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RELATIVE STUDY ON THE PERFORMANCE OF LEACH AND ILEACH PROTOCOL IN WIRELESS SENSOR NETWORK

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ABSTRACT

In wireless sensor network, sensor nodes are furnished with non-chargeable, low power, and irreplaceable battery source, and their lifecycle depends on these batteries. Consequently, these nodes consumed more energy while conveying their sensitive data to the desire destination, thus, sensor nodes may exhaust their

INTRODUCTION

Wireless sensor network (WSN) is a flexible network which comprises of many small battery-powered sensor nodes, also known as "motes" distributed in some geographical area which are capable of monitoring or tracking by sensing their environment, collecting data, processing and communicate with one another through wireless links for useful relaying information collection and routing (Afsar & Younis, 2019; Dattatraya & Rao, 2019; Mittal, Singh, & Singh, 2019; Rahayu, Lee, & Lee, n.d.; Rani, 2019; Sibahee et al., 2016). The sense data are transmitted from the source to the base station, also known as sink node for further examination and processing.

Originally, these sensor nodes were developed for military application such as battlefield surveillance which are used to sense various types of enemy's equipment(Al-mousawi, 2019;

energy after separate rounds of operation. LEACH Protocol is the first and most popular energy-efficient clustering algorithm for WSNs that was proposed for reducing power consumption. LEACH is a Clustering-based routing protocol which are cost-effective in terms of energy, scalability, fault tolerance, reduce latency, and decreases communication in WSNs. In LEACH, energy is preserved by splitting the network period into smaller groups referred to as a cluster and altering the character of the sensor node as "Cluster leaders" and as a " node members" in each round; thus, helps to dispenses energy amid all the nodes. The cluster leaders are accountable for data collection, accumulate data, afterwards diffuses the accumulated data Also, direct communication is used by each cluster head (CH) to forward the accumulated data to the base station (BS). However, the downside of LEACH is the unequal dispersal of nodes in different clusters. In addition, the residual energy of the sensors was not taken into consideration during the selection of cluster head in LEACH. Consequently, nodes with minimum residual energy may be designated as Cluster heads and could result in the early death of the nodes; this will also lead to failure of the network. Due to the drawback of LEACH, much research has been done to enhance LEACH for better routing and clustering approaches. Therefore, in this paper, we reimplement LEACH and ILEACH protocols and perform a set of simulations testing that have been used to improve network lifetime and minimize energy consumption of sensor nodes in WSN. The simulation was administered using MATLAB R2018b Additionally, we compared the performance of LEACH and ILEACH using two metrics, namely the network lifetime and network throughput and the result shows that the ILEACH protocol outperforms the LEACH protocols.

Index Terms: clustering, network lifetime, network throughput, routing, wireless sensor network

Marschall & Rahmann, 2008; Tulenkov, Parkhomenko, Sokolyanskii, & Stepanenko, 2018)

Increase in advancement in technology, has helped to improve the uses of these sensor nodes (Al, Javad, Osman, & Oguz, 2019; Arman, 2015; Bongale, 2017; Horng, Chen, Chu, & Pan, 2012; Liu & Ravishankar, 2011; Sivakumar & Radhika, 2018). Nowadays, these nodes are mostly used to sense physical properties such as temperature, humidity, sound intensity, illumination intensity, wind direction, speed, pressure, power-line voltage, chemical concentrations, pollutant level and vital body functions due to increase in performance in terms of correctness, robustness, throughput, energy efficiency and reliability of results (Ali, 2019; Eswar & Naresh, 2012; Nitin et al. 2018).

Power consumption remains one of the main challenges in WSN because sensor nodes are small in size and their lifetime solidly depend on non-chargeable and irreplaceable battery source which affect the lifetime energy efficiency of the sensor nodes in WSN (Bayraklı & Zafer, 2012; Fan, Teng, & Huo, 2014; Moorthi & Thiagarajan, 2020; Rahiman, Islam, & Derahman, 2019; Thiagarajan, 2020; Wang, Zhang, Yang, & Vajdi, 2018).

