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BRMFC: Design of a Bioinspired Routing Model with Fan Clustering for Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) are in constant need of power conservation, and as a result, a broad variety of protocols are recommended for low power clustering and routing activities. This is owing to the fact that WSNs need to save as much power as possible. However, the majority of these protocols have a higher level of complexity and a lower level of energy efficiency, both of which restrict their ability to scale to bigger networks. To overcome this drawback, a Bioinspired Routing Model with Fan Clustering for Wireless Sensor Networks is discussed in this text. The proposed model initially performs destination-aware Fan Shaped Clustering (FSC) and groups nodes based on their distance measures. These FSCs are further processed via use of a bioinspired model that uses Genetic Algorithm (GA) for selection of optimum routing nodes. These nodes are selected based on their residual energy & distance metrics. The model uses a light weight fitness function that assists in faster solution convergence, with better routing paths. It was evaluated on systems with small, medium, and large scales, and its Quality of Service (QoS) metrics were compared to those of other models that are considered to be state-of-the-art. The results of this comparison showed that the model that was suggested was capable of reducing power consumption by 5.9%, reducing delay by 8.5%, increasing PDR by 2.5%, and increasing throughput by 10.5%. As a result, it is extremely valuable for deploying real-time networks.

Keywords: *Wireless, Sensor, Network, Routing, Bioinspired, Fan, Shaped, Clusters*

1. Introduction

There is a large range of interdomain models that need to be taken into account when it comes to the process of routing data in wireless networks. Some of the models that are included in these models include clustering, geographical node placements, distance assessment methodologies, traffic management, energy concerns, and many more models. The illustration in Figure 1 depicts a wireless routing model that is common [1]; it shows the whole flow of invitation-based routing. This model is an accurate representation of the standard. In this section, the cluster heads, abbreviated as CH, will broadcast requests for invitations. The location of the CH, their current energy levels, and any other characteristics that are unique to the cluster will be included in these queries. The nodes are the ones that are responsible for providing a response to these requests with an acknowledgment of either Yes or No. This opens the door for CHs to either add the nodes to their cluster lists or remove them from those lists so that they may add other nodes. The Time Division Multiple Access (TDMA) slots that are now open are accessible for use by any nodes that have been granted permission to do so by CHs. As a consequence of this modification, the procedure by which the nodes communicate data from themselves to the CHs is made more straightforward. After that has been accomplished, the CHs will send this data to other nodes or CHs so that the node-to-node communication loops may be finished. In order to carry out application-specific routing and communications, models substitute measurements of distance and energy level with attributes that are context-specific. These context-specific features comprise a wide variety of factors, some of which include throughput, packet delivery ratio (PDR), and routing overheads.

