Webology (ISSN: 1735-188X)
Volume 18, Number 6, 2021

Improving Energy Consumption And Network Lifetime With Enhanced Clustering And Routing In Wireless Sensor Network

[1] **I. Adumbabu**, [2] **K. Selvakumar**

Research Scholar, Department of Electronics & Communication Engineering, Annamalai University, Chidambaram, Tamilnadu-608002, India

[2]Professor, Department of Information Technology, Annamalai University, Chidambaram, Tamilnadu-608002, India

Abstract

Wireless Sensor Networks (WSN) are being established as a critical tool for monitoring a variety of real-time applications, including ecological monitoring, wide-area surveillance, health care, etc. Despite the numerous benefits of WSNs, the current difficulty is to effectively regulate energy consumption and network lifetime. Clustering-based energy efficient routing methods have developed in wireless sensor networks, dividing neighboring nodes into different clusters and local cluster heads is selected to aggregate and broadcast data from each cluster to the base station. The consumption of energy is maintained by network node and the clustering approach is more efficient to progress the lifetime of network. In this paper, Heterogeneous Network based Clustering (HNBC) is proposed which is a a heterogeneous network-based cluster routing algorithm, mainly focus on solving the problems in lifetime of network and energy consumption and improves the performance of WSN. HNBC protocol is probability-based model which utilized the energy in node and selection probability of cluster head of various heterogeneous nodes for selecting the cluster head. The result show that the proposed method enhances the consumption of energy and the network lifetime.

Introduction

Wireless Sensor Networks have acquired a new dimension as a consequence of technological advancements in technology and an increase in mandate for smart gadgets. WSN technology consists of nodes that are identical or distinct in nature, as well as a base station. The BS transmits directives to the sensing region's nodes (Zhu et al. 2016). It receives data from sensor nodes, does basic processing, and delivers the information to consumers through the internet. WSNs may be utilized for a variety purpose such as catastrophe controlling, combat, ecological monitoring, traffic control, and more. WSNs, on the other hand, have resource limits. Limited battery power, bandwidth, and memory are among the resource limits. One of the key restraints is the low battery power. When the battery's energy runs out, it's difficult to recharge or replace it (Priyadarshi et al. 2018).

Using clustering, researchers investigated different efficient energy strategies for the operation of WSNs (Mhemed et al. 2012). The Clustering also seems to be an effective method for reducing consumption energy and hence increasing lifetime of network. The nodes are divided into several categories called clusters in the clustering process, with each cluster having a leading node, referred to as the cluster head. The cluster head's primary job is to gather data from group members and send it to the base station. Clustering methods in WSN are widely used for efficiently using network energy (Nikolidakis et al. 2013). Clustering techniques separate nodes into distinct clusters, with a cluster head assigned to each cluster. The cluster's nodes give over their data to the cluster leader. The cluster head collection procedure in the clustering protocol is aimed at extending the life of network. The effective cluster head selection contributes to the network's increased longevity. The major goal of using a clustering-based system to increase scalability of network, but this method also achieves an efficient energy data transfer routing technique. WSN is designed with low expenditure energy which is a significant parameter for designing the protocols for WSN (Shih et al. 2001).

The consumption of energy in active mode, consumption of energy in sleep mode, and consumption of energy in idle mode are the three types of energy consumption (Rasheed et al. 2017). Even in idle and sleep modes, the energy of the sensor node is dispersed according to device features. Energy saving at sensor nodes may be achieved through a variety of methods, including security in efficient energy, low-energy routing, and so on. The sensor's energy storage module is a battery, which is neither rechargeable nor replaceable in varied applications (Tuna and Gungor 2016). Many research has demonstrated that hierarchical routing and clustering strategies may be used to address the energy issue in WSNs. Routing methods can also be employed to extend the network's lifespan. In a WSN with increased energy usage, the sensor node's battery quickly depletes, isolating the nodes from the network. The separation of nodes has an impact on data collecting efficiency, multi-hop communication, and other factors (Conti et al. 2007).

