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OPPORTUNISTIC VOID AVOIDANCE ROUTING PROTOCOL FOR UNDERWATER SENSOR NETWORKS

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***Abstract*— To opportunistic void avoidance routing (OVAR) protocol has been proposed for UWSNs. It is an any cast, geographic and opportunistic routing protocol. OVAR switches to the recovery mode procedure which is based on topology control through the depth adjustment of the void nodes, instead of the traditional approaches using control messages to discover and maintain routing paths along void regions. Increasing attention has recently been devoted to underwater sensor networks (UWSNs) because of their capabilities in the ocean monitoring and resource discovery. UWSNs are faced with different challenges, the most notable of which is perhaps how to efficiently deliver packets taking into account all of the constraints of the available acoustic communication channel. The opportunistic routing provides a reliable solution with the aid of intermediate nodes' collaboration to relay a packet toward the destination. In this project, we propose a new routing protocol, called opportunistic void avoidance routing (OVAR), to address the void problem and also the energy-reliability trade-off in the forwarding set selection. OVAR takes advantage of distributed beaconing, constructs the adjacency graph at each hop and selects a forwarding set that holds the best trade-off between reliability and energy efficiency. The unique features of OVAR in selecting the candidate nodes in the vicinity of each other leads to the resolution of the hidden node problem. OVAR is also able to select the forwarding set in any direction from the sender, which increases its flexibility to bypass any kind of void area with the minimum deviation from the optimal path. The results of our extensive simulation study show that OVAR outperforms other protocols in terms of the packet delivery ratio, energy consumption, end-to-end delay, hop count and traversed distance.**

***Index Terms*— OVAR, USWNs, hidden node, candidate node, hop count, optimal path.**

I. INTRODUCTION

Wireless Sensor Network (WSN) is a collection of spatially deployed wireless sensors by which to monitor various changes of environmental conditions (e.g., forest fire, air pollutant concentration, and object moving) in a collaborative manner without relying on any underlying infrastructure support. Recently, a number of research efforts have been made to develop sensor hardware and network architectures in order to effectively deploy WSNs for a variety of applications. Due to a wide diversity of WSN application requirements, however, a general-purpose WSN design cannot fulfil the needs of all applications. Many network parameters such as sensing range, transmission range, and node density have to be carefully considered at the network design stage, according to specific applications. To achieve this, it is critical to capture the impacts of network parameters on network performance with respect to application specifications. A wireless sensor network (WSN) of spatially distributed autonomous sensors to *monitor* physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling *control* of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created.

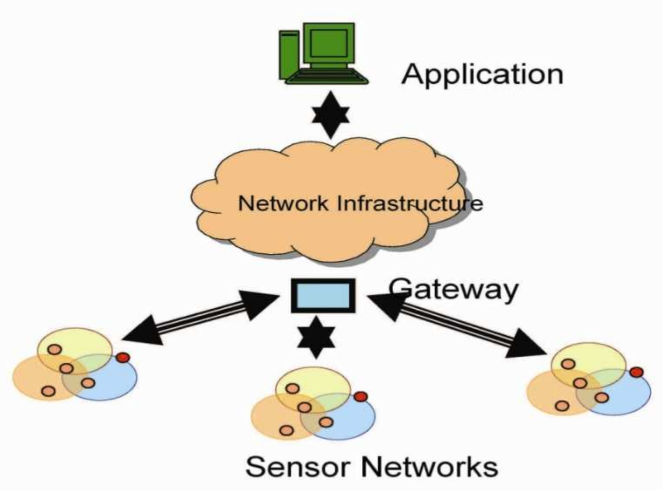


Fig 1.1 Sensor Network

The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding. A wireless sensor network (WSN) consists of a large number of distributed nodes with sensing, data processing, and communication capabilities. Those nodes are self-organized into a multi-hop wireless network and collaborate to accomplish a common task. As sensor nodes are usually battery-powered, and they should be able to operate without attendance for a relatively long period of time, energy efficiency is of critical importance in the design of wireless sensor networks.

A WSN is a collection of embedded sensor nodes with wireless networking capabilities. Collectively the sensor nodes establish a wireless network for transferring, processing and monitoring the sensed data. In order to ensure a small form factor, the sensor nodes are highly integrated and provide minor processing capabilities and limited memory. More stringent, the battery-powered nodes have to carefully orchestrate the power-hungry radio device if a yearlong independent operation is targeted. To make matters even worse, wireless communication is inherently unreliable and limited in range. Altogether this makes it a very demanding task to ensure a reliable, timely and energy efficient transport of the sensed data over possibly multiple hops. Reliability is of utmost importance in a safety-critical environment. Additionally, there are often regulations imposing strong demands in terms of message latency and the availability of the sensor nodes. A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, enabling also to control the activity of the sensors. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. A Wireless Sensor Network consists of small battery powered wireless devices, that are capable of monitoring environmental conditions such as humidity, temperature, noise, etc. Sensor networks do not have a fixed infrastructure but form an ad hoc topology. Wireless sensor networks are emerging as a promising platform that enable a wide range of applications in both military and civilian domains such as battlefield surveillance, medical monitoring, biological detection, home security, smart spaces, inventory tracking, etc. Such networks consist of small, low-cost, resource limited (battery, bandwidth, CPU, memory) nodes that communicate wirelessly and cooperate to forward data in a multi-hop fashion.

