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An Efficient Energy Aware ZRP-Fuzzy Clustering Protocol for WSN

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Abstract- Clustering protocol in WSN have a great impact on the performance of the network especially in regards to solve the energy constrained problem, thus, this paper presents a cluster head selection based on fuzzy logic implemented on ZRP protocol (CHFL-ZRP) to increase the life time of the network as much as possible by increasing the stability period of the node. Simulation results based on NS2 show that the proposed approach prolongs the life span of the network as compared to LEACH, LEACH-C, LEACH-ERE and CHEF protocols.

Index Terms— WSN, Sink, ZRP, Fuzzy, Base Station, Cluster Head, Clustering, Life Time.

1 Introduction

A WSN is composed of such sensor nodes that establish a network structure capable to communicate with other nodes either directly or indirectly. One or more than one node is dedicated to serve as a gateway base station (sink) for the WSN [1]. The efficiency of energy consumption represents the prime provocation that is facing designers in WSN. The main consumption in energy takes place inside the WSN is while the nodes are transmitting their data. It is very essential to control the energy consumption during the data collection phase. This is done by letting a minimum amount of nodes that are in direct communication with the base station, where collection of the application data is hosted. The developed algorithms for WSN clustering minimizes the number of nodes who are engaged in transmitting with the sink station. This is done by grouping the deployed nodes into clusters or sectors. Each cluster is controlled by a head node called cluster-head (CH). Other nodes found in the cluster become members of that cluster. The cluster member nodes only communicate with the cluster head within a limited transmission range and hence energy consumption is minimized. The data collected at those cluster heads from their member nodes are aggregated into one packet and forwarded by the CH to the BS [2]. Since all the nodes are targeting their data toward the sink station, where processing and decision making take place, the base station deployment in a WSN is of a major concern. For that, the issues concerning, power consumption, coverage of WSN and reliability are under investigation. It is generally assumed that the base stations are static in nature [3].

2 Related Work

There are several protocols which differ in their techniques in a way or another, but still use the same principle, the motivation of the use of clustering method started with LEACH protocol which is introduced by **(W. Heinzelman et al, 2000).** It is regarded as the mother of energy efficient clustering routing protocol. Also it is considered as a well proactive approximated network protocol. The protocol of LEACH comprises from two phases or periods: a setup one and steady state one. In setup stage, clusters are selected and formed by selecting the CH randomly. In the second phase, the CH's member nodes data are aggregated by the CH, then directly send to the BS in a single hop [4]. **(A. Manjeshwar & D. Agrawal, 2001)** proposed Threshold sensitive Energy Efficient sensor Network protocol (TEEN). It is considered as a reactive networks protocol, which firstly developed. The environment is continuously sensed by the nodes. The consumption level in proactive networks is probably much higher than the energy level in the networks using the reactive scheme. Two types are used for sensing energy soft and hard threshold. The performance evaluation is made for sensing a simple temperature application [5]. Hybrid Energy-Efficient Distributed clustering (HEED*)* protocol was developed by **(O. Younis & S. Fahmy, 2004**), CHs election and clusters formation are based on two combined parameters: The primary, which depends on the remaining energy in the nodes. The secondary parameter represents the cost of the communication during the intra clustering. In applying this protocol, nodes determine the nearest cluster head node to be a member of its cluster. Also, the data aggregated by CHs are send to the sink station using multi-hop route [6]. **(J. Kim et al, 2008),** proposed a fuzzy logic approach in the selection of CHs in WSN (CHEF). The location and residual energy are taken into consideration, to determine the selected list of CHs. CHEF is like LEACH, where clusters are configured at each round. The localized CH selection mechanism are used by CHEF, where the sink is not in need to collect the data directly from all nodes. The simulated case studies show that the results demonstrated using the CHEF protocol outperforms the LEACH by 22.7% [7]. **(A. kadhim and M. Wahhab, 2014)** Proposed two cluster based routing protocol, fixed node environment location based clustering protocol FLCRP and mixed node location based clustering protocol MLCRP. The operation of the proposed protocols also divided into two phased setup phase and steady state phase, the proposed method of this protocols are based on using the energy, location and the distance information in the clustering and routing process [8]. In this paper, an energy efficient algorithm for cluster-head selection is proposed, and so far named as (CHFL-ZRP). It is a hybrid (proactive-reactive) clustering routing protocol, intra-cluster communication, a proactive single-hop and inter-cluster communication, a reactive multi-hop, which considered as a centralized clustering scheme. The selection of cluster head nodes are performed by using the fuzzy logic approach. It is based on three input identifiers: energy, centrality and concentration of each node. Detailed description about the architecture of ZRP and the design and implementation of the proposed protocol will be discussed in the next sections.