The lifetime of network is analysed due to the restricted network energy in every clustering technique. The cluster head selection mechanism utilised in previous routing systems does not adequately account for the levels of energy in the nodes, resulting in a short network life. The suggested solution differs from others in that it makes use of the energy of various heterogeneous nodes in such a manner that it has a direct impact on the cluster head selection mechanism and energy use in the network. The suggested strategy concentrated on establishing an energy reliant on clustering method for sustaining the energy stability in the selection of cluster head operation, rather than modifying the clustering process of current approaches (Alarifi and Tolba 2019).

Related Work

The wireless sensor sector is rapidly expanding, especially as numerous new applications in the Internet. On the other hand, several forms of study are being conducted with a range of approaches and procedures in order to develop and enhance this knowledge in order to meet the necessity of this time period. The low battery is an impediment to sensor technologies. As a result, the majority of the following studies take these flaws into account and provide strategies and algorithms to address them.

(Amgoth and Jana 2015) The ERA algorithm, which incorporates a routing and clustering phase, was presented as an energy-aware routing algorithm. This approach demonstrated that cluster chiefs do not need to communicate messages. One technique was devised for grouping the cluster heads in different levels in order to create an aligned virtual backbone that would make data routing to the sink node easier. The use of this method resulted in a decrease in energy consumption and an enhance in network life time.

(Zeng and Dong 2016) The IHSBEF technique was presented which is regarded to be an enhanced variant of the HS harmony approach. A number of substantial changes were made to this approach in order to better cope with the routing issue. To begin, routing characteristics in WSNs were used to improve the encoding of harmony memory. Second, the new harmony approach has been improved. Dynamic adaptation was also included to prevent lack of progress in initial generations and to improve local search capabilities in subsequent generations. Finally, an active local search method was implemented in order to enhance the algorithm's speed of convergence and accuracy. Furthermore, the operational goal of this strategy, takes into account energy usage and route size, is to encompass the life of the network. The new genetic algorithm, in grouping with the k-means algorithm, has greatly reduced energy usage. That is, it minimises energy usage by employing an improved evolutionary method to discover the appropriate number of cluster heads.

(Liu and Ravishankar 2011) LEACH-GA, an efficient energy adaptive clustering technique for WSNs based on genetic algorithms, was proposed. This method uses an optimum probability estimate to achieve better performance in WSNs by increasing network lifespan. LEACH-GA is comparable to LEACH in that it includes all of the key LEACH stages. It also includes a separate training session that takes place prior to the commencement of the first round. LEACH-overall GA's performance increases with the addition of the preparation phase, and the technique attains optimal energy usage and extended WSNs network lifetime.

(Zhang et al. 2017) LEACH is a routing system which employs a clustering strategy in which cluster creation is randomised and adaptive. With localised control, data transfer is application-specific. The sensor nodes in LEACH are separated to clusters, with each cluster having a cluster head who manages a schedule and distributes aggregated data to the base station where it is needed. When the base station is placed far away from the cluster heads and the amount of data to be sent is similarly significant, this method consumes a lot of energy for data transmission. Because clusters are adaptable in nature, the clustering setup step may not have a significant impact on LEACH's overall performance.

(Elshrkawey, Elsherif, and Wahed 2018) An enhanced method for lowering energy usage in WSN is presented. The cluster head is chosen depending on the node's number of neighbours and leftover energy. In this case, the node with the largest neighbour count has a better chance of being chosen as the cluster leader. For scheduling, a modified TDMA algorithm is utilised, which has two phases: setup and stable. There are more time slots in the steady phase than in the setup phase. When compared to the smallest cluster, the largest cluster sleeps the least. Because the biggest cluster has greater active time, the network lifespan decreases.

Methodology

The block diagram of the proposed system is given in figure 1.

