Journal of Computer and Communications, 2022, 10, 74-89
https://www.scirp.org/journal/jcc
ISSN Online: 2327-5227
ISSN Print: 2327-5219

Effective Cluster Head Substitution Leach Protocol for Wireless Communication

Kabukila Kilotwa Michel, Hairong Yan, Njiraini Immaculate, Biaye Yaye

Department of Computer Science and Engineering, Beijing University of Technology, Beijing, China
Email: kilotwa.michel@herocean.com, yanhairong@bjut.edu.cn, immanjiraini@gmail.com, biayecoumba@outlook.fr

How to cite this paper: Michel, K.K., Yan, H.R., Immaculate, N. and Yaye, B. (2022) Effective Cluster Head Substitution Leach Protocol for Wireless Communication. *Journal of Computer and Communications*, **10**, 74-89.
https://doi.org/10.4236/jcc.2022.105005

Received: March 25, 2022
Accepted: May 28, 2022
Published: May 31, 2022

Abstract

In recent years, the demand for Wireless Sensor Network (WSN) in smart farming has had a tremendous increase in demand for its efficiency. Wireless sensor networks have very many nodes, and it is of no use when the battery dies. This is why there are several routing protocols being take into consideration to cub this problem. In this paper, in order to increase the heterogeneity and energy levels of the network, the M-LEACH protocol is proposed. The key aim of the Leach protocol is to prolong the existence of wireless sensor network by lowering the energy consumption needed for Cluster Head creation and maintenance, the proposed algorithm instructs a node to use high power amplification as it acts as the Cluster heads, and low power amplification when it becomes a Cluster Member, in the next stage. Finally, for better effectiveness, M-LEACH employs hard and soft threshold systems. Since it eliminates collisions and reduces the packet drop ratio for other signals, the M-LEACH protocol proposed works better than the Leach protocol.

Keywords

LEACH, Cluster Head, UAV, Wireless Sensor Network, Clustering, Threshold

1. Introduction

In the current world, many scientists and researchers are toiling to find an efficient design of wireless sensor network, which is a device equipped with numerous nodes that are used to gather data from both physical and environmental conditions such as light, pressure, heat, etc. These nodes are limited to sensing, analyzing and transferring or receiving data. They also require a stable source of power. In wireless sensor networks, a battery is installed on each node. The use of low power to make each node maximum lifetime is one of the most difficult problems in WSN. Better routing protocols and algorithms that can get the most out of limited power are necessary to maximize node lifetime. For this reason, several protocols have been developed to address the power issue in WSN. Any network's protocols must be very efficient in order for it to perform well, particularly wireless multi-hop networks. To address energy issues in sensor networks, a multitude of protocols have been created. The three most common varieties of routing algorithms are direct transmitting procedures, step-to-step distribution algorithms, and cluster-based algorithms.

Another issue that also needs to be addressed is how to cope with the vast volume of data that each node in a network senses and transmits (there may be thousands of nodes in a WSN.) Code integration and data fusion algorithms also have room for improvement. In order to maximize network throughput while preserving sensor node capability, an effective wireless sensor network requires an appropriate routing protocol with lower routing overhead and most well-planning packet forwarding processes. The progress that has been made on cluster-based routing of WSN, as well as areas that need to be configured for success, will be discussed on the following pages.

In this paper, we will go through the work. Cluster-based on routing of wireless sensor networks as well as the areas need to be optimized. Then, several changes were made to one of the most well-known routing protocols. Finally, tests and contrasts are performed and briefly discussed.

2. Related Work

Routing protocols nowadays play an important role in reducing power consumption in WSN's and military activities have gained worldwide devices in [1]. A significant number of sensor nodes are installed in these networks to ensure accurate surveillance and efficient environmental monitoring. In these years, most academics have shown an effort in creating power conservation procedures to gather valuable environmental data [2]. The sensor nodes are battery-powered and run out easily every time. In terms of robustness, energy consumption, data integration, and scale, cluster-based protocols can produce better results than other routing protocols. In this post, the most powerful hierarchical clustering technique of Leach at the same time introduces a replacement protocol that functions even better [3]. LEACH is the most extensively used protocol in WSN's, and it allows more efficient power distribution through a random distribution of cluster heads. An exhaustive search was performed for the variants of LEACH [4]. The Law Adaptive Clustering Hierarchy (LEACH) protocol is a common protocol in the sense of dynamic clustering [5]. The Leach protocol distributes cluster head collection at random across all nodes, allowing for more effective power delivery and making it one of the most well-known protocols on WSNs. Many current clustering protocols, such as Low-Energy Adaptive Clustering Hierarchy (LEACH) and threshold-based Leach (T-LEACH), seek to extend the lifespan of sensor networks [6]. The T-LEACH algorithm exploits the primary weakness in LEACH, which is its significant power loss. T-LEACH recommends that the CHs turn over at the end of each bath of rounds rather than at the beginning of each round. Nodes will continue to act as cluster heads until their energy level exceeds a certain threshold. Threshold-based on cluster head replacement (MT CHR). In MT-CHR, a new possibility of being a cluster head has been proposed for any node in any round, which are in a long distance away from the BS [7], so the clustering algorithms can be used to connect sensors that are far away from the BS the K means approach will assist sensor nodes in extending and sustaining their life cycle, thus extending the network's total live time. Cluster-based WSNs can be constructed in a number of ways. Since all neighboring boring sensor nodes generally have the same data about the same event and each node communicates to BS separately, power consumption is reduce and the nodes last only a short time [8]. CH designs are more energy efficient. Since all CH nodes send signal directly to BS, the other nodes only send gathered data to CH. As a result, the network's lifetime will be determined by the cluster-head selection.

