An Improved Solar Low Energy Adaptive Clustering Hierarchy (IS-LEACH) Technique

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Abstract: In recent years, the Wireless Sensor Networks (WSNs) have grown dramatically in many fields such as military applications, environmental applications, and health assistant applications. However, there are numerous problems associated with applying the WSNs. Such problems are related to power consumption, performance, reliability, installation cost, and hardware cost.

Thus, many algorithms in the WSNs context have been considered to propose an improved solar Low Energy Adaptive Clustering Hierarchy (LEACH) technique for maximizing the lifetime, increasing the performance, increasing the reliability, and decreasing the costs. This proposed technique improves the selecting Cluster Heads (CHs) process and powering it with a renewable energy (solar cell). The OMNeT++ tool has been employed to simulate such technique. After many scenarios have taken place with different data sets, this study finds that the lifetime of WSNs has been maximized, the performance has been improved, the reliability has also been improved, and finally the cost has decreased.

Keywords**:** WSNs, LEACH, and Solar Energy.

1. Introduction

Recently, the development of embedded systems has resulted in small, cheap, and portable devices. These devices have the ability to sense, compute, and route data. The Wireless Sensors Networks (WSNs) consist of many hundreds or thousands of such devices. These devices are deployed in random and unattended fashion [1] [25]. They have the ability to work with each other and report their collected data to a special node called sink node or Base Station (BS). Such nodes give the end-user the ability to monitor a specific phenomenon (temperature, humidity, seismic etc.) [5]. WSNs have many additional features once compared with other types of networks, especially Ad-hoc networks. For instance, WSNs have a higher number of nodes than any ad-hoc networks; WSNs nodes are deployed randomly in many cases; communications are not reliable due to the frequent change in network topology; and nodes in WSNs use broadcasting communication [3]. It is worth mentioning that many applications have recently moved to WSNs due to their low-cost and the feasibility in gathering interesting data, as the WSNs have the ability to give continuous and up-to-date data. The most common applications are military, environmental, health assistant, and home applications fields [3]. However, despite its advantages over other types of networks, WSNs have shown shortages related to high-energy consumption rate, especially in CHs, limited processing power, limited memory capacity, and low communication reliability.

More interestingly, the shortage in energy results in limited abilities and short network lifetime. Limitation on memory puts more pressure on communication media to ensure the delivery of data. [2]. Economic feasibility also is a major concern due to the extensive number of nodes in such networks. The WSNs nodes are operated in a very limited size, hence the production cost of hardware and software has to be considered before deploying these nodes.

Once the operational environment is well understood, this gives an idea under which conditions and circumstances the WSNs are expected to work. According to many researchers such as [24] [23] [27] the best type of routing data in WSNs are the hierarchical routing protocols. In clustering-based WSNs, the network is divided into two layers, and the nodes in the same layer have the same attribute. The most important clustering algorithm is a Low Energy Adaptive Clustering Hierarchy (LEACH) [12] [26]. Therefore, this study is conducted to improve the LEACH algorithm by energizing the networks with solar power and improving the selecting process of CHs.

2. Literature review

As previously mentioned, the most valuable clustering algorithm in WSNs is LEACH [12]. In this respect, many works have been conducted to propose algorithms to improve some issues related to the LEACH such as CHs distribution and cluster formation process.

Some of these algorithms are closed to LEACH and known as LEACH's descendants. The first attempt to solve some of LEACH problems was the work in [9]. The authors attempted to modify the selection of CHs by determining the component and to include the residual energy in the calculation. However, a serious issue is not considered while the nodes still must have the energy to send their data to BS in which the network will suspend. In order to solve this problem, the authors modified the equation with the probability of becoming CHs in the last rounds. Additionally, using residual energy in the selection of CHs improved the network lifetime, and introduced a new approach to defining the lifetime of WSNs using three new metrics that were

namely Node Dies (FND), Half of Nodes Dies (HNA), and Last Node Dies (LND). However, this approach still has some problems, especially in the communication between nodes and BS, and the assumption that all nodes can reach BS directly, which is impractical in actual terms.

