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IBEENISH: Improved Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol for Wireless Sensor Networks

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Abstract - Wireless Sensor Networks (WSNs) has different types of sensor nodes which are of low cost and scattered over a region to form the self organized network. These sensor nodes sense that data and send the report to the base station which requires lot of energy. In WSN developing energy efficient routing protocol is a major issue. Clustering is an efficient method which is used in sensor network to increase the energy efficiency. In heterogeneous protocols basically two levels or three energy levels of nodes are considered but actually there is high range of energy levels in heterogeneous WSNs. So we propose the improved version of BEENISH which is the IBEENISH (Improved Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol) with high range of energy levels. In this we assumed WSN having five energy levels of nodes. From the simulation result it is shown that IBEENISH performs better than existing routing protocols BEENISH (Balanced Energy Efficient Network Integrated Super Heterogeneous), Distributed Energy Efficient Clustering (DEEC), Developed DEEC (DDEEC) and Enhanced DEEC (EDEEC) in terms of stability, effective messaging and lifetime.

Keywords - CH, Heterogeneous, Residual Energy, Energy Efficiency, WSNs.

1. Introduction

Wireless sensor networks consist of a various networks which contains hundreds of different sensor nodes which are deployed in the area of interest. Various physical factors like temperature, vibration and humidity like factors are sensed by nodes. These are used in various applications like traffic monitoring, military surveillance and in disaster areas. These sensor nodes collect all the feasible data from sensing field and send that data to the base station also known as sink. Due to limited battery in WSN, nodes are power constrained. It is not always possible to recharge the battery in the network or replacement of nodes as it may present far away from the base station [1]. For this problem, a technique is evaluated known as clustering. In this cluster head in network field is selected from the members of the cluster for decreasing battery consumption. In the Hierarchical based routing protocol the nodes with more energy in the network are selected randomly for sending and process that data while the nodes which have less energy than the threshold energy only sense the data and then send information about the data to the cluster heads. By this method sensor networks are enabled to work more proficiently. For the long distance transmissions, we use clustering by which there is reduction in energy dissipation [2, 3]. Cluster head is selected by sensors which have highest energy from all the nodes in the network field. All the information from the sensor nodes are send to the cluster head which then send the aggregated information to the base station.

Clustering algorithms has two main phases: Setup phase in which election and creation of cluster head is performed and Steady phase in which data is send from the different member nodes to the cluster head and then aggregated that information to the sink node. It decreases the energy consumption of the sensor network and hence increases the lifetime.

There are basically two different types of networks in the wireless networks, homogeneous and heterogeneous networks. Clustering is done for these two types of wireless networks, on the basis of residual energy and the average energy of the network [4, 6]. In Homogeneous networks all the nodes start up with the same initial energy in the network. LEACH [7], PEGASIS [8] and HEED [9] are examples of cluster based protocols in homogeneous networks. In Heterogeneous networks all the nodes have different initial energy in the network. SEP [12], DEEC [13], DDEEC [14] and EDEEC [15] are examples of protocols in heterogeneous networks.

2. Related Work

The [7] clustering method in homogeneous WSNs is firstly introduced in the protocol which is named as LEACH (Low-Energy Adaptive Clustering Hierarchy). In this algorithm, CHs are selected randomly among the nodes and this selection criterion goes on over the entire network so that the entire energy load is distributed. PEGASIS [8] is a sequence based protocol which is an improvement of LEACH protocol and avoids cluster formation. So in chain only one single node is used to send data to the BS instead of using many nodes in the network.

In [10], a new energy efficient protocol is proposed named as Threshold sensitive Energy Efficient sensor Network protocol (TEEN). In this protocol hierarchical approach is used along with the data centric mechanism. The cluster head broadcasts two thresholds (hard and soft) energy values to the nodes. TEEN is suitable for time critical applications but not for those applications that require periodic reports because the user may not get information if any threshold does not reached. In[11] centralized clustering algorithm is proposed named as LEACH centralized (LEACH-C), which has same steady state as LEACH. In addition this gives better results and performance by dispersing all the cluster heads in the entire network.

In [12] a new heterogeneous protocol is proposed called as SEP to extend the time interval before the death of the first node. In this protocol every sensor node selects the CH based on its initial energy in the network and compared the initial energy to other member nodes. SEP protocol is dynamic in nature such that we do not need any assumption regarding division of different energy levels in sensor nodes in the network field. In [13] a protocol which is proposed based on heterogeneous WSN and it is named as DEEC. In this protocol, the election of cluster head is based on the probability of the residual energy of the network to the average energy of the network. From the simulation results it is shown that this protocol performance is far better than the other existing protocols.