By introducing the taxonomy of leach's various descendants and compared their performance based on scalability, data aggregation, mobility, and other indications, the author also suggested a unified Leach (S-LEACH) [9]. This is a hierarchical cluster procedure. It uses the base station to gather data on the location and power output of every node in the wireless sensor network. The base station then selects a minimum transmitting power, creating cluster and developed the power efficient selection in the sensor information system [10]. This algorithm relies on the creation of sensor node chain structure. It is important to note that all sensor nodes at the base station serve as communicators for nodes located father away from the base station.

Using the K means rule, we can prolong the network's life. When combined with clustering algorithm associates, this approach can assist sensor nodes in extending and maintaining their live time [11]. In fact, each network transmitter node, transmits and receives data aggregation, such as the low-energy adaptive clustering hierarchy protocol, however do not use clustering. Chain use and lack of cluster create a variety of threats, attacks and thus networking overhead is increasing Leach [12] [13], TEEN [14], DEEC [15], and PEGASIS [16] are the most common wireless sensor network routing techniques. Leach provides the key protocol for appointing a cluster head, which is supplemented by SEP and DEEC. TEEN incorporates the idea of thresholds, which have positive outcomes in terms of network lifetime by displaying a reactive existence. These thresholds may be introduced in any routing protocol to improve its utility. In Leach, the algorithm is split into three phases: cluster setup, ads and scheduling. Leach gives rise to a plethora of protocols. This protocol's procedures are lightweight and well-tailored to a homogeneous sensor setting [17]. According LEACH protocol, a new cluster head is elected for each round, resulting to the creation of a new cluster. As a result, unnecessary routing overhead requires an inefficient amount of finite room [18]. If a cluster head did not expend any energy in the preceding round at the lower power node would take its place as a cluster head in the next cluster head election round [19]. The number of cluster heads that can be changed at each round must be limited while keeping the available energy of existing cluster heads in mind.

Some clustering protocols, such as LEACH, use the same amplification energy to transfer data average distance between the source and destination. A propagation device that calculates the necessary addition energy for communicating with the CH or base station should also be present to save energy [20]. Broadcasting a packet to a cluster head with the same propagation power level as, say, a node at the farthest end of the network awareness and only allow nodes to decide how much signal to amplify, while using the entire network to find and measure distances.

3. Leach Protocol

In wireless sensor networks, if a specific cluster head node is used to gather the entire data in the whole region, there would be several problems with energy consumption. For example, the cluster head death rate is faster since the cluster head must aggregate, process, and forward the all data [21]. Turning off the power of the cluster head may cause the entire area to be disconnected, the nodes close to the C-head are mainly used to relay data routed to the cluster, and these nodes are quickly exhausted.

All these problems will seriously affect the service life and quality on the network. This problem can be minimized by randomly selecting the Cluster head [22]. Leach refers to the limited energy adaptive cluster-level routing algorithm for data fusion. Leach is one of the related network cluster protocol sensors, in which all sensor networks are fitted with the same power supply. **Figure 1** shows that any node has a possibility to be the head of a cluster in [n/N_c] set, N_c represents the number of cluster-heads an n represents total nodes in the region.

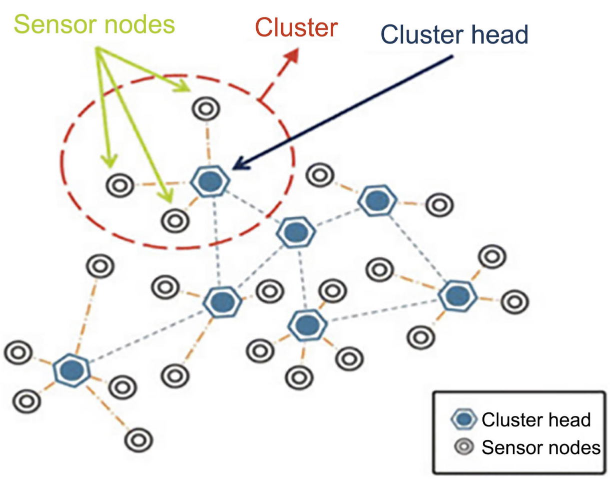

Figure 1. Leach clustering.

3.1. Setup Phase

Setup phase, create a cluster and select the cluster head [23]. Every node will have a different value random number in 0 and 1, compare it to the overall cluster head probability in the equation, if the limit is higher than that of the node, the node gests to be the cluster leader. The cluster headers can be chosen at random according to the following conditions:

$$CH_{prob}(n) = \frac{N_c}{n - N_c\left(r\,mod\Big/\dfrac{n}{N_{c0}}\right)} \quad \text{if } n \text{ belongs to } G \tag{1}$$

Otherwise, the number of clusters needed N_c, where n is the complete amount of nodes in the region, r is the existing round, and G is the aggregate node not considered to be the cluster head in the previous node $\{n/N_c\}$ set and R_n is a random integer evenly distributed between "0 to 1". If $Ch_{pro}(n)$ is large, R_n becomes the cluster head.

3.2. Steady-State Phase

All selected Cluster heads use the CSMA/CA protocol with the same cluster member (CM) node to broadcast advertisement and select their clusters. In the case of a tie, the nodes select the cluster Head whose advertisement has the highest received power, and then randomly selects the Cluster Head again. Each node use the CSMA/CA protocol to inform the cluster head of its choice [24].

Cluster Head creates a TDMA schedule, randomly picks up CDMA codes, and send them back to the nodes. Choose TDMA to prevent inter-cluster conflicts, and use CDMA to minimize intra-cluster intrusion. Besides, due to the use of dynamic clusters, the service life of the network can be extended. Using aggregation techniques, Leach decreases the data messages sent to the Base Station. In the setup process, the TDMA mechanism is used to reduce conflicts within clusters, eventually, because Leach is a shared protocol; no global network knowledge is required.