3 Zone Routing Protocol (ZRP)

It is a composition of two flat based protocols, proactive and the second is reactive. It uses good characteristics of both protocols. ZRP have been introduced to reduce the overhead control of proactive protocols and minimize the retrieval time produced from path finding in reactive protocols [9]**.** The architecture of the ZRP shown in Fig. (1). It is composed of the following elements:

- Network layer: the existing Protocols are "IP Internet Protocol" and "ICMP Internet Control Message Protocol"
- ZRP Entities are "IARP intra-zone routing protocol, IERP inter-zone routing protocol and BRP border cast resolution protocol".
- Additional protocols are "NDM Neighbor Discovery/Maintenance Protocol".

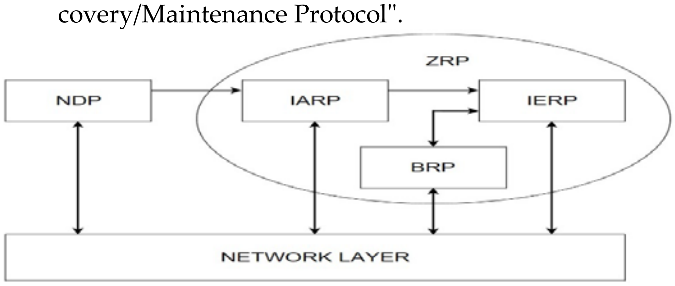

Figure 1: ZRP Architecture [10]

4 Proposed WSN Clustering Protocol

The operation of the CHFL-ZRP, divided into two phases: the first one is the set-up phase (cluster head selection and cluster formation) and the second one is the steady state phase (data gathering phase).

a) Setup phase:

Throughout the setup phase, the cluster-heads are determined by using fuzzy logic approach. Then the clusters, formed accordingly. The BS is responsible for initiating the order of starting the setup phase. A new set up phase initiated according to a cluster head request, when its remaining energy become less than a specified threshold level:

$$ECHth(j)=0.5\times ECHr(j) \qquad (1)$$

Where $ECHr$ represents the current energy remaining in head node j. The setup phase composed of two steps: the first is the head node selection and the second is the cluster formation.

1-Cluster Head Selection using Fuzzy Logic

Initially the square area of the WSN field is divided into (k equal size) clusters. In regards to the density and the layout of nodes in the network, the distribution of the node is made randomly in the field as shown in Fig. (2).

After that all of the nodes start to send its information to the BS represented by:

1- Node's location information: each node is assumed to be capable to find its location by using the GPS

2- The residual energy: each node is capable to determine its residual energy (S_i)

3- Concentration: A "Hello" packet is developed for neighbor discovery on the ZRP agent. The concentration (S_i) is determined at each node based on the neighbor table generated from "Hello" packet as mentioned earlier. It is calculated according to the following developed equation:-

$$CO(S_j)=\frac{n_c(S_j)}{D(S_j)} \qquad (2)$$

$$D(S_j)=\sum_{i=1}^{n_c(S_j)} d_j \qquad (3)$$

$$d_j=\sum_{i=1}^{n_c}\sqrt{\left(x_j-x_i\right)^2+\left(y_j-y_i\right)^2} \qquad (4)$$

