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AN ENHANCEMENT OF ENERGY CENTRIC CLUSTER BASED ROUTING ALGORITHM FOR WIRELESS SENSOR NETWORKS

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ABSTRACT
Wireless Sensor Networks is a network that can contain thousands of small autonomous nodes that are randomly deployed in an environment to collect data. These nodes are powered with non-rechargeable battery, and it is unrealistic for battery replacement because of the enormous quantity of sensors and expensive cost, nodes may also be deployed in an unfriendly environment. Hence there is the need for algorithms that minimize the energy consumption of nodes, so that the network lifetime can be maximized. we proposed an enhancement of an existing algorithm termed Energy Centric Cluster-Based Routing Protocol for WSNs (ECCR). In ECCR the cluster heads are changed after every round of communication and the current cluster heads serve as a caretaker for selecting the new cluster heads. The frequency of updating the current cluster heads about the prospective cluster heads tend to result in energy waste and also cluster heads nodes may be capable of maintaining the role of cluster head for some few rounds. We focused on extending the lifetime of the network by reducing the frequency of changing cluster heads and updating them on the prospective cluster heads in the network. A simulation model was developed and experiment was conducted to analyse the performance of the proposed algorithm with ECCR. Simulation result shows that the proposed Enhancement outperforms the existing ECCR, in terms of alive nodes, energy dynamics, and stability period.
Keywords: Wireless Sensor Networks, Energy, Cluster Based Routing, Sensor Nodes.

INTRODUCTION

The progression in the field of micro electro-mechanical systems (MEMS) has opened the way to develop affordable, low power, multi-functional, tiny sensor nodes (Arun, Hnin, Kai, & Peter, 2017). These tiny nodes have sensing, computation, and wireless communications capabilities. A typical architecture of a WSN is shown in Figure 1

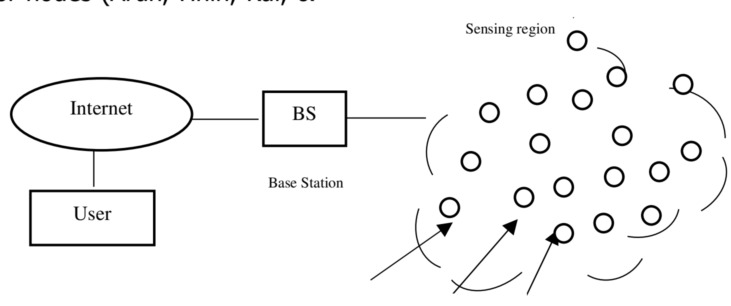

Figure 1 WSN Architecture

A WSN architecture consists of four entities. The users, network connectivity, base station and a number of autonomous sensor nodes. These sensor nodes are scattered in a network field to gather data related to environment conditions like temperature, humidity, sound, light, vibration, images, etc. they communicate with each other to perform aggregation if necessary, and then route the aggregated data to the base station. the base station serves as a destination node for the sensor nodes. User can access the data from the base station via a network connectivity such as internet or satellite. Figure 2 shows the architecture of a sensor node. These nodes in WSN comprises of some basic components, a sensing subsystem for data acquisition from the physical surrounding environment, a micro-controller (for data processing), memory (for data storage), and transceiver (for receiving and sending signals or data from one node to another). In addition, a power source which is typically a battery that supplies the energy needed by the device to perform the programmed task. This battery energy is limited, and it could be impossible or inconvenient to recharge the battery, due to enormous quantity of nodes or the hostility of the environment nodes are deployed to. Energy consumption is one of the main issues that affects the overall performance of the WSN implementation. Significant amount of energy consumption in the network is as a result of transmission and reception of data. Considering researches in this area, cluster-based routing has proven to be an effective way of minimizing energy consumptions due to data communication, in the static based clustering, the member nodes send their information along with their local data to the cluster head in every round of communication. The cluster heads receive all their respective member nodes information, based on the criteria for cluster head selection, the current cluster heads decide which member node will be a cluster head node for the next round. The frequency of sending and receiving this control message actually result in energy waste, as a cluster head node is capable of maintaining the role of cluster head for some few rounds. The idea of this paper is to increase the lifetime of the network by reducing the frequency of cluster head re-selection. Our contribution in this paper can be summarized as follows

I. Modification of the Energy Centric Cluster-Based Routing Protocol for WSNs (ECCR) algorithm was proposed.
II. Simulation model was developed for the evaluation and comparison of the proposed algorithm with the existing algorithms in terms of alive nodes, energy dynamics and stability period.