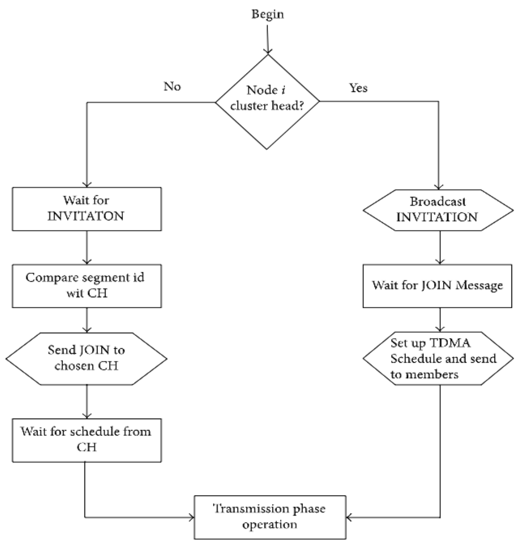

Fig 1. Flow of a typical energy aware routing model

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Any node that has been granted permission by CHs to utilise the Time Division Multiple Access (TDMA) slots that are currently available may do so at their discretion. Due to the fact that these slots are now vacant, these nodes are able to make use of them. As a direct consequence of this modification, the mechanism by which the nodes move data from themselves to the CHs has been simplified. This, in turn, has the effect of making the approach less difficult. After that stage has been finished, the CHs will send the data either to other nodes or to CHs in order to finish off the node-to-node communication loops. In order to carry out application-specific routing and communications, models substitute measures of distance and energy level with characteristics that are relevant to the environment in which the program is being executed. These qualities may include things like temperature or humidity. These context-specific features [2, 3, 4] are made up of a huge variety of factors, some examples of which include throughput, packet delivery ratio (PDR), and routing overheads, to mention just a few of the many possible examples. In the following section, an overview of such models, together with their subtleties, benefits, and limitations, as well as possible future study fields, will be detailed. As a result of this conversation, it was determined that the majority of these protocols feature a higher level of complexity in addition to a poor level of energy efficiency, both of which limit their potential to scale to bigger networks. In the following section, we will describe the construction of a Bioinspired Routing Model with Fan Clustering for Wireless Sensor Networks so that we may get over this disadvantage. The proposed model initially performs destination-aware Fan Shaped Clustering (FSC) and groups nodes based on their distance measures. These FSCs are further processed via use of a bioinspired model that uses Genetic Algorithm (GA) for selection of optimum routing nodes. These nodes are selected based on their residual energy & distance metrics. The model uses a light weight fitness function that assists in faster solution convergence, with better routing paths. This discussion will allow researchers to select best routing models that may be referred to for their deployments. As a direct outcome of this interaction, researchers will be able to choose the models that provide the greatest fit for their deployments and refer to those models while doing their research. This article comes to a close with a number of observations that inspire contemplation on the proposed model that have been explored, as well as a number of suggestions for ways in which their real-time performance may be further enhanced. These observations and suggestions are presented in the final section of the article. The concluding part of the paper is where these findings and recommendations are laid out for the readers that can be used for multiple scenarios.

2. Literature Review

Researchers have come up with a broad array of different routing models, and each of these models varies in terms of the levels of performance they achieve on their own. For instance, the research presented in [5, 6] proposes the use of an Energy-Saving Routing Protocol Based on Voronoi Adaptive Clustering (ESC VAD). This protocol combines a brainstorm optimisation with levy distribution (BSO-LD) based clustering process with a water wave optimisation with a hill-climbing (WWO-HC) based routing process. This combination assists in the continuous optimisation of routing and clustering processes. However, these models cannot be scaled up to accommodate more extensive network configurations. In order to address this constraint, the research presented in [7] recommends the usage of many objective ant-colony-optimization based QoS-aware cross-layer routing (MACO-QCR). This type of routing helps in the integration of many node and network situations in order to achieve high efficiency in routing use cases. The approach is extremely scalable and may be utilised with a wide variety of different kinds of networks. Similar models are discussed in [8, 9, and 10]. These models propose the use of full coverage of discrete points of interest (DPOI), Q-Learning-Based Data-Aggregation-Aware Energy-Efficient Routing Protocol, and Energy-Efficient Cooperative Routing the scheme for Heterogeneous Wireless Sensor Networks. These models can be utilised for application-specific as well as performance-specific use cases. These models are used in conjunction with other routing methods to integrate context-specific scenarios. They can be extended via use of Sustainable Multipath Routing Models [11], Markov Decision Processes (MDPs) with deep blockchains [12], Ensure the integration and authentication of nodes and BS of WSN [13], Centralized Routing Protocol [14], and Blowfish Algorithm-Based Secure Routing Model [15], that aim at integrating security measures for different network types.

Work in [16, 17, 18] further proposes use of Energy Harvesting with Dual Alternative Batteries (EH DAB), Software-Defined Routing via Reinforcement Learning (SDR2L), and Reading-based Dual Validation (RbDV), which aims at incrementally improving routing performance under large-scale network scenarios. Extensions to these models are discussed in [19, 20, 21], which propose use of Stable Election Protocol (SEP), QoS aware energy balancing secure routing (QEBSR), and Energy-Aware Geographic Routing (EAGR), that assisted in deployment of low complexity models for high-efficiency communication use cases. These models must be further extended via use of Energy Efficient Environment-Aware Fusion Based Reliable Routing [22], and Delay-Aware Green Routing (DAGR) [23], that assist in integration of performance-specific capabilities for multiple WSN scenarios. But these models are highly complex, and thus showcase limited scalability to larger networks. To overcome this drawback, next section proposes design of a Bioinspired Routing Model with Fan Clustering for Wireless Sensor Networks. The model was also evaluated under multiple use case scenarios.

