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Energy-efficient Cluster Head Selection for Life Time Enhancement of Wireless Sensor Networks

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Abstract: Wireless Sensor Network (WSN) are basically battery powered and they are basically power starving in nature. Aim of this study is to find an Energy efficient Cluster Head, which enhances the lifetime of the WSN. The energy dissipation is based on the position with respect to the sink and residual energy of the corresponding node. The energy dissipation due to transceiver operation is high when considered to sensing and processing operation. Energy dissipated due to transceiving operation is proposed in Radio Energy model. Taking this to account the energy dissipated by the node due to transceiving operation is reduced. Unequal clustering approach is done and Cluster Head (CH) is selected from the cluster that is near towards the sink so as to increase the lifetime of the sensor network. The proposed EECHS algorithm is compared with LEACH and ALEACH algorithms for its performance comparison. Experimental results show the EECHS has an increased lifetime and overhead when compared to other protocols. This EECHS suits its application on Industrial monitoring, Farming and militant application.

Key words: WSN-wireless sensor network, smart environments, unequal clustering

INTRODUCTION

Tiny sensing nodes which senses the physical parameters such as temperature, pressure, etc., forms to contribute a Wireless Sensor Network (WSN). Wireless Sensor nodes are battery enabled which is power starving in nature. Many researchers work in this area for enabling a energy efficient routing and to enhance the lifetime of WSN. Energy efficient routing has its application in Industrial monitoring, agricultural, militant applications and many other fields (Chong and Kumar, 2003). WSN is left unattended and it serves autonomously in many anti third environment. The Sensor Network works on two basic architecture namely, Layered and Clustered Architecture. The Layered Architecture works for the small networks which serve it purposes in underground or underwater sensor networks. The Clustered Architecture has the large scalable strength that can deal with large amount of sensor nodes deployed in the Region of Interest (ROI) which is the sensing area. The Clustered Architecture segregates the group of nodes into one cluster leaded by a CH based on some factors like distance, hop count and energy of the nodes in the corresponding cluster. The Clustered Architecture is initialized up with the setup phase followed by the steady phase (data communication to BASE STATION) (Abbasi and Younis, 2007). Any node inside the network can reach the Base station atmost in two hops. Selection of CH in the network is autonomous which is done by hierarchical algorithms such as LEACH, LEACH-C and ALEACH.

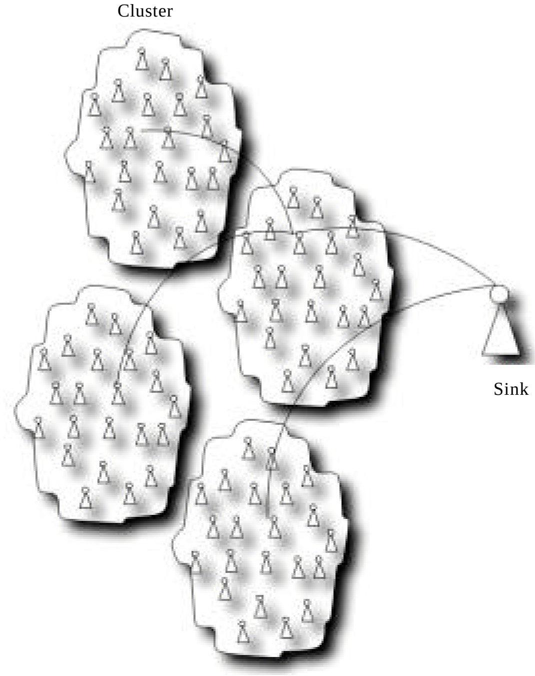

Fig. 1: Wireless sensor networks scenario

Figure 1 represents the basic clustering architecture of the WSN. Group of nodes forms a cluster based on

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some criteria such as location, energy etc. Clustered architecture is followed when the area of sensing is so large as illustrated in Fig. 1.

