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Multi Objective Energy Based Improved Jellyfish Swarm Optimization for Effective Cluster Head Discovery in UWSN

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Abstract: Underwater wireless sensor networks (UWSNs) have a huge amount of sensors located underwater to collect data from the underwater scenario. UWSN is considered a promising method for monitoring and exploring an underwater scenario. Energy-efficient and reliable data broadcasting are considered challenging tasks, because of the limited energy source of sensors. To address this issue, an energy-efficient cluster head (CH) selection and multi-hop routing are developed in UWSN. The multi objective energy based improved jellyfish swarm optimization (MOEIJSO) is proposed to select optimal CHs from normal sensors. The input parameters of MOEIJSO are residual energy, neighbor node distance, sink distance, and CH balancing factor. Next, multi-hop routing is developed by using ant colony optimization (ACO) for delivering the data packets. Therefore, the proposed MOEIJSO-ACO method is used to improve energy efficiency while increasing data delivery. The proposed MOEIJSO-ACO method is evaluated by using the alive and dead nodes, total energy consumption, data received in base station (BS), and life expectancy. The existing researches such as metaheuristics-based clustering with a routing (MCR) for UWSN, modified low energy adaptive clustering hierarchy (MLEACH) and cooperative energy-efficient routing (CEER) approach are used to compare the MOEIJSO-ACO method. The alive nodes of the MOEIJSO-ACO are 399 for 800 rounds, which is high when compared to the MCR-UWSN.

Keywords: Ant colony optimization, Energy efficiency, Life expectancy, Multi-hop routing, Multi-objective energy based improved jellyfish swarm optimization, Underwater wireless sensor networks.

1. Introduction

Earth is occupied by a 3/4 ratio of water using seas, lakes, canals, rivers and streams. Since a huge amount of unexplored and hidden resources exist underwater which require to be discovered whereas underwater environments are highly sophisticated for humans to discover. Accordingly, an exploration of the underwater environment is possible with the use of wireless technology [1, 2]. UWSN is developing technology that is utilized for observing and discovering the changes in an aqueous environment [3]. UWSN is a wireless network that comprises a group of sensors and autonomous underwater vehicles for collecting and sensing data. These sensors accomplish direct or indirect transmission of information to the surface sensor (i.e., sink). Next, the data from the sink is transmitted to an offshore monitoring center to analyze and study the gathered data [4]. The sensors of UWSN are located underwater for evaluating the monitoring features such as density, temperature, pressure and so on [5]. UWSN is extensively used in diverse fields such as military target tracking, oil/gas spill monitoring, submarine detection, offshore exploration, disaster prevention and so on [6]. The UWSN faces various issues such as strong network dynamics, expensive deployment, less available bandwidth and restricted battery energy [7].

The battery energy of underwater sensors is restricted whereas these batteries cannot be simply replaced or charged in the ocean. The energy consumption of the UWSN is high because of the higher communication power, restricted bandwidth capacity, higher and variable time delay and higher bit error rate [8-10]. The limited battery source of the node creates the failure nodes over the UWSN [11]. These aforementioned features of UWSN create an effect on sensor data gathering and long-distance communication. Hence, the routing is required to be developed as simple and energy efficient for UWSNs. This indicates that effective and reliable data broadcasting to the sink node is a highly challenging task as well as it is one of the essential concerns in UWSN [12, 13]. A cluster-based data collection is developed for improving the energy efficacy of the WSN [14]. The main objective of the clustering approach is used to separate the network into small divisions namely clusters. An entire cluster is represented by using the CH that gathers the observed information from sensors and it is broadcasted to the sink by utilizing the CH as the next hop. The developed clustering approach is used to minimize the overall routing distance and overhead of sensors [15].

The contributions are concise as follows:

- The MOEIJSO based CH discovery is developed for enhancing the energy efficiency of UWSN. The IJSO is chosen for this research because of its enhanced local search capacity which is used to obtain in best CH solutions.
- Further, the ACO-based route discovery is used for identifying the route from transmitter CH to BS. Therefore, the MOEIJSO-ACO is used to improve the life expectancy of UWSN while enhancing the data delivery.

The paper organization is sorted as follows: Section 2 delivers the related works of the energy-efficient data transmission of UWSN. The MOEIJSO-ACO based data broadcasting is detailed in section 3 whereas the results are presented in section 4. Finally, the conclusion is given in section 5.

2. Related work

This section provides the existing energy efficient data broadcasting-related research in UWSN.

