Threshold Based Protocol for increasing network lifetime in heterogeneous WSN

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Abstract— **In a Wireless Sensor Network sensor nodes have limited hardware resources thus, modelling and designing energy-efficient routing methods have become one of the most important strategies in wireless sensor networks (WSNs). A popular part of routing technology, cluster-based heterogeneous routing protocols have proven effective in topology management, energy consumption, data collection or fusion, reliability, or stability in a distributed sensor network. A heterogeneous clustering method based on distributed energy efficient clustering is proposed in this paper, which uses threshold criteria to select cluster heads. Based on quality metrics, including live nodes in the network, number of dead nodes and number of packets received by base station, the proposed model was compared with DEEC and DDEEC. Results of simulation show that the model proposed is more efficient than the other protocols and increases the lifetime of the sensor network significantly.**

Keywords- **Wireless Sensor Networks, Energy Efficient Routing, Network Lifetime.**

I. Introduction

Wireless sensor networks (WSNs) include small sensor nodes capable of transmitting data via data sensing, computing, and wireless communication channels [1]. One of the major problems in the WSN is that the sensor nodes have limited battery power. An important area is the routing of protocols around the WSN's work areas. Besides prolonging the life of the sensor nodes, a homogeneous distribution of the existing energy to the WSN is also desirable. The energy consumption of the power source is an important concept in the WSNs due to the limited power supply in the sensor nodes. When data is transmitted to other nodes via sensor nodes, maximum energy is used. A number of studies have been conducted for all these reasons to develop routing algorithms to extend the lifetime of a sensor network [2].

In two types of networks, i.e. homogeneous and heterogeneous networks, clustering can be done. Nodes with the same level of energy are called homogenous networks and nodes with different levels of energy are called heterogeneous networks. Low-Energy Adaptive Clustering Hierarchy (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS), Hybrid Energy-Efficient Distributed Clustering (HEED) are some algorithms designed for homogeneous WSN under consideration so that these protocols do not work effectively in heterogeneous scenarios because they are unable to treat nodes.

The SEP protocol is a "Stable Election Protocol"[2], a heterogeneous routing protocol for clusters. The SEP protocol is a two-level heterogeneous protocol as it has two set of nodes, i.e. Advance nodes (high-energy nodes) and Normal nodes (low-energy nodes) the SEP will ensure that Advance nodes become cluster heads more frequently than normal nodes, thus helping to extend the WSN's stable period. The DEEC protocol is a Distributed Energy Efficient Clustering' protocol [3] which is a distributed energy-efficient protocol for the heterogeneous wireless sensor network. It is also based on the basic Leach protocol, but the cluster head selection method here is different as the cluster head is selected based on probability between the residual energy ration. The DEEC upholds the distributed property while it can be implemented on the heterogeneous network of multi-level wireless sensors. Some other protocols like TSEP, ESEP, DDEEC, EDEEC etc. have been derived from the these two basic protocols.

In this paper, under three heterogeneous networks, we study the performance of heterogeneous WSN protocols. We compare DEEC, DDEEC, and Threshold based DEEC performance for three level heterogeneous WSN scenarios. Three levels of heterogeneous networks contain normal, advanced and super nodes, while super nodes have the highest level of energy compared to normal and advanced nodes.