A. Underwater Sensor Networks

Underwater sensor networks consist of number of underwater sensor nodes or just called sensor nodes which are equipped with acoustic transceivers that enable them to communicate with each other to perform collaborative sensing tasks over a given area from shallow water and seabed. USNs have many potential applications in ocean monitoring, such as current flow, oil pollution, seismic and tsunamis monitoring, to supply the high spatiotemporal resolution capability. Nowadays, resource discovery in the underwater environment has become one of the important goals to reduce dependency on land resources. However, it is a difficult and costly task to monitor and discover the underwater environment. Underwater sensor networks (UWSNs) have recently attracted much attention due to their significantly ability in ocean monitoring and resource discovery. Due to restrictions on the use of radio waves, acoustic transmission is most commonly used in the underwater environment. Required data are collected by the underwater sensors and directed towards the sink on the surface. Afterwards, the sink can transmit collected information to the monitoring centre via satellite for further analysis, .Some unique features of UWSNs make data forwarding in this environment a challenging task. This includes node movement, low available bandwidth, slow propagation speed, high deployment cost and a lossy environment. It also should be mentioned that the Global Positioning System (GPS) cannot be used in an underwater environment as a localization system because of the quick attenuation of its waves in water. Furthermore, nodes cannot be aware of their positions by pre-configuration, because they are not stationary due to the water current. Nevertheless, the depth of each node in the water can be estimated through an embedded pressure gauge. Then, depth information can be used during the data forwarding procedure. The presence of void areas, a high bit error rate and energy conservation are perhaps the most challenging issues from the perspective of routing protocols in UWSNs. A void communication area is a three-dimensional region between underwater nodes that lacks any nodes inside (similar to holes). The void area can prevent communication between some of the nodes in the network. There are various reasons for the presence of void areas, such as sparse topology, temporary obstacles, unreliable nodes or links, etc. In most cases, the lack of employing enough sensor nodes, due to their high cost, while covering a large monitoring area might lead to sparse deployment of the sensors and, consequently, the creation of some void area. Moreover, the relocation of underwater sensor nodes by the water current can potentially create a void area. On the other hand, the adverse characteristics of the underwater channel can cause a high bit error, resulting from high attenuation, channel fading, noise, Doppler spread, etc.

The communication channel quality varies at different ocean depths under varying pressure, temperature and salinity. The limited bandwidth of acoustic transmission also reduces the efficiency of communication between underwater nodes. Generally, nodes are considered connected to each other if the transferred signal between them can be decoded without any error. In terms of energy consumption, there are also some restrictions due to the difficulties of replacing or recharging batteries, which are the main energy supply for the nodes, in the adverse and often deep underwater environment. In addition, underwater sensors consume more energy than terrestrial sensors because they use acoustic communication. Thus, employing an efficient routing protocol is quite essential to prolong the whole network lifetime. Opportunistic routing is a promising scheme in sensor networks because of its remarkable ability to increase transmission reliability and network throughput. In this way, packet forwarding is enhanced by taking advantage of simultaneous packet reception of neighboring nodes of a forwarding node and their collaboration to forward the packet. However, applying a terrestrial opportunistic routing protocol in UWSNs without considering its specific features is not possible in most cases. In the underwater environment, forwarding set selection without a hidden terminal and prioritizing them are affected by features like a high error bit rate, energy consumption, node movement and slow propagation speed. Furthermore, some terrestrial opportunistic protocols are GPS-based, which make them inappropriate for the GPS-denied underwater environment. The redundant packet transmission issue is one of the influential factors on the opportunistic routing performance.

When a group of candidate nodes are selected to collaboratively forward a packet while placed out range of each other, they cannot notice the transmission of any packet by other candidates. Thus, each forwarding node sets its forwarding timer and forwards the packet separately, resulting in more collisions and energy consumption. If the forwarding nodes are selected within the transmission range of each other (without any hidden node), this increases the chance of hearing the packet transmission by other higher priority candidate nodes, although there is no absolute guarantee, because of other factors, like shadow zone occurrence. Nevertheless, some underwater routing protocols (e.g., Adaptive Hop-by-Hop Vector-Based Forwarding (AHH-VBF), HydroCast, Void-Aware Pressure Routing (VAPR)) take advantage of a group of forwarding nodes in the vicinity of each other with a timer-based coordination to eliminate the duplicated packet problem in the routing layer.

It should be noticed that the hidden terminal problem still may exist in the other layers of the network, which is out of the scope of this work. In this paper, we propose a new opportunistic void avoidance routing (OVAR) protocol in order to increase the throughput and reliability in the sparse and lossy underwater environment while imposing less overhead in comparison to those protocols using high cost localization to obtain their geographic coordinates in this environment. Furthermore, unlike the stateful protocols, which require global topology information, OVAR only depends on the information provided by one-hop neighboring nodes. Each forwarding node selects its forwarding set with the aid of information obtained from the distributed beaconing mechanism initiated from the sink node. OVAR is able to bypass void areas before being stuck in a void node and simultaneously selects a group of candidate nodes with the highest advancement towards the sink. The forwarding set is selected in such a way that its members can hear each other and suppress duplicate transmissions, which leads to a decrease in energy consumption and congestion. In order to prevent energy wasting in a high-density forwarding set, the number of receiving nodes can be appropriately adjusted.

