Energy Efficient Hop-by-Hop Retransmission and Congestion Mitigation of an Optimum Routing and Clustering Protocol for WSNs

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Abstract—In the past few decades, wireless sensor networks, which take a growing number of applications in the surroundings further than the human reach, have risen in popularity. Various routing pseudo codes have been suggested for network optimization, emphasizing energy efficiency, network longevity, and clustering processes. To the existing load balancing energy-efficient sleep awake, aware smart sensor network routing protocol, the modified load-balancing efficient-energy sleep active alert smart routing system for wireless sensor networks is presented in this paper, which takes network homogeneity into account. The modified protocol is the optimum clustering and routing protocol in wireless sensor networks (OCRSN), which simulates an enhanced network coupled node pair model. Our suggested modified approach studies and enhances factors such as network stability, network lifetime, and cluster monitor mechanism choice. The significance of typically combining sensor endpoints is applied to maximize energy efficiency. The proposed protocol significantly improved network parameters in simulations, showing that it could be a valuable option for WSNs. In wireless sensor networks, in addition to memory considerations and dependable transportation, this paper presents a hop-by-hop re-transmission strategy and congestion mitigation, which is the major contribution of this paper. It is a very consistent method based on a pipe flow model. After performing additional optimized overhead to improve the network lifespan of wireless sensors networks, the current algorithm can be paralleled to the less energy adaptive clustering hierarchy protocol. The optimal clustering in multipath and multihop technique intends to minimize the energy consumption highlighted for a circular area enclosed by a sink by replacing one-hop communication with efficient multihop communication. The optimum quantity of clusters is determined, and the energy consumption is reduced by splitting the network into clusters of nearly equal size. The obtained simulation results will demonstrate the increase in the network lifetime compared to previous clustering strategies such as Low Energy Adaptive Clustering Hierarchy.

Keywords—*Wireless sensor network; network lifetime; clustering strategies; clustering process*

I. INTRODUCTION

In recent years, a great deal of research has been done on low power protocols, network setup, routing protocols, and analysis issues in sensor networks. Several routing protocols can be used to accomplish optimal routing in the context of energy, such as proximity, multipath, and so on. Battery power is a critical component in the algorithm design for extending the network's endpoint lifespan [1]. To enhance overall network performance, it is ideal for increasing the lifespan of sensor endpoints. The numerous energy consumption sources in WSNs can be divided into "constituent" - "practical" pairs. The practical consists of the native foundations of energy dissipation required to complete the prescribed task at each endpoint. The energy wastage is due to inefficient medium access, routing, or topology control in the latter category [2]. Depending on the application environment, each consumer contributes to overall energy consumption. Energy control in WSNs was first classified into conservation and supply of energy. The former refers to providing energy to each endpoint during runtime to fully (or partially) power the sensor endpoints [3]. Outward power supply bases currently display non-continuous behavior in many circumstances, which can cause system failure [4]. Energy harvesting and conservation to be integrated into a unified ecosystem to avoid degeneration of the collected energy. From a data-centric standpoint, WSN applications can be classified into periodic sampling, event-driven, or hybrid situations based on convergent validity [5].

In the first group, the measured data must be transferred to the gateway regularly for processing. As a result, data traffic will be exceedingly dense, especially if acquisition durations are short [6]. As a result, the likelihood of errors, passive listening, and suboptimal routing increases. Unlike the previous classification, data transfer is less frequent in event-driven operations. Other sources of energy use, on the other hand, may be dominant. Finally, heterogeneous WSNs are considered in the third category of WSN applications, wherein the measured data is regularly communicated [7]. Simultaneously, the network samples the environment regularly to detect predetermined events. The energy-saving approaches can be classified into three categories: Data-oriented methods: Time-driven methods, and event-driven methods are classified into this category based on WSN applications. The first subcategory concerns the communication module, accounting for most energy usage in time period-centric scenarios. The latter group includes methods for reducing the strain of frequent data collecting or resource sensors [8 & 9]. In addition, local mechanisms for modifying components of each endpoint are included.

TABLE I. SUMMARY OF RELATED PAST RESEARCH WORK FOR CLUSTERING IN COMPARISON WITH PROPOSED WORK

Peer to Peer Network connection	Year	Methodology	Classification	Advantages	Disadvantages
Proposed Protocol	2022	C.H. voting technique with hop-by-hop re-transmission strategy and congestion mitigation	Synthesis clustering strategy	Simple, reliable, efficient, and easy to use	Fails to identify the voting of dead C.H. node during node selection
CFFB Protocol [29]	2019	Fuzzy – Neuro method	Adaptable strategy	Deep Learning-based technique for voting optimum C.H.	adds more load to the network
Optimized routing protocol with cluster-based energy-efficient large area WSNs [30]	2019	Derivative Independent Simplex Technique	Synthesis clustering strategy	Lessens the effective consumption of energy	Typical number of clusters in single round effects in a large delay of operations
C.H.E.S. – D.L.F. protocol [31]	2018	G.A./Fuzzy predictive strategy	Adaptable strategy	Efficient CH voting that improves time span of network	Extensive calculation such as hop count, density results in fast energy reduction
Multi-Criteria selection analysis strategy protocol [32]	2016	The algorithm scales the transmission rate, residual energy, distance to B.S.	Combined – Scaling technique	Enhances the network lifetime	Mathematical complexity
K-Means – Clustering method in WSN [33]	2015	Residual Energy scaling strategy and value of threshold node	Adaptable strategy	Enhanced are nodes deployed in the network	Power consumed in residual energy computed with threshold data is an extra burden on the network
Energy Efficient multihop clustering Protocol [34]	2014	Scaling the energy level	Synthesis clustering strategy	Enhanced connectivity and stability	With some nodes dead, the delay is caused
LEEACH [35]	2004	A randomized voting of cluster heads, formation of C.H.'s are self-configured	Deterministic techniques	Fast, simple, low overhead	Large redundant data, limitations due to random data

The approaches in this domain are combined with event-driven and time-driven WSN applications such as memory overflow and reliable transport with memory considerations, as illustrated in Table I, which depicts the summary and compares the past research works with the proposed work. The network-based techniques mainly aim for energy consumption for retaining network functionality.

