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Efficient Techniques for Data Aggregation in Underwater Sensor Networks

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One of the vast application of WSN (Wireless Sensor Network) technology is UWSN (Under Water Sensor Networks). More than 70% of earth is covered with water. So UWSN is used in detect underwater environment. In past few decades a variety of protocols have been designed for operative and qualitative research analysis. Protocols includes routing, localization, and node-deployment and clone detection. As in routing data must be travel from source to sink node with minimum energy consumption and lesser propagation delay. For this purpose aggregation of data is one of the protocol that is extensively used along with underwater sensor networks to attain improved results. In past large number of aggregation techniques has been proposed. Aggregation techniques can be categorized in cluster based, in which clusters are formed and cluster head will be responsible for all data aggregation, non-cluster based, and approached using some supplementary techniques for aggregation. This paper is presented comparative survey on various aggregation techniques. Based on survey some future challenges have been identified, on the bases of that researchers can build interest to work on same issue. Performance of all three types of algorithms have been tabulated and shown graphically.

Keywords: Aggregation, Cluster, Similarity based Functions, K-Means, Distance.

1. Introduction

The massive exploration has been done on WSN (Wireless Sensor Networks) in every field. Researchers show their attention towards Underwater Acoustic Sensor Networks (UASNs) being an emerging field of research. It is observed that underwater sensor networks (works on acoustic signals) are totally differs from terrestrial sensor networks (works on radio signals) in terms of power of communication, deployment of sensors, large memory to retain large data [1]-[5].

In earlier research author says that most of the aspects of earthy sensor network resemble on Underwater Sensor Network (UWSN). Nevertheless, earthy sensor networks protocols unsuitable for UWSN due to high propagation delay and restricted bandwidth. For illustration, the applications like terrestrial networks are not applicable in under water network for instance of routing protocol. Therefore, while considering the characteristics of underwater communication, excessive efforts have been made for designing efficient protocol. Routing protocols proposed state –of –the –art for UWSN routing protocols are categorized into four categories .i.e, protocols based on flooding, multi path based, cluster based and others protocols.

In this unit, routing protocols of state-of-the-art for UWSN are examined and exemplify in detail. The preferred routing protocols are classified based on the action engaged. Approach based on flooding, approach based on multi path and approach based on cluster. The other sections include the protocols that show different avenue other then the first three sections. Despite the article for UWSN are applicable in a number of surveys, through present analysis on routing protocol in UWSN, it considerate the direction and target the routing protocols.

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UWSN are moveable or immovable in nature that communicates through acoustic signals. UWSN is extensively used in numerous fields such as checking activities of flora and fauna, water pollution, to examine health of marine creatures, detection of oil leakage, oceanographic data collection, disaster prevention and many more [6]-[10].

It has been observed that there are various challenges were faced by researchers such as stability of sensors in flowing water, narrow bandwidth, limited energy, shadow zones, propagation delay, network connectivity, high bit error rates, harsh geographical atmosphere, etc. [11]-[14].

In the underwater sensor network the sensor nodes are organized to intellect the data or information and transmit it to the sink node of the network. These networks are used for observing purpose in small aquatic regions such as river, pond, lake & etc. But these protocols are not effective in large aquatic region such as ocean and sea as there are many factors in which are required to examined at real time in large water area such as pressure, level of water etc. To resolve these issues data aggregation techniques being used along with routing protocols where, there is a head node which aggregate all the information, transmit by nearby nodes in the region and then the head nodes transmit that information to the sink node. The data aggregation technique will produce positive result in form of energy consumption, data redundancy, data transmission, delay rate etc. [15]-[16] In last few years many disasters have occurred like Tsunami, Flood, Verdah cyclone in various different countries, to prevent from such disasters a disaster management should require. For active management of disaster, it is very vital for any node to have whole information about the influenced area, [17]. For this various an effective data aggregation technique is adopted to transmit the whole information to the sink node. The data aggregation is deployed on selected node. The data aggregation techniques repress the size of collected data or information, which helps in storing the data in lesser storage [44].

2. Related Work

The notation In UWSN, there are many algorithms exists, like integration of data, collection of data, aggregation of data, fusion and diffusion of data. All these existing techniques have their own advantage but the technique of data aggregation makes it best and hold the significant position. In some papers described by [1][12][15][16], have stated the significance of forwarding of data, node localization and deployment of node under the unstable condition of water, which were further divided on the basis of their functionality.