The rest of the paper is organized as follows: an overview of related work is given in section 2, followed by the system model in section 3. The proposed protocol is described in section 4. The result and comparison with existing protocols are given in section 5, followed by the conclusion in section 6.

RELATED WORKS

Wendi, Anantha, & Hari, (2000) proposed Low Energy Adaptive Clustering Hierarchy (LEACH), it is a hierarchical routing protocol which involves random selection of cluster heads. Energy of the network is considered by reducing the chances of reselecting previously selected cluster heads. The problem with LEACH is that inadequate node may be selected as cluster heads due to the random rotation of cluster heads. Georgios, Ibrahim, & Azer, (2004) proposed an improvement on LEACH, they suggested that a certain percentage of nodes should be equipped with more energy. The cluster head selection probabilities are weighted by the initial energy of a node relative to that of other nodes. Sang & Thinh, (2012) proposed a new protocol called LEACH with Distance-based Thresholds (LEACH-DT). In LEACH-DT, the probability for a node to become a CH depends on its distance to the BS. Transmission cost is moderately reduced here, however, nodes nearer to base station quickly die out. All of the above algorithms have a general problem of node isolation (a number of nodes not belonging to any cluster thereby independently transmitting their data to the base station) and re-clustering related overhead issue.

Several methods have been proposed, in which some directly while others indirectly address the node isolation problem, thereby improving energy saving in the network. Jiguo, Yingying, Gang Wang, Qiang, & Xin, (2011) proposed energy-aware distributed unequal clustering (EADUC) algorithm that addressed the node isolation problem. In their approach, a node that does not receive any head message from the tentative and neighbour cluster head(s), the node elects itself as a cluster head and broadcasts the head message. Ghaffari, (2014) employed multi-hop communication to transmit data to the base station. Vrinda & Rajoo, (2016). Proposed an improved energy-aware distributed unequal clustering (IEADUC) algorithm. Re-clustering related overhead still remain a common problem with all of these algorithms. Some researchers avoid the re-clustering overhead problem by introducing static cluster into the network sensor field. Shalli, et al. (2015) proposed a novel scheme for routing in WSN. Cluster are formed statically at the beginning of the network lifetime by dividing the network area into a number of horizontal grids. Cluster head are also selected randomly. Cluster head at the lower-level cluster transmit their data to the base station by intercommunicating with relay nodes. The problem with this approach is that a lot of energy is dissipated in transmitting data from the lower-level cluster to the base station. Abed, Ahmad, Khalid, & Moyawiah, (2018) proposed and enhancement of LEACH, they trade re-clustering process in LEACH with a static clustering. However, the only criteria for selecting cluster head is their order in the cluster as nodes are selected turn by turn, hence an inadequate node may be selected. Although the static clustering saves energy by avoiding the re-clustering related overhead problem, however the effectiveness of the static clustering is linear to its design and working mechanism.

A. S. M & Gi, (2018) proposed Energy Centric Cluster-based Routing in WSN, it is a static based clustering algorithm, where nodes with higher residual energy and minimum distance to the rest of the node in a cluster is selected as the cluster head. Cluster heads are changed after every round of communication and the current cluster heads serve as a caretaker for selecting the new cluster heads. The frequency of updating the current cluster heads about the prospective cluster heads tend to result in energy waste and also cluster heads nodes may be capable of maintaining the role of cluster head for some few rounds We propose an enhancement of ECCR that focus on extending the lifetime of the network by reducing the frequency of changing cluster head in the network, hence a cluster head remains a cluster head for some few rounds (tenure: number of rounds a cluster head is allowed to served). Within the time period of a cluster head tenure, member nodes transmit only their local data message to their cluster head, but in the last round of the tenure, member nodes transmit their weight information along with their local data.

