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GENETIC ALGORITHM WITH LEACH PROTOCOL FOR CLUSTER HEAD SELECTION IN WIRELESS SENSOR NETWORKS

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Abstract

Wireless Sensor Network (WSN) is the deployed randomly and on the far places to sense information. The security, quality of service and energy consumption is the major issues of WSN. To minimize the consumption of higher amount of energy in these networks, clustering is applied. The Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol is used for the cluster head selection in the network. The cluster head is selected based on the energy consumption and distance to base station. A node is selected as Cluster Head (CH) if it has the highest amount of energy and the least distance from base station. In this research work, genetic algorithm is applied with the LEACH protocol for the cluster head selection. The proposed work is implemented in Matlab. The results of existing LEACH protocol is compared with proposed LEACH protocol in terms of certain parameters. The comparative analysis and achieved outcomes show that the proposed approach performs well in terms of energy consumption as it consumes lesser amount of energy.

Keywords:

LEACH, Clustering, Genetic Algorithm, Cluster Head

1. INTRODUCTION

A network is deployed with the aim of monitoring the activities going on in the surrounding regions. There are several sensor nodes placed in the region to be monitored to collect all kinds of important information. This network is known as wireless sensor network (WSN). The sensor nodes are smaller in size and the tasks are processed using that limited amount of energy. Depending upon the changes in the surroundings, the important information is collected, processed and then forwarded to the users. This kind of network has limited computing and processing capabilities. Motes are deployed in the network for collecting information, which are basically the small sized computers [1].

Energy efficiency and multi-functioning are the two properties of these networks. Motes are deployed in several industrial based applications. They help in collecting the information in order to achieve particular objectives of application. Depending upon the configurations links are made by the motes with the aim of providing the highest performance outcomes. To perform communication, the motes use transceivers. WSN includes around hundreds to thousands numbers of sensor nodes As compared to the sensor networks, there are fewer numbers of sensor nodes deployed in the ad hoc networks in which no infrastructure is included. To design new kinds of applications for improving the monitoring capabilities of applications, WSNs have been deployed [2].

The environment is monitored, required data is processed and the processed data is sent and received from sensing nodes using WSNs. For performing processing, important parameters collected from surrounding are forwarded by the sensing unit available in sensor nodes. To digitize the analog signals being generated from sensors, the Analog to Digital converter (ADC) is used. The processing unit is an important part of sensor node. The processor helps in executing the tasks and handling the functionality of other components [3].

The energy utilization rate of processor is different depending upon the functionality of nodes. Energy is the most important factor to be considered in WSNs. To improve the network lifetime, saving the energy in hardware and software solution is important. The highest proportion of energy is consumed during data communication as compared to data sensing and processing [4].

Therefore, only short-range communications are used among the sensor nodes and the long-range data transmissions are avoided since the transmission power is limited. The events in most of the WSNs are sensed closer to the region of interest and at the distance from sink nodes. Therefore, the short-range communication is applied through which the data packets can be forwarded along the multi-path using intermediate nodes. There is huge difference in routing performed in wireless sensor networks and that performed in other networks. The routing protocols provide strict energy-saving needs in case of node failures. Generally, various researchers have used different routing protocols [5].

The categorization of routing protocols is done in different categories. Depending upon the information about the location of sensor nodes, routing is performed in case of Location-based protocols. To calculate the distance among two particular nodes, the information related to the sensor nodes is required. The data-centric protocols are not like other protocols as these protocols transfer data from the source sensor nodes to the base station. In case of the address-centric protocols, every sensor node uses an individual source to transfer data to the base station in independent manner. This hierarchical approach generates several clustered layers. A cluster head is selected after that constriction of clusters by nodes' grouping. The use of CH makes the routing possible from one cluster to other sinks or CHs [6].