Authors in [33] (2013) found four suitable functions similar to under water sensor networks data aggregation technique. After examination and associating of functions, the results gave the outstanding features of underwater sensor networks. In UWSN cosine distance and Euclidean distance is more appropriate in UWSN, for other applications hamming distance and Jaccard are suitable to work on application which work on collected data. All former works focused on data aggregation, they only discussed existing techniques of data aggregation in UWSN & WSN, except Kumar and Singh (2014) [27]. While we tried to shows the existing work on data aggregation in underwater wireless sensor network into different categories.

Underwater detector Network (UWSN) is main fascinating space as a result of its most respected applications like: disaster preventions, distributed plan of action police work, subsurface exploration, siesmal observation, environmental observation and lots of a lot of the look of energy economical routing protocol but may be a difficult issue as a result of in underwater setting the power source of detector nodes cannot be recharged simply. Majority of the researchers have custom-made the terrestrial WSN methodologies to beat this drawback however in underwater setting the terrestrial WSN approach isn't possible as a result of the acoustic communication and water current. This work focuses the key

limitation of this energy economical routing protocols. The simulation results with comparative analysis for energy economical routing protocols also are given during this analysis article; that helps the analyzers to search out the any research gap within the field of energy economical routing protocols. This analysis article focuses the energy economical routing algorithm for aquatic wire free detector network. The most purpose of it is to elaborate the protocols operations with its design, route discovery, route maintenance, knowledge forwarding, and energy consumed by detector nodes. The limitation of projected protocols can guide the analyzers to any research within the field of routing protocols. This analysis article any focuses the analytical analysis technique and numerical simulation analysis technique. In numerical simulation technique we have a tendency to determine that the ERP2R and R-ERP2R consumes the less energy as compare to remainder of the projected routing protocols that shows that these protocols have used the reliable methodology for energy potency.

3. Classification and State-Of-Art

Here some of the aggregation techniques for underwater sensor networks have been explained:

3.1. Aggregation based on Cluster

This technique is based on clusters. Clusters are the virtual entity in which similar nodes form a group. Each group has a cluster head. Cluster is assigned the duty to collect data from all the members and forward that collected data to the base station. These arrangements form a stable and concise arrangement. It is an exciting technique to minimize the energy depletion at network, which has recently increased courtesy in UWSN.

3.1.1. Techniques based on Mobility

In Underwater sensor networks nodes move with the water current. So here we require a routing protocol which is used to fulfill the requirement of nodes to move. Traditionally all existing techniques used a random mobility model. Most of the routing protocols on underwater sensor networks assume random node mobility. Some cluster based techniques are designed which changes dynamically with time. These techniques must change their position along the time. Some of schemes has been described below that are based on mobility based functions.

3.1.1.1. DUCS (Distributed Underwater Clustering Scheme)

In 2007, one algorithm have designed a scheme known as DUCS by Domingo et al., in this random mobility model had used. Data was reduced and timing was adjusted in this scheme. DUCS uses GPS-free routing protocol, it does not use any technique for flooding. It also decreases the exchange of routing messages. For reducing the data duplication data aggregation techniques are used. DUCS also reduces the data propagation delay and energy consumption.

3.1.1.2. TCBR

TCBR is known as Temporary cluster based routing and it is proposed by [23] that are appropriate for hybrid networks and apply for both mobile and mobility networks. Here shortest path has been selected for transferring the data and smaller number of nodes has been used in this arrangement. Also it is not considering the location of nodes. This

technique saves the energy by reducing the complexity in the algorithm. Here same amount of energy has been used by all the nodes.

3.1.2. Clusters based on Similarity function

As its name suggests, similarity based functions involves the combining of nodes based on the similarity function. This technique reduces the data redundancy but in turn, it can't be known that under which circumstances same similarity function give same number of clusters. Similarity based techniques may increases the data latency in a cluster communication.Next section explains some configurations that are based on similarity based gathering.

3.1.2.1. RBC (Round based clustering) technique

[40] Explained about his proposed scheme known as RBS. RBS works in rounds. It execute in various phases that are initialization of scheme, cluster head selection, create the cluster and aggregation of data.