Chenthil and Jesu Jayarin, [16] presented the multilayer clustering-based butterfly optimization routing (MCBOR) for broadcasting the data to the receiver without loss. The list of parameters such as energy, node coverage, processing power and communication cost were utilized to choose the candidate CH. Further, butterfly optimization was used for transmitting the data to the receiver. The developed MCBOR was used to improve the PDR and minimize the loss over the UWSN. Moreover, the developed MCBOR was required to be analyzed in a large-scale network.

Bhattacharjya, [17] developed an energy-efficient UWSN for reducing energy expenditure and improving performance in the underwater environment. The developed cluster-based UWSN (CUWSN) utilized the advantages of CH and multi-hop data transmission. Here, the CH was chosen based on the residual energy of the sensors over the network. The developed CUWSN was used to improve life expectancy based on multi-hop transmission. The CH discovery was considered only the residual energy, however, a data transmission distance was required to be considered in CUWSN.

Faheem, [18] developed the dynamic firefly mating optimization-based routing protocol namely FFRP for the UWSN scenario. A stable and reliable route was discovered by using the developed FFRP. A balancing of data traffic load using FFRP was used to reduce energy usage and latency. Accordingly, the data transmission over the stable link was used to improve the data delivery of the network.

Subramani, [19] presented MCR for UWSN to enhance energy efficiency. In MCR-UWSN, the cultural emperor penguin optimizer-based clustering (CEPOC) was developed for generating the clusters. The developed CEPOC considered the node's motion and average distance for discovering the CH. Further, the routing was developed by using grasshopper optimization according to the list of nodes, energy, and distance. For an effective CH selection, cluster balancing among the nodes was essential to enhance the performance.

Rizvi, [20] presented an energy efficient approach i.e., MLEACH for UWSN. The CHs were randomly chosen in this MLEACH for preserving the energy in each round. The non‑persistent carrier sense multiple access was used to establish the data transmission among CH and its respective node. The direct data transmission from the CH to BS was resulted in higher energy depletion of nodes.

Ahmad [21] developed the cooperative energy-efficient routing (CEER) approach for generating the reliable network and increasing the network lifetime. The problem of hotspot was eliminated by minimizing the energy utilization based on sink mobility approach. The network reliability was obtained by using the cooperative technique in UWSN. However, the clustering over the network

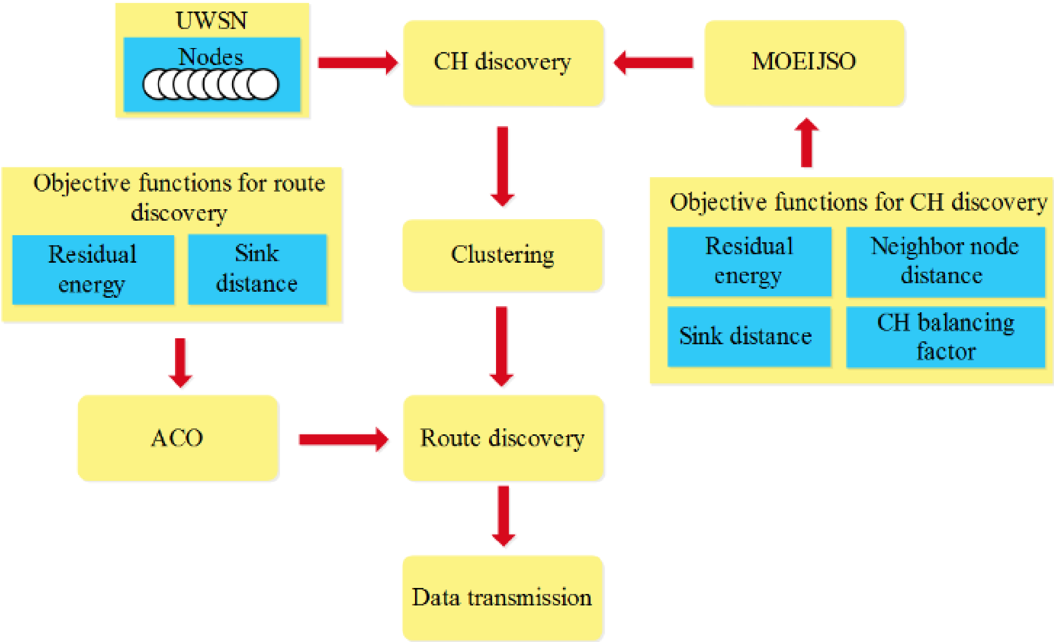

Figure. 1 Block diagram for the MOEIJSO-ACO

was required to be developed for an additional improvement of lifetime.

The limitations found from the related works are inadequate fitness function, higher energy usage and routing without clustering. In this research, an appropriate objective measures are used with MOEIJSO to develop an effective clustering and routing for minimizing the energy usage of overall network.

