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EDEEC-Enhanced Distributed Energy Efficient Clustering Protocol for Heterogeneous Wireless Sensor Network (WSN)

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Abstract: Wirless sensor networks(WSN) consists of widespread random deployment of energy constrained sensor nodes. Sensor nodes have different ability to sense and send sensed data to Base Station(BS) or Sink. Sensing as well as transmitting data towards sink requires large amount of energy. In WSNs, conserve energy & prolonging the lifetime of network are great challenges. Many routing protocols have been proposed in order to achieve energy efficiency in heterogeneous environment . This paper focuses on clustering based routing technique: Enhanced Distributed Energy Efficiency Clustering scheme(EDEEC). EDEEC mainly consists of three types of nodes in extending the lifetime & stability of network. Hence, It increases the heterogeneity and energy level of the network. Simulation results show that EDEEC performs better than DEEC & DDEEC.

Keywords: Clustering, Cluster-Head(CH), WSN- Wireless sensor Network, Energy Efficiency, DEEC- Distributed Energy Efficient Clustering, DDEEC-Developed Distributed Energy Efficient Clustering, EDEEC-Enhanced Distributed Energy Efficient Clustering.

1. INTRODUCTION

WSN is the network which consists of hundreds of tiny and compact sensor nodes that senses the physical environment. WSN have a wide variety of application including military, temperature, humidity, pressure, lighting condition[1] etc. Sensor nodes in WSNs are power constrained because of limited battery resources. Every sensor node consist sensing unit, processing unit, a transceiver unit and a power unit[2]. Routing protocols plays an important role in conserving energy in WSNs. Clustering technique[3] are used to minimize the energy consumption and hence increases the lifetime of network. Clustering technique can be implemented in two types of networks, homogeneous & heterogeneous networks. Homogeneous networks are those in which nodes are equipped with same initial energy while heterogeneous networks are those where initial energy differ.

Low Energy adaptive Clustering Hierarchy (LEACH)[4] is an example of heterogeneous WSNs, however, LEACH performance is poor in heterogeneous networks because in this algorithm the low energy nodes die more rapidly as compare to high energy nodes. Stable Election protocol(SEP)[5], Distributed Energy Efficient Clustering (DEEC)[6], Developed Distributed Energy Efficient Clustering(DDEEC)[7] are examples of heterogeneous networks.

DEEC[6] is cluster-based algorithm in which Cluster-Heads(CHs) are selected by probabilities based on ratio of residual energy of nodes and average energy of network. DEEC consists of two types of nodes i.e. normal nodes and advanced nodes where advanced nodes have more chances to be a CH than normal nodes. EDEEC follows the thoughts of DEEC and adds another type of node called Super node to enhance the heterogeneity.

The remainder of the paper is organized as follows: section2 contains the radio energy dissipation model, section 3 explains the heterogeneous network model, section 4 describes our proposed work EDEEC, section 5 lists the parameters used for simulation & also gives the result, section 6 consists of conclusion and section7 consists of references.

2. RADIO ENERGY DISSIPATION MODEL

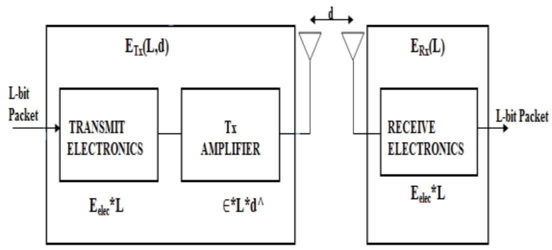

Fig. 2.1 Radio Energy Dissipation Model

Do Here, we use radio energy model based on [8]. The energy dissipated by node for radio transmission Etx(L,d) of message of L bits over a distance d to run both the transmitter electronics and transmitter amplifier is expressed as:

$$ETx(L,d) = \begin{cases} L \times Eelec + L \times \epsilon fs \times d^2 & \text{if } d \le do \\ L \times Eelec + L \times \epsilon amp \times d^4 & \text{if } d \ge do \end{cases}$$

Similarly, energy dissipated by a node for the reception ERx (L)[9] of message of L bits to run the receiver electronics is expressed by:

$$ERx = L \times Eelec$$

Where Eelec is transmitter electronics dissipation per bit is equal to receiver electronics dissipation per bit and ∈fs and ∈amp are transmit amplifier dissipation per bit per square meter.

Here, both the free space (d^2 power loss) and the multipath fading(d^4 power loss) channel models are used, depending on the distance between the transmitter(Tx) and receiver(Rx). If the distance is less than a threshold do, the free space channel model will be used otherwise multipath channel model will be used.

3. HETEROGENEOUS NETWORK MODEL

Here, we describe the network model. Assume that there are N sensor nodes, which are uniformly distributed within a M*M square area.

