PERFORMANCE EVALUATION OF DISTRIBUTED ENERGY EFFICIENT CLUSTERING WITH MODIFIED THRESHOLD PROTOCOL IN WSN

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Abstract—A wireless network consists of geographically distributed sovereign devices and uses sensors for cooperative monitoring physical conditions. It comprises number of small, and relatively inexpensive and low-power sensors that are connected to the wireless network, constituting a wireless sensor networks (WSNs). They had a wide range of applications e.g. in physiological monitoring, environmental applications, military applications and home security etc. We have developed a purely deterministic model using a Distributed Energy-efficient Clustering Protocol with Modified Threshold (DEEC-MT) by clustering nodes to organize the WSN. The DEEC-MT is dynamic, distributive, self-organized and more energy efficient than the existing protocols. Simulation results showed a better performance with respect to energy consumption, which is reflected in the network lifetime under both homogeneous and heterogeneous settings, when compared with the existing protocols. The approach estimates an optimal solution for the balanced energy consumptions in ordered wireless sensor networks.

Keywords – WSN; DEEC; BCDEEC, DEEC-MT, clustering energy, cluster head, energy efficient algorithms

I. INTRODUCTION

A wireless sensor network (WSN) often outlined as a network, consist of low-size and low-complex devices, and are referred as sensor nodes. The sensor nodes can sense the environment and gathered the knowledge from the field and communicate through wireless links. Information collected is forwarded through multiple hops to a sink (also known as controller) which it used had domestically or in an alternative networks. Therefore, designing the protocols and applications for such networks needs focus on energy to prolong the networks' lifetime. Because of the low deployment of cost requirement of WSN's, sensor nodes having simple hardware and the severe resource constraints. Therefore, it is a demanding task to provide dynamic solutions to data gathering problem. Among these efficient solutions to data gathering issue [11]. Among all these constraints, power of battery is the most defining factor in the designing WSN protocols. The substitution of connected batteries is a troublesome method, when the nodes are fit in or installed. Each node has limited energy resource and battery power, and therefore, the replacement of battery is practically impossible. The energy constraint is improbable to be solved shortly due to the slow progress in the development of battery capacity. Therefore, the credible possibility in this direction is to find an efficient algorithm which can provides energy for a larger lifetime. The average number of sensors in a WSNs varied between is 500 and 1000. An energy efficient sensor can increase the lifetime of the whole sensor network system to a great extent. The clustering is carried out based on two important condition, energy level and coordinates of sensor nodes [1]. Numerous clustering techniques are available which reduce the energy consumption, but the well known and widely used clustering approach is the Low Energy Adaptive Clustering Hierarchy (LEACH). Several studies have used clustering to manage WSNs [5 7, 10-17, 20, 23]. The clustering process involves electing leaders among the sensor nodes. Once the cluster-heads are elected, they gather the information from their respective cluster members. The gathered information is refined using data compression techniques, and then the aggregated data is transmitted to the base station (BS). The formation of cluster-head is an energy consuming task [2, 20]. The rotating cluster-head involves energy gains, compared to the fixed cluster head. Therefore, the most important factor for protocol design of a distributive WSN is the management of energy consumption. Previously, the rotation of cluster-heads is carried out in a randomized manner, and the election is not guaranteed to be optimal. But, we have used an DEEC-MT technique that uses a residual energy of sensors for the election of a cluster-heads.

II. PROBLEM FORMULATION

Several researchers have used the probabilistic-based model to manage energy consumption in WSNs [12, 15, 17-18]. The prime objective of such protocols was to extend the WSN lifetime using the global information derived from the network without considering the local information i.e. the residual energy of each node. The major disadvantage of such protocols is that there is no guarantee that the desired number of cluster heads will be elected or the elected cluster heads will have enough energy to perform its duty as a leader. There is a report, that a deterministic cluster's head selection algorithm that can outperform the probabilistic-based algorithm which in terms of the energy consumption [19]. However, the model used is still probabilistic-based with deterministic components introduced. The model suffering from same problem that of unguaranteed cluster head(CH) election per round same as with the other models [6, 12, 15, 17-18]. Although, LEACH protocol proposed an best settings that assure the best performance by their stochastic model, but most of the time the result could be sub-optimal due to the uncertainties in the cluster-head election process. A generic probabilistic model used by these protocols is given in Eq. (1).

