ENHANCED-BALANCED ENERGY-EFFICIENT NETWORK INTEGRATED SUPER HETEROGENEOUS PROTOCOL FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

As much as Wireless Sensor Networks (WSNs) have found vast use in all aspects of life, continuous efforts are made every day to make them more energy efficient. Clustering the nodes to avoid redundancy of data is a way to go. Further, numerous routing protocols have been proposed which select optimum path for data routing. In reality, nodes have many levels of energy, thereby constituting a heterogeneous network. We propose and evaluate Enhanced Balanced Energy-Efficient Network Integrated Super Heterogeneous (E-BEENISH) Protocol for Wireless Sensor Network. It assumes that WSN has five levels of energy and clusters them into groups accordingly. Node with maximum amount of residual energy within the cluster is elected as a cluster head. The scenario is simulated using MATLAB, and the results clearly show that the protocol we proposed is an improvement on already existing routing protocols. We achieve significant improvement in network lifetime and stability.

Keywords: Wireless Sensor Networks; cluster head; energy efficiency; heterogeneous; system lifetime; residual energy

1. INTRODUCTION

The wireless sensor networks (WSNs)[1,2,3] have emerged as an important part of our lives as they are known to support a wide variety of applications in day-to-day life; also because of their property of flexibility they pose as a research challenge. The nodes use wireless communication, mostly wireless radio, to connect with each other and also with base station [4,5,6]. The data collected is rarely processed by the nodes due to memory and battery limitations; hence it is passed on to remote device where it is analysed, processed upon or stored. It will consume a lot of energy if a node had to send its data in a single hop to the base station and will deplete its resources much faster than the node that is in close proximity to the base station.

Also nodes deployed in the same geographical location may sense same data. It will be useless to pass on duplicate data to sensor. This is sheer wastage of time and resources. Clustering of the nodes helps overcome these limitations. Only processed and concise data should be forwarded to the base station. It is up to the nodes to employee an efficient routing policy which sends data to destination through a number of hops. Additional features of increased node stability, system lifetime, throughput and fault tolerance are incorporated in the routing protocol.

This paper is organized in such a way that it starts with an introduction about the existing related routing protocols, and our protocol (Enhanced-Balanced Energy Efficient Network Integrated Super Heterogeneous, EBEENISH) is discussed in detail in the third section. Upcoming fourth section deals with analysis of protocol performance and its comparison with the existing protocols is. Finally the results are compared into a comprehensive conclusion.

2. RELATED WORK AND MOTIVATION

Efficiently grouping the sensor nodes into clusters helps us achieve our goal of energy efficiency. Nodes which lie in close proximity of each other are likely to pick-up same data. To avoid sending the duplicate data to base station, this data must be aggregated. This process is known as data aggregation and this task is entrusted with the cluster head. Data aggregation may also be explained as local compression to reduce global communication. Another responsibility of the CH is to select a MAC protocol for collision avoidance and reliable delivery of the information. WSNs are grouped into two forms based upon the energy levels of the nodes: homogeneous and heterogeneous networks. They are defined as follows:

Homogeneous Networks: All the nodes constituting the network have their initial energies at same level. Many cluster based routing protocols have come into picture for homogeneous WSNs e.g. Low-Energy Adaptive Clustering Hierarchy (LEACH) [7], Power-Efficient Gathering in Sensor Information System (PEGASIS) [8], and Hybrid Energy-Efficient Distributed clustering (HEED) [9]. Their performance is limited in the case of non-equable energy consumption by nodes due to radio channel characteristics, fault in links or morphological features of field.

Heterogeneous Networks: There are more than one energy levels present for the nodes. Stable Election Protocol (SEP) [10], Distributed Energy Efficient Clustering (DEEC) [11], Developed DEEC (DDEEC) [12], Enhanced DEEC (EDEEC) [13] and BEENISH [14] are protocols for heterogeneous WSNs.

3. THE RADIO DISSIPATION MODEL

We make use of standard Radio Dissipation Model [7,8] to calculate the average energy of the network and trends in which energy is dissipated per bit and per round bases.

