Zone Based Routing Protocol for Homogeneous Wireless Sensor Network

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Abstract:

Wireless Sensor Networks, are made of low-cost, low-power, small in size, and multifunctional sensor nodes. The efficient energy utilization is one of the important performance factors for wireless sensor networks survivability be-cause nodes operate with limited battery power. In this paper we propose and analyze a new approach of zone based clustering head selection algorithm for wireless sensor network of homogeneous nodes. Nodes in the network are uniformly distributed. In this clustering algorithm, network performance is improved by selecting cluster heads on the basis of the residual energy of existing cluster heads, and nearest hop distance of the node. In this paper we evaluate various performance metrics like energy consumption, network life time, number of channel heads metrics in each round and compare these with respect to random algorithm i.e. LEACH. We conclude that proposed protocol effectively extends the network lifetime without degrading the other critical overheads and perform-ance metrics.

Keyword:

Wireless Sensor network, Zone, Clustering Algorithm, Residual Energy.

1 . Introduction

A sensor network consists of a large number of very small nodes that are deployed in some geographical area. The purpose of the network is to sense the environment and report what is happening in the area in which it is deployed. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of wireless sensor networks [1]. Due to recent technological advances, the manufacturing of small and low cost sensors became technically and economically feasible. The sensing electronics measure ambient conditions related to the environ-ment surrounding the sensor and transform them into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor [2]. Sensors have the ability to communicate either among each other or directly to an external base-station. A greater number of sensors allows for sensing over larger geographical regions with greater accuracy. Each sensor node comprises sensing, processing, transmission, mobilization, position finding sys-tem, and power units. Despite the innumerable applications of WSNs, these networks have several restrictions, e.g., limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes.

The main constraint in designing a routing protocol in WSNs is limited power of sensor nodes that mandates the design of energy-efficient communication protocol. There are many protocols proposed for other wireless networks like mobile or ad-hoc. How-ever, these protocols cannot be used directly due to resource constraints of sensor nodes like limited battery power, computational speed, and human interface of node device and density of nodes in network. Much research has been done in recent years, but even after many efforts, there are still many design options open for improvement. Thus, there is a need of a new protocol scheme, which enables more efficient use of energy at individual sensor nodes to enhance the network survivability. In this paper, we analyze energy efficient homogeneous clustering head selection algorithm for WSN. We first describe the protocol and then we provide simulation results in MATLAB [9] and determine performance analysis of given protocol compared with benchmark clustering algorithm LEACH.

The paper is organized as follows. Section 2 summarizes the related previous works Section 3 discusses the basic radio energy model. Section 4 describes the proposed homogeneous clustering algorithm. Simulation results are presented in section 5 .Comparisons with random LEACH algorithm in section 6. Conclusions and suggestions for future work are given in section 6.

2 . Related Work

Routing is a process of determining a path between source and destination upon re-quest of data transmission. A variety of protocols have been proposed to enhance the life of WSN and for routing the correct data to the base station. Battery power of individual sensor nodes is a precious resource in the WSN [3]. For example, the power consumed by a Berkeley mote to transmit 1-bit of data is equivalent to the computation of 800m instructions. When the battery power at a sensor node expires, the node is called as a dead node and the sensor node discontinues its operations in the network.

In general, routing in WSN can be divided into **flat-based routing, hierarchical-based routing, and location-based[10]** routing depending on the network structure. In flat-based routing, all nodes are typically assigned equal roles or functionality. In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes positions are exploited to route data in the net-work.

Hierarchical routing performs energy-efficient routing in WSN, and contributes to overall system scalability and lifetime. In a hierarchical architecture, sensors organize themselves into clusters and each cluster has a cluster head, i.e. sensor nodes form clusters where the low energy nodes are used to perform the sensing in the proximity of the phenomenon. For the cluster based wireless sensor network, the cluster information and Cluster Head (CH) selection are the basic issues. The cluster head coordinates the communication among the cluster members and manages their data [11].

According to the manner the data are collected, cluster based WSNs are classified into three broad categories namely (i) homogeneous sensor networks, (ii) heterogeneous sensor network , (iii) hybrid sensor network.

