International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

A Novel Approach for Energy Efficient Cluster-based In-Network Data Fusion (CBDF) in Wireless Sensor Networks (WSN)

A.Gnana Soundari[1], K.Suresh[2], A.S.Prakaash [3], I.Vasantha Kumari[4]

Submitted: 22/07/2022 **Accepted**: 25/09/2022

Abstract: In recent days, the usability of Wireless Sensor Network (WSN) has been immense in various applications, including environmental monitoring, disaster management, medical observance, military application, etc. WSN is a collection of numerous wireless sensor nodes interconnected with one another. It is widely used for sensing, communicating, and computing data efficiently. WSN is famous for its salient features like efficiency, minimum cost, flexibility, and ease to use. However, it is subject to severe challenges, especially in consuming enormous energy and minimum network lifetime. We proposed a Cluster-based In-Network Data Fusion (CBDF) for WSN. The proposed work is developed to minimize data fusion and clustering energy consumption. In WSN, if the in-network data fusion cannot minimize outgoing data size, it is a critical issue. The proposed CBDF restructures the network into multiple clusters based on its size. As a result, each cluster can communicate with the data fusion center in a synchronized approach. An optimization approach is used to reduce the distance of intra-cluster communication. The proposed structure is compared to other current data aggregation structures, and simulation results show that using the data aggregation process, the proposed approach successfully minimizes energy consumption and delays.

Keywords: *Wireless Sensor Network, Data aggregation, In-network data fusion, Clustering, Cluster Head*.

1. Introduction

A Wireless Sensor Network (WSN) is structured with numerous dully implemented sensor nodes. Wireless Sensor Networks (WSNs) are a protocol that allows continuous technological development to transform distributed systems in all mediums (large, small, tiny, etc.) [1]. Sensors are used to find the changes in the circumstances. As every sensor's coverage region is small, a sensor network must observe the huge environment. WSNs are vast systems comprised of several small, low-energy, and distributed sensor nodes. All such nodes are generally transmitted over a particular area to gather environmental data [2]. Numerous latest applications are based on WSN, like medical monitoring, environmental observance, and disaster management. The collected data are often transmitted to the base station (BS), known as sink processing and testing. The sensor node in this network contains minimum energy and lifespan because of the restricted non-rechargeable power of tiny batteries. The round describes all nodes' network lifetime have been killed, and sensor node is described as killed if its power is exhausted [1]. On account of the massive effects of communication over node power conservation, the main difficulties of those systems are restricted life span and reduced channel bandwidth.

Consequently, effective energy usage to meet these difficulties and lengthen network lifespan is the key challenge in WSNs [3]. Clustering is a reduction method and one of the most efficient strategies for preserving WSN energy. The sensor nodes are organized through this clustering into optimized cluster counts with a minimum node. Every cluster should contain a minimum of one node operating as a cluster header, referred to as a CH, which collects and aggregates sensed information before transmitting it to the BS. Therefore, the transmitted packets are minimized, preserving the communication bandwidth. The main objective is to utilize minimal energy to transmit more sensed information [4].

Routing is executed for several network types, including telephone networks, transportation networks, and electronic data networks. A significant proportion of routing algorithms only uses one network path at a time. When various alternative paths are used to send information, the energy of every sensor node is controlled. Wireless sensor networks utilize a wide range of routing methods. Every node in the Flat routing protocol generally works the same way, and sensor nodes work cooperatively to operate the sensing task. Increased energy nodes in a hierarchical architecture are utilized for data processing and transmitting, while reduced energy nodes operate target sensing processes. Hierarchical routing effectively decreases power consumption by data aggregation and fusion that limits the total data transferred to the BS. The distance among adjacent nodes in location-based routing depends on incoming signal strengths. If there is no task, a few location-based strategies place nodes into sleep mode to preserve energy.