Additionally, sensor nodes waste resources due to retransmitting packet because of packet collision. Furthermore, some applications uses direct transmission to relay their sense-data directly from the source node to the destination node (Rahiman et al., 2019; Wang et al., 2018). As a result of these limitation, these sensor nodes consumed more energy while sensing their environment, collecting data, processing data, communicating, and relaying their sense data to the sink station which affect the performance, throughput, and lifetime of the network.

Thus, innumerable routing protocols have been developed to find out the ways to increase the lifetime of WSNs. Among all these routing protocols, clustering is found to be the most effective technique to increase lifetime along with improving the throughput of sensor nodes in WSN (Barai, 2014; A. Kansal, 2019; Logambigai, Ganapathy, & Kannan, 2018).

Clustering is a grouping of nodes in the WSN to form a cluster, and the local communications between cluster members are controlled through a cluster head (CH). The CH is accountable for data collection, aggregation of the collected data and relaying the data to the sink station (Shaymaa et al. 2019; Mervat, 2019). The cluster heads can also form another layer of clusters among themselves before reaching the base station.

The foremost popular hierarchical clustering and routing algorithm for WSNs called "Low Energy Adaptive Clustering Hierarchy (LEACH) protocol" proposed by Heinzelman et al. (2000). Sensor nodes having an equivalent energy state are deployed within the network field, and therefore, the field is split into clusters, each having a leader referred to as the "cluster head." During this protocol, the network lifetime is split into several rounds, and individual round consists of two phases, namely the "setup and steady phase." The operation commences with the setup phase and is basically for cluster formation in which sensor nodes decide on nodes to act as the Cluster Heads (CH) for the present round based on a condition that sensor nodes recently chosen as cluster heads in any round are disqualified until all the nodes have participated in the selection.

Therefore, to choose leaders for the current round, each mote picks out a number between 0 and 1 randomly, and If the arbitrary number is lower than the calculated Threshold function shown in equation 1 below, the node becomes the cluster head for that round (Heinzelman, Chandrakasan & Balakrishnan, 2000).

$$R(m) = \int_0^{\frac{P}{1-P*(r\,mod\frac{1}{p})}} \qquad \begin{matrix} \forall\, n \in R(m) \\ \forall\, n \nexists R\,(m) \end{matrix} \qquad \text{equation (1)}$$

Subsequently, the newly elected cluster heads in the present round, communicate and send an announcement message to the other nodes for the establishment of the cluster. Hence, if an ordinary node receives a high signal strength advertisement message, then it needs minimum energy for data transmission with that cluster head. Therefore, the ordinary nodes may decide to join the cluster in the present round based on the communication signal power of the announcement message of the cluster head. Furthermore, to ensure evenly dispense energy load amid the sensor nodes, Cluster Heads alternation is done at a separate round by creating a new announcement phase based on threshold function. After the cluster formation in the setup, the next phase is the steady state in which each cluster head uses "time division multiple access (TDMA)" to generate a time slot for all the non-clusters motes to relay their sensitive data to the cluster leader. The purpose of using TDMA is to decrease inter-cluster and intra-cluster collisions. On receiving the arrival of the sensed data, the cluster heads, compress, accumulates the data subsequently forward it to the sink node directly (Heinzelman et al., 2000; Moorthi &Thiagarajan, 2019; Shokouhifar & Jalali, 2015).

The LEACH protocols help to maximize energy consumption by lessening communication costs between cluster heads, non-cluster nodes, and the sink node. Also, by randomly rotating cluster heads, it gives a better chance to all other sensor nodes that have not participated to be cluster head. The aim is to prevent sensor nodes from draining more energy and dies quickly (Muhammad, 2018, p2.; Moorthi &Thiagarajan, 2019, p. 92).

However, the drawback of LEACH is the unequal dispersal of nodes in different clusters. Also, the residual energy of the motes was not taken into consideration during the selection of cluster head in LEACH. Consequently, motes with minimum residual energy may be designated as Cluster heads and could result in the early death of the nodes; this will also lead to failure of the network. Also, LEACH uses single-hop communication for transmitting data, therefore not suitable for a vast region where thousands of motes are deployed in the network environment. Aside, in a smaller region, the consequence of using single communication in transmitting sensed data is that sensor node farther away from the sink node drains more energy while relaying their sensed data and dies quickly (Younis & Fahmy, 2004; see also Tianshu, Gongxuan, Xichen & Ahmadreza, 2018, p.197; Oluwatosin & Raja 2018, p. 1384)

Due to the weakness of LEACH, much research has been done to enhance LEACH for better routing and clustering approaches (Younis & Fahmy, 2004; Shokouhifar & Jalali, 2015; Sohn, Lee & Sang, 2016; Batra & Kant, 2016; Tianshu et al., 2018; Wang et al. 2016).