3. Radio Energy Dissipation Model

In the radio energy model, transmission of 1-bit message in a network over a distance d is described and shown in Figure 1. This is the radio hardware energy dissipation model in which the energy of transmitter is dissipated to run in the electronics and in the power amplifier, and the energy in receiver end is dissipated to run the radio electronics in the network [5, 6].

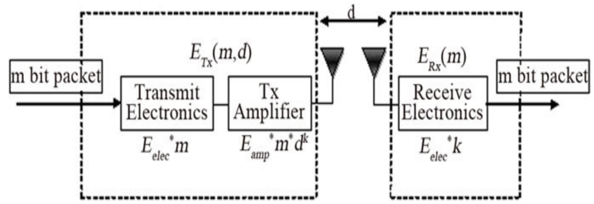

Fig 1: Radio Energy Dissipation Model

For achieving an acceptable Signal-to-Noise Ratio (SNR) while transmitting m−bit message in the network over a distance d, the energy is calculated by the radio is shown as:

$$E_{Tx}\,(m, d) = \begin{cases} m \cdot E_{elec} + m.\varepsilon_{fs} \cdot d^2 \text{ if } d \le d0 \\ m \cdot E_{elec} + m \cdot \varepsilon_{mp} \cdot d^4 \text{ if } d > d0 \end{cases} \quad (1)$$

Where E_{elec} is the energy parameter which is used as per bit to process in transmitter or receiver circuit. The parameters fs and mp are represented as free space and multi path model respectively. fs is used when the distance is less than the threshold value which we set in the network and if the distance is far from the destination then mp is used. These both values depend and work on the transmitter amplifier model in the network field. The value d is the distance which is calculated between the sender and the receiver. WhereE_{elec}, depends on different factors in network such as the digital coding, modulation, filtering, and scattering of the signal which is useful to reduce the error in the network, whereas the radio amplifier energy depends totally on the distance to the receiver and the acceptable bit-error rate.

For a particular round in the network, total energy dissipated is given below, as supposed in [10, 11].

$$E_{round} = k\,(2NE_{elec} + NE_{DA} + h\varepsilon_{mp}{d^4}_{toBS} + N\varepsilon_{fs}{d^2}_{toCH}) \quad (2)$$

Where h represents number of clusters
E_{DA}= Data aggregation cost expended in CH
d_{toBS}=Distance between the CH and BS
d_{toCH}=Distance between the cluster members and the CH

The value d_{toBS} and d_{toCH} can be calculated by the following equation by assuming all the nodes is uniformly distributed in the network.

$$d_{toCH} = \frac{M}{\sqrt{2\pi h}},\ d_{toBS}=0.765\frac{M}{2} \quad (3)$$

The value of h_{opt}optimal number of clusters is calculated by finding the derivative of E_{round} with respect to h to zero.

$$h_{opt}=\frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}.\frac{M}{{d^2}_{toBS}} \quad (4)$$

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4. IBEENISH Protocol

The details of IBEENISH protocol is presented in this section. IBEENISH implements the same concept as in BEENISH as it is the improvement of BEENISH protocol. The selection of cluster head is totally based on residual energy level of the nodes in the network with respect to average energy of the network. BEENISH uses the concept of four level hierarchy model which has four types of nodes; normal, advance, super and ultra-super nodes while IBEENISH uses the concept of five level hierarchies which contain five types of nodes; normal, intermediate, advance, super and ultra-super nodes.

Each node is passed through various rounds to become a cluster head and referred to as rotating epoch. A node is denoted by (s_i) for a number of rounds (n_i). CH should consume more energy because node with high energy select as CH and all the other cluster member nodes have less energy compared to CH. In IBEENISH for the cluster head election process, the ultra-super nodes are mostly used because these nodes have highest energy as compared to super nodes, advance nodes, intermediate nodes and normal nodes.

