EFFECTIVE DATA AGGREGATION THROUGH CLUSTERING TREE (EDACT) : AN INITIATIVE TO IMPROVE ENERGY EFFICACY IN UNDER WATER SENSOR NETWORKS

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ABSTRACT

An Underwater Sensor Network (UWSN) is a sort of wireless sensor network (WSN) that is specifically developed for use in underwater situations. These networks are made up of interconnected sensor nodes placed beneath the water's surface to monitor and collect information about aquatic ecosystems, marine life, and underwater structures. Given the demanding underwater environment and the challenge of battery replacement or recharging, energy efficiency is crucial to the design and operation of underwater sensor networks (UWSNs). One of the key objectives of UWSNs is to increase the network's lifespan while preserving dependable data collecting and communication. Clustering has a substantial impact on the performance, efficiency, and scalability of underwater sensor networks (UWSNs). Underwater habitats, where energy limitations, changeable topography, and harsh circumstances pose significant challenges, benefit greatly from this hierarchical structure. Underwater sensor networks require data aggregation for optimal data transfer, effective resource use, and improved network efficiency. It solves the issues of energy scarcity, bandwidth constraints, long delays, and environmental unpredictability, making it a critical component of UWSN design and operation. This paper focuses on a new methodology which incorporates clustering and data aggregation to minimize energy utilization in under water wireless sensor networks and the results of simulation shows that the proposed methodology "Effective Data Aggregation through Clustering Tree (EDACT)" performs well in terms of network coverage, energy consumption and packet delivery.

Keywords: UWSN, clustering, data aggregation, energy

I. INTRODUCTION

Underwater Wireless Sensor Networks (UWSNs) are specialized sensor networks that are installed underwater to monitor, gather, and send information about the aquatic environment. These networks are made up of sensor nodes, underwater vehicles, and base stations that are engineered to operate in harsh underwater conditions. UWSNs communicate largely by acoustic waves rather than radio waves because radio waves do not transmit well underwater and optical signals are significantly attenuated. Acoustic channels have limited bandwidth, resulting in substantially slower data transfer rates than terrestrial networks. Nodes are powered by batteries, which might be difficult to recharge or replace underwater. Nodes must survive extreme pressure, salt, and corrosion over time. UWSNs are useful for monitoring water quality, temperature, salinity, dissolved oxygen, and pollution levels. It also aids in the early detection of tsunamis, undersea earthquakes, and other natural disasters. It also monitors offshore drilling, undersea pipelines, fish farms, and optimizes aquaculture operations. Nodes can sense factors including temperature, salinity, pH, and pressure by being deployed on the seabed, floating in the water column, or affixed to marine structures. The base station is where all data from the undersea environment is processed and analysed. Energy efficiency is crucial in Underwater Wireless Sensor Networks (UWSNs) due to the unique limits and challenges of the underwater environment. Energy is a scarce resource in UWSNs, as the majority of underwater sensor nodes are powered by batteries that are difficult or impossible to replace or recharge once deployed. Efficient energy consumption has a direct impact on network longevity, performance, and dependability. UWSNs are primarily used for long-term monitoring missions like oceanic research or environmental monitoring. Extending the lifespan of individual nodes means that the network is operational for a longer duration. The constraints of underwater deployment make replacing or maintaining underwater nodes expensive. Energy-efficient designs lessen the need for regular maintenance or replacement. Energy depletion in some nodes might cause communication disruptions or loss of connectivity, particularly if these nodes function as relays. Energy-efficient processes help to ensure network reliability. The need for fewer deployments and longer-lasting nodes decreases UWSN's environmental impact on aquatic environments. Clustering and data aggregation are important approaches in Underwater Wireless Sensor Networks (UWSNs) for increasing energy efficiency, scalability, and network lifetime. Both approaches seek to maximize resource use by eliminating duplicate transmission and processing data efficiently. This paper primarily focuses on a new clustering and data aggregation approach “Effective Data Aggregation through Clustering Tree (EDACT)” which focuses on minimizing energy utilization and data redundancy in Underwater Wireless Sensor Networks (UWSNs).

