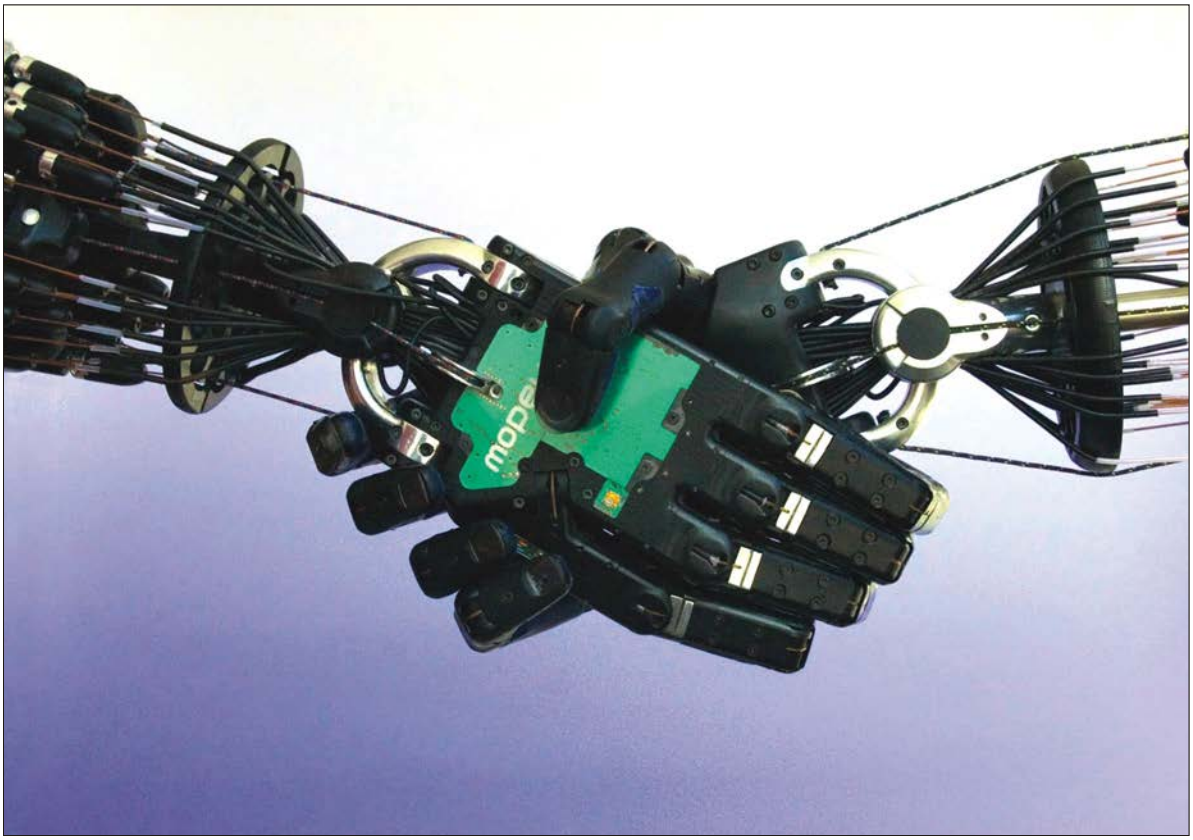

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BACHS-Battery Aware Cluster Head Selection

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ABSTRACT

Wireless Sensor Network (WSN) serves the purpose of monitoring the physical quantities from the real world. The WSN are battery powered and energy depleting in nature. Energy enhancement of WSN has attracted many researchers in enhancing the energy of the Sensor Node (SN). This study concentrates on enhancing the lifetime of the WSN and increasing the throughput of the network based on the battery voltage of the SN. Energy depletion due to radio model is taken into consideration, the distance between the sender and receiver plays the major role in lifetime of WSN. Apart from distance, the battery curve of the SN is taken into consideration. Node functionality is assigned as per these factors and an unequal clustering is formed for avoiding energy hole attack in the WSN. The proposed BACHS algorithm outperforms the other 2 protocols in terms of lifetime by 1.7.