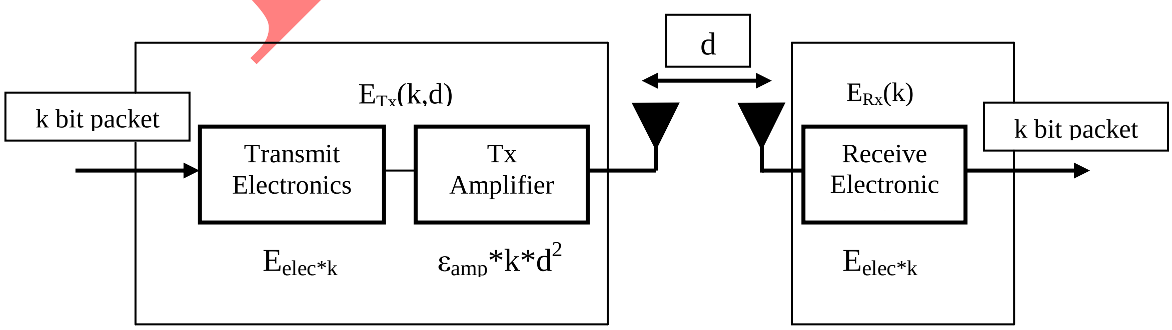

Fig.1 Radio Energy Dissipation Model

Every time data is sent, the radio unit of sensor node dissipates some amount of energy. This energy is consumed by the electronic circuitry at both transmitter and receiver ends. To save more energy the radio unit should be put to sleep in the situation where there is no data to be shared. The mathematical equations that come into play are

$$E_{Tx}(l,d) = f(x) = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2, & d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4, & d \geq d_0 \end{cases} \quad (1)$$

where, E_{elec} is energy consumed per bit

Power control is achieved by taking the different model based on the threshold d_0; if distance is less that d_0, free space (fs) model is put to use; otherwise multi-path (mp) model.

Energy dissipation per round, E_{round} is given as follows

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

where, k= number of clusters,
E_{DA}= Data aggregation cost expended in CH
d_{toBS}= Average distance between CH and BS
d_{toCH}= Average distance between cluster members and CH

Value of d_0 is calculated by

$$d_0 = \frac{\varepsilon_{fs}}{\varepsilon_{mp}} \quad (3)$$

Assuming uniform distribution of nodes in the field;

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}}, d_{toBS} = 0.765\frac{M}{2} \quad (4)$$

Finally, the optimum number of clusters that need to be formed to cover the entire field are found out by:

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\frac{M}{d^2_{toBS}} \quad (5)$$

4. THE E-BEENISH PROTOCOL

In this section, we present and explain upon our protocol. Enhanced Balanced Energy-Efficient Network Integrated Super Heterogeneous protocol works on the guidelines of BEENISH i.e. CH are dynamically selected based on residual energy of individual node and overall average energy of the network. The difference lies in quantization of energy levels. BEENISH had nodes classified into four types: Normal, Advanced, Super and Ultra-Super nodes. Here we introduce one more type of node, Extreme node, along with exciting four types. It lets each node expend energy evenly by rotating the cluster-head role among all nodes.

Any node s_i(i=1,2,...N) becomes CH after n_i rounds, where n_i is rotating epoch. Node that assumes the role of CH has more energy expenditure. We need to maintain p_{opt} N CHs in each round . LEACH achieves this by making each node as CH after every $n_i = 1/p_{opt}$ rounds as all nodes are assumed to be possessing equal amount of energy. In the case of Heterogeneous networks, we cannot keep equal epoch for all nodes. If done so, the nodes with low energy will die out soon. E-BEENISH applies the approach to calculate epoch for each node based on its residual energy, $E_i(r)$. Sensor nodes with higher energy are moe likely to be selected as CHs. So in our protocol, E-BEENISH, extreme nodes get to be CH more often than others. This ensures equal distribution of energy among all the nodes.

We also need to calculate average energy of network for r^{th} round. This is done using the following formula [11]

$$\bar{E}(r) = \frac{1}{N} E_{total}\left(1 - \frac{r}{R}\right) \quad (6)$$

where, R is the number of rounds till all nodes die. The calculation for R is done as same in DEEC.

$$R = \frac{E_{total}}{E_{round}} \quad (7)$$

where, E_{round} is energy dissipated per round.

