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Original scientific paper

An Efficient Scyphozoa Swarm Optimization and Fuzzy Density Based Clustering Routing for Underwater Wireless Sensor Networks

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Abstract: Underwater Wireless Sensor Networks (UWSNs) are placed in waterways including oceans, seas, rivers to keep an eye on military actions, carry out rescue missions, and mine for resources. Security is essential in UWSN system because the UWSN environment is vulnerable to several security threats. It is also susceptible to malicious assaults and threats. Earlier cluster-based routing protocol was working better but Heavy transmission use of energy puts nodes' lifespans in danger. Thus, it became crucial to provide solutions for network-based issues like level of service, protection, network variability, congestion prevention, efficient routing, and energy efficiency. The design of Scyphozoa Swarm Optimization (SSO) and Fuzzy Density Based Clustering (FDC) secure energy efficient data aggregation Routing protocols (SEDARP) is the solution to extending the lifespan of the network and named as SSOFDCSEDARP RP. This work describes routing protocol for UWSNs using multi-agent reinforcement learning. The two primary stages of the suggested hybrid routing technique are intra/extra cluster routing and cluster creation. A cluster head selection technique utilizing SSA is suggested, which allows nodes to independently determine that they can operate as cluster heads cantered on routing and environment data, hence reducing the likelihood of hotspot production without requiring extra network overhead. The suggested adaptive clustering routing protocol exceeds current methods according to routing efficacy, power usage, and network longevity, according to simulation findings.

Keywords: cluster-based routing protocol; data aggregationp; fuzzy density based clustering; scyphozoa swarm optimization; underwater wireless sensor network

1 INTRODUCTION

Acoustic communication is the process of delivering and receiving messages in an aquatic setting by using sound transmission. For instance, to carry out cooperative monitoring and data gathering activities, UWSNs deployed a large number of vehicles and sensors in certain regions [1]. Oceanographic sensors are utilized to monitor the sea level. They are placed in a fixed spot, where data is recorded, and the devices are recovered once the operation is finished. The primary drawbacks of the old technique are the absence of interactive contact among the various ends, the inability to access recorded data during a mission [2], and the destruction of stored data in the event of an error. Numerous applications are supported by UWSNs [3], such as commercial exploitation of the marine ecosystem [4], oceanographic data gathering, river and sea pollution detection and tracking, and aquatic surveillance. Underwater warfare and environmental condition monitoring are just two applications for UWSNs [5].

UWSN technologies are replacing classic marine monitoring devices. Large sensor nodes with the capacity to store data were previously physically positioned in the target area beneath the sea. Each node operates independently for the duration of the operation with the intent to gather data in compliance with a preset programme [6]. After the procedure is over, SNs are collected, and the data collected is retrieved and analyzed. The sea sensor nodes deliver real-time data relaying skills to an offshore or on-shore management facility for instant examination. Through an interface, control signals can be sent from the control station to the underwater sensor network deployment, enabling interactive control of the system. When compared to traditional monitoring techniques, UWSNs offer substantial advantages [7].

Limitations on UWSNs include minimal power, significant propagation delay, and restricted bandwidth. Not every oceanic site can be reached by radio or optical waves for communications reasons. The sole method that UWSNs are allowed to use under these restrictions is the acoustic signal, which nature has been using since the beginning of the deep sea [8]. The sound speed is assumed to be constant in an aquatic atmosphere. Nonetheless, the temperature, salinity levels, and depth of the undersea ecosystem all affect sound speed. The speed of sound varies in an undersea atmosphere due to several reasons. Many aquatic users shared a large portion of the aquatic audio channel frequencies spectrum, particularly on mid-frequencies.

2 RELATED WORK

A brand-new routing technique dubbed FFRP for the internet of UWSN apps, influenced by dynamical firefly mating optimization. A self-reliance oriented firefly mating optimization knowledge is utilized by the suggested FFRP system throughout the events collecting data to determine the extremely reliable and stable routing paths to route packets across connecting voids and shadow sectors in UWSNs. The suggested approach balances the data traffic load uniformly in a large-scale network, hence minimizing unused energy and delay difficulties while data transfer. Nevertheless, the elevated power use of the suggested approach stems from significant control communication expenses in the network [9-11].

