International Journal on Applications in Basic and Applied Sciences
Volume 5 : Issue 1: December 2019, pp 8 – 14 www.aetsjournal.com ISSN (Online) : 2455 - 1007

ROBUST DATA COLLECTION WITH MULTIPLE SINK ZONE IN 3-D UNDERWATER SENSOR NETWORKS

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Abstract— An Underwater Wireless Sensor Network has diverse characteristics as compared to those of a terrestrial one. The Autonomous Underwater Vehicles used to collect a sensed data from a sensor node, based on a user defined path. The Multiple Sink Zone in 3-D Underwater Sensor Networksis used to get a spatiotemporal solution and also it provides robust Data Collection. Contribution of Multiple Autonomous Underwater Vehicles supports an application of multiple-sink Mobile Geocast Routing Protocol for Underwater Sensor networks and also they congregate a large number of sensor events or phenomena within a short time. Aquasim an NS-2 based simulator used to analysis many number of parameters, they are network throughput and packet delivery ratio, Successful delivery rate, Power Consumption, MessageOverhead.

Index Terms: Underwater Sensor Networks, Mobicast routing, Autonomous Underwater Vehicles.

I. INTRODUCTION

Wireless communication through the ocean is one of the technologies empowering the development of approaching ocean scrutiny systems and WSN is playing a vital role in achieving it.Figure 1.1 demonstrates the Underwater Sensor Network Model. The Sensor nodes in an underwater locationdeployed for cooperatively monitoring the ocean environments. To collect the sensed data at sink node and to communicate with the sensor nodes, because of harsh environments the underwater sensor network uses the acoustic communications. Acoustic signal is the only communication medium that might work well in underwater environment. Compared to RF communications in terrestrial wireless sensor networks the sound has better dissemination characteristics in ocean environments, hence it is the most adopt proficiency for underwater communications. The USNs differ from the terrestrial wireless sensor networks in a variety of ways [3][4], such as Communication mode, Power, Expenditure, Deployment, Node Mobility, Memory, and Spatial Correlation.

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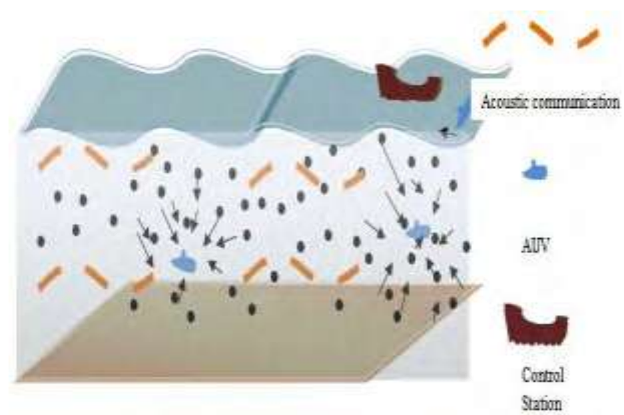

Figure 1.1 Underwater Sensor Networks

The primary threats in the formation of underwater acoustic networks are as follows [3]:

- The solar power cannot be utilized because the battery powers in USNs cannot be rechargeable.
- The marine environments consists extremelylowbandwidth.
- Due to Ocean Current effect the network breakages are occurred.
- The Underwater Sensors are high cost because it needs extra protective sheaths and only limited suppliers.
- Long and variable propagation delays, fading and multi-path problems are occurred inUSNs.
- Sensors in Underwater environments are prone to failures because of fouling, corrosion,etc.
- High Bit errorrates.

To communicate with sensor nodes the AUV is equipped with communication devices. To collect data from sensor nodes based on spatio-temporal is one of the major issues in USNs. Hence, the spatiotemporal solution for Underwater Sensor Networks is used to maximizing the data collection while reducing the power consumption. Because of critical challenges of Underwater Sensor Networks, the data collection and power savings are most important concerns. The Mobicast or Mobile Geocast is used to deliver data with spatiotemporal paradigm, which is suitable for AUV to collect the sensed data from sensornodes.