II. Literature Review

There are many studies in the literature on energy-efficient protocol clustering for WSNs. For homogeneous WSNs, where sensor nodes are randomly determined as CHs (Cluster Heads) and the energy load of the system is shared with the WSN, a routing algorithm with LEACH clustering adaptation is presented in one study[4]. A new routing protocol for energy optimization based on LEACH is proposed in[5]. It is understood that by selecting cluster heads equally, this algorithm is more efficient than the LEACH algorithm. A modified LEACH derived from the LEACH algorithm is presented in the paper[6]. In[7], an energy-efficient algorithm improved mobile sink is presented and compared to mod-LEACH and PEGASIS[8]. For single pass, heterogeneous WSNs, a new energy-efficient (EE) clustering method is proposed in[9]. MATLAB simulations show that the above method is 1.62-1.89 times more stable than known protocols like LEACH, DEEC, and SEP. In[10], cluster stability is reduced as the LEACH protocol on an irregular network causes aggregate data efficiency to decreaseThis article[10] therefore suggests a method for selecting a cluster head to improve the LEACH protocol to increase the stability of the cluster head. A LEACH variant is proposed for this purpose in combination with HEED and LEACH protocol and this method is approved by simulation. In [11], two energy efficient route planning routing protocols are proposed for three levels of heterogeneous WSNs, namely, Central Energy Efficiency Clustering (CEEC) with Two-Hop Heterogeneity awareness (THCEEC) and Advanced Equalization (ACEEC). Comprehensive simulation results have provided improved reliability and energy efficiency performance for CEEC, ACEEC, and THCEEC central cluster deployments, providing better network life and successful data transmission than traditional distributed routing protocols from LEEC, SEP, ESEP, and DEEC. Furthermore, ACEEC performs CEEC and gives more time to stabilize the network. Analytical assessment shows that THCEEC performs routing protocols for CEEC, ACEEC and other existing road planning. The study[12] suggests an effective method of gathering data in the WSN using a support vector. In[13], clustering protocol performance assessment is presented in WSNs. Sensor node clustering is an effective technique to achieve these goals. With this technique, other clustering models (LEACH, LEACH-C, and HEED) were evaluated and compared. At the end, clustering methods are compared with multiple criteria such as convergence speed, cluster stability, cluster overlap, location awareness, and support for node mobility. In another study[14], the study of different sensor network routing models offers a classification survey on behalf of model types. The three main categories examined are data-centric, hierarchical, and location-based. Routing methods and algorithms each have a common purpose to better output and extend the useful life of the sensor network. A comparison was made between flood and direct diffusion, two routing protocols based on network throughput and lifetime. The study[15] presents random analysis of coverage and connectivity in three-dimensional heterogeneous WSNs. The study[16] suggests that, based on the first energy relative to the other sensor nodes of the sensor network, the SEP algorithm in which each sensor node in a two-level heterogeneous sensor network independently identifies itself as a CH. The study[17] presents a method called DEEC by which the selection of CH is considered dependent on the ratio of the node's remaining energy and the sensor network's average energy. The DDEEC protocol is presented in another study based on energy recalibration for CH[18]. The public wireless network has optimized this protocol. In this sense, advanced nodes are more likely to be selected as CH in the first broadcast rounds. These sensor nodes will also have the same CH selection probability as normal sensor nodes when energy is reduced.

III. METHODOLOGY

The research work done here has mainly focussed on realistic situational aspect of the Wireless Sensor Networks. With the kind of application for which the wireless sensor nodes are employed its important for them to have situational awareness which is directly linked to their energy consumption. If we can keep an eye on the situation and acoordingly monitor and control the energy being used in the Wireless Sensor Networks,hence improving the efficiency of the network. Following the thoughts of LEACH, DEEC lets each node expend energy uniformly by rotating the cluster-head role among all nodes. cluster-heads are elected by a probability based on the ratio between the residual energy of each node and the average energy of the network. The round number of the rotating epoch for each node is different according to its initial and residual energy, i.e., DEEC adapt the rotating epoch of each node to its energy. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes. The proposed protocol here also monitors the behaviour of the nodes and Cluster Heads with respect to energy and distance. In this proposed algorithm, once the potential of each node is calculated, the head of cluster head (CH) or the leader node is selected on the basis of the energy level of the various nodes. The distance of all nodes from the base station or sink is then evaluated to locate the nearest and farthest nodes in the network. Based on a threshold distance level a temporary leader node is selected for each cluster. The energy and distance from the base station is then evaluated and the ratio between them is evaluated. If this ratio is above the threshold value then the cluster head is the optimal selection for this round for that cluster. The process is continued further by continuous monitoring of the values of energy of nodes and the distance from the base station.