3. MOEIJSO-ACO method

In this research, effective data transmission is obtained by using a MOEIJSO based optimal CH selection and ACO based routing in UWSN. The energy usage of sensors is minimized by developing a clustering along with a multi-hop transmission using MOEIJSO-ACO. The reduction in energy utilization helps to improve the life expectancy of the sensors which results in higher data delivery. The block diagram of the MOEIJSO-ACO is presented in Fig. 1.

3.1 Sensor initialization

The nodes are positioned randomly in the WSN followed by the CHs chosen using MOEIJSO. The clusters are formed in the UWSN, once the CHs are chosen from the network. Further, the route from the transmitter CH to receiver BS is discovered using ACO. The optimal CH and route discovery are explained in the following sections.

3.2 Discovering optimal CH using MOEIJSO

The MOEIJSO is used for discovering the optimal CHs from the sensors of UWSN. The conventional Jellyfish Swarm Optimization (JSO) is motivated based on jellyfish's search-feeding activities and movement patterns through the ocean. The main difference between JSO and IJSO [22] is that the incorporation of the sinusoidal factor for improving the local search capacity resulted in the best optimal solutions. Further, the IJSO is developed as MOEIJSO for selecting optimal CHs from the sensors.

3.2.1. Representation and initialization

An initial solution of MOEIJSO i.e., jellyfish has a set of nominee nodes to be chosen as CH. Here, each jellyfish is initialized with the ID of a random node between 1 and N, where the total amount of nodes in the underwater scenario is denoted as N. The MOEIJSO's i th jellyfish is denoted as $X_i = (X_{i,1}, X_{i,2}, \dots, X_{i,dim})$, where dim denotes each jellyfish's dimension as amount of CHs.

3.2.2. Iterative process

The IJSO has three different rules that are mentioned as follows: 1) two types of motion exist in jellyfish such as following the ocean current motion and moving in the jellyfish population. Here, the time-controlled mechanism is used to switch among these motions; 2) Jellyfish moves in the ocean for searching food, where the jellyfishes are attracted to the position with more food, and 3) Food position and objective value defines the amount of discovered food.

3.2.2.1. Following the movement of ocean current

The movement way of current is denoted as $\overrightarrow{trend}$ that defines the average of the overall vector sum from every individual current location of jellyfish to the current finest location. Eq. (1) shows the current $\overrightarrow{trend}$ for the direction of motion.

$$\overrightarrow{trend} = X^* - DF \tag{1}$$

Where the optimal location is denoted as X^* and the difference between the current jellyfish placed in an optimal location and the average location of all jellyfish is denoted as DF is expressed in Eq. (2).

$$DF = e_c\mu \tag{2}$$

Where, the parameter which defines the food attractiveness to jellyfish is denoted as e_c which is expressed in Eq. (3) and the average location of all jellyfish is denoted as μ.

$$e_c = \beta \times rand(0,1) \tag{3}$$

Where, the distribution coefficient is denoted as β. Eq. (4) shows the jellyfish's location update for following ocean current motion.

$$X_i(t+1) = X_i(t) + rand(0,1) \times \overrightarrow{trend}$$
$$= X_i(t) + rand(0,1) \times (X^* - \beta \times rand(0,1) \times \mu) \tag{4}$$

Where, $X_i(t)$ is jellyfish's current location and $X_i(t+1)$ is location obtained after updating in search space.

3.2.2.2. Group movements

The jellyfish's group motion is categorized into passive (i.e., Class A) and active motion (i.e., Class B). The movement of Class A occurs, when the swarm of jellyfish is generated whereas the movement of Class B is carried out after the Class A movement. The class A motion is accomplished as the jellyfish traveling around their current location. In IJSO, the sinusoidal adaptive factor (S) shown in Eq. (5) is used for improving the local search capability.

$$S = 1 + \sin\frac{\pi(2T+t)}{2T} \tag{5}$$

The location update of class A motion with sinusoidal adaptive factor is expressed in Eq. (6).

$$X_i(t+1) = X_i(t) + S \times \gamma \times rand(0,1) \times (u_b - l_b) \tag{6}$$

Where lower and upper bound are denoted as l_b and u_b respectively; jellyfish's movement coefficient is denoted as γ where it is taken as 0.1. Accordingly, the range of motion is mainly based on l_b, u_b and γ.

