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A Power Aware Three Tier Hierarchical Clustering Algorithm for WSN

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Abstract: Wireless Sensor Network (WSN) is the network of tiny sized sensor nodes. Due to the limited size, sensor node is limited in processing, energy and memory. The restriction of energy and memory in sensor node create challenges for routing in WSN. Recently clustering increases interest for energy efficiency in WSNs. A sensor node represents all other sensor nodes in the cluster called cluster head (CH) and collects sensed data from them. The load on cluster head is larger than normal sensor node there for two type of sensor node, first is heterogeneous (more energy than normal sensor node) sensor node and second is normal sensor node are considered. To balance the energy consumption among sensor nodes in the network, the CH should be rotated among all sensor nodes. The computation and communication process is the major source of energy consumption. In this paper proposes, Power Aware Three Tier Hierarchical Clustering Algorithm (PA-THC). PA-THC elects CH based on residual power (energy) of the sensor nodes. The network arrange in three tire architecture: at the lower level normal sensor nodes are connected, at the middle level cluster head are reside to receive data from normal sensor nodes and at the higher level superior nodes are work as the interface between cluster heads and base station. In WSNs data reporting to base station over long distance consumed large amount of energy that reduce lifetime of the network. In this paper, energy heterogeneity is considered in the cluster head selection in order to increase the network stability and lifespan. Moreover, the re-clustering of cluster head conserves the energy in data reporting to base station. The simulation results show that PA-THC conserves more energy in data reporting compared to the well-known exiting clustering algorithms SEP and TL-LEACH. PA-THC also prolongs the network stability period up to 2020 rounds in medium area (compare to TL-LEACH) and 300 rounds for large area (compare to SEP).

Keywords: Wireless sensor network, clustering, energy conservation.

1. INTRODUCTION

Wireless sensor network is the network of tiny sensor nodes having limited radio range, memory, processing power and most important power [1]. WSN uses in many applications like monitoring, target spotting, tracking etc. But there are few applications where human cannot survive like disaster, battle field, etc. In this type of the application a WSN needed which is self-configurable. But in this kind of application battery is not replicable. There are many protocols for clustering to conserve energy of WSN, but they are not much energy efficient in data reporting to base station. LEACH is the clustering protocols use a threshold for cluster head selection but does not consider the remaining energy of the sensor nodes. SEP is the first clustering protocol introduces energy heterogeneity. Most of the threshold based clustering protocols considered parameters like remaining energy of sensor nodes, relative distance from cluster head to base station, number of time a sensor node already has become cluster head and number of neighbor node a cluster head has [15, 16]. But they do not focus on the reliability and power consumption of data reporting to base station. In this paper parameters uses to calculate the threshold is remaining energy of sensor nodes. Using this threshold protocol will select frequently cluster heads which having more energy to serve the cluster member. PA-THC also reduces the power consumption in data reporting using re-clustering process. The re-clustering process increases the stability period and network life time of the sensor network.

The remaining part of the paper is organized as follows. In Section 2, we included related work. In section 3 present the radio energy model. In Section 4, we propose PA-THC for energy conservation in WSN. In Section 5, we provide simulation results and performance analysis of PA-THC. In Section 6, we conclude this paper.

2. LITERATURE REVIEW

In wireless sensor network energy minimization using clustering protocols is a primary issue to increase the network lifespan [2]. It is arduous to create energy efficient clustering protocol because of the complicated energy configuration and network procedure. There are many communication protocols have been proposed to recognize power efficient communication in these networks. LEACH was the first hierarchical routing protocol developed for wireless sensor networks [3]. This protocol picks out cluster heads periodically according to the threshold and balance energy consumption by rotation role of sensor nodes. LEACH performs well in homogeneous network, but not in case of heterogeneous network. In PEGASIS, sensor nodes organized in the network as a chain, only one sensor node of the chain congeries all data and send this data to the base station [4]. The trouble in this protocol is that it is based on the requirement of the all knowledge of the network topology. Another distributed cluster based routing protocol is HEED protocol. In this protocol the selection of cluster head dependent upon the residual energy of the sensor node and also choose these cluster heads stochastically [5, 6]. SEP was the first clustering protocol developed for heterogeneous network by Georgios Smaragdakis et. al. Author introduced the concept of energy heterogeneity in clustering protocol and significantly improved the network lifetime than homogeneous clustering protocols [7]. SEP protocol is similar to the LEACH protocol except energy heterogeneity and energy awareness in cluster head selection process. In EECS which selects the cluster heads with more residual energy by local radio communication [8]. In cluster formation stage, EECS see the trade-off of energy expenditure between sensor nodes to the cluster heads and the cluster heads to the base station. But, it increases the need of all knowledge about the distance between the cluster heads and the base station [9]. In EECRP the Base Station picks up the Cluster Heads for

