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# A Survey of Underwater Acoustic Sensor Network using R-MAC-MAC Layer Protocol and VBF-Routing Protocol

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## Abstract

**Objectives**: Under-Water Sensor Network (UWSN) has many potential applications. For these applications it is necessary to have efficient and reliable communication. For efficient communication we need to develop efficient networking solutions to overcome the underwater environment challenges. **Methods**: To develop efficient solutions for networking we require to understand the potential applications for the underwater sensor network it is also necessary to understand the limitations of the environment. It is also essential to understand different architectures that are there in UWSN. Using these information's, we have designed a network with 6 nodes and simulated it using Aquasim software. We have selected one specific MAC layer and network layer protocol. For this we have simulated for the Packet Delivery Ratio (PDR), throughput and energy consumption parameters. **Findings**: Paper talks about the 2D UWSN architecture, the challenges in the implementation of UWSN, the MAC and Network layer used. We can anticipate the general energy consumption, through put and PDR for this combination of Radio Multiple ACcess (RMAC) and Vector-Based Forwarding (VBF) protocols. This simulation shows us that this combination follows the required trend and they are the suitable protocols to be used in UWSN implementations. **Improvements**: Applications of UWSN are fast gaining popularity to make it possible to monitor the ocean, surveillance of deep sea, various entities tracking of aquatic environment, etc. For all these applications the energy efficiency is ansignificant factor for communication. Comparative studies show that R-MAC is the most energy efficient MAC layer protocol and VBF has better PDR and throughput compared to other network layer protocols.

**Keywords:** Data Throughput, Energy Consumption, Packet Delivery Ratio, Radio-Multiple ACcess (R-MAC), Under-Water Sensor Network (UWSN), Vector Based Forwarding

## 1. Introduction

UWSN finds potential applications that can help monitor and guess the ocean behaviour. The network that are used for these applications contain AUVs. The UWSN are different from the terrestrial sensor network (TSN). UWSNs have high latency,low bandwidth, and high network dynamics. For the applications to be viable we need to have communication between the nodes of the network. The network consists of sensors and underwater vehicles that communicate using the acoustic link. For the communication within the nodes to be efficient and reliable we must consider the MAC layer and the network layer

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protocols that provide efficient and reliable communication.

The applications of UWSN are:

- UWSN can carry out synoptic and adaptive sampling of ocean environment in the coastal region using the ocean sampling network,
- UWSN helps to find reservoirs and underwater oilfields, undersea cables laying and valuable minerals search using the undersea exploration networks,
- UWSN aid to measure the seismic activities for remote locations to prevent tsunamis using disaster prevention,
- UWSN frequently monitors seismic activity form underwater fields and provide reservoir management approaches,
- UWSN can monitor and remotely control the expensive equipment after deployment and to determine failure in deployment during initial operations or detect problems,
- UWSN helps to identify seabed hazards, shipwrecks that are submerged, mooring positions, rocks in shallow waters and for performing bathymetry,
- UWSN can be sued for surveillance, reconnaissance, intrusion detection and targeting, and
- They help to detect mines and for rapid environmental assessment.

The paper surveys the protocols to be used for designing the sensor network. Section 2 describes the network architecture and the design challenges. Section 3 we review the Medium Access layer protocol and the Network layer protocol. Finally, section 4 provides conclusion.

## 2. Challenges in Designing Underwater Sensor Network

- Limited bandwidth
- Multipath and fading cause severe impairment of the underwater channel
- Propagation delays is five time more than radio frequency used in terrestrial network and it varies extremely
- Unreliable characteristics of the channel causes high bit error rates and temporary connectivity losses.
- Battery limited, and it cannot be recharged
- The sensors may fail due to corrosion and fouling.