But it also has certain disadvantages [25]. Cluster-heads is randomly selected, and the nodes of the cluster head do not consider the remaining energy formation. The cluster head distribution in the network is uneven. Sometimes, these nodes will concentrate on the part of the network that has lost training energy [26].

After aggregation, since LEACH id not suitable for large networks, cluster heads send data to the receiver in a single hop. In each set, every sensor nodes takes part in the formation of latest energy-consuming clusters. If it is possible to consume the data in the data packet, data aggregation should be applied to every set, which will waste some unnecessary cluster head energy.

In **Figure 2**, the same energy model as the conventional Leach model is used. Sensor nodes need to relay k pieces of data, and energy dissipates in two forms that are used to handle the data form sensors is limited and relies on the uncontrollable volume of data. The energy needed for their propagation is also dependent on the amount and distance of the data.

In Figure 3, the separation problem between transmitters can be solved, which is the main source of energy consumption. At the receiving end, the energy needed for the data transmission process (with the exception of amplification). While a portion of energy is needed with each amplifier, we did not take into account all the received energy, as when using a drone as a rechargeable unit for receiving. Transmission methods also have a great impact on energy use. Let us use K to indicate the size of the message, D to indicate the distance from the transmitter to the receiver, E_{elec} consumes energy to power the transmitter while E_{amp} consumes energy to enhance the message. The energy needed to transfer K-bit data to the Distance table.

$$E_{Tx} = E_{elec} * K + E_{amp} * K * D^2 . \quad (2)$$

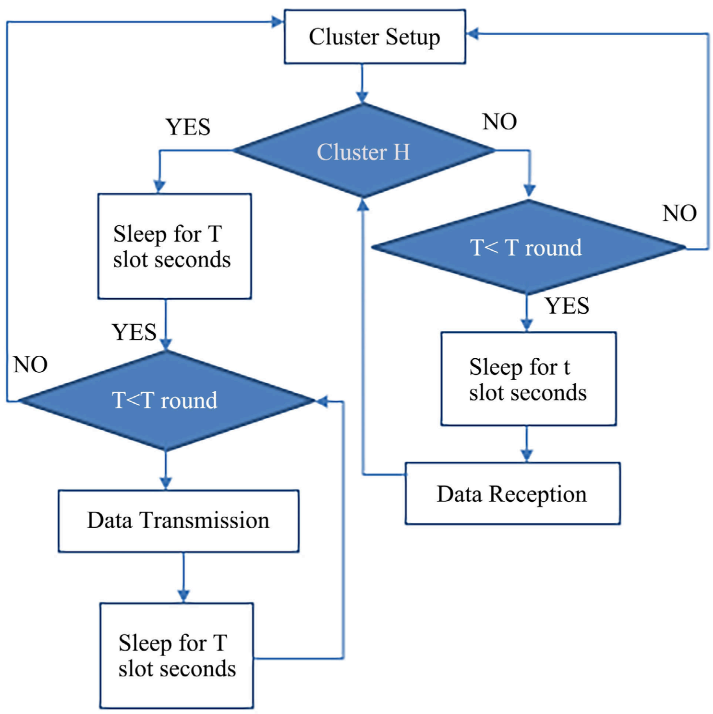

Figure 2. Steady-state.

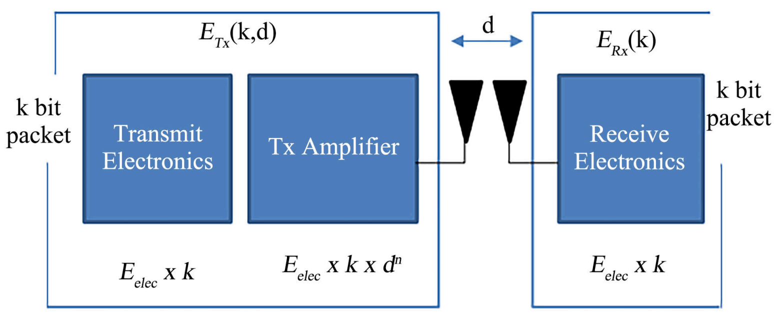

Figure 3. The radio energy usage model of leach.

The data transmitted through the direct connection as seen in the **Figure 4**. Assuming that each and every node is evenly spaced at the same distance *d*, if the node is at *n* hop, energy required to transfer *k* bits is the lowest transmission energy.

The energy cost for a single exchange of data becomes:

$$E_{transmitting} = k\left(2n-1\right)E_{elec} + E_{amp}nD^2 . \tag{3}$$

Leach has many variants. As started earlier, in leach protocol, new cluster heads are selected after every round, leading to new cluster formation, hence excessive use of energy. If the current cluster head hasn't really expended enough power throughout its round, and it has more energy than. The necessary threshold, it will continue to be the cluster head in the next round [27]. Depending on the mission, the cluster heads begin to lose energy in each round. If the energy spent is minimal but exceeds the necessary threshold, the cluster head will move on to the next round.

In the case where the cluster head will be replaced if it has less power than the necessary threshold, based on the current LEACH algorithm. This article proposes an improved version of leach, that is, introduce a threshold per round, every node higher than the threshold may become a contender in the next threshold, and then it can also compete for cluster head in the next round.

4. Proposed Protocol

The aim of this paper is to solve the T-Leach protocol's problems. Threshold-based protocol (T-Leach) recommends that cluster heads switch over a set of rounds instead of every round. Nodes can continue to serve as cluster heads as long as their energy exceeds a certain level. The suggested MT-CHR approach agrees with the LEACH protocol's assumptions. In the Modified-Threshold based cluster head replacement approach allows nodes in every round to become cluster heads [28].