The jellyfish accomplishes the motion of class B and approaches the discrete jellyfish with huge amount of food at its position and collects with food as its target. The location update of class B motion is expressed in Eq. (7).

$$X_i(t+1) = X_i(t) + \overrightarrow{step} \tag{7}$$

Where, i th jellyfish's step length with the direction of motion is denoted as $\overrightarrow{step}$ which is expressed in Eq. (8).

$$\overrightarrow{step} = rand(0,1) \times \vec{D} \tag{8}$$

Where, ith jellyfish's motion direction is denoted as $\vec{D}$ which is shown in Eq. (9).

$$\vec{D} = \begin{cases} X_j(t) - X_i(t) & , if\ f\big(X_i(t)\big) \geq f\left(X_j(t)\right) \\ X_i(t) - X_j(t) & , if\ f\left(X_j(t)\right) \geq f\big(X_i(t)\big) \end{cases} \tag{9}$$

Where, i th and j th jellyfish's location are represented as $X_i(t)$ and $X_j(t)$ respectively; the objective function according to the X is denoted as f.

3.2.2.3. Time control mechanism

The time control mechanism is used for performing the switching among three modes of movement of jellyfish where the time control function $c(t)$ is expressed in Eq. (10).

$$c(t) = \left|\left(1 - \frac{t}{T}\right) \times (2 \times rand(0,1) - 1)\right| \tag{10}$$

Where, the current iteration is denoted as t; maximum iterations are denoted as T and the random number is generated in the range of $[0, 1]$. If $c(t) \geq 0.5$, then the jellyfish movement is controlled in ocean currents; otherwise, the jellyfish movement is controlled by the intra-group motion of jellyfish.

3.2.3. Derivation of multiple objective functions for MOEIJSO

Multiple objectives used in this MOEIJSO for selecting the optimal CHs are residual energy (f_1), neighbor node distance (f_2), sink distance (f_3) and CH balancing factor (f_4). Eq. (11) shows the multiple objective functions used in MOEIJSO for improving the searching process during the CH discovery.

$$f = \psi_1 \times f_1 + \psi_2 \times f_2 + \psi_3 \times f_3 + \psi_4 \times f_4 \tag{11}$$

Where, $\psi_1 - \psi_4$ is the weight value assigned to each objective value. The multiple objectives are defined as follows:

- The energy usage of CH is essential in UWSN, due to the different processes such as information collection, aggregation, and distribution over the network. For an effective transmission, the node with huge remaining energy is desired as a CH and Eq. (12) shows the computation of remaining energy.

$$f_1 = \sum_{i=1}^{dim} \frac{1}{E_{CH_i}} \tag{12}$$

Where, E_{CH_i} denotes the remaining energy of the ith CH

- The distance between the sensors shown in Eq. (13) is the neighbor node distance and the distance between the CH and BS shown in Eq. (14) is the sink distance. The energy depletion of the sensor is proportional to the distance among the sensors. Therefore, the CH with a lesser broadcast distance is preferred as CH.

$$f_2 = \sum_{j=1}^{dim} \left(\sum_{i=1}^{CM_j} dis(N_i, CH_j) / CM_j \right) \tag{13}$$

$$f_3 = \sum_{i=1}^{dim} dis(CH_i, BS) \tag{14}$$

Where, the number of cluster members for jth cluster is denoted as CM_j; distance from node i to CH j is denoted as $dis(N_i, CH_j)$ and distance from the CH i to receiver BS is denoted as $dis(CH_i, BS)$.

- In UWSN, there is a possibility that some big clusters are formed along with the small clusters. Therefore, the CH balancing factor shown in Eq. (15) is used for balancing the clusters which result in improved energy balancing over the UWSN.

$$f_4 = \sum_{i=1}^{dim} \frac{AN}{dim} - CM_j \tag{15}$$

Where the amount of alive nodes is denoted as AN.

The above-mentioned objective values are utilized for selecting adequate CHs from normal sensors. The remaining energy of the sensors is used to compute the possibility of a failure node during the data broadcasting because the failure node needs to be avoided for increasing the data delivery. On the other hand, the distance factors and CH balancing factor is used for improving the energy efficiency of the UWSN.

3.3 Cluster formation

After selecting the CHs using MOEIJSO, the cluster members are assigned to their respective CHs. The distance and residual energy are considered in a potential function shown in Eq. (16) for creating the clusters.

$$Potential\ function\ (N_i) = \frac{E_{CH}}{dis(N_i, CH)} \tag{16}$$

3.4 Route discovery using ACO

The route among the transmitter CH and receiver BS is discovered by ACO, once the clustering is done in the network. The initial weight value of each path is calculated according to the distance between the nodes. The node transition rule is the possibility of selecting m as relay CH for the lth CH computed by ant n is expressed in Eq. (17).

$$P_{lm}^{n} = \begin{cases} \frac{[\tau_{lm}(t)]^{\alpha}[\eta_{lm}(t)]^{\beta}}{\sum_{o \epsilon \mathcal{N}_n}[\tau_{lo}(t)]^{\alpha}[\eta_{lo}(t)]^{\beta}} & if\ m \epsilon \mathcal{N}_n \\ 0 & otherwise \end{cases} \tag{17}$$

Where, P_{lm}^{n} denotes the probability of node selection; τ_{lm} and η_{lm} denotes the pheromone intensity and heuristic value respectively; α and β are used to control the relative importance of τ_{lm} and η_{lm}, and the set of CHs n that doesn't visit the ant is denoted as $\mathcal{N}_n$.

