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Enhancing the Lifetime of Underwater Wireless Sensor Networks

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Abstract— There is no denial in the fact that a huge portion of the underwater world whether its seas, oceans or rivers not been explored yet. In recent year, researchers are finding ways to explore and study the underwater resources. Underwater wireless sensor networks, developed for gathering information from the undersea environment. Due to the undersea environment features, enhancing the network lifetime is a significant object. In this paper a 3D node deployment strategy, an algorithm for relay node setting in underwater wireless sensor network (UWSN) with enhancing performance of routing in underwater wireless sensor network has presented. The 3D node deployment strategy targets 3D UWSN and not only improves the routing protocol performance in terms of end-to-end delay and energy consumption but also provides reliability in data transmission and increases network lifetime. For fixing a relay node in an appropriate place, an algorithm which is named Relay Node Setting Algorithm (RNSA) that works in a 3D UWSN has presented. The proposed algorithm for improving the network lifetime, upon entry the relay node, finds an appropriate place for it. Routing protocol performs route discovery and route maintenance phase which tries to minimize the network data and packet collision.

***Keywords*— Underwater Wireless Sensor Networks, Network Lifetime, 3D Node deployment, relay node, routing techniques.**

I. INTRODUCTION

The importance of water resource is highly concerned. Earth covers 70% of water, so there are plenty of resources still untouched. Underwater wireless sensor network have been developed for monitoring environmental events, undersea exploration, seismic monitoring, etc. Therefore, it's needed to monitor, search and manage the water resource. To support these applications, reliable network is required. Because of the characteristic of underwater network such as low propagation speed, high delay, high bit error rates and limited power. UWSNs nodes are deployed widely in underwater. An underwater sensor network is a composition of a group of sensor nodes anchored to the sea bed which are connected to other underwater gateways by acoustic links. The signal shared at each sink within cluster is sent to surface stations through a vertical link. The surface station with the help of acoustic transceivers handles multiple parallel communications with the sinks deployed under the water. The network lifetime is presented by the battery source and power that consumes each sensor node (SN).

In an underwater environment, exchanging the battery is hard, therefore, reduction the energy consumption of each node is an efficient way to increase the network lifetime. The power consumption of nodes for transmission is a nonlinear function of the distance between them, hence, the solution for decreasing the power consumption is to shorten the distances. The place of SNs cannot be changed, when fixed in the network. In this topology, the distance between some SNs may be large, so the transmission between them will be deficient and the network lifetime will be short. In order to make the short distance between SNs and subsequently increase the network lifetime, the solution is adding some additional nodes which are named relay nodes (RNs).Routing protocol ensures reliable data transmission from the source node to the destination node. The performance of a sensor network highly depends on efficient forwarding of sensed data from the source to the destination node. This is a highly challenging goal to achieve in underwater environment. Sensor nodes communicate wirelessly, mainly by means of acoustic waves, hence there is high propagation delay, limited bandwidth capacity and high error probability as compared with radio wave communication. In addition to this, limited battery supply, three-dimensional (3D) underwater environment and dynamic behavior of sensor nodes due to water current makes the overall performance goals even more difficult to achieve.

II. RELATED WORK

In the last few years, much research work has been done on the networking layer of UWSNs. There are a number of routing protocols being developed. Some of them claim to consider 3D network configuration in the future work. The flooding based routing approaches for UWSN (such as VBF[1], FBR [2], DBR [3], H2-DAB[4], SBR-DLP [5] and others) are simple at computation and have acceptable end to-end delay, low processing overhead and can be utilized for delay sensitive applications [6]. However, the energy consumption in duplicate transmission, congestion and channel sharing remains a problem [7]. This has been tried to be overcome by some specific individual approaches in each protocol to some extent. However, the existence of Void regions and changing network configuration limits this approach. Some of flooding based approaches involves localization, another energy overhead, as the network configuration is constantly changing with water. Hence localization is an issue in itself for UWSNs.