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Therefore, in this paper, we compared the performance of LEACH and ILEACH that have been used to improve network lifetime and minimize energy consumption of sensor nodes in WSN.

The remaining part of this paper is structured as follows. Section 2 provides the research objectives. Section 3 presents the materials and methods used for this research. Section 4 presents the evaluation framework used and discusses the simulation results. Finally, Section 5 concludes and highlights the paths for the future enhancement of this work.

RESEARCH OBJECTIVES

The focus of this study is to implement and perform a set of simulation testing on LEACH AND ILEACH protocol using MATLAB simulator that have been used to improve energy efficiency and network lifetime in WSN and compare their performance using two metrics which are Network lifetime and network throughput.

MATERIALS AND METHOD

A. METHODOLOGY

ILEACH protocol is an enhancement over the LEACH protocol. The goal of ileach protocol is to minimize energy wastage during cluster formation in LEACH by modifying cluster head selection within the setup phase. In leach protocol, efficient energy is often achieved by rotating the cluster-head role consistently amid all nodes; however, the residual energy of the sensor node was not considered during the choice of cluster head in LEACH. Consequently, this might cause picking Cluster heads with the lowest residual energy and will lead to the early death of the cluster head.

Ileach protocol separates the network lifecycle into numerous rounds, and in each round exist two phases, namely the setup and steady phase, which are used for cluster formation and transmission of packets from the cluster head to the sink. The setup begins by splitting the network field into various clusters, then after, cluster heads are assigned to each cluster by randomly selecting cluster heads. The choice of cluster heads in the first round is the same as the

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LEACH protocol where each node picks a random number [0,1] and will be compared with the threshold rate. A node can be head of the cluster only when the random number is reduced than the threshold rate, and then the nodes will serve as the cluster head within the first round. The newly elected cluster-heads broadcast a billboard message to the ordinary nodes to introduce themselves as the cluster heads for the existing round. After that, ordinary nodes join the cluster with the most substantial signal strength. The final phase for the first round is the steady stage where each cluster head uses "time division multiple access (TDMA)" to generate a time slot for all the ordinary nodes to relay their sensitive data to the cluster head. The steady phase uses three approaches of relaying packets, namely the intra-cluster (none cluster head to CH transmission), inter-cluster (CH to CH transmission), and cluster-head (cluster head to sink transmission) communication. Hence, the energy required for relaying packets in each approach is different. The non-cluster head is allocated with a low energy amplification level, and a high energy amplification level is allocated to the cluster head for the current round because it consumes more energy than the ordinary nodes for receiving packets from the non-cluster, accumulating data, removing redundant data and forwarding packets to the ultimate destination. In subsequent rounds, if the role of the previous cluster head changes to an ordinary node, the Ileach algorithms change the high energy amplification level of the nodes to low energy amplification energy.

There are modifications for selecting cluster heads in the subsequent rounds and is aimed at reducing communication cost and increase the energy efficiency of the network, after, all other procedure remains the same as in the first round. In iLEACH, the picking of cluster head is based on the residual energy of every node, numbers of neighbouring node and the minimum distance between the cluster head and sink node which is compared with the threshold function shown in equation 1 and 2 below.

$$T(n) = \frac{P}{1-P*(r \bmod \frac{1}{p})} * \frac{Er}{Ere} * \frac{Aveg\ DCH\ to\ BS}{D\ to\ BS} * \frac{No\ of\ neig\ node\ r}{Aveg\ Neig\ node\ r} \quad \text{equation (2)}$$

Otherwise,

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$T(n) = 0 \qquad \forall\, n \nexists G$ equation (3)

