EIMHT-LEACH: ENHANCING THE PERFORMANCE OF THE IMHT-LEACH PROTOCOL

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Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is one of the routing protocols that have been developed to enhance the data transmissions along the Wireless Sensor Networks (WSNs). Many protocols have been appeared to improve the LEACH protocol, of which an Improved MHT-LEACH (IMHT-LEACH) proposes a technique that allows forwarding the clusters' data to the Base Station (BS) through more levels. This paper suggests a new approach for enhancing the IMHT-LEACH protocol. Simulation results reveal that the proposed protocol managed to enhance the performance of WSN in terms of lifetime, stability and throughput compared with IMHT-LEACH and conventional LEACH protocols.

Keywords: Wireless Sensor Networks; LEACH; IMHT-LEACH; Lifetime; Stability; Throughput

1. Introduction

Wireless Sensor Networks (WSNs) have become an inspiration area for many researchers, where the rapid developments in the technology have paved the way to manufacture different types of sensor nodes [1]. In most cases, WSN typically contains hundreds of sensor nodes, which are scattered into a specific environment for gathering data, doing some processing on it, and then forwarding it to other neighboring nodes, or to the Base Station (BS) [2]. Based on the aforementioned, WSNs have been widely used in a plenty of applications that are useful to humanity. For instance, WSNs were successfully utilized in the area of tracking targets, surrounding surveillance and protection, healthcare supervision and monitoring and others [3-5]. On the other hand, WSNs face some limitations that make their tasks more difficult [6]. In fact, the energy dissipation of network nodes is considered a critical issue that challenges this type of networks, and that it is impractical to recharge them again. Thus, prolonging the lifetime of WSN is considered as the main objective for many research papers. In WSN, most energy of nodes is consumed in transmitting their data. For this reason, many protocols have emerged to facilitate the data transmission in a sensor network, which also

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take into account the energy cost and throughput of network [7]. LEACH protocol is one of these protocols that have taken widespread acceptance in the WSN, where the hierarchical approach is used to distribute all nodes among the clusters [8]. Hence, all sensor nodes will be able to organize themselves in clusters, which usually happens during the specific interval time that is called the round. In LEACH, the network lifetime is split into rounds, where each round comprises two phases: the first one is the set-up phase, while the second one is the steady state phase. Unfortunately, the conventional LEACH protocol has a number of drawbacks, such as the collected data of every Cluster Head (CH) is directly sent toward the BS. Aiming to reduce the impact of this aspect, a new version, Multi-Hop Technique for Improvement of LEACH Protocol (MHT-LEACH) protocol, has been proposed in [9]. Instead of using the single-hop approach, the MHT-LEACH protocol supposes that the aggregated data can be forwarded to the BS through more hops by splitting the network into two levels based on a threshold value (d_o). Here, the d_o value is measured in meter (m). Furthermore, the Improved MHT-LEACH (IMHT-LEACH) protocol has been proposed in [10]. The main objective for the IMHT-LEACH protocol was to reduce the energy that is needed in transmitting the data in the MHT-LEACH protocol. Hence, IMHT-LEACH protocol proposed an approach based on splitting the entire network environment into more levels, where the length of each level is equal to $d_o/2$. It should be noted that the IMHT-LEACH protocol considers a process divided into four phases: the initial phase, the announcement phase, the routing phase, and the redundancy phase [10]. In the initial phase, the IMHT-LEACH protocol supposes that all the sensor nodes are scattered into the environment, and the clustering formation has been already done. Moreover, each CH uses the Global Positioning System (GPS) to determine its position and to compute its distance to the BS. Accordingly, each CH can determine its level. In the announcement phase, each CH broadcasts announcement messages to the neighbor CHs, where each message contains information about its coordinates. In the routing phase, each CH creates its routing table (RT) depending on the announcement messages, which are received from the neighboring CHs in the lower levels. Based on the RT, each CH chooses its route and computes the amount of the energy that is required for every route. For minimizing the data redundancy in the network, the redundancy phase has been proposed as part of the IMHT-LEACH protocol. By doing so, the CHs will have a new task to eliminate the copies of packets. The results showed that the IMHT-LEACH protocol achieved a number of benefits in comparison with the conventional LEACH and MHT-LEACH, as follows: it prolongs the lifetime, increases the throughput, and improves the stability of the WSN [10].