E-PULRP for dense 3D UWSN. Utilizing on-the-fly navigation, the E-PULRP sensor nodes communicate data to a static sink node. There are two phases to E-PULRP: layering and interaction. During the layering stage, a layering architecture is shown which nodes surround a sink node by occupying various strata that resemble concentric shells. The likelihood of an effective data transfer and the need to minimize the total energy consumption during packet transmit are taken into account when determining the layer widths and transmit energy in every layer [11-14]. In the interaction stage, they provide a structure to analyze the energy optimization accomplished by E-PULRP and suggest a mechanism to dynamically pick successive relay nodes for packet delivery from the source node to the sink node. Yet in an extremely dense and sparse UWSN, they encounter certain typical issues like cluster heads scheduling, network strength, damaged data packets, and expensive routing table expenses.

A biobjective routing protocol for UWSNs. It is discovered that the depth and vector based routing protocols experience high latency transfer problems because they are unable to resolve these competing goals. To find pareto-optimal routes, a biobjective optimization of route duration and dependability is suggested. This method utilizes the use of a revised greedy optimum first search heuristic and an uninformed search approach. It is discovered from simulations that the biobjective protocol outperforms reliability-, and delay-based routing protocols. Appropriate for bigger networks, the altered greedy optimum first search heuristic yields sub-optimal routes with fewer computations without sacrificing the standard of the solutions [15-17]. Yet, while locating or fixing damaged links, the majority of them deal with poor link quality problems and controlling message expenses, which increases node energy use and delay.

MCBOR approach utilizing butterflies to carry data packets to their target without any loss. The study suggested seeks to lower transmission loss and raise PDR. By contrasting the suggested MCBOR's efficiency with that of cutting-edge techniques, its effectiveness is assessed [18]. The suggested MCBOR yields a packet delivery ratio of 0.98%, a final delay of 6.3 s, and residual energy of 0.47 J, according to the assessment results. It has been demonstrated that MCBOR is effective in PDR and lowers transmission loss. Higher data rates and network capacity are observed with enhanced efficiency of the suggested method; yet, this comes at the cost of higher control message expenses. An energy saving opportunistic routing employs the EPO-Q for UWSN. It is composed of base stations, sink nodes, sensor nodes, and multiple acoustic channels. For surveillance reasons, source nodes are positioned at various oceanic depths. Acoustic channels are utilized to transfer data among a source and a sink node, but they have problems with high packet error rates and low network throughput (NT).

3 THE PROPOSED METHOD

For data transfer among diverse items, routing protocols play a critical role in resolving previous problems. To lessen commuting overhead, use of energy, and network lifespan, data consolidation techniques are crucial in gathering and combining data. It is difficult to establish delay-aware, dependable, and sustainable route planning in data aggregation settings for UWSN applications. By merging SSO and FDC, the research suggests a Cluster-based Energy-efficient Data Aggregation Routing protocol in the UWSN to address these issues. The two primary stages of the suggested hybrid routing method are intra/extra cluster routing and cluster formation. The suggested approach utilizes neighbour energy, power level, collision reduction, and the distance among the cluster head node and target as clustering parameters. Additionally, by optimizing and balancing the number of clusters as seen in Fig. 1, it intends to contend the hot spot problem and imbalanced energy use.