3. Design of the Proposed Bioinspired Routing Model with Fan Clustering for Wireless Sensor Networks

After referring the literature review, it is clear that the complexity and energy efficiency of the current clustering and routing models for WSNs are higher, limiting their ability to scale to larger networks. A Bioinspired Routing Model with Fan Clustering for Wireless Sensor Networks is discussed in this text as a solution to this problem. Figure 2 depicts the flow of the suggested model. Within this picture, it is possible to see that the proposed model first conducts Fan Shaped Clustering (FSC), which groups nodes in accordance with the distance measurements that have been taken between them.

These FSCs are then processed further using a bio-inspired model that chooses the best routing nodes using a Genetic Algorithm (GA). These nodes are chosen based on metrics for residual energy and distance. The model employs a light fitness function that aids in quicker convergence of the solution and better routing paths. Its Quality of Service (QoS) metrics were assessed on small, medium, and large scaled networks and contrasted with those of other standard models.

The model initially collects multiple datasets for network-based, node-based & QoS-based parameters.These parameters include, node locations, their residual energy levels, their packet delivery ratio (PDR) performance, their throughput levels, and network received signal strength indicator (RSSI) levels.

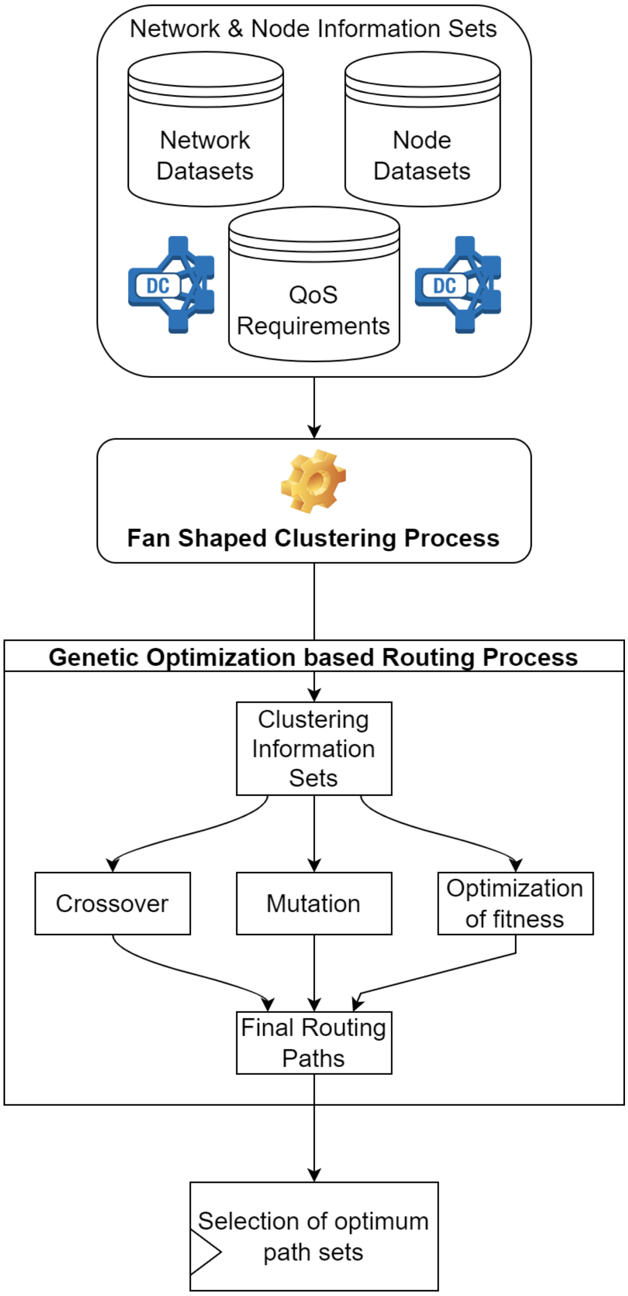

Fig 2. Overall flow of the proposed FSC based GA Model for clustering & routing optimizations