### 2.1 Architecture

Architectures for 3D underwater networks are introduced. Energy consumption depends mainly on the reliability and capacity of a network. So, while engineering the topology we need to take care. Because of high cost of the underwater nodes the entire network is very expensive. Reliability of the network important to prevent of single or multiple devices failures. The topology influences the capacity of the network. The design of the network is crucial to reduce communication bottleneck as the underwater channel capacity o is narrow[1,2].

These are the basic 3 network topology:

- Ocean bottom monitoring is carried out using Static 2D UWSNs. By anchoring to the nodes to ocean bottom the network is created. Monitoring underwater tectonic plates and environment are the applications for which static 2D UWSN are used.
- Static 3d UWSNs can be used for ocean column monitoring. Sensor node depths are controlled. These are used for ocean phenomenon monitoring or surveillance.
- AUVs are part of the 3D network. The network is made up of fixed as well as mobile nodes. The AUVs for the mobile nodes[1,2].

### *2.1.1 Static 3-D UW-ASN*

Ocean bottom sensors cannot observe certain phenomena. Using 3D underwater network these phenomena can be observed and detected. Observation of a given phenomenon using sensor nodes is done by making the nodes at different depths float. This is possible by attaching a wire, the length of which can be adjusted which helps to connect uw-sensor node to surface buoy, and thus adjust the UWSN sensor node depth as shown in Figure 1.

It is easy to deploy such networks, but they may cause difficulties for ships on the ocean surface or it can be sound easily and be deactivated by enemies. Due to tampering, pilfering and weather these floating buoys can be damaged. The approach of anchoring the nodes to the ocean bottom should be different due to the reasons stated above. By using floating buoys, the sensor nodeattachesto theocean bottom.The buoy helps the sensor to get pushed upwards to the ocean surface. Using the electronically controlled engine the length of the wire is adjusted by doing so the depth is eventually adjusted. The mechanism used to change the sensor depth are affected by the ocean currents. 3D monitoring is enabled to overcome the challenges if the architecture which includes:

- Sensing coverage. Based on the sensing ranges the sensors should be placed at such depths that ocean column can be covered in 3D. Desired phenomenon sampling at different depths should be possible, and
- Communication coverage. The sensors of this network must be able to use multi hop path to send data to surface station. The network devices should always be connected. To have one path to send data to surface station the network needs to coordinate their depths[1,2].

## 3. Protocols Used

### 3.1 Routing Protocol: VBF

Energy constraint is an important parameter in sensor networks as the nodes run on battery which are tough to replace under many scenarios. The node movement and the energy efficiency need to be handled by the routing protocols efficiently. VBF satisfies these requirements. Every packet in VBF carries the information of the position of the destination, the intermediate nodes used for

