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Architecture, Routing Protocols and Data Aggregation in Underwater Wireless Sensor Networks – A Review Based Description

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Abstract

A Wireless Sensor Network is an evenly distributed independent sensor monitoring the data available around them. This is applied even to underwater study also. Underwater Wireless Sensor Network (UWSN) methodology is extensively used in several areas like underwater monitoring and exploration applications and has demonstrated its high significance in its adoption. In this survey, the concept of UWSN with Cluster based data gathering works experienced and exposed by the researchers were discussed for the efficient data transfer, decreasing the data redundancy and improving the life time of the system. The data gathering procedures are useful to tackle the energy consumption of the Sensor Node. Hence this paper mainly concentrate on the information regarding algorithms which are compatible for wireless sensor networks requiring minimum energy demand, thereby saving the energy in UWSNs.

Keywords: Data Gathering, Underwater Wireless Sensor Networks, Power Saving, Cluster Based Structure, Sensor Node.

INTRODUCTION

This review of literature of UWSN is stated with the definitions of the basics of the networking system for better understanding and comprehension, prior to dealing with the actual study of the scholars experimented with UWSN with various protocols and architecture. The WSNs framed with sensors capable of reading, handling, collecting, storing and transforming information to other sensor nodes in unidirectional or multidirectional domains. There are five types of WSNs used for monitoring the environment on the earth, above and below the earth with the data from the sensor nodes. They are Terrestrial, Underground, Underwater, Multimedia and Mobile WSNs. Large numbers of underwater acoustic sensor nodes are clustered in underwater wireless sensor network (UWSN). UWSNs are positioned in an undersea or marine environment and nearby surroundings inundated wrecks, for oceanographic data gathering and calamity prevention, etc [1], [2].

In UWSN, the sensor nodes are integrated in a network to gather information and pass on to the sink node. In general, UWSN differs from normal sensor networks interms of acoustic signal, cost, memory space, data size, energy and deployment. Mainly the UWSN protocols were used to monitor the areas and collect the information from the various water sources such as streams, canals, pools, ponds etc., But, in the case of ocean, marine etc., as they are large and almost borderless in surroundings and several parameters like size of the area, water position, energy, quality etc., are essentially to be investigated on real time. But in these, UWSN protocols sometime fail to receive the information from the sensor node may be due to lack of power supply. In order to overcome this effect, reducing the data redundancy, better energy management and the data aggregation techniques are used with protocol wherein larger reading is collected and combined at the cluster head before transmitted to sink node. In UWSN, various data aggregation techniques are used to monitor the areas on the basis of similarity, mobility, and distance with a cluster based approach and Mobile sink and Relay based as Non-cluster. The collected data are transformed to the sink or UW-Sink using the communication interface like acoustic, optical and electromagnetic waves.

UWSNs ARCHITECTURE

The UWSN are communicating the information using electromagnetic wave, optical wave and acoustic wave. Compared to electromagnetic and optical wave, the acoustic waves are most preferred signal for many applications relevant to underwater research, because the signal travels longer with less absorption. The static 2D UWSNs, static 3D UWSNs and 3D with Autonomous Underwater vehicle are the types of UWSNs architecture used in ocean based research process.

A. Static Two Dimensional UWSNs

In a static two dimensional UWSN, an UW-sink collects data from the sensor nodes by the horizontal link and then transmits the reading to the sink node by the vertical link.

B. Static Three Dimensional UWSNs

In a static 3D UWSN: every node is organized with hanging buoy that can be expanded by a pump. The sensors are pulled by the buoy towards the ocean surface. The sensed data is transmitted to the central station by the buoy using sensor signal. The sensors are randomly distributed at the bottom. The sensor is joined with anchor by adjusting the length of the wire, so that the sensor depth is synchronized.

C. 3D with Autonomous Underwater Vehicle

The 3D with AUV consists of static sensors together with some Autonomous Underwater Vehicles (AUVs). AUVs are considered as super nodes, having higher energy, moving independently and with router exist between nodes.

DEPLOYMENT OF SENSOR NODES

Compared to deployment of terrestrial, mobile, multimedia, and underground sensor, the underwater sensor is more difficult due to environmental and situational conditions. The bandwidth, propagation delay, connectivity, energy, data failure and attenuation are the various factors considered at the time of deployment of UWSNs.