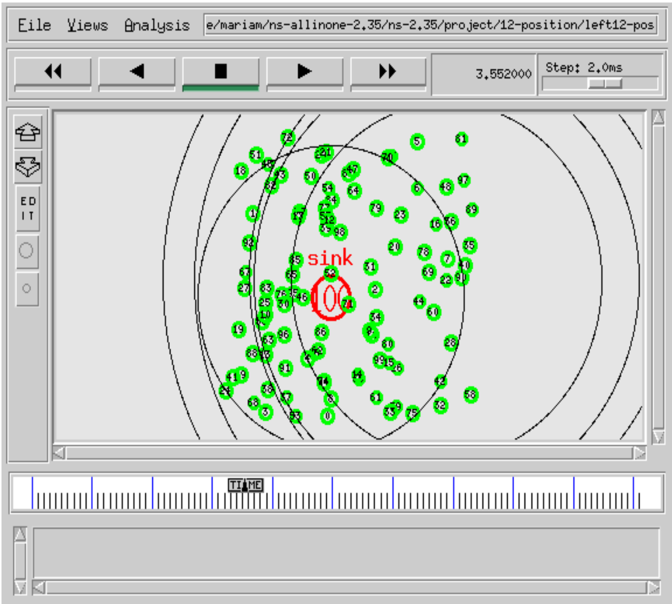

Figure 2: Network Topology and Node Distribution

Fig. (3) Shows the relation for the nominated node (the one to be a cluster head (S_j)) and the other nodes from the neighbor table which are lying within its transmission range (r), n_c indicate the number of nodes inside the cluster *j*.

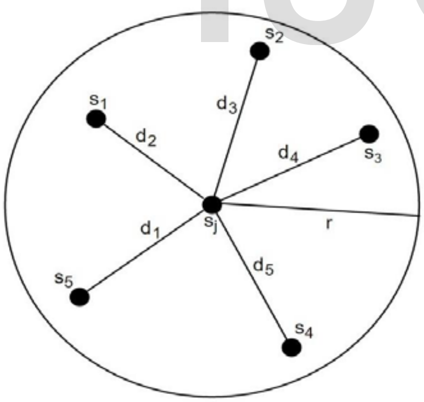

Figure 3: The CH and Other Regular Nodes within its Transmission Range

Whenever the calculated (S_i) is high; this indicate that number of neighbor of the selected node (S_j) are large, hence consuming less energy in transmitting or receiving packets.

4- Centrality of the node: Centrality is calculated for each node as the difference between the location of node (*i*) and the center of the cluster (*j*) of squared distances from other nodes to the candidate node using the following equation:

$$CE(S_i) = \sqrt{\left(x_{c_j} - x_i\right)^2 + \left(y_{c_j} - y_i\right)^2} \quad (5)$$

$$\forall\, i \neq j \text{ where } i = 1, \ldots .n_{c_j}$$
$$j = 1, \ldots ..K$$

Where n_{c_j} represent number of nodes in the cluster and K represent number of clusters. The lower distance means higher value of centrality, resulting in the lower amount of energy required to transmit the data.

After the BS receive the above mentioned information, the fuzzy logic algorithm is started in a centralized manner. Gupta et al, introduced a method to overcome the problems associated with LEACH protocol. Fuzzy logic approach has been successfully applied to a broad scope of applications in various domains [11]. There are mainly two types of a ruled base fuzzy system. One is the Mamdani type FLC, and the other is the Takagi-Sugeno (TS). Structure for the both types are the same, the only difference is related to the definition of the output in the consequent field of the rule base. TS type uses a crisp values for the output in the rule base, where it is a fuzzy linguistic in the case of Mamdani type [12]. This paper uses the most commonly used fuzzy inference technique (Mamdani method) as shown by Fig. (4) the FIS which performs its task in four steps:

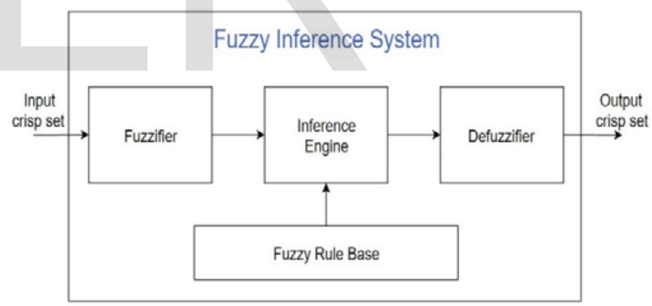

Figure 4: FIS block [12]

Step 1: After the BS received the information packet from all the nodes, the fuzzy system starts predicting the chance of this nodes by applying these crisp values μ_{Er} , μ_{CO} and μ_{CE} in accordance to a defined fuzzy sets assigned to each variable. Three fuzzy variables (energy, concentration and centrality) $(E_r(S_i), CO(S_i)\ \&\ CE(S_i))$ were used for fuzzy if-then rule as in table-1, the type of member- ship functions are chosen to be of triangles form, for simplicity. The "chance" which represent the output is defined by seven membership function for best qualification.