II. REVIEW OF LITERATURE

A unique cluster-based routing protocol known as the Energy Efficient UWSNs Clustering Protocol (EEUCP) was suggested by Bhaskarwar et.al. [1]. The EEUCP is an integrated clustering and routing algorithm that helps with energy conservation and network lifetime enhancement in UWSNs. Initially, the underwater sensor nodes deployed in various layers of the ocean column are sorted into clusters using a simple K means technique. The Fuzzy Logic (FL) technique is then used to choose the best Cluster Head (CH) for each cluster in the network. The FL rules are constructed with three input variables: Residual Energy (RE), Distance to the Surface Sink (DSS), and Packet Delivery Ratio (PDR) for each sensor in the cluster. To address the problem of void communication, the reliable forwarding relay selection problem is stated and addressed directly using the sensor nodes' periodic fuzzy trust values collected during the CH selection phase. To lower the energy consumption and number of transmissions from the CH to the sink node, a hybrid data reduction and Compressive sensing (CS) technique has been implemented. For data reduction, a lightweight high similarity data analysis mechanism is used. The hybrid CS approach is used, in which random CS measures are applied to the periodically aggregated CH data before sending it to the surface sink node. The simulation findings show that the EEUCP protocol greatly reduces energy usage while improving network quality of service. A centralized control-based clustering technique (CCCS) for UASNs is presented by Tian et.al.[2]. In this strategy, a node density-based adaptive clustering approach is used, intra-cluster controllers are formed within clusters, and the relay nodes and relay clusters are chosen to achieve energy balancing and route optimization. Simulation results show that, when compared to similar technologies, CCCS can balance node energy usage and significantly enhance the lifetime of a UASN.

The Energy Balanced Reliable and Effective Clustering (EBREC) approach was developed by Kaveripakam et.al. [3] to ensure that data packets arrive at their intended destination undamaged. This was done to prevent the complexities that would arise from these considerations. The presented endeavor also aims to reduce PDR and transmission losses. The predicted EBREC's performance is evaluated by comparing it to a number of previously specified benchmarks. According to the evaluation report, the simulation results show that

EBREC outperforms the other techniques in terms of residual energy of 0.615 J, consumed energy of 2.3 mJ, throughput of 10Mbps, PDR of 97.6%, network lifetime of 1750 seconds, and number of alive nodes of 91%. Khan et.al. [4] proposes a sensor node clustering technique for UWSNs called adaptive node clustering (ANC-UWSNs). It employs a dragonfly optimization (DFO) technique to identify the optimal measure of clusters required for routing. The DFO algorithm is inspired by dragons' swarming habit. The proposed methodology is compatible with various algorithms, including the ant colony optimizer (ACO), comprehensive learning particle swarm optimizer (CLPSO), gray wolf optimizer (GWO), and moth flame optimizer (MFO). Grid size, transmission range, and node density are employed in a performance matrix that changes during simulation. The results indicate that DFO outperforms the other algorithms. It provides a greater number of optimized clusters than other algorithms, which improves overall routing and boosts network life span. The study by Omeke et.al. [5] covers the implementation of a new clustering approach for extending the lifetime of WUSNs. They present a new procedure for cluster head selection known as the distance- and energy-constrained k-means clustering scheme (DEKCS). A possible cluster head is chosen based on its position in the cluster and its remaining battery capacity. They dynamically update the residual energy criteria specified for possible cluster heads to ensure that the network runs completely out of energy before disconnecting. Also, they use the elbow approach to dynamically determine the ideal number of clusters based on network size, making the network scalable. Chinnasamy et.al [6] proposes an Energy-Aware Multi-level Clustering Scheme to improve the lifetime of an underwater wireless sensor network. The undersea network region is represented as three-dimensional concentric cylinders with multiple layers. Furthermore, each level is separated into blocks, each representing a cluster. The suggested algorithm uses vertical communication from the seabed to the surface area in a bottom-up manner. Multiple levels of differing heights alleviate communication challenges caused by strong water pressure on the seabed. Simulations are carried out to demonstrate the efficiency of the proposed algorithm, which outperforms in terms of network lifetime and average residual energy. The simulation results reveal a considerable improvement in network longevity compared to current techniques. Given the underwater (UW) limitation, this work proposes an energy conservation mechanism for UWSNs that makes use of the LEACH computation method. The simulation results of the proposed hierarchical clustering technique for UW networks are compared with the hierarchical clustering strategy of LEACH for terrestrial networks, demonstrating that the suggested methodology for UWSNs is equivalent to LEACH for terrestrial WSNs. Similar to the LEACH procedure, the proposed methodology by Rizvi et.al. [7] minimizes total energy usage and extends the life of the UWSN. In a given cycle, the number of active nodes and the network's life stay constant. A clustering dormancy scheduling algorithm is then suggested by Zhang et.al. [8]. As a result, a vulnerability restoration technique is described, taking into account the sensitivity of sensor nodes to mortality caused by external sources. The proposed algorithm defines the following terms: failure node, coverage vulnerability, coverage matrix, key position, and supplemental node. The method also examines the coverage matrix and vulnerability edge nodes to decide whether the overlay vulnerability needs to be repaired. Experimental results show that this technique is more effective and efficient than similar algorithms. An adaptive energy-efficient clustering strategy for UWSNs based on multidimensional game theory was proposed by Xie et.al [9] . By developing a multidimensional clustering game model during the selection of candidate cluster head (C-CH) nodes, MDGTC increases the likelihood of the possible ideal CH node acting as C-CH again. Subsequently, an adaptive CH competition mechanism is established to improve the CH selection strategy by taking into account the energy and energy consumption status of local nodes and global networks. Furthermore, by integrating a hierarchical architecture and a hybrid CH rotation mechanism, the suggested model's stability is assured, resulting in more balanced energy usage across network nodes. In conclusion, MDGTC provides an effective distributed energy management architecture for UWSNs. [10] Joshi et.al. suggested an enhanced efficient data aggregation protocol in a hexagonal grid with energy optimization (IEDA-HGEO) for effective data transfer using an optimal clustering approach. It is also compared to the ERP2Rn energy-efficient routing protocol and the EGRC (Energy-efficiency Grid Routing based on 3D Cubes). The three techniques stated above are carefully evaluated for their suitability for underwater communication, and their performance is compared in terms of energy consumption, efficiency, throughput, packet delivery ratio, and delay. The proposed approach achieved the following results: 41% delay, 48% energy consumption, 95% efficiency, 95% throughput, and 92% PDR. [11] Zhang's research proposes an energy-efficient algorithm for data aggregation in UWSNs. The revised ACO (Ant Colony Optimization) algorithm maximizes packet delivery ratio, improves network lifetime, reduces end-to-end delay, and uses less energy. [12] Ayaz et.al. suggested technique, Multilayer Dynamic Data Forwarding (MD2F), is ideal for large and deep underwater areas. MD2F is scalable since it has a multi-sink design, and single or several autonomous underwater vehicles (AUVs) can be used depending on the area under surveillance. Implementing hop-by-hop transmission and clustering-based data collecting at several tiers balances the network load, extending its life. The results reveal that MD2F outperforms Multilayer Cluster-based Energy Efficient (MLCEE) and Energy Efficient and Link Reliable Routing (E2LR) schemes, which have very similar working characteristics. The results are promising in terms of delivery ratio, network throughput, and end-to-end latency. Along with meeting these goals, the network saves energy through load balancing.

