K-LEACH: An improved LEACH Protocol for Lifetime Improvement in WSN

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***Abstract*— A Wireless Sensor Network is the collection of large number of sensor nodes, which are technically or economically feasible and measure the ambient condition in the environment surrounding them. The difference between usual wireless networks and WSNs is that sensors are sensitive to energy consumption. Energy saving is the crucial issue in designing the wireless sensor networks. In this paper, a modified algorithm for Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is proposed. The modified protocol called "Kmedoids-LEACH protocol (K-LEACH) for clustered WSN" is aimed at prolonging the lifetime of the sensor networks by balancing the energy consumption of the nodes. The proposed protocol uses the k-medoids clustering algorithm for uniform clustering and Euclidean distance and maximum residual energy (MRE) is used to select the cluster head (CH). The performance of K-LEACH with that of the LEACH protocol is compared using simulations. Simulation result shows that K-LEACH improves the network lifespan over LEACH.**

***Keywords*— LEACH, Wireless sensor network, Routing protocols, K-LEACH**

I. INTRODUCTION

A sensor network is defined as being composed of a large number of nodes with sensing, processing and communication facilities which are deployed either inside the phenomenon or very close to it. Each of these nodes collects data and route the information back to a sink [5]. In Current years, Wireless sensor networks becomes the furthermost exciting networking technologies to offer the sensed collected data to the base station with restricted power ability . Sensor nodes are battery driven devices with restricted energy resources. Once installed, the minor sensor nodes are usually unapproachable to the operator, and thus auxiliary of the energy source is not practicable. Stretching network lifespan for these nodes is a vital issue [7].

Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar. Applications of the WSNs include to monitor a wide variety of ambient conditions like temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, In Military for target field imaging, Earth Monitoring, Disaster management. Fire alarm sensors, Sensors planted underground for precision agriculture, intrusion detection and criminal hunting [5].

In general, routing in WSNs can be divided into *flat-based* routing (*data-centric* routing), *hierarchical-based* routing, and *location-based* routing depending on the network structure. In hierarchical-based routing, nodes will play different roles in the network. The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster. Here data aggregation and fusion is performed in order to decrease the number of transmitted messages to the sink. Here all nodes get a chance to become cluster head for the cluster period [2]. LEACH is one of the widely used dynamic clustering hierarchical routing protocol for sensors networks [2]. In the following section, we will describe LEACH protocol and it's shortcomings. To avoid the shortcomings of LEACH protocol here new K-LEACH protocol is proposed to reduce average energy consumption of network and enhance the network lifetime which ensures high availability of sensor nodes and so high reliability of data transmission to sink node which ultimately makes the entire network reliable.

II . RELATED WORK

Here a brief overview of LEACH protocol and it's advantages and shortcomings are described.

A. *Low-Energy Adaptive Clustering Hierarchy (LEACH)*

W.R.Heinzelman, [1] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Cluster Hierarchy – protocol (LEACH). It is one of the most popular hierarchical routing algorithm [11]. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads (CHs) as routers to the sink. This will save energy since the transmissions will only be done by CHs rather than all sensor nodes. Optimal number of CHs is estimated to be 5% of the total number of nodes [1]. All the data processing such as data fusion and aggregation are local to the cluster. CHs change randomly over time in order to balance the energy dissipation of nodes. This decision

is made by the node by choosing a random number between 0 and 1. The node becomes a CH for the current round if the number is less than the following threshold:

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

where p is the desired percentage of CHs , r is = the current round, and G is the set of nodes that have not been selected as cluster heads in the last 1/p rounds [1]. The nodes die randomly and dynamic clustering increases lifetime of the system. Fig.1, redrawn from [3] shows the clustering in LEACH protocol.