The hoping of data from one to other layer covers large distances although the transferring is carried out from one node to another node merely. Low-energy adaptive clustering hierarchy (LEACH) is an energy efficient clustering algorithm. This approach minimizes the energy expenditure [7]. Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is an improvised version of LEACH protocol. This protocol generates the sequence of sensor nodes for transmitting and receiving data from the neighboring node. This protocol selects just one node from the generated sequence to forward data to the sink [8]. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) protocol groups sensor nodes into clusters. Every cluster has its individual cluster head. The sensor nodes in the cluster carry out the reporting of sensed information to the cluster head.

2. LITERATURE REVIEW

Huang, et al. [9] investigated and explored a new clustering routing algorithm based on multi-cluster head. The main aim here was to balance the energy consumed by different sensor nodes in a WSN. This work was also focused on improving the stability and extending the life span of the network. This work considered cluster as the main component and carried out the division of WSN into many clusters. This work provided the detail of Energy Consumption Model (ECM) of the WSN. Moreover, it simulated and analyzed the recommended routing algorithm. The tested outcomes revealed that the recommended algorithm had the ability to balance the energy consumed by the multiple nodes in the WSN. The recommended algorithm efficiently extended the life span and improved the constancy of WSN. The recommended algorithm could be used to serve different purposes.

A new model for improving the energy efficiency of WSNs [10]. This model was called Advanced first order Energy Consumption Model (A-ECM). The achieved outcomes demonstrated the efficacy of recommended model in real-time conditions. However, this work only considered first order modeling of the ECC (Energy Consumption Cost) at the network layer. Therefore, the future work would be focused on expanding the range of this work to two proposals. These proposals are second order modeling of the ECC (Energy Consumption Cost) at the network layer and the MAC (Medium Access Control) layer.

The major purpose of a WSN was to collect environmental data using multiple sensor nodes [11]. Energy consumption by sensor nodes was a major factor in this network. EC (Energy Consumption) influenced the life span of WSN to a large extent. It was a complex task to alter the already defined WSN designs. A representative node had an inbuilt sensor system and it was completely dependent on different applications. This work was focused on the energy consumed by sensor nodes based on a particular cluster and LEACH protocols.

Jia et al. [12] introduced a new approach for reducing energy consumption in a WSN. The new approach was called LEFD. Initially, this work made use of time correlation information of sensor devices' for detecting faulty devices in LEFD. Afterward, this work implemented the spatial correlation information for detecting the residual faulty devices. Moreover, it was not required for the nodes to share information with the neighboring nodes in the recognition method as LEFD adopted the data sensed by node for detecting some fault types. This phenomenon efficiently reduced the energy consumed by the nodes. At last, LEFD also took into account the nodes having the possibility of transient errors. The achieved simulation outcomes confirmed the efficacy of recommended approach in terms of improved data transferring and decreased power expenditure.

Bingyue Liu [13] recommended RBF based cross-application energy efficient approach for WSNs for decreasing the power consumed by sensor nodes. This work used Neural Network radial basis function (NNRBF) based *k*-means clustering self-arranging algorithm to estimate the cluster hub. Afterward, this work used Least Mean Square (LMS) algorithm for adjusting and modifying the cluster hub's weight matrix to understand data synthesis. The achieved simulation outcomes demonstrated that the recommended approach decreased the use of energy to a large extent reduced after some stages.

Khriji et al. [14] stated that WSNs faced a major issue of energy consumption. With the time, various researchers developed different approaches for reducing energy consumed by these networks. The selection of a low energy consumption and cost efficient circuit was carried out in this work for measuring the energy consumed by these networks in the past. This work also measured the left over power of the deployed batteries. This work made use of wireless node panStamp for performing several tests. The future work would be focused on carrying out more empirical tests to compute the left over power of deployed network nodes.

Tutunovic et al. [15] stated that energy consumption affected the efficiency of WSN to a large extent. It could be pricey at the same time complicated to perform tests with real-time tools and networks. Therefore, a simulation tool could be employed an option for simplifying the investigation scenario. This work made use of Cooja tool for simulation purpose. In this work, five different experiments were carried out with four metrics for measuring the power usage with different number of sensor devices without making any change in the location of the base station. The achieved outcomes depicted that average energy consumed by every nodes was not essentially related to the minimum number of nodes.