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sensing field [10]. The cluster head selection process is completed in two stages. In the first stage, all the sensor node become candidate nodes for being CH are listed, according to the parameters like relative distance of the candidate node from the Base Station, probable number of the candidate node and neighboring sensor nodes can have, left energy level and the number of times the candidate node was Cluster Head. But EECRP protocol is centralized, which consume lot of energy in communication between sensor nodes and base station for parameter collection [11, 12]. In three layered LEACH, cluster-heads selected at first stage [15]. Cluster heads does not communicate directly with base station [16]. Authors reselect other nodes as the cluster heads to send data to the base station. Information from remaining other cluster heads will be fused in these nodes and then be transmitted to the base station. When the stage 1 cluster-heads selection finished, stage 2 cluster-heads which communicate with base station will be selected among these stage l cluster-heads based on the left power of them. The TL-LEACH is not worthy for densely deployed sensor network. A distributed approach is needed which consider parameter as many as possible.

3. RADIO ENERGY MODEL

According to the radio energy dissipation model, to attain an acceptable Signal-to-Noise Ratio (SNR) for transmitting an l -bit message over distance d, the energy consumption by the radio is given by:

$$E_{TX}(l,d) = \begin{cases} lE_{elec} + l\,\epsilon_{fs} d^2, d \le d_0 \\ lE_{elec} + l\,\epsilon_{mp} d^4, d > d_0 \end{cases} \qquad (1)$$

Where

E_{elec} *is the energy dissipated per bit to run the transmitter or the receiver circuit*

ϵ_{fs} *and* ϵ_{mp} *depend on the transmitter amplifier model*

d *is the distance between the transmitter and the receiver*

By equating the two expressions at $d = d_0$, we have

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}.$$

To receive an l -bit message the radio expends

$$E_{RX} = l * E_{elec}$$

4. PROPOSED PROTOCOL

In this section, proposed PA-THC protocol for wireless sensor networks. The following assumptions with respect to the PA-THC protocol are made.

- Sensor nodes and base station are static.
- The base station not limits by energy.
- Sensor nodes do not aware about their geographic location.
- Sensor nodes know the relative position of the base station in the field.
- The distributions of sensor nodes are random over sensing field.
- The Sensor nodes are densely deployed in the sensing field. This dense deployment of sensor network achieving Quality of Service.
- Sensor nodes are heterogeneous in energy level.
- Sensor nodes are able to measure the current energy level.

4.1 The PA-THC

In the PA-THC clustering process accomplish in 2 stages, it requires $2 * T_{max}$ (T_{max} is the time require for clustering).In first stage cluster head is picked up according to the probabilistic threshold (based on residual energy). At the end of first stage all the cluster heads are selected and formation of cluster is accomplished. In second stage re-clustering process starts where all the selected cluster heads reselect the new superiors on the basis of threshold used for cluster head selection with different probability. After the completion of second stage superiors receive aggregated data from nearest cluster heads and again aggregate this data then send it to the base station. This extends the time interval before the first node decease. It is very essential for many applications where reliability about feedback needed.

4.1.1 Stage –I

The first stage includes cluster head selection as well cluster formation process. In the cluster head selection procedure each sensor node chooses a random number between 0 and 1 separately. If this number is lower than the calculated threshold $T\,(i)$ for node i, then the sensor node i become a cluster head.