The present paper proposes a new approach for improving the lifespan, stability and throughput of the network compared with IMHT-LEACH and conventional LEACH protocols, it is organaized as follows: Section 2 discusses

the related literature work. In section 3, the proposed approach is discussed. Section 4 presents the simulation results. Finally, the conclusion is included in section 5.

2. Related Work

Many routing protocols were found for WSN to extend the durability of the network as much as possible. Some of these protocols' structures depend on the clustering. Hence, the number of transmissions has been reduced. An Improved LEACH (I-LEACH) protocol has been emerged to minimize the total energy dissipation of the WSN. It tries to detect the twin nodes and assigns a sub-CH for each cluster [11]. The Energy-Low Energy Adaptive Clustering Hierarchy(E-LEACH) protocol introduces a modification approach for choosing the CHs in the set-up phase of the LEACH protocol [12]. All sensor nodes can become CHs at the first round, since they are initiated with the same amount of energy. Then, the nodes energy begins receding gradually. The E-LEACH supposes that the nodes that have higher residual energy will be chosen as CHs in the next rounds. The previous assumption makes a balancing in the energy load between all the nodes of the network. Centralized-Low Energy Adaptive Clustering Hierarchy (LEACH-C) protocol has modified the setup phase of the LEACH protocol [13], especially the CHs election process. In the LEACH-C, the network's CHs are chosen by the BS, which in turn selects the nodes that own the highest remaining energy. The concept of dividing each cluster into cells has been introduced in [14]. Each cluster comprises of a CH and 7 cells. Meanwhile, every cell has a cell head, whereas the sensed data is aggregated by the cell-heads, and then transmitted to the CH. The Dynamic Multi-Hope Technique for WSNs (DMHT-LEACH) protocol proposed in [15], it uses a technique for dynamically choosing the next hop toward the BS. The Enhancing DMHT-LEACH (EDMHT-LEACH) protocol has been proposed in [16]. It was introduced in order to enhance the performance of the DMHT-LEACH protocol. Thus, it suggests a new approach for electing the CHs and it aims to improve the dynamic routing approach that is used in DMHT-LEACH protocol.

3. The proposed protocol

As it results from the analysis above, the IMHT-LEACH protocol aimed to improve the data transmission of CHs to the BS, but it has left the clustering process without any change. This paper proposes an algorithm, EIMHT-LEACH, to address the drawbacks of the IMHT-LEACH protocol. The proposed protocol comprises of three phases, as follows: The intial phase, the announcement phase and the routing phase.

A. *Initial phase:*

This phase is similar to that used in [16], which aims to perform the clusters formation and to elect the eligible CHs for them. Hence, the CH election process takes into consideration the remaining energy in the network nodes during this phase. Each node *n* picks out a random number located between 0 and 1. Then, this random value is compared with a variable threshold $T'(n)$. If it is smaller, this node will be a CH at this round. The value of the threshold can be computed by the equation 1, which is proposed in [17].

$$
T'(n) = \begin{cases} max\left(\dfrac{p}{1 - p\left(r \, mod \, \dfrac{1}{p}\right)} \times \dfrac{E_{residual}}{E_{max}}, T_{min} \right) & \forall_n \in G \\ 0 & \forall_n \in G \end{cases} \tag{1}
$$

In equation (1), the *p* indicates the percentage of the CHs that is needed to be in the network. The *r* denotes the round's number. The *G* represents the set of the sensor nodes that have not been chosen CHs in the last *1/p* rounds. The $E_{residual}$ refers to the remaining amount of the energy in the node, the E_{max} indicates the amount of the energy that initiates the sensor node. The T_{min} refers to the minimum threshold, which is used when the amount of the $E_{residual}$ in the nodes becomes very small. Afterwards, the process of clusters formation begins. In this phase, the EIMHT-LEACH protocol uses two conceptions:

- Number of member nodes within the cluster

The conventional LEACH and most of its successor protocols, which are proposed to improve it, suffer from that some of the clusters have a huge number of member nodes, while other clusters own fewer member nodes. In this case, the unbalance in the energy load between the clusters becomes clearer. Thus, the CHs that are followed by higher number of member node die rapidly, and this diminishes the stability of the network. The distance between the CH and the nodes, which link to it, is another issue that can effect on the total energy dissipation in WSN, where in some cases the ordinary nodes join CH that is relatively fara way from them. Based on the above, the proposed protocol supposes that each cluster will have a limited number of member nodes. Thereby, if we suppose that the *J* parameter denotes the number of sensor nodes that are scattered along a specific area, then the expected number of clusters will be:

$$
Number \; of \; the \; CH_s = \sum_{J=1}^{J} p \times 1 = J \times p \tag{2}
$$

While the expected number of member nodes within each cluster is:

$$Number\ of\ nodes\ within\ the\ cluster(N_O) = \frac{J}{Number\ of\ the\ CH_S} \qquad (3)$$

Then, all the CHs broadcast advertisement messages (ADVs) to ordinary nodes. Usually, each ADV message has a CH ID and its coordinates. On the other side, when the node receives an ADV message from any CH, it will calculate the distance to it and adds this CH and its distance to a selection table (ST). To join the cluster, the proposed protocol supposes that the distance between the node and its CH should be less than d_o. On this basis, the node arranges the CH distances in its ST, checks if it has distances values less than d_o, and then chooses the CH whose distance is the lowest. After choosing its CH, the node transmits JOIN-REQ message to it. On the other hand, when the CH receives the JOIN-REQ, it checks its TDMA schedule. If it is still available, then it allocates a time slot for this node and sends the response. By doing so, this node becomes a member node in that cluster. Otherwise, if the node receives a refusal for its request, it sends another JOIN-REQ to the CH that has the second lowest distance in the ST, and so on.

- Independent Nodes (INs)

Occasionally, some of the ordinary nodes become isolated, which means that they were not joined to any CH. These nodes are called Independent Nodes (INs). Like the CH, each IN has the ability to select its route to the BS. In addition to their sensing tasks, the proposed protocol gives the INs a new task, which is meant to facilitate the transmission of CHs data to the BS. Fig. 1 represents the topology of network using the proposed protocol, while Fig. 2 shows the flow chart of the initial phase.
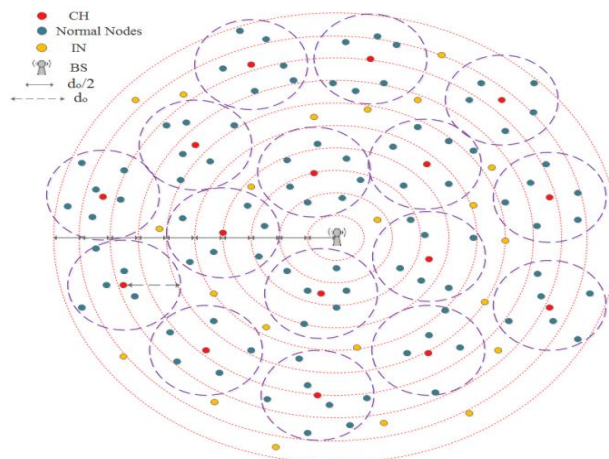