EDEEC considers three types of sensor nodes[10] with different energy levels i.e. normal nodes, advanced nodes, super nodes. Normal nodes have energy E_o. Let m be the fraction of advanced nodes have atimes more energy than normal nodes i.e. $E_o(1+a)$ while m_o is the percentage of total number of nodes n have b times more energy than normal nodes called super nodes i.e. $E_o(1+b)$. As N is the total number of nodes in network, then Nmm_o, $Nm(1-m_o)$ and $N(1-m)$ are the number of super , advanced, and normal nodes in the network, respectively.

The total initial energy of super nodes in WSN:
Esuper = NmmoEo(1+b)
The total initial energy of advanced nodes in WSN:
Eadvanced = Nm(1-mo)Eo(1+a)
The total initial energy of normal nodes in WSN:
Enormal = N(1-m)Eo
The total initial energy of three-level heterogeneous WSNs is calculated as:
Etotal = Esuper + Eadvanced + Enormal
Etotal = NmmoEo(1+b) + Nm(1-mo)Eo(1+a) + N(1-m)Eo
Etotal = NEo[1+m(a+mo(b-a))]
The three-level heterogeneous WSN has $m(a+m_ob)$ times more energy as compared to the homogeneous WSN.

4. EDEEC PROTOCOL

Figures EDEEC uses the same views of probabilities for CH selection depends on initial energy, remaining energy levels of nodes & average energy of the network as proposed in DEEC.

The average energy of r^{th} round is estimated from equation(1) is follows as:

$$E(r) = 1/N*E_{total}*[1-r/R] \qquad (1)$$

Where R denotes the total rounds of network lifetime.
R can be calculated as:

$$R=E_{total}/E_{round} \qquad (2)$$

where E_{round} is the enrgy dissipated in network in single round.

$$E_{round}= L(2*N*_{Eelec} + N*E_{DA} + k*\varepsilon mp*d^4_{toBs}+ N*\varepsilon f*d^2_{toCh)})$$

Where kis the number of clusters, E_{DA} is the cost expended in data aggregation by Ch, d_{toBS} is the average distance between Ch & Bs and d_{toCH} is average distance between CH members &CH.

d_{toBS} & d_{toCH} is calculated as:

$$dtoCH = M/\sqrt{2\pi k},\ dtoBS = 0.765*M/2 \qquad (4)$$

By finding the derivative of E_{round} w.r.t k to zero, we get optimal number of cluster k_{opt} as:

$$kopt =\sqrt{N}/\sqrt{2\pi}*\sqrt{\varepsilon f s}/\sqrt{\varepsilon mp} * M/ d^2BS \qquad (5)$$

During each round , node decide whether to become a CH or not based on threshold calculated by suggested percentage of CH and the number of times the node has been a CH so far. This decision is taken by nodes by chososing a random number between 0 & 1. If number is less than threshold T(s), the node become a CH for current round. Threshold is calculated as:

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i(r mod \frac{1}{P_i})} & if\ s_i \in G \\ 0 & otherwise \end{cases} \qquad (6)$$

P_i is suggested percentage of CH, r is current round &G is the set of odes that has not been cluster-head(CH) in previous $1/p_i$ rounds. Therefor, EDEEC consider Normal, Advanced and Super nodes. The probability for these three types of nodes are:

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ s_i\ is\ the\ normal\ node \\ \frac{p_{opt}(1+a)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ s_i\ is\ the\ advanced\ node \\ \frac{p_{opt}(1+b)E_i(r)}{(1+m(a+m_0b))\bar{E}(r)} & if\ s_i\ is\ the\ super\ node \end{cases} \qquad (7)$$

Threshold for CH selection is calculated for normal, advanced and super nodes by putting in equation(6):

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i\left(r\ mod \frac{1}{p_i}\right)} & if\ p_i \in G' \\ \frac{p_i}{1-p_i\left(r\ mod \frac{1}{p_i}\right)} & if\ p_i \in G'' \\ \frac{p_i}{1-p_i\left(r\ mod \frac{1}{p_i}\right)} & if\ p_i \in G''' \\ 0 & otherwise \end{cases} \qquad (8)$$

G' is the set of normal nodes that has not been become CHs during previous $1/p_i$ round od epoch where si is the normal node. G'' is the set of advanced nodes that have not been become CHs during past $1/p_i$ rounds of epoch. G''' is the set of super nodes that has been not been CH last of $1/p_i$ rounds of epoch.

5. SIMULATION & RESULTS

This section prents simulation result for DEEC, DDEEC, EDEEC and Proposed protocol for three level heterogeneous WSN using MATLAB.