The AUV or Mobile Sink is continuously collect the sensed data from the sensor nodes deployed in marine environments based on route path which is defined by the user and finally report the sensed information to the control station within short route path [5]. It is more crucial to prolong network lifetime for USNs when compared with terrestrial sensor networks [6].The network lifetime is improved by utilizing the Autonomous Underwater Vehicles. Especially, in 3-D USNs the network lifetime is one of the important factors to measure the performance of the Underwater Sensor Networks. The AUVs can travel at any depth in an ocean environment to collect a sensed data and it enhances the capacities of Underwater Sensor Networks. In last few years, the usage of AUVs in USNs enhanced in many ways.

One of the foremost challenges in Underwater Acoustic Sensor Networks is to provide the efficient Data Collection. The user defined a path to efficiently collect the data and minimizing the travel time. Hence, one of the main problems for efficient data collection in Underwater Sensor networks is to endow with an appropriate path. The scheduling protocols [7] are simulated to find out the best Routing Path Algorithm to improve the data collection while minimizing the AUV travel time. The Underwater Data Collection Using Robotic Sensor Networks [8] uses the Communication Constrained Data Collection Problem (CC-DCP) which is directly associated with the Travelling Salesman Problem and it provides an AUV path planning algorithms to improve a performance of multi-nodescommunication.

To achieve the purpose of the reliable data collection, an AUV is usually used to effectively collect the sensed data from sensor nodes [9]. Because of Ocean current effect, network disconnection is occurred in USNs. In multiple UUV-Approaches [9], the multiple underwater unmanned vehicles used to enhance the network connectivity. In this Approach , the underwater vehicles deploy more sensors to repair the network disconnectivity and also it can serve as local sinks to sensors in the isolated partitions, and ferry the data from the isolated sensors to the nearest connected part of the network. The Multiple mobile data collectors [10] are introduced to maximize the network life time. Integer Linear Program (ILP) used to find the optimal placement of data collectors and with multi-hop routing paths to transfer information from sensors to datacollectors

The Mobicast Routing Protocol [11], is the first Mobicast routing protocol for underwater sensor networks and the main aim of this paper is to triumph over the hole problem, diminishing the energy consumption whereas exploiting the data collection. This protocol is well suited for AUVs to collect the sensed data with spatial and temporal solution. Here, the AUV continuously collect the sensed data from the series of 3-D spherical region based on the user-defined direction path. The main problems in this paper is efficient data collection because the sensor nodes usually is in sleep mode and waking up of sensor nodes in the next 3-D region while providing notification messages to reduce power consumption and network disconnection. In Mobicast Routing Protocol, the Autonomous Underwater Vehicles (AUVs) continuously collect the sensed data from the sensor nodes in underwater environments even if it is drifted by the ocean currents. The ocean currents driftedthesensornodesandalsoitcausesanetworkfrag mentationorholeproblem.Theapplesliceisusedto secure the routing path stability by building the several segments and also solve the hole problem or network fragmentation.

The mobile Sinks data collection route is designed as a whirlpool motion track[12].The underwater sensor nodes are immobile. The sink moves on a particular planned path, stopping at various datacollection points, using one hop communication to gather data from the nodes, recording the node IDs, and moving on until it completes the Data Collection cycle that is collecting data from all the nodes in that specific geographical region.

