wireless networks. Sensor networks will always remain sensitive to energy requirements. This however is not the case with the old-fashioned wireless network. In order to minimize the volume of messages that require transmission via the sink in the case of large scale wireless networks, the introduction of clustering in the network topology is considered necessary. In addition, “energy harvesting” technology which has also become available enables sensor node to attain an infinite quantity of energy. This in a way helps the sensor in the network to achieve neutral state of energy.

In this research work, we proposed a neutral energy LEACH (EN-LEACH) routing protocol for “harvesting of energy” in the case of wireless sensor networks. We further developed a network model that is based on “energy harvesting”. The MATLAB programming environment was used to simulate the model. The simulation results obtained showed that the energy requirement per cluster-heads for any given round in EN-LEACH was far lower compared to LEACH. In one instance, just about after 50 rounds, LEACH gulped about 42% of energy whereas EN-LEACH gulped about 15%. We further observed that failure of cluster was successfully prevented in EN-LEACH through ensuring a neutral energy state in the entire network. This however contributes to improved network data output coupled with consistency in delivery. We conclude this work by saying that the performance of energy neutral LEACH outsmarts LEACH.

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