Key words: Wireless sensor network, BACHS

INTRODUCTION

Small tiny embedded sensing machines together communicate with each other to form a network called Wireless Sensor Network (WSN) (Akyildiz *et al.*, 2002). These tiny embedded machines monitors the temperature, pressure, humidity and other physical parameters to monitor the event taking place in the Region of Interest (ROI). The monitoring serves the purpose in military, agriculture, health care, industry and several regions. These sensor nodes are powered by battery since it monitors events in an anti-third environment. Replacement of power resource or charging up the battery resource in these areas is termed to be impossible. This makes the WSN prone to energy constraint and making researchers to concentrate on building a energy efficient network which survives for greater lifetime duration (Lindsey and Raghavendra, 2002; Chamam and Pierre, 2010; Farooq *et al.*, 2010; Loscri *et al.*, 2005; Gou and Yoo, 2010). The WSN has 2 basic architecture namely layered architecture and clustered architecture. The layered architecture is mainly meant for monitoring small Region of Interest (ROI). Clustered architecture based sensor network are mainly used for monitoring very large acres of area such as crop field, industrial areas and other volcanic regions (Jung and Nittel, 2008; Chung and Yang, 2009; Al-Ali *et al.*, 2010).

Figure 1 shows the basic clustered architecture of the WSN. The sink is where the data from all the SNs is collected and surveillance is done in the sink. The cluster has their own individual cluster head which sends the data to the sink in a single hop fashion (Yang and Zhang, 2009; Xin *et al.*, 2008; Wang *et al.*, 2011). Energy efficiency is an important issue which affects the lifetime of the WSN (Dhulipala *et al.*, 2012). LEACH is the first hierarchical clustering protocol (Heinzelman *et al.*, 2002; Akyildiz *et al.*, 2002). Farooq *et al.* (2010) proposed multi hop routing