Numerous efforts with various mechanisms are presented for minimizing the power and extending the network lifespan among the WSN clusters. The most basic protocol for WSN clustering is

[1] Professor, Department of Computer Science and Engineering, Saveetha School of Engineering, SIMATS, Thandalam, Chennai-602105, India, Email: soundarivenkat77@gmail.com
[2] Assistant Professor, Department of Computer Science and Engineering, PSNA College of Engineering and Technology, Tamil Nadu 624622, India, Email: ksuresh85@psnacet.edu.in
[3] Associate Professor,Department of Mathematics, Panimalar Engineering College,Poonamallee Chennai- 6000123, Tamil Nadu, India, Email: prakaashphd333@gmail.com
[4] Assistant Professor,Department of Computer Science and Engineering, Siddhartha Institute of Technology and Sciences, Narapally, Hyderabad, Telangana-500088.India. Email: vasantha.mytrayasa@gmail.com

LEACH [5]. It organizes the sensor node into various small-sized clusters. Every LEACH round contains the following two phases: such as setup phase and steady-state phase. In the setup phase in which the clusters are created, and the CH for each cluster is selected in this phase. In the steady-state phase, the collected information is communicated to the BS through CHs. Randomly, LEACH selects one node at irregular intervals as CH for a single round. So every node randomly chooses a number between 0 and 1. If the selected value is less than or equal to the threshold - T(n), the node becomes elected as CH. If not so, it remains normal.

This work aimed to reduce the WSN's energy consumption by utilizing the Cluster-based Data Fusion (CBDF) technique for determining which CH is responsible for conducting all functions related to receiving, aggregating, and delivering data to the BS.

Organization of the paper: In section 1 introduction is described, section 2 discusses various existing works, section 3 illustrates a detailed explanation of the proposed mechanism and its working process, and section 4 states the experimental work and result from the discussion. Finally, the conclusion part is described in section 5.

2. Related Works

Several literatures work related to improving the efficiency of the WSN are discussed in this section. The hotspot and energy hole challenges should be resolved in active WSN.

Sert et al. [6] proposed this work to improve multiple objective fuzzy clustering algorithms (MOFCA) for WSN. The researchers looked at the competence of the energy in all kinds of circumstances and flexibility in real-time sensor deployment in both stationary and developing networks. MOFCA contemplates three primary aspects: node's density for selecting CH, distance to sink, and node residual energy. Additionally, the researcher addressed it will decrease the energy hole issue because there is no need of fundamental decision node for selecting the CH. The simulation is classified into four scenarios, with a different node distribution and sink location. All four situations are analyzed based on multi-hop routing or direct rounting to the destination. This analysis introduces a technique logically performs various conventional methods concerning overall residual energy.

The researchers from [7] introduced a cluster manager-based cluster head selection—CMBCH—to minimize the CH workload. The cluster development phase in this research is first imposed upon, preceded by the cluster manager shortlisting process and the CH election process. The selected cluster manager generally maintains the backup information of CHs that minimizes the memory capability limitation issue met by cluster heads in the mobile environment. In the re-clustering stage, the cluster manager selects the next CH concerning the current CHs remaining distance and energy to the other nodes. The researchers state CMBCH is highly energy-effective and maximizes the packet delivery ratio (PDR) compared to the other conventional techniques, depending on the simulation results.

In 2020, the researchers of [8] proposed an energy-efficient mobility-based cluster head selection method that depends on a mobile sensor environment (EEMCS). In this method, the cluster head is selected depending on the remaining energy, total neighbors, and distance to BS, which is explained as:

$$\text{Weightage} = \frac{E_r * w1 + Degree * w2}{ML * w3 + D_{toBS} * w4}$$

When distinguished from different traditional algorithms, EEMCS outperformed concerning network lifespan, energy usage, average energy, and throughput.

The researcher from [9] proposed an energy-effective head election protocol for clustering methods for WSN. The networks experience a lack of energy and a shorter lifespan, including minimal channel bandwidth. Bandwidth depicts the primary issues of the process owing to vast effect on node's power conservation and communication costs. Clustering is defined as the most optimal method for preserving WSN energy. The LEACH-low energy adaptive clustering hierarchy protocol is considered the foundational task of WSN clustering.

At the beginning of the 2000s, Heinzelman et al. [10] proposed an energy-effective communication protocol known as LEACH-low-energy adaptive clustering hierarchy. The LEACH method is used to minimize power utilization by a clustering method. Some CHs are elected depending on cluster rotation and the connection of other nodes to create clusters. The sensed information is transferred to the corresponding CH, and there it aggregates, then sent to the base station through the CH.