LEACH-Centralized (LEACH-C): was proposed in [11]. In this modified version of LEACH, BS has the control over the entire network which means decreasing in autonomy.

LEACH-Fixed number of clusters (LEACH-F): was proposed in [12]. In this technique, the number of clusters through the entire network will be fixed, which means that any node can become CH only in its cluster. The problem with this technique is the network dynamism. Thus, adding or removing the nodes is not feasible and all nodes must be stationary.

LEACH-Balanced (LEACH-B) was proposed in [7]. In LEACH-B technique, every node must know its position and the position of the final receiver. Each node also must calculate the energy dissipation to a final receiver. Based on this calculation, the node can choose its CH. LEACH-B used a decentralized technique which improves the network lifetime. However, a GPS may be required, which is not feasible in WSNs.

Solar LEACH was proposed in [22]. Solar LEACH modified the LEACH protocol to become solar aware. According to the authors, it is a good way to energize the CHs with a permanent power supply.

Tow Level-LEACH (TL-LEACH): was proposed in [17]. TL-LEACH used two levels of CHs denoted as primary CHs and secondary CHs. The secondary CHs collects data from sensing nodes, performs data aggregation, and sends it to the primary CHs. With this technique, better energy balance was achieved, especially in high-density WSNs. Additionally, it used local coordination to enable scalability and robustness of WSNs

LEACH-Energy Threshold (LEACH-ET) was proposed in [16]. LEACH-ET employed an energy threshold (ET) to evaluate the CHs. The CH will be changed only if they reached ET. In the same respect, any node reaches ET, it will be eliminated from the process of selecting CHs.

Advanced solar –aware LEACH (As-LEACH) was proposed in [13]. As-LEACH was an improvement over the previous work introduced in [22].

Time Based-LEACH (TB-LEACH): was proposed in [14]. The selection of CHs and the formation of clusters in TB-LEACH depend on a random timer and they are without any global information about the network or the nodes.

Mobile Agent based-LEACH (MAT-LEACH): was proposed in [10]. In this protocol, a mobile agent is used as CH, since the CHs in LEACH are the most consuming energy nodes. Also, this protocol introduced how to effectively process data using a mobile agent.

Advanced-LEACH routing protocol for micro-sensor networks (Armor-LEACH) was proposed in [4]. This protocol was introduced to large-scale networks. The simulation results showed that there are three times more improvements in lifetime and performance compared with the LEACH.

The work in [24], used a single clustering algorithm. It selected the optimal CHs locations, then powered some nodes with solar energy and used them as relay nodes between the base station and CHs.

The proposed works in [24] [6], introduced hierarchical network architecture. In these works, the primary nodes are equipped with a renewable energy source, and the secondary nodes are equipped with the chemical battery.

3. Methodology

In trying to solve the energy problems in WSNs, a finite resource of energy should be used. Moreover, the WSNs should be designed in order to be able to equip such resources.

There are many energy resources in the environment, but these resources need to be converted into electrical energy and used as permanent power resources in WSNs. The environmental resources of energy, will ensure economic feasibility due to a decrease in maintenance and batteries replacement cost, and to increase the degree of autonomy of the nodes in the network, these resources of energy are more suited for the long-term applications[19]. There are many energy resources that are available in the environment, but the most available, accessible, and harvestable resource of energy is the solar energy. However, other types of energy such as wind energy, RF energy, and the energy that extracted from human movement power are not as feasible as solar energy. According to the authors in [18] [20] [15] solar energy is the most reliable resource of renewable energy. It is daily predictable and seasonal. In addition, solar energy is available and accessible in most of the time and in every place. Moreover, solar cells are small enough to fit in the WSNs nodes easily. However, the solar energy is uncontrollable. This issue does not have that strong impact to affect the use of solar energy.