The key contributions of this research work are as follows:

1) With new green algorithms and technologies, this research presents a hop-by-hop re-transmission and congestion mitigation, a very consistent method in WSN based on a pipe flow model [10, 11].

2) This research further attempts to create an efficient-energy framework for ad-hoc clustered routing while protecting edge devices from attacks that drain their batteries [12].

II. LITERATURE REVIEW

A survey of efficient-energy hierarchical cluster-based routing in wireless sensor networks was conducted. The research investigated several elements: low power protocols, network topologies, routing protocol, and wireless sensor network coverage issues. Different routing protocols can be used to accomplish optimal routing in the context of energy, such as location-aided, multipath, data center, mobility, QoS [13]. Next, a cluster routing method, DECSA, provided an efficient-energy clustering routing algorithm based on energy residual and distance for wireless sensor networks. The improved algorithm properly balances energy consumption, extends the lifetime by 31%, helps conserve by 40%, and performs better than the original LEACH procedure [14]. However, additional performance characteristics such as quality of service constraints and performance level were overlooked. The research was performed on a clustering routing protocol for the energy balance of wireless sensor networks based on simulated annealing and genetic algorithm. In this protocol, the simulated annealing and genetic algorithm were used to cluster the sensor endpoints while also considering the residual energy of the endpoints and the average energy of the cluster to obtain a more reasonable cluster head distribution in the lower level of the network [15]. A study on network load balancing and its application to the lifecycle of wireless sensor networks was neglected here. The efficient-energy hierarchical unequal clustering in wireless sensor networks was proposed, using an unequal clustering strategy for even energy distribution [16]. It also lowers overall energy usage, which extends the network's lifespan. The model assumes that all endpoints are immobile after deployment, that they can determine their location using GPS receivers, and that the network is homogeneous. A WSN-assisted IoT strategy was developed using an adaptive fuzzy rule-based efficient-energy clustering and immune-inspired routing protocol [17]. A bio-inspired optimization technique is applied for routing to improve data transmission dependability. Cluster-based routing is an effective method of lowering energy use. Compared to existing clustering and routing approaches, it improves QoS characteristics. The limitation was an optimum routing with large residual energy for multihop communication within the clusters, deploying many base stations to reduce the burden on cluster monitors near each base station to increase energy efficiency. Overall, network lifetime in wireless sensor networks was not explored. The proposed method uses simple fuzzy rule-based neural networks combined with clustering to properly exploit energy while avoiding the wastage caused during the head and cluster patterning selection. The practiced

system allows cluster patterning and routing to make better decisions about which endpoints to send data to, resulting in a transmission system that is faster, more efficient energy, and less prone to failure. But only the placement of the base station at the center of the network will reduce the number of hops for data transmission. Hence, the minimum energy consumption is one of the limitations identified in this research work. In addition, an efficient-energy clustered gravitational and fuzzy-based routing algorithm in WSNs was proposed [18]. This paper omitted the impact of effective communication among endpoints on the availability of residual energy, which is a drawback noted here. The swarm intelligence–based efficient-energy clustering with multihop routing algorithm for maintainable wireless sensor networks is proposed. The study developed a unique wireless sensor network clustering and multihop routing protocol based on swarm intelligence [19]. An improved particle swarm optimization technique selects cluster heads and efficiently organizes clusters. The optimization-based routing procedure is then used to identify the network's best pathways. The research significantly improved particle swarm optimization–the optimization approach takes advantage of both the clustering and routing processes, resulting in optimal energy efficiency and network longevity. Sensor endpoints can operate in sensing mode to detect physical variables or communication mode to send information to the base station. Each endpoint's connectivity manages traffic, and each endpoint is assigned to a location index. The connection between endpoints is similar, and the distance between them may be determined by measuring the signal power received. An efficient-energy smart routing in WSN employing a dominant genetic algorithm is provided, and a heuristic-based efficient-energy communication strategy is used [20, 21]. To find the best efficient-energy routing channel between sensor endpoints and define the best efficient-energy trajectory for mobile data gathering endpoints, a novel development in the genetic algorithm known as Dominant Genetic Algorithm (DGA) has been proposed. Because of its natural occurrence, the dominance of high fitness solutions has been integrated into the Genetic algorithm [22]. The constraint here is that it is assumed that there is no sensor mobility in the first situation, whereas in the second case, cluster heads are already present. Clusters have already formed, and the amount of energy expended to determine the route of a mobile data gathering endpoint is calculated using DGA.

III. METHODOLOGY ADOPTED

In this research, developing a modified load-balancing efficient-energy sleep active alert intellectual routing system for wireless sensor networks, the endpoints send location data to the base station, and the base station uses central coupling at minimum distance. All endpoints are combined with random neighbors, and the base station transmits their position data if they are coupled. The endpoints receive status updates and come to be alert of the attached endpoint [23]. Each attached endpoint compares its distance from a base station to its partner distance to the base station endpoint remains active if there is a reduced distance than a neighbor endpoint. If there is an awake mode, all the endpoints are in active mode, and else all the endpoints switch to sleep mode. Next, transmit network advertisement, listen and wait to the selection medium and

receive the awake request from the endpoints. If the mode is not active, receive the channel advertisement and relate with the received strength signal indicator, quality, link, and variant node. Finally, send a request to cluster head with energy information, receive TDMA slot, and transmit detected data in the allocated slot.