The threshold $T\,(i)$ is given by

$$T(i) = \left(\frac{P}{(1 - P \times mod\,(r, round\,(1/P)))}\right) \qquad (2)$$

Where

P is the optimal probability for intial cluster head

r is the current round

The probability P for sensor nodes may vary depends on its type; for heterogeneous sensor node the probability is

$$P_h = \left(P * (1+\alpha)/(1+\alpha*\omega) \right) \qquad (3)$$

For normal sensor node the probability is

$$P_n = \left(P/\,(1+\alpha*\omega) \right) \qquad (4)$$

Where

α is a constant represent the time of energy level of heterogeneous node

ω is a constant represent the percentage of heterogeneous node

In the process of cluster formation each cluster heads broadcast a join message within the sensing field. On reception of join message each non cluster head sensor node decide to join the cluster head, if more than one join messages is received then sensor node join nearest cluster head. After a constant time interval cluster head received join request messages from non-cluster head sensor nodes. It creates a TDMA schedule for data transmission within the cluster and sends to its cluster members.

4.1.2 Stage –II

The second stage includes re-clustering process and data aggregation process. In the re-clustering process superiors are selected on the basis of threshold and random number. The threshold $T(l)$ for superiors shown below:

$$T(l) = \left(\frac{q}{(1 - q \times mod\,(r, round\,(1/q)))}\right) \qquad (5)$$

Where

q is the optimal probability for superior sensor node.

The probability q for cluster heads may vary depends on its type; for heterogeneous cluster head node the probability is

$$q_h = \left(q * (1+\alpha)/(1+\alpha*\varpi) \right) \qquad (6)$$

For normal sensor node the probability is

$$q_n = \left(q/\,(1+\alpha*\varpi) \right) \qquad (7)$$

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Where

ϖ represent the number of heterogeneous cluster head node

After the superiors selection re-cluster the cluster head under the newly selected superiors. Each superior broadcast the join superior message within the sensing field. Cluster head join the nearest superior by sending confirm message. After a constant time each superior create a TDMA schedule for cluster head and send to its respective members cluster head. Each cluster head send aggregated data at the time slot allocated to it.

In the data aggregation stage each normal sensor nodes send sense data to its respective cluster heads in the allotted time slot. The cluster heads receive data from all cluster members and aggregate this data. Cluster head send it to the respective superiors in the allotted time slot. The superiors receive data from its member cluster heads and aggregated it then send this data to the base station. Clustering process of PA-THC shown in figure 1.