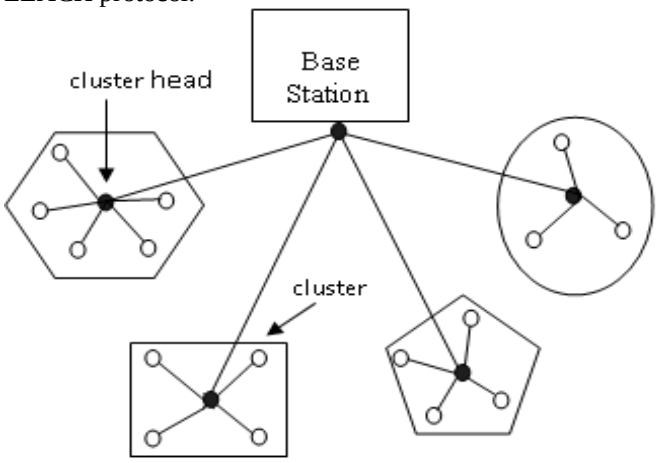

Fig.1 : Clustering in LEACH

LEACH protocol provides a conception of round. LEACH protocol runs with many rounds. Each round contains two states: cluster setup state and Steady state. In cluster setup state, it forms clusters and select CHs, in steady state, it transfers data. The time of second state is usually longer than the time of first state to minimize the overhead. LEACH is based on rounds & system repeats clustering & transmission for each round.

There are two phases of the round [1] [3] :
(1) Set-up phase:

- Based on T(n), threshold , CHs are selected
- All CHs broadcast ADV message to all non-CH nodes
- All non-CH nodes select their CHs, based on RSSI of ADV message
- After selecting cluster, it (non-CH node) sends Join-REQ back to CH Now, CHs create TDMA schedule & send it to the all non-CH nodes

(2) Steady-state phase:

- Sensor nodes begin sensing & transmitting data to CHs as per their TDMA Schedule
- After receiving data, CHs aggregates data to the BS in one-hop manner, thus reducing the no. of transmissions & hence saving energy
- After certain time, N/W goes back to set-up phase again & enters another round
- Each cluster communication, using different CDMA codes to reduce the interference from other cluster nodes

B. *Advantages of LEACH Protocol [1]:*

(1) LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication and a factor of 4-8 compared to the minimum transmission energy routing protocol
(2) The nodes die randomly and dynamic clustering increases lifetime of the system
(3) LEACH is completely distributed and requires no global knowledge of network

C. *Shortcomings of LEACH Protocol [1] [10] [13]:*

(1) It assumes that nodes always have data to send & the nodes including CH are started with the same initial energy
(2) No. of CHs are predefined i.e. 5% or 10% of total nodes. It might not be sufficient to cover entire area when sensor nodes are not uniformly distributed
(3) The CHs are randomly selected rotationally and Residual Energy of the node is not considered for cluster formation
(4) CHs in the network are not uniformly distributed, so sometimes elected CHs will be concentrated in one part of n/w, hence some nodes in the n/w will not have any CH in their vicinity, so it not provides proper location of CH
(5) CHs send aggregated data to BS in single hop manner so LEACH is not applicable to networks deployed in large regions
(6) It consist of rounds while in each round, all sensor nodes take part in reconstructing new clusters and this action consumes a lot of energy.

There are several updated variants of LEACH like E-LEACH, LEACH-C,TL-LEACH, M-LEACH, V-LEACH etc. For details of these protocols , refer [3][10].

LEACH-Centralized (LEACH-C) uses a centralized clustering algorithm and same steady-state protocol. During the set-up phase of LEACH-C, each node sends information about current location and energy level to base station (BS) [3] [7]. The BS will determine clusters, CH and non-CHs of each cluster. The BS utilizes its global information of the network to produce better clusters that require less energy for data transmission.

As long as optimal energy consumption is concerned, it is not desirable to select a cluster head node randomly and construct clusters. The main problem of LEACH is that residual energy of a node is not considered for cluster formation and so clusters are not formed uniformly. The proposed protocol overcomes these shortcomings by uniform clustering and proper CH selection. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols [12].

III. PROBLEM IDENTIFICATION AND WORK DONE

The objective of this section is to propose the improved routing technique that is used to form most appropriate clustering and selection of cluster heads, which reduces average energy consumption and enhance the network lifetime by balancing load of network among all active participant sensor nodes.