[13] Zheng suggested an efficient data aggregation method for underwater acoustic sensor networks that relies on function approximation and characterisation. To begin, the spatial function model is developed by characterizing the network's sensor nodes using the spatial variation features of feature-level data in UWSNs. Second, by fully utilizing the wireless broadcasting characteristics of underwater acoustic signals, a sequential optimal subset selection method and an optimal local error criterion are proposed, resulting in the optimal distributed approximation of the spatial function with the least sensor feature data. Furthermore, three techniques are proposed to implement distributed fast approximation of spatial functions: distributed threshold separation, a probabilistic competition mechanism for node self-selection, and a dynamic backoff timing mechanism based on the MAC layer. Finally, the simulation results demonstrate the method's good performance, which can overcome the bottleneck of energy consumption and data aggregation delay in an underwater acoustic sensor network, significantly extending network lifetime and reducing aggregation latency. [14] Chenthil et.al. research describes an Energy-aware QoS-based cluster routing with an aggregation management technique (EQoS-CRAM) that provides efficient path discovery with low energy usage for UWSN. To avoid collisions, data is aggregated using the cluster area's sleep wake scheduling procedure. The EQoS-CRAM technique provides priority-based QoS data delivery with reduced delay. According to experimental results, the EQoS-CRAM methodology outperforms previous systems in terms of packet delivery ratio, energy usage, collision rate, and network longevity. This research by Ramasamy et.al [15] addresses energy consumption and security limits in reconfigurable WSNs, with the goal of increasing network lifetime and ensuring data privacy. The network consists of scattered nodes that reconfigure to meet user requirements. Their proposed solutions enhance network lifetime by reducing traffic and enabling effective reconfigurable routing. Our proposal involves employing hashing distance computation (HDC) to reduce duplicate packets at the node level within the network. They developed a power-efficient, reconfigurable cell-by-cell golden sector-based emperor penguin colony (CbC GSEPC) system for trust-based routing. A suggested lightweight key expandable cryptography approach ensures data security in