The average p_{opt} of CHs in each single round for homogeneous networks, LEACH assumes each node to become CH once in the every network field $n_i = \frac{1}{\text{popt}}$ rounds. In the WSN all the nodes have different remaining energy in the network. So, in LEACH protocol if the value of n_i should be same for all nodes then the distribution of energy in the network field is not efficient and the nodes which have less energy will die before nodes having high energy. IBEENISH uses different criteria from LEACH by choosing different n_i for different nodes with respect to their different remaining energy in the network E_i(r). Nodes which have high energy in network are elected as CH firstly with respect to low energy nodes. Here we assume that probability of each node to select the CH during n_i rounds is uniform. If the every energy level for all the nodes has same value at each epoch then there is the probability factor which determines that all the nodes may die at same time. So if the all nodes have dissimilar energy then p_i larger than p_{opt} for the nodes with more energy.

In IBEENISH, the energy of r^{th} round can be obtained as follows:

$$E(r) = \frac{1}{N}\, E_{\text{total}}\, (1 - \frac{r}{R}) \quad (5)$$

R represents the total number of rounds from the start of network till all nodes die and can be calculated as:

$$R = \frac{E_{\text{total}}}{E_{\text{round}}} \quad (6)$$

To achieve the optimal number of CH, node s_i decides that either to become a CH or not it is based on the probability of threshold calculated with the following equation:

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i (r \bmod \frac{1}{p_i})} & \text{if } s_i \in G \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

Where G represents the number of nodes that are adequate to become CH in the network. The any node that doesn't have any chance to elect the CH in recent case then it belongs to the set of G. If the value is less than threshold T (s_i), then for the current round that node is selected as CH.

WSNs contain three or four energy levels of nodes in the real scenarios. For the random CH selection, large range of energy levels is required in the network. The results should be better in terms of energy efficiency if we quantize the different energy levels and uniform probability which is defined for each energy level. In IBEENISH, we use the concept of five level heterogeneity networks which are having normal, intermediate, advance, super and ultra-super nodes. The probabilities for each type of nodes are as follows:

$$p_i = \begin{cases} \frac{p_{opt} E_i(r)}{\left(1+m\,(a+m_o(-a+b+m_1(-b+u)))\right)E(r)} & s_i \text{ is the normal node} \\ \frac{p_{opt}(1+a) E_i(r)}{\left(1+m\,(a+m_o(-a+b+m_1(-b+u)))\right)E(r)} & s_i \text{ is the intermediate node} \\ \frac{p_{opt}(1+b) E_i(r)}{\left(1+m\,(a+m_o(-a+b+m_1(-b+u)))\right)E(r)} & s_i \text{ is the advanced node} \\ \frac{p_{opt}(1+c) E_i(r)}{\left(1+m\,(a+m_o(-a+b+m_1(-b+u)))\right)E(r)} & s_i \text{ is the super node} \\ \frac{p_{opt}(1+d) E_i(r)}{\left(1+m\,(a+m_o(-a+b+m_1(-b+u)))\right)E(r)} & s_i \text{ is the ultrasuper node} \end{cases} \quad (8)$$

Simulation results show that the IBEENISH is more stable protocol than DEEC, DDEEC, EDEEC and BEENISH for WSN which containing five level heterogeneity which shows better result in first node die and last node die.

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5. Simulations and Results

In This section the results of the Improved BEENISH protocol are obtained as well as its comparison with other protocols like DEEC, DDEEC, EDEEC and BEENISH. All of the algorithms are simulated in Matlab. The initial parameters taken to implement the IBEENISH protocol are mentioned in Table 1.

Table 1: Initial parameters for implementing the IBEENISH protocol

Parameter	Description	Value
xm x ym	Dimensions of Field	100m x 100m
N	No of Nodes	100
P	Probability of a node to become CH	0.1
Eo	Initial energy of each node	0.5 J
ETX	Transmission energy of node	50*0.000000001 J
ERX	Receiving energy of node	50*0.000000001 J
EDA	Data aggregation energy	5*0.000000001 J
Efs	Energy dissipation for free space	10*0.000000000001 J
Emp	Energy dissipation for multi-path delay	0.0013*0.000000000001 J
Packet	Packet size	4000

In the implementation procedure, a multilevel clustering model is employed in which all the nodes with dissimilar energy levels are randomly deployed within a space region called field.

Figure 2 represents the total number of nodes alive during the lifetime of the network. Stability period and lifetime of IBEENISH is far better as compared to other protocols and has less unstable period. Figure 3 represents the total number of nodes dead during the lifetime of the network. Figure 4 shows the comparison in terms of number of data packets received to the base station which is called sink. It is clear that IBEENISH has more numbers of data packets that is it has more throughput value which is received at base station with comparison to the other existing protocols.