(i) In the homogeneous sensor networks, all the sensor nodes and base stations are identical in terms of hardware capability and initial battery power. In this method, the static clustering elects cluster heads (CH) only once for the entire lifetime of the net-work. This results in overload on

cluster heads. As proposed in LEACH [4], the role of cluster heads is randomly and periodically rotated over all the nodes to ensure the same rate of dissipation of battery power for all the sensor nodes.

(ii) Heterogeneous sensor networks, has two or more different types of sensor nodes with different hardware capabilities and battery power are used. The sensor nodes with higher hardware capabilities and more battery power compared to other sensor nodes act as cluster heads and perform as a normal sensor node.

(iii) In hybrid sensor networks several mobile base stations work cooperatively to provide fast data gathering in a real-time manner.

Low-energy adaptive clustering hierarchy (LEACH) is a popular energy-efficient adaptive clustering algorithm that forms node clusters based on the received signal strength and uses these local cluster heads as routers to the base station [7]. LEACH is an application-specific data dissemination protocol that uses clusters to prolong the life of the wireless sensor network. LEACH utilizes randomized rotation of local cluster heads to evenly distribute the energy load among the sensors in the network [4]. LEACH uses three techniques namely (i) randomized rotation of the cluster heads and corresponding clusters, (ii) localized coordination and control for cluster set-up and operation, and (iii) local compression to reduce global communication. LEACH clustering terminates in a finite number of iteration, but does not guarantee good cluster head distribution and assumes uniform energy consumption for cluster heads.

The author in [8] has proposed a theoretical model for energy efficient routing in homogeneous sensor network but did not implement and evaluate the performance of the protocol in any simulator. In this study we consider the impact of the model and its behavior with respect to benchmark LEACH protocol. Our paper has highlighted the practical implementation of protocol in MATLAB and determines various performance metrics like energy consumption, network lifetime, number of cluster heads in each round.

3 . Network and Energy Consumption Model

We assume that the energy consumption of the sensor is due to data transmission and reception. Cluster head consume energy for the data aggregation before it sends the data to BS. We use the same radio model as stated in [4] and shown in Figure 1, using this model the energy consumed in transmitting one message of size k bits over a transmission distance d, is given by

$$E_{Tx}(k,d) = k(E_{elec} + \epsilon_{AMP}d^\gamma) = E_{elec}k + k\epsilon_{AMP}d^\gamma,$$

where   k=length of the message,
         d=transmission distance between transmitter and receiver, E_{elec}= electronic energy,
         ϵ_{AMP} =transmitter amplifier, γ = Path Loss
         ($2 <= \gamma <= 4$),
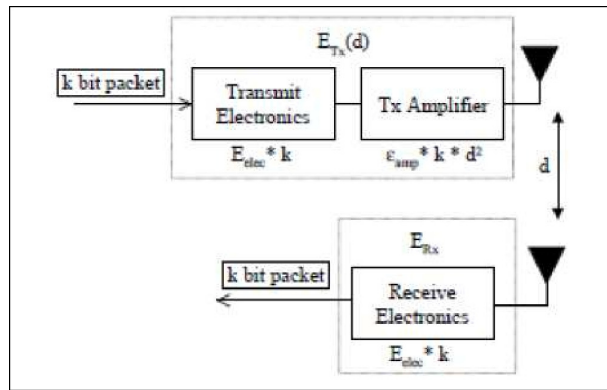Also, the energy consumed in the message reception is given by

$$E_{rx} = E_{elec}k,$$

Figure 1: Energy Model for algorithm

4. The Proposed Homogeneous Clustering Algorithm [8]

4.1 Basic assumptions for the clustering algorithm

- Number of nodes in network are 100.
- The base station (BS) is located outside the deployed area and fixed.
- All nodes can send data to BS.
- The BS has the information about the location of each node.
- Data compression is done by the Cluster Head.
- Data Compression energy is different from the reception and transmission.
- In the first round, each node has a probability p of becoming the cluster head.
- A node, which has become cluster head, shall be eligible to become cluster head after 1-$1/p$ rounds.
- All nodes are of same specification.
- All nodes in the network are having the same energy at starting point and having maximum energy.
- All nodes consume same energy for transmission and reception.
- Energy of transmission depends on the distance (source to destination) and data size.
- Nodes are uniformly distributed in network.

