Cluster-Head Techniques for Single-hop Routing protocol in Energy Efficient Wireless Sensor Networks

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Abstract. Energy efficient routing protocols are an active research area in Wireless Sensor Networks (WSNs). Like prior research works in efficient-efficient routing protocols, we enhance the LEACH cluster-head (CH) threshold mechanism. Our approach mainly focuses on the idea of maximizing the network lifetime on the basis of CH nodes remaining energy levels. In LEACH, CH changes occur during every round of the network irrespective of their energy levels. In this scenario, we propose an energy threshold function as well as an optimal CH threshold function to specify the dynamicity of the CH, whether to change the cluster-topology often or not with the consideration of its current energy levels. In this regard, simulation results show that the proposed mechanism can maximize the network lifetime effectively and delivers three times more data messages while comparing with the other known energy-efficient protocols from the literature.

1. Introduction

The advantages of Wireless Sensor Networks (WSNs) bring many potential applications, such as industrial control systems, vehicle tracking, home and office automation, water supplies, surveillance, wildfire monitoring, pollution monitoring, weather forecasting and enumeration are considered in the environmental monitoring applications [1–3].

In sensor networks, clustering protocols have the higher network performances in terms of network lifetime, less transmissions and low latencies than the traditional communication methods. In WSNs, there has been a great deal of research conducted on energy efficient clustering protocols, and several well-known methods have also been studied in the literature, such as [1, 4–11].

This paper presents a Single-hop Cluster-Based and Energy Efficient Protocol (SCEEP) Wireless Sensor Networks for prolonging the network lifetime based on Cluster-Heads remaining energy and optimal CH range levels. It is mainly considered to reduce the communication over-heads and unnecessary cluster-head changes at every round.

Section II describes the proposed SCEEP algorithm and features of the work are presented. Simulation results and comparisons are discussed in section III. Final section concludes the paper and suggestions for future work are given.

2. SCEEP Algorithm

In SCEEP, we consider a homogeneous sensor network model with an initial amount of energy for the sensor nodes. We used a first order energy model from [5] to design this work. Our approach mainly targets to reduce the communication overheads and unnecessary cluster-head (CH) changes at every round. In this proposal, we have been followed two kinds of clustering principle to elect the cluster-heads. The first principle follows LEACH algorithm of Eq.(1) to initialize the random sensor network at time interval t, and the mathematical expression of the CH probability threshold function is given as

$$P_i(t) = \begin{cases} \frac{K}{N-K(R \ mod \ N/K)} & C_i(t) = 1 \\ 0 & C_i(t) = 0 \end{cases} \tag{1}$$

Where K denotes the initial amount of optimal cluster head range, N is the total number of nodes in the network, R is the current round and, $C_i(t) = 1$ if the node i has not been already a cluster head in the last N/K rounds at given time instances t, otherwise $C_i(t) = 0$. According to Eq. (1), nodes always have the equal chances to become a cluster head for every round, regardless how much high or little amount of residual energy in the nodes have had. In this scenario, cluster topology or CH changes occur every round without considering the remaining energy levels of the nodes, which may lead to earlier nodes death and communication overheads or degrading the network lifetime. For avoiding the communication overheads and maximizing the network lifetime, we propose the second principle of clustering threshold function, which has been designed based on CHs remaining energy and fixed optimal cluster-head ranges at every round. However, the recent literature works have presented some advanced energy-efficient protocols in [9], [10] and [11], based on nodes residual energy of the network or using different sorts of nodes in the cluster-topology like a heterogeneous model, in which they still failed to reduce the communication and computational costs completely. In our approach, CHs check their energy status and optimal CHs range through the Algorithm 1 before calling for new cluster-heads request, as we can see it below. The proposed significant features of SCEEP protocol as follows

(i) Initial set-up phase of the network, we use LEACH cluster-head selection algorithm to elect the CHs during its first round.

(ii) After completion of the network first round (in seconds) simulations, current CHs check their energy levels $E_{CH_i(t)}$ to continue their intra-cluster communications with the nodes or not, by using energy threshold function E_{Th}. According to the network setup, the energy threshold value can vary based on the given initial energy levels of the nodes. If the current CH energy levels is greater than or equal to the energy threshold level, it continues its intra-cluster activities to receive the data among the cluster member nodes, otherwise CH destroys the current cluster and calls for the new cluster formation.

(iii) In this case, we fixed an optimal CHs threshold function $\hat{P}_{Th}$, if the CHs optimum level $\hat{P}$ is lower than the optimal threshold range, then it goes back to the Cluster-head election mechanism for electing new cluster-heads. In this regard, we fixed the optimal threshold range at 3.

(iv) If current CHs are higher than or equal to the minimum required CHs range, then it continues receiving the data from their corresponding member nodes.