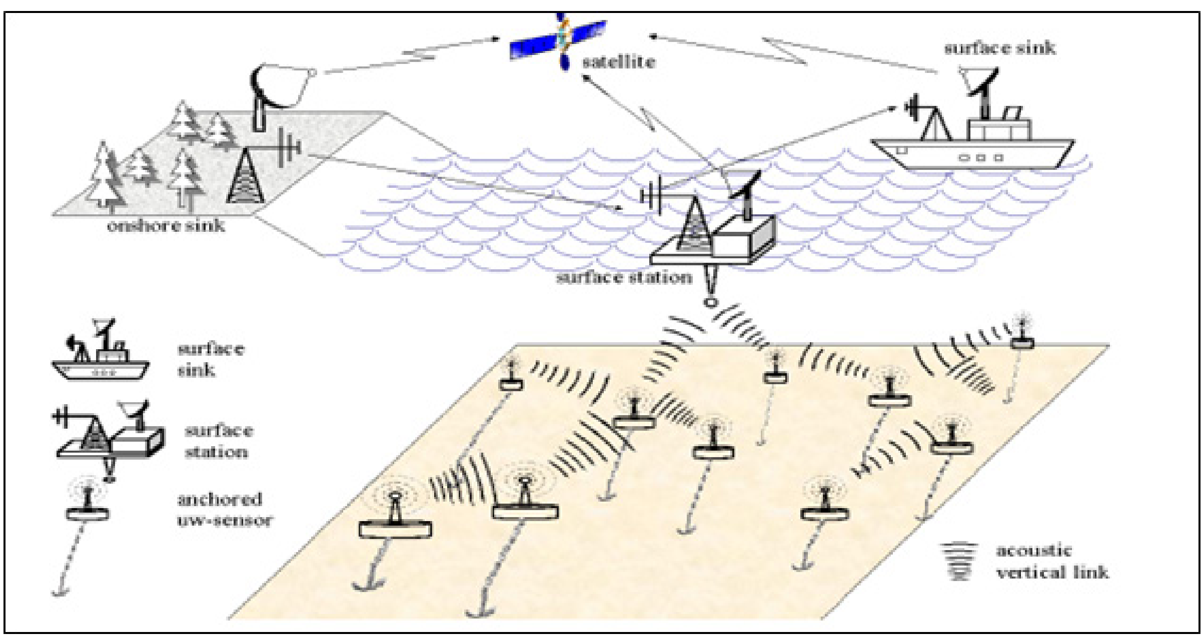


**Figure 1.** 3D UWSN.

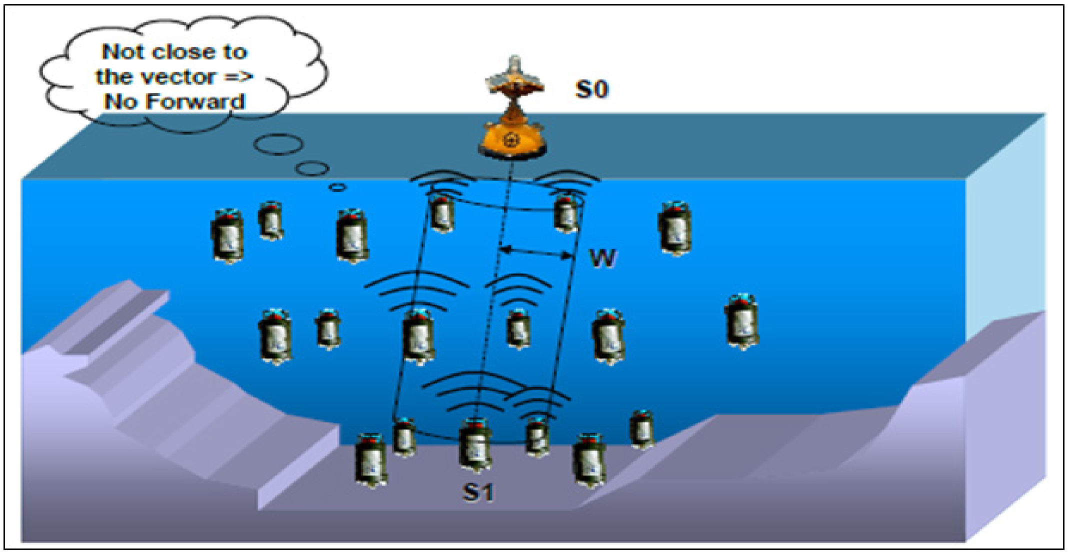


**Figure 2.** VBF in UWSNs.

forwarding and the source. The path through which the packet is forwarded from source to destination is specified in VBF. For deciding the node through which the packet must be forwarded its relative position is calculated by measuring the distance of the closest node that can be used for forwarding and the arrival angle of the signal. All nodes that receive packets their positions are calculated in the similar fashion. In[3] nodes closely located to the routing vector are used for packet forwarding; else the packet is simply discarded. The nodes form a pipe line network when they are near the routing vector and the nodes that are part of the pipe are only used for forwarding the packets gives basic idea of VBF.