After comprehending the LEACH protocol mechanism, the presentation of cluster head replacement scheme focused on restricting energy consumption during cluster formation. This scheme focuses on eliminating cluster heads based on the amount of energy they have retained I. each round; for example, if a current cluster-head has not lost much power throughout its round and have far more power than the appropriate threshold, it will continue to be CH for the next phase [29]. Depending on the mission, the cluster heads begin to lose energy in each round. If the energy spent is minimal but exceeds the necessary threshold, the cluster head will move on to the next round. The CH will be replaced if it has less energy than the necessary threshold, according to the LEACH algorithm. Inter cluster or CH to base station transmissions should have a different minimum amplitude power than intra cluster communication. For both kinds of transmissions, the amplification energy in Low Energy Adaptive Cluster Head is set to be the same. As compared to cluster-head to Base Station propagation, using a low power level for intra-cluster transmission saves a lot of energy.

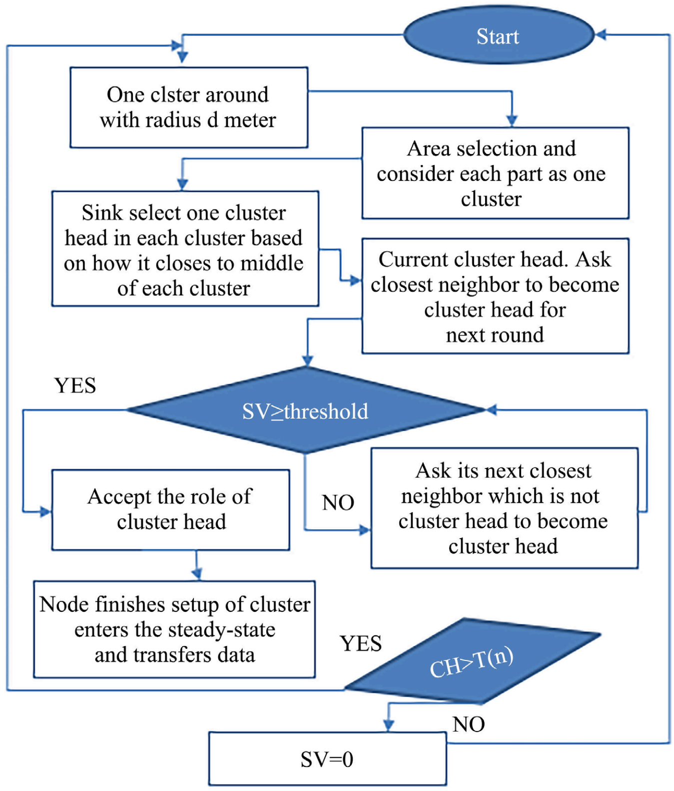

Figure 4. Proposed M-LEACH Chart.

Furthermore, the use of various power levels reduces the data rate, crashes, and/or signal disturbance. In this scenario, we expect a cluster to grow to a maximum size of 10 × 10 m in a 300 × 300 m area. Energy needed to relay at the far ends of 300 × 300 m area should be reduced tenfold for intra-cluster propagation. The routing algorithm instructs a node to use high energy amplification when it serves as a cluster head, and low level energy amplification when it serves as a cluster member.

In this article, the various degrees addressed of amplification power signals based on the on the type of the transmission. Depending on different ways of transmission in Cluster based networks, we also set different amplification energy for different kinds of transmission within a CH from the cluster head to the BS, for example, are used to conserve a significant amount of energy [30] [31]. The proposed algorithm instructs a node to use high power amplification as it acts as the CHs, and low power amplification when it becomes a Cluster Member (CM) in the next stage. Finally, for better efficiency, M-LEACH employs hard and soft threshold systems. The M-LEACH protocol is depicted in the flow chart below.

5. The Outcomes of the Simulation

All the outcomes were carried out using MATLAB software, version (R2021b). The Table 1 represents the parameters for simulation as proposed protocols and the simulations demonstrate that M-LEACH outperforms other networks in term of performance, network life time, and CH formation that is optimized [32] [33]. The network is diverse in nature.

There are n nodes dispersed arbitrarily over the territory. The main region is subdivided into clusters, which are usually referred to as subgroups. Every cluster consists of a number of nodes, one of which serves as the Cluster-H. Each CH gets information from all of its client nodes and compresses it using some iteration. The compressed data is sent to base station by all CHs. Within each cluster, all nodes are considered nomadic or fixed, and the network topology does not alter abruptly. Three crucial factors, p is probability of picking a cluster-H, s is the low threshold, and h the high threshold, are explored in this study, and their values set to $p = 0.1$, $s = 2$, and $h = 100$. We experimented with various adjustments in all of these factors to see how they affected the network's performance and other characteristics. In estimating of the threshold (h) in the last set of trials by holding (p) constant then vary it, and repeating the trails. On this premise, the following collection of data was generated:

When comparing the input of h from 100 to 400, the proposition of first dying node out to the highest rounds decreases continuously, then increases to almost the same value at $h = 500$ as it did at $h = 100$, then decreases again until $h = 800$, and the same actions are repeated for higher values of h and different standards of p. As a result, setting h to 100 or 500 yields the same result, but setting it to 200, 300, or 400 yields a compromise between network stability and network life-time, which is again centered on the purpose for which the network is wanted (**Table 2**).

Table 1. The infuence of p and h variations on network throughput life-time.

s	h	p	Max round in the network	The network's first dead node	Ratio x = First dead node/max round
1	100	0.1	1095	160	0.146
2	200	0.1	1248	148	0.123
3	300	0.1	1200	148	0.118
4	400	0.1	1261	131	0.104
5	500	0.1	1106	162	0.146
6	600	0.1	1216	159	0.131
7	700	0.1	1102	143	0.129
8	800	0.1	1207	133	0.110
9	100	0.2	1313	103	0.0784
10	200	0.2	1503	88	0.0585
11	300	0.2	1259	98	0.0778
12	400	0.2	1371	83	0.0605
13	500	0.2	1231	86	0.0698
14	600	0.2	1262	88	0.0697
15	700	0.2	1244	82	0.0565
16	800	0.2	1255	71	0.0431

Table 2. Simulation parameters for our proposed M-LEACH implementation.