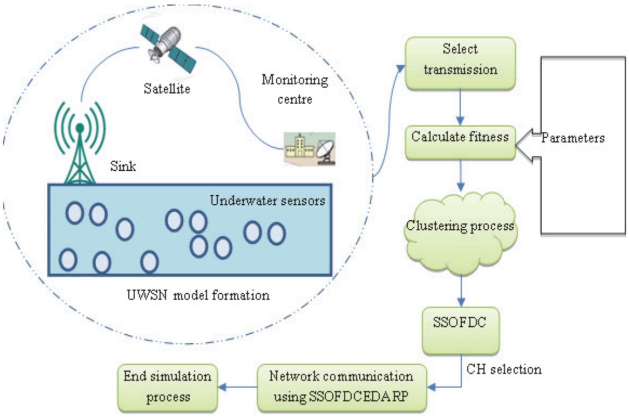

Figure 1 Block diagram of proposed system

3.1 UWSN Model

The undersea network is composed of the Cluster Head (CH) and Surface Gateways (SG). Stationary nodes attached to buoys at the surface are called SGs. Their connections are acoustic and electromagnetic, accordingly. SGs connect the undersea system to the Internet via an electromagnetic connection. To send and receive packets to the submarine system, SG utilizes an acoustic connection. Every SG may have a connection to one or more CHs. The network structure of UWSNs is depicted in Fig. 2, whereas the source node (SN), the relay nodes (RN_1 and RN_b), the destination/sink node (DN), and the attacker nodes (AN_1 and AN_b) are all deployed in UWSNs. Out of all the relay nodes that are accessible, including RN_1 and RN_b, RN_b has been determined to be the finest. The direct communication route is shown by the dark line in Fig. 2, while the cooperative routes are represented by dotted lines. The cooperative routes are utilized in situations where the direct path is impractical or inaccessible. The relay node will be examined to determine if it is an attacker node or not; if so, it will not be chosen to transmit data. The network's sensor nodes are uniform in nature and use multiple communication radius to transmit the necessary data. The sink node, also known as the BS, is often located on the sea's level. When the number of dead nodes in the network surpasses a certain limit, the system is deemed to be deceased.

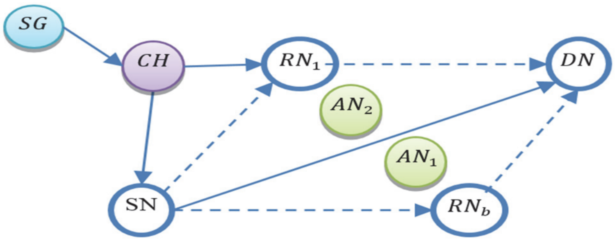

Figure 2 Network model of UWSN with one cluster

3.2 Trust Model

One potential security solution for UWSNs is trust administration, as nodes must trust one another in order to complete tasks and missions with collaboration and coordination. Durability and efficiency metrics are part of the Quality of Service (QoS), which is utilized to determine credibility. Node energy and packet delivery ratio indicate a node's dependability, but network lifespan and overall latency indicate efficiency. Thus, the primary characteristics used to determine a UWSN node's trust value are T = {packet delivery ratio, signal strength, end-to-end delay, nodes energy, and total packets loss}. The Trust constraint is employed to evaluate the functionality of the link and determine whether data routing is reliable. If not, a route management technique is implemented for reliable data routing.

3.3 Energy consumption model description

To transmit a data packet with size k in the distance of D, energy consumption E for the transmitter Tr is considered by Eq. (1).

$$E_{Tr}\left(k, D\right) = \begin{cases} k \cdot E_{tc} + k \cdot \in_F \ D^2 D < D_0 k \cdot \\ \cdot E_{tc} + k \cdot \in_A \ D^2 D \geq D_0 \end{cases} \tag{1}$$

In Eq. (1), E_{tc} is the amount of energy utilized by the transmission circuit tc to send a single data bit. The value set for power amplifiers is pertinent to the chosen energy consumption strategy. Additionally, A denotes multipath attenuation transmission and F denotes free space communication. The boundary condition utilized in Eq. (2) to distinguish between the two frameworks is D_0. Eq. (3) calculates the energy usage of the receiver when receiving k bit data. According to the network approach, cluster head nodes that received Rr combined the data from all of their cluster members within a single fxed-length packet. As a result, it utilizes the energy required by the method of aggregation E_{AG}, as determined by Eq. (4).

$$D_0 = \sqrt{\frac{\in_F}{\in_A}} \tag{2}$$

$$E_{Rr}\left(k, D\right) = k \cdot E_{tc} \tag{3}$$

$$E_{AG} = k \cdot E_{dg} \cdot n \tag{4}$$

In Eq. (4), k specifies the number of the data packet bits, E_{dg} is the energy required for data aggregation, and n is the quantity of nodes having part in the aggregate procedure.