The protocols utilizing multi-path transmission (such as MVSA [8], RRA [9] and REBAR [10] etc.) compared to flooding based approaches offers acceptable reliability, energy efficiency, low end-to-end delays, less congestion and interference but more computation is involved in maintaining more paths [6]. Therefore, efficient solutions are needed to avoid repetitive transmission. In addition, the changing network configuration has been completely ignored and this will cause loss of connectivity in randomly deployed sparse network [7].

In [11], [12], the RNs is added to the network for providing a connected network. In some works such as [13], the RN setting is based on the provision fault tolerance in the network by constructing the k-connected network. In [14], [15] the goal is setting the minimum number of RNs for various demands in WSNs. For example, in [14], the authors proposed a density function for relay node setting to balancing energy consumption in the network. In [15], with minimum number of relay nodes, the k-connected network is constructed. For decreasing energy consumption in 3D UASN, a greedy routing is proposed in [16]. In order to increase the network lifetime of the 3D UASN, the authors in [17] have proposed a bisection algorithm for setting RN in the network, that the x-y and z coordinate of each RN is determined separately, hence the location of each RN becomes suboptimal.

G.L.Saini at AODV uses solitary route reply along overturn path. E-AODV route detection succeeds in smaller amount tries than AODV [18]. Acoustic signals also have limited bandwidth delivering data rates. Coupled with low data rates, the long propagation delay makes UASNs a challenged network compared to its terrestrial counterparts [19], [20].

III. 3D NODE DEPLOYMENT STRATEGY

In the 3D node deployment strategy, the main direction of communication is vertical from sea bed to sea top unlike terrestrial WSN adopted designs which normally consider horizontal direction of communication. In sea, the sensed data from under the sea is required to travel to the base station which is located at the sea top. Hence, the preferred path of data flow is vertical from sea bottom to sea top. A Vector Based Forwarding (VBF) [1] used as a baseline routing protocol. It is a well known routing protocol in the UWSN research community. In VBF for the data packet delivery a virtual pipe around the vector from the source node to destination node is formed and the packet is forwarded to the nodes within that virtual pipe. Here we used 3D node deployment strategy.

We used Aqua-Sim [21] . It is an extension of the popular ns-2 simulator which is extensively used among the networking research community. A variable number of sensor nodes in 3D configurations to observe the network performance and finally propose a 3D node deployment strategy for efficient network performance. We consider an underwater volume of 500×500×500m3 and deploy variable number of sensor nodes. Each of these sensor nodes has 10000 joules initial energy, 2 Watts transmit power, 0.75 Watts receive power and 0.008 idle power consumption [23]. Each sensor node is equipped with an omnidirectional antenna of 100m range with spherical spreading. The data packet size is 50 bytes and the bit rate is 10kbps.

IV. RELAY NODE SETTING

The main goal of RN setting in a 3D UWSN is increasing the network lifetime. Since the lifetime of total network specifies by the node which has the minimum lifetime, therefore, increasing its lifetime, increase the total network lifetime. For this reason, the solution is reducing the power consumption of that node with the minimum lifetime. Hence, here the RNSA algorithm is introduced to appropriate RN setting:

Step1: Across whole nodes in the network, the node which has the minimum lifetime should be selected and characterized by *s.* This node is the bottleneck of the network and its lifetime will be increased in the RNSA algorithm.
Step 2: Across whole adjacent nodes of node *t*, that are exist in its transmission range, the node which exists in the largest distance of node *s* should be detected and characterized by *t*. In order to shorten the distance between node *s* and *t*, the relay node *r* should be placed between them. The coordinates of *r* assign in the next step.
Step 3: In the last step, appropriate place of the node r for increasing the network lifetime should be specified. For this goal, we consider two criteria:

- First, since the RN is added to the network for increasing the lifetime of node s, it should be closer to the node *s* than node *t.*

- Second, the lifetime of the node *r* should be considered.