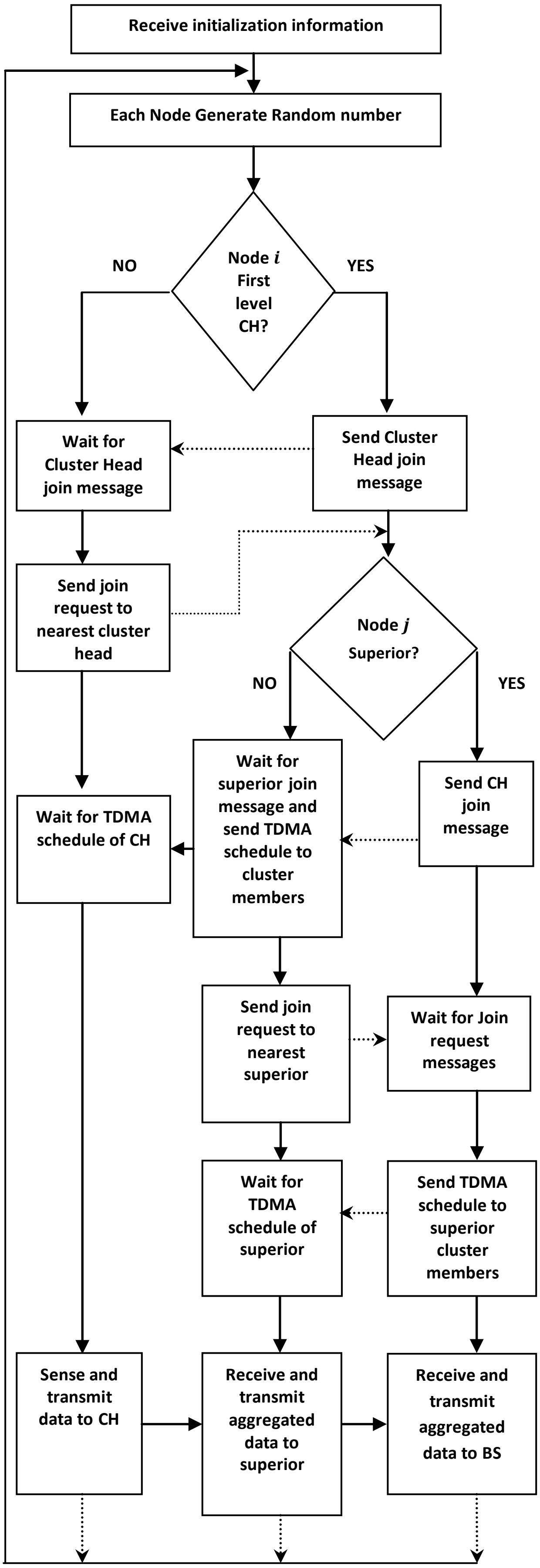

Fig 1: The flow chart of PA-THC

5. SIMULATION RESULT

We simulate a clustered wireless sensor network in a field with $100 \times 100\, m^2$ dimension. The sensor nodes are randomly distributed over the sensing field. The base station is inside the sensing field. The radio characteristic uses in simulation are summarized in table 1 show in below.

Table 1: Simulation Parameters

Parameter		Value
Network size		$(100 \times 100\, m^2)$
Number of sensor node (n)		100
Base station position		$(50\, m, 50\, m)$
Initial energy	Heterogeneous node	1 J
	Normal node	0.5 J
P		0.05
q		0.2
Transmitter/Receiver electronics E_{elec}		50 nj/bit
Data aggregation (E_{DA})		$5\, nj/bit/report$
Reference distance (d_0)		$87\, m$
Transmit amplifier ϵ_{fs}		$10\, pJ/bit/m^2$
Transmit amplifier ϵ_{mp}		$0.0013\, pJ/bit/m^4$
Message size (l)		$2000\, bits$

5.1 Stability period and Network lifetime

The stability period and network lifetime are used as key indicators to evaluate performance of the proposed protocol. The stability period shows that the time interval from the start of the operation to the first node demise. Stability period of the PA-THC is about the 2020 rounds as shown in figure 2. The network lifetime is the time interval from the start of operation till the last node demise. Network lifetime of PA-THC is greater than 5000 rounds as shown in figure 2. The data transmissions from sensor nodes were simulated until all the sensor nodes died.

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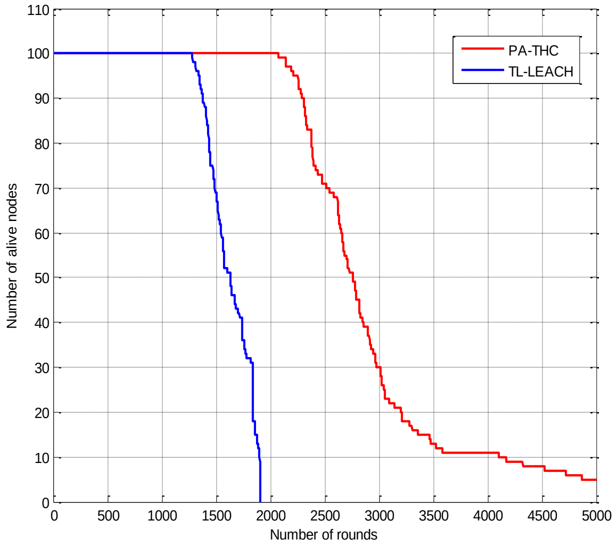