PROTOCOLS IN UWSNs

Sending packet from a source node to sink node is a challenging task for each node. At the time of routing the data, the energy and mobility are considered. There are three categories of protocols to routing the packet and they are reactive, proactive and geographical. Proactive protocol routes the packet periodically. Reactive type of protocol may be used in dynamic networks, but they cause large delays in order to create the packets. Geographical routing protocol sends the packets to the geographical location of the destinations. The data sent from a node to the sink or any other node can be in the form of all-to-all, any-to-all, all-to-any and any-to-any and the forms are classified into three categories: i.e., Vector, Directional and Hierarchical. Figure 1 introduced for routing protocols and data aggregation approach based on the perception of the review.

A. Greedy Classification

The VBF (Vector Based Forwarding), HH-VBF (Hop by Hop VBP), VBVA (Vector Based Void Avoidance), ES-VBF (Energy Saving VBF) and CVBF (Clustering VBF Protocol) are geographic routing protocol used to forward the information. A source node includes the position of the receiver in the data packets and it identifies the next hop according to the optimization process.

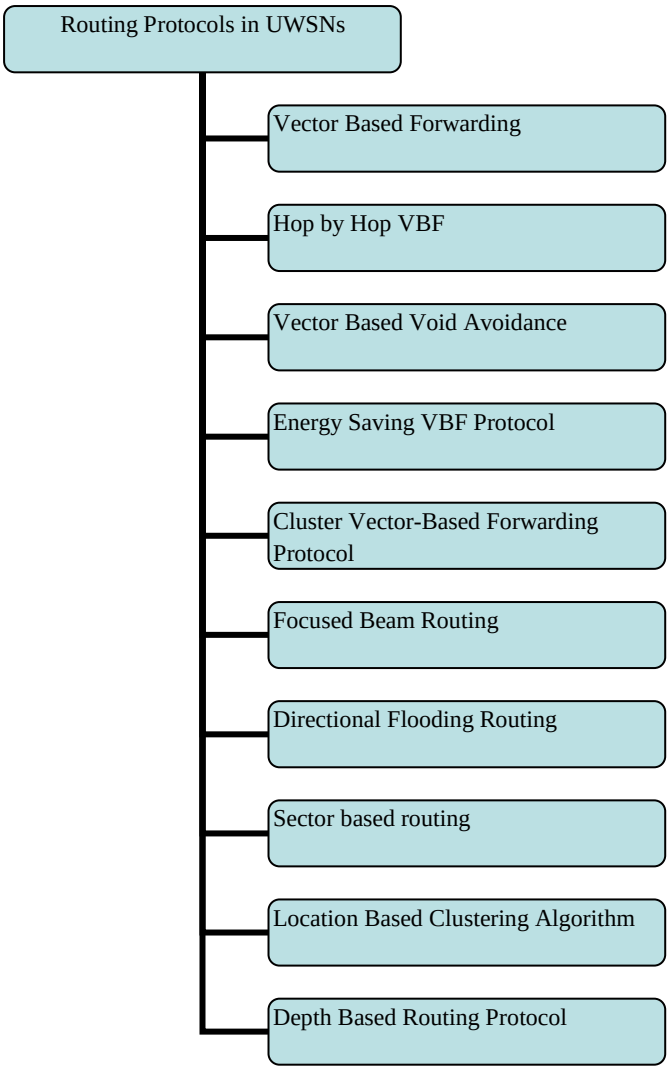

Figure 1. Routing Protocols

1) Vector Based Forwarding (VBF)

VBF considers location information to transmit data packet. The header in the packet carries information about the routing process. The packets are transferred from source to destination with routing vector along with a predetermined radius. Whenever a node receives a packet, the node in the network finds its distance to the nearest node and angle of arrival of the signal. The received data routed to the forwarder depends upon the node near to the routing vector.

2) Hop by Hop VBF (HH-VBF)

A timer is maintained by every forwarder node, depending on the desirability aspect. The node waits before forwarding the packets. Whenever the timer raised the time, then the node forwards the packet.

3) Vector Based Void Avoidance (VBVA)

Routing vector takes the accountability for the forwarding path of a packet from sensor node to the sink node. VBVA uses either vector-shift or back pressure mechanism.

4) Energy Saving VBF Protocol

In this, the two factors namely position and energy are considered. In VBF protocol, the energy may be exhausted due to routing failure. ES-VBF adds the value of energy consumption into desirableness factor to decide the waiting time.

5) Cluster Vector-Based Forwarding Protocol

A cluster is framed, and then the packets are routed through the VBF.

B. Directional Flooding

The Focused Beam Routing (FBR), Directional Flooding Routing (DFR) and Sector based routing with destination location prediction (SBR-DLP) are some examples of Directional Flooding. In the restricted directional flooding, the source node distributes the packet to all neighbors in the direction of destination. The receiving node checks the node within the set of nodes, then it forwards the packet, else the packet is dropped.