Further, the PCHs allocated the TDMA slot for transmission by transmitting the TDMA list, receiving data from endpoints, and aggregating received data from member endpoints. The active nodes are considered during the selection of the cluster heads. All the nodes have the same initial energy in the first round. The nodes in active mode will select themselves as cluster heads based on the probability of selecting cluster head with distributed algorithm 1and each node select the random number between 0 and 1 and compares it to a threshold A_H is as illustrated in equation (1) as follows.

$$A_H = \begin{cases} P_D \Big/ 1 - P_D * (\text{Initial Round}) \bmod \frac{1}{P_D} \, ; \text{ if } n \in T \\ \\ 0; \text{ Otherwise} \end{cases} \quad (1)$$

Where T is the set of active nodes in the first round. If a node's random number is smaller than the threshold (A_H), the node will elect itself as a cluster head and is referred to as Root-Cluster-Heads (RCHs). When a node is designated as an RCH, it sends an advertisement message to the entire network. Active-mode nodes only hear the broadcast messages from different RCHs. They choose their RCHs based on the advertising' Received Signal Strength Indication (RSSI). To avoid collisions, when an Active-mode node determines which cluster it wants to join, it sends a request to that RCH via the Carrier Sensed Multiple Access (CSMA) M.A.C. protocol. Active-mode nodes additionally send their energy statistics to RCH along with their requests. The RCH calculates the remaining energy and its distance from each node, then chooses a C.H. for the following round, known as Sub-Cluster-Head (S.C.H.). In the network transmission phase, if there are M amount of nodes and L are the optimum quantity of cluster heads, then the average nodes in one cluster will be,

$$\left(\frac{M}{L} - 1 \right) \quad (2)$$

For the data transmission to begin, the transceiver of the non-cluster head node dissipates $Energy_{(TX)}$ to run the transmission circuit and $TX_{(Amp)}$ to achieve an acceptable signal to noise ratio (SNR), therefore for the transmission of the message bit M_{BIT} a non-cluster head node will expand to equation (3).

$$Energy_{non-CH} = \left(\frac{M}{L} - 1 \right) (Energy_{(TX)} * M_{BIT} *$$
$$TX_{(Amplifier)} * M_{BIT} * d_{to-CH}^2 \quad (3)$$

To receive the data from a non-cluster head node on by the transceiver on cluster head expands in each cluster by equation (4) as follows:

$$E_{Recieve} = (E_{RX} * M_{BIT}) \left(\frac{M}{L} - 1 \right) \quad (4)$$

Where the dissipated energy by each circuitry is denoted by E_{RX} for data receive and dissipated energy by cluster head to

total data is data received ($E_{Recieve\ Data}$) from its nodes associated is illustrated in equation (5) as follows.

$$E_{Total} = (E_{Recieve\ Data} * M_{BIT}) * \left(\frac{M}{L}\right) \qquad (5)$$

`The energy of transmission (E_{Trans}) dissipated by cluster heads to transmit the total data D_{Total} to the base station is given by equation (6) as follows

$$E_{Trans} = Energy_{(TX)} * D_{Total} * TX_{(Amp)} * d_{to-BS}^2 \qquad (6)$$

Here d_{to-BS}^2 is the distance between a base station and the cluster head. The total energy dissipated by the cluster head in one round is given by equation (7) as follows

$$E_{CH-Total\ Energy} = E_{Recieve} + E_{Total} + E_{Trans} \qquad (7)$$

The dissipated total energy by cluster head is the dissipated energy in data reception from the nodes associated. The following Algorithm 1 describes this approach:

Algorithm 1: Algorithm for EESAA protocol

Start
The endpoints transmit position data to a base station
Base station uses significant combination at a minimum distance
If coupled:
    All nodes are coupled with any of the neighbors
    B.S. Broadcast their status information
    Nodes receive status updates
    Nodes become aware of coupled partner
    Every coupled node compares its distance to B.S. ->
    ->to its partner distance to B.S.
    The endpoint remains active if distance < partner endpoint
 If (Alert mode):
    Yes: All endpoints are active
    Else if:
a.   **No:** Endpoints switch to sleep mode
    If (C.H.):
b.   **Yes:** Transmit cluster head
c.   Delay and eavesdrop to the intermediate endpoint until a certain range.
d.   Obtain requests from endpoints
    Else if:
e.   **No:** Active mode
f.   **If (in RCHs range):**
g.   **Yes:** loop over to step c
    Else if:
h.   **No:** Receive C.H.s advertisement
    If (S.C.H.s)
i.   **No:** loop over to step h and compare RSSI, Link, quality, and type
    Else if:
    Yes:
    Transmit request to cluster head with energy statistics
    Receive TDMA slot and transmit detected data in the assigned slot
    Switch (to step (e)):
    Case 1:
j.   **If (RCHs):** C.H.s assign TDMA space for transmitting data
    Broadcast TDMA list and Receive endpoint data
    Aggregate received data from member endpoints
    (Go To): Base Station
    End

Next, we perform the setup phase for LEACH, and in this, we assign node$_{(i)}$ as the monitor of the cluster and the corresponding broadcast status of the cluster monitor. Then with delay for link communication request, next produce TDMA time slot and transmit to cluster points (t=0) with a stable-state operation for t=T$_{(round)}$ seconds [24]. In the next step, wait for broadcasts from the monitor of the cluster, with transmitting for join-request to chosen cluster heads and pause for cluster monitor (t=0) schedule. This approach is presented in the following Algorithm 2.

Algorithm 2: Algorithm for setup phase for LEACH protocol

Start
If cluster monitor Endpoint$_{(i)}$
Yes:
a.   broadcast cluster monitor status
b.   Wait for link request communications
c.   Create a TDMA schedule and send it to cluster members (t=0)
d.   balanced-state operation for t=T$_{(round)}$ seconds
    Else if:
    No:
e.   Wait for messages from the cluster monitor
f.   Transmit for link-request to selected cluster monitors
g.   pause for cluster monitor (t=0) schedule
h.   Loop over to step d
    End

In the optimum clustering and routing protocol in the wireless sensor networks (OCRSN) stage, the Input number of endpoints is defined and generates a random position of each endpoint. An endpoint neighbor discovery cluster head selection cluster creation and routing table creation [25, 26]. Further, there is time slot assignment along with communication to the base station, and finally, the data tracing process is done in this stage. Algorithm 3 describes this approach as follows.

Algorithm 3: Algorithm for setup phase for LEACH protocol

Start
Input number of endpoints
Generate random position of each endpoint
Endpoint neighbor discovery
Cluster head selection
Cluster creation and routing table creation
Time Slot assignment
Communication to the base station and data tracing
Display the result
End

The methodology is further extended to the flow pipe strategy, a robust transport method in wireless sensor networks, as illustrated in Fig. 1.