Fig 2: Comparative graph of PA-THC and TL-LEACH

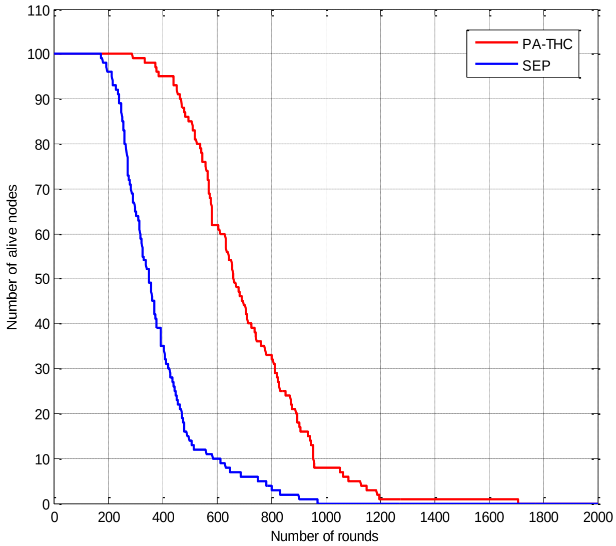

Fig 3: Comparative graph of PA-THC and SEP

Figure 2 shows the comparative results of TL-LEACH and PA-THC for network stability period and lifespan [11]. The stable region of PA-THC is about 2020 rounds which is larger than TL-LEACH stable region (1400 rounds). The network lifetime also increased from about 1900 rounds to more than 5000 rounds. Figure 3 shows the comparative results of SEP protocol and PA-THC for network stability period and network lifespan [5]. The PA-THC and SEP protocol are simulated in $100 \times 100\ \mathrm{m}^2$ sensing area where 100 senor nodes are spreads and base station positioned at $200\ \mathrm{m}, 200\ \mathrm{m}$. The packet length is 4000 bits for this simulation. The stable region of PA-THC is about 300 rounds which is larger than SEP stable region (198 rounds). This shows that PA-THC protocol is more reliable than SEP protocol. The network lifespan of PA-THC is also larger than the SEP protocol. The observation has been made that the PA-THC protocol is best in the second level clustering protocols because it has higher stability period as well as higher network lifetime. This protocol is most suitable for large area WSN or where base station placed outside of sensing field.

5.2 Packet transmission from cluster head to base station

After the cluster formation, each cluster head transmit aggregated data to base station is called inter cluster communication. The huge amount of network energy is consumed in inter cluster communication. Here the analysis is made on cluster formation and packet transmission. The figure 4 shows that the number of clusters formed in a round, that is up to 18 clusters. This shows that the more clusters reduces the intra cluster communication energy consumption. The figure 5 shows the number of packet received by cluster heads in each round.

