Energy Enhancement of WSN with Deep Learning based SOM Scheduling Algorithm

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Abstract

Energy efficiency is one of the primary requirements for designing a successful Wireless Sensor Network (WSN) model. The WSN systems are generally made with a group of nodes that are operated with a small size battery device. To improve the energy efficiency of such WSNs several methodologies like clustering approach, mobile node technique and optimal route planning designs were developed. Scheduling method is yet an efficient model that is widely used in WSN applications, that allows the nodes to be operated only for a certain prescribed time. The proposed work utilizes the Self Organizing Maps (SOM) approach for improving the performances of the scheduling algorithms to a certain limit. SOM is a kind of artificial neural network that analyzes the problem based on competitive learning rather than the backpropagation methods. The work compares the proposed algorithm with the traditional Ant Colony and Software Defined Network approaches, wherein the proposed approach has shown an improvement in terms of energy conservation and network lifetime.

Keywords: Network lifetime, network energy management, scheduling approach, clustering, routing method, neural network in WSN

1. Introduction

Wireless sensor networks are attracting more attention in the recent days due to the development of reliable IoT based applications. The IoT applications are running like a backend platform that allows a user to monitor and operate the decisions of any hardware modules from a remote place. The WSNs are acting in such applications as like a frontend model that collects the information from the primary source with a help of sensors with

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limited energy [1, 2]. Experimentally, the IoT applications are connected with a sensor module with a direct power supply or huge rated battery device but while going for real-time application it is not possible to connect the sensor nodes with a power supply or a huge battery source. In practical scenario, the sensor modules are designed in a small size structure that helps to place the module at any critical place. Especially the WSNs that are used for medical application need not to be connected with a direct power supply for the safety of a patient. The major architectural differences between the IoT and WSN applications are shown in Table 1.

Table 1. Architectural difference between WSN and IoT

WSN	IoT
• Internet connection is not required	• Internet connection is required
• Only sensors can be used for data gathering	• Sensors, cameras, phone, and PC can be used for data gathering
• Low cost and low power devices	• High cost and high power devices with complex circuits
• Battery powered	• Electric powered
• Limited memory	• High memory
• Average security	• Better security
• Robust in nature on fault tolerance	• Non-robust

1.1 WSN energy enhancement techniques

1.1.1 Clustering model

Clustering is a process of grouping a list of sensors that are placed near to each other with minimum distance. The clustering model makes a particular node to act as a head for such clustered group to organize its process on data transmission. The data that are transmitted from a node will be collected by a cluster head for transferring it to the destination. However, the process of selecting an appropriate node as cluster head is a challenging task for WSN. Hence different decision making approaches are widely implemented on different applications [3]. This approach allows the nodes to save their energy by minimizing the failure rate on data transmission. It also avoids the packet drop due to transmitting the information for a longer distance.

1.1.2 Mobile node technique

The mobile nodes are allowed change their location in the connected network for saving the energy on data transmission loss. The mobile nodes are equipped with an in-built battery backup for its own power supply and that allows the node to move to certain range toward the destination node for enabling a successful data transmission [4]. This method avoids a repetition of data transmission and reduces the data loss to long range of communication. Though, the design of mobile node application is comparatively complex than the other methods.

1.1.3 Routing design

The routing algorithms are designed to find the shortest path between the available nodes for data transmission. The operational time variation among the available nodes makes the process slightly complicated in deciding their path. Therefore several optimization algorithms were utilized for such application to predict the right choice of route in the connected network [5]. The main motive of the routing approaches is to find a route that can transmit the data with lesser delay and minimal energy consumption.

1.1.4 Scheduling algorithm

The scheduling algorithms were developed to make a traffic free environment over the sensor node networks. It is done by the help an intelligent algorithm to monitor the surroundings of the sensor nodes to enable a collision free process. This reduces the energy wastage on data transmission. It also reduces the time delay on the information sharing application [6]. The following section explores the different techniques and their attainments on scheduling algorithms.