For every source & destination pair, the network evaluates node-level number via equation 1,

$$NLN_i = \frac{d(i, dest)}{d(hop)_i} \dots (1)$$

Where, $d(i, dest)$ represents distance between i^{th} node to destination node, while $d(hop)$represents maximum one-hop distance of the nodes. Based on this distance, nodes are clustered into fan shaped levels (or layers), as depicted in figure 3, wherein central sink node is responsible for clustering other nodes. The distance between each node in one layer must not be more than $d(hop)$ which enabled the fan-shaped clusters to be uniformly evaluated & scanned for multiple scenarios. After the fan formation is completed, then a Genetic Algorithm based model is used to route data between different fan clusters. This model works via the following process,

- To start with, setup following GA parameters,
  - o Total optimization iterations (N_i)
  - o Total optimization solutions (N_s)
  - o Rate of optimization, that will control crossover & mutation operations (L_r)

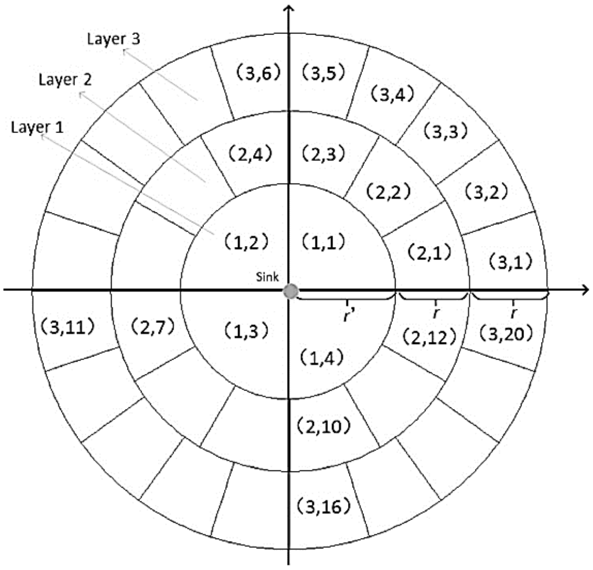

Fig 3. Clustering of nodes into fan-shapes levels

  - o Also, mark all solutions as 'mutate', so that the model is able to generate solutions in the initial iterations
- Once the parameters are setup, then iterate through N_i iterations, and scan all solutions via following process,
  - o Skip the solution if it is marked as 'crossover', and go through next solution in sequence
  - o Else, generate new solution via following process,
    - ▪ Stochastically, select one node from each layer until the source layer is reached, and make sure selected node follows equation 2,

$$d(N_{sel}, src) < d_{ref}, d(N_{sel}, dest) < d_{ref} \dots (2)$$

Where, $d(N_{sel}, src)$& $d(N_{sel}, dest)$ represents Euclidean distance between selected node to source, and selected node to destination respectively, while d_{ref} represents reference distance between source & destination nodes.

- ▪ For each selected path, evaluate solution fitness via equation 3,

$$f = \sum_{i=1}^{N_{levels}} \frac{d(i, i+1)}{E(i) * PDR(i) * THR(i)} \dots (3)$$

Where, d, E, PDR & THR represents distance between nodes, residual energy levels, temporal packet delivery ratio, and throughput levels for selected nodes, while N_{levels} represents total number of levels formed during the cluster formation process.

- ▪ Evaluate this fitness for each solution, and at the end of each iteration calculate iteration threshold fitness via equation 4,

$$f_{th} = \sum_{i=1}^{N_s} f_i * \frac{L_r}{N_s} \dots (4)$$

  - o At the end of each iteration, change status of solution to 'mutate' if $f > f_{th}$, else make it 'crossover' for consecutive iterations
- Repeat this process for all iterations, and select solution with maximum fitness levels.

Based on this light weight & low complexity process, the model is able to generate routes that showcase low delay, low energy consumption, high throughput and high packet delivery ratios under multiple requests. Performance of this model is evaluated in the next section of this text.

4. Performance Evaluation & Comparison

The proposed model uses a combination of GA with Fan Shaped Clustering which assists in low complexity and high efficiency communication deployments. In order to evaluate performance of the proposed BRMFC model, it was evaluated with Wireless Multiple Channels, Two Ray Ground propagation, with Wireless Physical Network, and Mac802.16 model, that uses Priority Queues, and Omnidirectional antennas. The model was tested on 50 to 500 nodes, which were controlled by the AOMDV routing model, with 400m-by-400m size of network, and 2000 bytes per packet with 0.001 seconds per packet intervals.