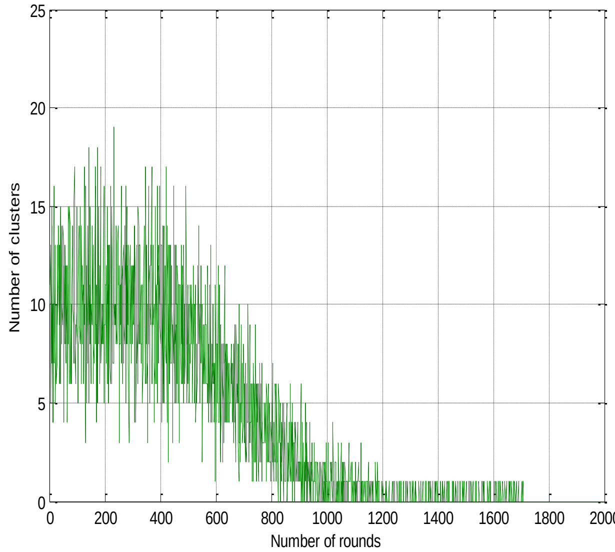

Fig 4: Number of clusters formed per round

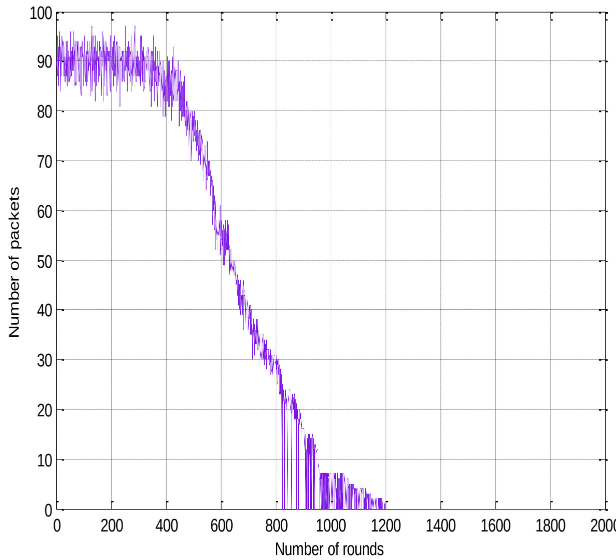

Fig 5: Number of packets received at cluster heads

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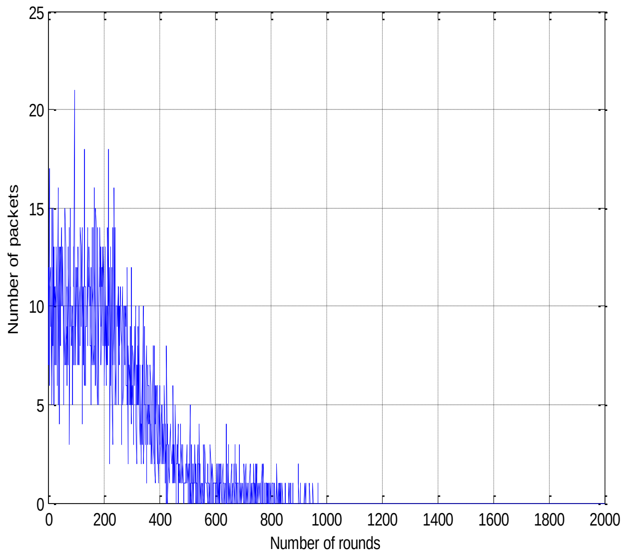

Fig 6: Number of packets received at base station in SEP

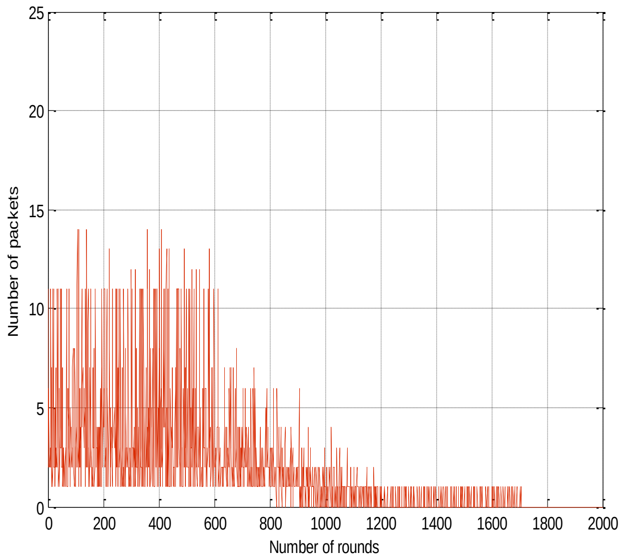

Fig 7: Number of packets received at base station in PA-THC

The figure 6 shows the number of packet received at base station in SEP protocol which is up to 20 packet, but figure 4 and 7 shows that the number of packet transmitted to base station is lower than the clusters formed in field. This reduces the inter cluster communication which saves 70% energy in communication. In the PA-THC packet transmission is also lower than SEP protocol as shown in above figures.

6. CONCLUSION

In this paper a new clustering protocol PA-THC has been proposed to conserve the energy in clustering process. A threshold has been formulated for cluster head selection which is based on the remaining energy of the sensor node. A re-clustering approach also has been proposed to decrease the power consumption in data reporting to the base station. Simulation results show that PA-THC protocol has longer stability period and network lifetime than SEP and TL-LEACH. In future more parameters will consider for threshold calculation.

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