Table 1. Simulation Parameters

Parameter	Value
Network Field	(100m , 100m)
Eo(Initial energy of the Normal Node)	0.5J
Message Size(L)	4000bits
Eelec	50nJ/bit
ϵfs	10 pJ/bit/m2
ϵamp	0.013 pJ/bit/m4
EDA	5 nJ/bit/signal
do(Threshold Distance)	70m
Pop(Suggested Percentage)	0.1
Number of Nodes (N)	100

The performance metrics use for evaluation of clustering protocols for heterogeneous WSNs is FND, HND, Number of Alive Nodes, Number of Dead Nodes and Network Remaining Energy. We consider a network containing 20 normal nodes having 0.5J energy, 30 advanced nodes having 1.5 times greater energy than normal nodes & 50 super nodes having 3 times greater energy than normal ones.

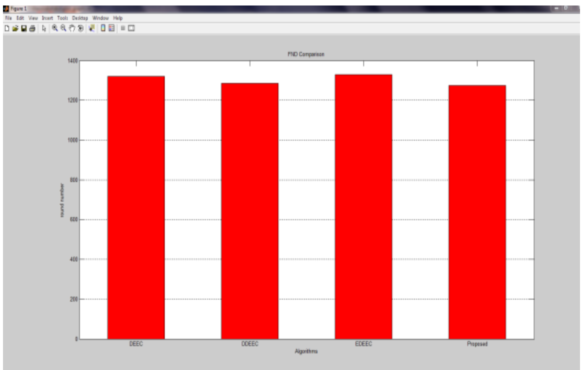

Fig.1 First Node Dead Comparison

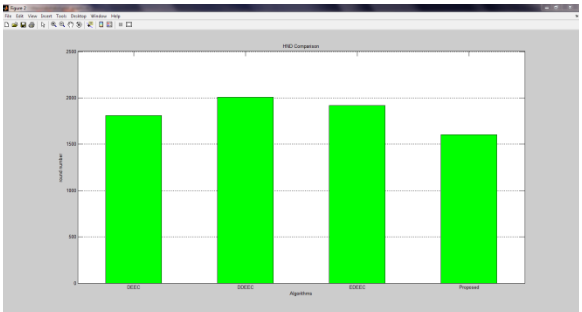

Fig.2. Half Node Dead Comparison

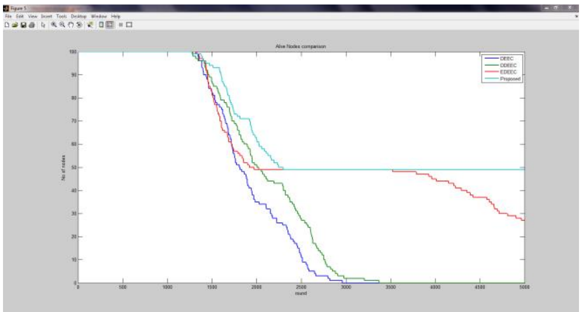

Fig.3. Alive Node Comparison

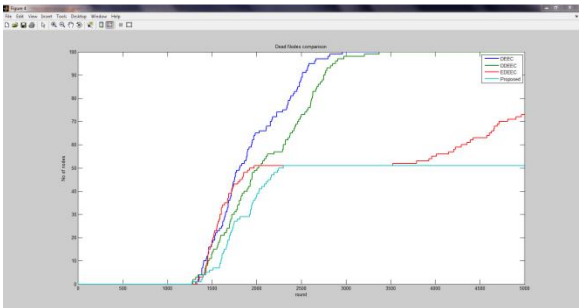

Fig.4. Dead Node Comparison

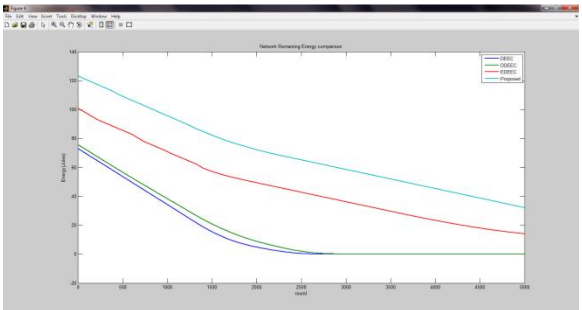

Fig.5. Network Remaining Energy

Fig.1. Shows that First node for DEEC, DDEEC, EDDEEC , Enhanced EDEEC dies at 1320, 1286, 1330, 1275 rounds respectively. Fig.2. shows that Half node dies at 1807, 2007, 1919, 1602. Fig.3. shows the Alive node comparison. Fig.4. Shows Dead node comparison. Fig.5. shows Network

remaining energy in Proposed protocol is more than that of DEEC , DDEEC and EDEEC.

6. CONCLUSION

Due to limited energy resources , energy conservation is one of the major challenge in design of protocol for WSNs. The ultimate objective of this protocol is to achieve the energy efficiency by prolonging network lifetime. EDEEC is and adaptive as well as energy aware routing protocol. This protocol increases heterogeneity by including concept of super nodes. The simulation analysis shows the Proposed protocol shows better result than DEEC, DDEEC, EDEEC. Hence Proposed protocol is most efficient among all protocols.

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