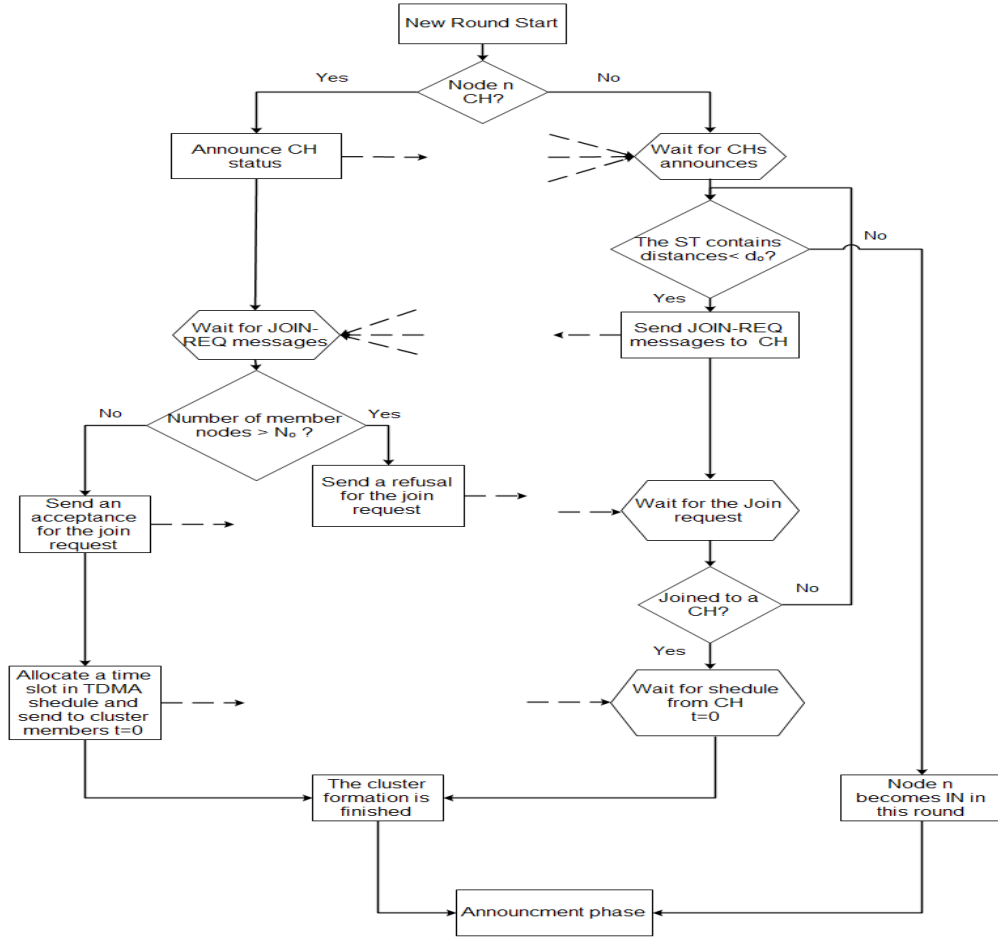Fig. 1. Topology of the WSN using the proposed protocol.

Fig. 2. Flowchart of the Initial Phase in EIMHT-LEACH protocol.

B. Announcement phase:

In this phase, all the CHs and the INs broadcast announcement messages, where each message contains the ID of the sender, its coordinates, and its distance to the BS. Based on this message, all the CHs and INs try to create their RTs. For this reason, the announcement messages that are only received from the lower levels are taken, whereas other announcement messages will be neglected. Similar to the IMHT-LEACH, the EIMHT-LEACH assumes that the length of each level around the BS will be $d_o/2$.

C. Routing phase:

Based on the announcement messages, all the CHs and the INs nodes can create their RTs, which let them decide their routes to the BS in this round.

Therefore, this phase includes three cases for selecting the CH and IN routes toward the BS. It should be noted that each case selects the CH and IN routes and computes the amount of energy dissipation for each route, as shown in Table 1. After choosing the route, a JOIN-REQ message is sent to the destination node, which checks the availability in its TDMA, and replies its response. Furthermore, the RTs let the CHs and INs to change their routes in case that the TDMA schedule in the destination node is full. Finally, we use the energy dissipation model, which is proposed in [13], in order to compute the amount of energy that is needed to transmit and receive *k*-bit packets respectively, as follows:

$$E_{Tx}(k,d) = \begin{cases} E_{elec} * k + \varepsilon_{fs} * k * d^2, & d < d_o \\ E_{elec} * k + \varepsilon_{mp} * k * d^4, & d \geq d_o \end{cases} \tag{4}$$

