Energy Conservation in Wireless Sensor Networks through HEECA Mechanism

Gurjot Singh Gaba1*, Ruchi Pasricha2, Rajan Miglani1 and Paramdeep Singh1

1Lovely Professional University, Jalandhar - 144411, Punjab, India; gurjot.17023@lpu.co.in, rajan.16957@lpu.co.in, paramdeepsingh.15905@lpu.co.in
2Chandigarh Engineering College, Mohali - 140307, Punjab, India; cecm.ece.rps@gmail.com

Abstract

Wireless Sensor Networks (WSN) consists of large amount of nodes spread either arbitrarily or non-arbitrarily in the region of interest for sensing an event. The main constraint in WSN existence is the consumption of energy by tiny sensor node during operation. For increasing the lifetime of WSN, various clustering techniques have been evolved in the last decade. Energy Consumption by the node primarily depends upon the distance between nodes to Cluster Head (CH), CH to Base Station (BS) and the Length (L) of the packet being transmitted. It has been analyzed that combinations of two different techniques i.e. EECA-F and H-PEGASIS can solve variety of issues. In this paper, two techniques are combined together to form Hybrid Energy-Efficient Clustering Technique (HEECA). Results revealed that in HEECA mechanism, nodes consume 1.75J energy even after 80 rounds whereas in EECA-F the toll reaches 3J. On analyzing, it is found that clustering through HEECA protocol can save 41.7 percent energy in nodes thus making them live longer and eligible to be used in robust applications where replacing battery of a node is a tedious task.

Keywords: Clustering, Energy Conservation, LEACH, PEGASIS, Wireless Sensor Networks

1. Introduction

WSN consists of huge number of sensor nodes functioning jointly. There are two kinds of WSNs: structured and unstructured. An unstructured WSN is one which has a thick set of sensor nodes. Sensor nodes can be arranged in ad hoc fashion into the region. Formerly arranged, the system is absent to carry out check and coverage purpose. System preservation such as overseeing connectivity and perceive crash are not easy as there are several nodes in an unstructured WSN.

Sensors within diverse region of the field can work together to collect the information and give additional precise reports concerning their confined region within this case. Wireless Sensor Networks are prone to natural calamities thus nodes must be made fault tolerant. The main motive of research is to conserve energy in a WSN using the HEECA. HEECA is combination of Energy Efficient Congestion Avoidance in Wireless Multimedia Sensor Network (EECA) and Hierarchical - Power-efficient gathering in sensor information systems (H-PEGASIS). HEECA proved to be a better substitute than Hybrid Energy Efficiency Protocol (HEEP).

2. Conventional Clustering Strategies

The idea of Hybrid Routing Protocol (HRP) is used to carry out efficient routing in WSN which split the whole system into diverse layers of clusters. Nodes are crammed into clusters which have a Cluster Head (CH) in every cluster. While in LEACH there are 2 stages; the first one being the “Set-up Phase”: within this stage clusters are shaped and Cluster Heads are formed. The second stage

*Author for correspondence
is “Steady state Phase”: within this stage associate nodes transmit out its information to CH's through Time Division Multiple Access (TDMA) agenda. After that CH's combine and broadcast information towards the Base Station (BS). One round of transmission is said to be completed when the CH transmits its collective information towards BS. It is a continuous process and new cluster heads will evolve with the passage of time. This will normalize the energy consumption of all the nodes in the network. A lot of research has been carried out in the field of Clustering and routing to conserve power.

Further, random rotation of cluster head can help to distribute the load evenly between various nodes thus saving a single node to ruin all the energy for relaying the information of others. LEACH is the oldest protocol in defining the rules to configure the network into clusters. LEACH is inconsistent in choosing the cluster head because CH is elected based upon an empirical formula and no other real time input is taken into consideration. Research carried out to resolve the inconsistency issue of LEACH and resulted in origin of HEED protocol. HEED chooses the cluster head based upon the two parameters: node degree and residual energy of nodes.

EECA-F (Energy Efficient Congestion Avoidance in Wireless Multimedia Sensor Network - Fixed) has an improved concept as compared to Genetic Algorithm Based Energy Efficient Clusters (GABEEC) in terms of energy consumption. In this technique, a new parameter was used i.e. weight parameter is included which works on three functions:

- Degree of nodes.
- Energy consumption by each node.
- Distance of each node from the Base Station.