In Initialization phase, all the nodes are deployed in the system including sensor and sink nodes. Every round is initialized by Sink node for a particular time interval. In second phase cluster head is selected. Cluster head is selected based on some specific parameters like residual energy, location coordinates and distance from the sink node. After the selection of cluster head, clusters are formed based on geographical region in third phase. Third phase is data aggregation phase where data is aggregated and aggregated data is transmitted to the sink node.

After data transfer, Re-clustering phase occurs. After each data transfer that is end of each round clusters are reconstructed New cluster head will do re-clustering whenever any fluctuations occur in system circumstances due to energy depletion, movement in network etc. Re-clustering prolongs the lifetime of network.

3.1.2.2. EDAA

Efficient data aggregation approach is known as EDAA. It is proposed by Tran in [41] and it explains the aggregator node can be saying as cluster head collects the sensed data and grouped it in a vector. Cluster head or aggregator node identified the similar data and grouped that together. Similar data is identified based on some threshold function value. If the collected data is above the threshold value in context of similarity function, then it is not mandatory to communicate all data to the sink node. Some functions for similarity that can be used are: Cosine similarity, Euclidean distance and Jaccard similarity etc. This technique decreases the energy consumption and also decreases the data packet size. Authors of this paper have shown the efficiency of clustering algorithm based on similarity functions by dropping the packet size also dipping repetition of recorded data in cluster-based underwater sensor networks.

3.1.2.3. Techniques based on K-Means and ANOVA

This technique is based on similar reading data based aggregation proposed by [39]. It is presumed that data has been sent to sensor nodes to sink node in the form of readings. This scheme consists of two levels of aggregation of data. In the first level, previous readings at each node is cleared to decrease the data duplication, at the cluster head level. After the transmission of data, K-means algorithm has applied on data. K-means based on one-way ANOVA model is pragmatic to check for the similar data then aggregation is done on that

data and aggregated data is sent to the sink node. Authors in 2016 named Saranya and Arthi have explained a new clustering method which is used to periodically sent data to the cluster-head based on similarity function. In this, two tier approaches has been explained, in the first tier data redundancies has been removed and at second level categorize the nodes who is generating similar identical data sets, aggregated that data before sending to sink. Data has been sent periodically from source to sink. This technique has been used for efficient data transfer and reduces consumption of energy.

3.1.2.4. WSSF (Well-suited similarity function)

[38] have designed a similarity function based underwater senor network technique. This scheme based on Euclidean distance and the cosine distance function. It reduces the size of data packet and decrease the duplicity of data. In this technique initially the data is collected based on the appropriate similar function and then data aggregation applied to increase the lifetime of network.

3.1.3. Distance based techniques

The rules of wireless transmission determine the relative behavior of attenuation and distance covered. The techniques for data forwarding must be based on direction. Nodes which are at higher depth must send data to lower depth nodes since the sink nodes are at lower depth. It must be direction in higher to lower depth direction. The entire sensor node sends data to nearest sensor nodes. Lowest depth node send data to nearest sink nodes. Therefore distance based techniques consider the shortest distance algorithm to send data to the sink node.

3.1.3.1. Self-healing clustering (SHC).

One cluster based algorithm has been developed by Huang et al. (2011a, b) that involves data aggregation technique and ensure energy efficient routing. In this all sensor nodes formed direction sensitive cluster. Here a special node is assigned the responsibility of CH. CH will receive data from all nodes and aggregated data is send to sink node. Also it considers the concept of re clustering for self-healing of the cluster head. The development of extreme re-clustering increases the toughness of underwater sensor networks.

3.1.3.2. MARPCP

MARPCP is (Minimum average routing path clustering Problem) proposed by Kim et al. in [26] explained the aggregation technique based on clusters. In this technique cluster head is formed based on the minimum distance available from the sink node. It used minimum weighted scheme to decrease the high complication of MARPCP. They have designed a fast estimate algorithm for average routing path problem.

3.1.3.3. CDA (Cluster based data aggregation)

Data aggregation technique based on clustering has been proposed by authors in [24]. Along with aggregation technique authors has proposed the cluster election technique. Data can be transferred from source to sink by using aggregation or without aggregation.