3. RESEARCH METHODOLOGY

In this research work, the genetic algorithm will be applied with the LEACH for the path establishment from source to destination. LEACH protocol is referred as Low Energy Adaptive Clustering Hierarchy. Basically, this cluster routing protocol includes three steps. Each cluster head communicate directly to transmit data to the sink. The use of clusters prolongs the service tome of WSN is extended using the clusters. LEACH protocol compresses the original data for the transmission of merely important information to the individual sensors. It is called aggregation and used within LEACH protocol. It is a self-organizing protocol. This protocol makes use of a randomized rotation of CHs for the even distribution of energy load amid the sensor nodes in the network.

This protocol improves the scalability and robustness of routing and data distribution by controlling the volume of data selected for transmitting to the base station. In order to give same chance to all the sensor nodes to be selected as CHs, the high-energy CH location is rotated in random manner within LEACH rather than selecting the CHs in static manner. The depletion of energy at lesser time periods can be avoided using this protocol. This protocol includes two different stages. The first stage is known as Setup stage. The network is sorted out in clusters in this stage. The second stage is called steady-state. In this phase, data is compressed and the information is transmitted to the base station to carry out data aggregation.

The general process of LEACH protocol is described here. The sensor nodes will originate a number between 0 and 1 (including 0 and 1) in random manner in the set-up phase of clusters. In this round, the node will be selected as a CH (Cluster Head) if the random number is lesser than the threshold $T(n)$. The threshold $T(n)$ can be computed using the formula given below:

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left[r \bmod \left(\dfrac{1}{p}\right)\right]} & N \in G \\ 0 & Otherwise \end{cases} \quad (1)$$

In Eq.(1), p symbolizes the percentage of cluster nodes accounting in the overall number of sensor nodes. It is the probability of nodes making cluster heads. The variable r represents the existing number of rounds or periods. N refers to the total number of sensor nodes. G corresponds to the set of nodes which do not turn out to be cluster heads in the $1/p$ round. The genetic algorithm will be applied which can establish path from cluster head to cluster head for the data transmission.

Similar to neural networks, Genetic algorithms (GA) are biologically inspired algorithms. These algorithms represent a novel computational model with its roots in developmental sciences. In general, genetic algorithms refer to optimization process in a binary search space. In contrast to the conventional hill climbers, these algorithms do not assess and enhance a solo solution but a set of solutions or hypotheses known as population. These algorithms generate successor solutions by mutating and recombining the optimal existing identified hypotheses. Therefore, offspring of the fittest solutions replaces a part of the current population after every iteration process. In particular, the searching for a space of candidate hypotheses is carried out for identifying the optimal solution. This solution is termed as the optimization of a specified mathematical measure [21]. It is known as hypothesis or solution fitness. GA is also called global heuristic algorithm (GHA).

Fitness Parameters of genetic algorithm in WSN: The fitness of a chromosome finds out the level of minimum energy consumption and maximum coverage. In WSN, some significant fitness parameters of GA are described below:

Direct Distance to Base Station (DDBS): It represents the sum of direct distance among all sensor nodes. The BS denoted by di is given as in Eq.(2).

$$DDBS = \sum_{i=1}^{m} d_i \quad (2)$$

In this formula, the variable m represents the number of nodes. The large WSN consumes a lot of energy. In addition, DDBS is suitable for small scale networks. In these networks, number of close nodes is not significant.

Cluster based Distance (CD): It determines the distance between the total cluster heads and base station and the sum of the distance between the determined member nodes and their CHs.

$$CD = \sum_{i=1}^{n}\left(\sum_{j=1}^{m} d_{ij}\right) + D_{is} \quad (3)$$

In Eq.(3), the variable n represents the number of clusters while m represents the related members. The variable d_{ij} refers to the distance amid a node and its cluster head. D_{is} represents distance among the cluster head and the base station. The solution is appropriate for networks having huge number of distantly located nodes.