MATERIALS AND METHODS

Cluster-Head Selection Phase

This phase has a duration of *T2*. The rank value of nodes is a considered criteria to select a cluster head. at the first round of communication each node sends a $Node\_Msg$ broadcast that span the distance from a node to the farthest alive node in a cluster. This $Node\_Msg$ contains nodes rank value. A nodes rank defines a node residual energy and average distance from the rest of the nodes in the cluster, this is given in Eq. (1).

$$rank(s_i) = \frac{\alpha \cdot E_{res}}{E_{ini}} + \frac{(1-\alpha)}{d_{avg}} \qquad (1).$$

where *a* is a weight factor interval of [0,1]. E_{ini} and E_{res} are the initial energy and current energy of a node s_i, respectively. At the same time, every node in the same cluster receives the $Node\_Msg$ and updates its CMT. From the Eq. (1), the highest-ranking node will have the smallest average distance from the member nodes and the highest energy level. The highest rank node is selected as a cluster head. Thereafter the cluster head node sends a time-division multiple access (TDMA) schedule list to all the nodes in its cluster by broadcasting a $Schedule\_Msg$. We observed from the simulation of the existing algorithm that cluster head node has sufficient energy to maintain the cluster head role for some few rounds, hence allowing the cluster head to serve for more than one round will ultimately reduce control messages, thus saving energy.

Proposed Cluster Head Selection Modification

We propose that a cluster head remains a cluster head for more than one round (tenure: number of rounds a cluster head is allowed to served). The detail of the modification is given by the pseudo-code in Algorithm 1 and 2.

Algorithm 1 Cluster head selection for first round

1.Start(cluster head selection)
2. While(T_2 has not elapsed) do
3. $state \leftarrow Candidate$
4. Broadcast $Node\_Msg$
5. Recieve and update CMT[s_i]
6. Find a higher rank node
7. $state \leftarrow Normal$
8. CMT[s_i].$state \leftarrow Head$
9. $tenure \leftarrow r + 2$
10. Broadcast $tenure$ along with $Schedule\_Msg$
11. end
12. end

We considered 2,3,4 as the input cases for the value of round in a tenure. The pseudo-code above uses two. In the last round of the tenure, member nodes transmit their control message (rank and residual energy) along with the local data to the cluster head. These rank value and the node energy level is used by the cluster head for subsequent cluster head selection, the cluster head simply hand over cluster head role to the node with highest rank value in the cluster. This is done by sending a $Handover\_Msg$ to the selected node, the $Handover\_Msg$ contains cluster head id and missing node id, nodes are considered missing or dead when a cluster head does not receive data from them, they are excluded from the network and from the rest of the process. Thereafter the selected node updates its CMT with the received message and sends a $Schedule\_Msg$ broadcast to its cluster, the $Schedule\_Msg$ contains a TDMA schedule list along with the current cluster head tenure information. The cluster member receives the broadcast and updates their respective CMT. If no $Schedule\_Msg$ has been broadcasted from a cluster head within a predefined time, the processes that happen at the first round is repeated. This phase is given by the pseudo-code in Algorithm 2.

Algorithm 2 Cluster head reselection

```
Start(cluster head reselection)
if( r > 1) then
   if(tenure - r ==0) then
      send rank value and current residual energy to cluster head
      Find a member node with a higher rank
      Find missing node id
      Send Handover_Msg
      Find cluster head id
      state ← Normal
      CMT[s_j].state ← Head
      tenure ← r + 2
      Broadcast tenure along with Schedule_Msg
      if(no Schedule_Msg has received) then
         Repeat the cluster head selection process as r == 1
      end
   end
end
end
```

Performance Evaluation

The simulation model was developed and executed to evaluate the performance of E-ECCR. Firstly, we present the simulation set up and the parameters settings. Then, the performance of E-ECCR was examined and compared with the existing algorithm, for tenure value (2,3,4), in terms of stability period, alive nodes with progression of communication round, the energy of the network with progression of communication round.