1) Focused Beam Routing

Each sensor node identifies its own location and final destination. The nodes cannot know final destination locations of other nodes.

2) Directional Flooding Routing

Nodes know their own location as well as, their own hop neighbours' location and the sink location. The node can also measure the link quality with neighbours.

3) Sector based Routing

The destination nodes pre-plan the movements. This process is typically predefined earlier to creating the network.

C. Hierarchical

Large numbers of sensor nodes are involved in the process. Location Based Clustering Algorithm (LCAD), Depth Based Routing Protocol (DBRP) and Constraint Based Depth Based Routing Protocol (CBDR) are employed in this process.

1) Location Based Clustering Algorithm

Entire system is sectored into 3D grids. Gird comprises of cluster. The selection of cluster head is based on the sleep/wake pattern along with residual memory and energy of the Cluster Head.

2) Depth *Based* Routing Protocol

Packets forwarded from deeper depth to shallow depth sensor nodes on the basis of depth.

CLUSTERED & COMPRESSED DATA AGGREGATION

In Clustered approach, the entire arrangement is segregated into identified numbers of clusters. All nodes are allocated under the cluster heads based on geographic location with the parameters of similarity, distance and mobility. Any one of the nodes is selected as cluster head, and the balance nodes transmit the data packets to their respective heads. Finally, the cluster head transmits the packets to the sink node. Cluster formation always makes a network look smaller reducing network's energy consumption. In a similarity based approach, the cluster head receives the packets from the nodes based on the similarity parameters. In the distance based approach, cluster head forwards the aggregated packets towards the sink or uw-sink based on the shortest path or nearest distance sink. In the mobility based techniques, various Autonomous Underwater Vehicles (AUVs) are deployed in aquatic environment for data collection. In non clustered techniques, the sensor nodes are deployed randomly. They are either dynamic or stationary. The packets are forwarded to the sink or uw-sink directly by the sensor nodes.

The figure 2 shows the data aggregation and compressed sensing techniques used in UWSNs derived from the review.

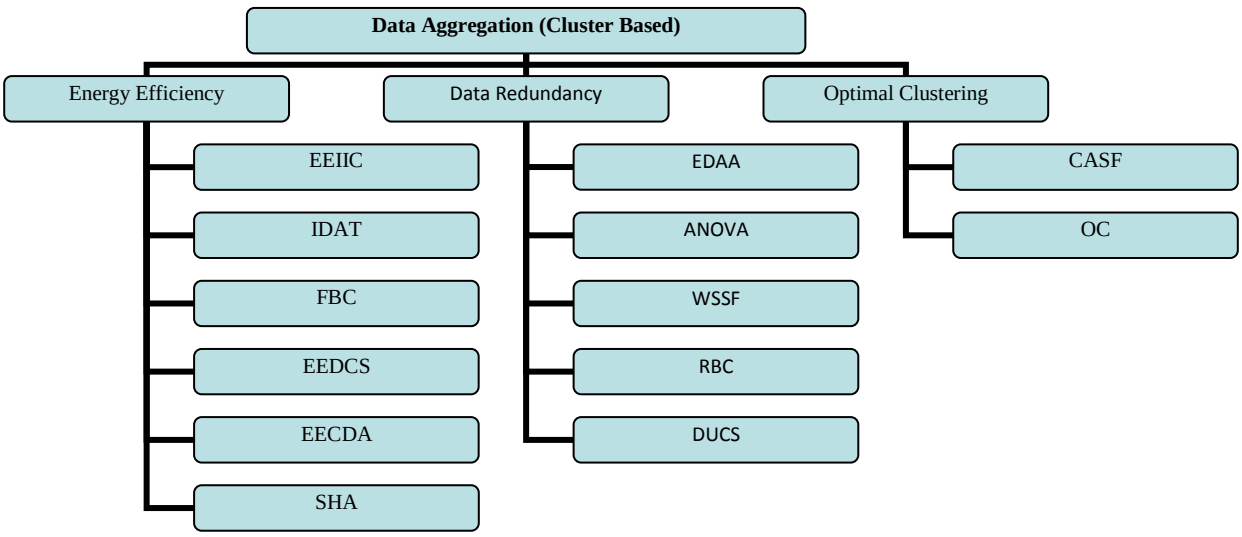

Figure 2. Data Aggregation Approach

A) Round based clustering

Khoa Thi-Minh Tran et al. [8] have designed a concept named as Round-Based Clustering (RBC). The round based approach carried out, consists of four phases: initialization, selection of CH, clustering process and aggregation. To improve the network life time, the CH can be reorganized. A combination of data aggregation with a similarity functions to improve the throughput; reduced the overall network consumption, and increased the data accuracy. In RBC, initialization phase, the clusters were constructed on round pattern. Cluster Heads are selected based on position, energy and distance from the sink node during the second phase. In the next phase, clusters were framed with its nodes. Finally, the readings are transmitted from the nodes are received by CH. Every round, the clusters are reconstructed and CH also reselected. This approach reduces the use of energy consumption, thereby it enhanced throughput of the network.