The real ant's foraging process is replicated by artificial ants. The rule of node transition is used to select the next relay CH when the transmitter CH is required for transmitting the data. The path is retraced to the transmitter CH, when the relay CH i.e., ant reached the BS. Accordingly, the pheromone value of the path is updated according to the pheromone update rule expressed in Eq. (18) which includes pheromone evaporation and reinforcement. The pheromone evaporation and reinforcement minimize or maximize the path's pheromone respectively.

$$\tau_{lm}^{new} = (1-\rho)\tau_{lm}^{old} + \sum_{n=1}^{A} \Delta\tau_{lm}^{n} \quad (18)$$

Where, the amount of ants in ACO is denoted as A and the pheromone decay coefficient is ρ. Eq. (19) shows the computation of pheromone quantity.

$$\Delta\tau_{lm}^{n} = \begin{cases} \frac{Q}{a_n} & if\ the\ ant\ n\ travelled\ route\ (l,m) \\ 0 & otherwise \end{cases} \quad (19)$$

Where, the constant value is denoted as Q and the objective function of the route is a_n that is shown in Eq. (20). The objective function of ACO uses the residual energy and sink distance

$$a_n = \varepsilon_1 \times \sum_{i=1}^{dim} \frac{1}{E_{CH_i}} + \varepsilon_2 \times \sum_{i=1}^{dim} dis(CH_i, BS) \quad (20)$$

Where, ε_1 and ε_2 are the weight parameters assigned to objective values considered in route discovery. The failure node is avoided by considering the remaining energy whereas the distance is considered for minimizing the energy by generating the route with less transmission distance.

4. Results and discussion

The outcomes of the MOEIJSO-ACO are detailed in this section. The implementation and simulation of the MOEIJSO-ACO are developed in MATLAB R2020b where the system uses the i5 processor and 6GB of RAM. The underwater scenario is designed with 50 sensors deployed in the area of $100 \times 100 \times 50m^3$. The base station for this UWSN scenario is located in the coordinates of $50, 50, and\ 50$ whereas the sensors are equipped with 5J of energy. Table 1 shows the simulation parameters considered for this MOEIJSO-ACO method.

4.1 Performance analysis

The MOEIJSO-ACO method is analyzed by using alive and dead nodes, total energy consumption, data received in BS and life expectancy. Classical approaches such as Low Energy Adaptive Clustering Hierarchy (LEACH) and Distributed Energy Efficient Clustering (DEEC) are used to evaluate the MOEIJSO-ACO method.

Table 1. Simulation parameters

Parameter	Value
Number of sensors	50
Location of BS	$50, 50, 50$
Network size	$100 \times 100 \times 50m^3$
The initial energy of sensors	5J
Size of packet	4000s