3.1.3.4. IICC

Inter and intra cluster communication technique has been explained by Goyal in [12]. In this author have used fuzzy logic schemes to describe the ideal selection of cluster head. Further it also estimation the size of cluster. Authors used HMR-LEACH algorithm for inter-cluster communication and MARPCP algorithm for intra-cluster communication. This project has been simulated and showing the improvements consumption of energy, packet delivery ratio and reduced delay in data delivery.

3.2. Non-cluster based techniques

In this type of technique no clusters are formed, also nodes are moved with water no any nodes are stationary. They are dynamic in nature. These nodes can transfer data directly to the sink node. These techniques can be classified as follows:

3.2.1. Techniques based on Mobile sink

This technique includes the use of mobile sink nodes. Sensor nodes sense the environment. Mobile sinks or autonomous underwater vehicle (AUV) are used to collect the data from the sensor nodes. Various types of AUVs, boats and ships are used in underwater environment to collect the sensed data and send that to sink nodes. Data collection is done by AUVs, use of AUVs increases the coverage and connectivity in network area.

3.2.1.1. PRADD

PRADD has been explained by Nowsheen in [32] for the delay disruption in underwater environment. In this a node, having higher reliability in data transmission is chosen as next connecting node to forward data this it increase the data delivery. Mobile data collection devices are used to collect the urgent data from the nodes. These are proposed to have the enhanced lifetime and network coverage. Authors have also proposed a gateway scheme for better results. This approach uses the localization scheme to locate the location of the nodes in the initial phases. Anchored nodes are used to increase the coverage of network area.

3.2.1.2. SEDG

Ilyas in [20] have explained a technique named SEDG (Scalable and efficient data gathering). It improves the ratio of delivery of data and reduces energy. It assigned the nodes to all the gateway nodes. Along with it AUV movement in water provide the facility to collect the data by reducing the ratio of packet drop and gives higher network throughput.

3.2.2. Relay based techniques

This technique says in underwater sensor networks data is provided from one node to another and forwarded towards the sink nodes. Node in between source and sink are called relay nodes in this technique. Acoustic signals are used to forward data from source to sink. Relay nodes are designated based on the various factors like residual energy and the distance from the sink[26-43].

3.2.2.1. PERP

Power efficient routing protocol provides the solutions to the underwater sensor networks problems. Proposed by Huang in [16-19]. In this technique a next hop node is selected based on the appropriate forwarding node selector algorithm. A promoting tree trimming method is functional to avoid unnecessary persistent of forwarded data packets.

3.2.2.2. ERMTG (Extended RMTG)

A geo-cast technique has been proposed by Dhurandher [6] for underwater sensor networks. It was an energy efficient UWSN. ERMTG algorithm considers the current energy of the node to identify the next node. The energy consumed in transmission is depends on the distance between the distance between the source node to the next hop node. This considers the shortest path for data communication and decreases the energy consumption and life period of nodes.

4. Performance Analysis

In this paper comparative analysis of various aggregation protocols have been carried out in NS3. In this UnderwaterPropagation, UnderwaterMAC and UnderwaterChannel has been used for simulation. Data rate used is constant bit rate type.

4.1 Scenario I

In under water sensor networks, sink node are usually placed at the water surface and all sensor nodes placed at various heights in UWSN environment. Each node has to send data towards sink node through one or two hops. Data aggregation is done at a particular node. That node combines data and send to sink node. Some routing techniques have been analyzed in this paper for showing the performance of aggregation. The techniques proposed by [40][15][8] named as round based clustering, K-means clustering and Distributed clustering respectively. Simulation parameters have been described in Table 1. Algorithms have been compared for energy consumption, propagation delay and number of packet drops[43].

4.1.1 Simulation Parameters

We estimate the presentation of the proposed protocol as per the below parameters:

Delivery Ratio: It is defined as the ratio of the received packets successfully to the total number of transmitted packets.

Delivery ratio= Packets received/ Total no of packets

Average Delay: It is the average time taken in transmitting data packet from source node to sink. It is also includes the fault detection and recovery delays.

Energy Consumption: It is the energy consumed in transferring in data packets. It is the energy consume in transferring and receiving data. It is the average value of energy consumption of all the nodes in the network.