From the Figure 2, it is seen that:

- S1--- source node,
- S0 ----sink node,
- routing vector, and
- S1 to S0 is the direction of data forwarding.
- Routing pipe is made up by nodes close to routing vector with pre-controlled radius. W.

For each node state information is not requires in VBF. This makes VBF scalable to any network size. Packets are routed by the nodes along the forwarding path which saves energy of the network[4,5].

### 3.2 MAC Layer Protocol --R-MAC Protocol

Periodical listen and sleep are used in RMAC protocol by each node. Energy required in idle state and for overhearing is reduced due to this. Both the durations are same. There is no scheduling and synchronization used in R-MAC as the nodes randomly schedule the listen and sleep patterns.In absence of traffic around the neighbourhood of any node, it simply listens and sleeps periodically. For data transfer between nodes, a reservation-based access is used for synchronization, in a distributed way, to avoid data collisions during transmission. Period announcement, latency detection and periodic operation are three phases of RMAC.

Synchronization of nodes in the neighbourhood is done by the first two phases and the third phase is used for listen/sleep operations.Detection of propagation latency of the node is done in the detention of latency phase. As listen/sleep schedule of the node is selected randomly it is broadcasted in the announcement period phase. The data are transmitted in the periodic operation phase[5].

## 4. Experimental Analysis

NS2 Aqua-sim[6] which is a packet level simulator we have used for implementation. Using this experiment, the performance the network with 6 nodes is studied. The network uses R-MACalong with VBF routing protocol. The nodes are uniformly placed in a scenario of cubic 100m area. The range of transmission range is set 250 meters and the data packet size ranges from 5 to 60 bytes. From the resulting trace file, we obtain energy consumption, throughput and packet delivery ratio.

The simulation parameter is given in Table 1.

**Table 1.** Simulation parameters

| Simulation Software | Aqua-sim |
|---|---|
| Topology Size | 100m×100m |
| Number of nodes | 6 |
| Transmission range | 250meters |
| Packet size | 5-60bytes |
| Simulation time | 1000sec |
| Initial energy | 1000J |
| Idle power | 0.01W |

### 4.1 Energy Consumption

Size of nodes in a network defines how much energy will be required. It is required to keep the energy consumption as low as possible even though the nodes are big in size, so it is important to analyse this parameter. The transmitting, receiving and idle energy of a node is measure using this parameter. Energy consumption is calculated by taking the difference between the current energy value and the initial energy of the node during simulation. Figure 3 shows total packet power consumption. Energy consumption increases with increase in simulation time[7]. X-axis shows time (seconds) and y-axis represents power (watts).

