AN ENERGY-EFFICIENT PROTOCOL BASED ON LEACH FOR SMART HOME

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ABSTRACT

In Smart Home (SH) the devices and appliances can be controlled automatically and remotely via the internet. Sensors in a smart home detect changes, which are processed and used to make intelligent decisions, such as automatically turning on the lights. To be effective, a smart home's sensors must be connected, establishing a wireless sensor network as the backbone for the smart home's functionalities. For many researchers, the performance of WSN faces several challenges. Power consumption is the most crucial factor since nodes require power to collect, process, and send data but have limited energy. As a result we propose an improved protocol for WSN in smart homes called EEP-LEACH (Energy Efficient Protocol - Low Energy Adaptive Clustering Hierarchy) based on the LEACH protocol. Matlab was used for the algorithm's performance analysis, and the simulation result showed that, compared to others protocols the death time of the nodes was longer, thus managing to balance the consumption of energy of the network nodes. Python and Arduino are used in this research to perform some simulations.

KEYWORDS

Smart home, LEACH protocol, wireless sensor network, Arduino, Python.

1. INTRODUCTION

WSN, IoT, and various programming languages like Java, Arduino, and Python can all be used to make a smart home. A "smart home" is defined as one that requires minimal user involvement and intervention in order to make life more secure and efficient and allow for independent living in a safe and secure environment. It includes automation that monitors temperature, humidity, energy, smoke, and wind. Various body temperature, cooling, motion, and heart rate sensors can be used to manage security automatically. Additionally, automation reduces the amount of energy used [1]. For example, daylight can be used as a partial replacement for electrical lighting by using sensors and smart controls. Numerous wireless-enabled sensors are working together to achieve a common goal in a smart home's sensor network, which makes it more efficient. Base stations in a WSN also receive data from sensors and help process the collected data [2].

In wireless sensor networks (WSNs), energy is used by nodes to collect, process, and send data, the lifetime is determined by its ability to use available energy efficiently[3]. The author with the ref. [4] energy consumption is one of the main interests of WSNs, and many strategies have been proposed to evaluate it. However, these approaches often do not consider reliability issues and the power consumption of applications running on the network. For the author [5], WSNs deploy a large number of economic and low-power sensor nodes to monitor the environment in remote or big areas. WSNs are now often utilized in many field like industries, military, disaster detection, habitat monitoring, and smart homes. However, the limited operating time of the WSN

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nodes is a problem derived from the limited capacity of their batteries, for which various studies have been carried out to reduce their operational energy consumption. For automation of homes and houses in general, several publications have generated solutions [6, 7] implementing sensor networks to control household appliances such as lights, fans, doors, and gas levels and measure energy consumption [8] using various sensors such as the LM35, infrared, LDR modules, and processing devices like the ESP8266 MCU node and Arduino UNO.

In this study, we propose and evaluate EEP-LEACH, a new energy-efficient protocol for homogeneous wireless sensor networks. By rotating the cluster-head role among all nodes, each node uses energy equitably in accordance with the LEACH lets' ideas. This research will concentrate on wireless sensor networks in the context of a smart home. To close the gap, the paper first investigates how various automation systems work in a smart home before delving into wireless sensor networks.

1.1. Research Highlights

1. A literature review of available resources in understanding Smart Home and WSN technologies.
2. Propose a new routing protocol for indoor WSNs that is energy efficient. To verify our model, we will compare the current survey to other past surveys and analyze the various design possibilities.
3. Simulation and Implementation of various smart home features to give a better understanding.

This article is structured as follows: In section 2, we briefly review related work. The fundamental basis for LEACH and EEP-LEACH is described in Section 3. Section 4 shows the performance of EEP-LEACH by simulations and compares it with LEACH, LEACH-DCHS, SEP, and TSEP. Also, this work performs various smart home features. Finally, Section 5 gives concluding remarks.

2. Related Work

The concept of smart homes that have appeared with the advancement of technology is innovative and focuses on energy saving, safety, and comfort for users. Smart home management systems play a key role in smart grid [9] Internet of Things (IoT) programs. One important application in wireless sensor networks is a smart home, and with the advancement of technology, it will become the future direction, as it can meet people's demand for convenience, practicality, and humanization of the home system.

2.1. Cluster- based Routing Protocols in Smart Home

LEACH is among the most classic algorithms in the application of wireless sensor networks [10]. This hierarchical routing protocol's core idea is to adopt the cluster head rotation mechanism; thus, it can balance the power load in the whole network, improve the lifespan and reduce the power consumption of the network. However, the clusters are chosen randomly in each round, and this leads to an uneven load distribution on the network, and this event produces an increase in energy consumption.