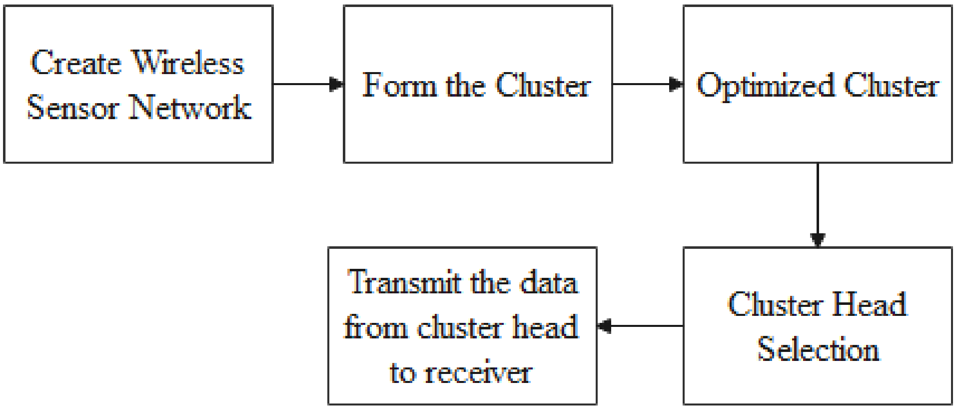

Figure 1: Block diagram of proposed methodology

1. **Network Model**

The cluster heads are determined by the central control in the proposed system. Cluster heads connect to the base station directly in the network, which is a hop model. The base station is attentive of the energy level and the location of system nodes during each loop. Each node perceives and gathers data from its surroundings in each round. The information is then processed and sent to the cluster head in the system of a data packet. Following that, each cluster head gets information pertaining to all of its cluster's member nodes, then send the data in packet format to the base station in a single hop.

2. **Energy Model of Wireless Sensor Network**

The wireless network routing algorithms are more concerned with the overall energy usage of the system. According to a simple concept, the transmitter consumes energy to route the electronics and the power amplifier, while the receiver scatters energy to run the radio electronics. The distance among the transceiver causes power attenuation. The distance between the transceivers causes power attenuation. Propagation loss may be described as inversely proportional to l for relatively short distances, and as inversely proportional to l for larger distances. By configuring the amplifier at the receiver to assure a specified power, power instruction may be utilized to reverse this loss.

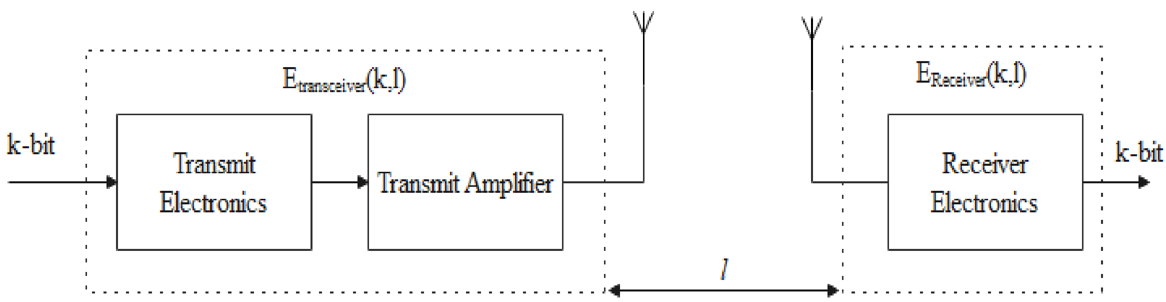

Figure 2: Energy Model of wireless sensor network

The energy consumption model is based on the network model and characterized using heterogeneous network-based clustering algorithm. The k-bit data is transmitted with the distance l. While transmission and receiving the data to the cluster head, energy consumption is calculated using system model. The required energy for transmitting and receiving the k-bit of data over the distance l is given as

$$E_{transmit}(k,l) = \begin{cases} k * E_{ele} + k * \varepsilon_{FS} & l \leq l_0 \\ k * E_{ele} + k * \varepsilon_{m} & l > l_0 \end{cases}$$