2. Related Works

An ARIMA model -based scheduling algorithm was developed to improve the efficiency of a WSN. An experiment was conducted to find the performances of various ARIMA models and the result indicates that the energy utilized on 10 sensor nodes without ARIMA model is enough to run 50 sensor nodes with ARIMA model [7]. A combination of breadth first search and color connected dominated set algorithm was designed to provide an optimal scheduling process for WSN. The breadth first search algorithm was utilized to find the exact distance between the primary node and the secondary node. Similarly, color connected dominated set algorithm was used to forward the packets between the nodes without any collision [8]. Dijkstra's algorithm based scheduling method was proposed to enable scheduling practice on sensor node data transmission. It avoids the chance of data re-transmission and that minimizes the data collision on their transmission process. The experimental analysis indicates a betterment of 54.74% aggregation latency [9].

A multi-node Q learning-based cooperative computing approach was structured to make a sleep scheduling strategy. The work represents an acceptable energy balance ratio and that leads to better network lifetime [10]. Cluster based sleep scheduling algorithm was introduced to improve the network lifetime of WSNs. The work enforces a probability based technique for selecting the cluster heads and the particle swarm optimization model was utilized for the sleep scheduling process. An improved lifetime of 64% is achieved over the EBCS protocol with 95% of stability period [11]. A hybrid multi-task scheduling approach was developed using fuzzy Dijkstra's algorithm and deep neural network. The work follows queuing strategy by estimating the light weight characteristics of the sensor nodes [12].

An energy efficient data aggregation system was developed by analyzing the availability, throughput and network lifetime of the connected nodes. The simulation result indicates an acceptable lifetime maximization and energy efficiency over the previous techniques [13]. A multi-objective clustering methodology was proposed to do node sleep scheduling in WSNs. The work is equipped with a wolf optimization technique for clustering and a selective track search algorithm was implemented to predict the optimized path for node movement [14]. An optimized backoff sleep protocol was designed to find various parameters of sensor nodes and that makes the network to schedule the data transmission between the inside their cluster region. The performance improvement on network lifetime and active node count was increased in the work over the LEACH and HEED protocols [15].

A novel ring partitioned based MAC protocol was structured to improve the energy efficiency of the WSN through a better routing approach. The cluster model was incorporated with a weighted Voronoi diagram by giving a weighted value for each node. The experimental work indicates a throughput outcome of 95.44% [16]. A metaheuristic algorithm based scheduling algorithm was modelled to schedule the packet movement in an adjustable sensing range. The simulated result indicates an improvement on network lifetime around the given sensing range [17]. A reinforcement Q-learning algorithm was designed to reduce the information loss during the packet transfer between the nodes and cluster heads. The work gives a better energy consumption and provides a better improvement on live node counts [18].

A special purpose energy efficient content based hybrid MAC protocol was proposed to improve the network lifetime by making a scheduled packet transmission on dual hop networks. A residual energy improvement of 75% was achieved in the work even at high traffic condition [19]. A web based cross layer optimization algorithm was designed to organize the energy efficiency of the WSN. A dynamically adapted sleep scheduling model is also incorporated in the work to optimize the energy dissipation of each sensor nodes. The outcome represents a better improvement on packet loss over the LEACH and optimized LEACH models [20]. A multilevel dynamic feedback scheduling algorithm was framed to address the data prioritizing issue in WSNs. The proposed algorithm prioritizes the sensor node information into three categories for a better transmission [21]. It has been found from the literature that the scheduling is one of the efficient processes for WSN on saving their energy. The proposed work tries to experiment the efficiency of an SOM based algorithm on scheduling process.

3. Proposed Work

Self Organizing Map (SOM) follows an unsupervised learning approach on competitive learning method in an artificial neural network. In general, the SOM techniques are widely employed for clustering and dimensionality reduction applications. The SOM is efficient in terms of reducing the multi-dimensional parameters into a single or lower dimensional factor. The SOM is constructed with an input and output layer and its architecture is shown in figure 1 with two numbers of clusters.

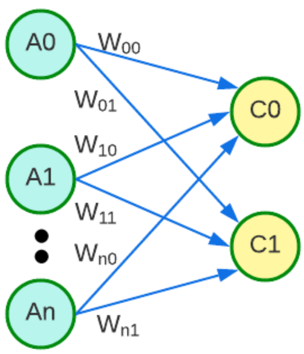

Figure 1. Architecture of SOM

SOM input sample comprises of two information namely training samples count and their feature count. The input layer determines the weight sizes of the input by estimating the cluster count. The input data is further iterated for detecting the shortest distance vector trained from the given samples. The weight updating rule of SOM is estimated by the following equation.