Step 2: Evaluation of the rule base is computed after the fuzzification process (step 1) on the linguistic variables. The generated values of the memberships are passed to the rule base which is represented by table (1).

Step 3: The Rule Outputs aggregation

Aggregation is the process of unification of the outputs of all rules. The aggregation is a step of combining all fuzzy outputs obtained from rule base, then a new fuzzy set is generated for the chance list.

Step 4: Defuzzification

This step combines the consequent (result) of all the fired rules (fuzzy outputs of the rules) into one crisp value. This output is representing the chance for the node (i) to be a CH for the inputs of its concentration, centrality and energy.

Table 1: Fuzzy rule base table [11].

	Energy	Concentration	Centrality	Chance
1	Low	Low	Close	Small
2	Low	Low	Adequate	Small
3	Low	Low	Far	very small
4	Low	Medium	Close	Small
5	Low	Medium	Adequate	Small
6	Low	Medium	Far	Small
7	Low	High	Close	rather small
8	Low	High	adequate	Small
9	Low	High	Far	very small
10	Medium	Low	Close	rather large
11	Medium	Low	adequate	Medium
12	Medium	Low	Far	Small
13	Medium	Medium	Close	Large
14	Medium	Medium	adequate	Medium
15	Medium	Medium	Far	rather small
16	Medium	High	Close	Large
17	Medium	High	adequate	rather large
18	Medium	High	Far	rather small
19	High	Low	Close	rather large
20	High	Low	adequate	Medium
21	High	Low	Far	rather small
22	High	Medium	Close	Large
23	High	Medium	adequate	rather large
24	High	Medium	Far	Medium
25	High	High	Close	very large
26	High	High	Adequate	rather large
27	High	High	Far	Medium

2- Cluster Formation:

After the determination of the CH nodes, the base station announce to the regular nodes to select in which cluster to join as a member of its group. It will select the nearest head node by calculating the distance between itself and the CH list received from the BS node.

b) Steady State Phase:

At this stage all ordinary nodes are triggered by the BS to send their data packet to the appropriate CH. This phase demonstrates the roles of Inter-cluster communication as shown in the flow chart of Fig. (5).