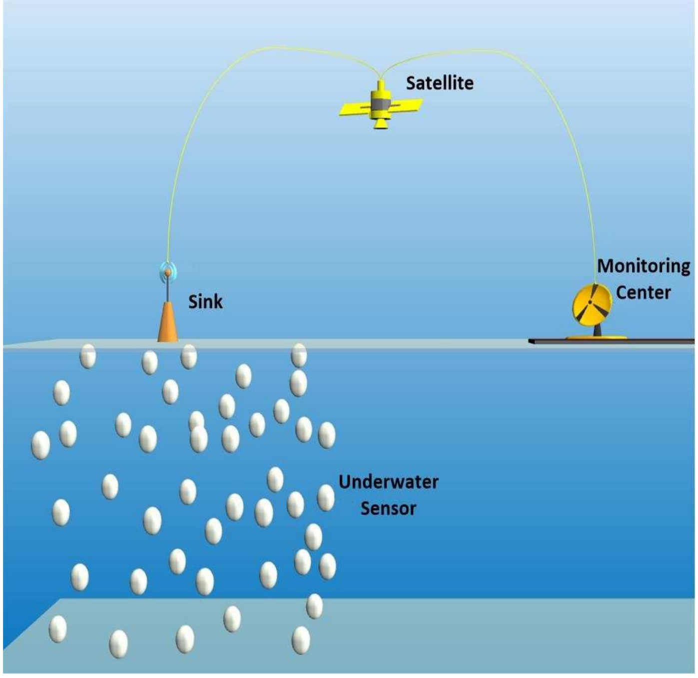


Fig 1.2Underwater Sensor Network

Underwater sensor networks are envisioned to enable applications for oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Multiple unmanned or autonomous underwater vehicles (UUVs, AUVs), equipped with underwater sensors, will also find application in exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions. To make these applications viable, there is a need to enable underwater communications among underwater devices. Underwater sensor nodes and vehicles must possess self-configuration capabilities, i.e., they must be able to coordinate their operation by exchanging configuration, location and movement information, and to relay monitored data to an onshore station. Wireless underwater acoustic networking is the enabling technology for these applications. Under Water Acoustic Sensor Networks (UW-ASNs) consist of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. To achieve this objective, sensors and vehicles self-organize in an autonomous network which can adapt to the characteristics of the ocean environment. The above described features enable a broad range of applications for underwater acoustic sensor networks:

- Ocean sampling networks. Networks of sensors and AUVs, such as the Odyssey-class AUVs, can perform synoptic, cooperative adaptive sampling of the 3D coastal ocean environment. Experiments such as the Monterey Bay field experiment demonstrated the advantages of bringing together sophisticated new robotic vehicles with advanced ocean models to improve the ability to observe and predict the characteristics of the oceanic environment.
- Environmental monitoring. UW-ASNs can perform pollution monitoring (chemical, biological and nuclear). For example, it may be possible to detail the chemical slurry of antibiotics, estrogen-type hormones and insecticides to monitor streams, rivers, lakes and ocean bays (water quality in situ analysis). Monitoring of ocean currents and winds, improved weather forecast, detecting climate change, under-standing and predicting the effect of human activities on marine ecosystems, biological monitoring such as tracking of fishes or micro-organisms, are other possible applications. For example, in, the design and construction of a simple underwater sensor network is described to detect extreme tempera- ture gradients (thermoclines), which are considered to be a breeding ground for certain marine micro-organisms.
- Undersea explorations. Underwater sensor networks can help detecting underwater oilfields or reservoirs, determine routes for laying undersea cables, and assist in exploration for valuable minerals.
- Disaster prevention. Sensor networks that measure seismic activity from remote locations can provide tsunami warnings to coastal areas, or study the effects of submarine earthquakes (seaquakes).
- Assisted navigation. Sensors can be used to identify hazards on the seabed, locate dangerous rocks or shoals in shallow waters, mooring positions, submerged wrecks, and to perform bathymetry profiling.
- Distributed tactical surveillance. AUVs and fixed underwater sensors can collaboratively monitor areas for surveillance, reconnaissance, targeting and intrusion detection systems. For example, in, a 3D underwater sensor network is designed for a tactical surveillance system that is able to detect and classify submarines, small delivery vehicles (SDVs) and divers based on the sensed data from mechanical, radiation, magnetic and acoustic micro sensors. With respect to traditional radar/sonar systems, underwater sensor networks can reach a higher accuracy, and enable detection and classification of low signature targets by also combining measures from different types of sensors.

- Mine reconnaissance. The simultaneous operation of multiple AUVs with acoustic and optical sensors can be used to perform rapid environmental assessment and detect mine-like objects. Underwater networking is a rather unexplored area although underwater communications have been experimented since World War II, when, in 1945, an underwater telephone was developed inthe United States to communicate with submarines. Acoustic communications are the typical physical layer technology in underwater networks. In fact, radio waves propagate at long distances through conductive sea water only at extra low frequencies (30–300 Hz), which require large antennae and high transmission power. For example, the Berkeley Mica 2 Motes, the most popular experimental platform in the sensor networking community, have been reported to have a transmission range of 120 cm in underwater at 433 MHz by experiments performed at the Robotic Embedded Systems Laboratory (RESL) at the University of Southern California. Optical waves do not suffer from such high attenuation but are affected by scattering. Moreover, transmission of optical signals requires high precision in pointing the narrow laser beams. Thus, links in underwater networks are based on acoustic wireless communications.

B. *Underwater Sensing Applications*

The need to sense the underwater world drives the development of underwater sensor networks. Applications can have very different requirements: fixed or mobile, short or long-lived, best-effort or life-or-death; these requirements can result in different designs. We next describe different kinds of deployments, classes of applications and several specific examples, both current and speculative.