Transfer Energy (E): It refers to the level of energy consumption needed to transfer all the gathered data to the base station. Consider m as the number of neighboring nodes in a cluster; then E is achieved by

$$E = \sum_{i=1}^{n}\left(\sum_{j=1}^{m} e_{ij} + mE_R + e_i\right) \quad (4)$$

In Eq.(4), e_{jm} represents the energy needed for transferring data from a node to the equivalent cluster head. Therefore, the first term in the summation of i represents the total energy consumption required to transmit aggregated data to cluster heads. The summation i in the next term represents the total energy needed for collecting data from members. At last, e_i represents the energy needed to transfer data from the CH to the base station or sink node.

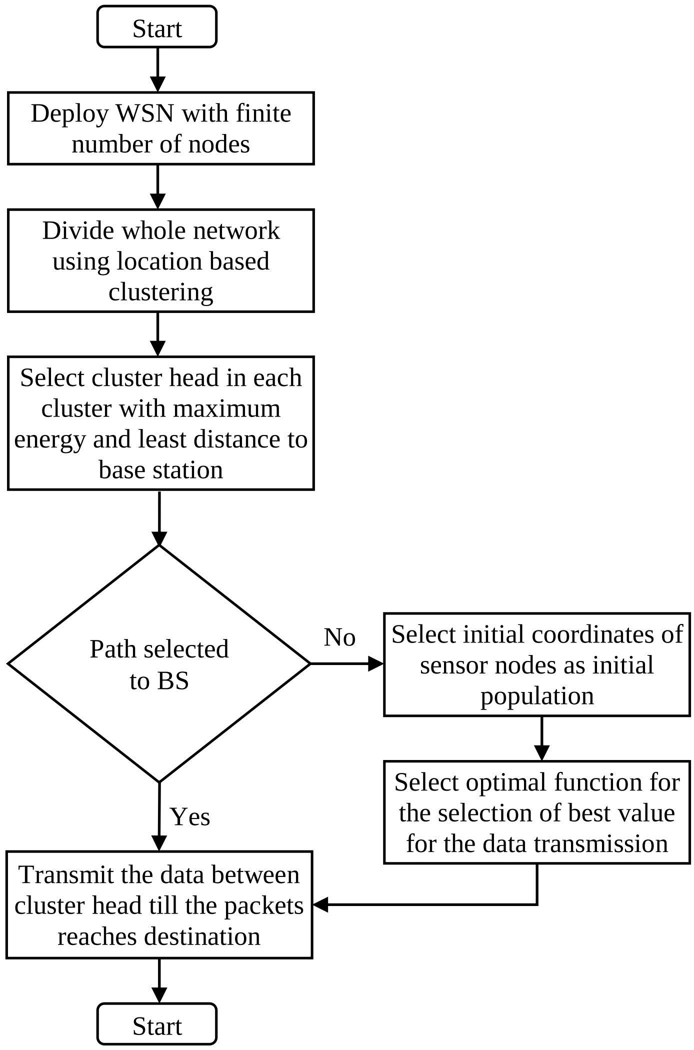

Fig.1. Proposed Flowchart

4. EXPERIMENTAL RESULTS

Matlab simulator is used to implement and evaluate the proposed approach by calculating few performance measures and comparing the outcomes with results of previous approaches.

As shown in Fig.2, the LEACH protocol is executed in the network for the data transmission to base station. In the cluster head get selected in each cluster based on energy and distance to base station. The cluster head transmit data to base station for further processing. The genetic algorithm is applied with the LEACH protocol for the path establishment. When genetic algorithm is implemented, the numbers of dead nodes are reduced in the network as compared to basic LEACH protocol.