energy-constrained environments. Reading-based dual validation (RbDV) analyzes sink-level information to detect intrusions and pinpoint suspicious nodes. Simulations using NS-3.26 reveal that the proposed approach consumes 5.82% less energy than the existing 2D-WSN while providing end-to-end secrecy and node reconfiguration options. [16] Khan et.al proposed an innovative, dependable AUV-based data collecting routing protocol for UWSNs. The suggested protocol uses a route planning mechanism to collect data with AUVs. The sink node commands AUVs to collect data from sensor nodes in order to save energy. Sensor nodes are first organized into clusters for improved scalability, and then these clusters are divided into groups, with an AUV assigned to each group. Second, each AUV's travel path is designed using the Markov decision process (MDP) to ensure trustworthy data collecting. The simulation results demonstrate that the proposed technique is successful and efficient in terms of throughput, energy efficiency, latency, and dependability. [17] Jain et.al devised a cluster-based data aggregation technique known as Scalable Clustering Algorithm for Data Aggregation (SCADA). In this technique, each cluster consists of a single cluster head (CH) and many cluster relays (CR). The number of CRs in a cluster varies according to its geographic location in reference to the base station. We guarantee that using multi-hop short-distance data transfer saves electricity. In hybrid modes, the CHs are rotated at regular intervals to decrease control packets. The proposed technique is new and well-suited for both homogeneous and heterogeneous WSNs since it employs a hybrid CH selection mechanism, a threshold-based CH rotation mechanism, and a system for allocating dedicated CR to each cluster. [18] Kaveripakam et.al presented a clustering-based dragonfly optimisation (CDFO) algorithm with decentralised forwarding for wireless networks. The CDFO-UWSN technique is used to determine the number of clusters required for routing. The proposed method has been linked to similar algorithms, such as the Ant Colony Optimizer (ACO), Adaptive Node Clustering for UWSN (ANC-UWSN), Grey Wolf Optimizer (GWO), and Moth Flame Optimizer (MFO). During the simulation, a performance matrix will be employed to account for various aspects such as grid size, transmission range, and node density. The results demonstrate that CDFO-UWSN outperforms all of the algorithms examined. By establishing more clusters than competing systems, it improves overall routing and increases network longevity. This allows a network to function for an extended period of time. [19] In this research, an AUV (Autonomous Underwater Vehicle)-assisted acoustic correspondence convention, namely the Energy Efficiency Maximization Algorithm (EEMA), is presented by Pasupathi et.al to reduce energy usage. Underwater sensor networks rely on the hub's continuous functioning, limited communication transfer capacity, and hub longevity, which creates operational challenges for USWN. The suggested system will extend the lifespan by reducing the number of bounces between sensor transmissions, hence reducing time utilization and lifetime. Dynamic AUV routes and dynamic gateway assignments will improve the submerged system's lifetime-proficiency balance. To reduce system energy consumption, an appropriate conveyance fraction is recommended. The experimental results reveal that the proposed methodology outperformed related techniques in terms of energy. [20] In this research, a CS-based UWSNs data collecting model is developed by taking use of the spatial sparsity of underwater environment data to reduce the number of sensor nodes required. By taking into account the impact of channel fading on instantaneous power, a packet transmission strategy is developed to assure the successful reception of a given amount of packets. Furthermore, a CS-based energy-efficient collection technique is developed based on the model and approach to achieve efficient target field monitoring while reducing UWSN energy consumption. A performance study is performed, and real-world examples are supplied to demonstrate the validity of the suggested strategy.

III. PROPOSED WORK

The proposed work **Effective Data Aggregation through Clustering Tree (EDACT)** concentrates on two main mechanisms namely clustering and data aggregation to save energy in wireless sensor networks. The nodes are deployed randomly in a 2D plane. The proposed protocol will be implemented in 3 steps namely Hop tree Construction, Clustering and Data Aggregation.

Hop Tree Construction:

The sink will be the root node, broadcasting a Hop_{init} message to all nodes in the network. Initially, the value of Hop_{init} will be set to 0. Each node keeps track of the hop counts of its nearby nodes. The hop count is set to one if the node is only one hop distant from the sink. The remaining nodes use equation 1 to get their hop count.

$$Hop\ Count = HC_r + 1 \qquad (1)$$

Where HC_r is the received hop count. Nodes update their freshly received hop count if it is less than their existing hop count. Each node chooses a parent node from its neighbours depending on the minimum hop count and residual energy. As the nodes propagate, they form parent-child associations, resulting in a tree structure rooted at the sink. Nodes regularly share hop count information when topology changes or nodes fail. If a parent node is moved or loses energy, the tree is recreated. If the current parent node fails, each node finds an alternative parent depending on the residual energy.