The lifetime of the whole WSN is dominated by sensor node distance between the source and sink. The wireless sensor node, senses the data, transmits the data, receive the data and transceives the data to the sink. The distance between each node and the layout of the network is understood by the GPS sensors enabled in individual motes in the network (Haque *et al*., 2009). The network architecture of these tiny nodes is based on Layering and Clustering approach. Clustering methodology is the key way to enhance the lifetime of the WSN (Akyildiz *et al*., 2002). Past literature survey on lifetime enhancement of WSN provides an enhanced lifetime based on energy consumption and remaining energy of the battery. Low Energy Adaptive Cluster Hierarchy (LEACH) is the basic methodology for a clustering based approach which reduces the power consumption of WSN (Yang and Zhang, 2009; Xin *et al*., 2008; Wang *et al*., 2011). The CHs are the important members in the sensor network which dissipates more power in transceiving the data to the sink. The election of the CH is the important key factor in order to enhance the lifetime of the network as given by Aimin Wang (Lindsey and Raghavendra, 2002), other improved clustering approach such as PEGASIS (Kim and Chung, 2006), LEACH mobile (Chamam and Pierre, 2010), Energy Efficient Cluster Formation protocol (EECF) (Torkestani and Meybodi, 2011), Localized Learning Automata-based Clustering Algorithm LLCA (Dhulipala *et al*., 2012) proposed a power efficient routing algorithm, which lags in considering the CH selection based on the distance between the sink and CH. Most of the energy consumed in the wireless sensor node is because of transceiving the data from source to sink (Ali *et al*., 2008). Researchers have improved LEACH in many ways which lags in considering selection of optimal CH based on the distance. Ali *et al*. (2008) proposed an algorithm Advanced LEACH which improved the CH selection and enhanced lifetime of the WSN but, the network is not aware of the position of individual node and CH selection based on the distance is not considered (Al-Fares *et al*., 2009; Handy *et al*., 2002; Gou and Yoo, 2010; Liu and Li, 2009; Ehsan and Hamdaoui, 2012; Chipara *et al*., 2006; Kandris *et al*., 2009; Sutar and Bodhe, 2010; Bajaber and Awan, 2009; Watfa *et al*., 2009).

In taking the factors like cluster size and form, criteria of CH selection, and distance into account, clustering approach is done in this study. This study presents an improved algorithm of dividing the cluster based on the position of sink in the network. This improved protocol is called EECHS algorithm which proves to be energy efficient in nature.

MATERIALS AND METHODS

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

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

K is the number of CHs, N is the number of nodes in the network, r current number of rounds, the $C_i(t) = 0$ if node already been a CH and 1 otherwise. The ordinary nodes in the clusters send the data to the CH 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 the 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 a enhanced lifetime of the network.

ALEACH: Similar to LEACH, ALEACH introduces the current state probability for the original threshold given as equation below. The node with more residual energy has higher probability to be a CH. Obviously the threshold generated by equation 1 is not regarding the distance where distance is the main factor to be considered:

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

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

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

Receiver's energy consumption is:

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

wherem 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.

Equation 3, 4 signifies the energy dissipated by the node in sending the data from one node to another. 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 the data with respect to distance is given in Eq. 3. The energy of the sensor nodes is represented in Joules.

Proposed work: Most of the energy dissipated by the node is through the radio model of the node. The energy dissipated by the sensor node is proportional to the distance between the source and the sink of the node as per Eq. 3. By taking distance, as the consideration in this study the probability of the CH selection is made based on the distance with the sink and the CH. In this proposal the clusters are separated in semi cluster which is near to sink when compared to the other half. The cluster is evaluated with the help of Voronoi diagram. The corresponding position of the first node and the last node in the cluster is found and the cluster is divided as per the positions of the two nodes. The CH dissipates more amount of power when compared to other nodes since it transceives the data from ordinary nodes to the destination.

In LEACH protocol the probability of selection of CH is as per Eq. 1:

$$P_i(t)=\begin{cases}\dfrac{k}{N-k\left(r \bmod \dfrac{N}{k}\right)}, C_i(t)=1\\ 0, C_i(t)=0,\end{cases} \quad (5)$$

The above equation describes the probability of being a CH in LEACH protocol. The CH probability selection is not based on the distance with the sink. In case of agricultural and industrial monitoring system the sink is far away from the cluster and distance plays a main role in CH Selection.

Thereby:

$$P_i(t)=\begin{cases}\dfrac{k}{N-k\left(r \bmod \dfrac{N}{k}\right)}\times\dfrac{d_c}{d_s}, C_i(t)=1\\ 0, C_i(t)=0,\end{cases} \quad (6)$$

Where:
k→No. of CHs
r→No. of rounds
N→No. nodes in the network:

$$\frac{d_c}{d_s}\rightarrow\left(1-\frac{d_{is}}{d_{js}}\right)$$

Where:
d_{is}→distance between the corresponding node to the sink
d_{js}→distance between the last node of the corresponding cluster to the sink

Figure 2 represents the Probability of choosing the Cluster Head within a cluster. Sensor node represented inside the circle in Figure 2 belongs to same cluster. Node with red top is having a highest probability of being a cluster head since it very near to the sink.