$$E_{Receive}(k,l) = k * E_{ele}$$

$E_{transmit}$- Energy utilized for data transmission

$E_{Receive}$- Essential energy to receive data

E_{ele}- Energy for transmitting the data bit to receiver

ε_{FS}- Free space model

ε_{m}- Multipath model

The threshold model l_0 is given by

$$l_0 = \sqrt{\frac{\varepsilon_{FS}}{\varepsilon_{m}}}$$

3. Adaptation in Selection of Cluster Head HNBC Algorithm

The proposed HNBC routing system is intended to extend the life of the network while also improving its performance. The suggested scheme's radio energy model calculates the amount of energy used in several network operations such as communication data, reception data, aggregation data, and so on. The proposed scheme's network model performs clustering, which comprises cluster creation, cluster head selection, and data transfer to sink. The suggested technique makes advantage of a heterogeneous network. The nodes in a heterogeneous network are classified into several kinds based on their initial energy. At the start of the network's creation, energy is distributed to the nodes. The overall amount of normal nodes is larger than the number of advance nodes. The heterogeneity model improves network performance by providing varied energy levels to nodes. The network lifespan can be influenced by the cluster head selection policy. The effectiveness of a cluster node determination policy can improve network performance and longevity. The proposed scheme's cluster head selection is based on a probability system that takes into account energy levels of node. The HBNC method is classified as startup phase, clustering phase and transmission phase in clustering process

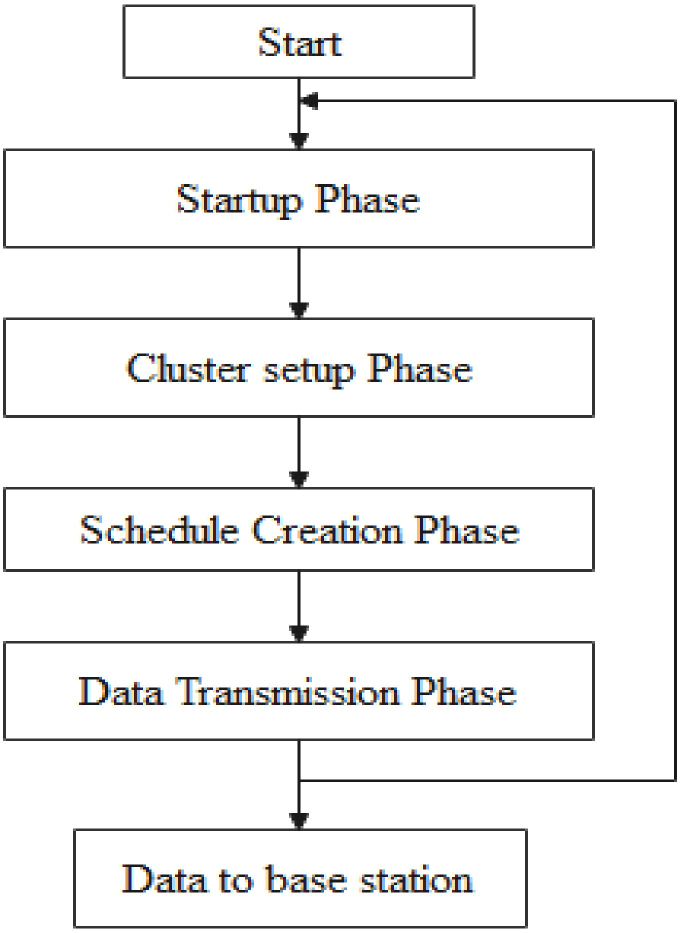

Figure 3: Flow diagram of HNBC

3.1 Startup Phase

The selection of ideal cluster heads by the HNBC the base station in each round, the central station sends a message to the chosen cluster heads informing the linked nodes of the cluster head's role in the current node. The cluster heads are designated then tell all other nodes in the network of their position as the current round's cluster head. As a result, each cluster head sends out a message over the whole network. The Normal nodes choose a cluster head for the next round by choosing a node that takes the least amount of energy to communicate with. The intensity of the signals received from various cluster heads is used to make that determination. In other words, the nearest cluster head is considered the controller and maintaining of each non-cluster head node.