3. Proposed System

A Cluster-based Data Fusion (CBDF) is proposed in this work. Initially, the network is deployed randomly with node sets. The deployed nodes are organized into clusters, and each cluster is provided with a CH. Next, the proposed redesigned network includes a data fusion center. The node's initial energy is measured at each cluster, and the node contains maximum energy level is selected as CH. The CH's goal is to gather information from its cluster members. After the data collecting procedure, the network is updated by updating each step size, which is signified by the CHs present in each cluster. If the cluster members' gathered data is fusible, the cluster head can execute data fusion on the obtained or incoming data, reducing the quantity of outgoing data. The fusion center receives this fused data output for additional processing.

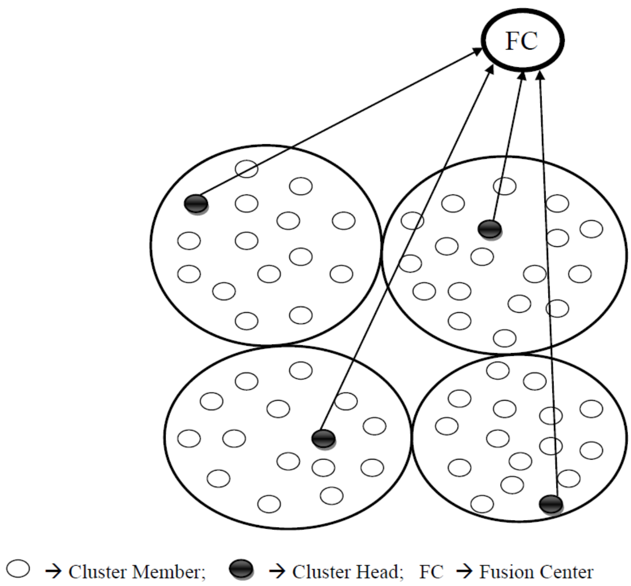

Fig. 1. Proposed Network Architecture

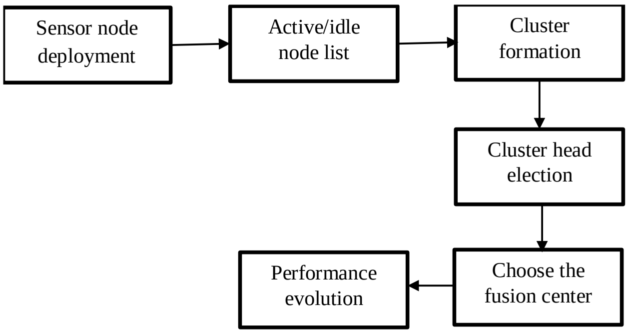

Fig. 2. Proposed architecture

Figure 1 illustrates the proposed network architecture with cluster members, cluster heads, and a fusion center. As shown, four clusters are there, each cluster contains several cluster members, and each cluster is provided with a cluster head. Figure 2 illustrates the details workflow of the proposed architecture. According to this, initially, the sensor node deployment process is executed. Next, active and inactive nodes are identified in the deployment nodes. It is done by propagating a "Hello message" the node responding to the hello message is labeled an active node, and non-responding nodes are labeled inactive nodes. The distance of the active node from the neighbor nodes is consider for forming the clusters. Next, the member with the highest energy is selected as the cluster head within the cluster member in the cluster. These CH collect data fusion and transmits those data to fusion center.

The proposed algorithm then focuses on reducing the node's size of transmitting data, energy consumption and communication distance. The optimization strategy is applied to shorten communication distance, which reduces energy consumption. For example, packet transmission requires more energy if the destination path is very long. As the distance from the source to the destination is reduced and the energy consumption also minimized. Even in-network data fusion does not give a reduction in packet size on the incoming data to produce smaller outgoing data. A changed network structure is also proposed; a tree-based network that ensures the length of data aggregation would be considerably decreased. As previously stated, the sensor nodes are organized into single-layered clusters of various sizes. As a result, all clusters communicate with the fusion center in an interleaved form through cluster heads in each cluster. The network structure of the modified algorithm is shown in Figure 1.

4. Experimental Results

The experimental work is conducted in the simulation environment using Network simulator-2. In which 100 nodes are deployed within the range of 1800 × 1800 m2 using the Random way mobility model. The IEEE standard of 802.11 Mac protocol is used as the link-layer protocol, and the traffic is generated through a multicast constant bit ratio. In this setup, both 802.11b and IEEE 802.11e protocols establish WLAN heterogeneous traffic. The TCP or UDP network topology is used for establishing the data connection. The packet used for this experiment is about 2000 bytes with 24 Mbps of data rate, and the node mobility range fall between 10-35/ms. The other parameters which are used in the experimental work are listed in table 1.