ILEACH accepted first order radio model proposed by Heintzelman et al., 2000 mostly employed by other researchers (Agarwal, Agarwal, & Muruganandam, 2018; Geetha, Kallapur, & Tellajeera, 2012; Islam, Khan, Islam, & Akhtar, 2019; Tanwar, Thakkar, Thakor, & Singh, 2018; Yousaf, Ahmad, Hamid, & Khan, 2019) to compute the energy depletion of sensor nodes in WSN. The first radio model made up of the transmitter that dissipates energy to run the transmitter radio electronics and power amplifier. Therefore, the receiver dissipates energy to run the receive radio electronics with a distance of separation, depends on the space between the transmitter and the receiver. The free space model (fs) is employed for a shorter distance, while the multipath ($E_{mp)}$ is employed for long-distance. Multipath (ε_{mp}) model is employed for long distances which is shown the equation below:

Energy for transmitting the packet:

$E_{Tx}(f,d) = E_{Tx\_Elec(f)} + E_{Tx\_amp}(f,d)$ equation (4)

$ETx\,(f, d) = Eelc * f + \varepsilon_{fs} * f * d^2$ for $d \leq d_o$ equation (5)

Otherwise,

$ETx\,(f, d) = Eelc * f + \varepsilon_{mp} * f * d^4$ for $d > d_o$ equation (6)

Energy to receive the packet:

$ER_x(f,d) = E_{Rx\_Elec(f)} + E_{Rx\_amp}(f,d)$ equation (7)

Where

E_{elc} represents the energy cost per f-bit by the transmitter and receiver.

ε_{mp} represents the energy cost by signal amplification when conveying f-bit data.

ε_{fs} is factors for the free space model and is employed for a short distance.

ε_{mp} is the factor for multipath model and is employed for long-distance.

d^2 is the energy used up by the amplifier for short distance transmissions.

d^4 is the energy used up for long-distance transmissions.

d_o is the distance threshold, which is calculated as:

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$d0 = \sqrt{\varepsilon fs / \varepsilon mp}$
equation (8)

ASSUMPTION AND SIMULATION PARAMETERS

The assumptions used for the simulation environment are as follows:

1. The network lifetime is divided into multiple rounds.
2. The network field is split into a cluster.
3. We have three kinds of Sensor nodes namely sink nodes, cluster head nodes, and non-cluster heads.
4. The sink is sited at the centre of the network field and has enough energy to receive sensed data.
5. The sensor node is randomly deployed in the network field within 100m x 100m / 200m x200m.
6. The initial energy of sensor nodes is 0.5J / 1J.

The other parameters used to simulate the LEACH, and ILEACH protocol is shown in Table 1 below:

TABLE 1: PARAMETERS USED TO SIMULATE THE LEACH AND ILEACH PROTOCOL

Parameters	Values
Network field	$100m^2 \times 100m^2$,
	$200m^2 \times 200m^2$
Number of sensor nodes	100, 200, 400
E_{elc} is the energy cost per f-bit by the transmitter and receiver	50nJ/bit
ε_{amp} is the energy cost by signal amplification when conveying f-bit data	100 pJ/bit/$m2$
ε_{fs} is factors for the free space model and is employed for a short distance	100 pJ/bit/$m2$
ε_{mp} is the factor for multipath model and is employed for long-distance	0.0013/pJ/bit/m4
Energy for data aggregation ***EDA***	5 nJ/bit/m^4
Probability of CH	p=0.01 / 0.02
Packet size	4000/bits
Numbers of rounds	2000

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SIMULATION RESULTS & DISCUSSIONS

A. Simulation Environment

In this research work, the simulation was administered using MATLAB R2018b and was operated on a system with an Intel CPU Core i5-8250U, 16 GB RAM, and Windows 10 to simulates the LEACH and ILEACH protocol

B. PERFORMANCE METRICS

The performance metrics used for this study are network lifetime and throughput and are explained below:

i) **Network lifetime:** This is used to evaluate the time interval from the commencement of the sensor node's operation until the death of the last node in the network field. This network lifetime is defined as first node death (FND), and last node death (LND).

ii) **Throughput:** This metric is used to evaluate the total packets received by the cluster head from the non-cluster heads members; also, it measures the total packets cluster heads relay to the sink node.