Recently, the increase in work on cluster-based routing protocols for Smart House applications has been considerable. By integrating the fading feature of the Smart home with an enhanced hierarchical routing algorithm was proposed by the author [11]. The nodes' remaining energy plays a significant role in the cluster head (CH) selection process. The three-order polynomial logarithmic distance loss model also determines energy usage to represent the path loss in actual use. The internal structure of SH is combined for the first time in this improved routing technique for regional partition clustering. Security issues in the smart home are one of the limitations of this work. A new energy-efficient routing protocol named EELP is proposed [12]. According to the author's considerations, it can be applied in various environments, apartments, offices, buildings, etc. However, it is not fully confident whether satisfactory results will be obtained indoors for smart homes.

2.2. LEACH-based Hierarchical Routing Protocols

Lindsey and Raghavendra [13] proposed a protocol called PEGASIS (the power-efficient gathering in sensor information systems). By just exchanging information with immediate neighbors and sending to the base station alternately, each node uses less energy per round. Improves the lifetime of the network concerning the LEACH protocol. For many applications where the sensor network's feedback must be trustworthy, the author with reference to [14] introduced SEP, a heterogeneous-aware protocol to extend the time before the first node dies (what we refer to as the stability period). Based on the energy remaining in each node, SEP calculates the weighted election probabilities of each node to become the cluster head. This protocol uses two different kinds of nodes. These nodes can be basic or advanced. In heterogeneous contexts, advanced nodes are more powerful than standard nodes and can send messages more efficiently than existing clustering protocols. It has the limitation that it does not work for multilevel heterogeneous wireless sensor networks.

This protocol, called LEACH-DCHS (LEACH-Deterministic Cluster Head Selection), is proposed by Handy et al. [15] for prolonging the network lifetime. To obtain such results, the value of the threshold $T(n)$ was first modified for the selection of CHs. Second, an approach was implemented to define the useful life of the network in addition to applying a deterministic group head selection algorithm with low energy consumption. Energy heterogeneity has a crucial impact on the lifetime of a network. Therefore, the TSEP protocol proposed by Kashaf et al. implements three levels of energy heterogeneity and can get better results than two levels of energy heterogeneity. Being a reactive protocol with three levels of heterogeneity, it has three types of nodes (normal node, advanced node, and supernode), where the supernodes have higher initial energy than the advanced ones. However, TSEP cannot be energy efficient to ensure balanced load distribution. The proposed protocol on ref. [16] increases the overall lifetime of the WSN by considering the residual energy and the distances from the nodes to the BS, taking these parameters into account when selecting the cluster heads and using multi-hop communication. The author with ref. [17] developed a centralized LEACH protocol based on a centralized algorithm over a distributed algorithm. The CH is selected using the node location information of each BS. The BS central controller works efficiently because it contains the global cluster information to manage the cluster and data transfer. However, the energy consumption of the network is not suitable. In this work [18], the authors proposed a routing protocol with three types of nodes to prolong the lifetime and stability of the network by achieving heterogeneity and a high level of energy in the whole network. It uses a dynamic clustering technique, which leads to a large energy consumption in the nodes for cluster formation. As part of the study conducted by [19] presented the importance and factors that affect clustering in wireless sensor network protocols. However, the proposed algorithm does not require total knowledge of the network energy.

3. BACKGROUND AND PRELIMINARIES

The operating principles of the LEACH and EEP-LEACH algorithms are discussed in the next subsections, those algorithms main ideas are incorporated into the proposed protocol. There are several ideas about indoor deployment offered.

3.1. Architecture of SH

The constant evolution of technology opens up an infinite world of possibilities and tools that denote an improvement in the way of carrying out tasks and activities, as well as in the way of living; an example of this is the Implementation of different technologies with the purpose to create Smart Spaces. Smart Spaces technologies generally aim to improve smart homes' efficiency, safety, and security. Fig 1 shows the distribution of an intelligent house elaborated following the standards [20].