Clustering

To facilitate effective data transfer, the nodes of the tree are arranged into local clusters. The cluster head of each cluster is in charge of gathering data from member nodes, combining it, compressing it, and sending it to the sink. Every member node makes a single hop to deliver data to the cluster head, who uses a multihop to send data to the sink via intermediary nodes. To keep the nodes' energy from rapidly running out, cluster chiefs rotate their responsibilities among cluster members. A node's initial probability of becoming the cluster head is determined using Equation 2.

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$$CH_{PROB} = \frac{N_{rec}}{N_{max}} * N_{prob} \quad (2)$$

Where N_{rec} is the node's residual energy, N_{max} is the maximum battery capacity and N_{prob} is a small constant fraction used to set an initial percentage of cluster heads. CH_{PROB} is not allowed to fall below a small probability threshold $prob_{min}$. The members of the cluster calculate their distance to the cluster head using equation 3.

$$d_i = v_{sig} * T_{arr} \quad (3)$$

Where d_i is the distance between the member node and cluster head, v_{sig} is the speed of the signal which is $\approx 1.06\ x\ 10^7\ m\ /sec$ and T_{arr} is the time of arrival. The speed of the signal underwater is computed using equation 4.

$$v_{sig} = \frac{C}{\sqrt{\epsilon_r}} \quad (4)$$

Where c is the speed of light in a medium $\approx 3\ x\ 10^8\ m\ /sec$ and ϵ_r is the dielectric constant which is ≈ 80 for water. The process of CH selection involves control message exchanges (e.g., CH announcements, node responses). The energy consumption is given in equation 8 below:

$$E_{CH} = N.k_{ctrl}.E_{elec} \quad (5)$$

Where N is the number of nodes, k_{ctrl} is the size of control messages in bits and E_{elec} is the energy required to process and transmit one bit of data. Following CH selection, CHs establish connectivity by interacting with other CHs or the base station. The following equation provides the energy used to send control data from a CH to the base stationor other CHs.

$$E_{CH\_comm} = M.(k_{ctrl}.E_{elec} + k_{ctrl}.\epsilon_{amp}.d_{CH}^{n}) \quad (6)$$

Where M is the number of cluster heads, ϵ_{amp} is the energy consumption of the amplifier and d_{CH}^{n} is the distance between the cluster head and the sink.

Member nodes transmitting data to the CH is known as intra-cluster communication, and the equation that follows is used to determine how much energy each node utilizes.

$$E_{intra-cluster} = \sum_{i=1}^{M}\sum_{j=1}^{N_i}(k.E_{elec} + k.\epsilon_{amp}.d_{node-CH}^{n}) \quad (7)$$

Where M is the number of cluster heads, N_i is the number of nodes in cluster i, k is the number of data packets , E_{elec} is the energy required to process and transmit one bit of data, ϵ_{amp} is the energy consumption of the amplifier and $d_{node-CH}^{n}$ is the distance between the node and cluster head. So the total energy consumption during clustering is given by equation 8.

$$E_{clustering} = E_{CH} + E_{CH\_comm} + E_{intra-cluster} \quad (8)$$

Data aggregation

To increase energy efficiency, data recognized by member nodes is compressed before transmission, and the cluster heads are rotated after a predetermined number of rounds. Run length encoding is used to remove redundant data as viewed by member nodes (equation 5), and threshold-based spatial correlation is used to remove redundant data at cluster heads (equation 6 below).

$$x_{RLE} = (value, count) \quad (9)$$

Where $value$ is the sensed data and $count$ is the repetition of the sensed value by the member node.

$$SC_{(i,j)} = \begin{cases} 1 \; if \; |x_i - x_j| \leq \in \\ 0 \; if \; |x_i - x_j| > \in \end{cases} \quad (10)$$

Where x_i and x_j are the sensor readings from nodes i and j and ∈ is a defined threshold which defines how similar the data must be considered.

Data fusion combines data from multiple sensor nodes to provide a more full, trustworthy, and compact version of the information. It reduces the quantity of data that must be conveyed to the sink node by grouping comparable or correlated data. After the redundant data has been removed, data collected from numerous member nodes is combined. Data fusion is critical for data aggregation in WSNs because it condenses data from multiple sensor nodes into a single, more compact, and reliable piece of information. Aggregation employs fusion techniques to reduce energy use, improve data quality, and conserve bandwidth. It makes WSNs more efficient, especially in large-scale installations, by lowering communication overhead and boosting network lifetime. Data fusion is accomplished using the equation below.

$$D_f = \sum_{i=1}^{N} P_i . D_i \qquad (11)$$

Where P_i represents the probability of each node's data being accurate and D_i is the data from the nodes. Aggregation operations consume a defined amount of energy per bit, and the energy consumed during data aggregation is calculated using the following equation.