A parametric study of QoS parameters is carried out by using the standard wireless network characteristics that are provided. These characteristics consist of the end-to-end communication latency, the average packet delivery ratio (PDR), the average throughput per communication, and the energy consumption that is used for each individual communication. The following tables include the results of an evaluation that was done in order to compare the effectiveness of the model with 500 node-to-node communications, that were suggested to the performance of regular trust-based models and routing models. For the purpose of this comparison, a high efficiency trust-based routing model is employed in ESC VAD [5], and for the same purpose, a high efficiency routing model is utilized in QE BSR [20].

Num. Nodes	Delay (ms) ESC VAD [5]	Delay (ms) QE BSR [20]	Delay (ms) BRMFC
100	0.53	0.52	0.44
125	0.63	0.60	0.51
150	0.72	0.71	0.60
175	0.82	0.80	0.67
200	1.01	0.99	0.83
225	1.30	1.27	1.07
250	1.69	1.65	1.39
375	2.17	2.12	1.79
500	2.65	2.59	2.19

Table 1. Communication delay for different nodes

When compared with the system implementations ESC VAD [5] and QE BSR [20], the end-to-end latency has been reduced by 15 percent, as can be seen from the evaluations that have been done and which are shown in table 1. This can also be seen from the graphical depiction of this parameter, which can be seen in figure 4 and is described in the following way,

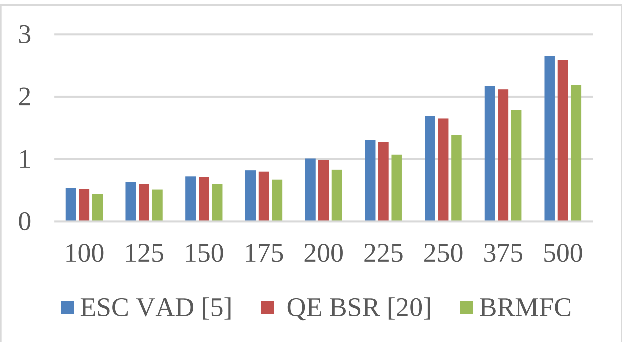

Fig 4. Communication delay for different nodes

Evaluation in terms of energy consumption can be observed from table 2 & figure 5 as follows,

Num. Nodes	Energy (mJ) ESC VAD [5]	Energy (mJ) QE BSR [20]	Energy (mJ) BRMFC
100	6.28	7.34	5.45
125	7.09	8.40	6.20
150	8.05	9.58	7.05
175	9.19	11.04	8.10
200	11.32	13.54	9.95
225	14.58	17.40	12.79
250	16.93	20.28	14.88
375	19.47	23.32	17.12
500	21.10	25.32	18.57

Table 2. Communication energy needed for different nodes

When compared with ESC VAD [5], this evaluation reveals that the overall network lifetime has improved by almost 10 percent, and when compared with the routing implementation in QE BSR [20], this evaluation reveals that the overall network lifetime has improved by almost 20 percent. These findings can be seen in figure 5, which is organized as follows,

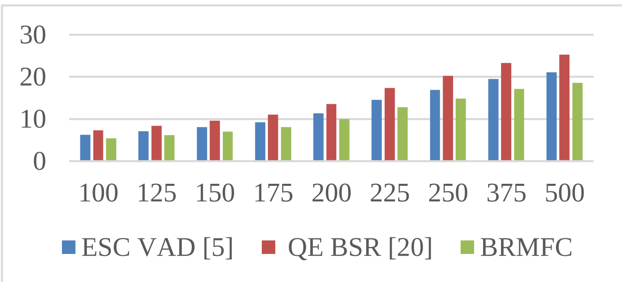

Fig 5. Communication energy needed for different nodes

The technology may now be used for real-time use cases including financial and agricultural networks thanks to this development.