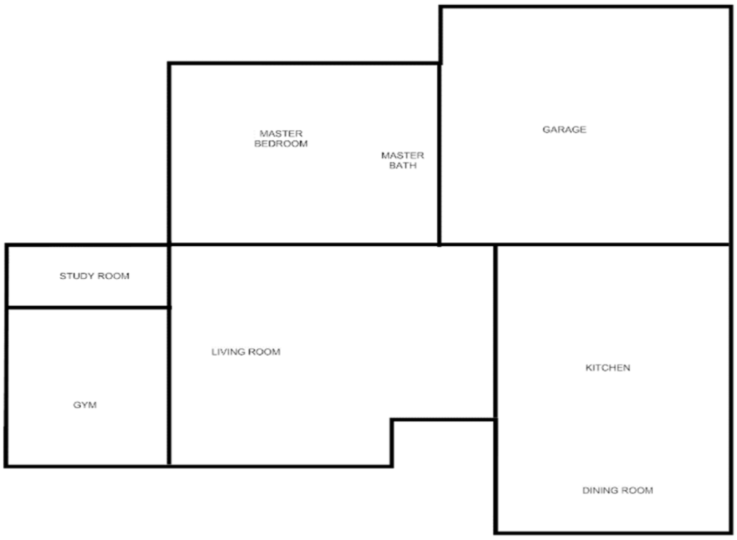

Fig. 1. Region partition of SH

In the same subregion, the separation between two fixed nodes is greater than the detection radius but smaller than the transmission radius. The node deployment is shown in Figure 2. In specifically, the BS is situated in the center of the field.
There are two types of networks on WSN [21]:

- **Unstructured:** It comprises a dense collection of nodes deployed ad hoc, possibly randomly. Once deployed, the network operates unattended, monitoring and reporting information. Due to many nodes, maintenance, connectivity management, and fault detection are difficult.
- **Structured:** All or some of the nodes are deployed in a pre-planned manner, placed in fixed positions. They have the advantage of requiring fewer nodes to achieve area coverage, with lower administration and maintenance costs.

Our project is focused on structured networks.

3.2. Deployment Specifications

This section suggests applying the EEP-Leach Communication Protocol to a smart home's wireless sensor network, the chosen design of which is given in accordance with the following figure. Each sub-region is assigned nodes with various sensors, such as smoke, gas, temperature, and humidity. To reduce the negative effects of random distribution on coverage and connectivity for these permanent nodes, manual and periodic deployment is used. For the simulations of this work, the sensor nodes are randomly deployed, except for the sink, whose position will be in the center of the field. The simulator randomly generates positions.

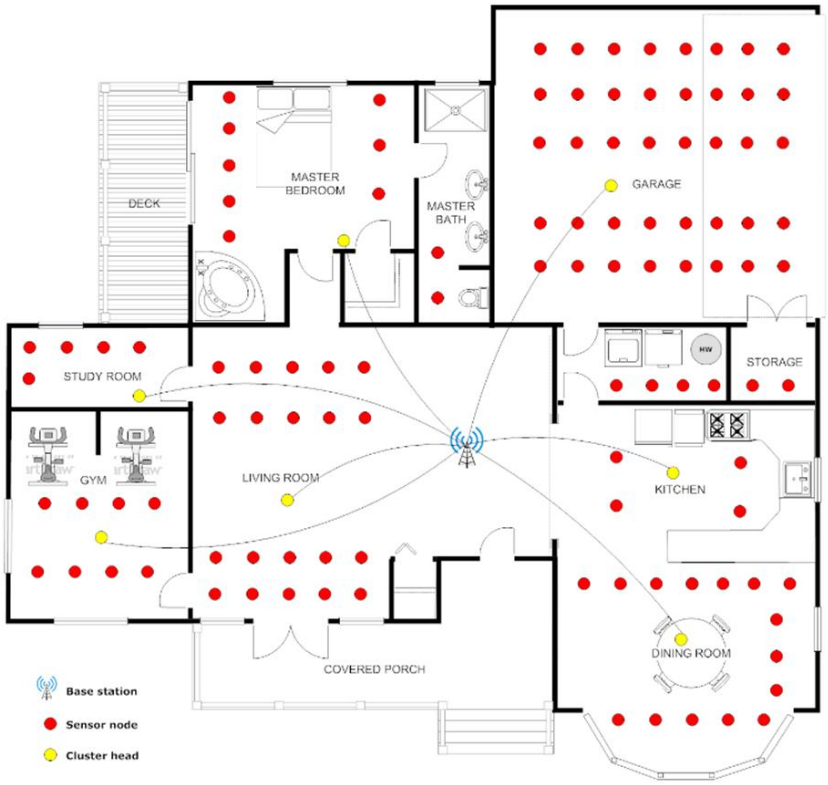

Fig. 2. Layout of nodes in SH

While attempting to increase the network's life, data communication is one of the key architectural issues faced by WSNs. [22] provides a summary of certain design considerations that are important for a successful deployment and have an impact on the routing process:

3.2.1. Deployment

The deployment of the nodes depends on the application and affects the protocol's performance. When the deployment is deterministic, the data is routed through predefined paths. When random, the network structure is created ad hoc, and routes will likely be made up of multiple wireless link hops.

3.2.2. Data Reporting Model

Data sensing and reporting depend on the application and its time requirements and can be classified as continuous, by event, query, or hybrid. In the continuous model, the sensors sense and transmit periodically. In the event and query reporting models, the sensors react to a sudden and drastic change in the sensed value because an event has occurred or to respond to a query initiated by the base station. The required model heavily influences the routing protocol.