The Limitations of LEACH protocol and the key ideas of proposed technique are as follows:

(1) The proposed protocol K-LEACH uses the *K*-medoids clustering algorithm to obtain highly uniform clustering of nodes and very good choices of cluster heads and it is a very well known fact that energy retention of a WSN is highly dependent on the grouping or clustering of transmitting and receiving nodes. In LEACH protocol, however, cluster formation is random and this may lead to non-uniform cluster sizes as well as poor formation of clusters. Some clusters may have more nodes and some may have very few nodes.

(2) K-LEACH considers least distant from the center of cluster as a criterion for a node to be chosen as a cluster head (CH) during cluster head selection procedure (from second round onwards), whereas LEACH protocol does random selection of CHs, this again may lead to poor to very poor selection of CHs which will consequently lead to highly inefficient energy retention by the network.

The K-LEACH protocol improves the clustering and cluster head selection procedure. For the first round of communication, in setup phase we use the K-medoids algorithm for cluster formation, which ensures uniform clustering. The cluster formation by Kmedoids algorithm ensures best clustering and selection of cluster head using Euclidian distance at the nearer or at the center of cluster always gives most energy efficient solution in WSN. From second round onwards cluster heads are selected based on the next nearest node to the first round cluster head and so on. We have applied clustering till the smallest cluster nodes are not considered. Then we have applied MRE till we get unique cluster heads, but as soon as we get duplicate cluster heads due to dynamic clustering we switch to random selection of cluster head nodes from amongst the alive nodes.

K-LEACH is divided into many rounds, and each round contains *cluster formation phase* and *Steady state phase.*

Cluster formation phase:

(1) For the first round clusters are formed using *K*-medoids cluster formation algorithm and cluster heads are selected as a node which lies at the center or nearer to the center of cluster using Euclidian distance. For rest of the rounds nodes nearest to the cluster head of the first round selection is chosen as cluster head.
(2) Some nodes that turn into cluster heads as per above conditions send their cluster head announcement information to inform other nodes. The other nodes turn up as non cluster head nodes send cluster joining information to cluster head.
(3) Cluster heads prepare their TDMA schedule.

Steady state phase:

(1) Nodes in a cluster, sends their data according to TDMA schedule, and cluster head receives, and aggregates the data.
(2) The cluster heads will send their data directly to the base station.

This way the limitation of random clustering of LEACH protocol is addressed by uniform clustering to balance the load of entire network among all the nodes.

A. *RADIO ENERGY DISSIPATION MODEL*

The following Radio Energy Dissipation Model is used by the LEACH protocol as well as by the Proposed Technique. In this model, the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics. Thus, to transmit *k*-bit message a distance *d*, the radio expends [1][4][6]:

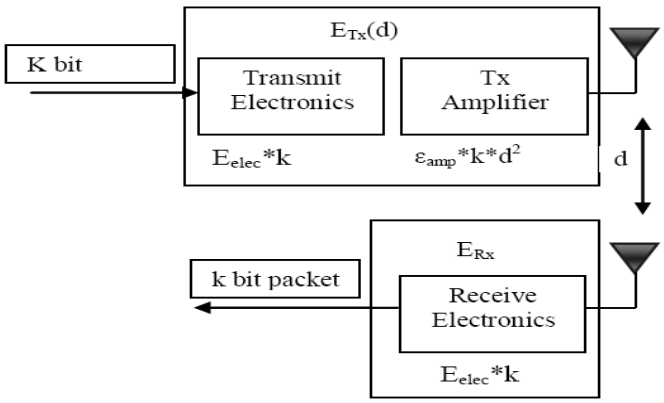

Fig. 2: Radio energy dissipation model

$$E_{Tx}(k,d) = E_{Tx\text{-}elec}(k) + E_{Tx\text{-}amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec}*k + \epsilon_{amp}*k*d^2 \quad (2)$$

And to receive this message, the radio expands:

$E_{Rx}(k) = E_{Rx\text{-}elec}(k)$

$E_{Rx}(k) = E_{elec}*k$ (3)

B. SYSTEM MODEL

There are several assumptions that are considered in LEACH protocol, so we will also focus on these assumptions in our proposed technique [4][6][8]:

(1) The base station (sink node) is located far away from the sensing field.
(2) Nodes are location-aware, i.e. equipped with GPS capable antennae.
(3) The communication channel is symmetric.
(4) Nodes are left unattended after deployment. So, battery re-charge is not possible.
(5) All the nodes are homogeneous and no mobility of sensor node.