V. ROUTING PROTOCOL

In this section, a low overhead routing protocol for underwater network is discussed. The protocol tries to reduce the control overhead in route maintenance technique than existing routing protocols. The routing protocol is compared with the two most popular techniques in the reactive category i.e., AODV and DSR [24]. Since a low overhead routing protocol is based on reactive protocol, it consists of two operations: route Discovery and route Maintenance. The route discovery process is similar to that of AODV. The protocol has a fixed length header and every operation is maintaining the same length format. The protocol has 3 types of operational message at the moment Route Request, Route Reply and Route Alive. Route Request and Route Reply are used for Route discovery while Route Alive is optional message which serves two purposes; (i) it is used to check route alive process and (ii) helps for route recovery process. The route maintains is similar procedure as that of AODV and DSR. Communication in the network layer is performed by using the Internet Protocol Suit, where each layer provides a well-defined service to the immediate layer. The routing protocol operates at the Network Layer. Low overhead routing protocol can avoid the problems with existing route maintenance procedures by monitoring traffic flow at the network layer. Moreover, the route is maintained at the source node and the destination node to concern about route maintenance. The low overhead routing protocol, its avoid the need of neighbour maintenance with periodic messages or executing the NHDP protocol separately. Its avoid the timer maintains for individual entries in the routing table as done in AODV and DSR. Then it does not have separate route recovery mechanism.

VI. RESULTS AND DISCUSSION

The plots of Figure below show a comparison of the results of Test 3D and Test Rand as a function of data packet size. These plots give a picture of how the data varies in 3D environment for proposed 3D node deployment strategy and the random node deployment strategy. Figure 1(a) shows that the total energy consumption for Test Rand is almost 25% more than Test V initially and after that the energy consumption in Test Rand drops and becomes non linear. This difference in energy consumption will have a high impact in regions Figure 1: Simulation results comparison for Test 3D and Test Rand. (a) Total energy consumption (b) Total end-to-end delay, where there is no back-up path available which means if one node dies there will be loss of connectivity in that particular region. The nonlinearity in the graph indicates packet loss due to congestion and no alternative back-up paths available. This implies that the random node deployment, under the boundary conditions to provide connectivity from the source node to the sink node may provide connectivity but will have a serious impact on the reliability of data transmission by having no alternative paths for some of the sensor nodes. If one (or more) of those critical sensor nodes runs out of battery, the communication will be interrupted and there will be loss of data. Whereas for the total energy consumption in Test V we only get a nonlinear plot but there is no depreciation in the graph. This shows that for larger data packet size there will be congestion, bottlenecks and retransmissions but no packet loss as there are sufficient alternative paths available for the transmission of data in Test 3D.