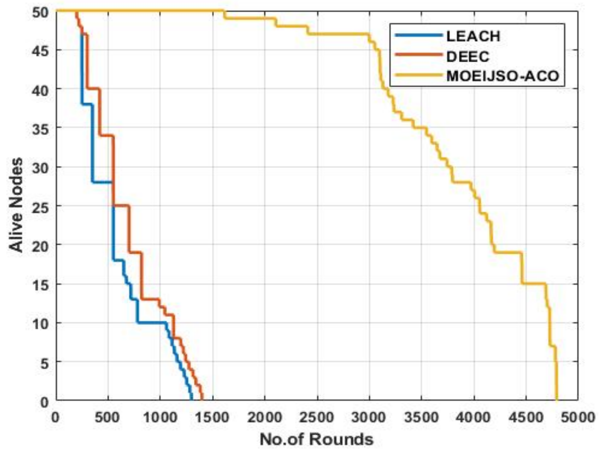

Figure. 2 Alive nodes vs rounds

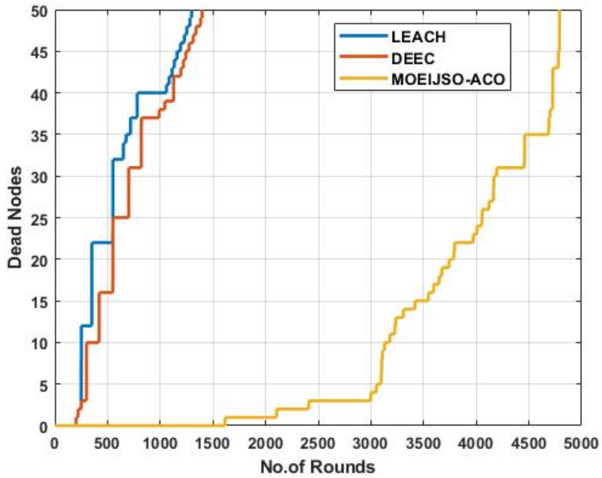

Figure. 3 Dead nodes vs rounds

4.1.1. Alive & dead nodes

The amount of nodes with sufficient energy to perform the communication is alive nodes whereas dead nodes don't have sufficient energy to accomplish the data transfer over the network. The alive nodes and dead node comparison for MOEIJSO-ACO with LEACH and DEEC are shown in Fig. 2 and Fig. 3 respectively. The alive nodes of MOEIJSO-ACO are increased than the LEACH and DEEC by minimizing the energy usage of the nodes. The energy usage of nodes for MOEIJSO-ACO is reduced based on effective balancing between clusters and shortest path discovery.

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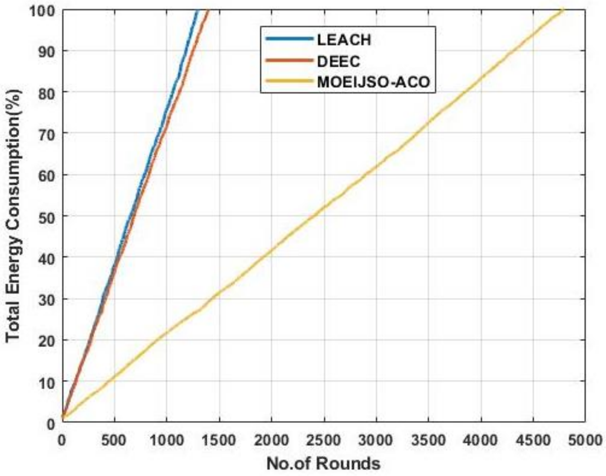

Figure. 4 Total energy consumption vs rounds

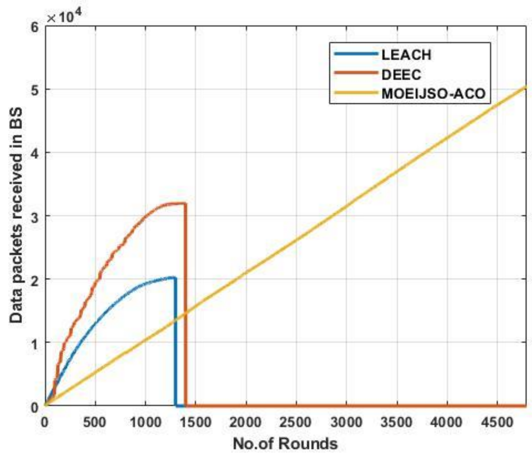

Figure. 5 Data packets received in BS vs rounds

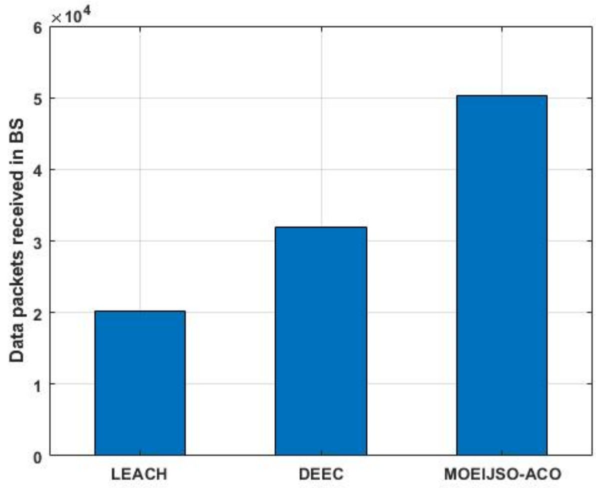

Figure. 6 Maximum data packets received in BS

4.1.2. Total energy consumption

The energy depleted while transmitting and receiving the data is total energy consumption. Fig. 4 displays the energy expenditure analysis for MOEIJSO-ACO with LEACH and DEEC. This