3.4 End-to-end Delay Model Description

The "end-to-end delay" states the quantity of time which a packet needs to move from an initial node to the final node over it. The average end-to-end delay ($AEED$) is considered utilizing Eq. (5).

$$AEED\left(s\right) = \sum\nolimits_{i=1}^{tp} \sum\nolimits_{k=1}^{tn} \left(\frac{D\left(Tr_k^i\right) - D\left(P_k^i\right)}{T_k^i} \right) \cdot \frac{1}{tp + tn} \tag{5}$$

where $D\left(P_k^i\right)$ and $D\left(Tr_k^i\right)$ signify the propagation and transmission delays, individually, for each k-th packet and i-th node. T_k^i denotes the total quantity of packets sent across a network. tn and tp specify the number of transmitted nodes and packets, individually. The amount of time needed to send every packet bit across the transmission channel is known as the transmit delay. The largest determinants of it are data size and network bandwidth. L/R, where R is the transmission rate and L is the packet length, yields the transmission delay Tr. The amount of time needed for a bit to move from one end of the network to the other is known as the propagation delay. Electronic signals are used to transmit the bits. The propagation speed of electromagnetic signals is dependent on the medium they travel through. D/S, where D is the distance among the sender and the recipient and S is the transmission speed across the connection, is the formula for calculating the propagation P delay.

3.5 Network Lifetime Model Description

The network lifetime NL signifies the amount of time that passes from a simulation's beginning and the appearance of a node that has run out of energy. The network lifespan in the suggested routing protocol is computed utilizing Eq. (6).

$$NL = \sum\nolimits_{i=1}^{n} \frac{E_i}{E_{Tr}\left(k, D\right) + E_{Rr}\left(k, D\right) E_{AG}} \tag{6}$$

where E_i denotes the nodes initial energy, E_{Tr} is transmitter's energy consumption. E_{Rr} is receiver's energy consumption quantity, and E_{AG} denotes the energy needed to aggregate data.

3.6 Packet Delivery Ratio Model Description

The percentage of effectively getting packets to their targets relative to all packets transmitted is known as the packet delivery ratio. The average packet delivery ratio, or $APDR$, in the suggested routing protocol is determined using Eq. (7),.

$$APDR = \sum\nolimits_{j=1}^{tp} \frac{S_j}{T_j} \cdot \frac{1}{tp + tn} \tag{7}$$

where S_j and T_j are the total amount of packets distributed and the number of packets received effectively by the target j-th node, correspondingly.

3.7 Fitness Function Calculation

The suggested routing protocol incorporates the fitness function into consideration to improve node energy use, packet delivery ratio, end-to-end latency, and network longevity. The fitness function is defined as F in Eq. (8).

$$F = \varepsilon \cdot T + \kappa \cdot E + \lambda \cdot AEED + \mu \cdot NL + \nu \cdot APDR \tag{8}$$

where E is energy utilized to transmit and receive data packets among cluster heads and base stations as well as among node sources and cluster heads, amongst cluster heads and source nodes, and amongst base station and cluster heads, known as the $AEED$. NL is the network lifetime, and $APDR$ amongst base station and cluster heads as well as amongst source nodes and cluster heads is calculated. Similarly, ε, κ, λ, μ and v are the variables in [0, 1] interval and utilized to standardize the estimated outcomes for T, E, $AEED$, NL and $APDR$.

Here, the hybrid technique of integrated Scyphozoa Swarm Optimization (SSO) and Fuzzy Density Based Clustering (FDC) the UWSN's network clusters to create an effective data aggregation tree and optimal routing, as illustrated in Fig. 3. The two primary stages of the suggested routing protocol are intra/extra cluster routing and cluster creation.