$$T(Px) = \left\{ \frac{\frac{Px}{1 - Px[r \bmod (1/Px)]} X\, Q, \quad if \quad nx \in G';}{0 \quad , \quad otherwise} \right\}$$

(1)

Where, 'x' could be *nrm, adv and sup* i.e. normal, advanced or super nodes respectively and 'Q' is an additional quantity that can be defined as a function of the ratio of the residual energy of each node or just a constant value. For example in [4,12, 15, 18] Q is set to one. However, a deterministic quotient for the value of Q, which is computed for each round for all the nodes in order to improve the LEACH protocol [19]. According to the threshold indicator function in Eq. (1), every node decides the cluster-head for each round r. The sensor node chooses a random number between 0 and 1. If this is lower than the threshold for node n, $T(n)$, the sensor node becomes a cluster head. Here G denotes a set of non-elected cluster-member and Px is the probability of being elected as cluster head. Distributed Energy-Efficient Clustering Protocol (DEEC) [16], improved LEACH by considering a two-node heterogeneous setup. Similarly, Balanced and Centralized Distributed Energy-Efficient Clustering Protocol (BCDEEC) [12], improved the DEEC and LEACH, by using a three-node heterogeneous setup. Both the BCDEEC and DEEC protocols adapted the indicator function in Eq.(1) to fit their model estimations by using intermediate and advanced nodes, respectively.

Eq. (1) also defines different probabilities (Px) for different nodes used in the network to improved lifetime. According to these protocols, the operation of the clustering process begins with a setup phase when all nodes use the indicator function for election as cluster heads. The elected cluster heads broadcast advertisement message (ADV) using the non-persistent carrier sense multiple access (CSMA MAC) protocol. This message contains the cluster heads (CH's) ID and a header indicates an announcement message. The non-elected nodes are called cluster members which determine their cluster and choose the cluster head by minimum communication cost that based on the received signal's strength of the advertisement message. The cluster members send Join-request to their chosen cluster head using CSMA MAC protocol. This message contains the CM-ID (cluster member-ID), CHID (cluster head-ID) and the header which indicates that message like a request. The cluster heads' set-up a TDMA for their intra-cluster communication, which ends the set-up phase. The steady-state phase begins when sensed data are sent from cluster members to the cluster heads and from cluster heads to Base Station [3]. The inter-cluster communication is achieved using the direct sequencing spread spectrum (DSSS). Therefore, proposed a deterministic based model that can yield a better lifetime and ensures the nodes with the largest residual energy to be elected as the cluster head. This method provides a more ideal solution for energy consumption in wireless sensor networks (WSNs). Therefore, It is an attempt to use a deterministic model that can guarantee a fixed number of cluster-heads elections per round.

III. NETWORK MODEL

The energy dissipation and data aggregation model were considered as used in a number of previous studies [6, 12, 15, 17-19] shown in Fig. 1. To transmit the data bits over a distance (*d*) with an acceptable Signal to Noise Ratio (SNR), the amplification energy (ϵ) is expended to overcome either the free space (*fs*) or multi-path (*mp*) loss, depending on the transmission distances. Therefore, to transmit *k* bits, the energy consumption is:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$

$$= \begin{cases} kE_{elec} + k\,\epsilon_{fs}\,d^2, & if\ d < d_0 \\ kE_{elec} + k\,\epsilon_{mp}\,d^4, & if\ d \geq d_0 \end{cases}$$

(2)

Where, *Eelec* is the energy dissipation per bit for the transceiver circuit and *do* is the distance threshold for swapping amplification models, which can be calculated as

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$$

(3)

To receive a *k*-bit message, the radio will expend

$$E_{Rx}(k) = E_{elec}k$$

(4)

Now assume a symmetric radio channel, i.e. the same amount of energy is required to transmit a *k*-bit message from node A to B and vice versa. Also in the previous protocols such as in LEACH assumed a perfect data aggregation in which packets from multiple sources i.e., cluster members are aggregated by their respective cluster heads and only a single packet is forwarded to the BS.