Mathematical Proof: Energy spent by clustered head is:

$$EN_{rec}=\sum_{i=0,j=0}^{k}\sum_{i=0,j=0}^{r} d_{ij}\times lE_{elec} \quad (7)$$

Where:
EN_{rec}→energy dissipated during receiving data
k→No. of nodes in the corresponding cluster
r→No. of rounds in simulation
d_{ij}→total No. data from cluster nodes to CH

From radio model Eq. 4, the energy dissipated by CH in receiving the data is given by the equation above, which depends on the distance between the ordinary node and the CH:

$$EN_{trans}=\sum_{i=o,j=0}^{k}\sum_{i=o,j=0}^{r} d^{*}_{ij}\times lE_{elec}+l\varepsilon d^4 \quad (8)$$

Where:
EN_{trans}→energy dissipated during transmitting data to BASE STATION
d_{ij}^{*}→total No. of data sent on each node during its role as CHS

The energy dissipated by the CH during the transmission of data to the sink is given by the above equation.

On substituting Eq. 7, 8 the total energy dissipated is the factor of distance and is given by:

$$E_{CH}=\sum_{i=0,j=0}^{k}\sum_{i=0,j=0}^{k} d_{ij}\times lE_{elec}+\sum_{i=0,j=0}^{k}\sum_{i=0,j=0}^{k} d^{*}_{ij}\times lE_{elec}+l\varepsilon d^4 \quad (9)$$

The CH transceives the data packet from the ordinary nodes to the Base Station which is at a long distance from

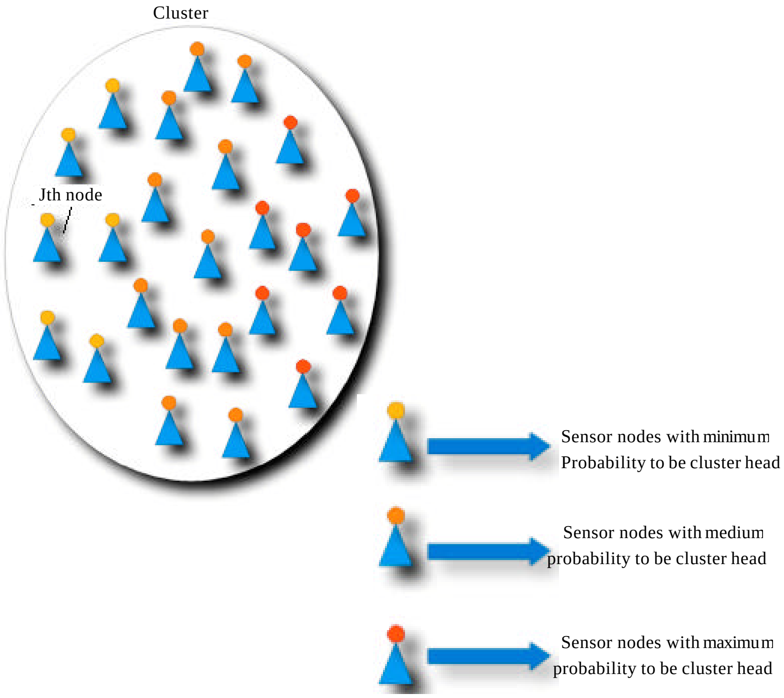

Fig. 2: Shows the proposed work cluster head selection

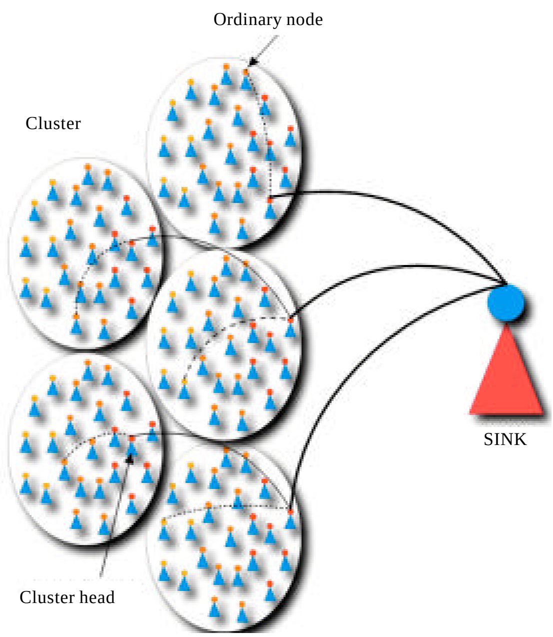

Fig. 3: Clustered architecture of the energy efficient cluster head selection

the cluster. On minimizing the distance between the CH and Base Station the energy dissipation is made minimum.