As previously mentioned, using the solar power in clustered WSNs will eliminate unnecessary maintenance, and will increase the degree of autonomy of the nodes. This will result in more trusted and self-controlled network. It is obvious from going through numerous previous literatures and the previous discussion that the best techniques in routing algorithms are the clustering techniques. Clustering made it easy to equip a solar cell to CH. The CHs in Cluster-based networks are similar to control centers [12], when those CHs are equipped with a solar cell, the problem of power consumption in those CHs will be solved. There is another benefit of using natural-based sources of energy, this is because they are not toxic, which introduces a new technology that reduces harm and threats to the environment [18] [20] [15]. Using solar cell in WSNs has many advantages.

Firstly, the nodes can receive and transmit the packets without consuming the battery energy.

Secondly, the batteries can be recharged if their energy is consumed during the absence of sunlight.

Thirdly, the batteries can be used as a backup whenever any failure occurs. It is clear that using natural-based resources of energy is one of the best solutions in WSNs [18] [20] [15]. However, Due to the economic feasibility and due to a large number of deployed nodes in the target area, it is not feasible to equip all nodes in the network with a solar cell. Thus, in this paper, only CHs are equipped with a solar cell.

As previously mentioned in the literature review section, some solutions were introduced to integrate the solar power with the WSNs, Some of these studies are related to electrical engineering and are out of the scope to this study.

Nevertheless, the introduced solutions in the literature are limited and do not solve the problem of increased overhead that is related to the selection of CHs and the randomized method of selecting CHs. Before the writing of this study, there has been a big gap in using solar power with WSNs in [22] [13]. Both papers have the problem of selecting CHs. sLEACH algorithm has increased the lifetime of the targeted WSN compared to LEACH. AsLEACH are introducing the same work with minor changes in selecting CHs based on scanning technique, which firstly choose CHs, and then the selected CHs choose CH with solar power, the proposed work made some changes on the radio model that is used in communications on the network. Other works such [24] is proposing the relay nodes between CHs and other nodes. Each relay node is equipped with a solar cell to maximize their lifetime. In [6] they are proposing a locater mechanism to choose the best location of CHs solar powered. However, the introduced solutions have the problem of selecting CHs, which is still randomized in nature, and the randomization technique gives every node whether it is solar powered or not the chance to become a CHs, which results in selecting low residual energy of CHs. After each round, different nodes will be selected as CHs. This technique is good in clustered WSNs because of its balanced energy consumption. However, if the nodes are equipped with solar cells and these nodes do not become CHs, the use of solar cell will become useless. In addition, this solution is not feasible in real life scenarios, because WSNs are expected to work in unattended and hostile environments.

In order to improve the techniques that are used in selecting CHs, an improvement has been introduced to select CHs in solar LEACH. Because the CHs are consuming energy at a higher rate than other nodes, the solar cell is equipped into CHs. This technique will accomplish the objectives of this study. Consequently, a simulator of solar LEACH has been modified accordingly to improve the process of selecting CHs based on their power status. The code of the simulator has Under the OMNeT++ simulator. The OMNeT++ provides a C++ Integrated Development Environment (IDE), which enables the writing, running, and debugging in the same IDE, and the simulation does not differentiate between the messages and events. OMNeT++ provides a method to save the results through the finalization function [21].

4. Improved Solar Leach (IS-LEACH)

In order to achieve the best results from the integrations between clustered WSNs and solar cell, modifications in the technique of selecting CHs have been introduced. The solar LEACH is dealing with the theoretical assumptions without giving any attention to the special nature of WSNs and its practical, environmental, and economical characteristics. In real life, only nodes with solar cell should become CHs to ensure the reliability of the deployed WSNs, maximization of their lifetime, and their performance. In addition, the overhead should be decreased because the overhead is consuming more energy in order to transmit control messages over the entire network and this consumption will be increased as the diameter and density of the network increases, which will put all the resources in the targeted network at stake. To ensure that the nodes that are powered only by the solar cell are selected as CHs, the selection of CHs that is based on their status is introduced, which means, if their status indicates that they are solar powered; they should be selected as CHs. If their status indicates that they are battery powered, they will be ignored from the selection of the CHs. This technique will ensure that the CHs with low residual energy will be ignored from the race to become CHs. The selection of the same CHs in each round has many benefits over the entire network. One of the major benefits is the stability of the network. If the network is stable, and every node knows its cluster without any additional communication and control messages, the lifetime and the performance of the network will be increased dramatically. The process of selecting CH based on their status is shown in figure 1. After selecting the CHs, the steady phase of LEACH initialize.