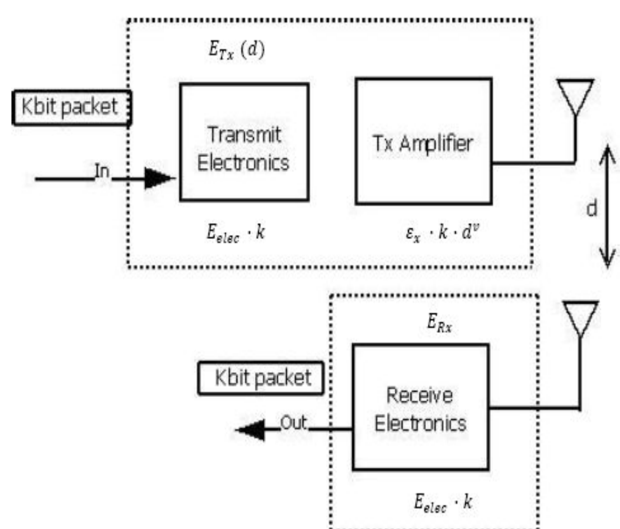

Fig.1. Network Model diagram

IV. DETERMINISTIC PROTOCOL

Routing in BCDEEC works in rounds and each sensor knows when each round starts using a synchronized clock. Let us assume the case where a percentage of sensor nodes are equipped with more energy resources than the rest of the nodes. We have used two types of nodes in the network, normal and advanced nodes. Eo is the initial energy of the normal nodes, and m is the fraction of the advanced nodes, which own a times more energy than the normal ones. Thus there are m.N advanced nodes equipped with initial energy of Eo (1 + a), and (1- m).N normal nodes that are equipped with initial energy of Eo. We assume that all nodes are distributed uniformly over the sensor field.[6]

- *Gateway Selection Algorithm*

Each advanced sensor elects itself to be a gateway at the beginning of each round with probability Pg. Pg is chosen such that the expected number of Gateway nodes for this round is kg. Thus, if there is N.m advanced nodes in the network, node s become a gateway at round r with probability Pgs (t):

(5) $$P_g s(t) = \frac{K_g}{N.m}$$

We define as T(sgat) the threshold for Gateway nodes

$$T(s_{gat}) = \begin{cases} \frac{P_g}{1 - P_g (r \bmod \frac{1}{P_g})} \times \frac{E_{s\_current}}{E_{s\_initial}} & \text{if } s \in G_{gat} \\ 0 & \text{otherwise} \end{cases}$$

Kg= Desired Gateway number

r = Current Round (6)

Gg = Set of nodes which have not been Gateway in 1/Pg rounds

Es_current is the current energy of the node.

Es_initial is the initial energy of the node.

- *Cluster Head Selection Algorithm*

The total initial energy of normal and advanced nodes is given by:

$$E_{tot\_normal} = N(1 - m)Eo$$
$$E_{tot\_advanced} = (m - b)N(1 + a)Eo$$

(7)

The total initial energy of network is:

$$E_{total} = E_{tot\_normal} + E_{tot\_advanced}$$
$$= N(1 - m)Eo + (m - b)N(1 + a)E$$

(8)

Where b is the fraction of the total nodes N which are elected gateways

BCDEEC implements the same strategy for estimating the energy in the network as proposed in DEEC [1]. Since the probabilities calculated depend on the average energy of the network at round r, hence the average energy is estimated as:

$$\overline{E}(r) = \frac{1}{N(1 - b)} E_{total} (1 - \frac{r}{R}) \quad (9)$$

Where Er is the average energy of the nodes at round r. R denotes the total rounds of the network lifetime.[6] R can be calculated as:

$$R = \frac{E_{total}}{E_{round}} \quad (10)$$

E_{round} is the energy dissipated in the network in a round. The total energy dissipated is equal to:

$$E_{round} = L[2N(1-b)E_{elec} + N(1-b)E_{DA} + K\varepsilon_{amp} d^4_{toBS} + N(1-b)\varepsilon_{fs} d^2_{toCH}]$$

(11)

Where k is number of clusters and d_{toCH} is the average distance between cluster head and the base station and d_{toCH} is the average distance between the cluster members and the cluster head. Because we are assuming that the nodes are uniformly distributed, we can get:

$$d_{toCH} = \frac{M}{\sqrt{2\pi k}} \qquad d_{toBS} = 0.765 \frac{M}{2}$$

(12)

By calculating the derivative of E_{round} with respect to k to zero we get optimal number of clusters as

$$K_{opt} = \sqrt{\frac{N(1 - b)}{2\pi}} \frac{M}{d^2_{toBS}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}}$$

(13)