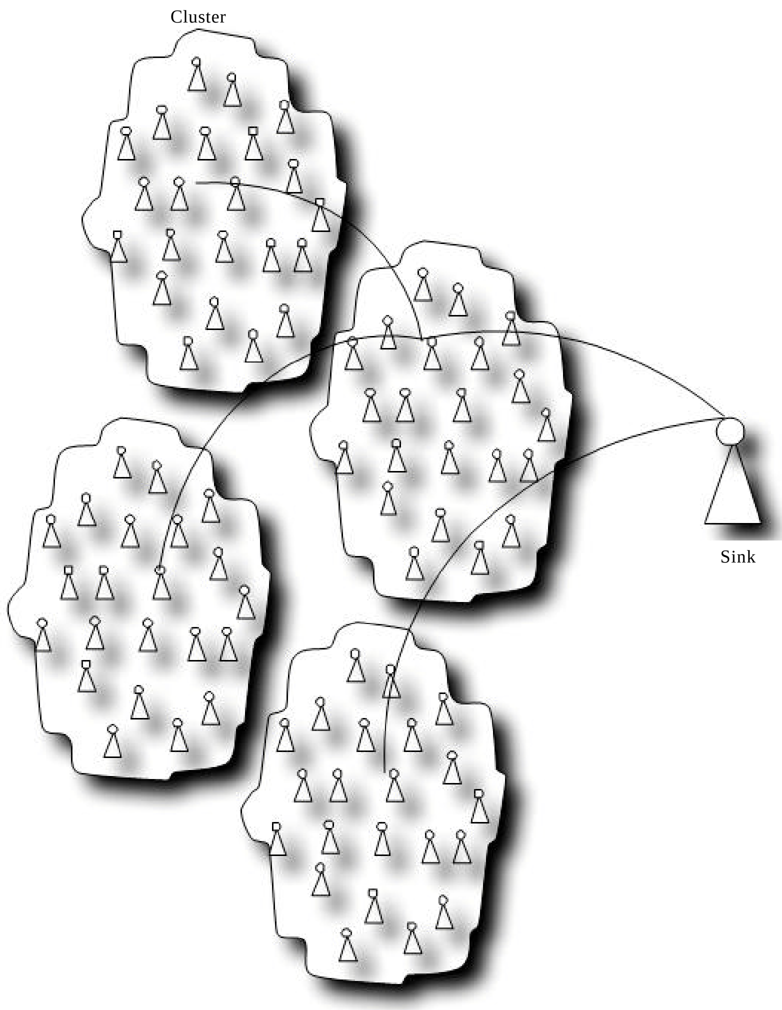

Fig. 1: Wireless sensor network scenario

with Low Energy Adaptive Clustering Hierarchy (MR-LEACH) which lags by addressing the energy issue existing in the WSN. Tabibzadeh *et al*. (2009) proposed a hybrid routing protocol for prolonged network lifetime in large scale WSN. Handy *et al*. (2002) proposed a deterministic cluster head selection algorithm based on hierarchical method. Sengottaiyan *et al*. (2010) proposed a hybrid class of routing protocol in wireless sensor network proposing combination of two algorithms. This study presents the algorithm which takes battery end voltage and current consumption of the battery during each participation in the network and the cluster head is selected. By choosing the battery end voltage as the criteria the network shown an improved lifetime and unequal clustering mechanism in the WSN.

MATERIALS AND METHODS

LEACH: In LEACH protocol, each node generates a random number in the interval between (0,1) at the beginning of election, if the number is less the threshold $P_i(t)$ calculated from equation given below:

$$P_i(t)=\begin{cases}\frac{k}{N-k(r \bmod n/k)}, C_i(t)=1\\ 0, C_i(t)=0\end{cases} \quad (1)$$

where, K is the No. of Cluster Heads (CH), N is No. of nodes in the network, r is current No. of rounds and $C_i(t) = 0$ if node already been a CH and 1 otherwise.

The ordinary nodes in the clusters send the data to the CH of the corresponding cluster and CH contributes the data to the sink in a single hop. The CH after dissipating the energy below a certain level, next CH is being selected for its contribution as CH for the corresponding cluster. Equation 1 shows the election probability of each node to be a CH which means that all the nodes can themselves have the chance to get elected as a CH no matter what far the distance they have with the sink. If the elected node is far away from the sink, node dissipates more energy in transceiving the data with the sink thereby it dies soon and makes the next election to the network. If the probability of nodes nearby the sink is high, it ensures the energy dissipation of the node to be low and in making an enhanced lifetime of the network (Akyildiz *et al*., 2002).

ALEACH: Similar to LEACH protocol, ALEACH considers the residual energy of the corresponding node so as to elect the CH as per the residual energy. Node with residual energy gets high probability of being a CH (Al-Fares *et al*., 2009):

$$P_i(t)=\begin{cases}\frac{k}{N-k(r \bmod N/k)}+\frac{E_{i-current}}{E_{i-max}}\times\frac{k}{N}, C_i(t)=1\\ 0, C_i(t)=0\end{cases} \quad (2)$$

Where:

$E_{i\text{-current}}$: Current energy of the node
$E_{i\text{-max}}$: Energy at the beginning

Radio energy model: The transmission of data is based on the radio model given below:

$$E_{tx}(I,d)=E_{tx-elec}(k)+ET_{-amp}(I,d) = \begin{cases} lE_{elec}+l\varepsilon_{fs}d^2, & d<d_0\\ lE_{elec}+l\varepsilon_{mp}d^4, & d\geq d_0\end{cases} \quad (3)$$

Receiver's energy consumption is:

$$E_{Rx}(l) = E_{Rx\text{-}elec}(l) = lE_{elec} \quad (4)$$

where, E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit. $\varepsilon_{fs}d^2$(pJ/bit-^{m2}), $\varepsilon_{mp}d^4$(pJ/bit-m^{-2}) = Energy dissipated per bit to run the transmit amplifier based on the distance between the transmitter and receiver. E_{tx} = Energy dissipated during transmission of data.

Equation 3, 4 signifies the energy dissipated by the node in sending the data between nodes. The energy consumed by node in sending the data and receiving the data is given in Eq. 3, 4. The energy dissipation of sending and receiving data with respect to distance is given in Eq. 3. The energy of the sensor nodes is represented in Joules. The equation helps in simulating the network and to show the energy dissipation in the network.