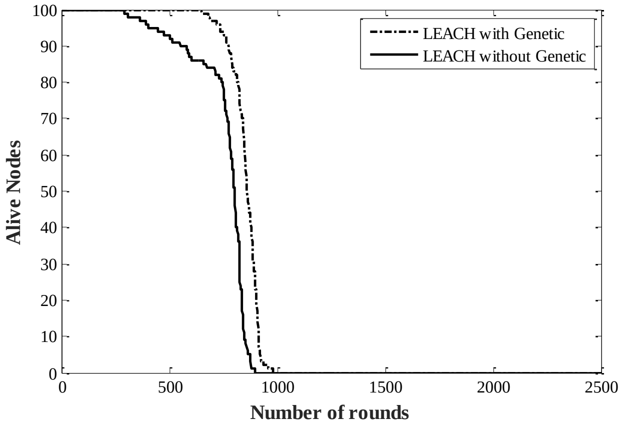

Fig.2. Number of Dead Nodes

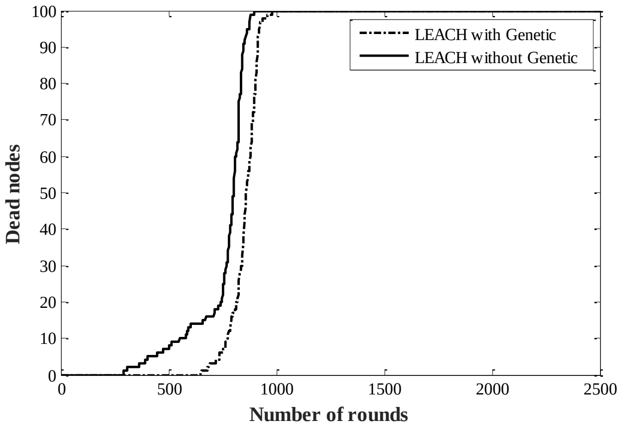

Fig.3. Number of Alive Nodes

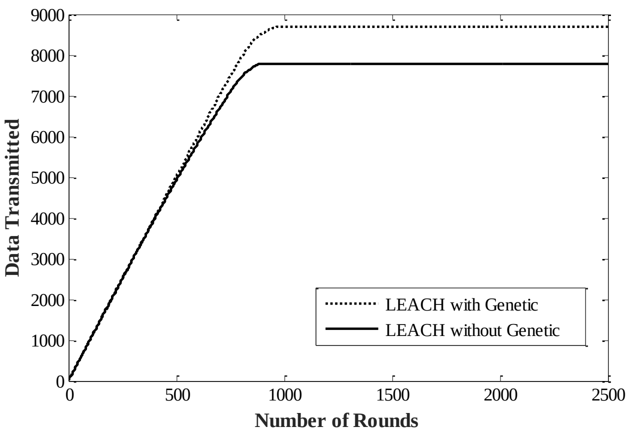

Fig.4. Number of packets transmitted

As shown in Fig.3, the genetic algorithm is applied with the LEACH protocol for the path establishment. When genetic algorithm is implemented, the numbers of alive nodes are increased in the network as compared to basic LEACH protocol.

As shown in Fig.4, the number of packets transmitted in basic LEACH protocol is compared with the LEACH and Genetic algorithm. The LEACH protocol has high number of dead nodes as compared to LEACH protocol with genetic algorithm. When the LEACH protocol with genetic algorithm have less number dead nodes it directly increase the number of packets transmitted in the network.