$$E_{agg} = k . E_{DA} \qquad (12)$$

Where k is the number of bits transmitted or received and E_{DA} is the energy energy required for data aggregation per bit. The most accurate method to determine E_{DA} is to measure the energy consumption of the node while performing the aggregation operation in a controlled environment.

$$E_{DA} = \frac{Measured\ Energy\ Consumption}{Number\ of\ processed\ bits} \qquad (13)$$

IV. RESULTS AND DISCUSSION

Hop trees help balance energy usage, extending the network's lifespan. The suggested algorithm, "Effective Data Aggregation through Clustering Tree (EDACT)," builds clusters after tree construction to minimize the number of transmissions needed to send data. This lowers energy consumption by distributing communication responsibilities across multiple nodes. To illustrate the efficacy of the suggested approach, the findings examine and discuss parameters such cluster size, energy consumption during clustering and data aggregation, packet delivery ratio, and network coverage. The performance of the proposed approach is compared to two existing clustering algorithms: Energy Efficient UWSNs Clustering

Protocol (EEUCP) (Bhaskarwar et al 2022) and Energy Balanced Reliable and Effective Clustering (EBREC) (Kaveripakam et al 2023).

Simulation Parameters		
1	Simulation area	100 m x 100 m
2	Number of nodes	200
3	Deployment	Random
4	Node Mobility	Fixed
5	Initial energy	1000 J
6	E_{fs}	$10 * 10^{-2}$ J
7	E_{tx}	$50 * 10^{-9}$ J
8	E_{rx}	$50 * 10^{-9}$ J
9	E_{agg}	$50 * 10^{-9}$ J
10	Radio propagation range	300 m
11	Channel capacity	2 M bits/s
12	Data packets	3200 bits
13	Simulation time	180 s

Table 4.1. Simulation Parameters

Cluster size: The number of sensor nodes under the control of a Cluster Head (CH) inside a single cluster is referred to as the cluster size. It serves as a cluster's logical or physical boundary and has an immediate effect on the network's scalability, energy usage, and performance. Fig. 4.1 illustrates how clusters form using various methods. While EEUCP and EBREC create clusters with varying numbers of nodes in each cluster, the suggested methodology EDACT creates balanced clusters with an equal number of nodes in each cluster. The suggested approach minimizes energy consumption during data transmission by creating clusters of balanced size that can communicate with one another in a single hop.

Fig 4.1. Comparison on Cluster size among the proposed and existing methods

Energy Consumption: The term "energy consumption" describes how much energy sensor nodes in Wireless Sensor Networks (WSNs) use for sensing, data processing, communication (transmission and receiving), and idle states. WSNs can save a lot of energy and increase the network's operational lifetime by combining data aggregation with energy-efficient clustering techniques. Figure 4.2 compares the energy usage of the suggested and current methods during data aggregation and clustering, whereas Figure 4.3 displays the overall energy used. Figures show that the suggested methodology EDACT utilizes less energy than the other two existing methods.

Packet Delivery Ratio: The ratio of packets transmitted from the source to those delivered to the destination is known as the packet delivery ratio, or PDR. Data packets delivered from sensor nodes to cluster heads are used in the suggested method to compute packet delivery. As can be seen from the results, the packet delivery ratio is high when compared to the current methodologies, EEUCP and EBREC. Figure 4.4 displays the number of packets delivered to the destination relative to the number of packets sent, and Figure 4.5 displays the packet delivery ratio of the existing and proposed methodologies.

Total number of packets sent	EDACT	EEUCP	EBREC
20	20	14	16
40	40	37	40
60	60	58	59
80	78	67	73
100	98	91	93