B) Efficient data aggregation approach

Tran K. T.M et al. [5] innovated an approach to compare the data sets using similarity function. The aggregator node collected the data from its member and grouped as a vector at a particular time. The data sets were compared with the similarity functions and checked with threshold value. If similar data is found, and then one data set is removed. Otherwise, data set transferred to the sink node. Euclidean distance, Edit distance, Cosine similarity, and Jacquard similarity functions were used in this approach. Similarity functions save energy consumption and reduces data packet size.

C) K-Means and ANOVA Based

Hassan Harb et al. [4] discussed the clustering method that depends upon spatial similarity between nodes reading function. The cluster heads (CHs) receives the readings periodically. The two-tier architecture is followed in this concept. Readings from the node can be cleared periodically to reduce the redundancy. Every CH uses the K-Means methods with One-Way ANOVA model indicating nodes producing same reading.

D) Well-suited similarity functions

Tran et al. [6] proposed a cluster based architecture without UW protocols. Data aggregation process is done using similarity functions like Euclidean and cosine distance. Duplication of Data and size of the packet are reduced.

E) Comparative analysis of similarity functions

Oh et al. [10] have presented the different methods of data aggregation process with similarity functions in UWSNs. They compared four similarity functions [Euclidean, Cosine, Hamming, Jacquard distances] and concluded with similarity thresholds.

F) Energy Efficient compressed data aggregation

Hongzhi Lin et al. [11] have constructed two layers compressed aggregation scheme. Compressed sampling is happening in lower layer and the aggregation is processed in upper layer. Compressed Aggregation Scheme included the technique to decide the total number of clusters and then the nodes would take part in data sampling or not using probability.

G) Optimal Clustering in UWSNs

Sadanand Yadav et al. [12] determined that the clusters are constructed in an optimal way using Gaussian distributed UWSN. Three communication techniques like acoustic, optical and EM wave were used. Best optimal clusters were framed with low bandwidth. Data aggregation ratio is affected by optimal clustering.

H) Random Access Compressed Sensing

Fatemeh Fazel et al. [13] proposed that the subset of nodes are selected in a random manner and channel used for sending the readings to fusion center. The packet is collided at fusion center. In order to avoid packet loss, the sufficient sensing probability is introduced. Thus, the network life time is prolonged. The efficient energy and bandwidth could be achieved with the concepts of randomly selection with compressed sensing. The process demands accurate time synchronization.

I) Distributed Underwater Clustering Scheme

Domingo et al. [15] narrated new clustering scheme, where nodes distributed randomly. Loss of data is reduced by continuously adjusting the timer. DUCS incorporated an energy conscious GPS liberated protocol. For selection of cluster head algorithm, data aggregation to reduce the unwanted reading and the concept of compensated high underwater propagation delays using timing were considered.

J) Fuzzy Based Clustering

Sihem Souiki et al. [16] have projected two architectures using Fuzzy C-Means mechanism. In the first round, cluster head collected readings from nodes are sent to base station. In the second approach, the receiver is uw-sink and the cluster head operates in multi-hop mode to forward data. These two algorithms were tested with static and dynamic deployment. Both algorithms produced the promising performance in terms of energy utilization and system life.

K) Improved Data Aggregation Technique

Nitin Goyal et al. [17] have advocated an enhanced data aggregation process. The sensed data were aggregated with sleep - wake up process and Time Division Multiple Access scheduled to elude collisions. It had shown improvement in

terms of data loss, delay and energy constraints. It minimized the energy consumption rate with the combination of data aggregation and data scheduling.

L) Energy Efficient Distributed Compressed Sensing

Deqing Want et al. [18] have contemplated a distributed compressed sensing scheme to restore sensor data at the fusion center and data aggregation process to reduce the communication cost with extended network life.

M) Energy Efficient Intra and Inter Cluster

Nitin Goyal et al. [19] have recommended two algorithms for clusters communication. The fuzzy logic approach is used for identification of CH and cluster size in an optimal way. The algorithms MARPCP, HMR-LEACH were used in Intra-cluster & Inter-cluster communication respectively. The data delivery delay, power consumption and delivery ratio results were improved with these algorithms.