Table 1. NS2 simulation parameter

Simulation Parameter	Value
Simulator	Network Simulator-2
Simulation time	200 seconds
Number of nodes	100
Simulation area	1800×1800 m^2
Mac Protocol	IEEE 802.11
Data rate	24 Mbps
Radio range	100 meters
Mobility model	accidental waypoint model
Antenna	Omnidirectional antenna
Node speed	10-35 m/s
Packet size	512 bytes
Traffic type	Multicast constant bit ratio

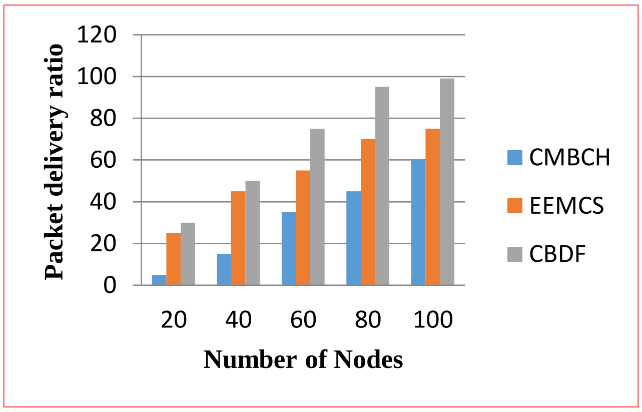

Fig. 3. PDR vs. Total nodes

Figure 3 states the comparison results conducted among the proposed CBDF with CMBCH & EEMCS. The comparison work is conducted on the packet delivery ratio concerning the total nodes. The x-axis defines the number of nodes participated, and y-axis defines the total PDR accomplished by each algorithm. At regular intervals, the total nodes involved are increased by 20 nodes. The obtained results are plotted graphically for better understanding. According to which all the node ranges, the PDR gained by the proposed CBDF is maximum than the CMBCH and EEMCS.

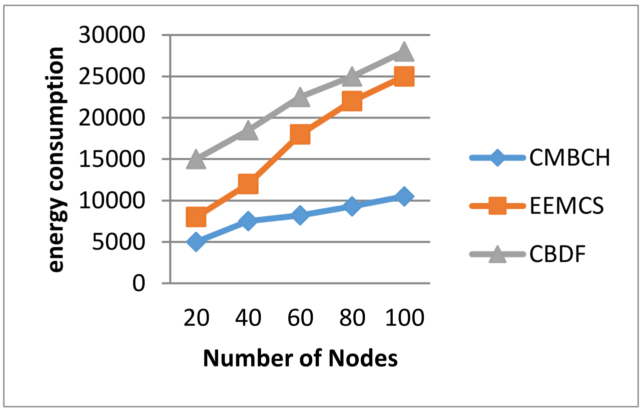

Fig. 4. Energy consumption Vs. Total nodes

Figure 4 illustrates the comparison results conducted among the proposed CBDF with CMBCH & EEMCS. The comparison work is conducted on the total energy consumed concerning the total nodes. The x-axis defines the number of nodes particpated, and the y-axis shows the total energy consumed by each algorithm. At regular intervals, the total nodes involved increase by 20 nodes. The obtained results are plotted graphically for better understanding. According to which all the node ranges, the energy consumed by the proposed CBDF is very minimum than the CMBCH and EEMCS. It proves that the proposed CBDF is more efficient than the others.

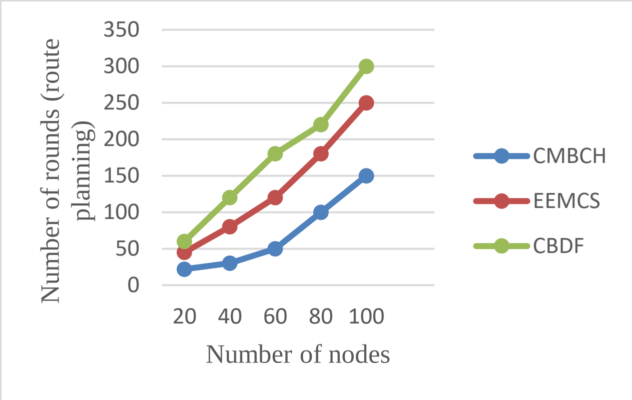

Fig. 5. Number of nodes vs. number of rounds (route planning)