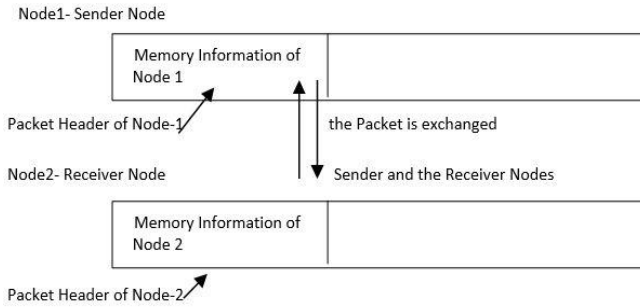The reliable transport with memory considerations is as shown in Fig. 2.

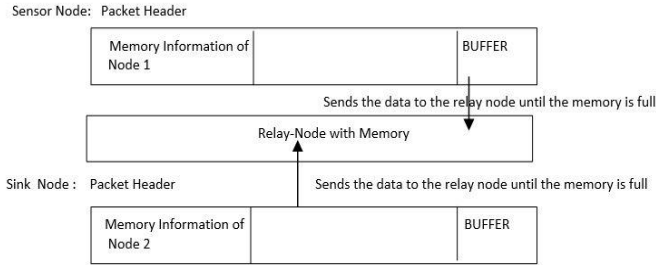Fig. 1.   Memory Overflow Prevention Strategy.

Fig. 2.   Reliable Transport with Memory Consideration.

The transmitter node obtains the receiving node's memory information in this manner. As a result, the solution described can prevent memory overflow [28]. The local variables linked with each node help in transmission in the nodes. As the source adjusts its transmission rate, the throughput can be enhanced using the memory information contained in each node's packet header. The techniques described above are effective on low-memory nodes and good use of the channel. Inter-segment data can be transferred from source to sink at a reasonable cost and with great reliability using the abovementioned approach.

The next section illustrates the results from the study performed in the existing load balancing intellectual sensor network routing protocol, modified in terms of load balancing efficient-energy sleep active alert routing protocol, which considers network homogeneity [27].

IV. RESULTS OBTAINED

The packet delivery ratio (PDR) is obtained by considering the homogeneous network into the account and is compared with the existing load balancing protocol concerning the modified load-balancing efficient-energy sleep active alert smart routing protocol is, as illustrated in Fig. 3. The comparison is made by considering the sensor radius of WSN The end-to-end delay is achieved by allowing for the homogeneous network into consideration. It is related to the existing load balancing efficient-energy sleep awake, aware smart sensor network routing protocol concerning the modified load-balancing efficient-energy sleep active alert smart routing protocol is illustrated in Fig. 4. The results are compared by considering the WSN endpoint's sensor radius vs. round trip delay (in seconds).

It is related to the existing routing protocol for varied load-balancing efficient-energy sleep active alert smart routing

protocol, as illustrated in Fig. 5. The results are compared by considering the WSN endpoint's C.H. formation delay (milliseconds).
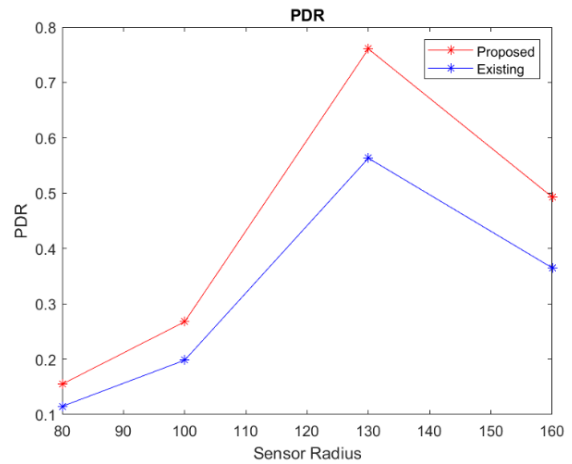

Fig. 3.   Comparison of Existing with Proposed Approach in Terms of P.D.R.
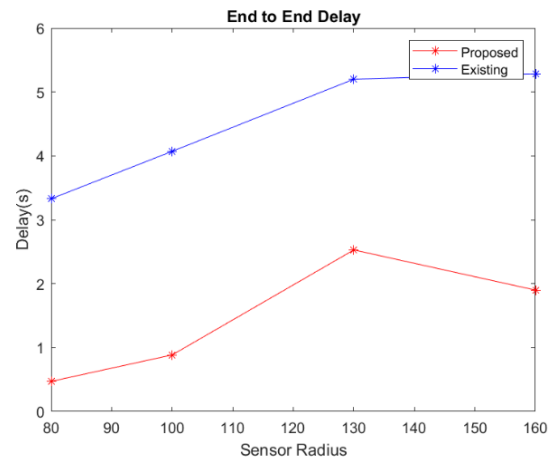

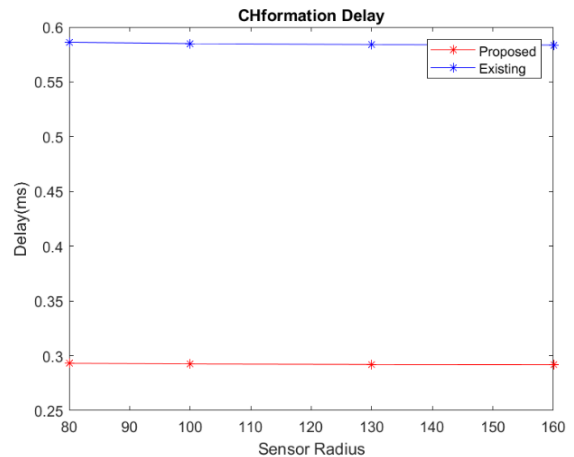Fig. 4.   Comparison of EESAA with m-EESAA in Terms of End-to-End Delay.