Parameters	Value
Field size	300×300 m^2
Number of Nodes	100
Packets/message size	4000 bits
Energy consumption(E_{elec})	50 nJ/ bit
Fusion Energy (F_{fs})	10 nJ/bit/report
Amplification energy (E_{amp})	0.0013 pJ/bit/m^2
Energy consumption of data gathering	5 nJ/bit/signal
Threshold Distance	88 m
Popt	0.1
Energy intra-cluster communication amplification $d \geq d_1$	$E_{fs}/10 = E_{fs1}$
Energy intra-cluster communication amplification $d \leq d_1$	$E_{amp}/10 = E_{amp1}$

Figure 5 shows the efficiency of wireless sensor networks is evaluated by characterizing certain parameters related to the number of nodes (alive or dead) and the network lifetime. Because of its efficient cluster head substitution system and dual transmission energy level for inter and intra cluster connectivity, M-LEACH has a longer stable time. The diagrams below show the outcomes of a simulation. M-LEACH has the longest network life span of any protocol. This is due to soft threshold concept, which restricts the number of transmissions, as well as an integrated cluster head replacement method, which conserves energy internationally and allows for multi-energy ratios for inter and intra cluster communication. Only when a predefined shift in sensed data is achieved in M-LEACH is the number of transmissions proven. This reduces the amount of packets in order to save a sensor node's remaining resources (the amount of packets is inversely proportional to the power of the sensor node).

Figure 6 shows distinct graph for network's living nodes, which demonstrate the network's stability vs the max rounds traveled while considering the various sink sites. Once again discover a trade-off between network stability and the largest number of cycles before the network collapses. However, in comparison to other LEACH the variances are much less this time, and the sink position in the middle of the network yields more interesting findings. The graph in Figure 7 are created by adjusting the value of the high threshold h while maintaining p fixed at some notional value and observing the existence of living nodes across the network; nevertheless, no notable alterations in the graphs of various amounts are detected. The same experiment was repeated with different settings of soft thresholds, and the stability duration did not change much. As a result, it is established that the low and high criteria have no significant influence on the network's stability period.

Figure 7 depicts charts for various values of p, taking into consideration the data packets sent to base station and the number of rounds where by the network is active. The graphs clearly demonstrate that when the value of p grows from 0.1 to 0.8, the throughput sent to the base station grows continually, as does the number of the packets sent to the cluster head from various nodes in a cluster. However, there are exchanges between different parameters when the value of p is changed. As a consequence, a value that can also balance other elements should be developed.

Each round, a certain number of cluster heads are selected. As a consequence, there is no substantial difference in cluster head forming or measurement process. M-LEACH, on the other hand, differs from LEACH. The packets sent to CHs in various phases of the network are displayed in **Figure 8**, taking into account the various positions of the sink, such as on the origin, on the x-axis, on the y-axis, in the center of the network, and so on. The sink at the origin produces the worst results (1.5 × 104 packets sent), while the sink in the center of the network produces the greatest results (5.5 × 104 packets sent). The rest of the plots are located in the middle of these two extremes.

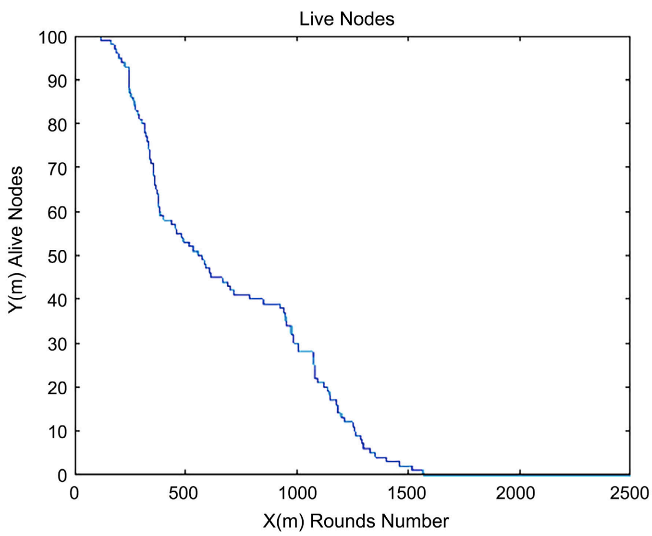

Figure 5. Number of nodes alive versus rounds.

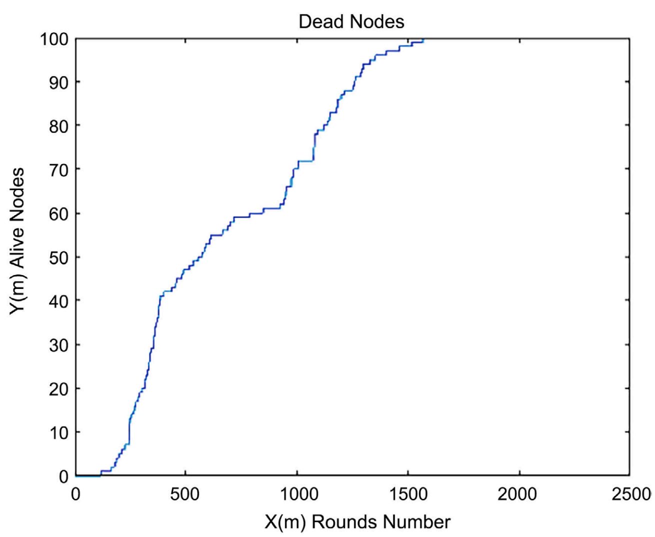

Figure 6. Number of nodes dead versus rounds.