1) *Deployments*

Mobility and density are two parameters that vary over different types of deployments of underwater sensor networks. Here, we focus on wireless underwater networks, although there is significantly work in cabled underwater observatories, from the sound surveillance system military networks in the 1950s, to the recent Ocean Observatories Initiative. Figure 1 illustrates several ways to deploy an underwater sensor network. Underwater networks are often *static*: individual nodes attached to docks, to anchored buoys or to the seafloor (as in the cabled or wireless seafloor sensors in figure 1). Alternatively, *semi-mobile* underwater networks can be suspended from buoys that are deployed by a ship and used temporarily, but then left in place for hours or days. (The moored sensors in figure 1 may be short-term deployments.) The topologies of these networks are static for long durations, allowing engineering of the network topology to promote connectivity. However, network connectivity still may change owing to small-scale movement (as a buoy processes on its anchor) or to water dynamics (as currents, surface waves or other effects change). When battery powered, static deployments may be energy constrained. Underwater networks may also be *mobile*, with sensors attached to AUVs, low-power gliders or unpowered drifters. Mobility is useful to maximize sensor coverage with limited hardware, but it raises challenges for localization and maintaining a connected network. Energy for communications is plentiful in AUVs, but it is a concern for gliders or drifters. As with surface sensor networks, network density, coverage and number of nodes are interrelated parameters that characterize a deployment. Underwater deployments to date are generally less dense, have longer range and employ significantly fewer nodes than terrestrial sensor networks. For example, the Sea web deployment in 2000 involved 17 nodes spread over a 16 km area, with a median of five neighbours per node.

2) Application domains

Applications of underwater networks fall into similar categories as for terrestrial sensor networks. Scientific applications observe the environment: from geological processes on the ocean floor, to water characteristics (temperature, salinity, oxygen levels, bacterial and other pollutant content, dissolved matter, etc.) to counting or imaging animal life (micro-organisms, fish or mammals). Industrial applications monitor and control commercial activities, such as underwater equipment related to oil or mineral extraction, underwater pipelines or commercial fisheries. Industrial applications often involve control and actuation components as well. Military and homeland security applications involve securing or monitoring port facilities or ships in foreign harbors, de-mining and communication with submarines and divers. While the classes of applications are similar, underwater activities have traditionally been much more resource intensive than terrestrial sensing. One can purchase commodity weather stations from US$100–1000, but deploying a basic underwater sensing system today starts at the high end and goes up, simply because of packaging and deployment costs. Scientific practice today often assumes sample collection and return for laboratory analysis, partly because the cost of getting data on-site requires maximizing the information returned. Inspired by low-cost terrestrial sensor networks, several research efforts today are exploring low-cost underwater options, but the fixed costs quickly rise for sensing in deeper water. Finally, underwater sensing deployments occur over shorter periods (several hours), rather than days to months or years common in terrestrial sensing. Primary reasons are deployment cost coupled with a large area of interest, and battery limitations. Underwater deployments can be harsher than surface sensing, with bio fouling requiring periodic maintenance. Powered or glider-based AUVs may be coupled with buoys or anchored deployments. Motivations for underwater sensor networks are similar to those for terrestrial sensor nets: wireless communications reduce deployment costs; interactive data indicate whether sensing is operational or prompts corrective actions during collection; and data analysis during collection allows attendant scientists to adjust sensing in response to interesting observations.

C. Opportunistic Void-Avoidance Routing Protocol

During the packet forwarding, if a relay node cannot find any qualified node with a positive progress towards the destination, the packet may be dropped, even though there exists a topologically-valid path from the sender to the destination. This phenomenon is called the local maxima or void problem. The performance of greedy-based routing protocols significantly degrades in the presence of a void area. The characteristics of an underwater sensor network can make the problem even more challenging. The mobility of most underwater nodes and three-dimensional holes in the routing path can lead to more packet failures. Moreover, some moving objects, like a ship, can temporarily create a void area by blocking the communication between two parts of the network. In dense networks, void areas can arise temporarily and with small volumes in some regions. On the contrary, sparse networks include many void areas, which severely affect routing performance. Some existing protocols often ignore void handling in their routings or employ high overhead methods to mitigate its effect. On the other hand, the underwater environment has higher path loss and more ambient noises in comparison to the terrestrial physical layer. The main sources of the noise include turbulence, shipping, waves and thermal noise. Moreover, packet loss depends on the traversed distance and the transmission power of the underwater acoustic signal. Thus, packet forwarding is more likely to be successful if packets are relayed over multiple short distances instead of traversing over long distances. These factors can influence the design of underwater sensor protocols, which are not properly resolved in the majority of the proposed protocols. Applying some simplistic methods, such as increasing the number of forwarding nodes or increasing the transmission power, mostly lead to a waste of energy overall. Energy consumption is another major concern in UWSNs, because it is hard to replace or recharge the sensor batteries in the harsh underwater environment. In the underwater acoustic networks, the energy consumed by the sensors is much more than what is consumed by the regular sensors in the terrestrial networks.

Therefore, energy efficiency is an essential requirement of routing protocols in UWSNs. To this end, it should be noted that the energy consumed by data processing is significantly less than that of data transmission. In contrast to the terrestrial networks in which the network topology is simplified into a 2D one, an underwater sensor network has a 3D network topology. In our underwater acoustic sensor network model, a single sink is considered on the water surface, which is equipped with an acoustic modem for underwater communication and a radio modem for out of water communication with the monitoring centre. Anchored nodes are located at the bottom of the ocean in the predetermined locations to collect the information and deliver it to the sink by using the relay nodes, which are located at different levels in between. Relay nodes and anchored nodes use acoustic signals to transmit the packets. Packets can be forwarded at longer distances by using the higher intensity of acoustic pressure. Moreover, the velocity of an acoustic signal depends on the varying pressures and temperatures. We assume that each node knows its current depth (i.e., vertical distance from each node to the water surface) by using an embedded depth sensor. Moreover, nodes can obtain their hop count distance to the sink with the aid of distributed beaconing. Nodes randomly move in the horizontal direction because of the water current, and their small vertical movements are negligible. The batteries are the energy suppliers of the underwater sensor nodes. Nodes are homogeneous in terms of energy consumption and transmission range. The Thorp model is used for designing the underwater acoustic propagation and adjusting the transmission power. Moreover, we consider a lossy channel in which path loss and bit error depends on the traversed distance and signal frequency.