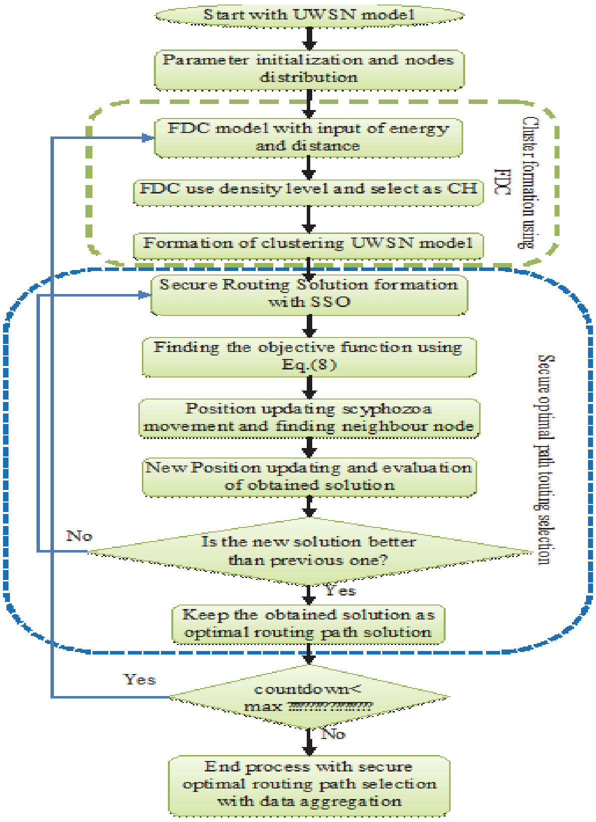

Figure 3 Flowchart of the proposed SSOFDCSEDARP based routing method

In the initial stage, different clusters of sensor nodes are assembled utilizing FDC. Employing SSO to identify appropriate pathways between cluster members and heads as well as amongst base station and cluster heads are two of the two sub-steps that comprise the second stage. The number of nodes in the system is equivalent to the number of scyphozoas. The IDs of the nodes that discovered route to each scyphozoa's destination are stored in an array. The route between cluster heads and source nodes, as well as between base station and cluster heads, is determined using the scyphozo for creating a solution.

3.8 Cluster Head Selection and Cluster Formation using FDC

The two input factors taken into consideration by this algorithm are the nodes' proximity to the base station and their remaining energy. Nodes E's residual energy: Since a node with more residual energy may cover more nodes, it has a higher probability of becoming the cluster head. The proximity of nodes to the base station D: A node will need more energy to send a packet to the base station as its distance from it grows. Consequently, the probability of a node obtaining the cluster head is decreased with a greater distance among it and the base station. In clustering techniques, CL's job is to rotate based on certain decision variables thus helping to prevent hot spot problems, node death, etc. The goal of this research is to create an opportunistic density-based FDC scheme that will extend the network's life span. The initial CL is selected at the beginning of the routing protocol, which is run at the base station. The sensor nodes are organized utilizing the FDC method into an OCH number of static clusters. Additionally, it divides the network's operations into several rounds. There are two stages to every round: the setup and communication stage. A novel CL is selected during setup, and throughout interaction, data is gathered and sent to the base station. The network activity then proceeds through numerous iterations of data transmission. Based on Su and Zhao, the ideal number of cluster heads OCH is computed [12]:

$$OCH=\sqrt{\frac{2nE_{Tr}\cdot cr^{2}}{nE_{AG}-4E_{Rr}}}\cdot D \tag{9}$$

3.9 Cluster Formation

All of the sensor network's nodes must send a probe message throughout every step of the data collecting procedure once the base station transmits the transmitted message. The probe message includes the ID of the node, its work and sleep times, its SW that is, when it switches from sleep to work state and versa and the IDs of any nearby nodes that are accessible. The FDC method is employed by the base station to organize the nodes into the OCH number of clusters after learning about their positions from the probe message. Each node is a member of a cluster, and membership values range from 0 to 1. The membership value is determined by the separation among the data point and the cluster centroid. The membership value is lower if the data point is located closest to the cluster centroid and its opposite. By identifying the node density parameter (d), this FDC utilizes density level to determine the first centroid. The optimal probability p of a node becoming a cluster head is chosen based on new distance measure nD given as in Eq. (10)

$$nD(i)=\sum\nolimits_{k=1}^{n}exp\left[\left|x_{i}-x_{j}\right|^{2}\right]\cdot\left[\frac{1}{d}\right]^{2}\cdot\left[\frac{1}{p}\right]^{2} \tag{10}$$