4.2 Proposed Algorithm

The proposed algorithm works in round. Each round has the setup and transmission phase.

Setup phase:

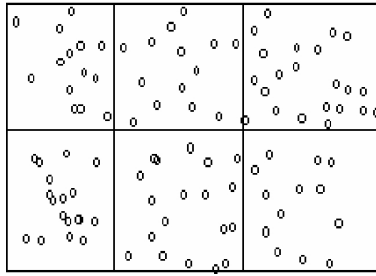1. Network is virtually divided in grid of 6 rectangles

Figure 2: Homogeneous Network with 100 nodes

2. All nodes send data to BS about their location.
3.   Nodes belonging to a rectangle create a group called pre-cluster.
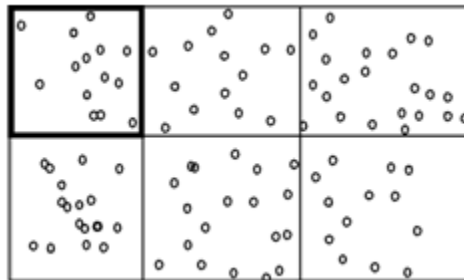

Figure 3:Precluster

4. A random node from the pre-cluster is selected as cluster head.
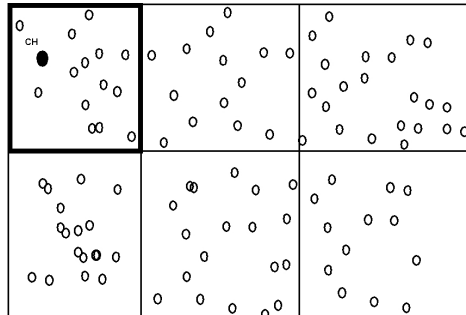

Figure 4: Cluster head

5. Selected cluster head sends advertisement of their cluster as joining request to all other nodes in   the network
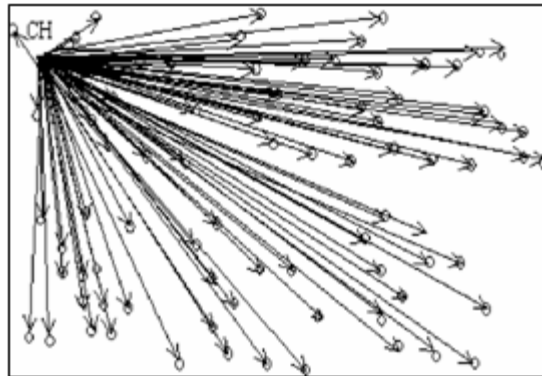
Figure 5: Selected cluster head send JOIN request to all other node in network

6. On the basis of the distance the nodes select one cluster head, which is most near to it.
7. The nodes send confirmation by **ACK** to cluster head. And final cluster formation is done.
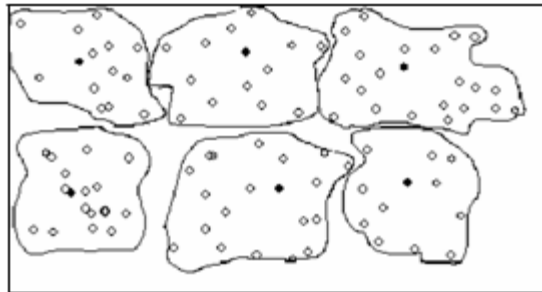

Figure6: Final Cluster formation

8. The node of a pre-cluster may lie in another final cluster.

Transmission Phase:

Nodes send the sensed data to the Cluster Head and CH performs aggregation and compression on data and sends it to Base Station.

New Cluster Head (CH) Formation

New CH is selected by checking the residual energy of cluster head. If the energy of the current CH is less then threshold level, new CH is selected . New CH is to be selected depending on the following criteria:

- A node has not become a CH for the past (1-*1/p*) round.
- The node is having the maximum residual energy in the cluster.
- The node, which is nearest to existing cluster head in cluster.

5 .Performance Evaluations

The performance analysis of above routing protocol is evaluated with the MATLAB. Then the protocol is compared to the LEACH algorithm (in which cluster selection is done by random

selection) in terms of the network lifetime.