$$W_{xy} = W_{xy}\,(old) + \alpha\,(t) * (i_x^k - W_{xy}(old)) \quad (1)$$

where,

α = learning rate with time (t)

y = shortest vector

x = x^{th} feature of training sample

k = k^{th} training sample from input sample

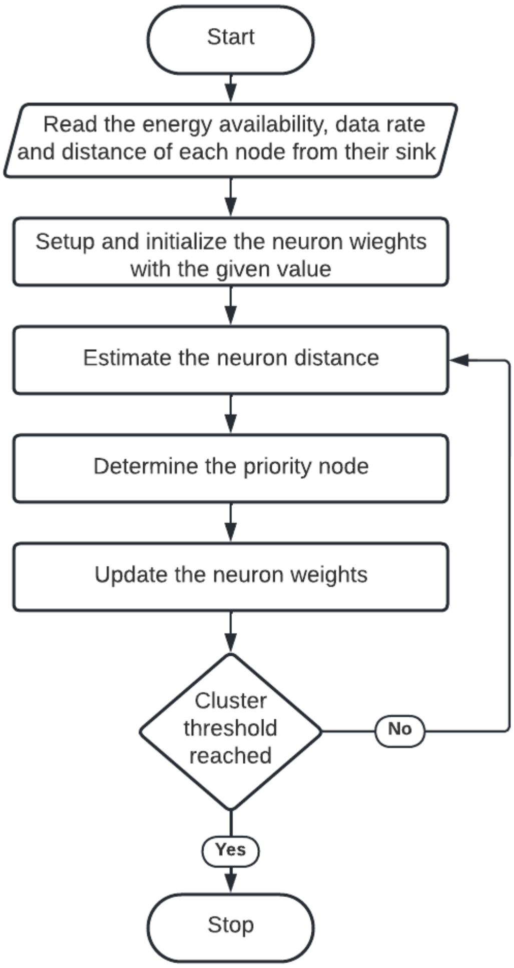

Figure 2. Workflow of the SOM in scheduling application

The workflow of SOM algorithm on the proposed scheduling application is shown in figure 2. The training data of the given problem comprises of the information like node number with their energy availability, data count with its distance information from the sink.

Based on the given information the neuron weights are initialized and the estimation was performed to find the prioritized neuron between each available node. Hence the algorithm forwards the information of that particular node and makes other nodes to be in sleep mode. Time estimation is performed in the algorithm for enabling the nodes after the transmission of data from the primary node with the updated neuron weights. A cluster threshold function is enabled to conclude the data transmission work at its value becomes zero in the connected node.

4. Experimental Analysis and Discussion

The proposed work generates the training data samples by creating a customized sensor network in the NS-2 platform and the neural network -based operations are performed in the MATLAB platform. The values that are generated in the NS-2 applications are converted into a spreadsheet form and that is incorporated to the MATLAB tool for making the neurons to understand the values. The experimental outcome of the proposed work estimates the energy conservation and network lifetime of the connected network over the traditional ant colony [22] and Software Defined Network (SDN) [23] models on various numbers of nodes ranging from 50 to 500. Table 2 represents the energy consumption of connected network for transferring the same amount of data on different techniques.

Table 2. Energy consumption study of the proposed model with the existing ones

Number of nodes	Total energy consumption in Joules		
	SOM	Ant Colony	SDN
50	25.2	30.55	42.78
100	51.01	63.1	76.3
150	77.68	90.9	102.05
200	99.7	114	128.6
250	128.35	144.63	158.9
300	154	170.1	184.44
350	175.5	193.2	216.2
400	201.1	220.3	233.7
450	227.26	244.01	265
500	256.08	285	297.7

Figure 3 represents a comparative analysis on energy consumption between the verified algorithms. A steady improvement on the SOM energy consumption is observed in the graph. The performance of SDN lags behind the ant colony algorithm. However, this slight variation on the energy consumption gives a major reflection to the network lifetime. Table 3 and 4 indicate the network lifetime of the sensor nodes on their first node failure and last node failure with respect to time.