$$p=\frac{OCH}{n_{w}}\text{ and }d=\frac{n}{T} \tag{11}$$

where n_w is the number of nodes in working mode and T is the throughput of the node. Initially, many aquatic sensor nodes are dispersed at random within a designated region. Owing to the heterogeneity of the network, nodes are arranged into two categories: normal and special nodes. Compared to ordinary nodes, the special s nodes have $1 + s$ greater energy. According to the FDC framework, every node determines its probability to receive a cluster head at every round. When the computed chance value is smaller than the threshold value, the normal or special sensor nodes are selected as the cluster heads. Considering the separation between them, the selected cluster leaders invite other nodes to join groups. The number of nodes that have the capacity to lead a cluster may rise in this manner. The quantity of cluster heads is prevented from rising above a predetermined amount by defining a threshold value, which solves the issue. The threshold *Th* value is considered utilizing Eq. (12).

$$Th = n(1-s)\cdot S_r + ns\cdot S_s \tag{12}$$

$$S_r = \frac{S_{ACH}}{1+ns} \tag{13}$$

$$S_{ACH} = \frac{S_{ACH}}{1+ns}\cdot(1+t) \tag{14}$$

where *s* denotes the special nodes, S_r is the option to choose regular nodes, S_s is the option to choose special nodes, S_{ACH} is cluster heads on average per round, where *t* is the time. Eq. (13) and Eq. (14) are used to determine the likelihood of choosing the regular and special nodes, accordingly. Algorithm 1 displays the pseudocode for the suggested approach to cluster head selection and cluster formation.

4 EXPERIMENTAL RESULTS AND DISCUSSION

Signals transmit vertically in oceanic surroundings, meaning that as the distance grows, the signal is transferred spherically and attenuation improves. While there are 225 sensor nodes established, there are only 10 sink nodes planted at the water's surface. Although empirical verification is an essential part of the study on SSOFDCSEDARP of UWSNs, simulation studies have evolved into a crucial tool for confirming the SAFCDARP efficiency of UWSNs due to the expensive nature of underwater testing. NS2 is currently included in popular line sensor network modeling software. The Origin software calculates and displays the simulation's findings as well as the outcomes of other equations. The following model is employed to test and validate the suggested protocol's efficiency. A Poisson distribution method is employed to arbitrarily produce data packets via 16 at random nodes. Tab. 1 displays the specifications of the channel.

Table 1 Channel parameter settings and values

Parameter	Value
Number of sensor node deployed	225
Number of sinks	10
Type of attack	DoS
Rounds traced	5000
Depth	100 m
Frequency	10 kHz
AI	5 dB
delay	0.65 s
Packet transmission rate	10 kbps
Slave node	16
Host	1
Topological area	500 m × 500 m
Transmission between nodes	30 - 60 m

Performance Evaluation Parameters: The efficacy of the SSOFDCSEDARP, SAFCDARP, SEECR, LBTSA, and ChOA-HGS protocols is assessed utilizing the subsequent variables in both attack- and non-attack-related situations.

1) Number of Alive Nodes: To determine the amount of nodes that are still surviving throughout the simulation, deduct the amount of nodes that have died from the overall amount of nodes.

2) Transmission Loss: It is the loss in transmission that occurs in a single round among the source and sink nodes. Decibels (dB) are employed to determine the transmission loss.

3) Throughput: All packets that make it to the sink node are included in this total.

4) Energy Consumption: When data is forwarded from the source node to the sink node, energy is used in the process. The calculation utilizes joules.

5) End-to-End Delay: It is the interval of time among the creation of a packet and its arrival at the sink. Milliseconds are employed in the calculation.