Packet Drop: It is defined as the number of data packets dropped during the data transmission.

Different scenarios have been taken for the simulation for better understanding. Simulation parameters used are shown in Table 1.

Table 1: Simulation Parameters

Simulation Parameters	Value
Network size	75 nodes
Simulation time	10, 20, 30, 40 and 50 s
Packet size	250 bytes
Delta value	0.5

4.1.2. Simulation results

The simulated results for various cluster based techniques have been presented in figures from 2 to 8. All algorithms have been for energy consumption, packet delay and packets drops for two scenarios i.e with or without aggregation.

A. Results for comparison of Average delay vs Time

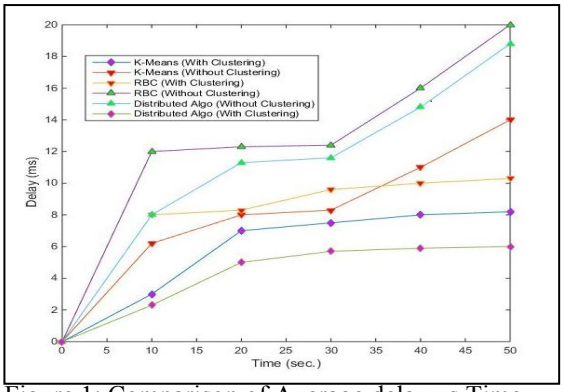

Figure 1: Comparison of Average delay vs Time

Cluster based techniques are compared for Average delay with respect to time. Graphical representations of results are shown for three algorithms in two cases, with aggregation (case 1) and without aggregation (case 2). K-means algorithm, Round based clustering approach and Distributed clustering algorithm for underwater sensor networks has been used for comparison. It is showing in figure 1 that underwater sensor networks experience more collision in data packets in case of without data aggregation compared to technique when aggregation is applied. K-means algorithm showing 27% less delay in case 1 than in case 2. Round based clustering algorithm showing 31% lesser delay in case 1 than case 2. Distributed clustering algorithm again experience 31% lesser delay in case 1 than 2.

B. Results for comparison of Average packet drop vs Time

Average packet drop has been measured with time and shown in figure 2. Packet drop occurs when collision increases. When aggregation not applied in algorithms, collisions are increased which result in the packet drop. However when aggregation applied collision is

decrease because of lesser number of packet generation. It is approx. 43% less, in k means clustering run with aggregation (case 1) than without aggregation (case 2). Packet loss is 43% less in case 1 than case 2 in case of RBC. There is also buffer overflow if data sent directly without aggregation. Distributed clustering experience 73% lesser packet drop in case of distributed clustering algorithm in case 1 than case 2.

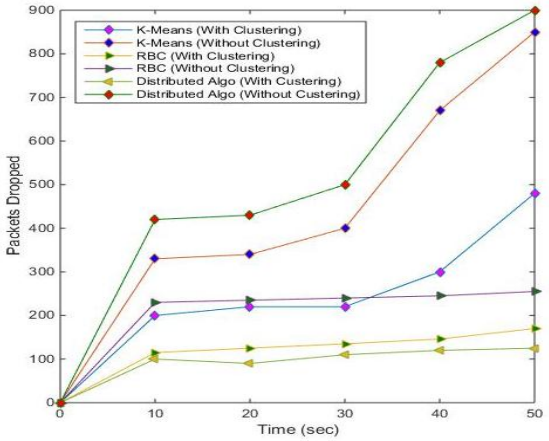

Figure 2: Comparison of Average packet drops vs Time

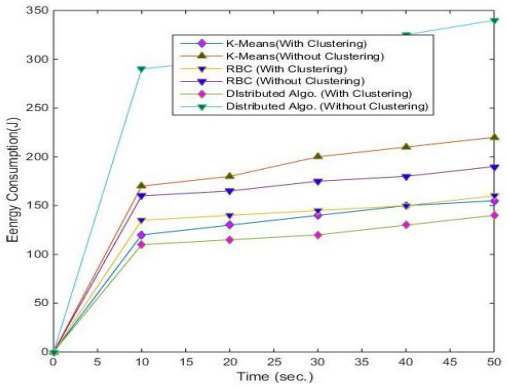

Figure 3: Comparison of Average energy consumption vs Time

C. Results for comparison of Energy Consumption vs Time

Energy consumption increases with time when number of dead node increases. In case 2 when algorithm run without clustering than it experiences aggregation, as shown in figure 3 K-means clustering technique experiences 25% smaller energy in with aggregation with aggregation as compared to without data aggregation scenario. One of the major reason for this is to have high redundancy while sending data without aggregation. RBC algorithm experiences 20% lesser energy consumption in case 1 than case 2. Distributed clustering algorithm has 38% lesser consumption of energy in case 1 than case 2.