The initial energy of the heterogeneous nodes is given as

Normal node is given as

$$\text{Normal node } E_n = E_0$$

$$\text{Advance node } E_a = E_0(1 + m)$$

Total energy in network is given as

$$t.E_0(1 - n) + t.n.E_0(1 + m) = t.E_0(1 + m.t)$$

E_0- Initial energy

m− Extra energy factor for advance node

t- total amount of node

n- amount of advance node

Each normal node should contact the corresponding cluster head after determining which cluster it belongs to in the current round. Cluster heads build a scheduling algorithm based on the number of cluster members to coordinate data transmission and avoid data collisions inside a cluster. The cluster head sends the scheduling software to the members of its cluster. As a result, no message collisions inside a cluster are ensured. This requirement also necessitates that all non-cluster head node radio elements be twisted off in all time spans save their own. As a result, the total consumption of energy in all nodes is lowered. All cluster nodes recognized the scheduling programme.

3.2 Clustering Phase

The network's performance in clustering stage is separated into a amount of frames, with each frame containing entire nodes of a cluster transmitting their information to the associated cluster head. It is assumed in the proposed approach in which all nodes are always synchronised with one another and that they begin the start up phase together. The central station sends synchronisation pulses to the network nodes to achieve this effect. In the current round, a power and energy management mechanism are utilised to regulate communication energy with the cluster head in order to reduce consumption of energy in each non-cluster head node based on the intensity of the received signal from the cluster head. Furthermore, non-cluster head nodes' radio elements are turned off except for their own time frames.

The transmission of data begins once clusters are formed and the scheduling table is set, and each node its own data is transmitted to the relevant cluster head in the time allotted. A distribution code is used to send the data acquired by normal nodes via multiple access mechanism to the respective cluster heads. Each cluster has its own distribution code, which is used by all nodes in the cluster to send data. Cluster heads also use distribution codes to filter the received signals. The data in cluster head dispatched, it should listen to the channel to see if another node is sending data through distribution code. Before data transmitted cluster head sends the data to the base station utilizing the distribution code

3.3 Transmission Phase

After the determination of cluster head transmission phase begins. The cluster head gets data from all of the sensor nodes in the cluster during this phase. To avoid a collision, the cluster head receives information from the member nodes according to a timetable. The cluster head collects the data, combines it to remove redundancy, and transmits the final aggregated data to the BS. Because data transmission from the cluster head to the base station consumes a large expanse of node energy, the cluster head node must be capable of doing so. If low-energy nodes become cluster heads in the first round, the network may become unstable, shortening the network's lifetime. The network maintains stability for a higher amount of rounds due to suitable deliberation of node energy throughout the cluster head determination process in the recommended HNBC protocol.

4. Result and Discussion

The result of proposed HBNC is analysed using different performance parameter. The parameter utilized for the performance analysis are lifetime of network, throughput, cluster head and consumption of energy. The proposed system is examined for predict the ability to improve the lifetime of network. The consumption of energy of nodes and data transmitted to base station is computed using HBNC protocol.