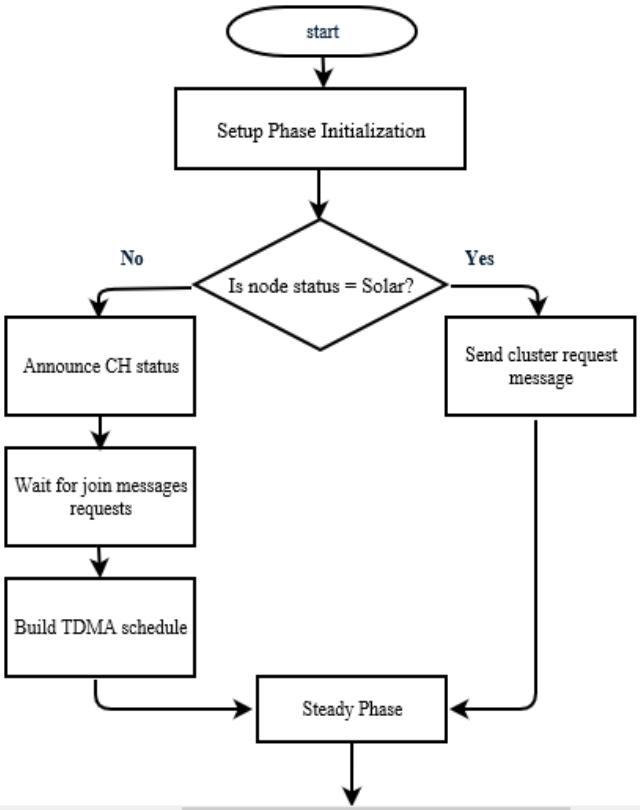

Figure 1. The process of selecting CHs

In both solutions, Time Division Multiple Access (TDMA) as medium access control (MAC) protocol. This type of MAC protocols has a significant impact on energy consumption on WSNs, due to its characteristics which include sleeping mode when the nodes in an idle status. Using sleep mode in nodes will surely decrease the energy consumption [8].

The environment parameters in the original solution and in the proposed solution are the same. The default transmission range is set to be 190 meters, but all nodes can reach BS and can adapt their transmission range. The node energy consumption is related to their distance from BS. In order to achieve the most accurate results, assumptions about the environment that the adapted solutions are expected to work are made. The sun duration is set to be 2400 units in both solutions. The rounds are set to be 500 rounds, but maybe half of the nodes will die before reaching this number of rounds. Every round consists of 10 frames, and the simulation ends when the half of the simulated nodes die,

which has, an implication for the reliability of the entire network. The percentage of CHs in each round is set to five CHs per round as in original LEACH, but this percentage can be tuned according to each individual network. The Computer specifications used in this simulation process are Processor: Intel (R) Core(TM) i5 CPU M 450 @ 2.40GHz (4 CPUs), ~2.4GHz, Random Access Memory (RAM): 4096MB RAM, Available OS Memory: 3766MB RAM, System Manufacturer: Acer, System Model: Aspire 5742, Operating System: Windows 7 Enterprise 64-bit (6.1, Build 7601) Service Pack 1 (7601.win7sp1_gdr.151019-1254).

5. Results

After many simulation scenarios, the improvements in the lifetime of simulated WSNs have been achieved according to the study objectives and metrics. The following figures show the comparison between the solar LEACH and the proposed IS-LEACH.