Num. Nodes	Thr (kbps) ESC VAD [5]	Thr (kbps) QE BSR [20]	Thr (kbps) BRMFC
100	355.16	316.61	447.85
125	392.55	356.52	499.38
150	443.53	405.28	565.87
175	507.73	470.37	652.06
200	624.38	574.98	799.57
225	804.35	738.97	1028.88
250	931.95	860.54	1194.99
375	1069.91	988.09	1372.00
500	1156.84	1071.38	1485.48

Table 3. Communication throughput achieved needed for different nodes

Figure 6 shows that there has been an increase in throughput of 8%, making the system suitable for high-speed communication applications,

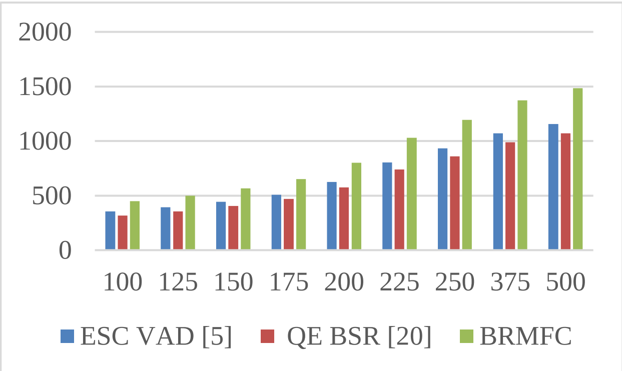

Fig 6. Communication throughput achieved needed for different nodes

Num. Nodes	PDR (%) ESC VAD [5]	PDR (%) QE BSR [20]	PDR (%) BRMFC
100	96.35	96.49	98.71
125	96.50	96.66	98.80
150	96.61	96.83	98.89
175	96.68	97.00	98.98
200	96.74	97.13	99.20
225	96.79	97.26	99.38
250	96.86	97.40	99.52
375	96.95	97.53	99.64
500	97.06	97.68	99.74

Table 4. Communication PDR achieved needed for different nodes

While conventional protocols ESC VAD [5] and QE BSR [20] have been shown to improve throughput and delay, the study shows that the suggested BRMFC implementation can maintain an acceptable packet delivery ratio while improving latency, energy, and throughput under multiple real-time scenarios.

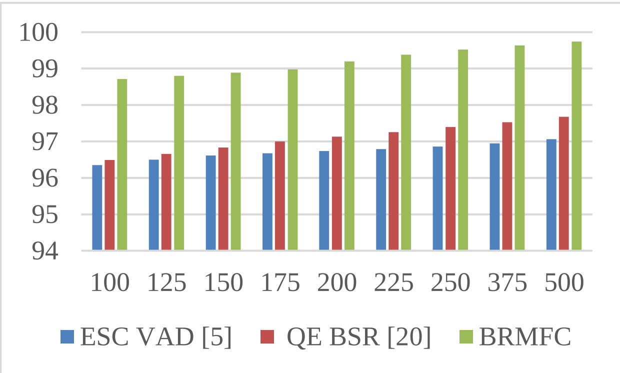

Fig 7. Communication PDR achieved needed for different nodes

As a result, the protocol may be used in real time. Forward error correction (FEC) is one example of an error correction method that may be used to enhance PDR for different input scenarios.

5. Conclusion and Future Work

The proposed model integrates low complexity clustering with high-efficiency routing process, which assists in improving overall performance of the model under various scenarios. The model initially performs destination aware clustering, which assists the routing layer in identification of low delay, low energy consumption, high throughput and high PDR routes. Because of this, the model when compared with the system implementations ESC VAD [5] and QE BSR [20], showcased that the end-to-end latency has been reduced by 15 percent, it also showcased that the overall network lifetime has improved by almost 10 percent w.r.t. ESC VAD [5], and when compared with the routing implementation in QE BSR [20], this evaluation reveals that the overall network lifetime has improved by almost 20 percent, which makes the model useful for high speed and low power applications withreduce delay by 8.5%. The model also showcased 10.5% better throughput, reduce power consumption by 5.9% and 2.5% higher PDR when compared with ESC VAD [5], and QE BSR [20], which makes it highly useful for high-speed and low-error communications. In the future, the model will need to be validated on larger data sets, and it can be enhanced by the application of Q-Learning, Incremental Learning, and other models that are designed to continuously improve QoS. Its security performance can also be improved via integration of blockchain-based storage layers, which will allow for immutable, traceable, transparent and distributed communication transactions under large-scale network scenarios.