Simulation Setup

We use NS2 to develop the simulation models for the study. NS2 is an open-source simulation tool that runs on Linux. It is a discreet even simulator targeted at networking research and provide substantial support for simulation of various network protocols. It is assumed that the location of the BS is set to (100,250) corresponding to the $(X, Y)-$coordinates of the sensor field. 100 nodes were randomly and uniformly deployed over a $(200X200)m^2$ sensor field. Nodes are equipped with initial energy interval of 0.5–1.5 J. Table 1 shows the simulation parameters.

Table 1: Simulation Parameters

Parameters	Values
E_{elec}	50nJ/bit
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4
E_{DA} (Data aggregation cost)	5nJ/bit/signal
R_{max} for IEADUC	100m
Threshold distance	**87.7m**
α, β, γ	0.3333
Control packet size	25 bytes
Data packet size	500 bytes
E_{elec}	50nJ/bit
R_{max}	188.56m
Diagonal length of grid D	94.28m
Weight factor α	0.8

RESULTS

The evaluation metrics used are: ***(1) Alive nodes***, which shows the number of actively participating nodes through the progression of communication rounds. ***(2) Energy dynamics***, indicates the degree of energy depletion in the network. We analysed the alive nodes and energy dynamics for the E-ECCR when number of rounds in a tenure (2,3,4). ***(3) Network stability period***, which refer to the number of communication rounds until the first node dies in the network. Figure 5 indicates a notable linear improvement in the life span of nodes in the network with respect to the given cases of input for the value of round in a tenure. Figure 6 indicates a notable linear improvement in minimizing the energy depletion in the network with respect to the given cases of input for the value of round in a tenure.

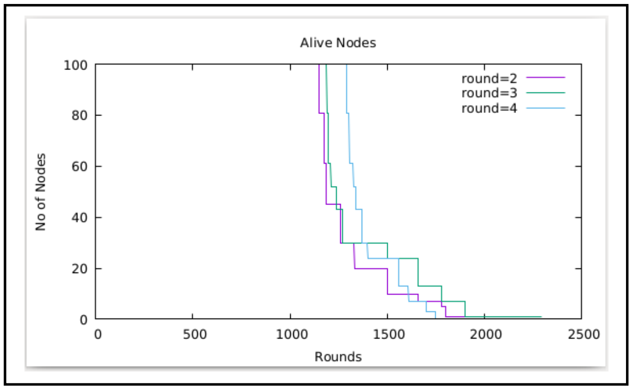

Figure 2 Alive Nodes

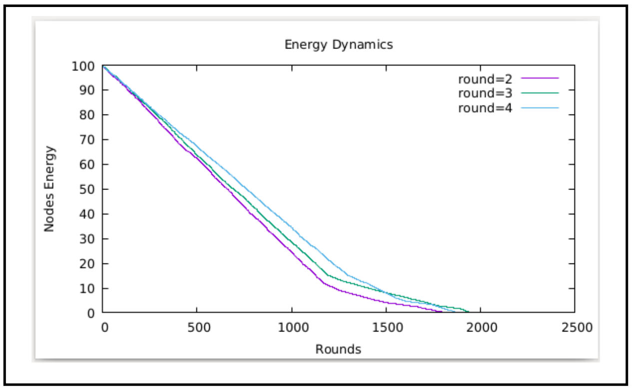

Figure 3 Energy Dynamics

Performance Comparison with ECCR

Here, we compared the E-ECCR with the ECCR, and also analysed their performance in terms of **Alive nodes** and **Energy dynamics** and **Stability period**. Figure 7 shows that, in a network of 100 nodes, the E-ECCR is able to keep 100 of these nodes. Operational for over 1300 rounds. ECCR on the other hand keep 100 nodes active for less than that, over 1000 rounds respectively. Also over 50% of nodes couldn't survive 1300 rounds with the existing algorithms. Applying E-ECCR increases network operational time to a larger extent than the ECCR. Figure 8 plots the energy dynamics in the network. Energy of the network will drop down to 0 when all nodes run out of battery. For E-ECCR, this happens after over 1700 rounds of communication, ECCR keeps the network operational for roughly 1600 rounds. The slope of the graphs also shows that ECCR has the steepest energy depletion rate.