On the basis of minimum weight, new cluster head is selected. After that transmission of data takes place. This consideration is very important as the sensor nodes run out of energy quickly. During the research it is also found that with just a failure of one node, network may get split and performs poorly. Yick et al. in 2005 also proposed a similar scenario but considering different parameters to quantify the performance of the network. In their paper, problems associated to clustering of mobile nodes have been discussed with their proposed solution. Results reveal that energy consumption is little bit decreased as compared to existing protocols while no enhancement is noticed in accuracy.

PEGASIS is considered to be best for information gathering in sensor systems which create a sequence of sensor nodes so that every node will receive packets from a nearer neighbor and forwards it to a next nearer neighbor in the path of transmission. Collective information goes from node to node and at the last, a distinct node (usually called as CH) conveys each the collective information to the BS. Thus energy is considerably saved as nodes are not directly approaching the BS. Younis et al. highlighted the importance of scalability in Wireless Sensor Networks. Results justified better response as compared to weight based clustering in several characteristics. Their efforts were to prolong the network lifetime. However, no tests are carried out to check the throughput and efficiency of the protocol. Various efforts are done to prolong the network lifetime through the use of energy efficient protocols or by avoiding implosion etc.

It is important to know that in WSN, nodes on-board energy available to process and forward the data is quite less. It means that the energy must be spent appropriately to enhance the lifetime of the network. Routing of information based on context and relaying through centralized gateways can also save substantial amount of energy. Though WSN nodes remain unattended still nodes have to be fault tolerant. Networks can also be classified based upon their mode of operation i.e. proactive and reactive. Optimized deployment of these modes in appropriate applications can lead to saving of energy at node end.

### 3. Proposed Method

HEEP has two necessary segments: the initial stage that outline series cluster, and choose CHs, followed by Communication stage where composed information is broadcasted. As communication remoteness is abridged, the impact of communication will be increased comparatively. The concept of HEECA is inspired from HEEP. HEEP algorithm is a hybrid formation of LEACH and PEGASIS. Hybrid formation is useful as the advantages of both the techniques are jointly collaborated to evolve the best technique as a resultant.

\[ \text{HEEP} = \text{LEACH} + \text{PEGASIS} \]

But with the passage of time more features have been incorporated in WSN leading to more intelligence in the sensor nodes. But these advancements have lead to more energy consumption in sensor nodes due to more tasks in
hand. To overcome this problem, a solution is proposed. The solution undertakes the two important techniques which are the subsets of HEEP technique. EECA-F is a subset of LEACH and H-PEGASIS is a subset of PEGASIS.

\[ \text{HEECA} = \text{EECA-F} + \text{H-PEGASIS} \]

In this proposed work, principle of both the techniques is combined to combat the existing problems.

4. Algorithm of HEECA

The algorithm proposes a clustering technique whose goal is to decrease energy consumption of sensor nodes and to enhance the system life span for the WSNs.

| Table 1. Parameters definition |
|--------------------------------|
| Parameters | Definition |
| M | No. Of nodes |
| Ec(u) | Energy consumed by node u |
| DisBS(u) | Distance between the node u and the BS |
| Weight(u) | Weight of u |
| X_BS | The X coordinate of the BS |
| Y_BS | The Y coordinate of the BS |
| DisBS_Max | The maximum distance of the BS |
| EI | Initial energy for each node |

Table 1 lists the various parameters which are being used for the purpose of constructing the proposed technique. The testing and simulation is done in MATLAB tool. Initially 100 nodes are generated in the area of 200 × 200 square meters. As HEECA is a hybrid technique, its first counterpart i.e. EECA-F will be used to select cluster head in the area among all the other nodes based on the energy parameter.

4.1 Energy Consumed

The total energy consumed by the sensor nodes for transmission \( E_{tx} \) and reception \( E_{rx} \) can be expressed as:

\[ E_c(u) = E_{tx}(N;d) + E_{rx}(N) \]  

The communication energy \( E_{tx} \) and reception energy \( E_{rx} \) are defined as follows:

\[ E_{tx}(N;d) = E_{elec} \times N + e_{amp} \times N \times (d^2) \]

\[ E_{rx}(N) = E_{elec} \times N \]

Where, \( E_{elec} \): Electronic Energy, \( E_{elec} = 50nJ/bit. \)

\( N \): message length (bits).