$$\text{Selection Potential (Q)} = \frac{E}{DtoBS} \quad (1)$$

The selection of child nodes i.e. the nodes that can potentially be cluster heads in the upcoming rounds is done subsequently using the same metrics i.e. the distance to base station and the energy of the nodes. Apart from this the distance between the all nodes under a particular cluster and cluster head is also evaluated and compared to a threshold value according to the round number. The nodes which do not satisfy the distance parameters i.e. who have the distance value less than the threshold for the current round from the cluster head it is assigned a new cluster. Thus ensuring the connectivity of all nodes in the network at a particular instant of time.

Cluster Setup Base:

As is the case with most cluster based techniques, the algorithm starts with the formation of clusters i.e. cluster setup phase. Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster-head for the current round. The probability of selection is is given as:

$$p(i) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & If\ n \epsilon G \\ 0 & Otherwise \end{cases} \quad (2)$$

Where P = the desired percentage of cluster heads (e.g., P = 0.05), *r* = the current round, and G is the set of nodes that have not been cluster-heads in the last *1/P* rounds. Using this threshold, each node will be a cluster-head at some point within *1/P* rounds. During round 0 (*r* = 0), each node has a probability *P* of becoming a cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next *1/P* rounds. Thus the probability that the remaining nodes are cluster-heads must be increased, since there are fewer nodes that are eligible to become cluster-heads.

After *1/P* -1 rounds, T=1 for any nodes that have not yet been cluster-heads, and after *1/P* rounds, all nodes are once again eligible to become cluster-heads. Future versions of this work will include an energy-based threshold to account for non-uniform energy nodes. In this case, we are assuming that all nodes begin with the same amount of energy and being a cluster-head removes approximately the same amount of energy for each node. Each node that has elected itself a cluster-head for the current round broadcasts an advertisement message to the rest of the nodes. For this “cluster-head-advertisement” phase, the cluster-heads use a CSMA MAC protocol, and all cluster-heads transmit their advertisement using the same transmit energy. The non-cluster-head nodes must keep their receivers on during this phase of set-up to hear the advertisements of all the cluster-head nodes.

The DEEC protocol is based on a two-level heterogeneous WSN in which the sensor nodes are assumed to have normal and advanced battery levels. The above formula for selection probability for the two types of nodes is thus given by:

$$p_i = \begin{cases} \frac{E_i(r)\, p_{opt}}{(1+a)\, E_{avg}} & if\ normal\ node \\ \frac{E_i(r)\, p_{opt} a}{(1+a)\, E_{avg}} & if\ advanced\ node \end{cases} \quad (3)$$

Distance Factor:

Apart from the conventional energy threshold criterion being used in most of the LEACH based techniques; this research work also incorporates the distance threshold for deciding the selection of cluster heads in the subsequent rounds. The two key matrices i.e. the Distance of the nodes from the base station as well as the distance of nodes in a cluster from the current cluster head is also evaluated and is used as the basis for selection of upcoming cluster head. Thus, this technique uses a combination of both energy and distance awareness of the nodes. This can be critical information because not only we can keep track of the nodes position but also provide complete coverage for all nodes, thus leading to energy efficiency. As mentioned in equation 4.1 the Selection Potential is a ratio between, energy and distance of nodes from base station. After this phase is complete, each non-cluster-head node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement.

$$d = \sqrt{(\mathrm{s(i).xd} - \mathrm{s(n+1).sink\ x})\wedge^2 + (\mathrm{s(i).yd} - \mathrm{s(n+1).sink\ y})\wedge 2} \quad (4)$$

Radio Model:

In our work, we assume a simple model where the radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and E_{amp} = 100 pJ/bit/m2 for the transmit amplifier to achieve an acceptable E_b*/No*. These parameters are slightly better than the current state of the art in radio design1. We also assume an r2 energy loss due to channel transmission. Thus, to transmit a k-bit message a distance d using our radio model, the radio expends:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} * k * d^2 \quad (5)$$

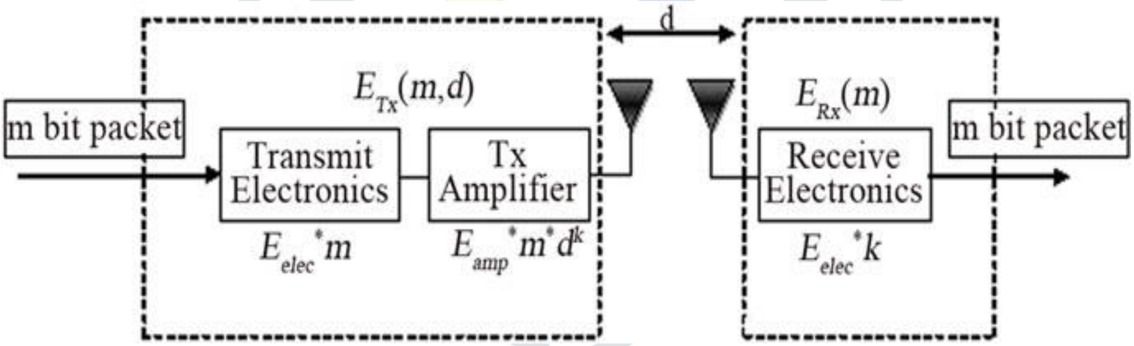

Figure 1: Radio Model

And to receive this message, the radio expends:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx} = E_{elec} * k \quad (6)$$

Proposed Work:

The proposed algorithm uses the same 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 below then nodes decide to become a CH for the given round. The threshold value T(s) 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.

$$T(s) = \left\{ \frac{P}{1 - P * (r mod \frac{1}{P})} * \frac{residual\ energy\ of\ a\ node * kopt}{average\ energy\ of\ the\ network} \right. \quad (7)$$

The average probability to be a cluster-head during ni rounds. When nodes have the same amount of energy at each epoch, choosing the average probability pi to be popt can ensure that there are popt N cluster-heads every round and all nodes die approximately at the same time.

According to the threshold equation, the cluster head selection is optimized.

If nodes have different amounts of energy, pi of the nodes with more energy should be larger than popt.

Let E(r) denote the average energy at round r of the network. To compute average energy each node should have the knowledge of the total energy of all nodes in the network to be the reference energy, we have the following equation:

$$E(r) = \frac{1}{N}\sum_{i=1}^{N} Ei(r) \quad (8)$$

The probability of the ith node selection can then be given by:

$$p_i = p_{opt}\, E_i\,(r)/\ \overline{E}_i\,(r) \quad (9)$$

IV. RESULTS & DISCUSSIONS

To evaluate the performance of our protocol, implemented it has been implemnted in MATLAB platform. The environment of wireless sensor network performed on a network of 100 nodes and a fixed base station. The nodes are placed randomly in the network. Cluster formation is done as in the DEEC protocol.

The various performance parameters are defined as below:

- Lifetime is a parameter which shows that node of each type has not yet consumed all of its energy.
- Number of nodes alive is a parameter that describes number of alive nodes during each round.
- Data packets sent to the BS is the measure that how many packets are received by BS for each round.