Algorithm 1 Cluster-Head threshold functions

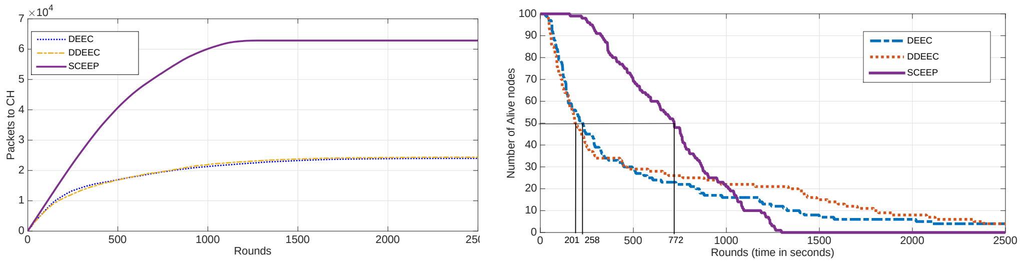
procedure : $Init(P_i(t), K, R, N)$
$E_{CH_i(t)}, E_{Th}, \hat{P}, and\ \hat{P}_{Th}$
Parameters: $t \leftarrow\ node\ time\ instances$
$P_i(t) \leftarrow\ CH\ Probability\ threshold\ function\ at\ time\ instance\ t$
$E_{CH_i(t)} \leftarrow\ current\ CH\ remaining\ energy\ level$
$R(RoundNumber) \leftarrow is\ the\ round\ iteration\ time\ in\ seconds$
$f(t) \leftarrow \sum_{i=1}^{N}\sum_{j=1}^{M} SN_i(X_j(t)),\ F(\hat{t}) \leftarrow \sum_{k=1}^{L}\sum_{l=1}^{K} CH_k(X_l(\hat{t}))$

    if $P_i(t) \leq K/(N - K(R\ mod\ N/K))$ then
        Start Cluster formation
        Count_CHs
    else if $E_{CH_i(t)} \geq E_{Th}$ then
        if $\hat{P} \geq \hat{P}_{Th}$ then
            Continue Data reception
        else
            Return to the network initialization $P_i(t)$
        end if
    else if $E_{CH_i(t)} < E_{Th}\ AND\ \hat{P} < \hat{P}_{Th}$ then
        Send `CH_candidates_clear()`
        Send `Clusters_Clear()` to destroy
        Return to the network initialization $P_i(t)$
    end if
end procedure

3. Simulation Results

In this simulation, SCEEP sensor network has been placed with 101 static sensor nodes, which are randomly distributed in a field of $400m \times 400m$. The initial energy of the node is 0.5 J and each data transmission size is equal to 4 kb.

The results of SCEEP simulations are shown in figure 1(a) and (b). We presented some measurement metric analysis through both figures. According to the figure 1(a) and (b), the packet reception rate is 3 times more with SCEEP compared to DEEC and DDEEC. In figure 1(a),(b) and figure 2 SCEEP, where the First Node Dies (FND) metric shows at round 172 while other protocols FND are at round 28 and 36 respectively, based on the FND metric differences can clearly show that the early nodes depletion rate is 3 times lesser than the DEED and DDEEC protocols. When comparing with Half of the Nodes Alive (HNA) metric, we can clearly observe the differences, where the pointed line indicates in figure. 1(b) at 50 nodes alive, SCEEP extends the network lifetime 500 rounds ahead than the other protocols. From the below measurement analysis and proofs, SCEEP indeed have outperforming results than the other protocols. In fact, DEEC and DDEEC are developed with powerful nodes consideration of heterogeneous network model, such as normal and advanced nodes, even though SCEEP extends the network lifetime better than the other protocols.



(a) (b)

Figure 1: (a) Number of data bits received and (b) Number of nodes alive over time.

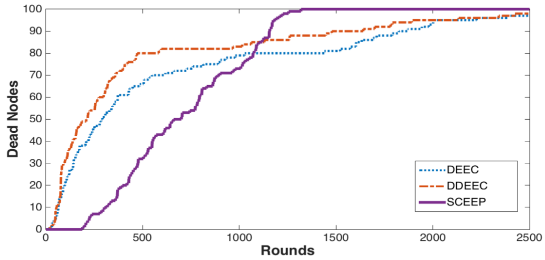


Figure 2: Number of depleted nodes over time.

4. Conclusion

A SCEEP distributed clustering protocol was presented, and the simulation results showed that the SCEEP have better performances than the DEEC and DDEEC protocols. In comparison, FND and HNA metrics demonstrate that SCEEP enhances the network lifetime and reduces depletion rate by a factor of 3 times. Then delivers 3 times more data than the other protocols. In addition, the further works on this paper that we are focused on to develop a new head node threshold function for initialization of the network or set-up phase clustering for multi-tier multi-hop heterogeneous sensor networks. Furthermore, we are also interested to deploy a sensor network using SCEEP on TelosB sensor nodes for measuring the system efficiency and throughput.

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