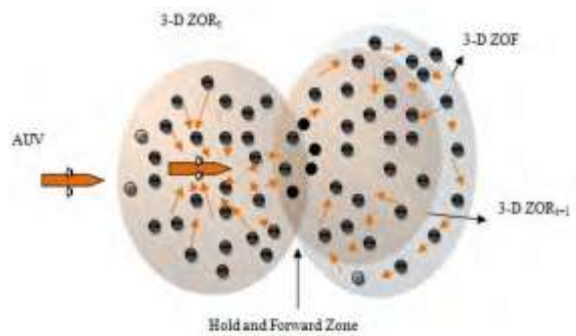

FIGURE 1.2 Mobicast Routing Protocol Model with single AUV

Sink stops by a fixed data collection point[14], broadcasts Communication Requests in the form of a hello packet which is also a wake-up call for the nodes in the sleep mode. The sink then waits for the reply from the nodes within the range. The Node on receiving the Hello Packet becomes active and verifiesthereceivedpacket.Onsuccessfulverification,itsends an Acknowledgment packet declaring it is active. Underwater node starts sending data, and sends an EOT packet when it is done. As soon as the Sink receives an EOT, it ends the session and records the Nodes ID and related Metadata.Scenario has also been considered, where unplanned data gathering points and route are considered using any random motion paths.

II. SYSTEM MODEL

By enumerating multiple AUV in Mobicast routing protocol, this paper supports the applications of multiple mobile sink mobicast routing protocol and collecting data by Whirlpool method in underwater sensor networks environments and also enabling communication of large number of sensor nodes within in a short interval. Here, the Underwater Sensors are randomly deployed in 3-D Underwater Sensor Networks environments. The Sensors in Ocean bottom cannot sufficiently sense some phenomena, hence the 3-D [4] are used to observe those phenomena by performing mutual sampling of the 3-D underwater environments.In order to detect a given phenomenon, the sensor nodes in 3-D USNs float at different depths. In this paper, we proposed a multiple AUV in mobicast routing protocol and whirlpool method to collect data, which is used to provide an application of multiple sink mobicast routing protocol and robust data collection for Underwater Sensor Networks environments.

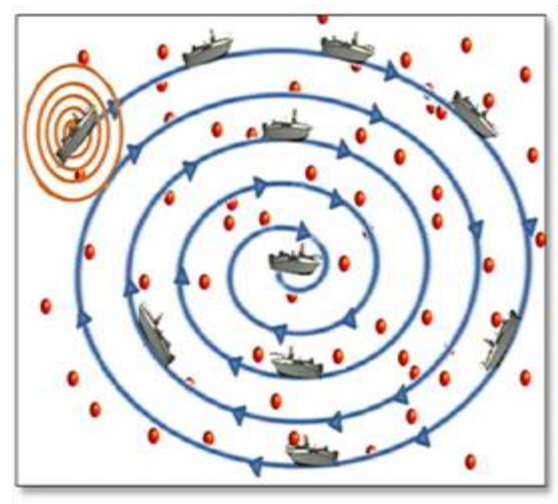

FIGURE 1.3 Whirlpool Data Collection Path

The AUV is normally equipped with sophisticated communication tools, more resources like memory storage, communication relays, etc. Here, the multiple AUVs are used to gather the sensed information from the sensor nodes available in 3-D underwater environments and the user defined routing path, phenomena need to collect data from sensor nodes for every AUV used in 3-D Mobicast routing protocol for Underwater Sensor networks.

The AUVs continuously create the 3-D Zone of Relevance [11] and used to gather the sensed data from the sensor node located only in the 3-D Zone of Relevance. The AUV ferry the sensed information from the corresponding sensor nodes. The spatiotemporal character of a mobicast is to collect the sensed data from sensor nodes that will be present at time t in the 3-DZOR, where both the location and shape of the 3-DZOR are a function of time over some interval (t_{start}, t_{end}) Assumed that an AUVs travels a circle path around a given observed areas. The AUVs constructs a series of 3-D ZORs over different intervals (t_{start}, t_{end}), and only sensor nodes located in the 3-D ZOR at the time interval (t_{start}, t_{end}) must wake up to send sensed data to the corresponding AUV. It is observed that 3-D ZOR is evolved and continuously moves with the AUV over time. To save power and send sensed data to the AUVs, sensor nodes in 3-D ZORs must be woken up and kept in the active mode to wait for the arrival of AUVs. The AUVs cannot successfully receive the sensed data in time if sensor nodes in 3-D ZORs are still in the sleep mode.