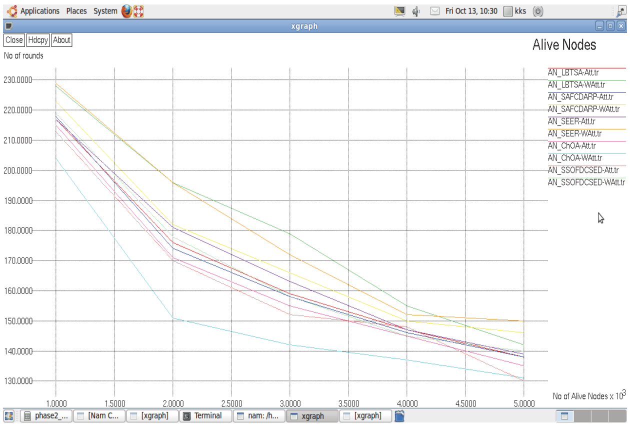

Figure 4 Number of alive nodes for different protocols with and without attack

The total number of active sensor nodes over the modeling process is displayed in Fig. 4. Together with the relay and source nodes, the total amount of sensor nodes deployed at first is 225. At the conclusion of the modeling, there are 132 and 139 live nodes in SEECR with and without an attack, and 132 and 138 live nodes in LBTSA with and without an attack. In SSOFDCSEDARP, there are 116 live nodes when there is an assault and 129 when there is not. The findings collected indicate that the attack has a considerable impact on energy use, which in turn causes a large decrease in the amount of viable nodes in SAFCDARP, SEECR, LBTSA, and ChOA-HGS with attack case.

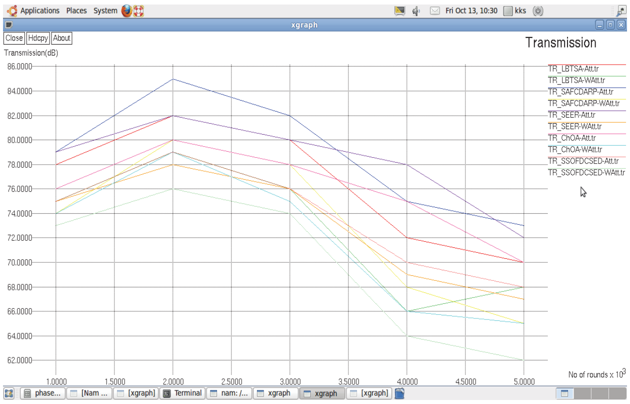

Figure 5 Transmission loss for different protocols with and without attack

The transmission loss of the SSOFDCSEDARP, SAFCDARP, SEECR, LBTSA, and ChOA-HGS protocols is displayed in Fig. 5 under various conditions, including attack and non-attack. As contrasted with SAFCDARP, SEECR, LBTSA, and ChOA-HGS, both with and without assault, the transmission loss of SSOFDCSEDARP is much lower, according to the findings presented. The SSOFDCSEDARP protocol's highly efficient technique greatly decreased transmission loss, outperforming SAFCDARP, SEECR, LBTSA, and ChOA-HGS routing protocols with transmission loss values of 60 and 59 for attack and non-attack, respectively. The CH is chosen from amongst the cluster heads via FDC to serve as the representative for sending a message to a base station, thus extending the network's lifespan. In addition, SSOFDCSEDARP integrates energy and distance to guarantee consistent energy consumption across the network. This characteristic results in superior energy usage stability and a longer lifespan as opposed to earlier techniques.

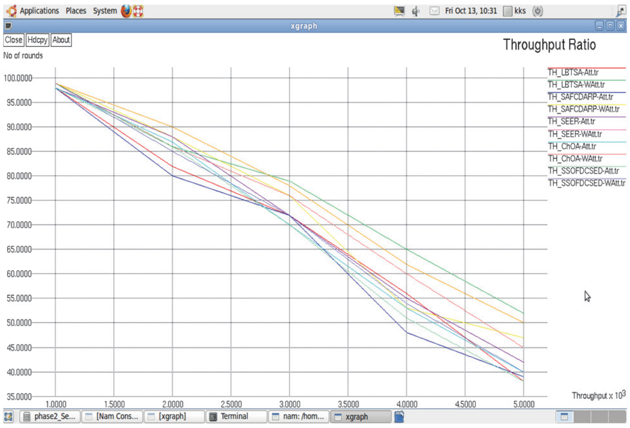

Figure 6 Throughput for different protocols with and without attack

The throughput of the SSOFDCSEDARP, SAFCDARP, SEECR, LBTSA, and ChOA-HGS protocols is displayed in Fig. 6 under various conditions, including attack and non-attack. The findings acquired demonstrate that the SSOFDCSEDARP protocol has a higher throughput as opposed to other protocols in both the scenarios of with and without assault, with values of 28 and 23, respectively. Because SSOFDCSEDARP uses a reliable and secure technique that utilizes trust and aggregation time, it has a higher throughput than the other two protocols.