1) OVAR Overview

In order to properly address the void problem and also to deal with the lossy nature of the underwater acoustic channel, OVAR uses an opportunistic routing algorithm to increase the transmission reliability and also the network throughput while excluding all routes leading to a void area. By taking advantage of the broadcast nature of the acoustic signal, forwarding nodes locally collaborate on packet forwarding with very low overhead. Having a single permanent destination, in the single-sink model, or a number of destinations, in the multi-sink model, is a unique useful feature in developing void-aware routing protocols for UWSNs, which has been perhaps neglected in most routing protocol developments in this field. Using this feature, the process of establishing a void avoidance route for all of the nodes in the network to their destination(s) can be initiated by the sink(s) and cascaded down by intermediate nodes, similar to the route establishment phase of some distance vector routing protocols in wireless ad hoc networks.

In order to obtain reach ability information and neighboring nodes' discovery, each node periodically broadcasts a beacon, which includes the hop count information (proximity of nodes to the sink) and also some neighboring information for updating the neighboring tables. The beaconing mechanism has already been implemented and utilized by some MAC protocols for neighboring nodes' discovery. This mechanism can be augmented to support the hop count information required by OVAR without imposing new overhead. It should be noted that OVAR is a soft-state routing protocol. In a soft-state routing protocol, some reach ability information (e.g., hop count distance, forwarding direction) can be provided and kept in each node. However, the scalability of the routing protocol should not be sacrificed.

Therefore, there is a trade-off between the protocol's scalability and reach ability information at each node. Although this information gives a general view of each node, all routing decisions should be made locally to hold the scalability of the protocol. Moreover, regarding the dynamicity of underwater currents (slow nodes' movement), it is assumed that routing can be accomplished much faster than topology changes. Therefore, the cost of information distribution is negligible against the cost of the routing and packet recovery. Therefore, no routing path is maintained in each node in OVAR apart from some reach ability information, which is useful for efficiency, but not essential, as it can be regenerated or updated if needed. OVAR employs a hop-by-hop forwarding set selection to deliver packets to the sink. Each packet holder uses local information of hop distance and packet advancement to determine its own forwarding set. In addition, the forwarding set should prevent the hidden terminal problem, which is caused by including the nodes that are out of range of each other.

In order to manage the energy, the number of collaborative nodes can be adjusted according to the density of the network. Afterwards, in order to priorities the multiple forwarding nodes, each node considers its depth as the second metric to set a relaying timer. The node with the highest priority (lowest depth) transmits the packet earlier, and other low priority nodes can drop the packet after hearing the transmission. This suppression mechanism along with the selecting of a path with a lower hop count leads to more energy savings and a higher delivery ratio. By employing hop-by-hop forwarding set selection, OVAR is highly scalable to be used in large underwater sensor networks. Finally, OVAR automatically excludes all of the routes leading to void areas and, therefore, does not need to switch any high overhead recovery mode for void bypassing.

OVAR only depends on the information provided by one-hop neighbouring nodes. Each forwarding node selects its forwarding set with the aid of information obtained from the distributed beaconing mechanism initiated from the sink node. OVAR is able to bypass void areas before being stuck in a void node and simultaneously selects a group of candidate nodes with the highest advancement towards the sink. The forwarding set is selected in such a way that its members can hear each other and suppress duplicate transmissions, which leads to a decrease in energy consumption and congestion. In order to prevent energy wasting in a high-density forwarding set, the number of receiving nodes can be appropriately adjusted. A new opportunistic void avoidance routing protocol in order to increase the throughput and reliability in the sparse and lossy underwater environment while imposing less overhead in comparison to those protocols using high cost localization to obtain their geographic coordinates in this environment.

II. OPERATING PRINCIPLE

Vector-Based Forwarding (VBF) protocol, each packet carries the positions of the sender, the target and the forwarder (i.e., the node which transmits this packet). The forwarding path is specified by the routing vector from the sender to the target. Void-Aware Pressure Routing (VAPR) protocol that uses surface reach ability information to set up each node's next-hop direction toward the surface through which local opportunistic directional forwarding can always be used for data packet delivery even in the presence of voids.

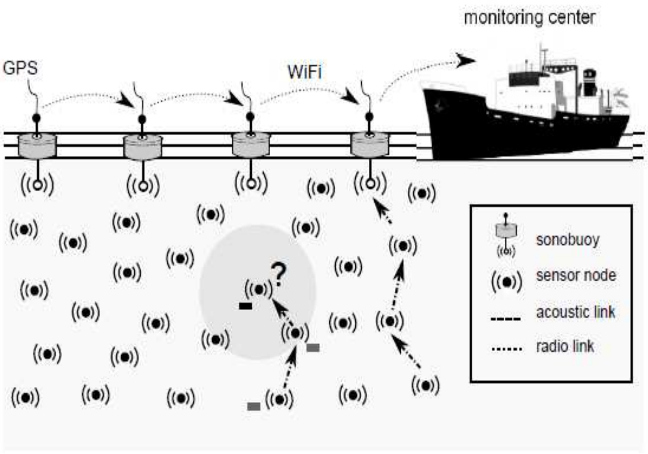


Fig 2.1 Sea Swarm Architecture and the Communication Void Region Problem

The communication void region problem occurs whenever the current forwarder node does not have a neighbour node closest to the destination than itself, *i.e.*, the current forwarder node is the closest one to the destination. The node located in a communication void region is called *void node*. Whenever a packet gets stuck in a void node, the routing protocol should attempt to route the packet using some recovery method or it should be discarded. It is a difficult and costly task to monitor and discover the underwater environment. GPS does not work in the underwater environment. Tries to recover them with a time-consuming procedure, leading to higher end-to-end delay. The disadvantages are, Communication void region problem, It is a difficult and costly task to monitor and discover the underwater environment, GPS does not work in the underwater environment, Tries to recover them with a time-consuming procedure, leading to higher end-to-end delay