N) Self Healing Algorithm

Huang et al. [20] have described the new topology pattern for identification of cluster head. Here, the process is reconstructed every time and new cluster head is selected based on position, energy. Self Healing mechanism was used to recover the network link. This had also enhanced the robustness of CUWSNs.

COMPARISON OF VARIOUS DATA AGGREGATION WITH CLUSTERING

The outcome of the literature study is the experiences of the research scholars who had already explored the Underwater Wireless Sensor Network are tabled for ease of comparison and comprehension.

S.No.	Proposed Data Aggregation Process	Authors	Type	Achieved	Opportunity for further study
1	Round Based clustering	Khoa Thi-Minh Tran et al., 2014	Euclidean Distance	High Throughput, Low Energy consumption	Collisions is occurred, Delay broadcasting due to round initialization
2	Efficient data aggregation approach	Tran K. T. M et al., 2013	Euclidean Distance, Cosine Distance	Reduced the packet size and minimized the data redundancy	-
3	K-Means and ANOVA Based	Hassan Harb et al.,2015	Spatial Similarity Enhanced K-Means and ANOVA	Data redundancy is reduced, Network life time is extended	Schedule that the Sensor node is no active, whenever the redundant data is generated
4	Well-suited similarity functions	Khoa Thi-Minh Tran et al., 2013	Euclidean Distance, Cosine Distance	Lossless Data process, Better energy consumption	Combination of similarity functions with protocol to implement high performance
5	Comparative analysis of similarity functions	Oh S.H et al., 2013.	Euclidean Distance, Cosine Distance, Jaccard and Hamming Distance	Minimized the data redundancy, and loss of packets	Optimal Clustering, data integrity is needed
6	Energy efficient compressed data aggregation	Hongzhi Lin et al., 2015	compressed Sampling	Reduced the number of sampling nodes and energy consumption	Packet Losing and Collision is occurred due to random sensing that could be modified
7	Optimal Clustering in UWSNs	Sadanand Yadav And Vinay Kumar,2017	Optical, electro-magnetic and acoustics	In acoustic, the optimal number of clusters can be achieved	Magnetic Induction Model may be used
8	Random Access Compressed Sensing	Fatemeh Fazel et al.,2011	Compressed Sensing and Random Selection	Efficient energy and Bandwidth	Downlink Feedback is not synchronized and could be taken up for synchronization
9	Distributed Underwater Clustering Scheme	Domingo, M.C., Prior, R., 2007	Energy-aware Protocol	High Packet delivery ratio, reduced the data redundancy	The essential features of DUCS can be applied in routing protocol

10	Fuzzy Based Clustering	Sihem Souiki et al., 2015	SH-FEER, MH-FEER algorithm	Promising performance in terms of energy consumption and network lifetime	Genetic algorithm or ant colony could be used to find the shortest path
11	Improved Data Aggregation Technique	Nitin Goyal et al.,2017	Sleep-Wake and TDMA Scheduling	better performance in terms of packet drop, end-to-end delay and energy consumption	Delay time is increased that could be tackled appropriately to decrease the delay time
12	Energy Efficient Distributed Compressed Sensing	Deqing Wang et al., 2016	Distributed Compressed Sensing, BUTM-DCS, BDM-DCS	Communication cost was reduced	Number of Transmission is occurred to be controlled
13	Energy Efficient Architecture for Intra and Inter Cluster	Nitin Goyal,Mayank Dave, Anil Kumar Verma,2016	MARPCP, HMR-LEACH	The data delivery delay, power consumption and delivery ratio results were improved.	Collision in Intra and Inter-cluster to be minimized
14	Self Healing Algorithm	Chenn-Jung Huang et al., 2010	SHC Algorithm	Better performance in throughput	It may be extended to address the Volcanic eruption, underwater currents etc.,

ISSUES AND CHALLENGES

Based on current research work in UWSN routing protocols, it is clear that the following issues are yet to be solved.

1. Protocols and algorithms are needed to take care of connection failures, unforeseen mobility of nodes and battery depletion.
2. Design of efficient routing protocols that balance between the nodes energy and the communication overhead; is to be carried out.
3. The aggregation process should be liberated from blockage and congestion.

CONCLUSION

In this review, architecture, protocol and data aggregation concept in UWSNs explored by various researchers are addressed. The routing protocols in UWSNs are discussed along with the data aggregation techniques with cluster based approach to increase the through put, reduce the energy, minimize the data redundancy and also to enhance the life of the network. The various existing data aggregation techniques with cluster based is presented in a table form. The problem faced by the researchers of data aggregation with cluster based approach in UWSN is identified.

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