5.1 Simulation Parameter

Table 1: Simulation Parameters

Parameter	Values
Simulation Round	3000
Topology Size	200 X 200
Number of nodes	100
CH probability	0.5
Initial node power	0.5 Joule
Nodes Distribution	Nodes are uniformly distributed
BS position	Located at (100,250)
Energy for Transmission (ETX)	50*0.000000001 Joule
Energy for Reception (ERX)	50*0.000000001 Joule
Energy for DataAggregation (EDA)	5*0.000000001 Joule

5.2 Simulation Result

1. **Energy Consumption**: -We simulated the proposed and random algorithm (LEACH) for 10 times and determined the cluster with the maximum number of nodes. We calculated the energy for the control packet size (ctrPacketLength) of 100 bytes.

   Power consumption in random selection method for cluster head is

   $E_{consume}$=Energy for the reception of data for all nodes in cluster
   + Send the CH information to Base station.
   =(ERX*ctrPacketLength *N)
   + EDA
   + (ETX *ctrPacketLength+Emp*ctrPacketLength)

(* Is path loss and we consider the same path loss for all the nodes. Path Loss can be in the range 2 to 4) (In the simulation we assumed path loss as 3.)

Table2: Simulation result

| No. of Simulation run	Max. no. of nodes in proposed algorithm	Max. no. of nodes in Leach	Energy consumed in Leach in J/mS	Energy consumed in proposed algorithm in J/mS
1	25	50	25.50050001	13.00050001
2	27	46	23.50050001	14.00050001
3	24	38	19.50050001	12.50050001
4	23	29	15.00050001	12.00050001
5	21	37	19.00050001	11.00050001
6	22	30	15.50050001	11.50050001
7	27	32	16.50050001	14.00050001
8	24	39	20.00050001	12.50050001
9	26	35	18.00050001	13.50050001
10	24	42	21.50050001	12.50050001
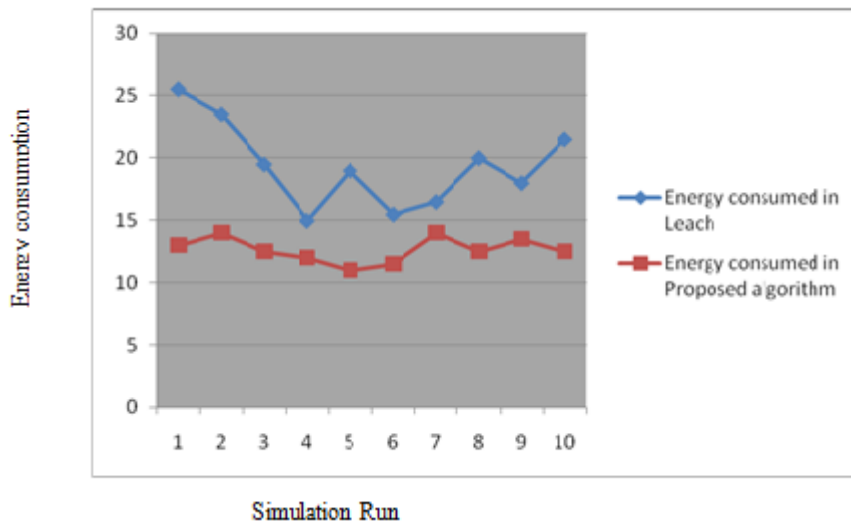
Figure7: Energy consumption of nodes for cluster selection.

2. **Network Life Time**: -

   When first node is nead:- In the random selection method cluster head selection in each round is done on the basis of 1/p, but not on the basis of residual energy.

   The cluster head is determined by the following function: -

$$T(n) = \begin{cases} \dfrac{P_t}{1 - P_t.(r.\bmod\ i/P_t)^2} & \text{if } n \in G \\[2em] 0, & \text{Otherwise} \end{cases}$$

Where Pt is the desired percentage of cluster heads, r is the current round number; G is the set of nodes that have not been cluster-heads in the last 1/Pt rounds.

When a node is dead in the network it will not be the part of the network. It shows that if a dead node occurs in early rounds of the algorithm, this may affect lifespan of the network or drag towards the early dead of all nodes.