3.2.3. Heterogeneity of Nodes or Links

The nodes may be homogeneous in capacity or may even differ in the role. For example, an application may require a combination of various sensors to monitor ambient temperature, pressure, and humidity, detect motion with acoustic signals and capture video of moving objects. The sensors can be deployed independently, or the different functionalities can be included in the same sensor nodes.

3.3. The LEACH Protocol

One of the most known hierarchical routing methods for sensor networks is the Low-Energy Adaptive Clustering Hierarchy Protocol (LEACH) proposed by [10]. For the purpose of balancing the energy usage between the nodes, LEACH selects a smaller number of nodes at random to serve as the cluster head. To limit the quantity of data that needs to be broadcast to the base station, the cluster head nodes utilize the data aggregation approach to compress the data they receive from the other cluster nodes. LEACH employs TDMA (Time Division Media Access) and CDMA as its two media access methods (Code Division Media Access).Together, these methods enable communication in two domains: one between cluster nodes, and another between head nodes and base stations. Information gathering is consolidated and done on a regular basis. This protocol is suitable for applications that require continuous monitoring.

The **setup phase** and the **steady state phase** are the two stages in which LEACH operates [23, 24]. The cluster head nodes are selected during the configuration process. Data transmission to the base station happens during the active state phase. The second stage takes longer to complete than the first. Figure 3 depicts the steps of the LEACH process.

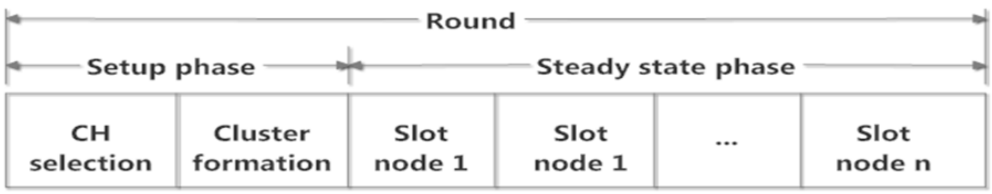

Fig. 3. Leach Operations with Setup and Steady Phase

A certain percentage of nodes are selected as head nodes during the setup phase. To do this, each node begins with a random value between 0 and 1 for its r, attribute, which varies with each setup step. If the number is less than a predetermined threshold $T(n)$, the node becomes a cluster leader for the current round.The threshold is generated based on an equation that includes the required proportion of nodes that must be headers and the set of nodes that have been headers in the previous $1/p$ rounds, represented as G in equation 1.

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \, mod \, \frac{1}{p}\right)}, & if \; n \in G \\ 0, & otherwise \end{cases} \quad (1)$$

All head nodes broadcast a message announcing their load on the network. The non-head nodes, after receiving the announcement, decide which cluster to associate with. This decision should be based on the signal strength of the received announcement. Non-leading nodes inform the leader node of their membership in the cluster. After nodes send their membership message, CHs create a TDMA scheme for media access from nodes in their cluster. Using TDMA to transmit data eliminates collisions inside each cluster [25]. The leader allocates a time slot for data transmission to each node. The established schema will be broadcast to all nodes in the cluster.

During the **steady-state phase**, the sensor nodes send their data to the head nodes, which then send it to the base station using a technique called "data aggregation." After a set period of time, the configuration phase will begin again. To minimize interference from other clusters' nodes, each cluster will communicate via a CDMA technique.

3.4. EEP-LEACH Protocol

This section describes the EEP-LEACH protocol and its improvements based on the LEACH [10] protocol.Our protocol aims to minimise energy consumption in order to prolong the network's lifespan and transmit more data to the sink. It is also adaptable for usage in smart homes and other interior spaces.

The approach for selecting CH depends on two variables: the energy correction term (EC_t) and the general probability term (G_p). Thus, the threshold value to become a CH depends on both terms in each round. So the threshold value $T(n)$ can be calculated by Equation 2 and the value of G_p and EC_t are derived from Equations 6 and 7 respectively.

$$T(n) = G_p * EC_t \qquad (2)$$

The G_p term of equation 2 is represented on the equation 1 described in the previous section. Multiplying the numerator and denominator by 1/p gives

$$= \frac{p * \frac{1}{p}}{\frac{1}{p} - 1\left(r \, mod \frac{1}{p}\right)} \qquad (3)$$

$$= \frac{1}{\frac{1}{p} - \left(r \, mod \frac{1}{p}\right)} \qquad (4)$$

substituting the value of p = 0.1 in equation 4

$$= \frac{1}{10 - (r \, mod \, 10)} \qquad (5)$$

$$G_p(n) = v[r \, mod \, 10] \qquad (6)$$

Then for any valor of r (round) the v (vector) value is the array of number $v = \left[\frac{1}{k}, \frac{1}{k-1}, \frac{1}{k-2} \dots 1\right]$ for any valor $1 \leq k \leq 10$.