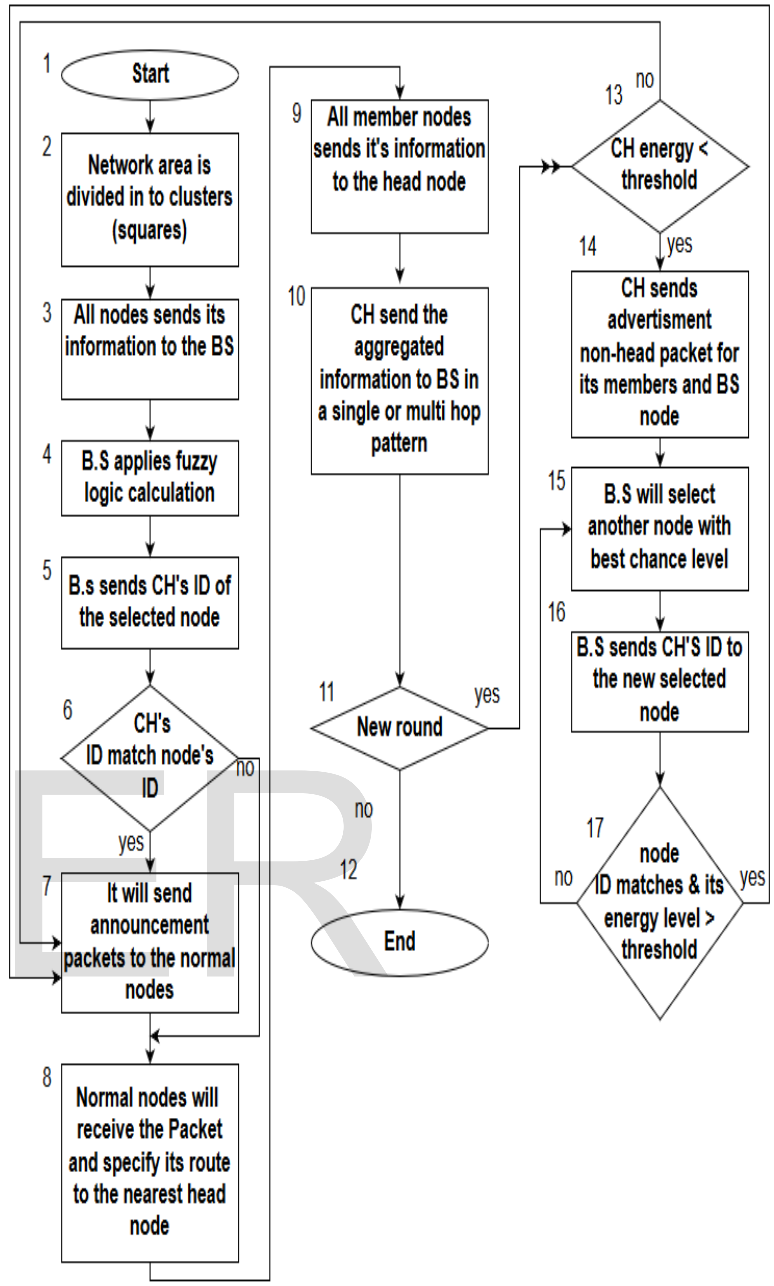

Figure 5: Flow Chart Summarizing CHFL-ZRP Operation

7 Simulation Environment

The simulation study of the proposed protocol has been done on NS-2.35. Fuzzylite library is used to create fuzzy logic algorithm by utilizing object-oriented programming. NS2 and the supported fuzzy library are installed on Linux operating system (Ubuntu 14.04 distribution). The geographical WSN area assumed to be (100*100)m^2. IEEE 802.11 MAC protocol was used in the experiments for the MAC layer. The BS is fixed throughout the overall simulation time. The type of antenna in all nodes is assumed to be Omni directional antenna. The energy model is considered to be battery model.

7.1 Performance evaluation and analysis

The proposed protocol are compared with LEACH, LECAH-C, CHEF and LEACH-ERE. The simulation parameters changed to be as in [13] for the fair of comparison as shown in table (2).

Table 2: Simulation Parameters for the CHFL-ZRP comparison

Parameters	Values
Simulations area	100*100 m^2
Proposed protocol	CHFL-ZRP (Fixed nodes & Fixed BS)
Initial energy of nodes	2J
Number of nodes	100
Bit rate	1 Mb/sec
Packet length	500 Byte

The comparison done based on the following metrics:

1- HND (Half Nodes to Die): Fig. (6) Shows the half number of alive node per round. The result shows that the proposed protocol outperforms the other protocols, whereas the distance between cluster-head and BS decreases, energy dissipation also decreases so the emergence of the HND delayed.

2- Number of Alive Nodes: Fig. (7) Shows a trajectory comparison of alive node with time. The figure shows that the proposed protocol is more stable than the others because of the delay in the appearance of the first death node as compared to LEACH, LEACH-C, LEACH-ERE and CHEF.

3-Average End to End Delay:

Fig. (8) Shows that the average end to end delay of CHFL-ZRP is smaller than LEACH and LEACH-C protocols due to the additional overhead needed in the cluster formation of LEACH and LEACH-C. While in LEACH-C the average end to end delay is more stable than LEACH because BS selects the CHs in case of LEACH-C.

5-Average Throughput: Fig. (9) Shows that the average throughput of the proposed protocol at the beginning of the simulation is high, then it begins to fall because of the traffic load increment, the average throughput of LEACH-C outperforms LEACH. In LEACH and LEACH-C the nearest nodes to BS are not loaded because the CHs nodes communicated directly to BS in a single Hope pattern so the average throughput is almost fixed.

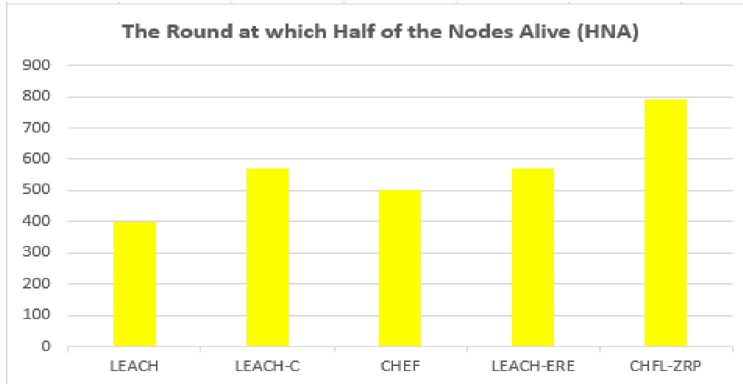

Figure 6: Half of Alive Nodes per Round for each Clustering Approaches.