Table 4.3 Number of data packets delivered Vs Number of data packets sent

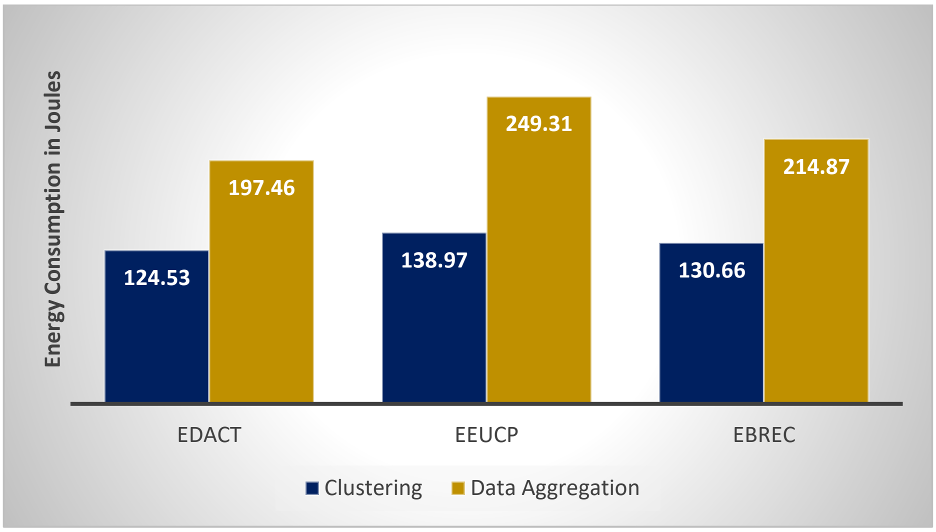

Fig 4.2 Energy Consumption during Clustering and Data Aggregation

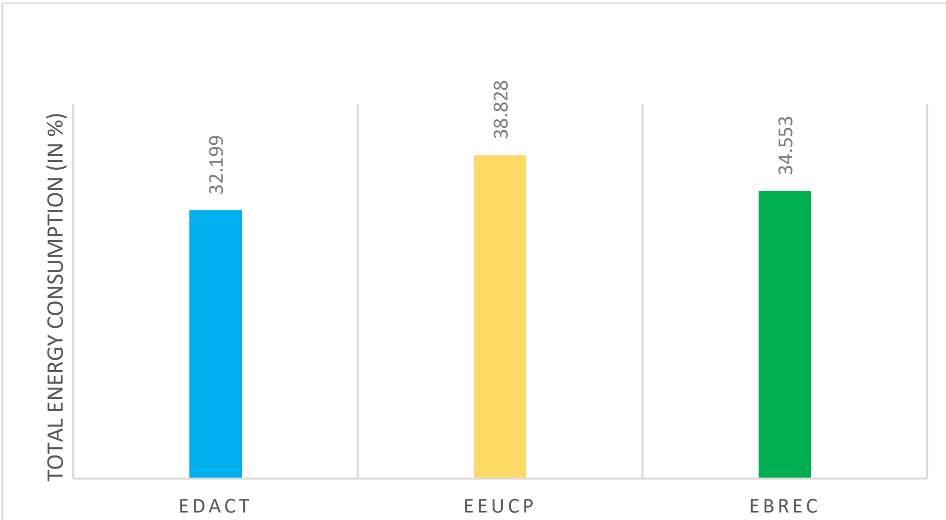

Fig 4.3 Total Energy Consumption during Clustering and Data Aggregation among the proposed and existing methodologies