$$E_{Rx}(k) = E_{elec} * k \tag{5}$$

Here, the E_{elec} parameter indicates the energy that is required to process the data, which will be sent and received along the network. The ε_{fs} refers to the free space propogation model, and it is used in evaluating the energy required to transmit data over distance less than d_o, whereas the ε_{mp} refers to the two-propogation model, and it is used when the transmission distance is greater than d_o. The value of the d_o can be calculated as follows:

$$d_o = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \tag{6}$$

Table 1

Routing phase cases

Case 1:	Case 1:

if (CH $_{D\text{-}BS}$ < d$_o$/2*)* **then**
     The CH sends its data directly to BS *;*
    $E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * CH_{D-BS}^2$ *;*
 end
 Where:
    CH**D-BS** = the distance between the CH and the BS.
	if (IN $_{D\text{-}BS}$ < d$_o$/2*)* **then**
	     The IN sends its data directly to BS *;*
	    $E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * IN_{D-BS}^2$ *;*
	 end
	 Where:
	    IN**D-BS** = the distance between the IN and the BS.

Case 2:	Case 2:

if (CH $_{D\text{-}BS}$ >= d$_o$/2 && CH $_{D\text{-}BS}$ < d$_o$)
    if (CH $_{D\text{-}BS}$ <= CH$_{D\text{-}L1}$) **then**
    The CH sends its data directly to BS ;
    $E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * CH_{D-BS}^2$;
    end
     else if (CH $_{D\text{-}BS}$ > CH$_{D\text{-}L1}$) **then**
       The CH sends its data to the CH or
       the IN, which has the minimum
	if (IN $_{D\text{-}BS}$ >= d$_o$/2 && IN $_{D\text{-}BS}$ < d$_o$)
	    if (IN $_{D\text{-}BS}$ <= IN$_{D\text{-}L1}$) **then**
	    The IN sends its data directly to BS ;
	    $E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * IN_{D-BS}^2$;
	     end
	     else if (IN $_{D\text{-}BS}$ > IN$_{D\text{-}L1}$) **then**
	       The IN sends its data to the CH or
	       the IN, which has the minimum

distance in level 1;
 	
 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * CH_{D-L1}^{2};$$
 end
 end
 Where:
    CH_{D-L1}= the distance between the CH at the second level with all CHs and INs that are located on the first level.
	distance in level 1;
	 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * IN_{D-L1}^{2};$$
	 end
	 end
	 Where:
	    IN_{D-L1}= the distance between the IN at the second level with all CHs and INs that are located on the first level.

Case 3:
 if (CH **D-BS** >= d_o)
   if (CH **D-BS** <= CH_{D-Ln}) **then**
     The CH sends its data directly to BS;
 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{mp} * k * CH_{D-BS}^{4};$$
    end
    else if (CH **D-BS** > CH_{D-Ln})
     { if (CH_{D-Ln}< d_o) **then**
     The CH sends its data to the CH or the IN, which has the minimum distance in level n ;
 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{mp} * k * CH_{D-Ln}^{2};$$
      else
      The CH sends its data to the CH or the IN, which has the minimum distance in level n ;
 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{mp} * k * CH_{D-Ln}^{4};$$
      end }
     end
   end
 Where:
 CH_{D-Ln}= the distance between the CH at the upper level with all CHs and IN_s that are located on the lower levels.
	Case 3:
	 if (IN **D-BS** >= d_o)
	   if (IN **D-BS** <= IN_{D-Ln}) **then**
	     The IN sends its data directly to BS;
	 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{mp} * k * IN_{D-BS}^{4};$$
	    end
	    else if (IN **D-BS** > IN_{D-Ln})
	     { if (IN **D-Ln** < d_o) **then**
	     The IN sends its data to the CH or the IN, which has the minimum distance in level n ;
	 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{fs} * k * IN_{D-Ln}^{2};$$
	      else
	      The IN sends its data to the CH or the IN, which has minimum distance in level n ;
	 $$E_{Tx}(k) = E_{elec} * k + \varepsilon_{mp} * k * IN_{D-Ln}^{4};$$
	      end }
	     end
	   end
	 Where:
	 IN_{D-Ln}= the distance between the IN at the upper level with all CHs and IN_s that are located on the lower levels.