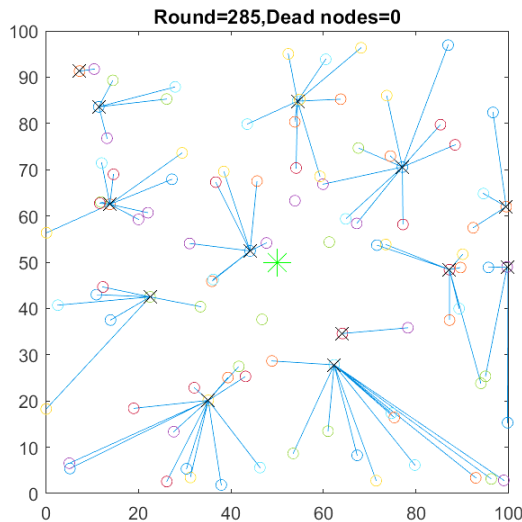Fig. 5.   Comparison of EESAA with m-EESAA in Terms of Cluster Head Formation Delay.

Fig. 6.   Calculation of the Number of Rounds and Number of Dead Endpoints of WSN.

The simulation of several rounds and the number of dead endpoints of the wireless sensor network endpoint is captured during the run time during the code execution and is illustrated in Fig. 6. The same is further optimized for the modified protocol cluster networks for optimum clustering and routing protocol in wireless sensor networks (OCRSN). Fig. 7 illuminates the Cluster network formation for optimum clustering and routing protocol in wireless sensor networks (OCRSN). In simulations, our proposed protocol significantly enhanced network parameters illustrating that it could be a valuable option for WSNs. After performing additional optimization overhead to enhance the network lifetime of wireless sensors networks, the current algorithm can be compared to the LEACH protocol as illustrated in the following Fig. 8., Fig. 9. to Fig. 14. Fig. 8 depicts the comparison of routing and clustering protocol (OCRSN). LEACH clustering protocol in terms of the average energies of each endpoint of the wireless sensor network (WSN).
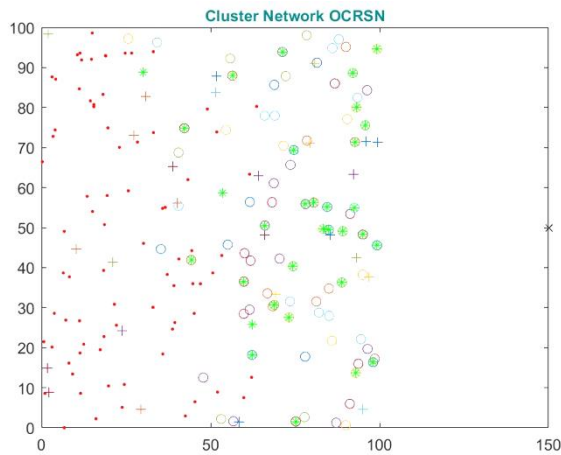

Fig. 7.   Cluster Network Formation for Optimum Clustering and Routing Protocol in Wireless Sensor Networks (OCRSN).
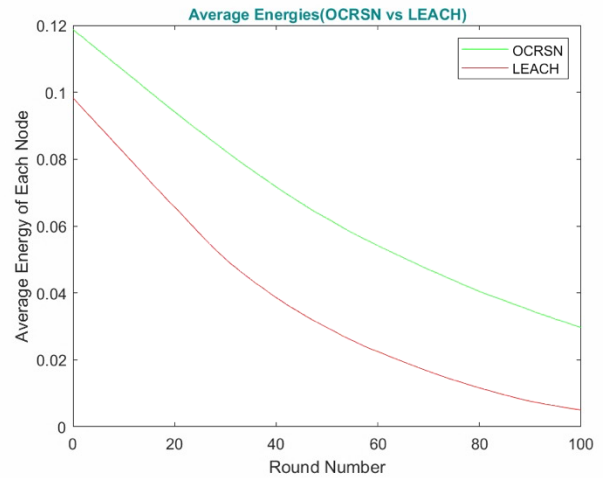

Fig. 8.   Comparison of OCRSN vs. LEACH w.r.t to Average Energies.

Fig. 9 illustrates the formation of the LEACH clustering protocol cluster network and is obtained for comparisons with our work. Fig. 10 shows the calculation of several dead endpoints concerning the round number in OCRSN (Our Work) versus the LEACH protocols. It is observed that OCRSN has a smaller number of dead endpoints compared to the LEACH protocol. Fig. 11 illustrates the calculation of several alive endpoints concerning the round number in OCRSN (Our Work) versus the LEACH protocols. Again, it is observed that OCRSN has more alive endpoints compared to LEACH protocols.

Further, Fig. 12 presents the formation of head clusters versus the round number, and the number of cluster heads is compared with OCRSN (Our Work) versus LEACH protocol. It is observed that OCRSN (Our Work) has more cluster heads than LEACH protocol. Next, Fig. 13 depicts the number of packets to cluster heads to the round number, and the number of cluster heads is compared with OCRSN (Our Work) versus LEACH protocol. The Fig. 13. Illustrates the formation of several packets to the base station with respect to the round number.
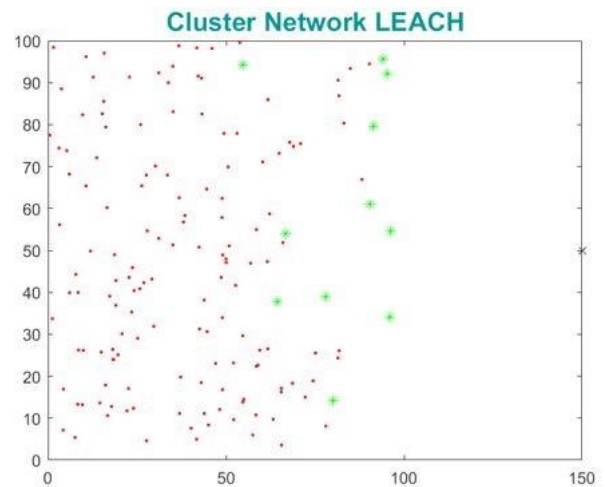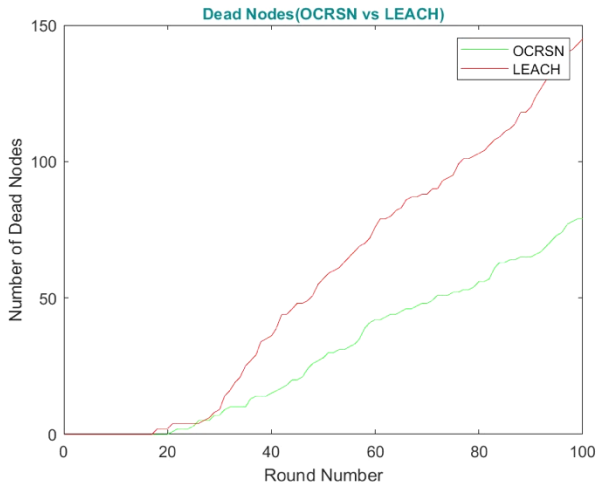

Fig. 9.   Cluster Network of LEACH.