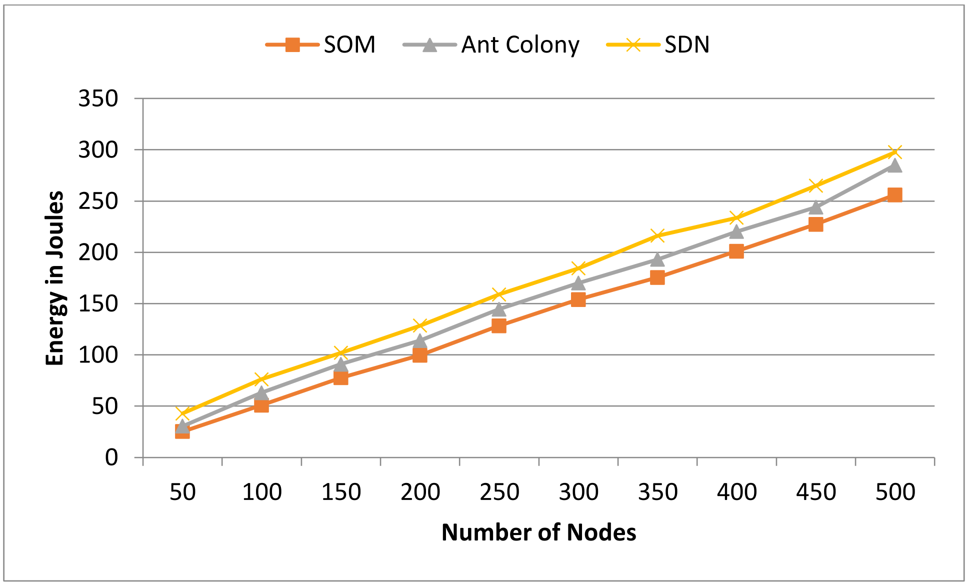

Figure 3. Comparison of the SOM energy consumption with the existing algorithms

Table 3. Network lifetime on first node failure

Number of nodes	Time consumed for first node failure in Seconds		
	SOM	Ant Colony	SDN
50	7.1	6.8	5.9
100	7.2	6.5	6.2
200	6.9	6.6	6.8
300	7.3	6	5.9
400	7.2	6.1	6.7
500	7	6.6	7.1

The network lifetime on first node failure is represented in figure 4 as a comparative study and that indicates that the SOM technique performs better in almost all the conditions except on the maximum count of sensor nodes. The performance of ant colony algorithm is found satisfied up to 200 sensor nodes than the SDN that found degradation beyond 200 sensor nodes.

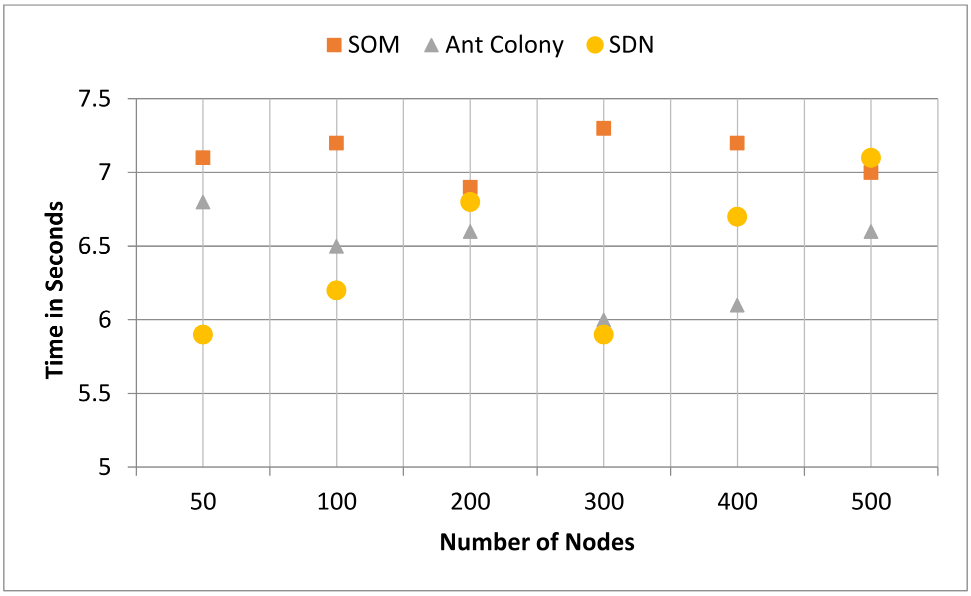

Figure 4. Comparison of network lifetime on first node failure

Table 4. Network lifetime on all node failure

Number of nodes	Time consumed for all node failure in Seconds		
	SOM	Ant Colony	SDN
50	35.4	27.8	24.2
100	32.8	31.1	26.4
200	39.3	26.9	25.3
300	41.2	28.7	27
400	37.8	30.6	30.1
500	43.7	28.3	23.7