Table3: Network Life Time (first dead node)

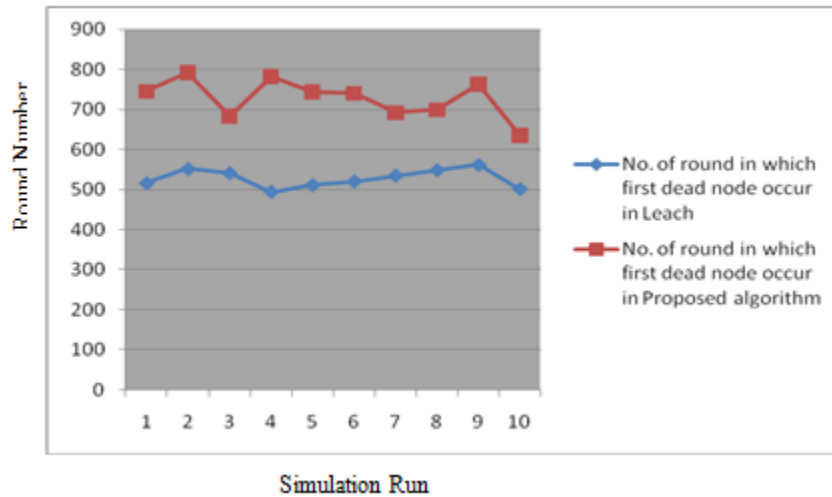| No. of simulation	No. of round in which first dead node occur in Leach	No. of round in which first dead node occur in proposed algorithm
1	*516*	745
2	*552*	792
3	*541*	683
4	*494*	782
5	*511*	743
6	*520*	740
7	*535*	692
8	*549*	699
9	*562*	763
10	*501*	635

Figure8: Network Life Time(first dead node)

When entire nodes get dead :-Similarly when all nodes are dead in the network, the lifespan of network is over. That is , lesser the round number when all nodes are found dead, lesser is the network lifespan. Hence the round number in which all nodes are found dead is the last round.

Table4: Network Life Time(all nodes dead)

No. of simulation	No. of round in which last dead node occur in Leach	No. of round in which last dead node occur in proposed algorithm
1	1813	1975
2	1721	2025
3	1801	2119
4	1695	2011

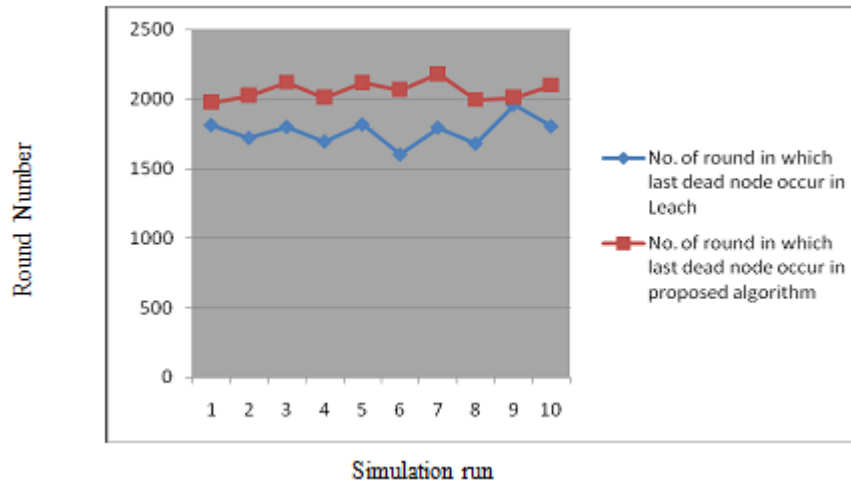|		
5	1819	2116
6	1601	2065
7	1795	2179
8	1680	1995
9	1961	2012
10	1805	2099

Figure9 : Network Life Time(all nodes dead)

3. Energy Consumption with varying message size:- We simulated with the maximum number of node that is 42 in Leach and 24 in the proposed method with different message size; energy consumption is shown in following table

Table 5: Energy Consumption for cluster head selection for different message

Message size in Byte	Energy Consumed in Leach in µJ	Energy Consumed in Pro-posed Algorithm in µJ
10	21.505000	12.505000
20	43.005000	25.005000
30	64.505000	37.505000
40	86.005000	50.000000
50	107.505000	62.505000
60	129.005000	75.005000
70	150.505000	87.505000
80	172.005000	100.005000
90	193.505000	112.505000
100	215.005000	125.505000