Our goal is to incorporate a new factor that depends on the energy condition of the network in the cluster head selection process. This factor has two contributions: first, it depends on the energy fraction of the node, while the second depends on the fraction of energy consumed. With this contribution, it is possible to keep the network balanced so that energy consumption is always proportional to the amount of energy remaining in the network. For this approach, in any round r, the probability that node n is chosen as cluster head is called the “Energy Correction Term” and is defined by the following equation.

$$EC_t(n) = \frac{f_{E_n}}{f_{E_p}} = \frac{\frac{E_r}{E_n}}{1 - \frac{E_r}{E_0}} = \left(\frac{E_r}{E_n}\right)\left(\frac{E_0}{E_0 - E_r}\right) = \frac{E_r E_0}{E_n(E_0 - E_r)} \quad (7)$$

Where:

$E_n =$ energy of node n in current round
$E_0 =$ initial energy of the network
$E_r = \sum_n E_n =$ total energy of the network in round r
$E_p = E_0 - E_r =$ energy consumed by the network from the beginning to round r
$f_{E_n} = \frac{E_r}{E_n} =$ fraction that represents the node energy in round r
$f_{E_p} = \frac{E_p}{E_0} =$ fraction that represents the energy consumed from the network in round r

So after putting the value of G_p and EC_t in Equation 2, the finalthreshold value will be represented by Equation 8.

$$T(n) = \begin{cases} v * \frac{E_r E_0}{E_n(E_0 - E_r)}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad (8)$$

G represent the set of nodes that have not been cluster-heads in the last $\frac{1}{p}$ rounds.

When proposing a modification to reduce energy consumption in the cluster head selection process. Applying the general probability and energy correction term improves the sensor node network lifespan compared to LEACH. According to our simulations, modifying the cluster-head threshold increase the lifetime of EEP-LEACH microsensor network by 30 to 70%.

As part of the wireless network model [26] utilized in this article, 100 sensor nodes are equally and randomly placed in a 100 m square region. In addition, every sensor has the different beginning energy and location. The energy is utilized mostly during data transfer reception. Figure 4 illustrates the transmission node power model.In this model, the transmission node's power consumption is determined by Equation 7, while the receiving node's is supplied by Equation 8.

$$T_{ex}(k,d) = \begin{cases} kE_{te} + kE_{fs}d^2 & d < d_0 \\ kE_{te} + kE_{amp}d^4 & d \geq d_0 \end{cases} \quad (7)$$

$$R_{ex}(k,d) = kE_{re} \quad (8)$$

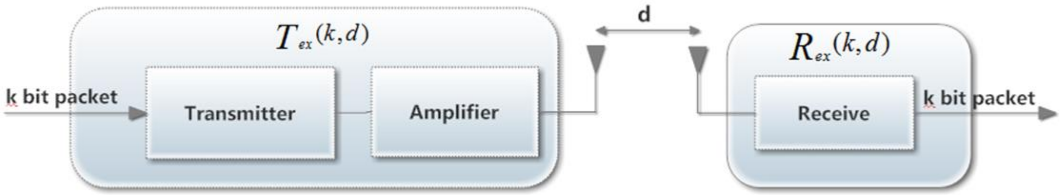

Fig 4. Radio energy dissipation

model coefficient, E_{amp} is the multi-fading model coefficient, and d_0 is the critical value for both models. E_{re} is the energy consumption by using the receiving device, $R_{ex}(k,d)$ Is the energy consumption for receiving k-bit data at distance d.

4. Results and Discussion

The interior of any smart home has a well-designed lighting control system. A lighting control system should be considered in the early stages of building a smart home. The days of having a simple ON/OFF switch for the lighting are long gone. "smart lighting" refers to the ability to easily and even automatically control lighting in the modern era. When lighting is integrated with logic or intelligence into luminaires, it can interact with the environment, other devices, and the occupants of a home [27-29]. It is possible to control multiple lighting features, from simple ON and OFF to more complex adaptive lighting that may involve changing the bulb's intensity. Smart lighting requires understanding the underlying concepts before a control system can be implemented.

4.1. Proteus 8 and Arduino Automatic Lighting Simulation

The devices used in proteus 8 to design the simulation are. 9C12063A3300FKHFT is a chip resistor, ARDUINO UNO R3 a programmable microcontroller, ERJ-14YJ103U a thick film resistor, LED- GREEN, YELLOW, and RED, are light-emitting diodes of respective color, LDR a light-dependent resistor, and LMO17L.