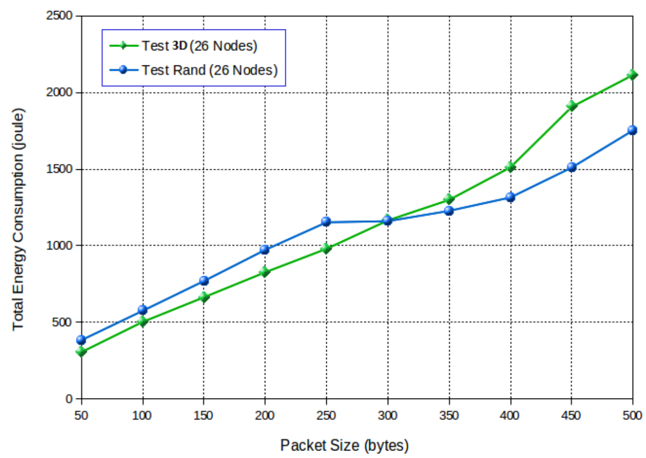

Figure 1a: Total energy consumption

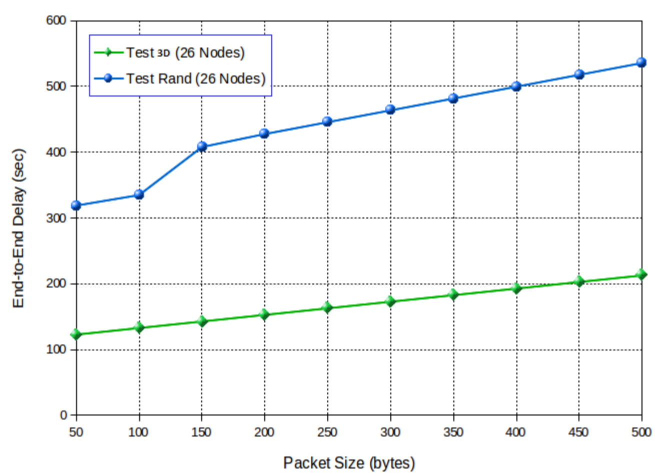

Figure 1b: Total end-to-end delay

The 3D node deployment strategy in Test 3D ensures reliable communication of data. Basically, by providing additional data forwarding paths by adding the Reliability Nodes. This 3D node deployment strategy not only increases the reliability of the overall communication it also increases the lifetime of the network by reducing the energy cost per node for reasonably large data packet size. This means that there will be back-up forwarding nodes available if the main forwarding nodes fail or drain their energy. It is seen in Figure 1(b) that random node deployment in 3D adversely affects the end-to-end delay, where as our 3D node deployment strategy ensures significant decrease in end-to-end delay.

In order to increase the network lifetime, RNSA algorithm decides about the place of each RN for all coordinates. The bisection algorithm in [22] is looking for a candidate RN for adjusting its depth, thus, improvement the network lifetime isn't guaranteed, certainly. For this reason, it is expected that the network lifetime in our proposed algorithm is more than the proposed method in [22].

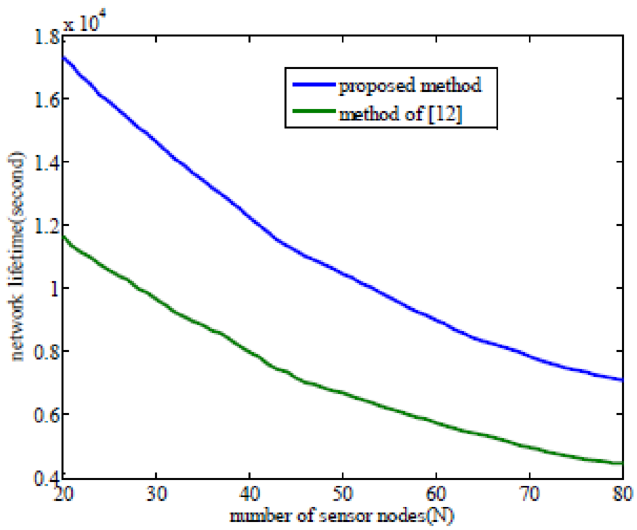

Fig. 2: Network lifetime result in two approach

"Fig. 2" shows the network lifetime. It is seen, the lifetime of proposed algorithm is more than the bisection algorithm in [12]. It is also observed that, by increasing the SN number, the network lifetime decreases, because when the number of SNs increases, the data generated in the network and hence the power consumption will be increased.

Since AODV is busy with route re-discovery, it generates more and more routing packets and these packets start to collide with data packets and with each other. Since LOARP routes do not time out automatically, it able to store routes for a longer time.

V. CONCLUSION AND FUTURE SCOPE

In this paper a 3D sensor node deployment strategy, relay node setting, routing protocol has been presented, after careful consideration of the unique characteristics of underwater communication and specific features of UWSN. 3D sensor node deployment strategy establishes full sensing, communication and back-up coverage of the monitored region. It ensures reliable data communication and improves the routing performance significantly in terms of end-to-end delay and energy consumption. Here reliable 3D sensor node deployment approach used instead of random node deployment schemes adapted from terrestrial WSN. This approach improves the networking protocol performance significantly as revealed by the results. In 3D underwater environment it is extremely difficult to ensure full sensing as well as communication coverage and reliable transmission by random node deployment strategies. However, this has been achieved by 3D node deployment strategy, providing several back-up paths to combat dynamic network configuration and node mobility in an UWSN. This strategy targets 3D UWSN and can be embedded with other routing protocol designs to improve their performance. Investigated has made for setting RN problem for enhancement the network lifetime of a 3D UASN. We have proposed an algorithm, that under three steps and by suggestion a cost function has tried to find an appropriate place for RNs.

The low overhead routing protocol, is proposed and its performance is compared with two most popular protocols (AODV and DSR) in the reactive category. LOARP perform better than two protocols in terms of throughput, packet delivery ratio, end-to-end delay and control overhead. In order to improve the performance of LOARP, other protocols should be explored.

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