C. SIMULATION RESULTS

i) **SCENARIO 1:** We considered a sensor network where 100 sensor nodes are deployed on a 100m2 x 100m2 network field, the sink node is sited at the centred of the network area (x=50, y=50). The initial energy of the sensor nodes is 0.5j, the energy cost per f-bit by the transmitter and receiver is 50nJ/bit, the energy for data aggregation EDA is 5 nJ/bit/m4, probability of cluster head is 0.1, and the number of the round is 2000. We repeated the simulation five times to evaluate the efficiency of LEACH and ILEACH protocols. The simulation result is shown in figure 1 and figure 2:

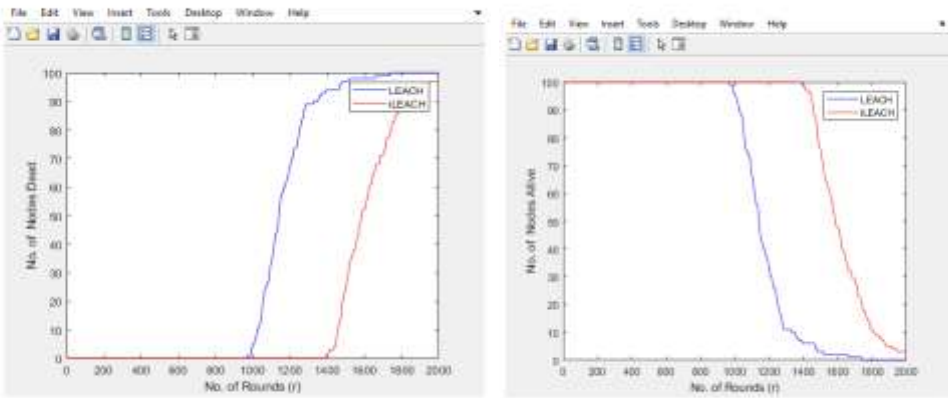

Figure 1: comparison of LEACH and ILEACH network lifetime

Figure 1 shows that all the LEACH protocol nodes were alive from round 1 until the first node died at round 967 and slowly increased until the last node died at round 1474. Based on observation from the figure above, 100% of the node were dead in the LEACH protocol; however, in the ILEACH curve for the number of dead nodes, the first node dead is at round 1346 and moderately increased in the number of the dead node. 97% of the nodes were in round 1991 and remain stable till the end network lifecycle.

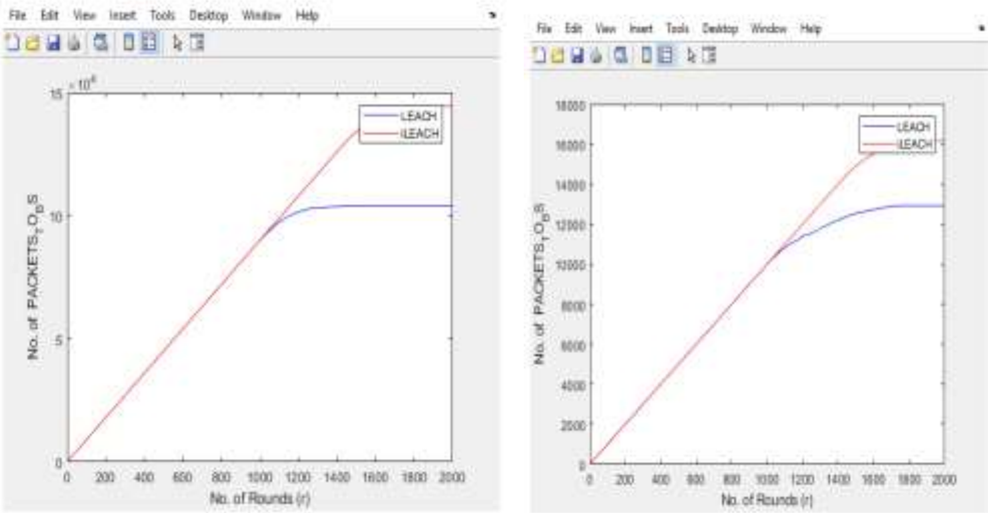

Figure 2: comparison of LEACH and ILEACH throughput

Figure 2 shows the comparison of LEACH and ILEACH throughput in terms of the number of packets received by the cluster heads from the non-CH members and the number of packet sink nodes received from the cluster head. Based on observation from the graph, cluster heads and sink nodes in ILEACH received a higher number of packets than the LEACH protocol because the energy load was squarely dispersed amid all the sensor nodes.