We need optimal number of CHs to cover the whole WSN area. So at the commencement of each round, each s_i node computes probability threshold [10, 17]. Based on the value obtained, the node makes a decision whether to be a CH or not.

$$T(s_i) = \begin{cases} \dfrac{p_i}{1 - p_i\left(r \bmod \frac{1}{p_i}\right)}, & if\ s_i \in G \\ 0, & otherwise \end{cases} \quad (8)$$

where, r is the current round and
G denotes set of nodes eligible to become CH.

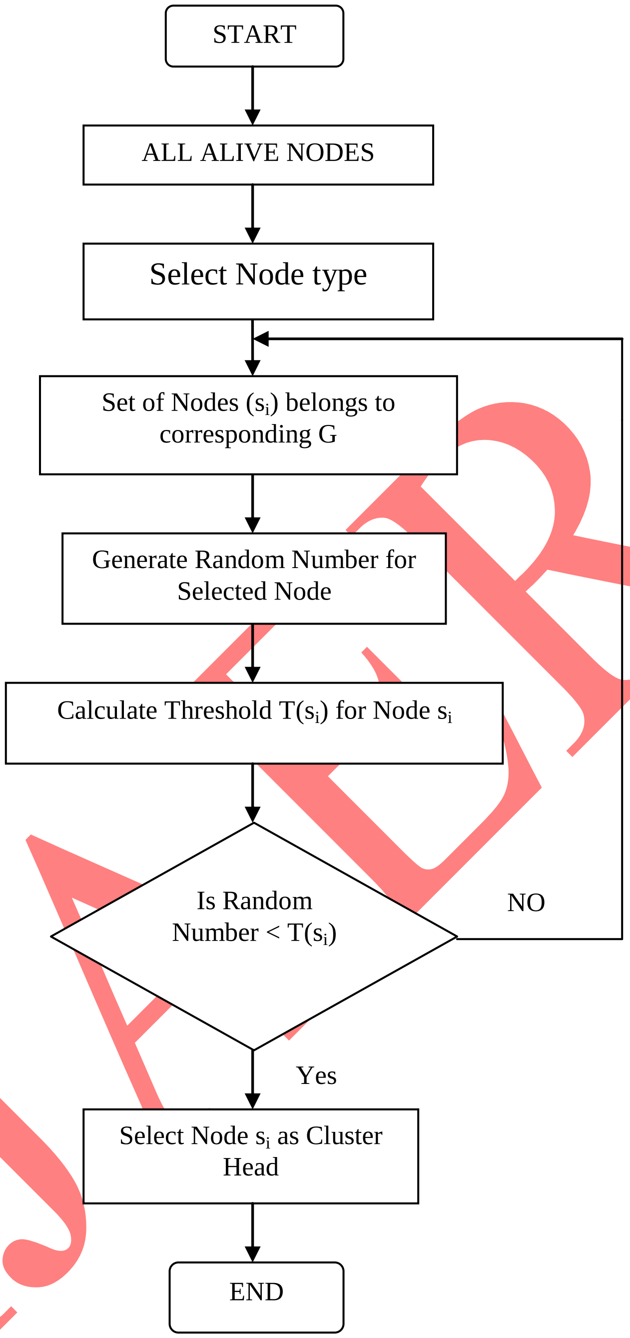

Fig.2 Flow Chart for Cluster Head selection

The node should not have been a CH in recent epoch n_i. All nodes in set G select a number between 0 and 1 randomly. For node s_i to be CH in current round, the number should be less than $T(s_i)$.

Practically we do not have discrete energy levels for nodes. The energy must be quantized for computational purposes. Giving greater probability to nodes with higher energy, to be selected

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as CH, helps in better distribution of energy and more reliable message transmission.

In E-BEENISH, we segregate the nodes into five types: normal, advanced, super, ultra-super and extreme nodes. The probability for their selection as CH is given as follows

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{\left(1+m\left(a+m_0\left(-a+b+m_1\left(-b+u+m_2\left(-u+mm\right)\right)\right)\right)\right)E(r)} & s_i \text{ is the normal no} \\ \frac{p_{opt}(1+a)E_i(r)}{\left(1+m\left(a+m_0\left(-a+b+m_1\left(-b+u+m_2\left(-u+mm\right)\right)\right)\right)\right)E(r)} & s_i \text{ is the advanced no} \\ \frac{p_{opt}(1+b)E_i(r)}{\left(1+m\left(a+m_0\left(-a+b+m_1\left(-b+u+m_2\left(-u+mm\right)\right)\right)\right)\right)E(r)} & s_i \text{ is the super no} \\ \frac{p_{opt}(1+u)E_i(r)}{\left(1+m\left(a+m_0\left(-a+b+m_1\left(-b+u+m_2\left(-u+mm\right)\right)\right)\right)\right)E(r)} & s_i \text{ is the ultra super nc} \\ \frac{p_{opt}(1+u)E_i(r)}{\left(1+m\left(a+m_0\left(-a+b+m_1\left(-b+u+m_2\left(-u+mm\right)\right)\right)\right)\right)E(r)} & s_i \text{ is the extreme nc} \end{cases} \quad (9)$$