Figure 5 illustrates the comparison results conducted between the proposed CBDF with CMBCH & EEMCS. The comparison work is conducted on a total round with the respective total nodes. The x-axis shows the total nodes involved in the experiments, and the y-axis defines the total rounds executed by each algorithm. At regular intervals, the total nodes involved increase by 20 nodes. The obtained results are plotted graphically for better understanding. According to which all the node ranges, the number of rounds discovered by the proposed CBDF is maximum than the CMBCH and EEMCS. It proves that the proposed CBDF is more proficient in executing route planning than the other existing algorithms.

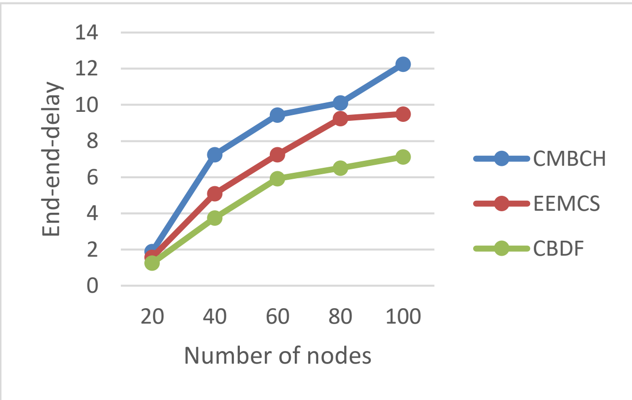

Fig. 6. Total nodes vs. End-End-Delay

Figure 6 represents the comparison results conducted among the proposed CBDF with CMBCH & EEMCS. The comparison work is conducted with the total delay observed by each algorithm with the respective total number of nodes. The x-axis defines the total nodes involved in the experiments, and the y-axis shows the delay that occurred in each algorithm. At regular intervals, the total nodes involved increase by 20 nodes. The obtained results are plotted graphically for better understanding. According to which all the node ranges, the end-to-end delay in the proposed CBDF is very minimal than the CMBCH and EEMCS. The proposed CBDF minimum delay illustrates its stability and performance efficiency more than the others.

5. Conclusion

Cluster-based In-Network Data Fusion (CBDF) with a reconfigured network structure is proposed in this research. The proposed algorithm is mainly focused on minimizing total energy in WSN. The sensor nodes are divided into single-layer clusters of varied sizes using the proposed modified network structure. Each cluster's design process is methodically handled, as the associated cluster heads communicate with the fusion center (FC) in an interleaved way, reducing data aggregation time. An optimization technique is employed to reduce the distance to reduce energy usage. The performance of the proposed CBDF is displayed in simulation results, and it is compared to the existing EEMS and CBDF. According to the findings, the proposed CBDF reduces energy consumption, maximizing the network lifetime.

6. Author Guidelines

The first author designed, developed, performed the experiments, analyzed the output, and compiled the manuscript. The second author assisted in composing and evaluating the manuscript. The third and fourth author guided the study and investigated the manuscript for its completeness.

7. Conflicts of Interest

The authors have no conflicts of interest to declare.

Reference

[1]. Xu L, Collier R, O'Hare GMP. A survey of clustering techniques in WSNs and consideration of the challenges of applying such to 5G IoT scenarios. IEEE Internet Things J Oct. 2017;4(5):1229–49.

[2]. Jairam B, Ashoka DV, Multiple Mobile Elements Based Energy-Efficient Data Gathering Technique in Wireless Sensor Networks, in Digital Business; Lecture Notes on Data Engineering and Communications Technologies, Springer, vol. 21, July 2019.

[3]. Guo X, Chen Z, Hu X, Li X. Multi-source localization using time of arrival self-clustering method in wireless sensor networks. IEEE Access June 2019;7:82110–21.

[4]. L. N. Balai, G. K. J. A. K. S. (2022). Investigations on PAPR and SER Performance Analysis of OFDMA and SCFDMA under Different Channels. International Journal on Recent Technologies in Mechanical and Electrical Engineering, 9(5), 28–35. https://doi.org/10.17762/ijrmee.v9i5.371

[5]. Zhang Y, Liu M, Liu Q. An energy-balanced clustering protocol based on an improved CFSFDP algorithm for wireless sensor networks. Sensors March 2018;18(3):881.