IV. SIMULATION AND RESULTS

Here the simulation is performed in MATLAB and have collected the outputs after specific number of rounds. The same simulation parameters are used for both LEACH and K-LEACH to simulate it. The simulation parameters and the results of simulation are shown below. We ignore the effect caused by signal collision and interference in the wireless channel and the radio parameters used are shown in Table-1.

TABLE I

SIMULATION PARAMETERS

Parameter Name	Value
Network area	100 m X 100 m
No. of nodes	100
No. of clusters	05
No. of rounds	35
Initial Energy	0.00004 joule
Sink location	(x=150m,y=150m)
Data Aggregation Consumption	1.5E-12 joule
Transmission Consumption per bit ($E_{Tx\text{-}amp}$)	1.0E-12 joule
Transmitter circuit consumption ($E_{Tx\text{-}elec}$)	6.0E-08 joule
Receiver circuit consumption ($E_{Rx\text{-}elec}$)	4.0E-08 joule
Receiver consumption per bit ($E_{Rx\text{-}recv}$)	1.0E-12 joule
Data packet size	10 bytes

In the simulation, we compared the performance of our proposed K-LEACH algorithm and with LEACH protocol in under the continuous delivery model. Our performance metrics are total residual energy per round in the network and total network lifetime, means number of alive nodes per round. Network lifetime is the number of round from the start of operation until the death of the last alive node. The network connectivity which depends on the time of the first node failure is a meaningful measurement in the sense that a single node failure can make the network partitioned and further services be interrupted. This performance metric is called "Length of stable region". Stability period is the period from the start of the network operation and to the first dead node. We also refer to this period as "stable region." When a sensor node is depleted of energy, it will die and be disconnected from the network which may impact the performance of the application significantly. The energy consumption due to communication will be calculated using the first order energy model. We assume that each sensor node generates one data packet per time unit to be transmitted to the BS. For simplicity, we refer to each time unit as a round.