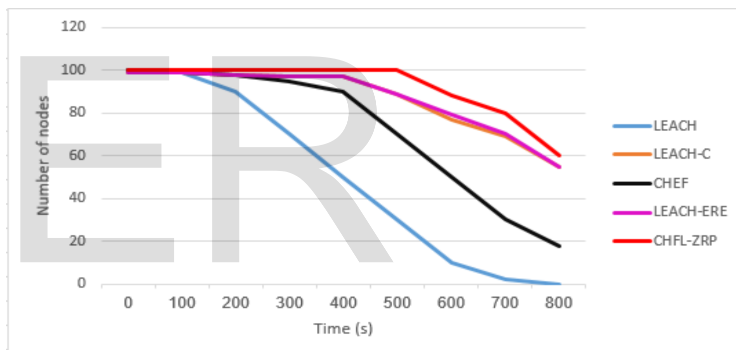

Figure 7: Trajectory of Alive Sensor Nodes Per Round

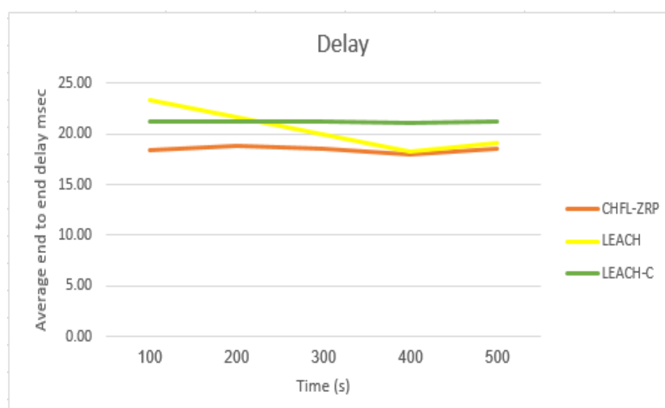

Figure 8: Average End to End Delay

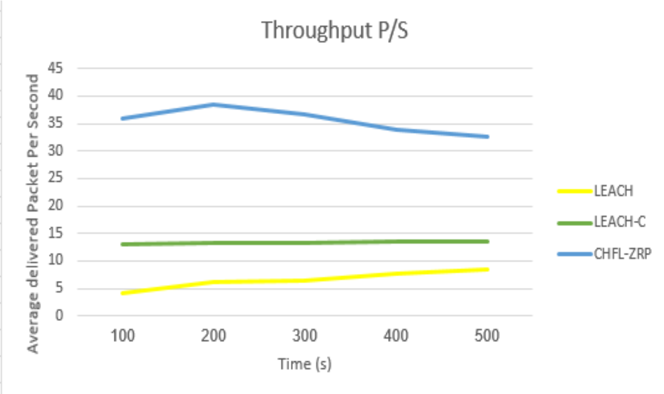

Figure 9: Average Throughput

Conclusion

A new WSN energy efficient clustering protocol is proposed in this study. The objective of this study is to design an efficient cluster head selection mechanism, this is accomplished by incorporating the fuzzy logic algorithm using different node features (energy level of the nodes, centrality of the nodes and the density of the sensor nodes around the elected node). The designed CHFL-ZRP enhance the reduction of the average energy consumption as compared with other protocols, further more ZRP is enhanced to work as a cluster based routing protocol by implementing the efficient fuzzy logic algorithm for cluster head selection because it is considered as a flat based routing protocol. It is considered as a centralized protocol because of the use of a central control in the base station, which has sufficient power, memory and storage capacity, thus, we overcame the limitations of resource restriction at each node. CHFL-ZRP uses single-hop intra cluster communication between the CH and its members and multi-hop inter cluster communication so it reduces the transmission range among CHs with the BS node. The designed protocol outperforms the LEACH, LEACH-C, LEACH-ERE and CHEF protocols in term of network lifetime and HDN.

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