[6]. Heinzelman WR, Chandrakasan A, Balakrishnan H, ''Energy-efficient communication protocol for wireless microsensor networks," Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, Maui, HI, USA, 2000, pp. 10 pp. vol.2

[7]. S. A. Sert, H. Bagci, and A. Yazici, "MOFCA: multi-objective fuzzy clustering algorithm for wireless sensor networks," Applied Soft Computing, vol. 30, pp. 151–165, 2015.

[8]. Roy, R., and D. A. . Kalotra. "Vehicle Tracking System Using Technological Support for Effective Management in Public Transportation". International Journal on Recent and Innovation Trends in Computing and Communication, vol. 10, no. 2, Mar. 2022, pp. 11-20, doi:10.17762/ijritcc.v10i2.5515.

[9]. S. Amutha, B. Kannan, and J. M. Kanagara, “Energy-efficient cluster manager-based cluster head selection technique for communication networks,” International Journal of Communication Systems, vol. 33, no. 14, article e4427, 2020.

[10]. Chaudhary, D. S. . (2022). Analysis of Concept of Big Data Process, Strategies, Adoption and Implementation. International Journal on Future Revolution in Computer Science &Amp; Communication Engineering, 8(1), 05–08. https://doi.org/10.17762/ijfrcsce.v8i1.2065

[11]. S. Umbreen, D. Shehzad, N. Shafi, B. Khan, and U. Habib, “An energy-efficient mobility-based cluster head selection for lifetime enhancement of wireless sensor networks,” IEEE Access, vol. 8, pp. 207779–207793, 2020.

[12]. Safa’a S, Saleh, Tamer F. Mabrouk a, Rana A & Tarabishi, “An improved energy-efficient head election protocol for clustering techniques of wireless sensor network”, Egyptian Informatics Journal 22 (2021) 439–445, https://doi.org/10.1016/j.eij.2021.01.003

[13]. Sharma, A. (2022). Some Invariance Results for Isometries. International Journal on Recent Trends in Life Science and Mathematics, 9(2), 10–20. https://doi.org/10.17762/ijlsm.v9i2.131

[14]. W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-efficient communication protocol for wireless microsensor networks,” IEEE Computer Society, vol. 8, p. 8020, 2000.

[15]. Sehirli, E., & Alesmaeil, A. (2022). Detecting Face-Touch Hand Moves Using Smartwatch Inertial Sensors and Convolutional Neural Networks. International Journal of Intelligent Systems and Applications in Engineering, 10(1), 122–128. https://doi.org/10.18201/ijisae.2022.275

[16]. Gopalakrishnan Subburayalu, Hemanand Duraivelu, Arun Prasath Raveendran, Rajesh Arunachalam, Deepika Kongara & Chitra Thangavel (2021) Cluster Based Malicious Node Detection System for Mobile Ad-Hoc Network Using ANFIS Classifier, Journal of Applied Security Research, DOI: 10.1080/19361610.2021.2002118

[17]. P. Mohan Kumar & S. Gopalakrishnan (2016) Security Enhancement for Mobile Ad Hoc Network Using Region Splitting Technique, Journal of Applied Security Research, 11:2, 185-198, DOI: 10.1080/19361610.2016.1137204

[18]. Ahmed Cherif Megri, Sameer Hamoush, Ismail Zayd Megri, Yao Yu. (2021). Advanced Manufacturing Online STEM Education Pipeline for Early-College and High School Students. Journal of Online Engineering Education, 12(2), 01–06. Retrieved from http://onlineengineeringeducation.com/index.php/joee/article/view/47

[19]. Gopalakrishnan, S. and Kumar, P. (2016) Performance Analysis of Malicious Node Detection and Elimination Using Clustering Approach on MANET. Circuits and Systems, 7, 748-758. DOI: 10.4236/cs.2016.76064.

[20]. Panimalar Kathiroli, Kanmani Selvadurai ",Energy-efficient cluster head selection using improved Sparrow Search Algorithm in Wireless Sensor Networks"Journal of King Saud University - Computer and Information Sciences, https://doi.org/10.1016/j.jksuci. 2021.08.031. 2021,