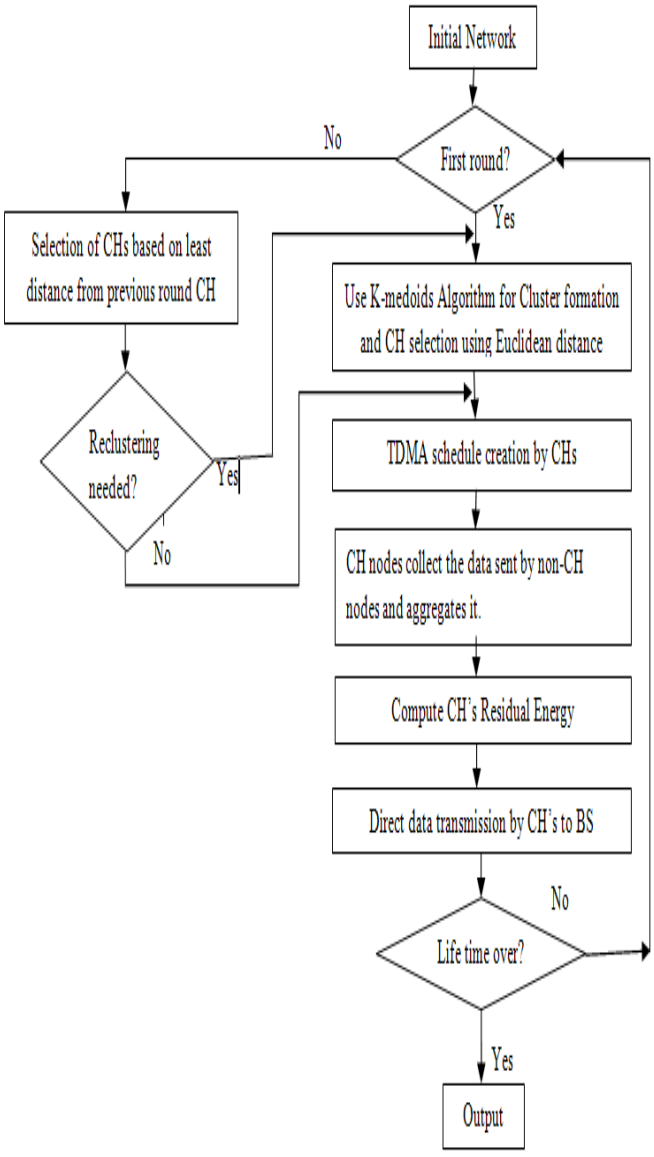

Fig. 3: Proposed (K-LEACH) Protocol Flowchart

Following fig.4 shows the clustering after 1st round for K-LEACH. When the nodes start with the same initial energy and the total number of nodes in a network is 100, the number

of dead nodes per round for both LEACH and K-LEACH is shown in Fig.5. It shows that the total network lifetime of our algorithm is longer than that of LEACH. During most of the network lifetime, K-LEACH runs with much more living nodes than LEACH. Table-2 shows the improvement of K-LEACH compared to LEACH.

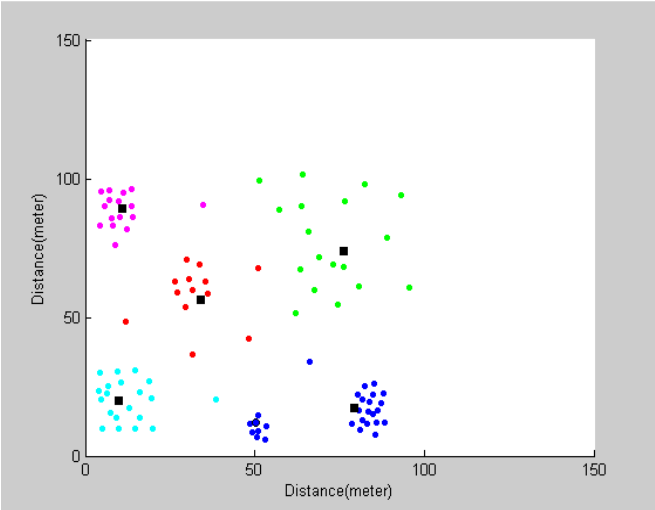

Fig. 4: Clustering in (K-LEACH) Protocol after 1st round, with 100 nodes random topology for 150m*150m network. Black square nodes represents the cluster heads(CHs)

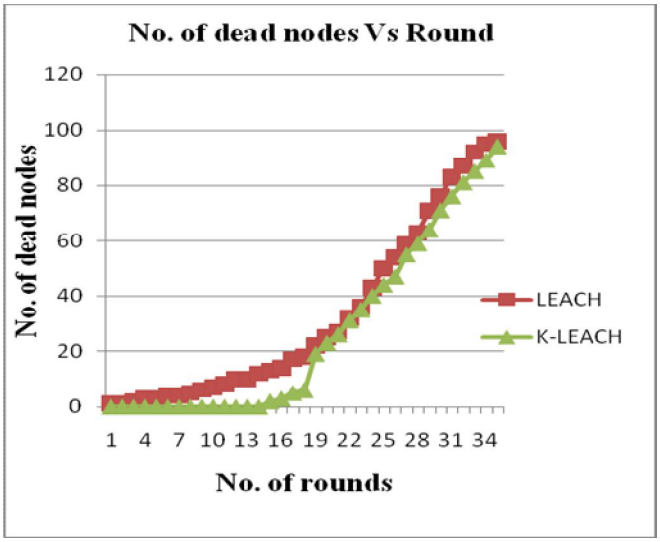

Fig. 5: Number of dead nodes per round for both LEACH and K-LEACH

Table 2 shows that the nodes are started to die in LEACH from the initial few rounds whereas in K-LEACH, 1st node died at round 15 that is after almost 50% of the network lifetime. Fig.6 shows this comparison in terms of FND, HND and LND. Average energy consumption of K-LEACH is almost similar to that of LEACH protocol. Fig. 7 shows the energy retention after each round for both LEACH and K-LEACH.