V. RELATED WORK

In DEEC-MT the multilevel clustering is employed in which three levels of nodes is defined which is better suited for defining heterogeneous environment as compared to two levels of nodes defined in the BCDEEC protocol. The new type of nodes which are added in DEEC-MT are called “Super nodes” which are having energy greater than all the two nodes (advanced nodes and normal nodes) .It must be noted that the total energy of network is kept same as that of DEEC protocol. Normal nodes contain energy of Eo, the advanced nodes of fraction m are having a times extra energy than normal nodes equal to Eo(1 + a) whereas, super nodes of fraction mo are having a factor of b times more energy than normal nodes so their energy is equal to Eo(1 + b). As N is the total number of nodes in the network, then Nmmo is total number of super nodes and Nm(1 − mo) is total number of advanced nodes. The total initial energy of three level heterogeneous WSN is therefore given by:

$$E_{total} = N(1-m)E_o + Nm(1-m_o)(1+a)E_o + Nm_oE_o(1+b)$$

$$E_{total} = NE_o(1+m(a+m_ob))$$

(14)

DEEC-MT uses same mechanism for CH selection and average energy estimation as proposed in DEEC. At each round, nodes decide whether to become a CH or not by choosing a random number between 0 and 1. If number is less than threshold Ts as shown in equation 24 then nodes decide to become a CH for the given round. In DEEC-MT, threshold value is adjusted and based upon that value a node decides whether to become a CH or not by introducing residual energy and average energy of that round with respect to optimum number of CHs. Threshold value proposed by DEEC-MT is given as follows as in:

$$T(n) = \begin{cases} \dfrac{p}{1-p(r \bmod 1/p)} * \dfrac{\text{residual energy of node}}{\text{average energy of network}} * Qopt. & \text{if } n \in G \\ 0 & \text{else} \end{cases}$$

(15)

This new clustering model helps in increasing the network stability in heterogeneous network. Moreover the lifetime of the improved has also increased as compared to BCDEEC.

TABLE 1. PARAMETERS USED IN DEEC-MT PROTOCOL

Parameter	**Description**	**Value**
Xm x Ym	Dimensions of field	100m x 100m
N	Number of nodes	100
Rmax	Maximum number of rounds	10000
P	Probability of a node to become cluster head (CH)	0.1
Eo	Initial energy of each node	0.5 J
ETX	Transmission energy of node	50 nJ/bit
ERX	Receiving energy of node	50 nJ/bit
EDA	Data aggregation energy	5 nJ/bit/message
Efs	Energy dissipation for free space	10 $pJ/bit/m^2$
Emp	Energy dissipation for multi-path delay	0.0013$pJ/bit/m^4$
Packet	Packet size	4000

VI. SIMULATION AND RESULT

Deployments of nodes are shown in Figure1.

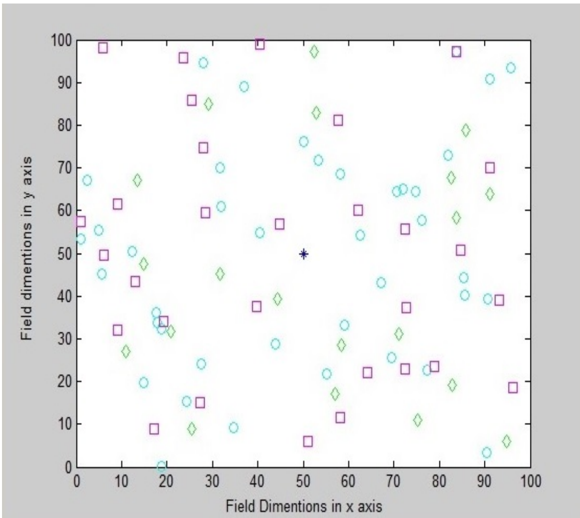

Fig. 3 Deployment of super nodes in field

The three levels of nodes are as follows: normal nodes, advanced nodes, super nodes

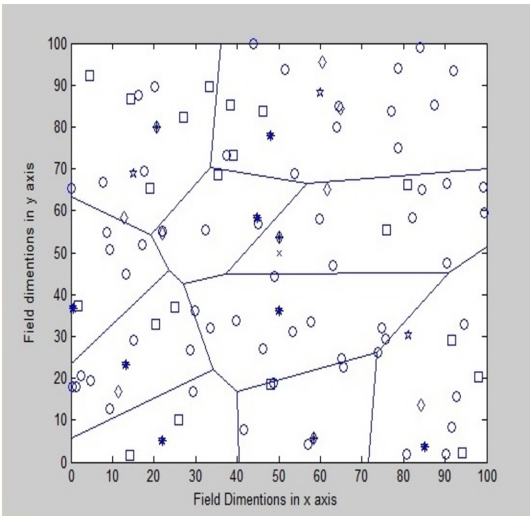

Fig. 4 clustering of network

In next step clustering is done, a cluster is a group of nodes in which one node act as leader and other nodes act as member nodes.