5. Simulation and Results

The EIMHT-LEACH protocol has been developed to improve the performance of IMHT-LEACH protocol. For this reason, it has been experimentally compared with the IMHT-LEACH and the LEACH protocol using programs developed in MATLAB. In the simulation scenario, 200 nodes are randomly deployed on an area of (300 x 250) m^2. Table 2 includes a list of all

simulation parameters. Fig. 3 represents the number of living nodes versus the rounds in three protocols. This graph also refers to the lifetime of the network within each protocol. As can be seen, the longest lifetime has been achieved using the EIMHT-LEACH protocol (in comparison with IMHT-LEACH and the LEACH protocols). Thus, the proposed protocol extends the lifetime of the network. There are a number of reasons behind this. First, the CHs election process becomes contingent to the remaining energy in the nodes. Moreover, the number of cluster member nodes has been limited, which means that the energy load on the CHs is relatively decreased. Furthermore, the INs decrease the energy dissipation in the WSN and facilitate the transmission of data through the levels.

Table 2

Simulation Parameters

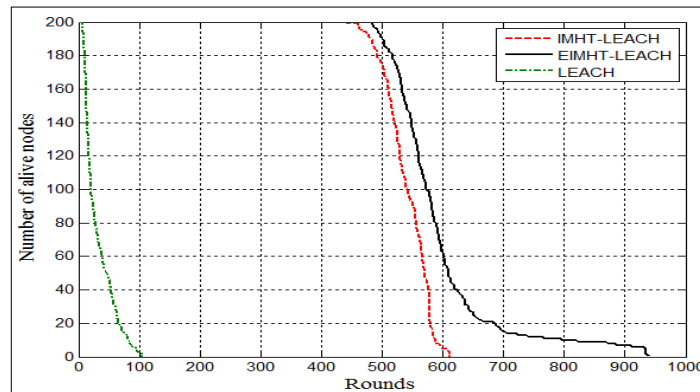| Parameters	Values
Area (X*Y)	(300*250) m^2
BS Coordinates (X,Y)	(150 m, 450 m)
Number of Nodes	200
Initial Energy (E_o)	0.5 J
The percentage of CH (p)	0.1
T_{min}	0.03
E_{elec}	50 nJ/bit
ε_{fs}	10 pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
Data Aggregated Energy (E_{DA})	5 nJ/bit
Control Packet size	200 bit
Data Packet Size	6400 bit

Fig. 3. Comparison of number of living nodes in the LEACH, IMHT-LEACH and EIMHT-LEACH protocols.

Fig. 4 offers the possibility to compare the stability of the network by measuring the number of the rounds required until the first, half and last node die

within the three protocols. Once again, the obtained results showed that the EIMHT-LEACH protocol achieved the best performance in comparison with the IMHT-LEACH and the LEACH protocol due to the fact that the EIMHT-LEACH minimizes the CHs energy load within the round. Moreover, it reduces the nodes participations in cluster formation, particularly the nodes that do not have any closer CH. Thus, the EIMHT-LEACH increases the interval time between the start of the network work until the first sensor node dies.

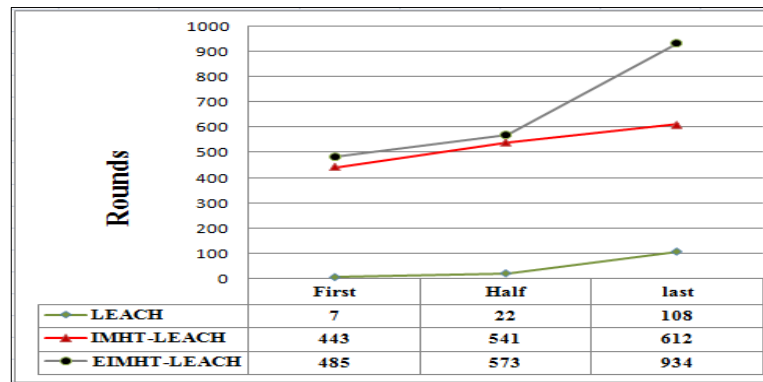| Rounds	First	Half	last
LEACH	7	22	108
IMHT-LEACH	443	541	612
EIMHT-LEACH	485	573	934

Fig. 4. Comparison of the stability in the LEACH, MHT-LEACH, and EIMHT-LEACH protocols.