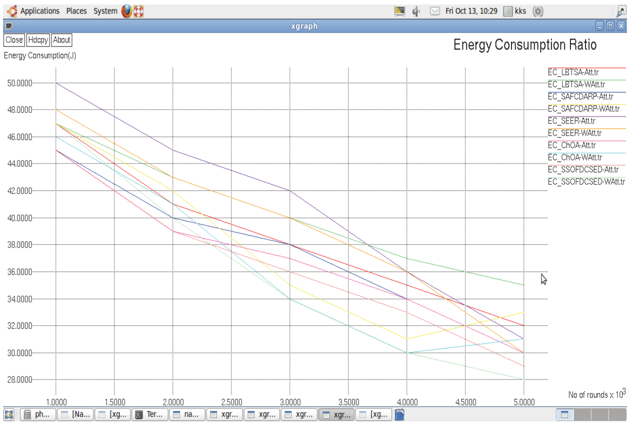

Figure 7 Energy consumption for different protocols with and without attack

The energy usage of the SSOFDCSEDARP, SAFCDARP, SEECR, LBTSA, and ChOA-HGS methods is displayed in Fig. 7 under various conditions, including attack and non-attack. The findings reported demonstrate that, in every case (attack and no attack), the energy usage of the SSOFDCSEDARP method is significantly lower than that of the SAFCDARP, SEECR, LBTSA, and ChOA-HGS protocols.

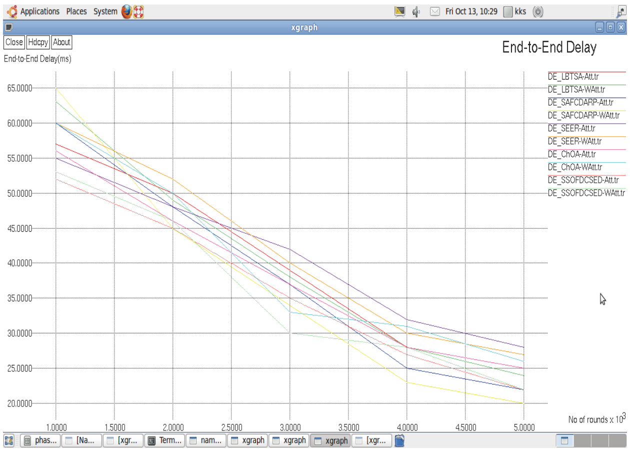

Figure 8 End-to-End delay for different protocols with and without attack

The end-to-end delays for the SSOFDCSEDARP, SAFCDARP, SEECR, LBTSA, and ChOA-HGS procedures are displayed in Fig. 8 under various conditions, including both attack and non-attack. The suggested approach takes into consideration five characteristics as fitness functions, including trust value, network longevity, distance among nodes, delay, and PDR, to provide secure, energy-optimized, and fewer transmission times. Additionally, the SSO-based LRV is utilized to swap out selfish nodes for normal nodes in order to increase PDR when data packets are being transmitted over the UWSN. As a result, the suggested solution improves the network's general efficiency.

5 CONCLUSION

The secure transfer of enormous amounts of data formed by sensor nodes is the main issue facing UWNS. Utilizing SSO and FDC, this study developed a unique routing technique for UWSN dubbed SSOFDCSEDARP. The two primary stages of SSOFDCSEDARP are intra/extra cluster routing and cluster creation. In the initial stage, grouped sensor nodes into ideal clusters utilizing the fuzzy logic framework. During the second stage, employed SSO to determine the most effective paths connecting cluster heads and members, and between cluster heads and the base station. SSOFDCSEDARP eliminates any potential energy hole close to the base station, makes instant re-clustering easier, and is suitable for large-scale UWSN. The SSOFDCSEDARP works better than earlier techniques with respect to energy use, end-to-end delay, packet delivery ratio, and network longevity, according to acquired experimental data from the Matlab simulator. Future research should take into account multi-objective limitations like movement and QoS throughout the routing procedure in order to provide a realistic interaction system. Additionally, plan is to assess the computing demands of the suggested approach and address the computational challenges of various blockchain-based routing techniques.

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