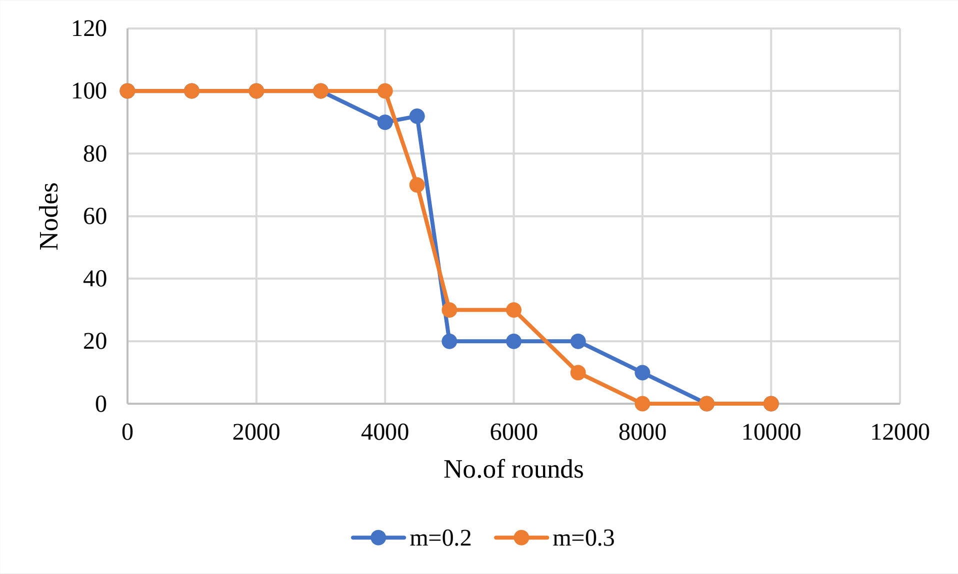

Figure 4: Network Lifetime

The lifetime of network is the amount of rounds till the last node of death in the wireless network to increase the network performance to maximize the lifetime. The figure 4 shows the lifespan of the wireless network, with regard to rounds of the proposed HNBC protocol's network lifetime. For the 10,000 rounds, the periodic round number is examined. The proposed HNBC protocol's performance in each cycle is used to assess protocol performance.

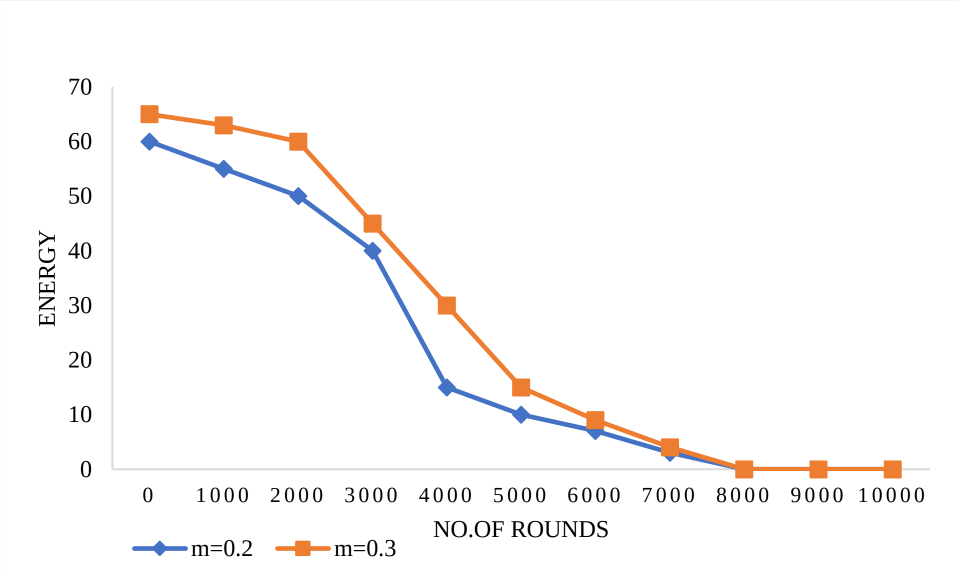

Figure 5: Energy of Nodes

The total energy spent by the nodes for transmitting and receiving the data bits is referred as energy consumption. The proposed HNBC protocol focuses on minimizing network energy usage in order to extend network lifetime. The heterogeneity factor m, reflects the fraction of advance nodes that have more energy. The figure 5 represents how the residual energy of 100 nodes is taken into account when assessing performance of network. The graph depicts the nodes' total energy in numerous rounds, and the performance is evaluated. The suggested HNBC protocol was create to have a large lifespan and has demonstrated its superiority by reducing network energy usage.