Fig. 10. Calculation of Number of Dead Endpoints (OCRSN vs. LEACH).
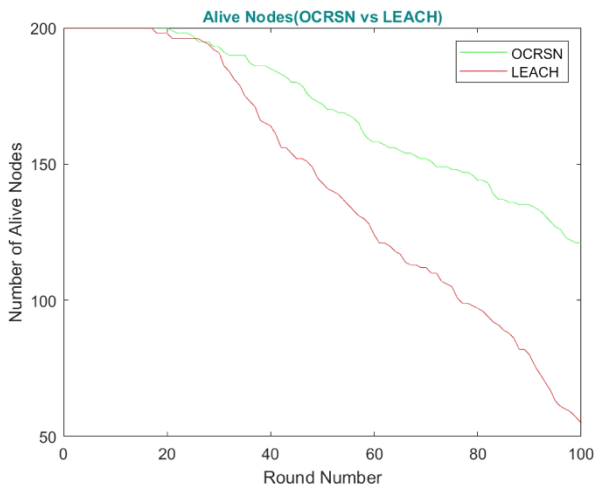

Fig. 13. Formation of Number of Packets to Cluster Head with respect to Round Number.

It is observed that OCRSN (Our Work) has more packets to the base station than the LEACH protocol. The enhanced network coupling node model is as illustrated in Fig. 14, it is observed that there are certain coupled node pairs aligned, and pipe connection is established between each of the aligned nodes. The isolated nodes are also observed at the bottom left and top right in Fig. 15. Table II illustrates the simulation parameters of measured simulation results obtained for the several network constraints with respect to the values obtained for each network constraint. Further from the overall simulations, it can be observed that:

1) LEACH can be chosen in reduced networks, where the sum of endpoints < 50 where achieves considerably enhanced performance than OCRSN.

2) OCRSN may be selected in more extensive topologies and once the experimental likelihood of cluster voting choice is more significant.

Fig. 11. Calculation of Number of Alive Endpoints (OCRSN vs. LEACH).
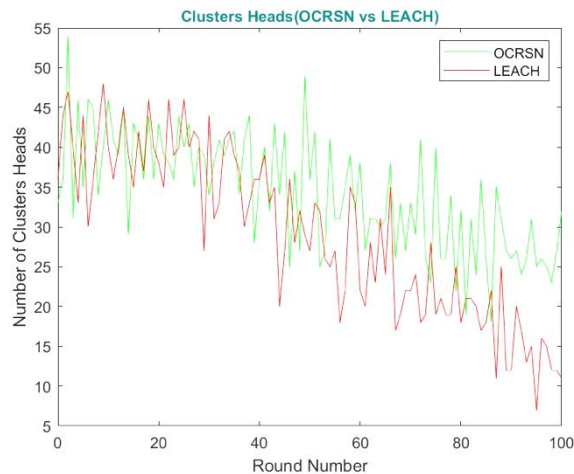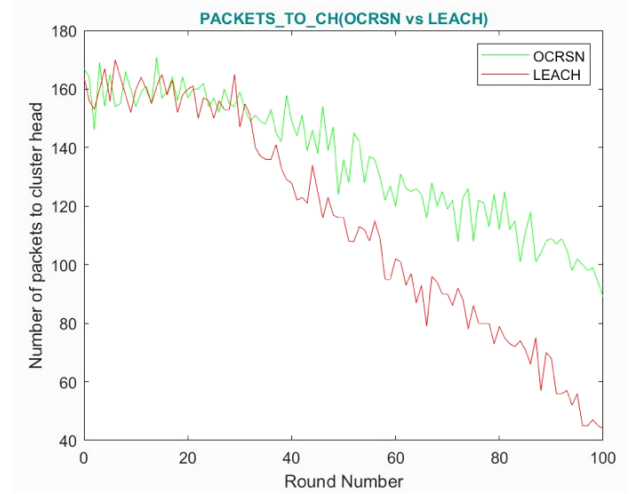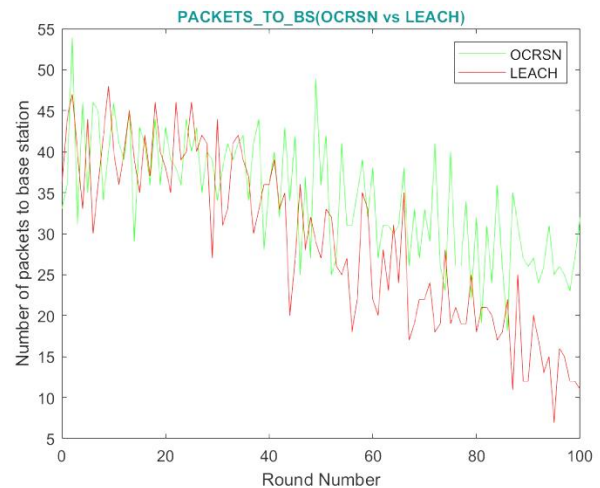

Fig. 12. Formation of a Head Cluster for Number of Rounds.

Fig. 14. Formation of Number of Packets to BS with respect to Round Number.