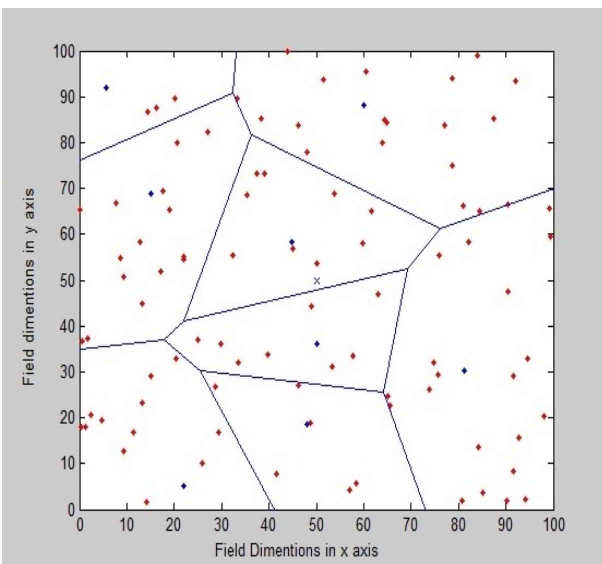

Fig. 5 Dead member nodes and cluster head

At the end of lifetime of the network after particular number of rounds, all nodes become dead. The dead member nodes are represented as red color and dead cluster heads are represented as blue color (Fig. 5).

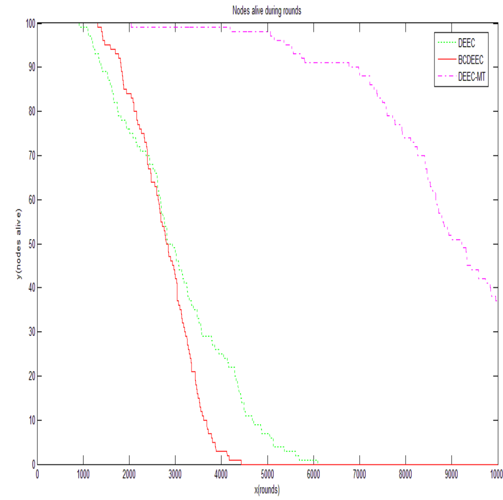

Fig. 6 Alive nodes versus rounds

The alive nodes versus rounds plot comparison of DEEC-MT with other existing protocols is shown in Fig. 6.

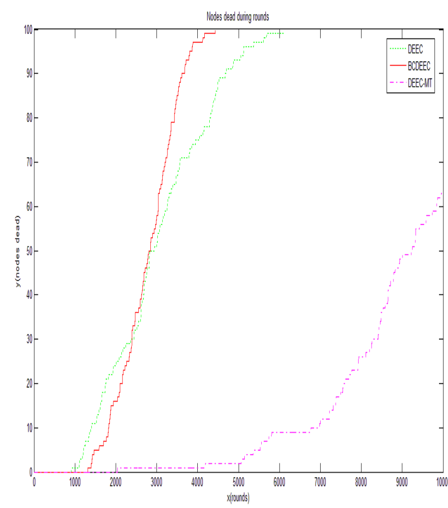

Fig. 7 Diagrammatic relationship between dead nodes versus rounds

Dead nodes versus rounds plot comparison of DEEC-MT with other existing protocols are shown in Fig. 7.

Comparison of existing protocols with the DEEC-MT protocol is shown below in Table 2.

TABLE 2. COMPARISON OF VARIOUS PROTOCOLS

Parameter	**DEEC**	**BCDEEC**	**DEEC-MT**

Number of rounds till first node died i.e. network become stable (FND)	1300	1832	1988
Number of rounds till network survived (LND)	2800	4300	9855
Number of rounds till rate of packets sends to BS is stable	-	-	10000

VII. CONCLUSION

In this paper, a purely deterministic protocol DEEC-MT was used that better utilizes the most valuable network resource (energy) in WSN. The suggested new protocol DEEC-MT, and had long lifetime for WSNs. The protocol improved the DEEC and BCDEEC by introducing a new node called "super node" in the network. Network protocol can be built on the shortcomings of DEEC to try and rectify them. Applications of the new algorithm are immense as the lifetime has increased considerably.

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