In Fig. 5 and Fig. 6, one can observe the total number of packets that were transmitted to the CHs and BS versus the rounds, respectively. Again, the highest throughput has been achieved by the EIMHT-LEACH protocol.
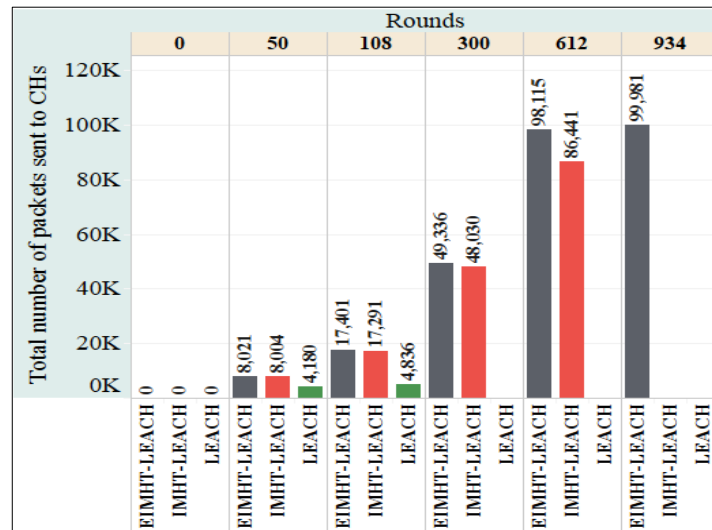

Fig. 5. Total number of packets sent to CHs in the LEACH, IMHT-LEACH, and EIMHT-LEACH protocols versus rounds.

The previous result has been fulfilled, because the number of rounds (lifespan of the network) is extended to 934 rounds by EIMHT-LEACH protocol compared with the LEACH and IMHT-LEACH protocols, which only achieved 103 and 612 rounds, respectively.
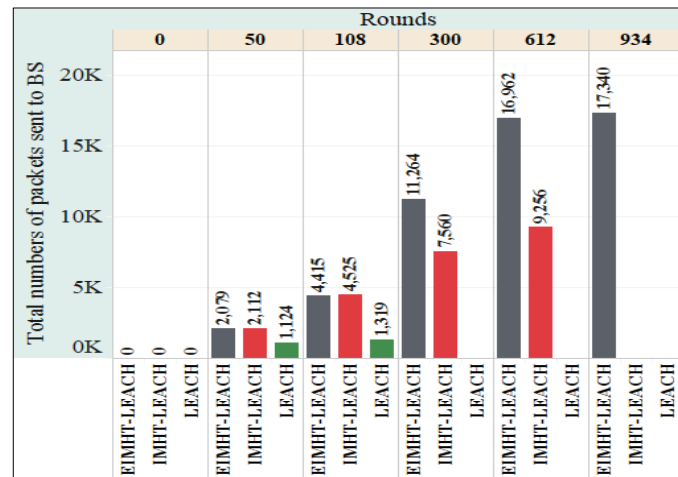

Fig. 6. Total number of packets sent to BS in the LEACH, IMHT-LEACH, and EIMHT-LEACH protocols versus rounds.

6. Conclusions

In the present study, a new improvement approach, which aims to save the network energy, has been proposed for the IMHT-LEACH protocol. To reach this purpose, the proposed protocol has improved the CH election process and the clusters formation. Furthermore, the data transmission among the levels has become more efficient with the INs suggestion. For the experiments, the results showed that the lifetime, the stability and the throughput of the network have improved if we compare the proposed protocol with IMHT-LEACH and the LEACH protocols.

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