Table I: Simulation Parameters

Parameter	**Value**
Number of sensor nodes	100
Network size (m^2)	100*100
No of round	5000
Base station location	(50,50)
Efs (pJ/bit)	10*10^(-12)
Eamp (pJ/bit)	0.0013*10^(-12)
ETX (nJ/bit)	50*10^(-9)
ERX (nJ/bit)	50*10^(-9)

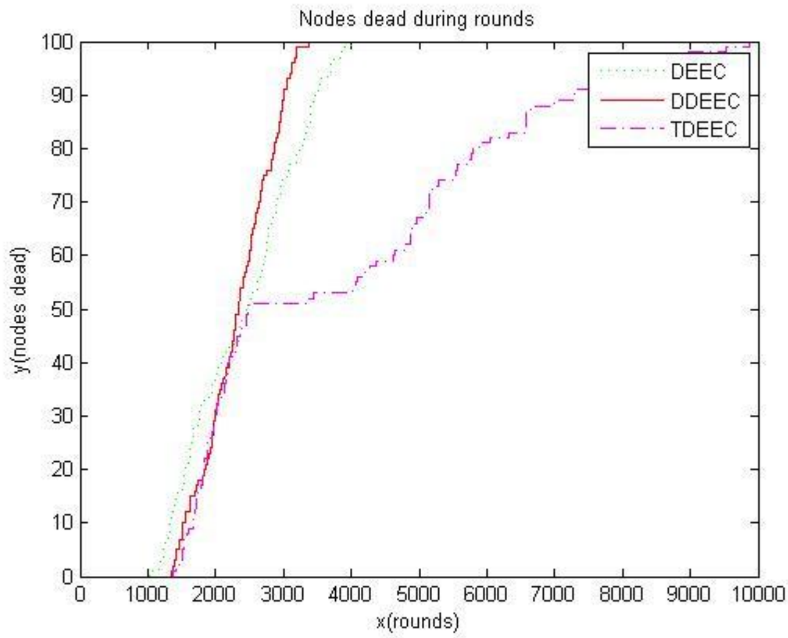

Figure 2: Number of dead nodes

Figure 2 shows a comparison of number of dead nodes after each round. As can be viewd from the graph, the for DEEC the nodes appear dying around round 1000, while for DDEEC the nodes start dying around 1030 rounds, while for the proposed Threshold based DEEC it starts around 1030. However, DDEEC loses all its nodes around 3000 rounds while DEEC gives a slightly better performance and the nodes become dead at around 4000 rounds while the threshold based DEEC loses its nodes at around 10000 rounds. Thus, the network lifetime of the Threshold based DEEC is better as compared to DEEC and DDEEC.

Similar results are shown in figure 3 below, which shows the number of alive nodes after each round. The figure 3 shows the packets transferred to the base station in all three protocols and as an obvious case the threshold based DEEC achieves better packets transfer due to its increased longevity.