References

[1] K. Wang, C. -M. Yu and L. -C. Wang, "DORA: A Destination-Oriented Routing Algorithm for Energy-Balanced Wireless Sensor Networks," in IEEE Internet of Things Journal, vol. 8, no. 3, pp. 2080-2081, 1 Feb.1, 2021, doi: 10.1109/JIOT.2020.3025039.

[2] N. R. Patel, S. Kumar and S. K. Singh, "Energy and Collision Aware WSN Routing Protocol for Sustainable and Intelligent IoT Applications," in IEEE Sensors Journal, vol. 21, no. 22, pp. 25282-25292, 15 Nov.15, 2021, doi: 10.1109/JSEN.2021.3076192.

[3] G. Arya, A. Bagwari and D. S. Chauhan, "Performance Analysis of Deep Learning-Based Routing Protocol for an Efficient Data Transmission in 5G WSN Communication," in IEEE Access, vol. 10, pp. 9340-9356, 2022, doi: 10.1109/ACCESS.2022.3142082.

[4] U. M. Durairaj and S. Selvaraj, "Two-Level Clustering and Routing Algorithms to Prolong the Lifetime of Wind Farm-Based WSN," in IEEE Sensors Journal, vol. 21, no. 1, pp. 857-867, 1 Jan.1, 2021, doi: 10.1109/JSEN.2020.3015734.

[5] N. Ma, H. Zhang, H. Hu and Y. Qin, "ESCVAD: An Energy-Saving Routing Protocol Based on Voronoi Adaptive Clustering for Wireless Sensor Networks," in IEEE Internet of Things Journal, vol. 9, no. 11, pp. 9071-9085, 1 June1, 2022, doi: 10.1109/JIOT.2021.3120744.

[6] S. Al-Otaibi, A. Al-Rasheed, R. F. Mansour, E. Yang, G. P. Joshi and W. Cho, "Hybridization of Metaheuristic Algorithm for Dynamic Cluster-Based Routing Protocol in Wireless Sensor Networksx," in IEEE Access, vol. 9, pp. 83751-83761, 2021, doi: 10.1109/ACCESS.2021.3087602.

[7] T. Kaur and D. Kumar, "MACO-QCR: Multi-Objective ACO-Based QoS-Aware Cross-Layer Routing Protocols in WSN," in IEEE Sensors Journal, vol. 21, no. 5, pp. 6775-6783, 1 March1, 2021, doi: 10.1109/JSEN.2020.3038241.

[8] Y. Xu, W. Jiao and M. Tian, "An Energy-Efficient Routing Protocol for 3D Wireless Sensor Networks," in IEEE Sensors Journal, vol. 21, no. 17, pp. 19550-19559, 1 Sept.1, 2021, doi: 10.1109/JSEN.2021.3086806.

[9] W. -K. Yun and S. -J. Yoo, "Q-Learning-Based Data-Aggregation-Aware Energy-Efficient Routing Protocol for Wireless Sensor Networks," in IEEE Access, vol. 9, pp. 10737-10750, 2021, doi: 10.1109/ACCESS.2021.3051360.

[10] L. . -L. Hung, F. . -Y. Leu, K. . -L. Tsai and C. . -Y. Ko, "Energy-Efficient Cooperative Routing Scheme for Heterogeneous Wireless Sensor Networks," in IEEE Access, vol. 8, pp. 56321-56332, 2020, doi: 10.1109/ACCESS.2020.2980877.

[11] X. Fu, Y. Yang and O. Postolache, "Sustainable Multipath Routing Protocol for Multi-Sink Wireless Sensor Networks in Harsh Environments," in IEEE Transactions on Sustainable Computing, vol. 6, no. 1, pp. 168-181, 1 Jan.-March 2021, doi: 10.1109/TSUSC.2020.2976096.

[12] I. A. A. E. -M. And and S. M. Darwish, "Towards Designing a Trusted Routing Scheme in Wireless Sensor Networks: A New Deep Blockchain Approach," in IEEE Access, vol. 9, pp. 103822-103834, 2021, doi: 10.1109/ACCESS.2021.3098933.