\( e_{amp} \): communication amplification coefficient, \( e_{amp} = 100pJ/bit/m^2. \)

\( d \): space amongst receipt node and transmit node (m).

4.2 CHs Election Procedure

Calculate the consumed energy \( E_c(u) \) in support of every node u. Calculate the space amongst u and the BS in support of every node u:

\[ \text{DisBS}(u) = \sqrt{((x - X_{BS})^2 + (y - Y_{BS})^2)} \]  

Calculate the joint weight in support of every node u:

\[ \text{Weight}(u) = \left( \frac{E_c(u)}{EI} \right) + \left( \frac{\text{DisBS}(u)}{\text{DisBS}_{\text{Max}}} \right) \]

Equation 5 demonstrates the use of weight parameter. The node having the minimum weight is elected as the CH and this elected node (CH) will have the maximum degree i.e. energy efficient node and closer to the BS. This process is repeated for the residual sensors also.

The whole concept of HEECA can be summarized as: Subdivide the cluster into the groups of two individuals according to H-PEGASIS except CH. After grouping, data transmission begins by the node towards the Cluster Head. Cluster Head is chosen with the help of weight parameter. The node within the cluster with the minimum weight is recognized as Cluster Head which is usually closer to the base station as compared to other nodes of the base station. All the data after passing through various nodes finally reaches to the Cluster Head. Cluster Head then aggregates the data by removing duplicates etc. and passes on the information to the Base station. This transfer of the data by all the nodes to the base station is considered as completion as one round of data transfer.

5. Results and Discussions

The results of the proposed technique are gathered from MATLAB tool. Area of testing is 200m X 200m and node communication Range is 40 m. The size of a measured information package is 4000 bits and EI is 1.5J.BS, coordinates are (100,100). The maximum space to the BS DisBS_Max is 200 m.

HEECA is comprised of two techniques i.e. EECA-F and H-PEGASIS. We know that EECA-F is a most advanced clustering technique which is an improved version of LEACH and H-PEGASIS protocol. The attributes
of both the techniques are together used in the HEECA protocol making it a better substitution in comparison with existing techniques.

Figure 1 shows energy consumption of nodes while using different protocols for one round only. Findings depicts that nodes using HEECA protocol consumed less energy in one round as compared to nodes working on EECA-F protocol. This significant drop in consumption of node energy can contribute a lot in overall enhancement of network lifetime.

Figure 2 shows energy consumption of nodes for different number of rounds. Calculations prove that HEECA saves an overall energy of 41.7% of sensor nodes as compared with the EECA-F. These figures clearly depicts that HEECA has a better performance than EECA-F in terms of energy conservation.

6. Conclusions

The impact of Wireless Sensor Networks has considerably increased with the advancement of Wireless Sensor Networks applications. Due to limited energy reserves, their applicability is restricted in some applications. Due to wider scope and practical applicability, most of the research is carried out in enhancing the lifetime of the network. HEECA is one such protocol designed by us for achieving the objective of increased network lifetime. HEECA protocol is a powerful protocol encapsulating EECA-F and H-PEGASIS attributes together. This protocol has not only proven as good energy conserving protocol by increasing the lifetime of the network by 41.7% as compared to EECA-F but also provided a reliable way to do the transmissions effectively and in proper manner. This invention has brought revolution in Wireless Sensor networks.