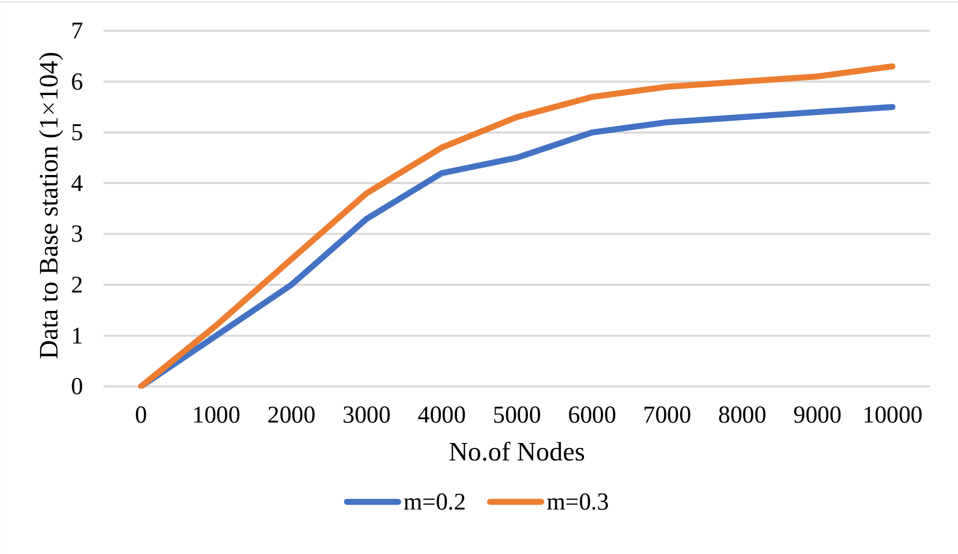

Figure 6: Throughput of network

Throughput is the total amount of data transferred effectively through the cluster head to base station. The throughput is maximized, if the sensor network maintains for longer time period.

The network throughput in various rounds is depicted in the figure 6. The data transmitted to the base station is graphed for various protocols in various rounds. The presented HNBC protocol provides the maximum throughput. The total data transported in the proposed system is roughly 55000, which is greater and has effectively used network resources to increase network performance.

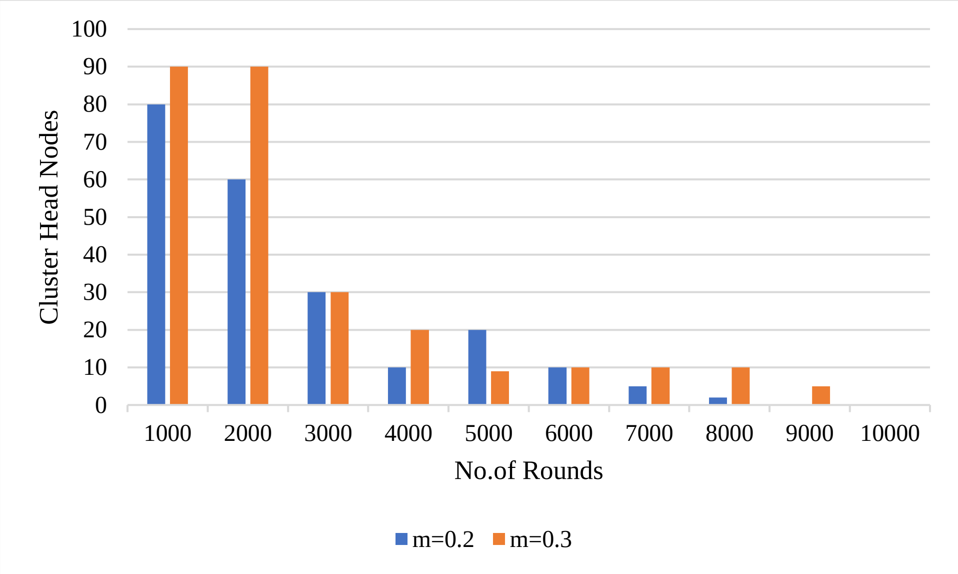

Figure 7: Cluster Head Count

The number of cluster head in the 10,000 rounds for the proposed HNBC protocol is shown in Figure 7. The cluster head count in each round is determined by the protocol's probabilistic model. As a result, the CH count varies between rounds. The suggested strategy has a higher cluster head count and has even cluster head selection in different rounds. The higher the cluster head count in different rounds, the more efficiently the suggested strategy uses node energy and reduces energy consumption. The proposed HNBC technique is effective when the heterogeneity is 0.3

5. Conclusion

The problems of clustering and routing in wireless sensor network is examined. The proposed heterogenous based clustering improves the performance of lifetime of the network. To prove the efficiency of the suggested HNBC technique, numerous performance criteria are used to analyses it. Energy levels of nodes are used in the cluster head determination process to increase network life and performance. The suggested HNBC approach is evaluated using various values of the heterogeneity factor and it consistently improves. In the future, the suggested technique might be improved by incorporating larger degrees of heterogeneity and various heterogeneity factors. The suggested HNBC protocol's performance may be improved further by employing alternative network area sizes, node counts, and performance characteristics such as packet delivery ratio and latency.