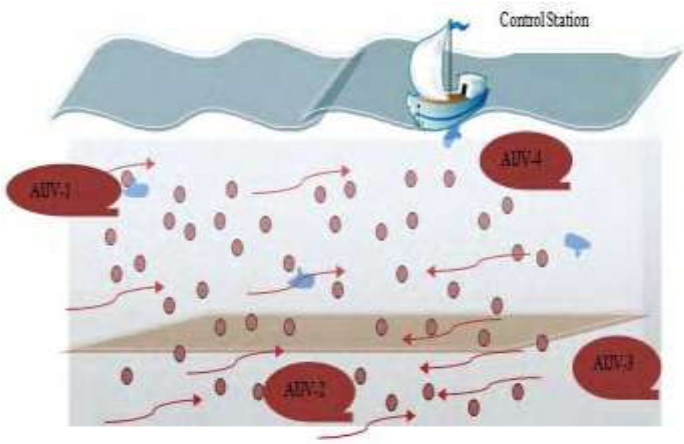

FIGURE 1.4 Multiple AUV for 3-D Underwater Sensor Networks

This problem is more serious in USNs because that propagation delay of USNs is larger than that of WSNs. A excellent mobicast routing protocol in USNs must alert the sensor nodes in 3-D ZOR at time *t*, even if there is hole problem and the ocean current effect. The specific characteristics of USNs, such as low communication bandwidth, huge propagation delay, and ocean current are significantly different from wireless sensor networks (WSNs). To think about the specific features of USNs, a new mobicast routing protocol is developed in 3-D USNs [11]. The major design challenge is to develop a power-saving mobicast protocol in 3-D USNs to overcome the unpredictable 3-D hole problem. A “apple peel” scheme of the mobicast protocol is proposed to solve the unpredictable 3-D hole problem.

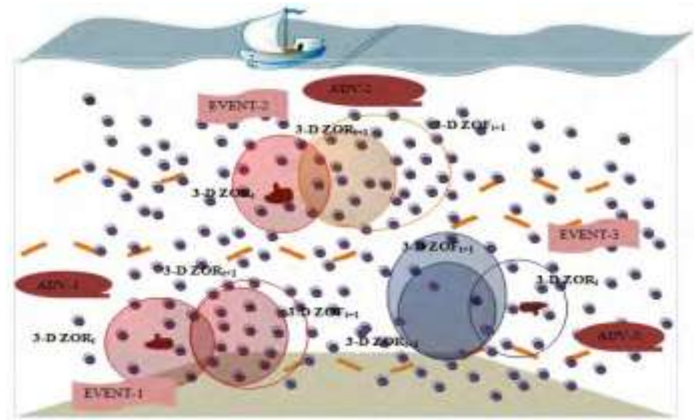

FIGURE 1.5 Multiple AUV for 3-D Underwater Sensor Networks with 3-D Sink Zone Formation

The 3-D ZOF_{t+1} is a spherical forwarding region created by every AUV at time t and this region has the responsibility to transfer a mobicast messages for all sensor nodes in 3-D ZORt+1(3-D spherical region at time t+1).The 3-D ZOF_{t+1} cover the region of 3-D ZOR_{t+1} for to wake up all sensor nodes while AUVs approaching to ferry the sensed data and assured the routing path continuity for mobicast message delivery. Therefore, to determine the size of the 3- D ZOF_{t+1} and there are two ways to determine the size of 3-D ZOF_{t+1}[11].

1. Larger in size of 3-DZOF_{t+1} over come the hole problem and it leads to higher successful delivery rate,
2. Smaller in size 3-D ZOF_{t+1}cannot cover the hole problem and unsuccessful to wake up all the sensor nodes in 3-D $ZOR_{t+1.}$ 3-D ZOF_{t+1} should be capable of sending the wake up message to all the sensor nodes in 3-D ZOR_{t+1}.