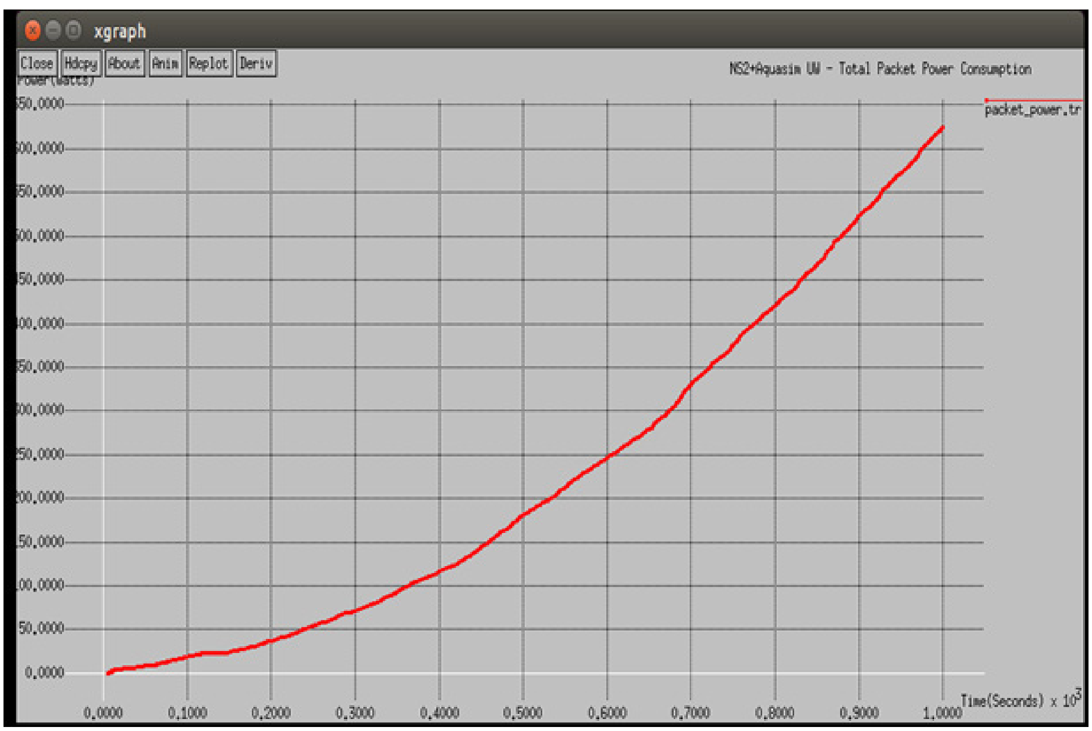


**Figure 3.** Energy consumption.

## 4.2 Throughput

Throughput is the amount of data packets delivered in a communication over a given period. In the simulation, we are counting all packets that are received by the network. Formula to calculate throughput is given as:

**THR= (received data × 8 / data transmission period).**

Figure 4 shows the throughput. As the simulation time increases the throughput Increases[7]. X-axis represents time (seconds) and y-axis is throughput (Kbits).

## 4.3 Packet Delivery Ratio

Receiving packets successfully at destination that are being transmitted from source is defined as PDR. PDR