Proposed work: The LEACH protocol and ALEACH protocol selects the CH based on the random number and residual energy of the nodes in the network. The proposed algorithm selects the CH based on the voltage level of the battery in each sensor node. The voltage of the battery is exponentially decaying in nature. The energy required to transmit a bit or to receive a bit is given in Eq. 3. Since the voltage of the battery is decaying in nature, in order to meet out the required energy, it demands more current from battery to meet out the requirement. CH has the major role in WSN of transceiving the data (i.e.) receiving and transmitting the data. It multihops the data to the sink. Therefore, an additional burden is given to the CH. In case of end node, it either transmits or receives data to the CH or from CH. This algorithm proposes a methodology of electing a cluster head based on the Eq. 5. The equation illustrates the battery drain curve of the SN. Probability of election of cluster head favours the cluster head selection and increases the lifetime of the network.

Figure 2 illustrates the proposed formation of cluster based on the battery voltage. Three stage of sensor nodes are depicted here, one with high charge indicating peak voltage (with three strikes). Second with medium voltage (with two strikes) and third one with very low voltage (with a single strike).

Figure 3 depicts the proposed algorithm based WSN, the node with more residual charge is likely to become the cluster head. The sink is always a non-power starving in nature. Once the

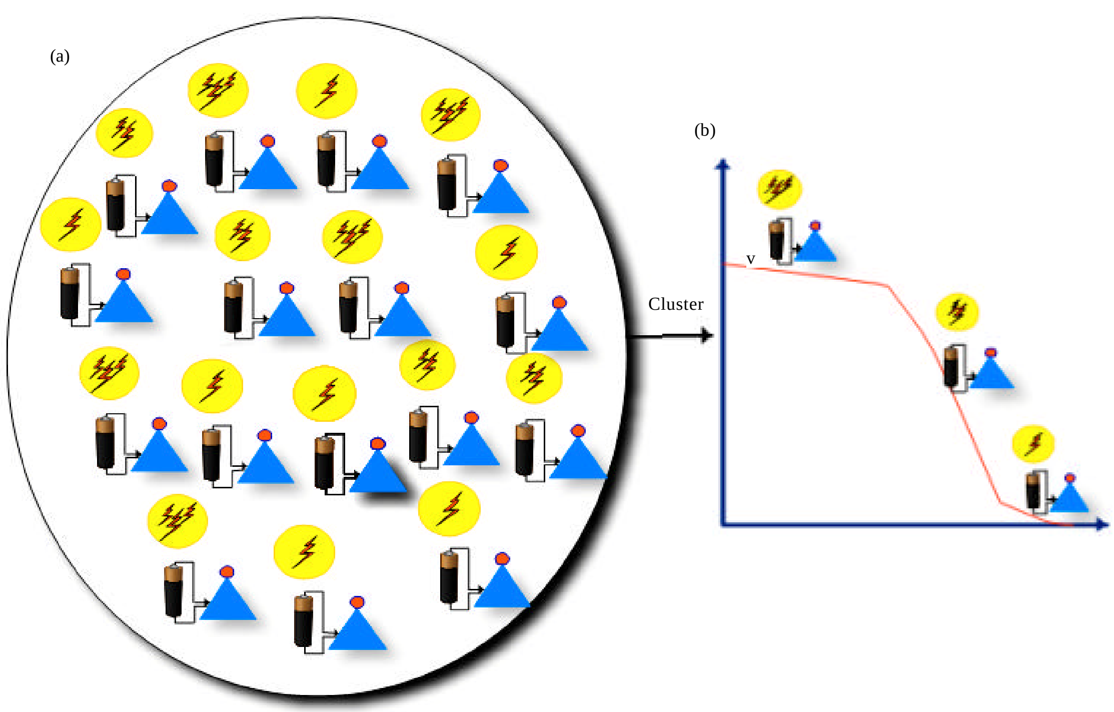

Fig. 2: Proposed work CH selection, (a) Cluster and (b) Voltage curve of SN battery