We have simulated and deployed all the nodes in wireless sensor network in a network sensing field of 100m x 100 m. Simulation parameters are used in the table 1. We estimated the performance of five level and multi-level heterogeneous WSNs in the network field. We examine the performance of DEEC, DDEEC, EDEEC, BEENISH and IBEENISH for five level and multi-level heterogeneous WSNs. We take the parameters; $m = 0.5$, m0 = 0.3, m1 = 0.2, m2= 0.1 a = 3, b = 1.5, c = 4.5, d=6. In our scenario, we have deployed 70% normal nodes which have $E0$ energy, 10% intermediate nodes have 2.5 times more energy than normal nodes, 8% advanced nodes have 4 times more energy than normal nodes, 7% super nodes have 5.5 times more energy than normal nodes and 6% ultra super nodes have 7 times more energy than normal nodes.

Figure 2 represent the total number of nodes alive during the lifetime of the network. It clearly shows that by introducing of ultra super nodes in network its lifetime increases. Stability period and lifetime of IBEENISH is longer as compared to BEENISH their first node dead at 1907 and 1755 respectively and unstable period of BEENISH and other protocol is longer than IBEENISH.

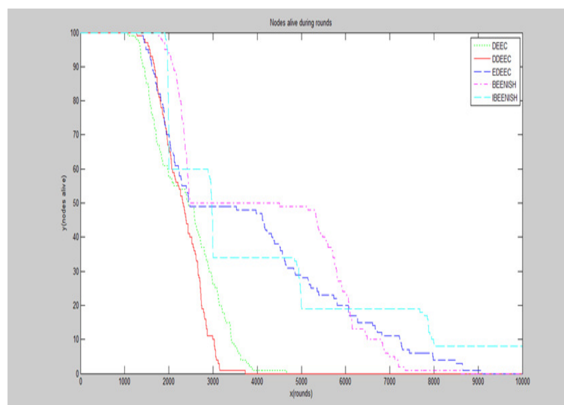

Figure 2 Alive nodes v/s rounds plot comparison of IBEENISH with other existing protocols

Figure 3 represent the number of nodes dead during the lifetime of the network. Stability period and lifetime of IBEENISH is longer as compared to BEENISH their all node dead at 10000 and 8231 respectively.

Figure 4 shows IBEENISH sends more data packets to the BS that is it has more throughput value than the DEEC, DDEEC, EDEEC and BEENISH. IBEENISH is more efficient when it is compared to the other protocols in terms of stability period of network, network life time and number of packets sent to the BS.

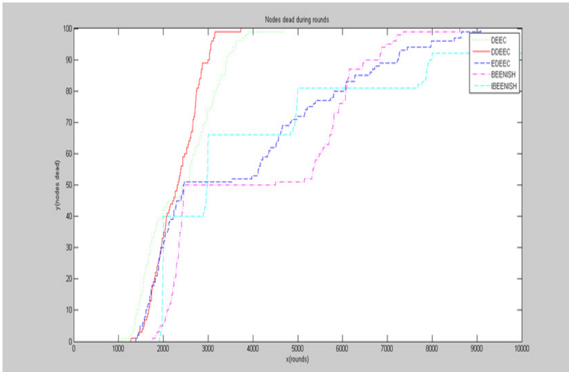

Figure 3 Dead nodes v/s. rounds plot for IBEENISH with other existing protocol

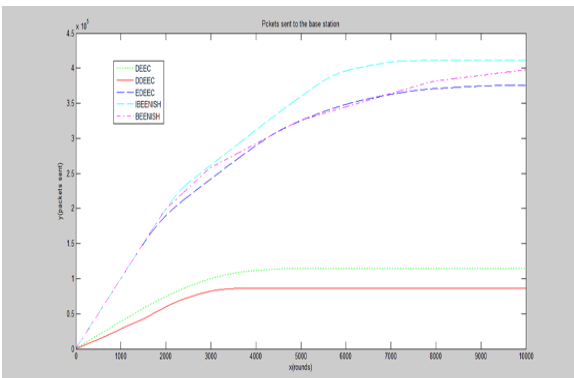

Figure 4 Packets to BS v/s rounds plot comparison

6. Conclusion

In summary, the results of the existing protocol DEEC, DDEEC, EDEEC and BEENISH with our new IBEENISH protocol are presented. From results and comparison it is proved and verified that IBEENISH protocol improves the throughput and stability as well as lifetime of wireless sensor networks by an order of magnitude which is significant when compared with existing BEENISH protocol as well as existing DEEC, DDEEC and EDEEC protocols.

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