The proposed routing protocol employs the greedy forwarding strategy by means of the position information of the current forwarder node, its neighbours, and the known sonobuoys, to determine the qualified neighbours to continue forwarding the packet towards some sonobuoys.

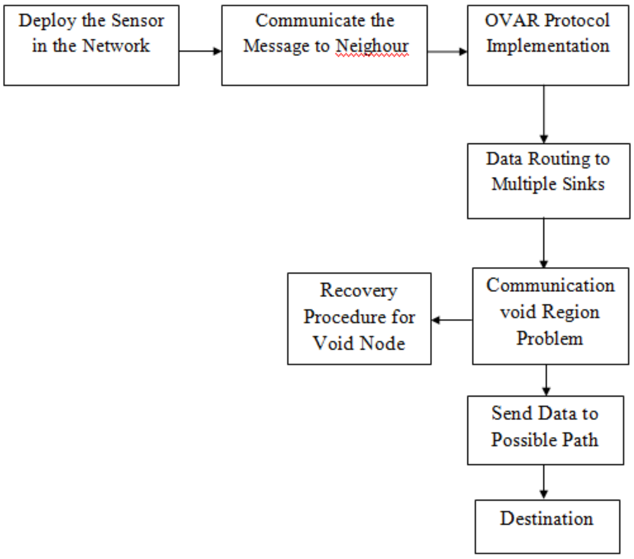


Fig 3.1 Block Diagram of Proposed System

OVAR Routing protocol is an any cast, that tries to deliver a packet from a source node to some sonobuys(sink).The proposed routing protocol employs the greedy forwarding strategy by means of the position information of the current forwarder node, its neighbours, and the known sonobuoys, to determine the qualified neighbours to continue forwarding the packet towards some sonobuoys. For that we need to find a next-hop forwarder selection to forward the data packet. In traditional multi hop routing; only one neighbour is selected to act as a next-hop forwarder. In opportunistic routing, takes shared transmission medium, each packet is broadcast to a forwarding set composed of several neighbours. The packet will be retransmitted only if none of the neighbours in the set receive it. During the transmissions, each node locally determines if it is in a communication void region by examining its neighbourhood. If the node is in a communication void region, that is, if it does not have any neighbour leading to a positive progress towards some surface sonobuoy, it announces its condition to the neighbourhood and waits the location information of two hop nodes in order to decide which new depth it should move into and the greedy forwarding strategy can then be resumed. After, the void node determines a new depth based on 2-hop connectivity such that it can resume the greedy forwarding. Increased the packet delivery ratio because of void node recovery procedure. Consume less energy compare to existing protocol like Depth based routing(DBR),Void avoid pressure routing(VAPR) and Geographical routing(GOR). OVAR efficiently reduces the percentage of nodes in communication void regions to 68% for medium density scenarios as compared with GUF and reduces these nodes to approximately 55% as compared with GOR. Consequently, OVAR improves the network performance when compared with existing underwater routing protocols for different scenarios of network density and traffic load.

A. *Network Creation*

The network is framed with multiple sinks on the surface of sea level. Each **Sonoboys** (sinks) is equipped with a GPS and uses periodic beaconing to disseminate its location information to the underwater sensor nodes. The monitoring center keep tracks the periodic information's from sonoboys.

B. *Routing*

Packet forwarding is more likely to be successful if packets are relayed over multiple short distances instead of traversing over long distances. The GEDAR (geographic and opportunistic routing) protocol is used for communication recovery over void region. The problem occurs whenever the current forwarder node does not have a neighbour nodes closet to the sonoboys. To avoid unnecessary transmissions, low priority nodes suppress their transmissions whenever they detect that the same packet was sent by a high priority node.

C. *Topology Control Algorithm*

The aim of the topology control algorithm is to move void nodes to new depths to resume the Geographic routing whenever it is possible. The depth adjustment is based on the neighbour nodes closet to the sonoboys location in order to organize the network topology and improve the routing task. The current forwarder node forward the packet to neighbour node closet to the sink based upon the energy based routing. It is compatibles in hard and difficult mobile scenarios of very sparse and very dense networks and for high network traffic loads. Improves the network performance when compared with existing underwater routing protocols. Improve the data routing in underwater sensor networks.