ii) **SCENARIO 2:** We consider a sensor network where 100 sensor nodes are deployed in a network area on a 200m2 x 200m2, the sink node is placed at the centre of the network area (x=100, y=100). The initial energy of the sensor nodes is 0.5j, the energy cost per f-bit by the transmitter and receiver is 50nJ/bit, the energy for data aggregation EDA is 5 nJ/bit/$m4$, probability of cluster head is 0.1, and the numbers of the round are 2000. We repeated the simulation five times to evaluate the efficiency of LEACH and ILEACH protocols. The simulation result is shown in figure 3 and figure 4

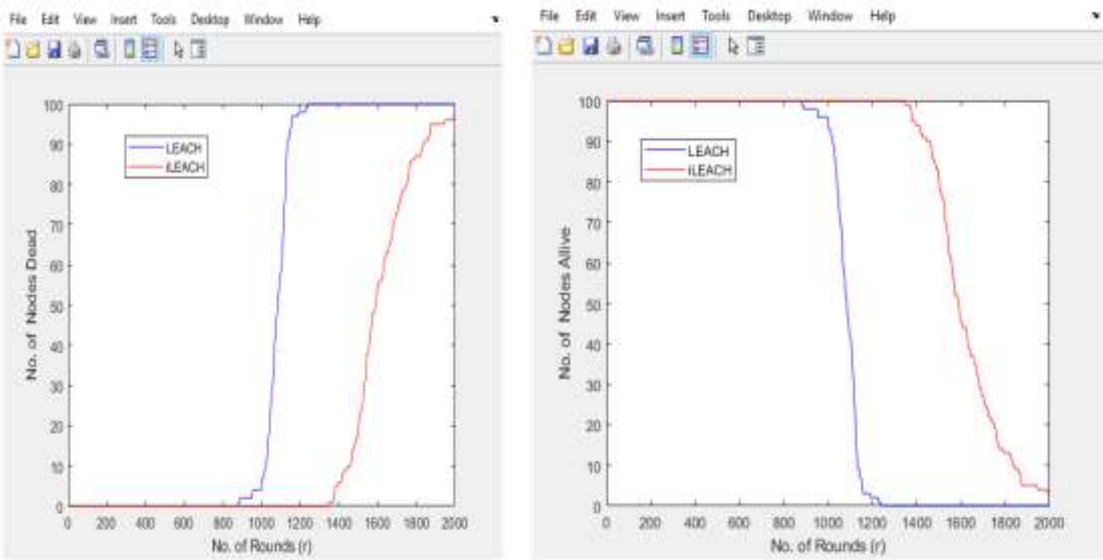

Figure3: comparison of LEACH and ILEACH network lifetime

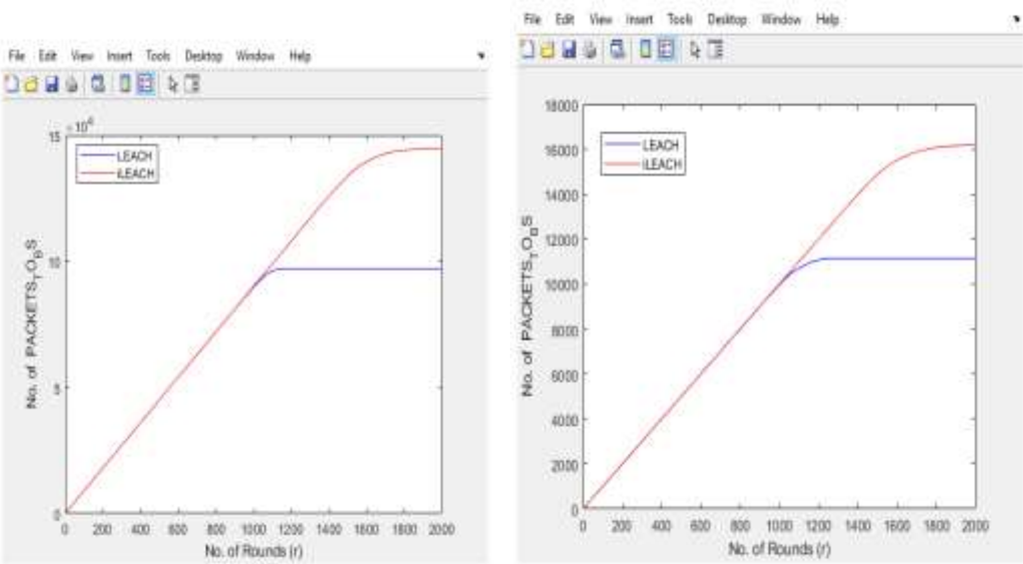

Figure 4: comparison of LEACH and ILEACH throughput

It is observed that when the sensor nodes are deployed into a more significant network area with **an equivalent i**nitial as in when they were deployed in a smaller area (100m2 x 100m2), there is an earlier dead rate

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of sensor nodes. More so, a lower number of packets was delivered to the cluster heads and sink node in both LEACH and ILEACH compared to when the nodes were deployed within a small field because these nodes consumed more energy due to the communication distance among the nodes. Figure 3 shows that all the nodes in the LEACH protocol were dead at 1238, while 4% of the nodes in ILEACH protocols are alive at the end of the network lifetime.

Table 2 and 3 below are the results of the network lifetime in terms of FND, LND, number of packets received by the cluster and sink node we obtained from the simulation we conducted using different parameter (Behera, Samal, & Mohapatra, 2018; FallahHoseini & Rafeh, 2018; Gantassi, Yagouta, & Gouissem, 2017; S. Kansal, Bhatia, & Goel, 2015).

TABLE II. COMPARISON OF THE NETWORK LIFETIME

SCENARIO	PROBABLITY OF CLUSTER HEAD	INITIAL ENERGY	NO OF NODE	AREA	LEACH FND LND		% DEAD	ILEACH FND LND		% DEAD