Hence, the 3-D ZOF_{t+1} size is determined based on the drifted distance of sensor nodes by calculating the velocity of ocean currents and the network density. If the larger number of sensor nodes is drifted by ocean currents the size of 3-D ZOF_{t+1} is enlarged up to cover all the sensor nodes in 3-D ZOR_{t+1} . The second method is used to determine the number of sensor nodes needed to transfer the mobicast notification messages. Hence, the “**Apple slice**” is used to determine the number of sensor nodes by divide the 3-D ZOF_{t+1} into numerous parts. The individual segments of ZOF_{t+1} are extended based on the sensor nodes drifted by oceancurrents.

As different routes or collection paths will bring about varied amount of energy being consumed during data collection from the deployed sensor nodes therefore the collection route must be planned cautiously in order to save as much energyas possible. In the proposed whirlpool method, the collection route design is laid on the following rules: The mobile Sinks data collection route is designed as a whirlpool motion track as shown in the figure 4. Mobile Sink is supposed to move on a carefully decided, premeditated route and select its next destination via the preloaded (saved) Tabular data. The route is designed such that it provides good area coverage, without leaving any nodes data uncollected. On the other hand, for comparison purpose, Randomor Unplanned Data Collection.

III.MULTIPLE AUV-MOBICAST ROUTING PROTOCOL

In Multiple AUV-Mobicast Routing Protocol, the multiple AUV incessantly generate the spherical region for every time interval based on the phenomena and route path provided by the user. Every individual AUV transfers the mobicast messages to the corresponding 3-D $ZOR_{t.}$ Besides, the sensor nodes belong to that 3-D ZOR_t might send the sensed data to the consequent AUVs. The AUVs ferry the same or different phenomenon or events data which is defined by the user. At the time of collecting the data from 3-D ZOR_t ,the AUVs create the 3-D ZOF_t which is used to transfer the wake up messages to the sensor nodes located at 3-D ZORt+1.The unpredicted hole problem and ocean currents are solved by the Apple Slice technique. In Multiple AUV the main problem is that the sensor nodes have a chance to receive wake up message from different AUV for different phenomena. To avoid that overlapping of requests, AUV send the AUV id and event id with mobicast message. Then, before sending the observed data to AUV, the sensor nodes verify the AUV id and event id, if it is same as for corresponding AUV and transfer the data.

The Multiple AUV-Mobicast Routing Protocol consists of three phase:

1. Creation and Notification Phase
2. Hole Problem ReductionPhase
3. Data Collection Phase

In Creation and Notification Phase, the AUVs create the corresponding 3-D $ZOR_t$and transfer the mobicast messages to all the sensor nodes in 3-D ZOR_t before some interval of time. While the AUVs approaching the sensor nodes in 3-D ZOR_tUSNs for the sensed result the AUVs must wake up. And the second phase is Hole Problem Reduction Phase, here the 3-D ZOR_{t+1} and 3-D ZOF_{t+1} is created by the Multiple AUV to avoid the unpredictable hole problem. At time t, the AUVs collect the sensed data from sensor nodes in corresponding 3-D $ZOR_{t,}$ at the same time the AUVs create the 3-D ZOR_{t+1} and 3-D $ZOR_{t+1.}$ The 3-D ZOF_{t+1} isused to wake up the sensors located in the 3-DZOR_{t+1} USN sat timet.The Apple slice technique is applied in every 3-D ZOF_{t+1} to avoid the unpredictable hole problem. In Data Collection Phase, the every AUV collect the data based on the phenomena or events which are defined by users.