Figure 10: Energy Consumption for different message size
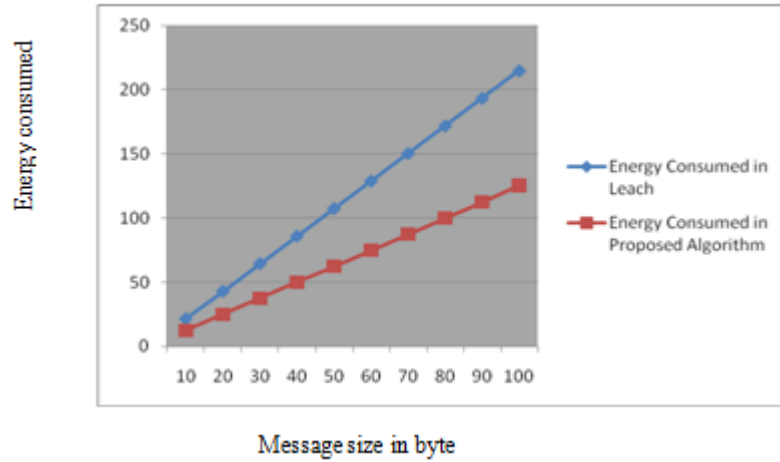
4. Residual Energy with varying message size:- We simulated with the maximum number of node that is 46 in Leach and 27 in the proposed method with different message size; residual energy is computed where initial energy Eo = 0.5Joules . Residual energy shown in following table.

Table 6: Residual Energy for cluster head selection for different message size

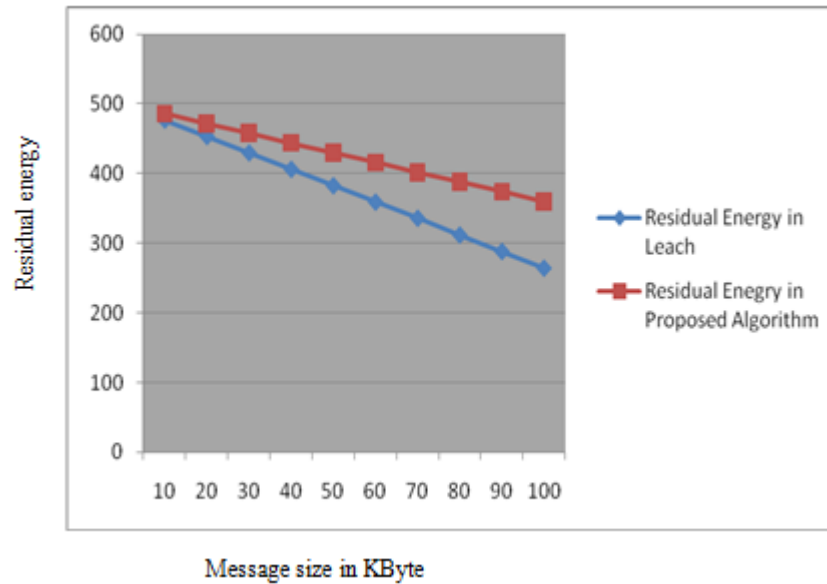| Message size in KByte	Residual Energy in Leach mJ	Residual Energy in Proposed Selection mJ
10	476.49	485.90
20	452.90	471.90
30	429.40	457.90
40	405.90	443.90
50	382.49	429.90
60	358.99	415.90
70	335.99	401.90
80	311.99	387.90
90	288.49	373.90
100	264.49	359.90

Figure 11: Residual Energy for different message size

6.Conclusion and future work:

In this paper, we have proposed a new technique to distribute the role of cluster head among some of the wireless sensor nodes based on their residual energy. The proposed new technique aims to increase the lifetime of the whole network, and to increase the number of nodes, which will remain alive for the maximum period of time. The performance evaluation in terms of network lifetime was conducted using MATLAB. We compared the LEACH protocol with the new technique under the same simulation condition and values. Results show that the new proposed technique has improved the performance in terms of increasing the network lifetime and we have also determined the impact of message length in the energy consumption. Since energy consumption increases with the message size, result shows that Leach consumes more energy than proposed method. The proposed algorithm is for the homogeneous network and we propose to extend this work for the heterogeneous network.

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