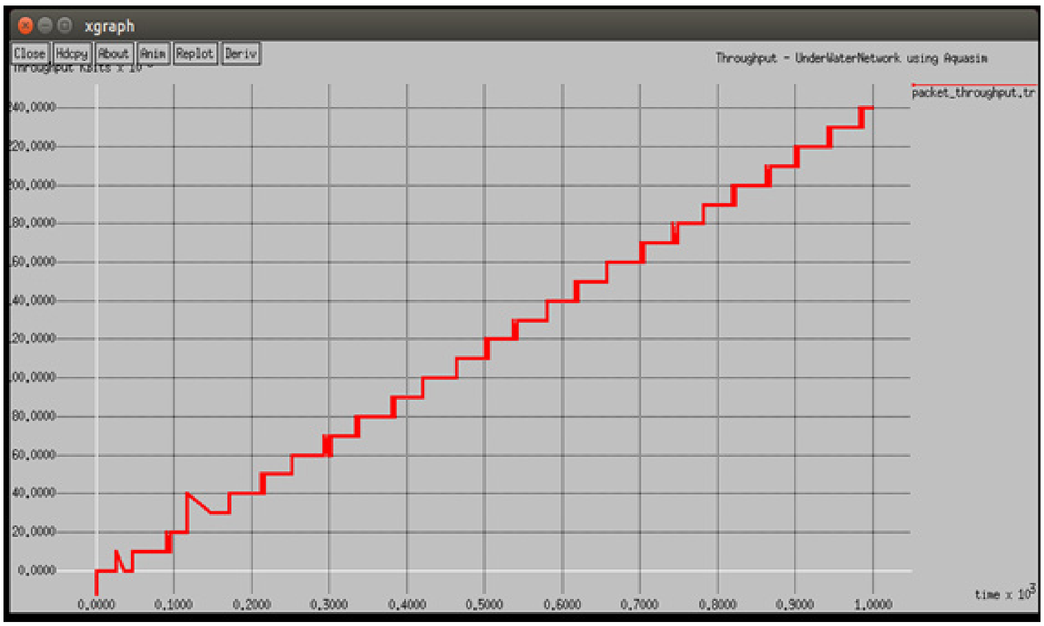


**Figure 4.** Throughput.

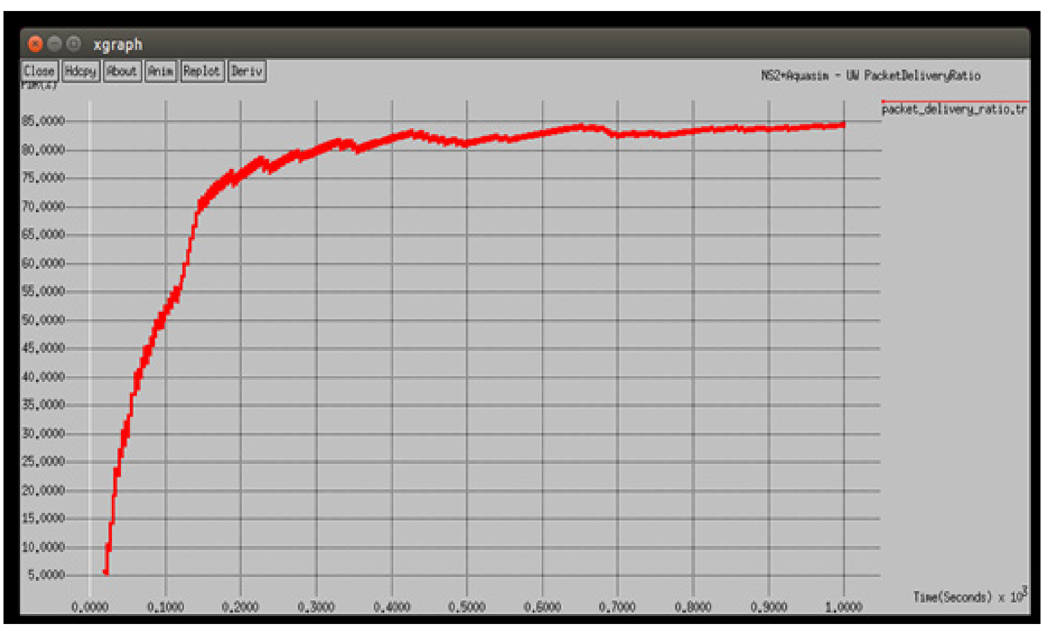


**Figure 5.** Packet delivery ratio.

is calculated by using number of the packets sent and received.

**PDR=total-packet-received / total- packet-sent.**

Figure 5 shows the ratio of packet delivery. Ratio of packet delivery is directly proportional to simulation time[7]. X-axis corresponds to time (seconds) and y-axis corresponds ratio of packet delivery.

## 5. Conclusion

We propose an UWSN 3D architecture, which use RMAC as the MAC layer protocol and VBF as the routing protocol. Both the protocols used can address challenges faced by the UWSNs in the Mac and the Network layer.

Mac layer needs to be energy efficient. Data and control packet transmission are scheduled in R-MAC to avoid data packets collision. The protocol solves exposed terminal problem but also avoids data packet collision. By using R-MAC energy consumption in idle state and overhearing is reduced as each node adopts periodic listen/sleep pattern. In R-MAC, the nodes can select schedule for synchronization. it also supports fairness. Acknowledgements are sent in bursts to improve channel utilization and reduce the control packet overhead.

Robust, scalable and energy efficient are terms that are used to define VBF routing protocol. In this, the packets do not carry the state information of the node, but they carry routing related information. Thus, it is scalable in terms of network size. Nodes that are close to the routing vector are used in VBF for data So, it is energy efficient. VBF provides robustness against node failure and loss of packets by using path redundancy.

Based on the qualities of the two protocols, we have combined the two protocols to get a reliable underwater sensor network that have low power consumption, high throughput, and high PDR.

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