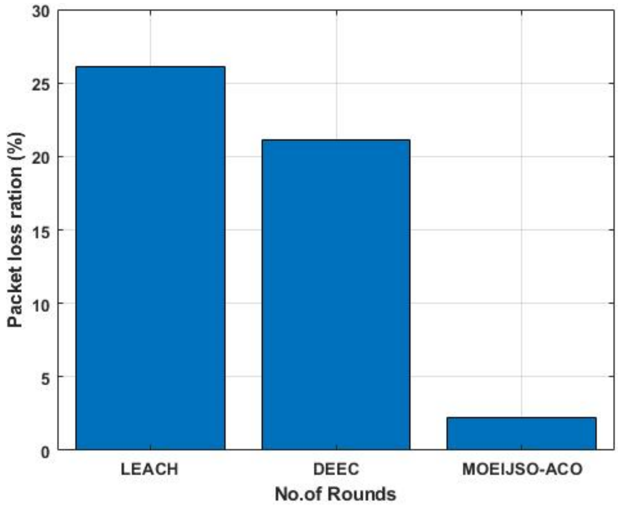

Figure. 7 Packet loss ratio

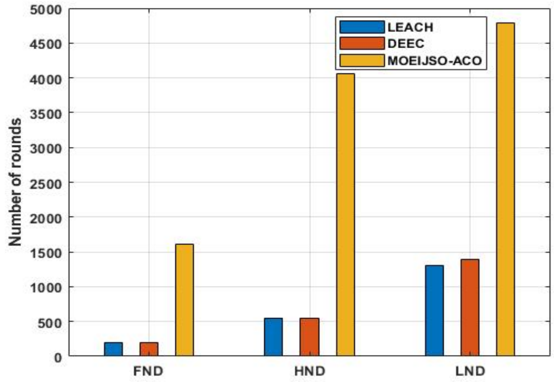

Figure. 8 Life expectancy

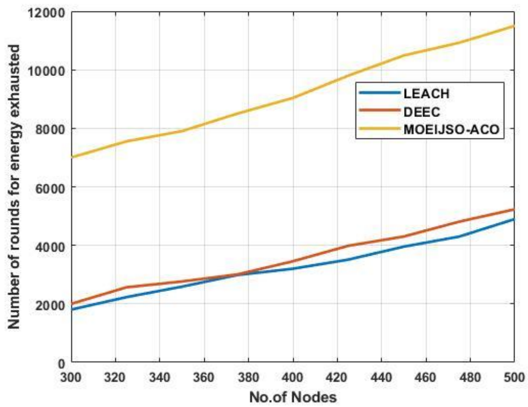

Figure. 9 Number of rounds for energy exhausted vs nodes

analysis shows that the MOEIJSO-ACO achieves lesser energy consumption than the LEACH and DEEC. An optimal CH selection using MOEIJSO along with the multi hop routing developed by ACO is used to reduce energy usage. The ACO-based shortest route discovery is also used to minimize the node's energy usage.

4.1.3. Data packets received in BS and PLR

The amount of data packets collected by the BS and its maximum value are illustrated in Figs. 5 and 6 where the MOEIJSO-ACO was compared with LEACH and DEEC. Further, the graph for PLR is shown in Fig. 7. This analysis shows that the MOEIJSO-ACO has high data delivery than the LEACH and DEEC. The mitigation of failure nodes in MOEIJSO based CH selection and reducing the energy consumption of nodes through ACO based multi hop data broadcasting helps to increase the amount of data packets gathered in BS.

4.1.4. Life expectancy

Life expectancy represents the time at which the nodes active during the transmission. There are three different parameters such as first node die (FND), half node die (HND) and last node die (LND) are used while analyzing the life expectancy.

The life expectancy comparison for MOEIJSO-ACO with LEACH and DEEC are displayed in Fig. 8. Further, the number of rounds for energy exhausted is shown in Fig. 9 in terms of nodes. This analysis depicts that the MOEIJSO-ACO has a better lifetime than the LEACH and DEEC.

4.2 Comparative analysis

The existing research of MCR-UWSN [19], MLEACH [20] and CEER [21] are used for evaluating the MOEIJSO-ACO method. Here, the comparison is made for 400 nodes, 50 nodes and 225 nodes variations. The MCR-UWSN [19] is taken for 400 nodes comparison, MLEACH [20] is taken for 50 nodes comparison and CEER [21] is taken for 225 nodes comparison. Tables 2, 3 and 4 show the comparison of MOEIJSO-ACO with MCR-UWSN [19], MLEACH [20] and CEER [21] respectively. The life expectancy comparison of MOEIJSO-ACO is shown in Table 5. The graph for life expectancy comparison of MOEIJSO-ACO with CEER [21] is shown in Fig. 10. This comparison shows the MOEIJSO-ACO has improved performance than the MCR-UWSN [19], MLEACH [20] and CEER [21]. The usage of energy is minimized in MOEIJSO-ACO based on balancing between clusters and shortest path discovery. The multi hop routing developed by ACO is used to achieve the reliable data transmission while reducing the energy. Thus, the life expectancy of the MOEIJSO-ACO is improved than the MCR-UWSN [19], MLEACH [20] and CEER [21].