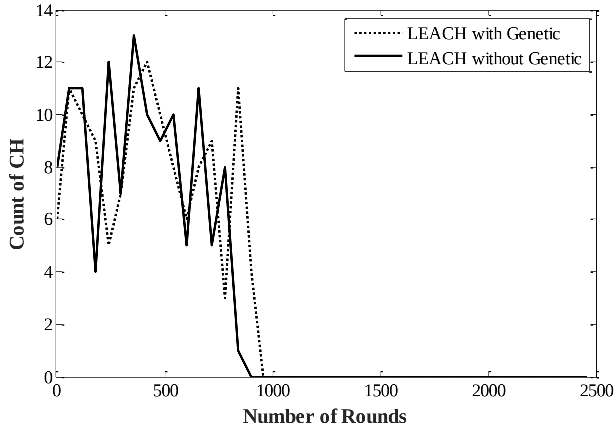

Fig.5. Number of Selected Cluster Head

As shown in Fig.5, the number of cluster head in basic LEACH protocol is compared with the LEACH and Genetic algorithm. The LEACH protocol has high number of less number of cluster head as compared to LEACH protocol with genetic algorithm. The LEACH protocols with genetic algorithm have high number of cluster heads selected in the network.

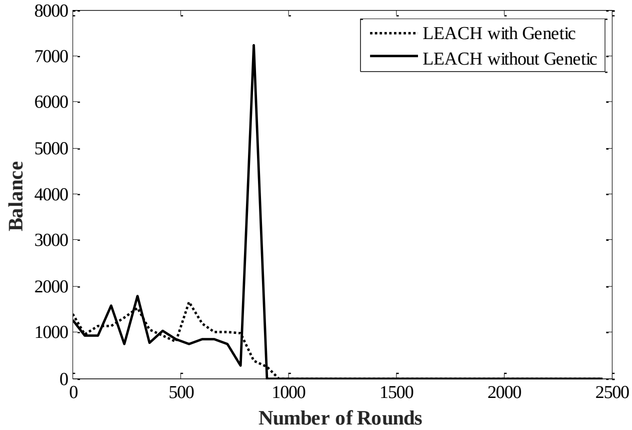

Fig.6. Balance Comparison

As shown in Fig.6, the number of balance in basic LEACH protocol is compared with the LEACH and Genetic algorithm. The LEACH protocol has high number of low balance cluster head as compared to LEACH protocol with genetic algorithm. The LEACH protocol with genetic algorithm has high balance in the network.

As shown in Fig.7, the energy consumption of the LEACH protocol is compared with the LEACH protocol with genetic algorithm. The energy consumption of the LEACH protocol with genetic algorithm is low as compared to LEACH protocol.

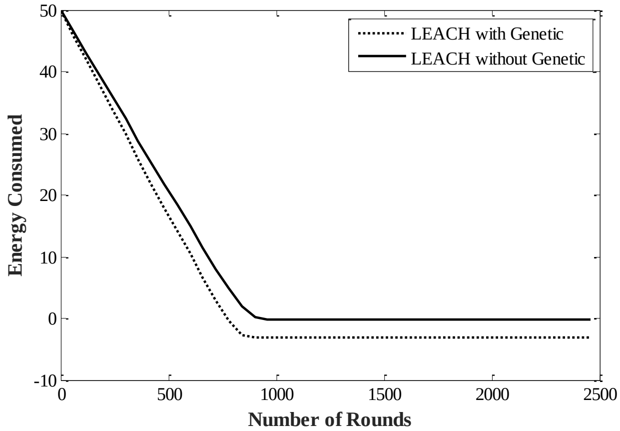

Fig.7. Energy Comparison

5. CONCLUSION

To improve lifetime of the WSN whole network will be divided into certain classes. The cluster heads start transmitting sensed information to base station. To establish shortest path from cluster head to base station genetic algorithm is applied in the network. The genetic algorithm take initial population of sensor node as coordinated of sensor nodes. The optimization function get applied which select shortest path from source to destination. The performance of LEACH protocol is compared with LEACH protocol and genetic algorithm. It is analyzed that LEACH protocol and genetic algorithm performs well in terms of number of dead nodes, number alive nodes etc.

REFERENCES

[1] B.K. Panigrahi and V. Ravikumar Pandi, "Bacterial Foraging Optimisation: Nelder–Mead Hybrid Algorithm for Economic Load Dispatch", *IET Generation Transmission Distribution*, Vol. 2, No. 4, pp. 556-565, 2008.