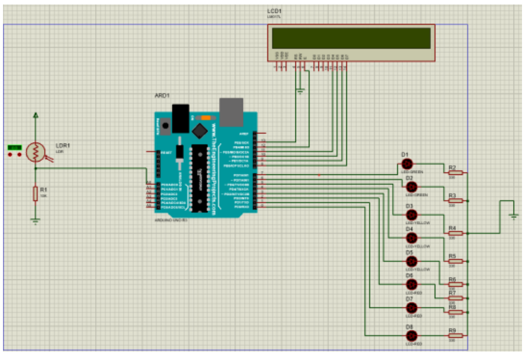

Figure 5. Proteus 8 Simulated Devices Layout and Connectivity

In figure 5, the LDR detects lights and sends the data to the Arduino UNO r3 via analog input pin A0. Arduino UNO r3 is a microcontroller that makes decisions depending on the analog input in A0. An Arduino code enables the ability to make decisions. On the right side, the board has 16 digital inputs and output pins, and the output can simply be controlled with Arduino if statements depending on the analog input, hence a way to control the bulbs connected from 0-7 pins. The LCD is used to display the LDR input.

Arduino Code for Automatic Lighting used in the simulation is integrated with the Proteus 8 software to give results. The LDR provides a value applied in the if statement to ensure lights behave differently depending on the light intensity. For example, if the LDR value is 0, all LEDs are set to "HIGH," meaning they light up.

All the bulbs light when the light intensity is 0, as shown in figure 6 below:

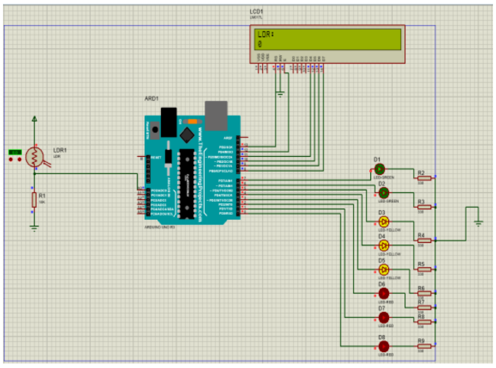

Figure 6. Lighting when there is 0 light intensity - All the bulbs light

When the light intensity is set to 2, as in figure 7 below, all the other bulbs light except the LED-green bulb.

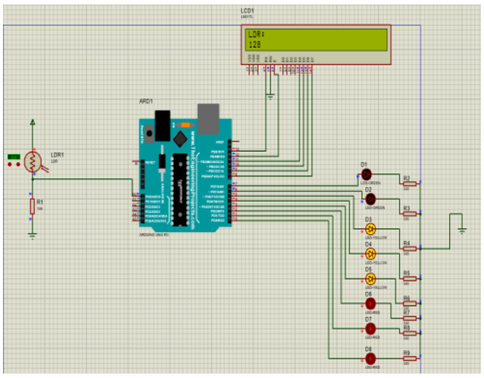

Figure 7. Lighting when light intensity is set to 2 – While the other bulbs light, the LED-green bulbs remain OFF.

As shown in figure 8 below, when the intensity is set to 10, only the LED-RED and one LED-YELLOW bulb lights as others remain off.

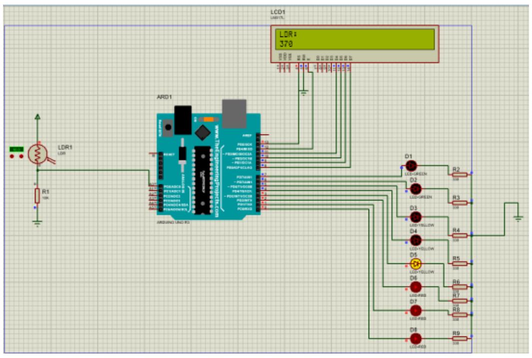

Figure 8. Lighting when the intensity is set to 10 – Only the LED-RED and one LED-YELLOW bulb lights.

When the light intensity is set to 47, only one LED-RED bulb lights, any higher light intensity causes all the bulbs to go OFF, as in figure 9.

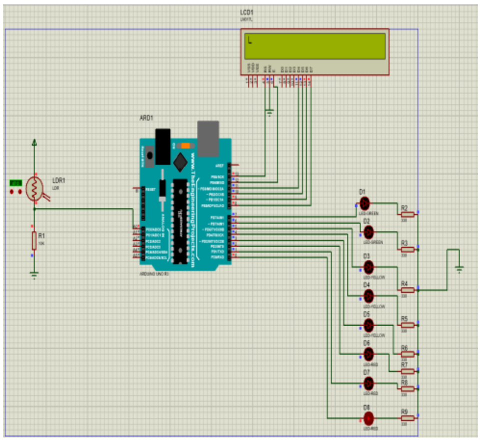

Figure 9. Lighting when set to 47, only one LED-RED bulb light and any higher, no bulb lights.