III. SIMULATION RESULTS

Simulation has become a very powerful tool on the industry application as well as in academics nowadays. It is now essential for an electrical engineer to understand the concepts of simulation end learn its use in various applications. Simulation is one of the best ways to study the system or circuit behavior without damaging it. The tools for doing the simulation in various fields are available in the market for engineering professionals. Many industries are spending a considerable amount of time and money in doing simulation before manufacturing their product. In most of research and development (R&D) work, the simulation plays a very important role. Without simulation it is quiet impossible to proceed farther. It should be noted that in power electronics, computer simulation and a proof of concepts hardware prototype is the laboratory are complimentary to each other. However computer simulation must not be considered as a substitute for hardware prototype. The objective of this chapter is to describe simulation of impedance source inverter with R, R-L and RLE loads using MATLAB tool. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

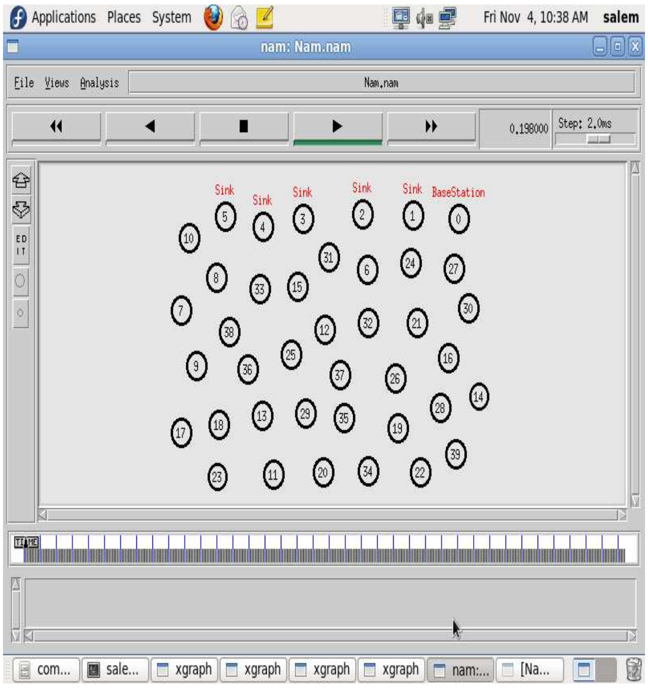
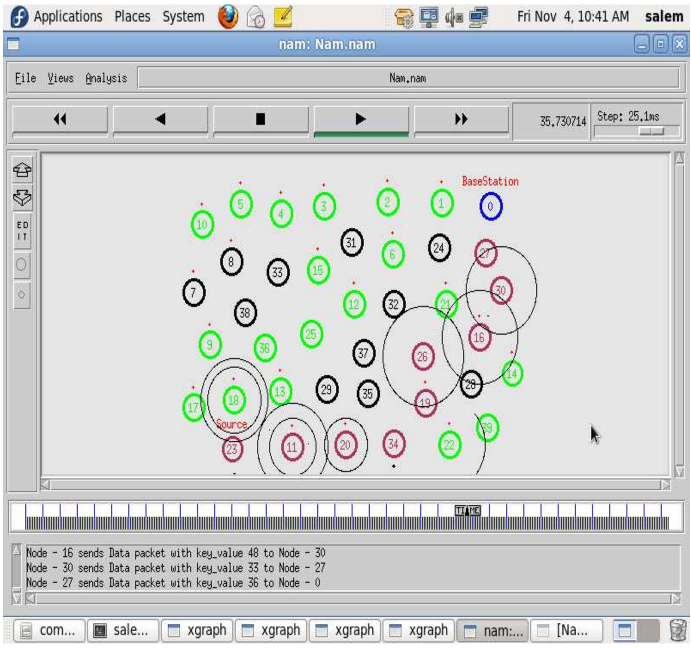


Fig 3.1 Node Generation in NS2

The above simulation result shows that void region in packed data protocol for under water wireless sensors.



```
Node - 16 sends Data packet with key_value 48 to Node - 30
Node - 30 sends Data packet with key_value 33 to Node - 27
Node - 27 sends Data packet with key_value 36 to Node - 0
```

Fig 3.2 Packed Data

The above figure result shows that packed data sends with key values to node from 0 to 30 in under water sensor network.

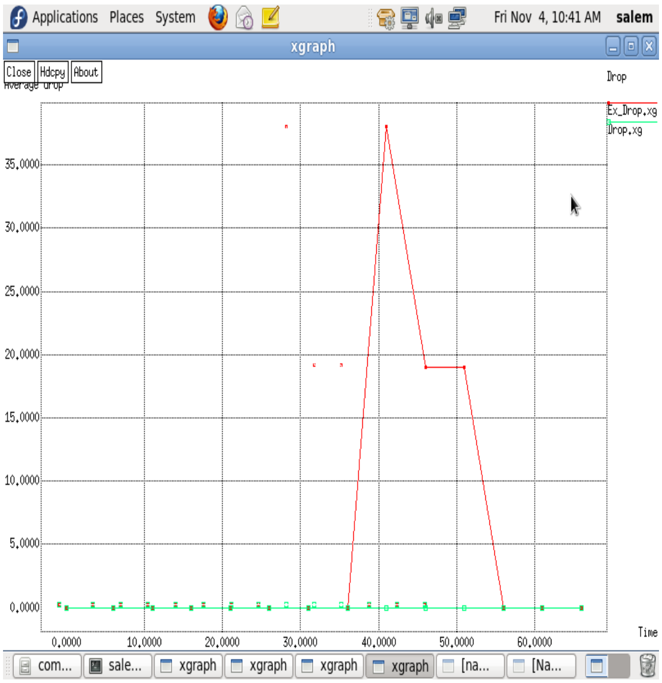


Fig 3.3 Drop the Void Region

The above graph shows that drops occurring in void region for under water sensor network.