1	0.1	0.5	100	100	967	1474	100	1346	1991	97
2	0.1	0.5	100	200	880	1238	100	1392	1946	96
3	0.1	0.5	400	200	931	1391	100	1415	1830	89
4	0.2	0.5	100	100	845	1782	100	1426	1987	98
5	0.2	0.5	200	200	1663	100	100	1439	1970	97

TABLE III. COMPARISON OF THE NETWORK THROUGHPUT

SCENARIO	AREA	NO OF MODE	NO. OF PACKET LEACH	ILEACH	%DIFFERENCE	
1		100	100	PACKETS TO CLUSTER	103960	144679
		39.17				
				PACKET TO BS	12915	16181
		25.29				
2		200	100	PACKETS TO CLUSTER	96973	
144686		49.20				
				PACKET TO BS	11131	
16207		45.60				
3		200	400	PACKETS TO CLUSTER	414588	579434
		39.76				
				PACKET TO BS	46530	
64512		38.65				
4		100	100	PACKETS TO CLUSTER	90334	133017
		47.25				
				PACKET TO BS	23621	33449
		41.61				

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5	200 52.85	200	PACKETS TO CLUSTER	86981	132952
			PACKET TO BS	22280	
33315	49.53				

CONCLUSION AND FUTURE WORK

Based on the simulation results, the number of dead nodes in iLEACH protocol decreased more than in LEACH protocol indicating better network lifetime in iLEACH than in LEACH. The packet to cluster heads and sink nodes in iLEACH increased than in LEACH which indicate better throughput in ILEACH than in LEACH.

Therefore, we conclude that iLEACH performs better than LEACH in both network lifetime and Throughput following the introduction of efficient cluster head Selection in iLEACH. Consequently, Cluster formulation based on iLEACH minimized energy consumption and provided prolonged network lifetime.

However, clustering formation and routing algorithms are NP-hard optimization problems. Hence, there is a need to use metaheuristic algorithms such as the Genetic Algorithm for well-ordered clustering and intelligent routing of sensitive data to lessen the energy depletion of cluster heads in WSN within a reasonable time. Therefore, in future research, we will enhance the research work by implementing Genetic algorithm and compare the performance with the two protocols used in this research work.

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