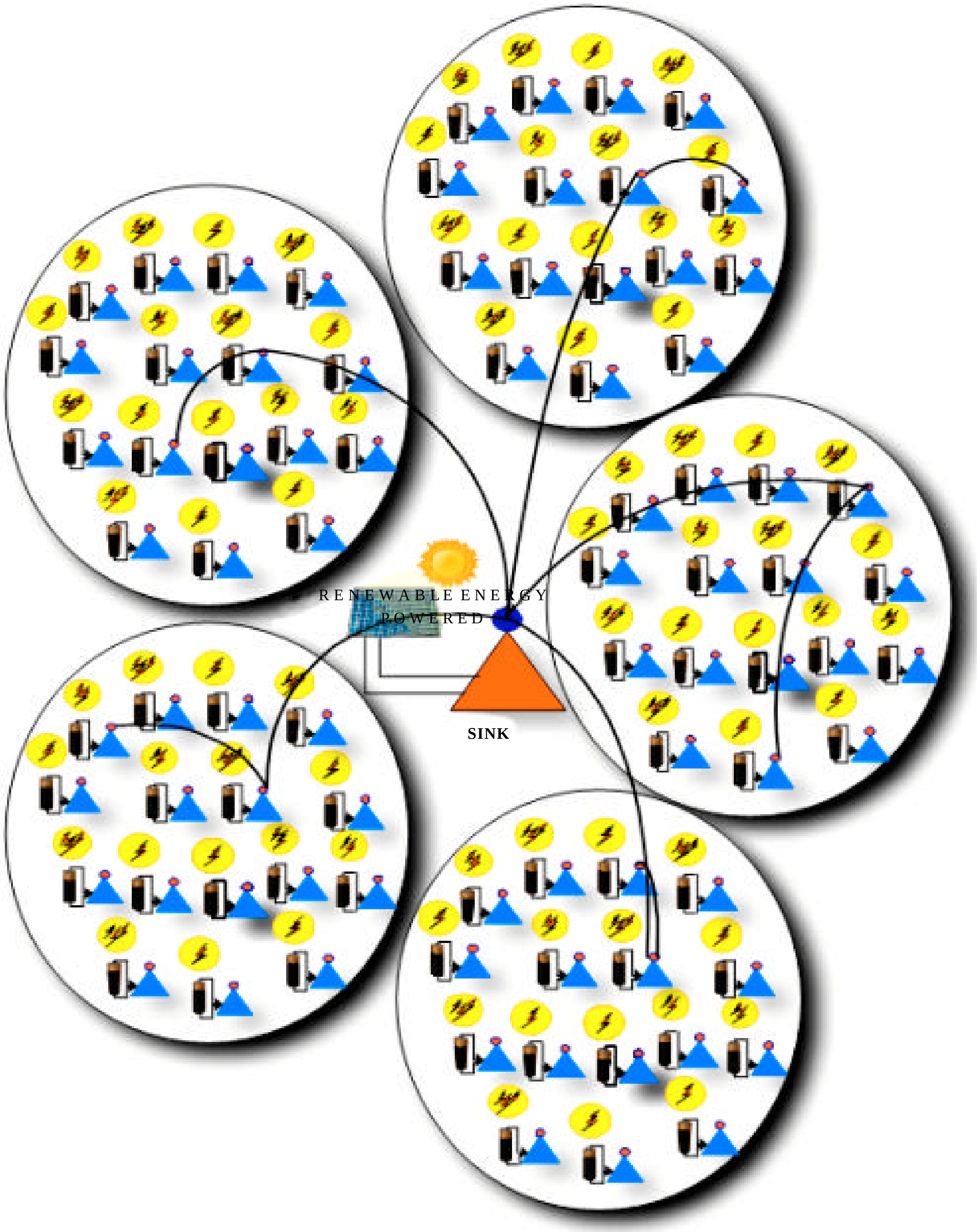

Fig. 3: Clustered architecture of the proposed work

sensor node drains its charge to a particular level, it loses its quality to be a cluster head and calls for a reelection. Then the candidate with high residual charge is selected as cluster head.

Mathematical proof: The voltage curve of typical sensor node is given by the Eq. 5:

$$F(x) = \alpha \sin(b_1 x + k_1) + \beta \sin(b_2 x + k_2) \quad (5)$$

where, F(x) = Favor factor of a node to become a cluster head.

Equation 5 represents the favor factor of a node to become a cluster head for the BACHS. Equation 5 describes the exponentially decaying voltage curve of the wireless sensor node. The voltage decreases as the charge stored in the battery is dissipated:

$$E = V \times I \times t \quad (6)$$

where, E is the energy required for transceiving purpose, V is the voltage of the battery, I is the current consumed by the sensor node, and t is the No. of bits transmitted time.