Table 2. Comparison of MOEIJSO-ACO with MCR-UWSN

Performances	Methods	Number of rounds				
		200	400	600	800	1200
Alive nodes	MCR -UWSN [19]	400	400	400	400	0
	MOEIJSO-ACO	400	399	399	399	394
Dead nodes	MCR -UWSN [19]	0	0	0	0	400
	MOEIJSO-ACO	0	1	1	1	6
Total Energy Consumption (%)	MCR-UWSN [19]	3	12	22	42	100
	MOEIJSO-ACO	2.12	4.2	7.15	9.53	11.54

Table 3. Comparison of MOEIJSO-ACO with MLEACH

Performances	Methods	Number of rounds				
		500	1000	1500	2000	2500
Alive nodes	MLEACH [20]	29	9	3	1	0
	MOEIJSO-ACO	50	50	50	49	47
Dead nodes	MLEACH [20]	21	41	47	49	50
	MOEIJSO-ACO	0	0	0	1	3
Total Energy Consumption (%)	MLEACH [20]	42	81	96	99	100
	MOEIJSO-ACO	11.63	22.38	33.39	44.01	52.49

Table 4. Comparison of MOEIJSO-ACO with CEER

Performances	Methods	Number of rounds				
		2000	4000	6000	8000	10000
Alive nodes	CEER [21]	223	204	182	145	134
	MOEIJSO-ACO	225	225	225	188	153
Dead nodes	CEER [21]	2	21	43	80	91
	MOEIJSO-ACO	0	0	0	37	72
Total Energy Consumption (%)	CEER [21]	23	38	49	63	71
	MOEIJSO-ACO	17.33	29.07	36.12	58.19	65.14

Table 5. Life expectancy comparison of MOEIJSO-ACO

Life expectancy	400 nodes		50 nodes		225 nodes	
	MCR-UWSN [19]	MOEIJSO-ACO	MLEACH [20]	MOEIJSO-ACO	CEER [21]	MOEIJSO-ACO
FND	852	182	110	1890	1700	6100
HND	1121	4185	600	4027	10200	11054
LND	1187	9089	1500	4851	12310	13008

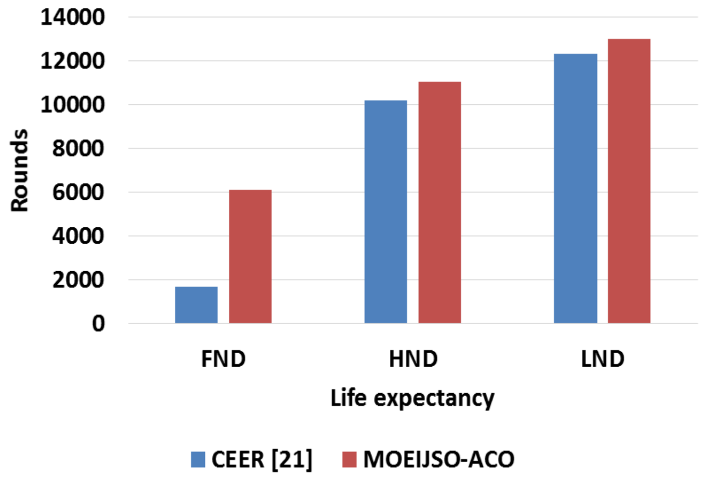

Figure. 10 Life expectancy comparison of MOEIJSO-ACO with CEER

5. Conclusion

In this research, energy-efficient CH and route discovery are performed for improving the energy efficiency of UWSN. The MOEIJSO is used for selecting the optimal CHs from the normal sensors by optimizing it with residual energy, neighbor node distance, sink distance and CH balancing factor. Next, ACO-based routing is developed for discovering the optimal route from the transmitter CH to BS. The sensor's energy usage is decreased by balancing the clusters and identifying the route with a lesser transmission distance. The reduction in energy usage is used to increase the UWSN life expectancy. On the other hand, data delivery is enhanced by improving energy efficiency and avoiding node failure. The MOEIJSO-ACO achieved better performances than the MCR-UWSN, MLEACH and CEER. The alive nodes of the MOEIJSO-ACO are 399 for 800 rounds, which is high when compared to the MCR-UWSN. In the future, modern optimization can be used to enhance UWSN performances.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

For this research work all authors' have equally contributed in Conceptualization, methodology, validation, resources, writing—original draft preparation, writing—review and editing.

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