From the figure 2, it could be seen that there is an improvement in the WSNs' reliability and lifetime, since the proposed technique of selecting CHs has achieved better reliability and prolongs the lifetime of the WSNs. Interestingly, the diamond shapes represent the lifetime of IS-LEACH, and the squared shapes represents the lifetime of LEACH. It can be inferred that there is an increase in the lifetime and reliability of WSNs.

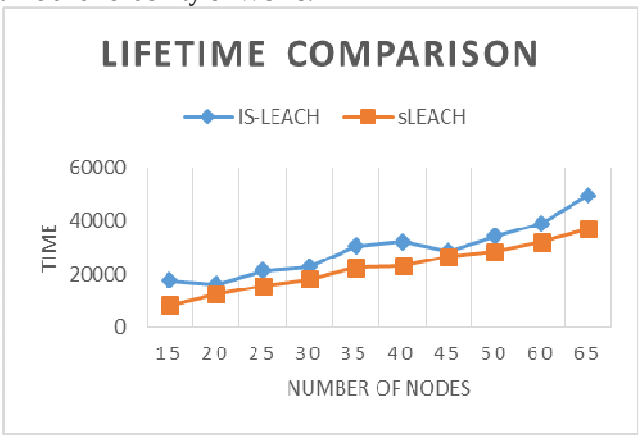

Figure 2. Life Time of WSNs

In addition, the IS-LEACH increases the number of rounds when half of nodes die. Figure 3 shows the number of rounds when half of the nodes die.

Increasing the number of rounds until the half of nodes die will improve the reliability of the entire network. Such improvement will make the network more reliable. There an increasing and decreasing in the IS-LEACH as seen in Figure 3, but in general, the number of rounds until the half of nodes die is better over the LEACH. Based on the figures above, the lifetime and reliability of the network are maximized which achieve the first and third objectives of this study. Also decreasing the number of dead nodes is one of the main objectives in every attempt in WSNs fields. From Figure 4, it could be seen that approximately the number of dead nodes in each run is static, and the highest number of dead nodes is five nodes when the number of nodes was 35 nodes.

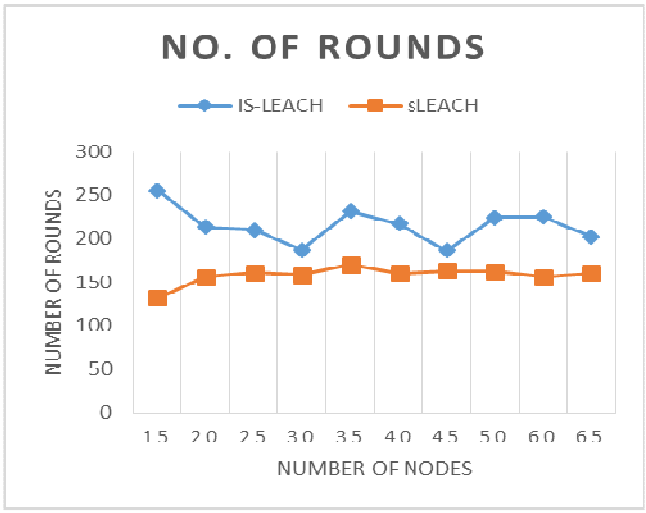

Figure 3. Number of Rounds.

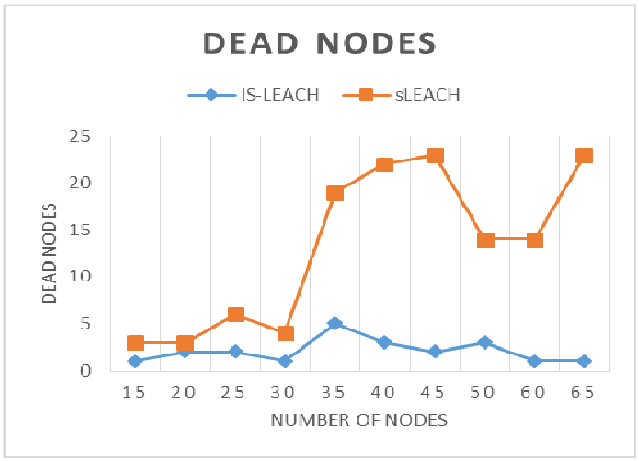

Figure 4. Number of Dead Nodes

In order to evaluate the performance of both solutions, a measurement of the number of locater created messages in the entire run has been created. The number of the messages created by both algorithms is shown in figure 5. In IS-LEACH, the number of created messages is 269736 for 50 nodes, and in LEACH, the number of created messages is 195208 for the same nodes number. This reveals that proposed IS-LEACH improves the performance of WSNs.