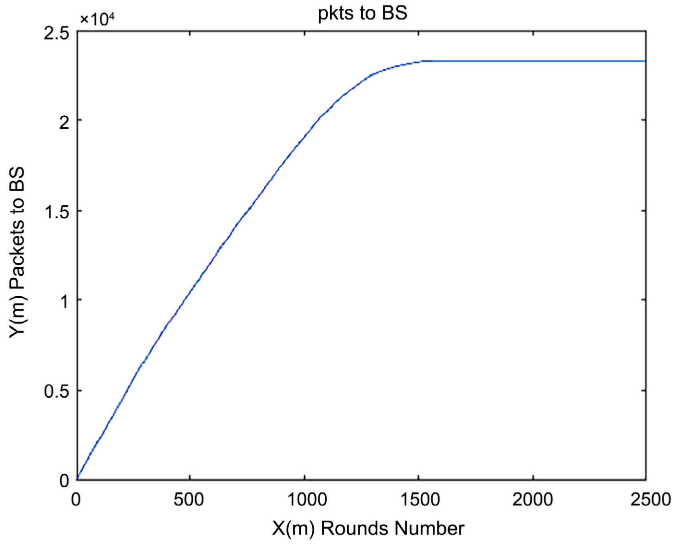

Figure 7. Packets sent to BS with different sink location.

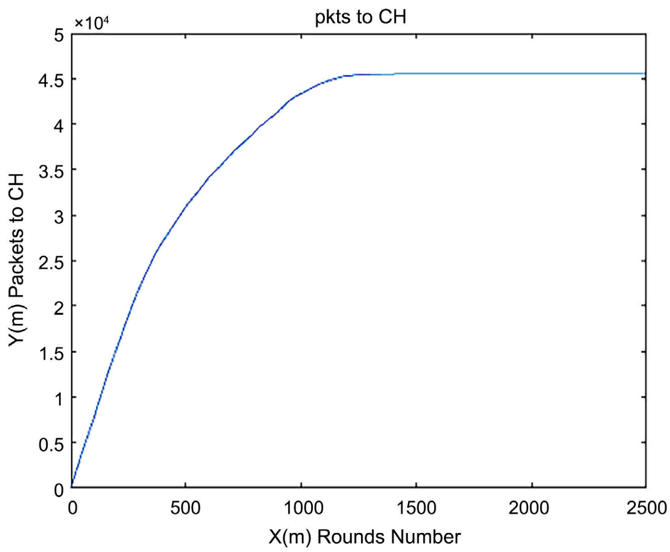

Figure 8. Packets to CH vs rounds.

The graph depicts the number of CHs as the value of p varies (probability of packing a CH). Figure 9 clearly show that the CHs triggered for the value of p = 0.1 are too few, where the CHs triggered for the value of p = 0.4 are too many (approaching 90 in the first 200 rounds); a number that is too large and can significantly contribute to the energy consumption; thus, the normal value for the selection of p for a reasonable generation of CHs is p = 0.4.

Figure 10 depicts the results of an experiment in which the value of p was kept constantly at 0.1 while the values of h were varied and the differences in packets delivered to the base station were observed. The values of packets delivered to BS steadily fall from h =100 to h = 400, then climb to h = 800. As a result, a trade-off was discovered between p and h. Changing the value of p = 0.2 and then modifying the values of h was used to repeat the experiment.

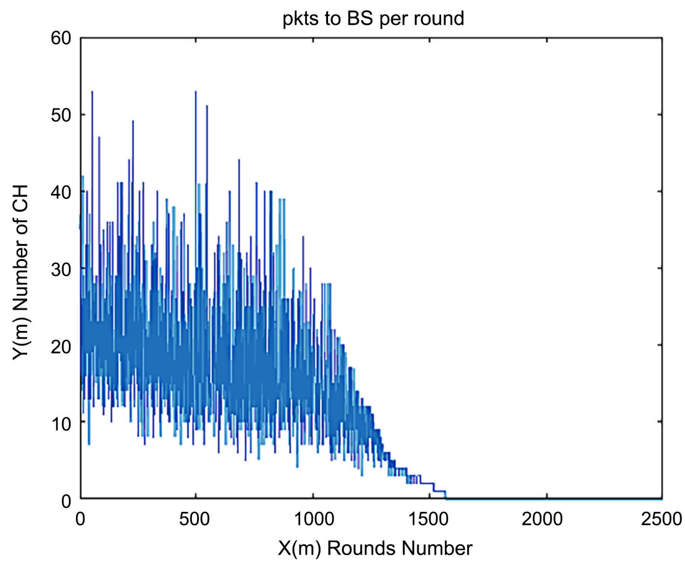

Figure 9. Number of nodes to BS with different *p* values.

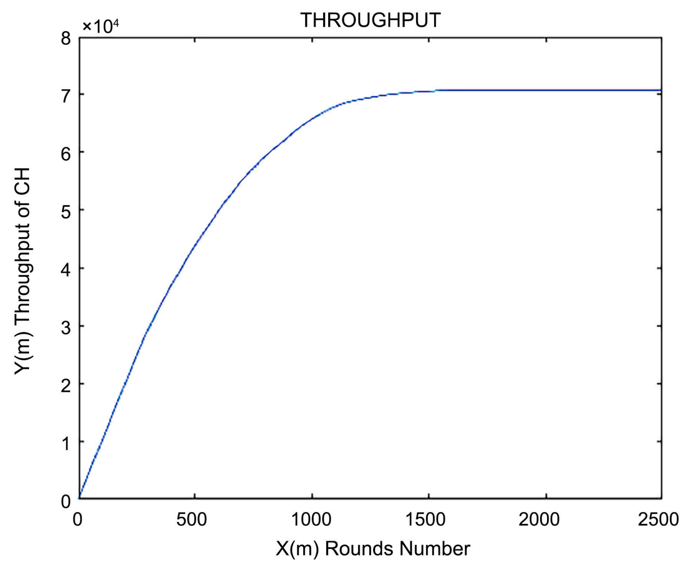

Figure 10. Packets send to BS with different *h* values.