Equation 6 represents the energy equation of the battery:

$$E = P \times t \quad (7)$$

where, $P = V \times I$ total power dissipated in sensor node.

Equation 7 represents the energy equation of the battery dissipated for a particular duration with respect to power and time.

When the voltage of the battery powering the sensor node reduces, the sensor node extracts more amount of current from the battery to compensate the demanding power required for transceiving operation. Hence more current is been dissipated more than the rated current hence draining the battery soon. By scheduling the operation based on the battery voltage level the battery life is extended.

Preliminaries:

- All the sensors are deployed in the ROI (Region of Interest)
- All nodes are energy starving and initially with same energy
- The nodes are simpler or CHs
- The nodes are immobile
- Sink node is connected with permanent power source

Simulation results and network parameters:

Parameters	Values
Network size (m^2)	500×500
Number of nodes	200
Base station location (m)	250×750
E_{elec} (nJ/bit)	50
Initial energy (J)	2
Probability of becoming a cluster head	0.1
Data message size (bytes)	2000
Header bytes (bytes)	50

RESULTS AND DISCUSSION

Figure 4 represents the sensor nodes are randomly distributed in the ROI. The nodes are deployed in ROI in the random manner. The nodes are distributed within the ROI only. All the nodes have equal energy at the beginning of the simulation.

Figure 5 illustrates the number of nodes vs. number of rounds of the proposed BACHs algorithm. The algorithm survives 1.7 times than the other 2 algorithms. The first node death in case of BACHs is also delayed when compared to other 2 protocols. Performance evaluation of proposed algorithm is done using MATLAB simulator, initially 200 nodes were deployed randomly in the region of interest and probability of becoming a cluster head among the nodes is given as 0.1. The sink is located in 250, 750 location of sink is placed far away from the ROI because this gives a good results on showing the protocol enhances unequal clustering. The energy efficiency of the 3 algorithms with respect to network lifetime is examined. The unequal clustering approach solves the HOT spot problem, thereby avoiding energy hole in the sensor network. BACHS also avoid individual node overloading and overloading the nodes nearer to the sink. The other 2 protocols provides energy holes in the network causing a break to the connection between the sink and the network.

Voronoi diagram illustrates the node within a single cluster, it also depicts the boundary of clusters in the ROI. The common boundary sharing 2 clusters are termed as voronoi edge, Fig. 6 represents the Voronoi diagram of the proposed BACHs. The Sink in the simulation is located

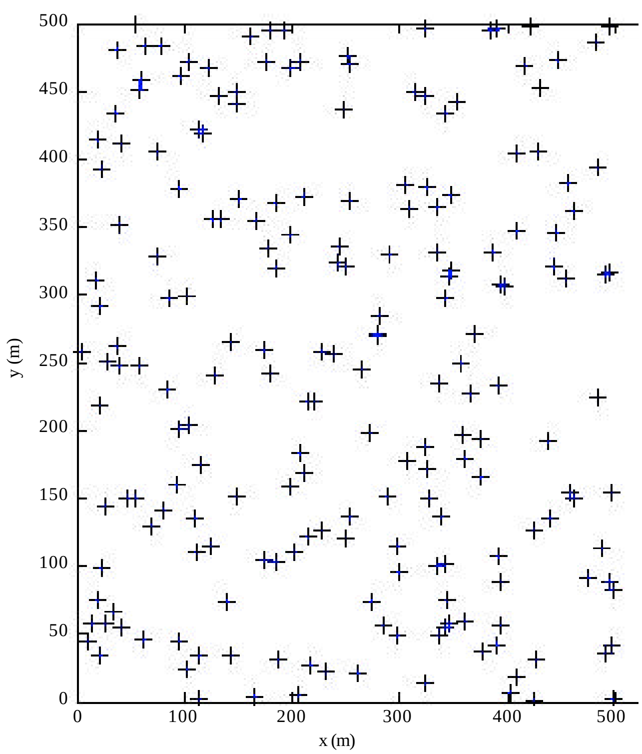

Fig. 4: Sensor node deployment in ROI (Region of Interest)