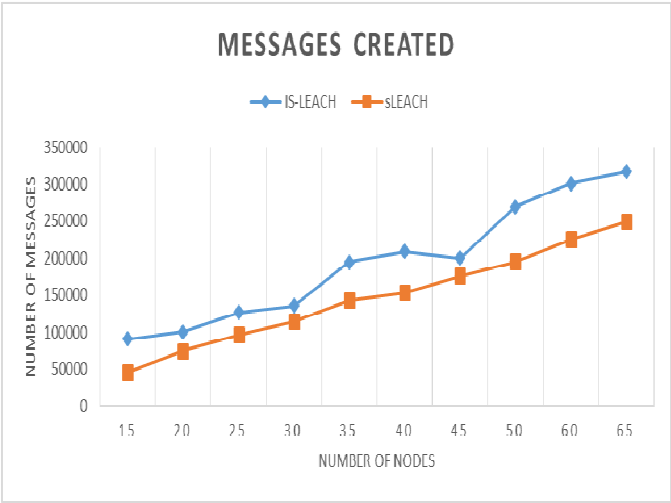

Figure 5. Number of created messages

6. Conclusion

WSNs are a special type of networks. This type has many limitations related to finite power resources. In such type of networks, a special attention must be paid when designing the network in general, and the routing protocols in specific. The node in WSNs is expected to work for years, but the problem that is related to the power supply is attached to each node. Nodes in WSNs are equipped with a small amount of energy, this energy is finite in nature, and when this energy is consumed, the node will stop doing its task. Another alternative is to use the technique of energy harvesting or scavenge from the environment. Energizing the node from the environment is not enough to improve the lifetime of WSNs. The routing protocols need to be designed in such way that the power consumption should be decreased as low as possible. Using clustered-based approach in WSNs is a good technique to manage the energy consumption in the entire network. Additionally, the clustering gives the designer more control over the network, and some transmission technique can be feasible, such as using the MAC protocols, which have been proven that they can decrease the power consumption [23]. Many researchers in the field of WSNs argued that the LEACH protocol is the best clustering protocol, and many recent protocols are either depended on or inspired by LEACH. Despite the many advantages in LEACH, the protocol needs some modification in order to achieve the best results. Many researchers have tried to solve LEACH issues, but using LEACH with environment power supply does not take that importance in literature, in this study, an improved version of sLEACH has been introduced to overcome the problem of CHs selection and stability. The results as previously mentioned showed that there is an improvement in both the lifetime and the performance of the network. From the discussion above, we conclude that combining the WSNs, especially the clustered-WSNs with solar cell will prolong the lifetime and increase the performance of the entire network. Furthermore, using such technique will decrease the number of dead nodes. Decreasing the number of dead nodes will extend the coverage area field that the network is expected to work through, and this will increase the reliability of the network, and decrease the cost of maintenance and installation cost. We recommend that a special attention must go to QoS since most researchers are giving all their attention into the lifetime. QoS in recent years has little attention, especially in real-time applications that modern WSNs are expected to work in fields such as industry monitoring or battle tracking. The static nature in WSNs needs to be reviewed. The researchers do not investigate the importance of adapting networks into the change in the environment or even into the network itself. Dynamism in WSNs could decrease the overhead that is associated with selecting CHs and cluster nodes. When the dynamism factor increases, the network could adapt itself to any changes in the environment in a good manner, which increases the throughput and increases the reliability.

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