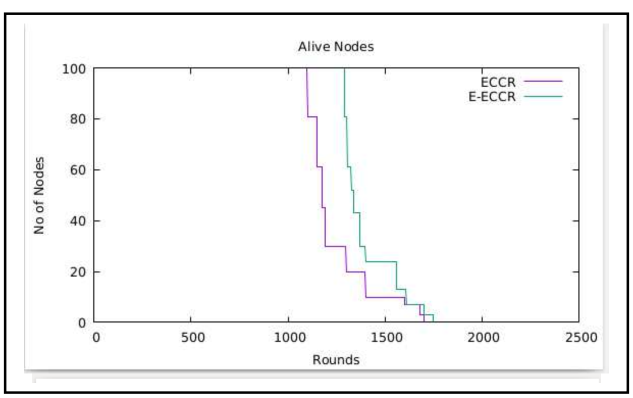

Figure 4 Alive nodes comparison with ECCR

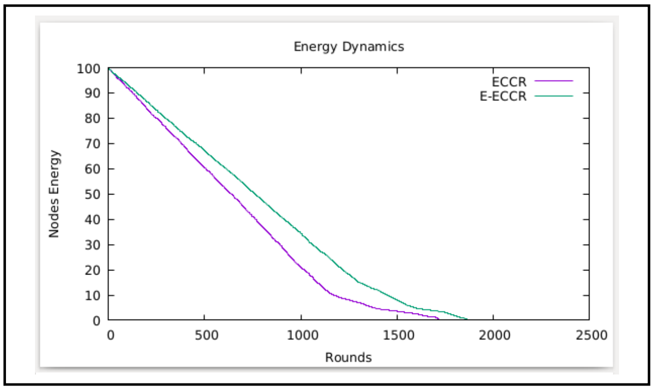

Figure 5 Energy dynamics comparison with ECCR

The Stability period is defined as the number of communication round until the first node dies. Figure 9 shows that E-ECCR also outperforms ECCR in term of stability period.

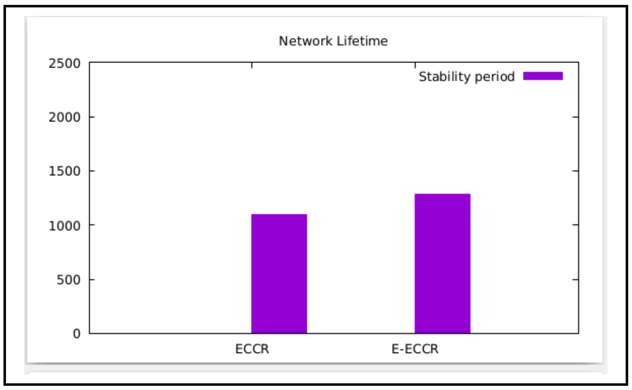

Figure 6 Stability period comparison with ECCR

CONCLUSION

Energy efficiency is one of the primary concerns in the design of WSN deployed in hostile environment. Significant percentage of the energy consumption is as a result of data communication. The work described in this study has proposed an Enhancement of ECCR, the idea entails reducing the frequency of changing cluster head, thereby increasing the number of rounds a node remains as a cluster head. We experiment the idea with some input cases for the value of round (Round= (2,3,4)), and the performance turnout was better than ECCR.

For future work, a thorough study of the input cases for the value of round can be explored, to identify the relationship between the input cases and the algorithm performance consequently leading to knowing the worst and best cases of input.

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