ALGORITHM:

A. Creation and Notification Phase:

Step 1: The AUVs and Sensors acquire the position based on range based or range-free localization techniques [12]. AUVs constantly create the 3-D ZOR^3 for to ferry the data from sensor nodes located in that 3-D $ZOR_{t.}$ And the 3-D ZOR_t is created based on the following formula [11].

$$Z_t\,(N_i) = (x_i\text{-}x_a)^2 + (y_i - y_a)^2 + (z_i\text{-}z_a)^2 - R^2 = 0$$

Step 2: Each AUV transfer the mobicast message Pm ($R_{id,}E_{id}$, N_i, Zt (N_i), m, r, VA) [11] to the sensor node which is needed to observe the given phenomenon. Where R_{id} is the id of AUV, E_{id} is the id of events or phenomena given by user.

Step 3: After sensor nodes woke up, it verify the following conditions.

if ((Z_t (N_i) ≤0 & (($R_{id,}E_{id}$ (received by individual sensor nodes)) = ($R_{id,}E_{id}$ of individual AUV))

Step 4: When above conditions is satisfied the sensor nodes transfer the observed data to the AUVs at time t and at the same time the AUVs create the 3-D ZOR_{t+1} and 3-D$ZOF_{t+1.}$

B. Hole Problem Reduction Phase:

Step 1: While collecting the data from the sensor nodes in 3-D $ZOR_t$the AUVs transfer the mobicast message to the 3-D ZOR_{t+1} by hold and forward zone. And also the 3-D ZOF_{t+1} transfer the wake up messages to the sensor nodes located in 3-D ZOR_{t+1} to avoid the unpredictable hole problem[11].

Step2: Theappleslicetechniqueisusedtotransferthe messagestoallsensornodesinsphericalregionattime t+1 even if it is drifted by the ocean currents[11].

C. Data Collection Phase:

Step 3: After sensor nodes at 3-D ZORt+1 woke up by the above steps, it verifies the following conditions.

if ((Zt+1 (Ni) ≤0 & ((Rid,Eid (received by individual sensor nodes in 3-D ZORt+1)) = (Rid,Eidof individual

Step 4: After satisfying the above conditions the sensor nodes at 3-D ZORt+1 transfer

the sensed data to the AUVs

IV. PERFORMANCE METRICS

A. Successful deliver rate:

Number of nodes located in ZOR_{t+1} which can successfully receive the mobicast messages and wake up, divided by the total number of nodes in $ZOR_{t+1.}$

B. Power Consumption:

The power consumed by all sensor nodes in USNs.

C. Message Overhead:

Total number of packets that all sensor nodes transmitted, including the control and mobicast messages, divided by the minimum number of packets used in our mobicast protocol.

D. Average Delay time:

The total delivery delay time divided by the total number of nodes in $ZOR_{t+1.}$

E. Throughput:

The total number of data packets which the AUV receives from sensor nodes in ZOR_{t+1} per second.

V. SIMULATION

Our paper presents the Multiple-AUV Mobicast Routing Protocol in Underwater Sensor Networks. The Aqua-sim (ns2 simulator) [13] and Aqua3-D emulator used for to simulate our routing protocol. The Aqua-sim is one of the ns2 based simulator used for 3-D Underwater Sensor Networks and effectively simulates the Underwater Acoustic channels. Our simulation consists 1000 of sensor nodes, and these nodes are deployed in 3-D Underwater Sensor Networks. The Communication range of AUVs and all Sensor nodes are 10 and 5 units respectively. The AUVs collect the sensed data with interval of 10seconds.The Power consumption of sensor nodes in sleep mode, transmission and receive mode are 8mW, 2W, 0.75W.

VI. CONCLUSION

In this paper, we present a Multiple Mobile-Geocast Routing Protocol for supporting the applications of Multiple AUV based Whirlpool Data Collection Path with spatiot emporal solution in 3-D Under water Sensor Networks. The AUVs are continuously creating the 3-D $ZOR_t$for efficiently collect the data with lower power consumption and the simulations may demonstrate the performance analysis in terms of Throughput, Average Delay time, Message Overhead, Power Consumption, Successful delivery rate.

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