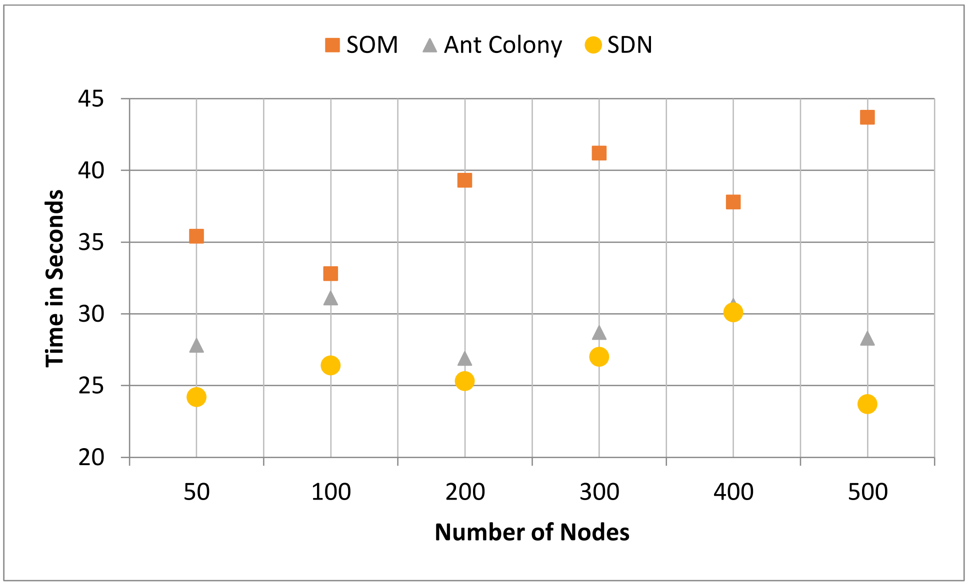

Figure 5. Comparison of network lifetime on all node failure

A study on overall network failure is shown in figure 5 and that indicates that the proposed SOM technique performs better than the ant colony and SDN approaches. Similarly, the overall performance of ant colony is found better than that of the SDN.

5. Conclusion

The WSN energy enhancement problems are widely addressed with metaheuristic algorithms, and that addresses the energy enhancement issue to a certain extent. The ant colony optimization is found to be one of the successful optimization algorithms on the energy improvement in WSN, and the software defined network approach is another technique implemented for WSN scheduling process. The proposed work utilizes the SOM technique for finding the efficacy of the deep learning algorithm on energy optimization problem of WSN. A comparative experimental analysis is performed in the work and is found satisfied with the outcome of SOM on energy consumption and network lifetime improvement. The work can be further improved by analyzing the performances of the WSNs with different kinds of deep learning approaches.

References

[1] Souissi, Ilhem, Nadia Ben Azzouna, and Lamjed Ben Said. "A multi-level study of information trust models in WSN-assisted IoT." Computer Networks 151 (2019): 12-30.

[2] Bajaj, Karan, Bhisham Sharma, and Raman Singh. "Integration of WSN with IoT applications: a vision, architecture, and future challenges." In Integration of WSN and IoT for Smart Cities, pp. 79-102. Springer, Cham, 2020.

[3] Wohwe Sambo, Damien, Blaise Omer Yenke, Anna Förster, and Paul Dayang. "Optimized clustering algorithms for large wireless sensor networks: A review." Sensors 19, no. 2 (2019): 322.

[4] Pang, Aiping, Fan Chao, Hongbo Zhou, and Jing Zhang. "The method of data collection based on multiple mobile nodes for wireless sensor network." IEEE Access 8 (2020): 14704-14713.

[5] Al Aghbari, Zaher, Ahmed M. Khedr, Walid Osamy, Ifra Arif, and Dharma P. Agrawal. "Routing in wireless sensor networks using optimization techniques: A survey." Wireless Personal Communications 111, no. 4 (2020): 2407-2434.

[6] Mahendran, N., and T. Mekala. "An Efficient Optimization Technique for Scheduling in Wireless Sensor Networks: A Survey." In Integrated Intelligent Computing, Communication and Security, pp. 223-232. Springer, Singapore, 2019.