[13] A. Kuthe and A. K. Sharma, "Review paper on Design and Optimization of Energy Efficient Wireless Sensor Network Model for Complex Networks," 2021 5th International Conference on Information Systems and Computer Networks (ISCON), 2021, pp. 1-3, doi: 10.1109/ISCON52037.2021.9702421.

[14] O. R. Ahutu and H. El-Ocla, "Centralized Routing Protocol for Detecting Wormhole Attacks in Wireless

Sensor Networks," in IEEE Access, vol. 8, pp. 63270-63282, 2020, doi: 10.1109/ACCESS.2020.2983438.

[15] M. Alotaibi, "Improved Blowfish Algorithm-Based Secure Routing Technique in IoT-Based WSN," in IEEE Access, vol. 9, pp. 159187-159197, 2021, doi: 10.1109/ACCESS.2021.3130005.

[16] T. Zhao, L. Wang, K. -W. Chin and C. Yang, "Routing in Energy Harvesting Wireless Sensor Networks With Dual Alternative Batteries," in IEEE Systems Journal, vol. 15, no. 3, pp. 3970-3979, Sept. 2021, doi: 10.1109/JSYST.2020.3007166.

[17] M. U. Younus, M. K. Khan and A. R. Bhatti, "Improving the Software-Defined Wireless Sensor Networks Routing Performance Using Reinforcement Learning," in IEEE Internet of Things Journal, vol. 9, no. 5, pp. 3495-3508, 1 March1, 2022, doi: 10.1109/JIOT.2021.3102130.

[18] K. Ramasamy, M. H. Anisi and A. Jindal, "E2DA: Energy Efficient Data Aggregation and End-to-End Security in 3D Reconfigurable WSN," in IEEE Transactions on Green Communications and Networking, vol. 6, no. 2, pp. 787-798, June 2022, doi: 10.1109/TGCN.2021.3126786.

[19] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand and A. H. Gandomi, "I-SEP: An Improved Routing Protocol for Heterogeneous WSN for IoT-Based Environmental Monitoring," in IEEE Internet of Things Journal, vol. 7, no. 1, pp. 710-717, Jan. 2020, doi: 10.1109/JIOT.2019.2940988.

[20] M. Rathee, S. Kumar, A. H. Gandomi, K. Dilip, B. Balusamy and R. Patan, "Ant Colony Optimization Based Quality of Service Aware Energy Balancing Secure Routing Algorithm for Wireless Sensor Networks," in IEEE Transactions on Engineering Management, vol. 68, no. 1, pp. 170-182, Feb. 2021, doi: 10.1109/TEM.2019.2953889.

[21] A. K. Sangaiah et al., "Energy-Aware Geographic Routing for Real-Time Workforce Monitoring in Industrial Informatics," in IEEE Internet of Things Journal, vol. 8, no. 12, pp. 9753-9762, 15 June15, 2021, doi: 10.1109/JIOT.2021.3056419.

[22] F. H. El-Fouly and R. A. Ramadan, "E3AF: Energy Efficient Environment-Aware Fusion Based Reliable Routing in Wireless Sensor Networks," in IEEE Access, vol. 8, pp. 112145-112159, 2020, doi: 10.1109/ACCESS.2020.3003155.

[23] S. Jain, K. K. Pattanaik, R. K. Verma, S. Bharti and A. Shukla, "Delay-Aware Green Routing for Mobile-Sink-Based Wireless Sensor Networks," in IEEE Internet of Things Journal, vol. 8, no. 6, pp. 4882-4892, 15 March15, 2021, doi: 10.1109/JIOT.2020.3030120.

[24] Dr. Sandip Kadam. (2014). An Experimental Analysis on performance of Content Management Tools in an Organization. International Journal of New Practices in Management and Engineering, 3(02), 01 - 07. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/27

[25] M, V. ., P U, P. M. ., M, T. ., & Lopez, D. . (2023). XDLX: A Memory-Efficient Solution for Backtracking Applications in Big Data Environment using XOR-based Dancing Links. International Journal on Recent and Innovation Trends in Computing and Communication, 11(1), 88–94. https://doi.org/10.17762/ijritcc.v11i1.6054

[26] Dhabliya, D. (2019). Security analysis of password schemes using virtual environment. International Journal of Advanced Science and Technology, 28(20), 1334-1339. Retrieved from www.scopus.com