Putting the computed values of p_i in $T(s_i)$ we find out corresponding probability threshold respectively.

The aim of computing $T(s_i)$ is to give higher probability to nodes with more residual energy $E_i(r)$ to become CH in comparison to nodes with lower energy. Along with optimal distribution of energy, parameters like stability of network which in turn depends on time when first node dies and Network Lifetime based on time at which last node dies, are also enhanced.

5. SIMULATION AND RESULTS

This section evaluates the simulation results of EBEENISH on MATLAB. The simulating environment comprises of 100 sensor nodes deployed in 100m x 100m field. All nodes are assumed to be either stationary of micro-mobile. We also do not take into consideration the inter-node signal interference that is due to dynamic random nature of channel and other environmental factors. The radio parameters taken in this simulation are given in Table 1. To show the improvement achieved, results of EBEENISH are compared with that of BEENISH and DEEC. As seen from Fig.3, first node die for DEEC, BEENISH and EBEENISH is at 1075, 1313 and 1337 rounds respectively. Also all nodes die at 2323, 3019 and 3797 rounds, respectively. Fig.4 supports our claim that more data is being sent to BS in EBEENISH over BEENISH and DEEC. EBEENISH is more competent as compared to all protocols in terms of stability period, network life time and packets sent to the BS, hence achieves our motive of energy efficiency.

Parameters used in Simulation	Parameter Value
E_{elec}	5nJ/bit
ε_{fs}	10 pJ/ bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
E_0	0.5 J
E_{DA}	5 nJ/bit/message
d_0	87.70 m
Massage size	4000 bits
p_{opt}	0.1