TABLE II.   KEY SIMULATION PARAMETERS

| Network Constraint	Value
a. Size of Network	100 x 100 m
b. Number of BS	2
c. Number of Nodes	100, 200, 300, 400
d. Packet Data Size	2K bits
e. Packet Control Size	20 bits
f. Node Initial Energy	3J
g. Calculated Rounds	52nJ/bit
h. Consumed Energy to drive transmit/receive signal	10pJ/bit/m2
i. Free space parameter	0.0012 pJ/bit/m^3
j. Energy consumption by CH member	6nJ/bit/signal
k. Number of Rounds	1500
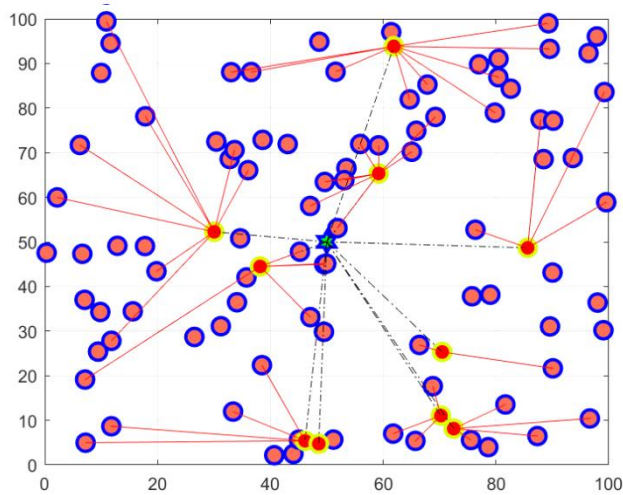
Fig. 15. Enhanced Network Coupling Node Model.

V. CONCLUSION

This paper presents the existing load balancing efficient-energy sleep awake, aware smart sensor network routing protocol. The modified protocol is developed for load-balancing efficient-energy sleep active alert smart routing system for wireless sensor networks, considering the network homogeneity. The modified protocol is the optimum routing and clustering protocol in wireless sensor networks (OCRSN). In the proposed modified approach, the study and enhancement of certain factors are proposed with memory considerations, and dependable transportation presents a hop-by-hop re-transmission strategy and congestion mitigation, a very consistent method based on a pipe flow model. The significance of characteristically pairing sensor endpoints is applied to maximize energy efficiency, and the simulations are obtained. The proposed protocol significantly improves network parameters, illuminating that it could be a valuable option for wireless sensor networks. After performing additional optimization overhead to enhance the network lifetime of wireless sensors networks, the current algorithm can be compared to the least energy adaptive clustering scheme protocol.

REFERENCES

[1] Pantazis, N., & Vergados, D. (2007). A survey on power control issues in wireless sensor networks. IEEE Communications Surveys & Tutorials, 9(4), 86–107. doi:10.1109/comst.2007.4444752.

[2] Sinde, R., Begum, F., Njau, K., & Kaijage, S. (2020). Refining Network Lifetime of Wireless Sensor Network Using Energy-Efficient Clustering and DRL-Based Sleep Scheduling. Sensors, 20(5), 1540. doi:10.3390/s20051540.

[3] Sarkar, A., & Senthil Murugan, T. (2017). Cluster head selection for energy-efficient and delay-less routing in wireless sensor network. Wireless Networks, 25(1), 303–320. doi:10.1007/s11276-017-1558-2.

[4] Gherbi, C., Aliouat, Z., & Benmohammed, M. (2018). A Novel Load Balancing Scheduling Algorithm for Wireless Sensor Networks. Journal of Network and Systems Management, 27(2), 430–462. doi:10.1007/s10922-018-9473-0.

[5] Wang, J., Gao, Y., Liu, W., Sangaiah, A., & Kim, H.-J. (2019). An Improved Routing Schema with Special Clustering Using PSO Algorithm for Heterogeneous Wireless Sensor Network. Sensors, 19(3), 671. doi:10.3390/s19030671.

[6] K.P, A. (2021). Comparison of Fuzzy-based Cluster Head Selection Algorithm with LEACH Algorithm in Wireless Sensor Networks to Maximize Network Lifetime. Revista Gestão Inovação e Tecnologias, 11(4), 1277–1288. doi:10.47059/revistageintec.v11i4.2186.

[7] Jan, S. R. U., Jan, M. A., Khan, R., Ullah, H., Alam, M., & Usman, M. (2018). An Energy-Efficient and Congestion Control Data-Driven Approach for Cluster-Based Sensor Network. Mobile Networks and Applications, 24(4), 1295–1305. doi:10.1007/s11036-018-1169-x.

[8] Punj, R., & Kumar, R. (2018). Technological aspects of W.B.A.N.'s for health monitoring: a comprehensive review. Wireless Networks, 25(3), 1125–1157. doi:10.1007/s11276-018-1694-3.

[9] Khedr, A. M., Osamy, W., & Salim, A. (2018). Distributed coverage hole detection and recovery scheme for heterogeneous wireless sensor networks. Computer Communications, 124, 61–75. doi:10.1016/j.comcom.2018.04.002.

[10] Farman, H., Javed, H., Jan, B., Ahmad, J., Ali, S., Khalil, F. N., & Khan, M. (2017). Analytical network process based optimum cluster head selection in wireless sensor network. PLOS ONE, 12(7), e0180848. doi:10.1371/journal.pone.0180848.

[11] Qu, Y., Zheng, G., Ma, H., Wang, X., Ji, B., & Wu, H. (2019). A Survey of Routing Protocols in W.B.A.N. for Healthcare Applications. Sensors, 19(7), 1638. doi:10.3390/s19071638.

[12] Chen, Z., & Shen, H. (2018). A grid-based reliable multihop routing protocol for energy-efficient wireless sensor networks. International Journal of Distributed Sensor Networks, 14(3), 155014771876596. doi:10.1177/1550147718765962.

[13] Yong, Z., & Pei, Q. (2012). A Energy-Efficient Clustering Routing Algorithm Based on Distance and Residual Energy for Wireless Sensor Networks. Procedia Engineering, 29, 1882–1888. doi:10.1016/j.proeng.2012.01.231.

[14] Mudathir, F.S.Y.; Rodrigues, J.J.P.C.; Khalifa, O.O.; Mohammed, A.B.; Korotaev, V. Service Redundancy and Cluster-based Routing Protocols for Wireless Sensor and Mobile Ad-Hoc Networks: A Survey. Int. J. Commun. Syst. 2020, 33, e4471.