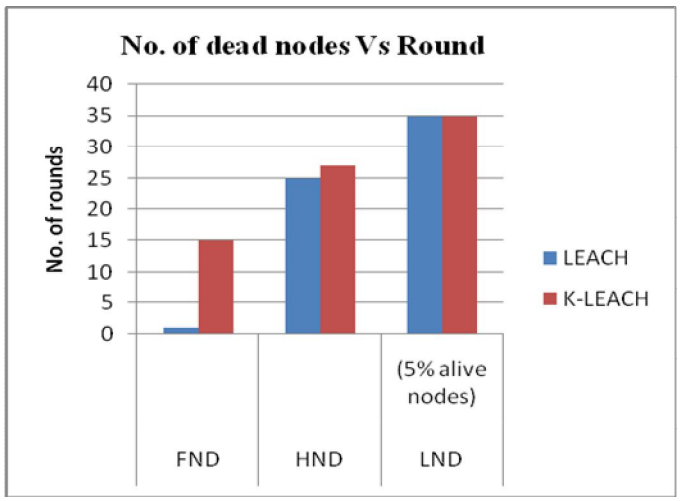

Fig. 6: Comparison of LEACH and K-LEACH results

TABLE II

IMPROVEMENT OF K-LEACH COMPARED TO LEACH

Protocol	FND(First node dies)	HND(Half nodes die)	LND (Last node dies)/ (5% alive node)
LEACH	1	25	35
K-LEACH	15	27	35
Improvement	**41.17%**	**5.88%**	**0%**

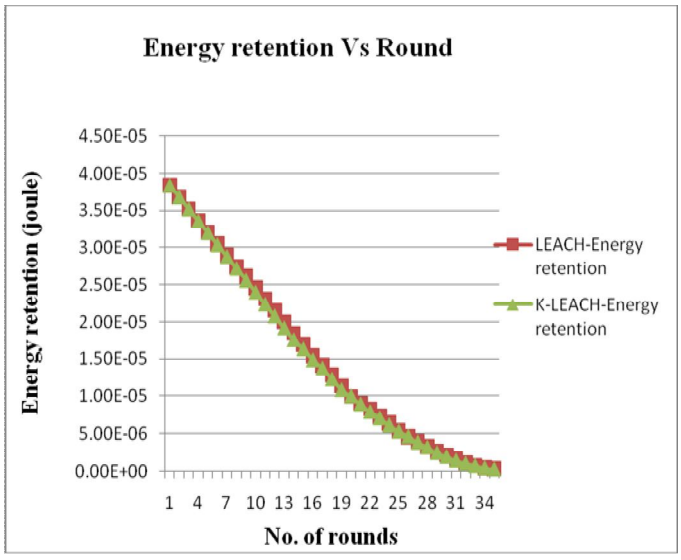

Fig. 7: Energy retention after each round in LEACH and K-LEACH

From our simulations, K-LEACH protocol has the following advantages:

- The stability period of the K-LEACH is prolonged than LEACH.
- The instability period is shortened for K-LEACH compared to LEACH.
- By uniform clustering and distance data structure load is balanced among all the active participant nodes of the network so energy dissipation is also balanced so lifetime is increased as compared to LEACH protocol.

To sum up, in our simulation we obtained a prolonged stability period and a reduction in the instability region in the network lifetime.

V. CONCLUSIONS

Wireless sensor networks are increasingly being used for health care, transportation, manufacturing, and much more. Routing in sensor networks is an emerging area of research. In this paper we present an improved version of LEACH protocol, K-LEACH, to extend the lifetime of a sensor network by uniform clustering through k-medoids algorithm and balancing the load of entire network among all active nodes. It ensures uniform clustering of nodes and gives proper location of CH. It uses the combination of clustering, maximum residual energy criterion and a random selection of CHs only after almost 50% of rounds of operations of the network gets over, whereas the LEACH protocol does totally random selection of CHs, which leads to very poor selection of CHs and thus leads to highly inefficient lifetime and energy retention by the network. The simulation results show that the proposed algorithm can maintain a balanced energy consumption distribution among nodes in a sensor network and thus prolong the network lifetime.

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