Aside from network lifetime, throughput is another parameter used to assess the performance of a routing protocol. The performance of the routing mechanism is confirmed when the BS receives additional data packets. In certain cases, but not all, the outcomes are influenced by network lifetime. Based on the simulated results seen in **Figure 10**, it was concluded that M-LEACH achieves optimal throughput.

As shown in **Figure 10**, compared to others Leach, M-LEACH has higher throughput for the same reasons, namely improved network life time and a superior CH substitute scheme. One more significant explanation is the network's dual transmission power ratios. Packet drop ratio is minimized as various amplification energies are used for transmissions.

6. Conclusion

This paper discussed the Leach protocol mechanism in detail. We have also given an overview of some related works, including most of the LEACH protocol variants in reference to different publications, and also suggested a LEACH protocol variant capable of minimizing energy consumption in cluster formation by allowing nodes in every round to become cluster heads depending on the amount of energy consumed during the previous rounds. Moreover, the M-LEACH protocol is designed with the aim of increasing network reliability and lifespan. The proposed protocol sets amplification energy the same for all transmissions. In order to save substantial amounts of energy, low energy is used for the transmissions within a cluster head, from the CH to the base station. As a result, the proposed M-LEACH protocol outshines all existing LEACH versions when contrasted from the beginning to the first node dies and finally the time duration from time zero to when no live nod is left in the network. In the future, we will carry out work to calculate the routing load of this M-LEACH analytically and apply effective transmission energy levels in other clustering routing protocols of wireless sensor networks to study their impact in a broader sense.

Acknowledgements

The authors state that they have no known conflicting financial interests or personal connections that may have impacted the work described in this paper.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Al-Zubaidi, A.S., Ariffin, A.A. and Al-Qadhi, A.K. (2018) Enhancing the Stability of the Improved-LEACH Routing Protocol for WSNs. *Journal of ICT Research and Applications*, **12**, 1-13. https://doi.org/10.5614/itbj.ict.res.appl.2018.12.1.1

[2] Jin, G.L., Seyha, C. and Ho, H.P. (2019) Energy-Efficient Cluster Head Selection for Wireless Sensor Networks Using Sampling-Based Spider Monkey Optimization. School of Electrical and Electronics Engineering, Chung-Ang University, Seoul.

[3] Spoorthi, S., Shadaksharappa, B., Suraj, S. and Manasa, V.K. (2017) Freyr Drone: Pesticide/Fertilizers Spraying Drone—An Agricultural Approach. *IEEE 2nd Communications Technology* (*ICCCT*-2017), Chennai, 23-24 February 2017, 252-255. https://doi.org/10.1109/ICCCT2.2017.7972289

[4] Khalid, A.D., *et al.* (2017) New Cluster Head Replacement Protocol for Wireless Sensor Networks. *IEEE European Conference on Electrical Engineering and Computer Science* (*EECS*), Bern, 17-19 November 2017, 472-476.

[5] Long, D., McCarthy, C. and Jensen, T. (2016) Row and Water Front Detection from UAV Thermal-Infrared Imagery for Furrow Irrigation Monitoring. 2016 *IEEE International Conference on Advanced Intelligent Mechatronics* (*AIM*), Banff, AB, 12-15 July 2016, 300-305. https://doi.org/10.1109/AIM.2016.7576783

[6] Yinka-Banjo, C. and Ajayi, O. (2019) Sky-Farmers: Applications of Unmanned

Aerial Vehicles (UAV) in Agriculture. Unmanned Aerial Vehicles. IntechOpen. https://doi.org/10.5772/intechopen.89488

[7] Abushiba, W., Johnson, P., Alharthi, S. and Wright, C. (2017) An Energy Efficient and Adaptive Clustering for Wireless Sensor Network (CH-LEACH) Using LEACH Protocol. 13*th IEEE International Computer Engineering Conference* (*ICENCO*), Cairo, 27-28 December 2017. https://doi.org/10.1109/ICENCO.2017.8289762

[8] Lindsey, S. and Raghavendra, C.S. (2002) PEGASIS: Power Efficient Gathering in Sensor Information System. *Proceedings*, *IEEE Aerospace Conference*, **3**, 1125-1130. https://doi.org/10.1109/AERO.2002.1035242

[9] Heinzelman, W.B., Chandrakasan, A. and Balakrishnan, H. (2000) Energy-Efficient Communication Protocol for Wireless Micro Sensor Networks. In *Proceedings of the* 33*rd Annual Hawaii International Conference on System Sciences* (*HICSS* '00), Maui, Vol. 8, 1-10.

[10] Vijayvargiya, K.G. and Shrivastava, V. (2012) An Amend Implementation on LEACH Protocol Based on Energy Hierarchy. *International Journal of Current Engineering and Technology*, **2**, 427-431.

[11] Ihsan, A., Saghar, K. and Fatima, T. (2015) Analysis of LEACH Protocols Using Formal Verification. 12*th IEEE International Bhurban Conference on Applied Science and Technology* (*IBCAST*), Islamabad, 13-17 January 2015, 254-262. https://doi.org/10.1109/IBCAST.2015.7058513

[12] Loscri, V., Marabito, G. and Marano, S. (2005) A Two-Level Hierarchy for Low-Energy Adaptive Clustering Hierachy. *IEEE* 62*nd Vehicular Technology Conference*, Dallas, 25-28 September 2005, 1809-1813.