4.2. Network Analysis and Simulation

In this section, using MATLAB Simulator [30] , we evaluate the performance of the EEP-LEACH protocol. During the simulation process, somes protocolos based in homogeneous and heterogeneous environment were considered, and their average results were taken to further analysis. The simulated network consisted of 100 nodes in a 100m × 100m stationary field. Before the simulation, each node was allocated an energy value between 0.5 and 0.7J, and it was anticipated that data reception and transmission would require the same amount of energy. After each simulated cycle, a red dot was placed on the dead nodes, while a star was placed on the CH. Experiments indicate that the proposed method increases the network's lifespan by 30 percent. Until all nodes consumed their given energy amounts, a continuous simulation process was maintained. Table 2 lists the parameters utilized in our simulations.

Table 2. The simulation factors used in this study

Parameter	**Value**
Network Field	(100,100)
Number of nodes	100
Distribution of sensors in the network	random
Protocol 1	LEACH
Protocol 2	LEACH-DCHS
Protocol 3	SEP
Protocol 4	TSEP
CH probability	0.1
Number of rounds	14000
BS position	Located at (50 × 50)
E_0	50 nJ/bit
ϵ_{fs}	10 pJ/bit/m^2
ϵ_{amp}	0.0013 pJ/bit/m^4
Data packet size	4000 bits

Our goals in doing simulations were to compare the performance of EEP-LEACH with TSEP[31], SEP[14], LEACH-DCHS[15], and LEACH[10] protocols based on energy dissipation and longevity of the network.

This simulation shows the network lifespan of the proposed EEP-LEACH protocol compared to other protocols. Figure 12 represents the number of dead nodes vs the number of rounds in WSNs. Table 3 displays the behavior of dead nodes for each protocol compared.

Table 3. The rounds number of the first death node

	LEACH	LEACH-DCHS	SEP	TSEP	EEP-LEACH
Round	515	1095	1122	2622	1095

However, the proposed EEP-LEACH does not begin to eliminate nodes until 1095 rounds have passed. In round 2622 of the TSEP protocol, nodes begin to die. Figure 10 shows the progress of the nodes; in the 14000th rounds, our protocol still has eight nodes alive, LEACH-DCHS has three, and the remaining protocols have none.

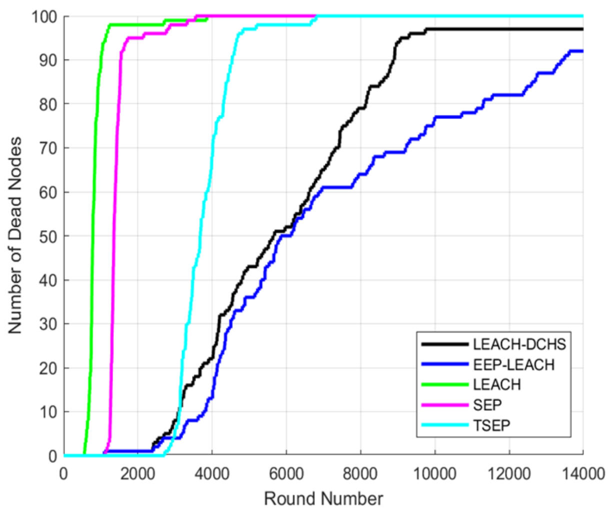

Fig. 10. Dead nodes vs rounds

As shown in Fig 11, the performance of the protocols has been shown, which is the number of nodes alive as the functioning of the wireless sensor network proceeds in terms of the number of rounds per node.