Table1. The Radio Parameters

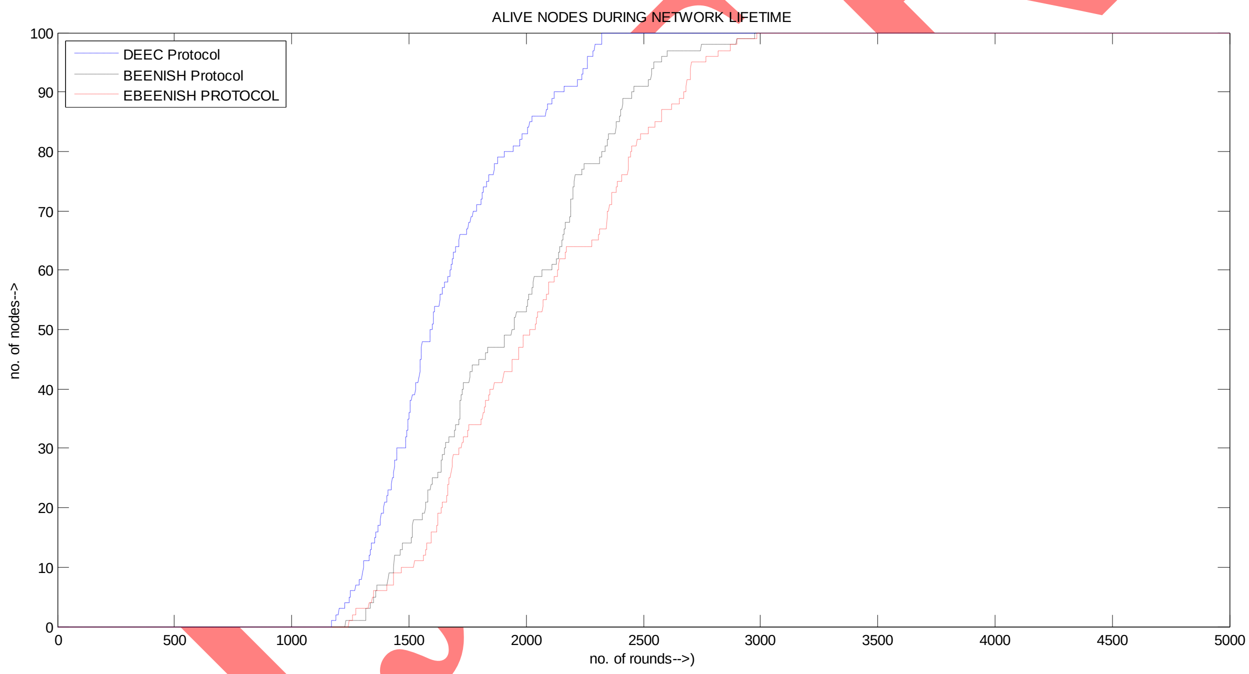

Fig.3 Alive Nodes during Network Lifetime

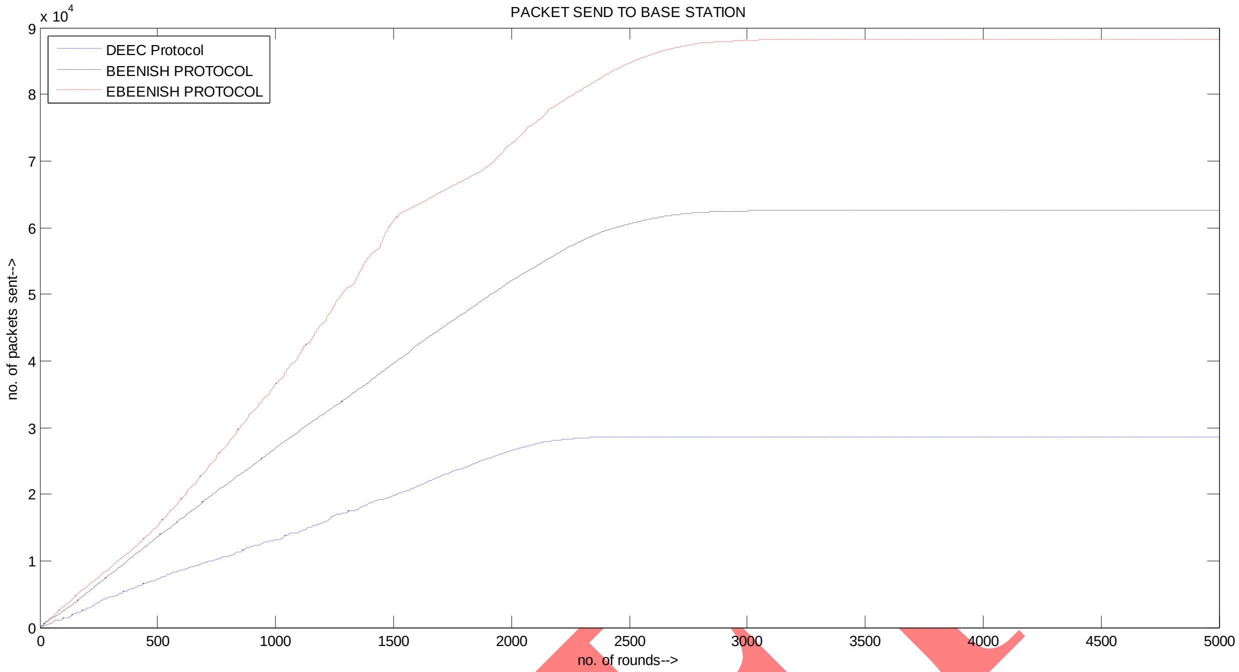

Fig.4 Packets sent to BS

6. CONCLUSION

Hence EBEENISH is a clustering based routing protocol that achieves energy efficiency by carefully assigning the role of cluster head to higher-energy node on probability bases. So, during different simulation time, each node has responsibility of gathering data from nodes in its cluster, local compression and transmitting it to the base station; forcing it to dissipate larger portion of its energy. Further, EBEENISH is dynamic in nature. This means that there is no prior allocation of the different levels of energy in the sensor nodes. Also this is a scalable protocol i.e. knowledge of precise location of each node in the field is not a mandatory criteria. Hence, distributing the energy consumption on round bases to all the nodes reduces global energy dissipation and achieves longer network lifetime and stability.

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