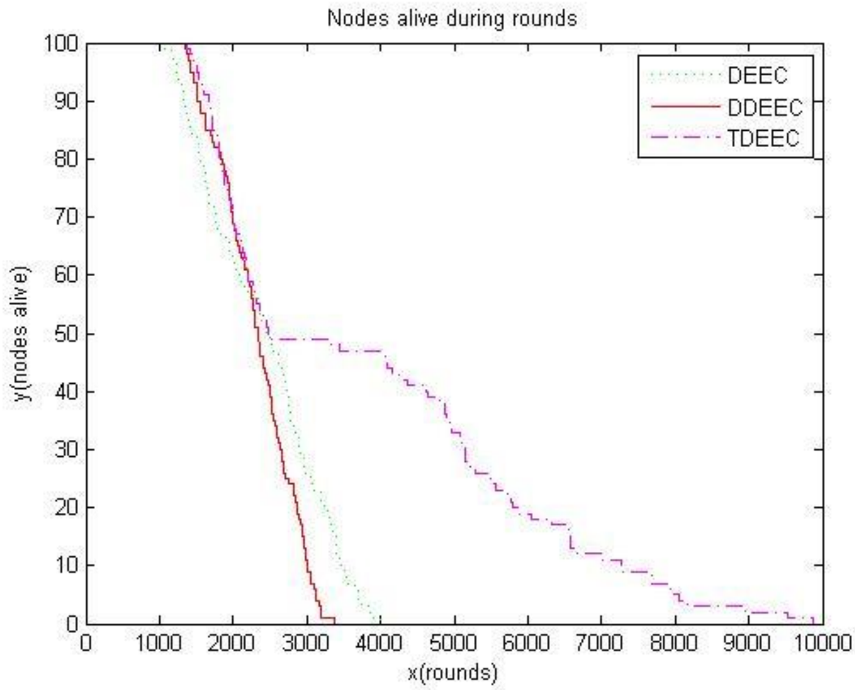

Figure 3: Alive Nodes vs Rounds

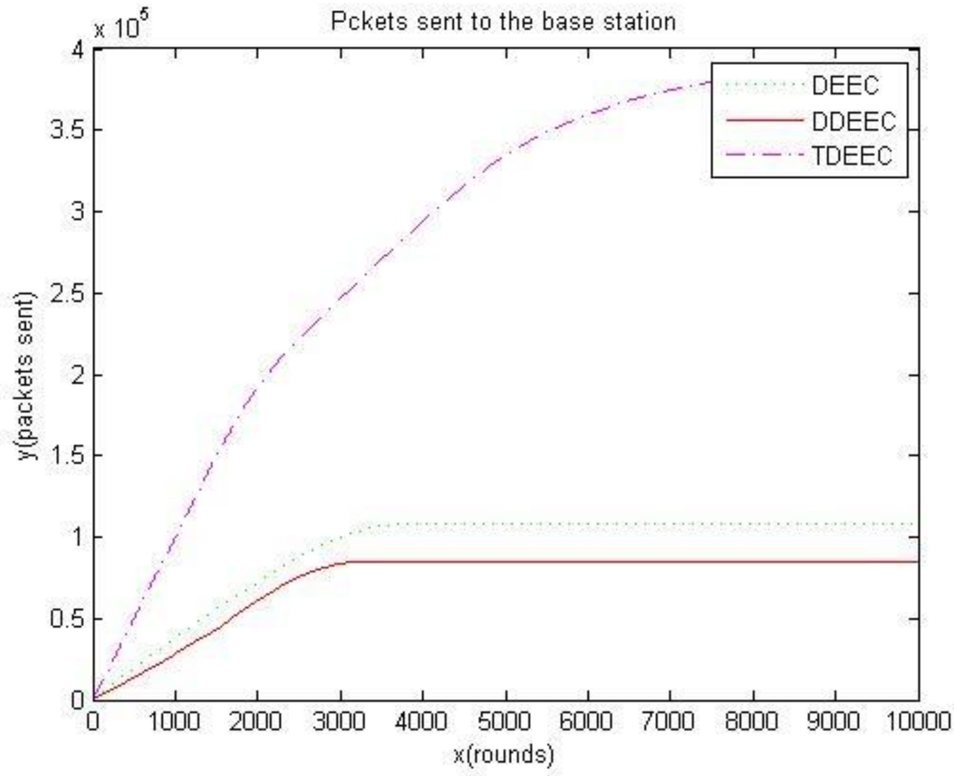

Figure 4: Packets Transferred vs Rounds

V. CONCLUSION

Threshold based Distributed Energy protocol has been proposed to increase energy efficiency in WSN. The awareness of the distance and average energy of the network helps to understand the network more effectively. Especially, in the case of multi path communication it helps to save the energy wastage. The selection potential i.e. the capability to become the cluster head in a particular round has been evaluated from this distance metric. In DEEC, every sensor node independently elects itself as a cluster-head based on its initial energy and residual energy. In the proposed Threshold based DEEC, a threshold criterion is also taken into consideration to select the cluster head. Only those nodes which satisfy this threshold criteria can become cluster head. The results obtained show that the proposed protocol performs better compared to earlier protocols in terms of stability of the network, network lifetime and energy efficiency.

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