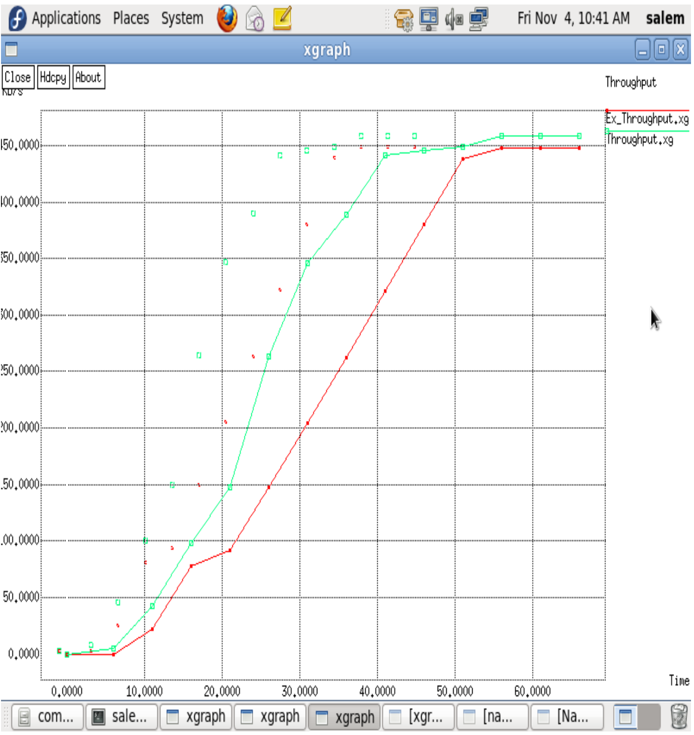


Fig 3.4 Throughput

The above graph result shows that M-EALBM protocol has better network performance than the underwater sensor network.

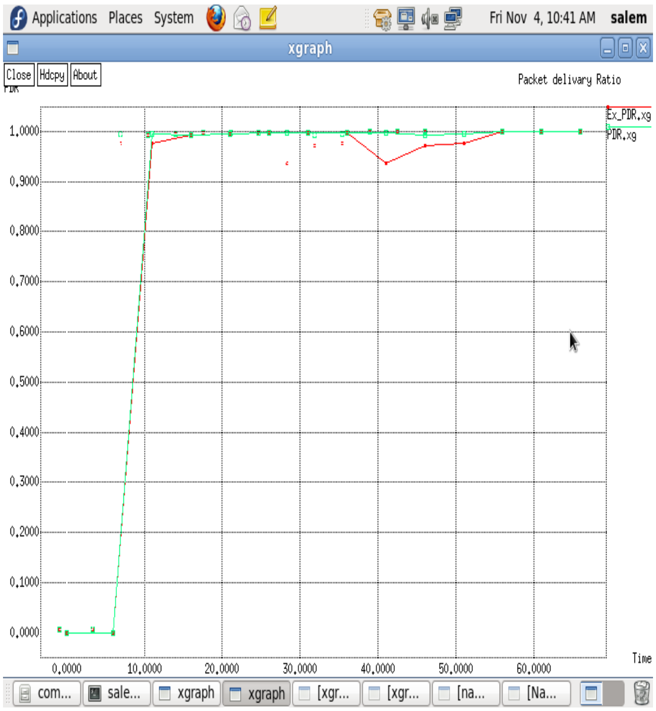


Fig 3.5 Packet Delivery Ratio

The above graph result shows that the packet delivery ratio.

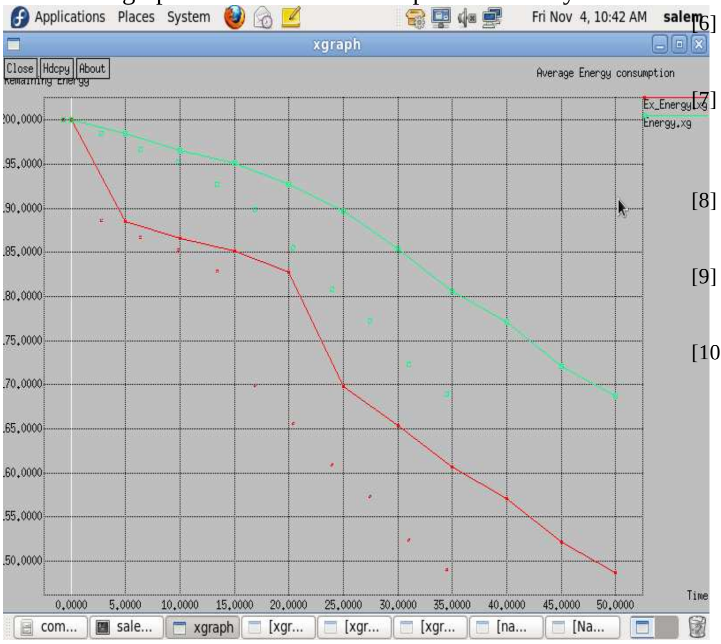


Fig 3.6 Average Energy Consumption

The above graph result shows that the average energy consumption ratio.

IV. CONCLUSION & FUTURE WORK

In this project, we proposed and evaluated the OVAR routing protocol to improve the data routing in underwater sensor networks. OVAR is a simple and scalable geographic routing protocol that uses the position information of the nodes and takes advantage of the broadcast communication medium to greedily and opportunistically forward data packets towards the sea surface sonobuoys. Furthermore, OVAR provides a novel depth adjustment based topology control mechanism used to move void nodes to new depths to overcome the communication void regions. Our simulation results showed that opportunistic routing protocols based on the position location of the nodes are more efficient than pressure routing protocols. Moreover, opportunistic routing proved crucial for the performance of the network besides the number of transmissions required to deliver the packet. The use of node depth adjustment to cope with communication void regions improved significantly the network performance.

As future work to investigate the relationship between the opportunistic data forwarding and network energy balance based on the residual energy distribution in the entire network.

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