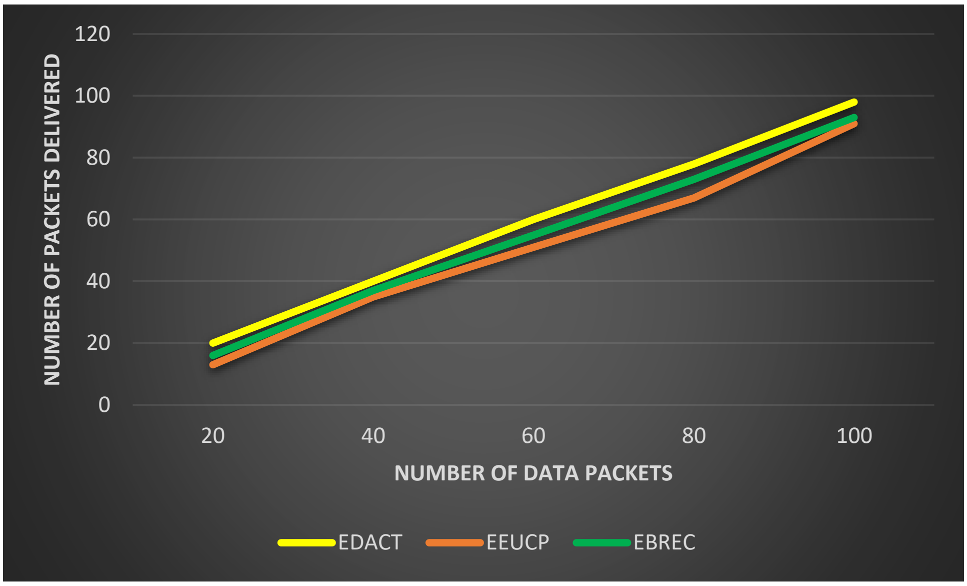

Fig 4.4 Packets delivered Vs Packets Sent

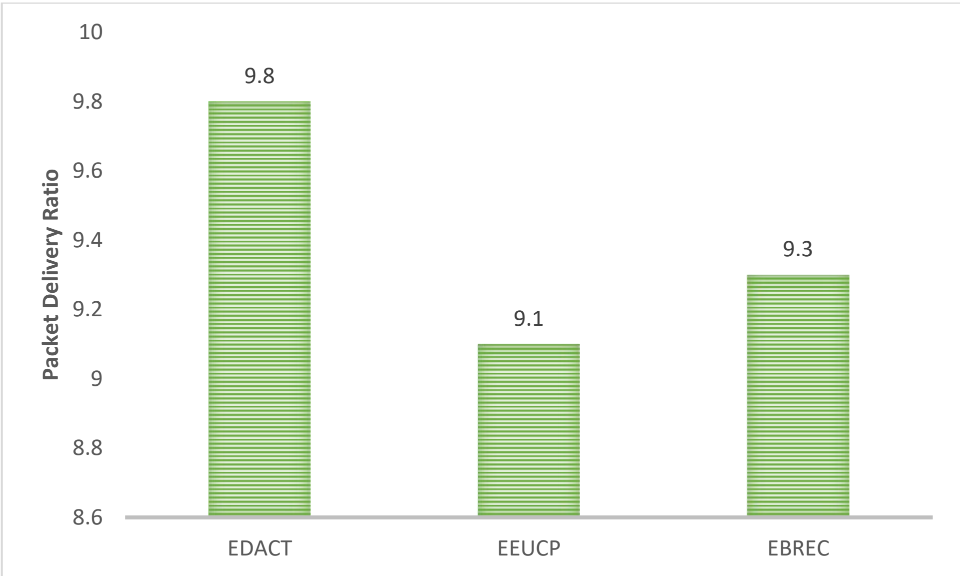

Fig 4.5 Comparison on Packet Delivery Ratio among the existing and proposed methodolgies

Network Coverage: The ability of a wireless sensor network (WSN) to efficiently monitor a particular area is referred to as network coverage. It shows how well the sensors that have been deployed are able to detect, gather, and send data from the area of interest. Reaching ideal coverage is essential to guaranteeing the network's efficiency, dependability, and functionality. The suggested technique works better than the current approaches in terms of network coverage, as seen in Fig. 4.6.

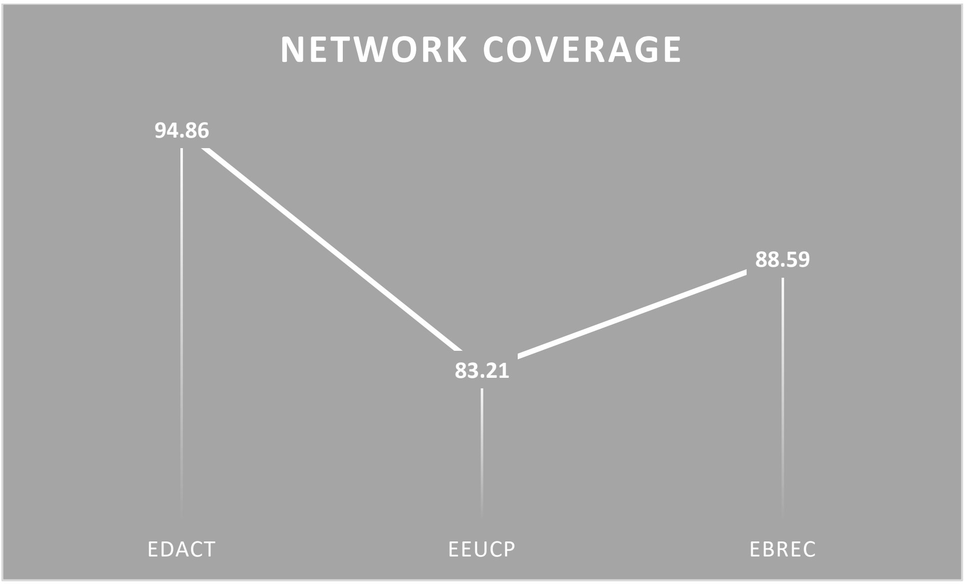

Fig 4.6 Network Coverage among the various methodologies

V. CONCLUSION

When implemented underwater, the suggested method "Effective Data Aggregation through Clustering Tree (EDACT)" performs better in terms of coverage and energy consumption. This project's research would keep calculating how much energy is used when data is sent to the sink using energy-efficient routing. The suggested work minimizes latency and packet loss while offering strong network coverage in the current phase. It is clear that energy is used effectively and that data may be shared safely.

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