Figure 3 illustrates the proposed work and probability of selection of cluster head with respect the Eq. 6. A group of clusters forms together monitors single event and sends the signal to the sink as shown in Fig. 3.

EECHS is based on LEACH protocol. It uses the location of the sensor using the GPS sensor devices and nominally selects the CH that is not been a CH in the previous phase.

In the steady state phase of EECHS each ordinary node is allocated time to send data to the CH and each node sends the packet at the corresponding slot. The ordinary nodes use the radio model equation given in Eq. 4 to dissipate the energy during transmission and reception of packet. The Base station calculates the distance between Cluster Heads and its own and selects the CH and sends the confirmation to all nodes alive in the network.

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

Table 1 represents the simulation parameters taken to support the proposed work. Table 1 discusses the Network size, Number of nodes, Base station Location, E_{elec}, E_{fs}, Initial Energy, Probability of becoming of CH, Data message size and Header bytes.

Table 1: Simulation results and network parameters simulation results and network parameters

Parameters	Value
Network size (m^2)	500×500
No. of nodes	200
Base station location	250×750
E_{elec} (nJ/bit)	50
E_{fs} (pJ/bit)	10
Initial energy (J)	0.5
Probability of becoming a CH	Based on position of node in the cluster
Data message size (bytes)	2000
Header bytes (bytes)	50

RESULTS AND DISCUSSION

To support the proposed work it is evaluated using MATLAB to compare with LEACH, ALEACH. A set of 200 nodes were randomly distributed in the ROI, and the data message size was fixed to be 2000 bytes with 50 bytes of packet header. The base station is located in 750, 250 outside the network since it is mainly framed for industrial and agricultural activity. The study evaluated the energy dissipation by using the radio model given from the Eq. 3, 4. The probability of being a CH is selected from Eq. 5.

A 500×500 area is taken as the simulation area. Figure 4 represents the sensor nodes are randomly distributed in the Region of Interest. The Base Station of the network is located in (750, 250) for better results as shown in above Fig. 4.

Figure 5 shows the graph which represents the number of rounds vs total number of nodes in which the EECHS is energy active for more rounds than ALEACH and EECHS. The EECHS protocol services for about 1851 rounds when compared to the other two protocols. EECHS effectively performs with the reduced energy consumption for industrial and agricultural applications. The threshold of the nodes becomes less on increasing in number of rounds, in order to avoid the energy whole problem the probability of node after being a CH is made zero until its next opportunity comes. So, that the nodes in the left side part actively participates in survival of network at the end stage. The total number of CH selection is made evenly throughout the simulation by this approach.

Figure 6 describes the total number of packets delivered to the Base Station located at (750, 250). EECHS proves to send more packets to the Base Station in an energy efficient manner. The total packets sent for every hundred rounds is graphed. EECHS on compared with previous algorithms give an enhanced lifetime and enhanced overhead.

Voronoi diagram divides the ROI into number of clusters; also it represents the CH and nodes closer to the corresponding CH. Figure 7 shows the Voronoi

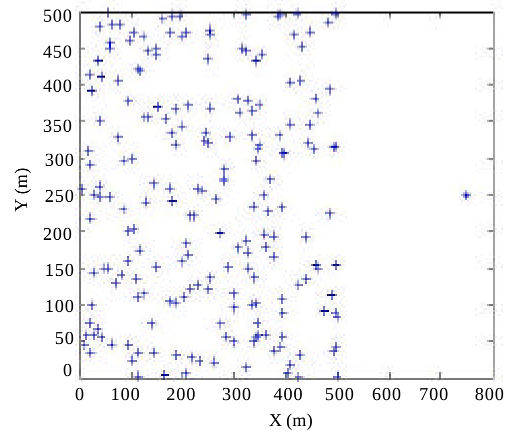

Fig. 4: Sensor node deployment in ROI (Region of Interest)