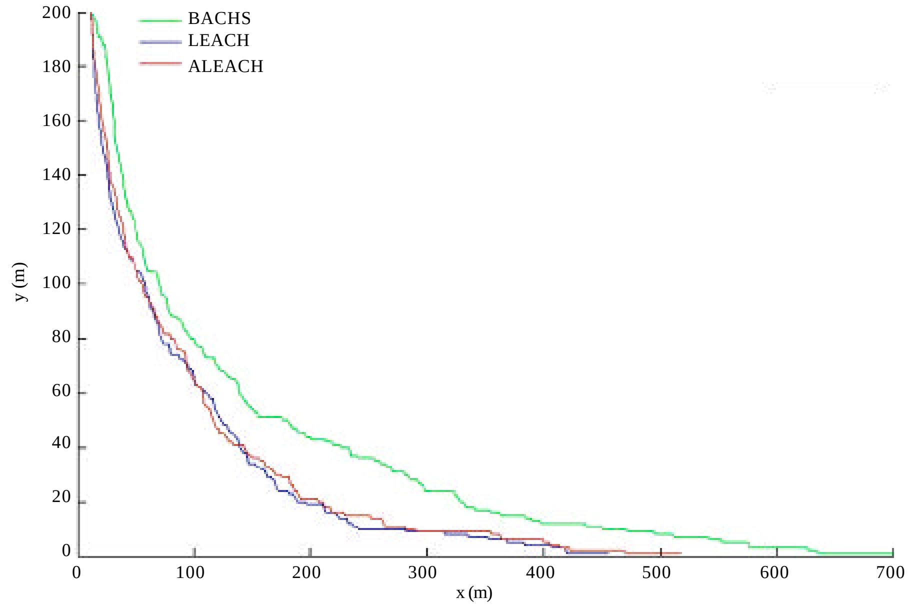

Fig. 5: No. of rounds vs. No. of nodes

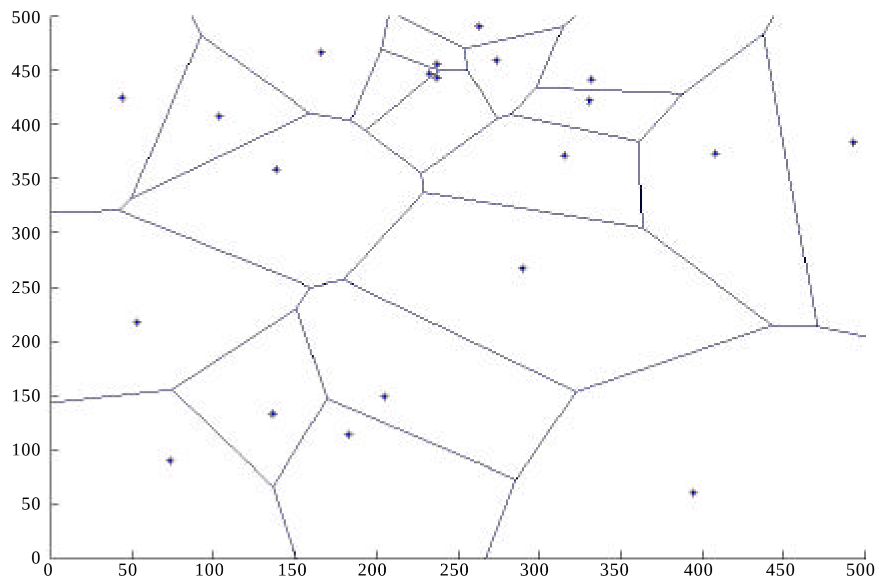

Fig. 6: Voronoi diagram of the BACHS

in location (250, 750) in order to check whether the algorithm is following unequal clustering. The voronoi diagram shows the cluster near to the sink is small and cluster far away from the sink is large, showing an unequal clustering approach.

CONCLUSION

This study proposed a novel cluster head selection method based on the voltage of the battery. This heuristic algorithm proposes that BACHS algorithm could perform better than the earlier works. Results show the better performance to support our algorithm. By optimally selecting the CH based on the voltage of the battery the lifetime of the battery and the network lifetime is improved. This algorithm serves its purpose in industrial wireless sensing systems, agricultural monitoring purpose and other remote monitoring location.

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