4.2. Scenario II

Scenario II analyses the data aggregation in three categories. First category is Cluster based techniques, second is other techniques than clustering and third is non-cluster based techniques. For showing the results of cluster based technique IICC algorithm presented by [12] has been analyzed. For other techniques presentation ROSS technique presented by Hong et. al., [16] has been used for analyzing. Energy Efficient Distributed Time Synchronization (E2DTS by Li et. al., [29]) is used to show the non-cluster based algorithm working. Various matrices like Average delay, Average Energy Consumption and Average packet drop has been compared with varying packet sizes.

4.2.1. Simulation parameters

For simulating scenario II, network area size of 1000*1000 m^2 has been used. Number of nodes deployed are 50 for the time interval of 50 sec. Also larger time intervals are not showing any change in results.

Table 2: Simulation Parameters for Scenario II.

Simulation parameters	**Parameter Value**
Network Size	50 nodes
Area size	1000 m *1000 m
Traffic rate	50 Kbps
Channel capacity	2 Mbps
Range	100 m
Packet size	50, 100, 150, 200 and 250 bytes
Initial energy	1000 J
Transmission power	2.0W
Receiving power	0.75W

4.2.2. Performance

Three categories of algorithms have been simulated and showing results in figure 5. Techniques based on clusters, non cluster based, and some other techniques are considered for simulation.

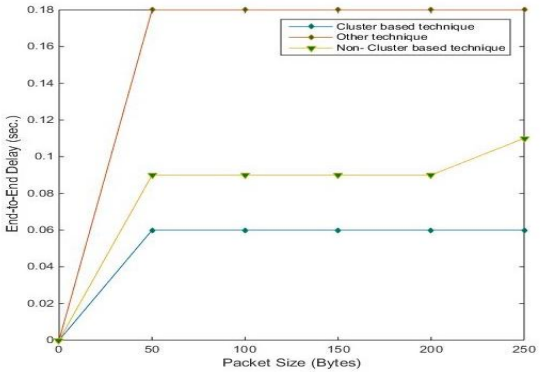

Figure 5: End to End delay Comparison vs Packet Size

ROSS, IICC, and E2DTS techniques have been used with various parameters like delay,

delivery ratio, and energy consumption w.r.t. varying packet size.

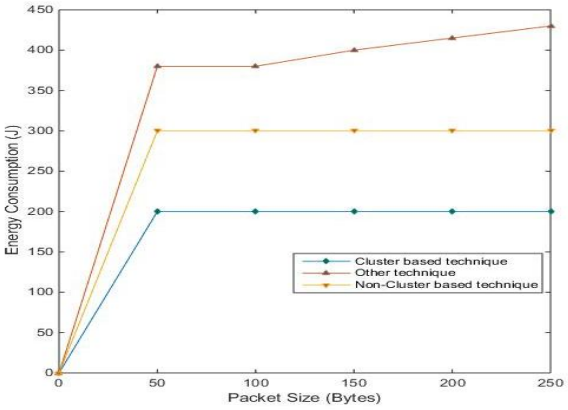

Figure 6: Energy consumption comparison vs Packet Size

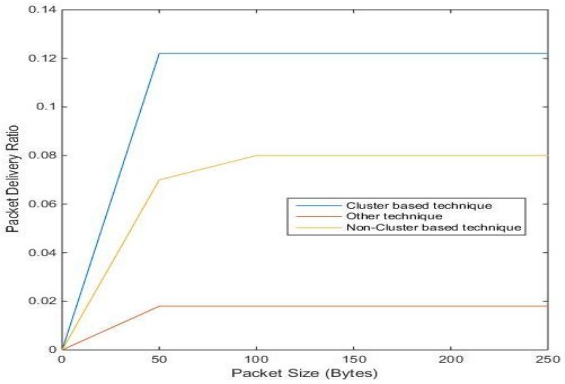

Figure 7: Comparison of Packet delivery ratio vs Packet Size

5. Comparison Table

Various aggregation techniques are discussed here in this paper, so for clear understanding a comparison table have been shown in table 3.