[13] Young, M.B., Al-Zou'bi, A., Khamayseh, Y. and Mardini, W. (2009) Improvement on LEACH Protocol of Wireless Sensor Network (VLEACH). *International Journal of Digital Content Technology and Its Applications*, **3**, 132-136. https://doi.org/10.4156/jdcta.vol3.issue2.yassein

[14] Halke, R. and Kulkarni, V.A. (2012) En LEACH Routing Protocol for Wireless Sensor Network. *International Journal of Engineering Research and Applications* (*IJERA*), **2**, 2099-2102.

[15] Itkin, M., Kim, M. and Park, Y. (2016) Development of Cloud-Based UAV Monitoring and Management System. *Sensors*, **16**, 1913. https://doi.org/10.3390/s16111913

[16] Khan, N.A., Brohi, S.N. and Jhanjhi, N. (2020) UAV's Applications, Architecture, Security Issues and Attack Scenarios: A Survey. In: *Intelligent Computing and Innovation on Data Science*, Vol. 118, Springer, 753-760. https://doi.org/10.1007/978-981-15-3284-9_81

[17] Chechetka, S.A., Yu, Y., Tange, M. and Miyako, E. (2017) Materially Engineered Artificial Pollinators. *Chem*, **2**, 224-239. https://doi.org/10.1016/j.chempr.2017.01.008

[18] Wided, A. and Tahar, E. (2017) New Approach for Selecting Cluster Head Based on LEACH Protocol for Wireless Sensor Networks. *Proceedings of the* 12*th International Conference on Evaluation of Novel Approaches to Software Engineering*, Tunisia, 2017, 114-120.

[19] Sohail, S., Nasim, S. and Khan, N.H. (2017) Modeling, Controlling and Stability of UAV Quad Copter. *IEEE International Conference in Innovations in Electrical Engineering and Computational Technologies* (*ICIEECT*-2017), Karachi, 5-7 April 2017, 1-8. https://doi.org/10.1109/ICIEECT.2017.7916559

[20] Li, J., Zhou, Z., Lan, Y., Hu, L., Zang, Y., Liu, A., Luo, X. and Zhang, T. (2015) Distribution of Canopy Wind Field Produced by Rotor Unmanned Aerial Vehicle Pollination Operation. *Transactions of the Chinese Society of Agricultural Engineering*, **31**, 77-86.

[21] Orey, N.S., Mehere, P.N. and Hedaoo, K. (2017) Agriculture Drone for Fertilizers and Pesticides Spraying. *International Journal for Engineering Applications and Technology*, Vol. 9, Issue 5.

[22] Reinecke, M. and Prinsloo, T. (2017) The Influence of Drone Monitoring on Crop Health and Harvest Size. *IEEE 1st International Conference in Next Generation Computing Applications* (*Next Comp*), Mauritius, 19-21 July 2017, 5-10. https://doi.org/10.1109/NEXTCOMP.2017.8016168

[23] Intel (2020) Intel Demonstrates Remote Drone Identification Solution. https://www.unmannedsystemstechnology.com/2018/08/intel-announces-new-open-standard-for-remote-drone-identification/

[24] Pattani, K., Christian, A. and Pithava, B. (2014) Optimization of Leach Protocol in Wireless Sensor Network. *International Journal of Computer Applications*, **93**, 26-30.

[25] Jeanneret, C. and Rambaldi, G. (2016) Drone Governance: A Scan of Policies, Laws and Regulations Governing the Use of Unmanned Aerial Vehicles (UAVs) in 79 Countries. CTA, Wageningen.

[26] Li, J. and Huo, J. (2016) Uneven Clustering Routing Algorithm Based on Optimal Clustering for Wireless Sensor Networks. *Journal of Communications*, **11**, 132-142. https://doi.org/10.12720/jcm.11.2.132-142

[27] Yan, J.F. and Liu, Y.L. (2011) Improved LEACH Routing for Large Scale Wireless Sensor Networks Routing. *Proceedings of International Conference on Electronics, Communications and Control* (*ICECC*), Ningbo, 9-11 September 2011, 3754-3757.

[28] Reddy, T., S.P. RM, Parimala, M., Chowdhary, C.L., Hakak, S. and Khan, W.Z. (2020) A Deep Neural Networks Based Model for Uninterrupted Marine Environment Monitoring. *Computer Communications*, **157**, 64-75.

[29] Perera, T., Priyankara, A. and Jayasinghe, G. (2019) Unmanned Arial Vehicles (UAV) in Smart Agriculture: Trends, Benefits and Future Perspectives.

[30] Nadal, A., Alamus, R., Pipia, L., Ruiz, A., Corbera, J., Cuerva, E., Rieradevall, J. and Josa, A. (2017) Urban Planning and Agriculture. Methodology for Assessing Rooftop Greenhouse Potential of Non-Residential Areas Using Airborne Sensors. *Science of the Total Environment*, **601-602**, 493-507. https://doi.org/10.1016/j.scitotenv.2017.03.214

[31] Li, J., Lan, Y., Wang, J., Chen, S., Huang, C., Liu, Q. and Liang, Q. (2017) Distribution Law of Rice Pollen in the Wind Field of Small UAV. *International Journal of Agricultural and Biological Engineering*, **10**, 32-40. https://doi.org/10.25165/j.ijabe.20171004.3103

[32] Radoglou-Grammatikis, P., Sarigiannidis, P., Lagkas, T. and Moscholios, I. (2020) A Compilation of UAV Applications for Precision Agriculture. *Computer Networks*, **172**, 107148. https://doi.org/10.1016/j.comnet.2020.107148

[33] Waskitho, N.T. (2015) Unmanned Aerial Vehicle Technology in Irrigation Monitoring. *Advances in Environmental Biology*, **9**, 7-10.