Reference

1. Alarifi, Abdulaziz, and Amr Tolba. 2019. "Optimizing the Network Energy of Cloud Assisted Internet of Things by Using the Adaptive Neural Learning Approach in Wireless Sensor Networks." Computers in Industry 106: 133–41.
2. Amgoth, Tarachand, and Prasanta K Jana. 2015. "Energy-Aware Routing Algorithm for Wireless Sensor Networks." Computers & Electrical Engineering 41: 357–67.
3. Conti, Mauro, Roberto Di Pietro, Luigi Vincenzo Mancini, and Alessandro Mei. 2007. "A Randomized, Efficient, and Distributed Protocol for the Detection of Node Replication Attacks in Wireless Sensor Networks." In Proceedings of the 8th ACM International Symposium on Mobile Ad Hoc Networking and Computing, 80–89.
4. Elshrkawey, Mohamed, Samiha M Elsherif, and M Elsayed Wahed. 2018. "An Enhancement Approach for Reducing the Energy Consumption in Wireless Sensor Networks." Journal of King Saud University-Computer and Information Sciences 30 (2): 259–67.
5. Liu, Jenn-Long, and Chinya V Ravishankar. 2011. "LEACH-GA: Genetic Algorithm-Based Energy-Efficient Adaptive Clustering Protocol for Wireless Sensor Networks." International Journal of Machine Learning and Computing 1 (1): 79.
6. Mhemed, Rogaia, Nauman Aslam, William Phillips, and Frank Comeau. 2012. "An Energy Efficient Fuzzy Logic Cluster Formation Protocol in Wireless Sensor Networks." Procedia Computer Science 10: 255–62.
7. Nikolidakis, Stefanos A, Dionisis Kandris, Dimitrios D Vergados, and Christos Douligeris. 2013. "Energy Efficient Routing in Wireless Sensor Networks through Balanced Clustering." Algorithms 6 (1): 29–42.
8. Priyadarshi, Rahul, Lucky Singh, I Sharma, and Sanjeev Kumar. 2018. "Energy Efficient Leach Routing in Wireless Sensor Network." Int J Pure Appl Math 118 (20): 135–42.
9. Rasheed, Muhammad Babar, Nadeem Javaid, Muhammad Imran, Zahoor Ali Khan, Umar Qasim, and Athanasios Vasilakos. 2017. "Delay and Energy Consumption Analysis of Priority Guaranteed MAC Protocol for Wireless Body Area Networks." Wireless Networks 23 (4): 1249–66.
10. Shih, Eugene, Seong-Hwan Cho, Nathan Ickes, Rex Min, Amit Sinha, Alice Wang, and Anantha Chandrakasan. 2001. "Physical Layer Driven Protocol and Algorithm Design for Energy-Efficient Wireless Sensor Networks." In Proceedings of the 7th Annual International Conference on Mobile Computing and Networking, 272–87.
11. Tuna, G, and VC Gungor. 2016. "Energy Harvesting and Battery Technologies for Powering Wireless Sensor Networks." In Industrial Wireless Sensor Networks, 25–38. Elsevier.
12. Zeng, Bing, and Yan Dong. 2016. "An Improved Harmony Search Based Energy-Efficient Routing Algorithm for Wireless Sensor Networks." Applied Soft Computing 41: 135–47.
13. Zhang, Ying, Jun Wang, Dezhi Han, Huafeng Wu, and Rundong Zhou. 2017. "Fuzzy-Logic Based Distributed Energy-Efficient Clustering Algorithm for Wireless Sensor Networks." Sensors 17 (7): 1554.

14. Zhu, Xiaojuan, Yang Lu, Jianghong Han, and Lei Shi. 2016. "Transmission Reliability Evaluation for Wireless Sensor Networks." International Journal of Distributed Sensor Networks 12 (2): 1346079.