6. Conclusion

For increasing the life time of a network, energy consumption must be reduced. As in direct data transmission from sensor nodes to base station a large number of energy is consumed. To save this energy many algorithms are proposed in past. These algorithms are categorized as cluster based algorithms, non-cluster based algorithms and other techniques such as diffusion and scheduling based. This paper elaborates a comparative survey on aggregation algorithms for underwater sensor networks. Cluster based aggregation techniques creates clusters based on some distance based, similarity function based and mobility based. In these, data is aggregated at the cluster head and forwarded the aggregated data to the base station. Likewise, non-cluster based algorithms assumed mobile data collector and hop based forwarding of data from sensor towards the sink node. This

paper compares all algorithms in two scenarios; with aggregation and without aggregation. Aggregation technique is used to reduce the energy consumption. Simulations has been done on these algorithms based on various QoS parameters like energy consumption, time, delay and packet drop. Out of these algorithms a method of data aggregation is used to reduce the power consumption. Delay, packet drop, energy consumption and time has been taken as QoS parameters for simulations.

Table 3: Comparisons of various aggregation techniques

S. N.	Year	Method Proposed	Metrics	Advantages	Disadvantages	Author Name
1	2014	Round based clustering to reduce redundant data transmission	Throughput, Energy consumption, Data received ratio	High-throughput and low energy consumption	Lack to achieve best performance for node mobility	Khao Thi-Minh Tran et.al.
2	2013	Similarity functions based Data Aggregation	Data Lost, Data sent ration and Data deleted ratio	Minimize data redundancy and packet loss	The combination of similarity function and underwater protocol are not explained	Khao Thi-Minh Tran et.al.
3	2015	Enhanced K-means and ANOVA based clustering	Data sent ration and Energy consumption	Decreased data redundancy	Higher Energy consumption	Hassan Hard et. al.
4	2012	Data aggregation technique for UWSN	Energy consumption	Less Energy consumption and extends the network life time	The proposed method did not explain about the resource utilization	Manjula R.B. et.al.
5	2007	A GPS-free clustered routing protocol	Routing overhead, Packet delivery ratio	Better delivery ratio and Minimized proactive routing exchange, data loss, overhead		Mari carmen Domingo and Rui Prior
6	2010	Temporary Cluster Based Routing Protocol	Packet delivery Ratio, End to end delay and power consumption	Reduce energy consumption	Node mobility issue with wide communication coverage	Mohammad Ayaz et.al.

7	2011	Forwarding Average Routing Path Clustering	Energy Consumption, Packet drop, delay packet delivery ration	Outstanding results in terms of data received at base station and number of active nodes	Energy consumption ratio is high	Chen Jung Huang
8	2007	Minimum Average Routing Path Clustering	Delay Throughput	Good performance ratio		Donghyun Kim et.al.
9	2015	Path Reliability-Aware Data Delivery Protocol	Packet delivery Ratio, End to end delay and power consumption	Low overhead and less energy consumption	Dint explain about the dynamic data transfer	Nusrat Nowsheen et.al.
10	2015	Scalable and Efficient Data Gathering Protocol	Energy Consumption, Packet drop, delay packet delivery ratio, Network lifetime	Maximize network lifetime, Packet delivery ratio	Ideal route of AUV collect or gather data efficiently remains an issue	Naved Ilyas et.al.
11	2013	Geocast technique using ERMTG algorithm	Packet delivery Ratio, End to end delay and power consumption	Good delivery ratio and less energy consumption		Sanjay K. Dhurandher et.al.
12	2011	Minimum Latency aggregation scheduling	Aggregation Latency	Reduced latency		Zuoding Wu et.al.
13	2007	Conservative Communications architecture using nonintrusive underwater	Delay, Delivery ratio and packet sent	Minimize data packet collision		Uichin Lee et.al.

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