7. References

1. Singh SP, Sharma SC. A survey on cluster based routing protocols in wireless sensor network. India India: International Conference on Advanced Computing Technologies and Applications. 2015; 45:687–95.
2. Bagaa M, Challal Y. Data aggregation scheduling algorithms in wireless sensor network. IEEE Communication Surveys and Tutorials. 2014; 16(3):1339–68.
3. Dohare U, Lobiyal DK, Kumar S. Energy balanced model for lifetime maximization in randomly distributed wireless sensor networks. Wireless Pers Comm. 2014; 78(1):407–28.
4. Samanta M, Banerjee I. Optimal load distribution of cluster head in fault-tolerant Wireless Sensor Network. Bhopal: IEEE Students’ Conference on Electrical, Electronics and Computer Science; 2014. p. 1–7.
5. Guiloufi AB, Nasri N, Kachouri A. EECA - Energy Efficient Clustering Algorithm for fixed and mobile wireless sensor networks. Nicosia: International Conference on Wireless Communication and Mobile Computing (IWCMC); 2014. p. 735–8.
6. Ranjan SS, Krishnan SR, Thangaraj C, Devi KV. Achieving energy conservation by cluster based data aggregation in wireless sensor networks. Wireless Pers Comm. 2013; 73(3):731–51.
7. Kumar N, Kim J. ELACCA: Efficient Learning Automata Based Cell Clustering Algorithm for wireless sensor networks. Wireless Pers Comm. 2013; 73(4):1495–512.
8. Aissa M, Belghith A, Drira K. New strategies and extensions in weighted clustering techniques for Mobile ad hoc systems. The 4th International Conference on Ambient Systems, Networks and Technologies. 2013; 19:297–304.
9. Nikolidakis SA, Kandris D, Vergados DD, Douligeris C. Energy efficient routing in wireless sensor systems through balanced clustering. Algorithms. 2013; 6(1):29–42.
10. Bayrakli S, Erdogan SZ. Genetic Technique Based Energy Efficient Clusters (GABECC) in wireless sensor systems. The 3rd International Conference on Ambient Systems, Networks and Technologies (ANT). 2012; 10:247–54.
11. Waware S, Sarwade N, Gangurde P. A review of power efficient hierarchical routing protocols in wireless sensor networks. International Journal of Engineering Research and Applications. 2012; 2(2):1096–102.
12. Chong SK, Gaber MM, Krishnaswamy S, Loke S. Energy conservation in Wireless Sensor systems: A rule-based approach. Knowl Inform Syst. 2011; 28(3):579–614.
13. Boubiche DE, Bilami A. Hybrid energy efficiency protocol based on chain clustering. International Journal of Sensor Networks. 2010; 10(1-2):25–35.
14. Wener-Eachen G, Lorincz K, Ruiz M, Marcillo O, Johnson J, Lees J, Walsh M. Deploying a wireless sensor system on an active volcano. IEEE Internet Computing. 2006; 10(2):18–25.
15. Yick J, Mukherjee B, Ghosal D. Analysis of a prediction-based mobility adaptive tracking algorithm. Proceedings of the IEEE, 2nd International Conference on Broadband Systems (BROADNETS). 2005; 1:753–60.
16. Younis O, Fahmy S. HEED: A hybrid, energy-efficient, dispersed clustering approach for Ad Hoc sensor systems. IEEE Trans Mobile Comput. 2004; 3(4):366–79.
17. Younis O, Fahmy S. Dispersed clustering in ad hoc sensor systems: A hybrid, energy-efficient approach. Twenty Third Annual Joint Conferences of the IEEE Computer and Communication Societies (INFOCOM). 2004; 1.
18. Akyildiz IF, Su W, Subramaniam YS, Cayirci E. A survey on Sensor Systems. IEEE Comm Mag. 2002; 40(8):104–12.
19. Younis M, Youssef M, Arisha K. Energy-aware routing in cluster-based sensor systems. Proceedings IEEE, 10th International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems; 2002. p. 129–36.
20. Manjeshwar A, Agrawal DP. TEEN: A protocol for enhanced efficiency in wireless sensor networks. San Francisco: Proceedings 15th International Parallel and Distributed Processing Symposium; 2001. p. 2009–15.
21. Heinzelman WR, Chandrakasan A, Balakrishnan H. Energy-efficient Communication protocol for Wireless Micro Sensor Networks. Proceedings of the 33rd Annual Hawaii International Conference on System Sciences; 2000. p. 1–10.
22. Lindsey S, Raghavendra CS. Power-efficient gathering in sensor information systems. IEEE Aerospace Conference Proceedings. 2002; 3:1125–30.
23. Basagni S. Dispersed clustering technique for ad hoc systems. Proceedings of the 1999 International Symposium Parallel Architectures. Algorithms and Networks; 1999. p. 310–5.