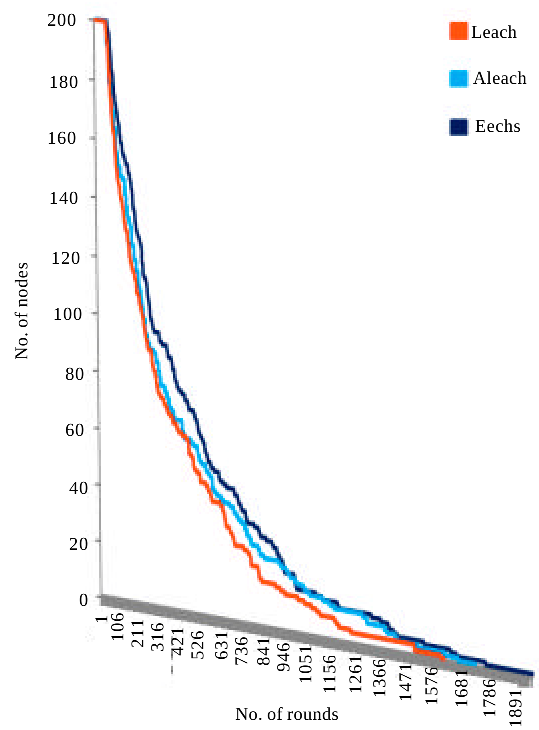

Fig. 5: No. of rounds (vs) Total No. of nodes

representation of the ROI, in which the nodes are discussed as clusters. The sensor nodes are being distributed as clusters, in which the node which is near to the Base Station is given more priority to be the CH in the Voronoi diagram. CH in most of the cluster is selected from the right half due to location of sink in the right side of the ROI.

Figure 8 illustrates the total number of packets sent by all cluster throughout the simulation, EECHS gives a

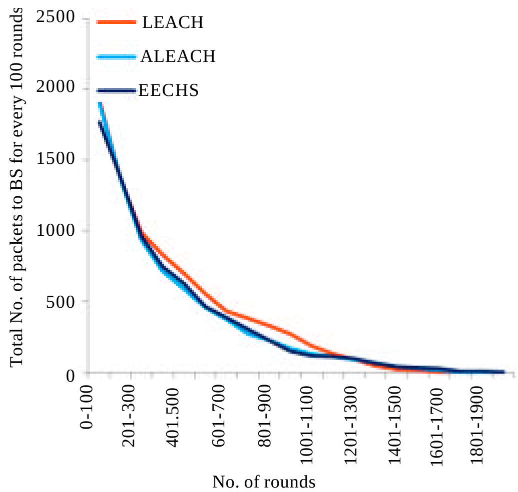

Fig. 6: Total packets sent to base station (vs) Number of rounds

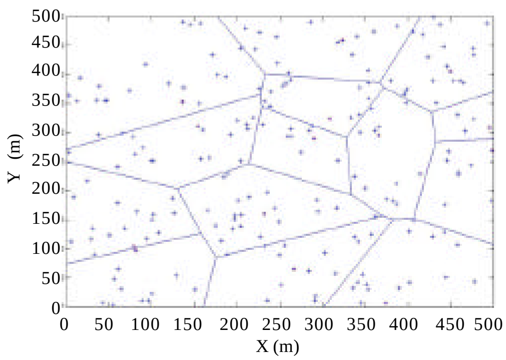

Fig. 7: Voronoi diagram of the proposed algorithm

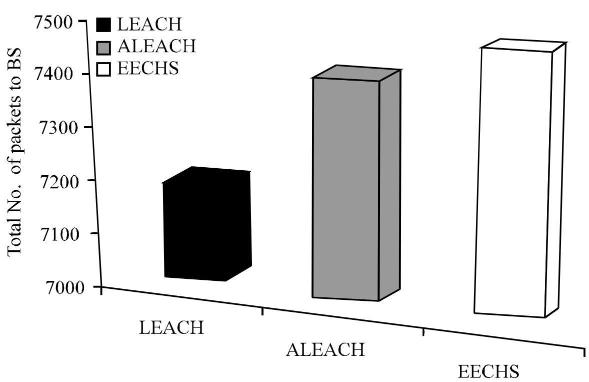

Fig. 8: Overhead comparison

high throughput when compared to other two protocols.

CONCLUSION

The proposed EECHS efficiently works in reducing the energy consumption of the WSN by optimally selecting the CH with respect to the location of the sink. Radio model mainly contributes in dissipation of the energy of the sensor nodes, which is proportional to the distance between the source and sink. By optimally selecting the CH taking distance as the main factor the energy dissipation is reduced. The simulation results shows the effectiveness of the proposed algorithm on comparison with LEACH and ALEACH protocols. This protocol serves it purpose in agriculture monitoring, industrial monitoring and civil construction application where the sink is located out the cluster in WSN. EECHS presents a increased lifetime of 1.28 times the LEACH survivability.

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