[2] H. Shen, Y.L. Zhu, X.M. Zhou, H.F. Guo, C.G. Chang, "Bacterial Foraging Optimization Algorithm with Particle Swarm Optimization Strategy for Global Numerical Optimization", *Proceedings of World Summit on Genetic and Evolutionary Computation*, pp. 497-504, 2009.

[3] Ramin Yarinezhada and Amir Sarabi, "Reducing Delay and Energy Consumption in Wireless Sensor Networks by making Virtual Grid Infrastructure and using Mobile Sink", *International Journal of Electronics and Communications*, Vol. 84, pp. 144-152, 2018.

[4] Abhishek Chunawale and Sumedha Sirsikar, "Minimization of Average Energy Consumption to Prolong Lifetime of Wireless Sensor Network", *Proceedings of IEEE Global Conference on Wireless Computing and Networking*, pp. 1-6, 2014.

[5] Jiaying Song and Yen Kheng Tan, "Energy Consumption Analysis of ZigBee-Based Energy Harvesting Wireless Sensor Networks", *Proceedings of IEEE International Conference on Communication Systems*, pp. 21-29, 2012.

[6] Changjiang Jiang, Yun Ren, Yuwei Zhou and Hancheng Zhang, "Low-Energy Consumption Uneven Clustering Routing Protocol for Wireless Sensor Networks", *Proceedings of 8th International Conference on Intelligent Human-Machine Systems and Cybernetics*, pp. 1-8, 2016.

[7] P. Murali, A. Challa, M.R. Kasyap and Chittaranjan Hota, "A Generalized Energy Consumption Model for Wireless Sensor Networks", *Proceedings of International Conference on Computational Intelligence and Communication Networks*, pp. 233-239, 2010.

[8] Bin Li, Wenjie Wang, Qinye Yin, Rong Yang, Yubo Li and Chen Wang, "A New Cooperative Transmission Metric in Wireless Sensor Networks to Minimize Energy Consumption per Unit Transmit Distance", *IEEE Communications Letters*, Vol. 16, No. 5, pp. 626-629, 2012.

[9] Jie Huang, "Research on Balanced Energy Consumption of Wireless Sensor Network Nodes Based on Clustering Algorithm", *Proceedings of International Conference on Computer Network, Electronic and Automation*, pp. 1-6, 2017.

[10] Ashfaq Ahmad, Nadeem Javaid, Muhammad Imran, Mohsen Guizani and Ahmad A. Alhamed, "An Advanced Energy Consumption Model for Terrestrial Wireless Sensor Networks", *Proceedings of International Wireless Communications and Mobile Computing Conference*, pp. 1-8, 2016.

[11] K. Praghash and R. Ravi, "Energy Consumption Architecture for Wireless Sensor Networks with Different Clusters", *Proceedings of 3rd International Conference on Science Technology Engineering and Management*, pp. 441-446, 2017.

[12] Shuang Jia, Lin Ma and Danyang Qin, "Research on Low Energy Consumption Distributed Fault Detection Mechanism in Wireless Sensor Network", *China Communications*, Vol. 16, No. 3, pp. 179-189, 2019.

[13] Bingyue Liu, "An Energy Consumption Control Scheme based on Radial Basis Function in Wireless Sensor Networks", *Proceedings of International Conference on Intelligent Transportation, Big Data and Smart City*, pp. 111-117, 2019.

[14] Sabrine Khriji, Ahmed Yahia Kallel, Sandeep Reedy, Dhouha El Houssaini, Ines Kammoun and Olfa Kanoun, "Dynamic Autonomous Energy Consumption Measurement for a Wireless Sensor Node", *Proceedings of IEEE International Symposium on Measurements and Networking*, pp. 1-6, 2019.

[15] Marija Tutunovic and Pongpisit Wuttidittachotti, "Discovery of Suitable Node Number for Wireless Sensor Networks based on Energy Consumption using Cooja", *Proceedings of International Conference on Advanced Communication Technology*, pp. 761-766, 2019.