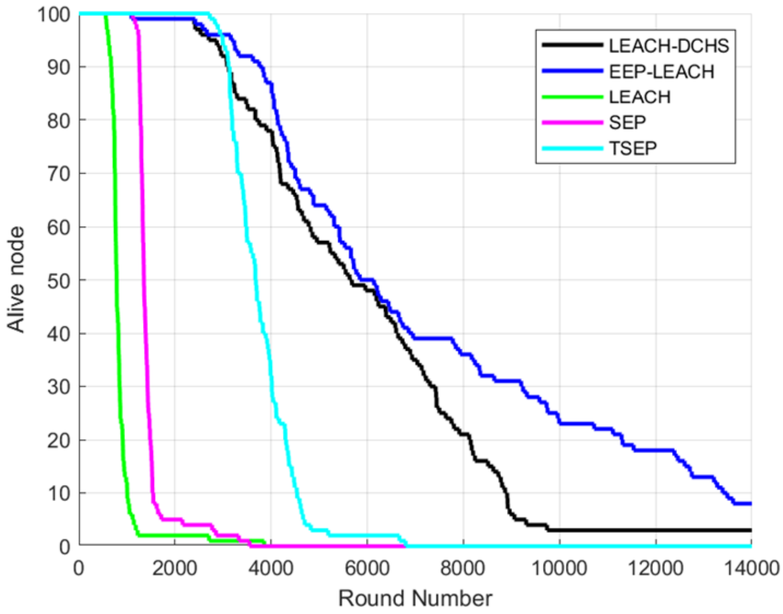

Fig. 11. Alive nodes vs rounds

Fig. 12 represents the number of Packets sent to the Base station (BS) per round, its shows that the total number of Packets sent to the Base Station is higher in the EEP-LEACH protocol than in the other protocols. Packet transmission will be defined by the network's lifetime that is increased in EEP-LEACH.

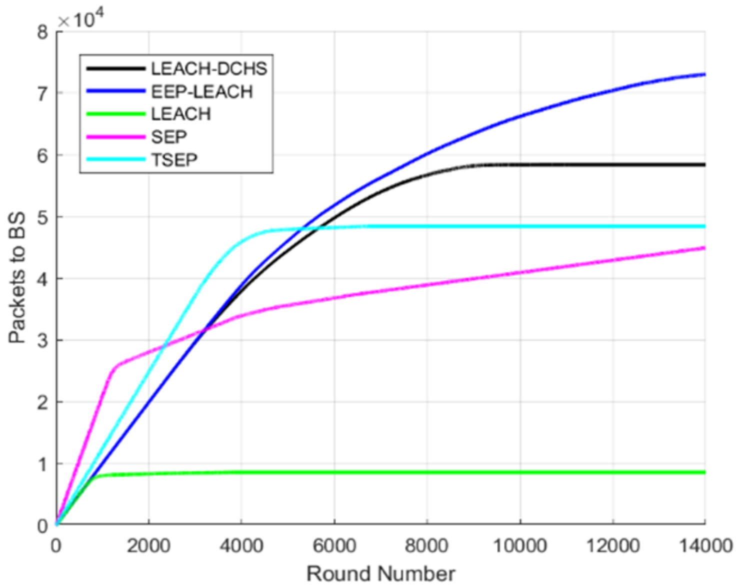

Fig. 12. Number of Packets to Base Station per Round

Figure 13 shows that the suggested protocol be able to balance the amount of energy used by each node. It has been demonstrated that the increased threshold decreases the power consumption of the nodes, and the EEP-LEACH protocol extends the life of the network with significantly longer cycle periods than the other protocols.

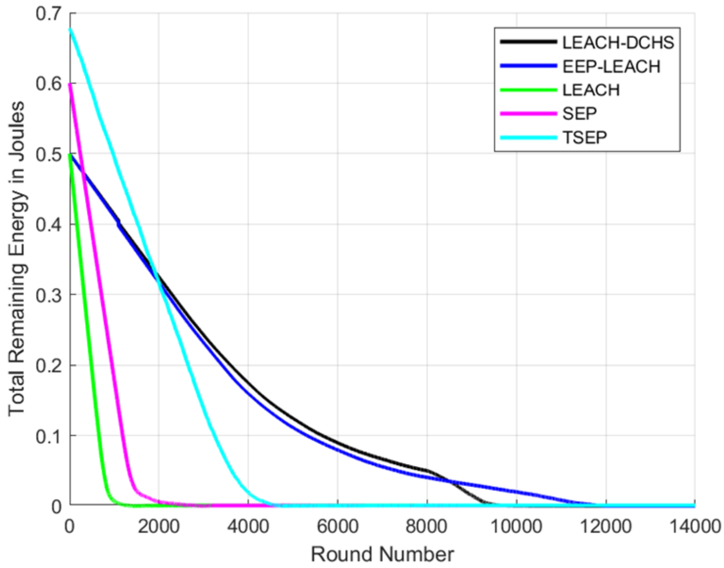

Fig. 13. Average energy of the whole network. When SEP E_0=0.6j, TSEPE_0=0.68jthe rest of the protocols E_0=0.5j

5. Conclusion

Well-designed control system features are key to building an effective smart house. These control systems are responsible for home automation, such as switching on and off the light, tracking user movements, and managing energy flow in the house. All these control features will only be effective if the wireless sensor network is effective, starting from the sensor node. An effective WSN is key to achieving a perfect smart home system. EEP-LEACH is a novel energy-efficient routing protocol developed to minimize energy consumption and increase the lifetime of WSNs in smart homes. Therefore, the proposed method reduces the total cost of communication and significantly increases the useful life of the network. Simulation results indicate that the proposed EEP-LEACH protocol provides more reliable and energy-efficient power distribution than other current methods.

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