[15] Baranidharan, B. (2013). Energy Efficient Hierarchical Unequal Clustering in Wireless Sensor Networks. Indian Journal of Science and Technology, 7(3), 301–305. doi:10.17485/ijst/2014/v7i3.2.

[16] Preeth, S. K. S. L., Dhanalakshmi, R., Kumar, R., & Shakeel, P. M. (2018). An adaptive fuzzy rule based energy efficient clustering and immune-inspired routing protocol for WSN-assisted IoT system. Journal of Ambient Intelligence and Humanized Computing. doi:10.1007/s12652-018-1154-z.

[17] S. Raj, J., & Basar, A. (2019). QOS Optimization of Energy Efficient Routing in IoT Wireless Sensor Networks. June 2019, 01(01), 12–23. doi:10.36548/jismac.2019.1.002.

[18] Guleria, K., & Verma, A. K. (2019). Meta-heuristic Ant Colony Optimization Based Unequal Clustering for Wireless Sensor Network. Wireless Personal Communications, 105(3), 891–911. doi:10.1007/s11277-019-06127-1.

[19] Selvi, M., Santhosh Kumar, S. V. N., Ganapathy, S., Ayyanar, A., Khanna Nehemiah, H., & Kannan, A. (2020). An Energy Efficient Clustered Gravitational and Fuzzy Based Routing Algorithm in WSN's. Wireless Personal Communications, 116(1), 61–90. doi:10.1007/s11277-020-07705-4.

[20] Elhoseny, M., Rajan, R. S., Hammoudeh, M., Shankar, K., & Aldabbas, O. (2020). Swarm intelligence–based energy efficient clustering with multihop routing protocol for sustainable wireless sensor networks. International Journal of Distributed Sensor Networks, 16(9), 155014772094913. doi:10.1177/1550147720949133.

[21] D L, S. (2020). Energy Efficient Intelligent Routing in WSN using Dominant Genetic Algorithm. International Journal of Electrical and Computer Engineering (I.J.E.C.E.), 10(1), 500. doi:10.11591/ijece.v10i1.pp500-511.

[22] Ho, J.-W., Wright, M., & Das, S. K. (2012). ZoneTrust: Fast Zone-Based Node Compromise Detection and Revocation in Wireless Sensor Networks Using Sequential Hypothesis Testing. IEEE Transactions on Dependable and Secure Computing, 9(4), 494–511. doi:10.1109/tdsc.2011.65.

[23] Praveen, J., & Nithya, V. (2016). Detection and Mitigation of Attacks in Cluster based Wireless Sensor Networks using Rule based I.D.S. Indian Journal of Science and Technology, 9(44). doi:10.17485/ijst/2016/v9i44/91477.

[24] Hsueh, C.-T., Wen, C.-Y., & Ouyang, Y.-C. (2015). A Secure Scheme Against Power Exhausting Attacks in Hierarchical Wireless Sensor Networks. IEEE Sensors Journal, 15(6), 3590–3602. doi:10.1109/jsen.2015.2395442.

[25] Thangaramya, K., Kulothungan, K., Logambigai, R., Selvi, M., Ganapathy, S., & Kannan, A. (2019). Energy aware cluster and neuro-fuzzy based routing algorithm for wireless sensor networks in IoT. Computer Networks, 151, 211–223. doi:10.1016/j.comnet.2019.01.024.

[26] Nalband, A. H., Sarvagya, M., & Ahmed, M. R. (2021). Spectral Efficient Beamforming for mmWave MISO Systems using Deep Learning Techniques. Arabian Journal for Science and Engineering, 46(10), 9783–9795. doi:10.1007/s13369-021-05552-4.

[27] Nalband, A. H., Sarvagy, M., & Ahmed, M. R. (2020). Power saving and optimal hybrid precoding in millimeter wave massive M.I.M.O. systems for 5G. TELKOMNIKA (Telecommunication Computing Electronics and Control), 18(6), 2842. doi:10.12928/telkomnika.v18i6.15952.

[28] Prashanth, B. U. V., & Ahmed, M. R. (2020). FPGA Implementation of Bio-inspired Computing Based Deep Learning Model. Advances in Distributed Computing and Machine Learning, 237–245. doi:10.1007/978-981-15-4218-3_24.

[29] BENMAHDI, M. B., & LEHSAINI, M. (2020). A GA-based Multihop Routing Scheme using K-Means Clustering approach for Wireless Sensor Networks. 2020 Second International Conference on Embedded & Distributed Systems (EDiS). doi:10.1109/edis49545.2020.9296444.

[30] Ramakrishnan, S., & Prayla Shyry, S. (2017). Distributed fuzzy logic based cluster head election scheme (D.F.L.C.H.E.S.) for prolonging the lifetime of the wireless sensor network. International Journal of Engineering & Technology, 7(1.5), 111. doi:10.14419/ijet.v7i1.5.9131.

[31] K.P, A. (2021). Comparison of Fuzzy-based Cluster Head Selection Algorithm with LEACH Algorithm in Wireless Sensor Networks to Maximize Network Lifetime. Revista Gestão Inovação e Tecnologias, 11(4), 1277–1288. doi:10.47059/revistageintec.v11i4.2186.

[32] Khan, B. M., & Bilal, R. (2020). Fuzzy-Topsis-Based Cluster Head Selection in Mobile Wireless Sensor Networks. Sensor Technology, 596–627. doi:10.4018/978-1-7998-2454-1.ch029.

[33] Yahya, H., Al-Nidawi, Y., & Kemp, A. H. (2015). A dynamic cluster head election protocol for mobile wireless sensor networks. 2015 International Symposium on Wireless Communication Systems (I.S.W.C.S.). doi:10.1109/iswcs.2015.7454362.

[34] Zhang, H., Zhang, S., & Bu, W. (2014). A Clustering Routing Protocol for Energy Balance of Wireless Sensor Network based on Simulated Annealing and Genetic Algorithm. International Journal of Hybrid Information Technology, 7(2), 71–82. doi:10.14257/ijhit.2014.7.2.08.

[35] Wicker, S. B. (2004). Self-Configuring Wireless Transmission and Decentralized Data Processing for Generic Sensor Networks. doi:10.21236/ada425425.