[7] Chaturvedi, Pooja, and Ajai Kumar Daniel. "Scheduling Optimization Based on Energy Prediction Using ARIMA Model in WSN." In Information Security Practices for the Internet of Things, 5G, and Next-Generation Wireless Networks, pp. 245-276. IGI Global, 2022.

[8] Srinivasa Rao, B. "A Novel Efficient Energy and Delay Balance Ensemble Scheduling Algorithm for Wireless Sensor Networks." In Proceedings of Second International Conference on Sustainable Expert Systems, pp. 101-114. Springer, Singapore, 2022.

[9] Joshi, Pallavi, Ajay Singh Raghuvanshi, and Sarvesh Kumar. "An Intelligent delay efficient data aggregation scheduling for distributed sensor networks." Microprocessors and Microsystems 93 (2022): 104608.

[10] Guo, Zhihui, and Hongbin Chen. "A reinforcement learning-based sleep scheduling algorithm for cooperative computing in event-driven wireless sensor networks." Ad Hoc Networks 130 (2022): 102837.

[11] Rawat, Piyush, and Siddhartha Chauhan. "Particle swarm optimization based sleep scheduling and clustering protocol in wireless sensor network." Peer-to-Peer Networking and Applications 15, no. 3 (2022): 1417-1436.

[12] Prakash, B. Guru, C. Balasubramanian Chelliah, and R. Sukumar Ramanujam. "HHFDS: Heterogeneous hybridized fuzzy- based Dijkstra's multitask scheduling in WSN." Concurrency and Computation: Practice and Experience 33, no. 3 (2021): e5354.

[13] KhadirKumar, N., and A. Bharathi. "Real time energy efficient data aggregation and scheduling scheme for WSN using ATL." Computer Communications 151 (2020): 202-207.

[14] Guruprakash, B., C. Balasubramanian, and R. Sukumar. "An approach by adopting multi-objective clustering and data collection along with node sleep scheduling for energy efficient and delay aware WSN." Peer-to-Peer Networking and Applications 13, no. 1 (2020): 304-319.

[15] Susila Sakthy, S., and S. Bose. "Dynamic model node scheduling algorithm along with OBSP technique to schedule the node in the sensitive cluster region in the WSN." Wireless Personal Communications 114, no. 1 (2020): 265-279.

[16] Movva, Pavani, and Polipalli Trinatha Rao. "Novel two-fold data aggregation and MAC scheduling to support energy efficient routing in wireless sensor network." IEEE Access 7 (2018): 1260-1274.

[17] Chen, Po-Hsun, Tai-Lin Chiu, Chun-Hung Fan, Huan Chen, and Chun-Wei Tsai. "An effective scheduling algorithm for wireless sensor network with adjustable sensing range." In International Cognitive Cities Conference, pp. 114-123. Springer, Singapore, 2019.

[18] Redhu, Surender, and Rajesh M. Hegde. "Cooperative network model for joint mobile sink scheduling and dynamic buffer management using Q-learning." IEEE Transactions on Network and Service Management 17, no. 3 (2020): 1853-1864.

[19] Ajmi, Nader, Abdelhamid Helali, Pascal Lorenz, and Ridha Mghaieth. "SPEECH-MAC: Special purpose energy- efficient contention- based hybrid MAC protocol for WSN and Zigbee network." International Journal of Communication Systems 34, no. 1 (2021): e4637.

[20] Chandravathi, C., and Krishnan Mahadevan. "Web Based Cross Layer Optimization Technique for Energy Efficient WSN." Wireless Personal Communications 117, no. 4 (2021): 2781-2792.

[21] Natarajan, Mahendran, and Shankar Subramanian. "A cross-layer design: energy efficient multilevel dynamic feedback scheduling in wireless sensor networks using deadline aware active time quantum for environmental monitoring." International Journal of Electronics 106, no. 1 (2019): 87-108.

[22] Xiao, Xingxing, and Haining Huang. "A clustering routing algorithm based on improved ant colony optimization algorithms for underwater wireless sensor networks." Algorithms 13, no. 10 (2020): 250.

[23] Wang, Yanwen, Hainan Chen, Xiaoling Wu, and Lei Shu. "An energy-efficient SDN based sleep scheduling algorithm for WSNs." Journal of Network and Computer Applications 59 (2016): 39-45.

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