QOS Analysis of Geographic Routing Protocols in UWSN

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***Abstract*— Underwater wireless sensor networks (UWSN), similar to the terrestrial sensor networks, have different challenges such as limited bandwidth, low battery power, defective underwater channels, and high variable propagation delay. A crucial problem in UWSN is finding an efficient route between a source and a destination. Consequently, great efforts have been made for designing efficient protocols while considering the unique characteristics of underwater communication. Several routing protocols are proposed for this issue and can be classified into geographic and non-geographic routing protocols. In this paper we focus on the geographic routing protocols. We introduce a review and comparison of different algorithms proposed recently in the literature. We also presented a novel taxonomy of these routing in which the protocols are classified into three categories (greedy, restricted directional flooding and hierarchical) according to their forwarding strategies.**

***Keywords*— Underwater Wireless Sensor Networks, UWSN, Geographic Routing**

I. Introduction

The earth is a water planet, because more than 70% of its surface is covered by the sea and ocean, the remaining part are covered by human being. Several reasons attract to discover this underwater world such as the still large unexplored surface, the biological and geological wealth, the natural and man-made disasters, which have given rise to significant interest in monitoring oceanic environments for scientific, environmental, commercial, security and military fields [1]. Due to these reasons, underwater wireless sensor networks (UWSN) are very promising to this hostile environment. They have many potential applications, including ocean sampling networks,undersea explorations, disaster prevention, seismic monitoring, and assisted navigation [2]. The function of a routing protocol in UWSN is a fundamental part of the network infrastructure to establish routes between different nodes.UWSN routing protocols are difficult to design in general. It is a challenging task, caused by the aquatic environment. UWSN are significantly different from the terrestrial sensor technology. First, the suitable medium of communication in underwater networks is the acoustic waves and is preferred to both radio and optical waves because they have great drawbacks in aquatic channel [3]. Secondly, the most terrestrial sensors are static, while underwater sensor nodes may be mobile with water movements and other underwater activities. Consequently the challenge imposed by UWSNs leads to the inability to adapt directly the existing routing protocols in terrestrial WSN, so new routing approach must be implemented for UWSN.

II. PRELIMINARIES ON UNDERWATER WIRELESS SENSOR NETWORKS

Underwater Wireless Sensor Networks (UWSN) provide a promising solution for discovering aqueous environment efficiently for military, emergency and commercial purposes. Unmanned or Autonomous Underwater Vehicles (UUVs, AUVs), equipped with underwater sensors, are also envisioned to find application in exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions.
The underwater environment is much different from terrestrial and a number of issues need to be addressed while using sensor networks as an effective technology for underwater systems. Due to the high dense salty water, electromagnetic and optical signals cannot be transmitted for long distances in ocean because of scattering, high attenuation and absorption effect. Acoustic communication can be used to overcome this problem which provides a better means of data transfer in such an environment. Hence, available propagation speed is shifted from the speed of light to speed of sound which is five orders of magnitude slower i.e 1500 m/sec, which brings long propagation latency and end-to-end delay. Available bandwidth is severely limited (i.e. <100 kHz). Sensor nodes are generally considered as static but underwater sensors can move upto 1 to 3 m/sec due to underwater activities. Also, underwater nodes are larger in size so they consume more power and replacement of nodes or batteries is not so easy. Underwater applications require multi-hop networks where nodes transmit data to one of more sinks located at the surface level. Sinks then forward the received information to onshore control stations via RF transmissions.

The routing protocols that require higher bandwidth result in large end-to-end delays and are not suitable for these environments. Some of the challenges in under water communication are propagation delay, high bit error rate and limited bandwidth.
Due to the unique challenges of underwater environment, the communication protocols proposed for terrestrial networks cannot be directly applied to UWSNs. Many protocols have been proposed for UWSNs taking into account the unique features of underwater networks, including media access

control, network and transport protocols. The routing protocols for UWSNs can be classified into localization-based and localization-free routing protocols. The routing protocols can take advantage of the localization of sensor nodes; however, the localization is not perfect because of the mobility of sensor nodes, and harsh environment. Rather localization-free routing protocols are highly demanded by research communities.

Recently, many routing protocols have been proposed for UWSNs. In this survey, we present some well-known routing protocols proposed for UWSNs, which can be broadly classified into two sections, localization-based and localization-free routing protocols.

- **LOCALIZATION-BASED ROUTING PROTOCOLS**

These routing protocols are based on the assumption of the localization of sensor nodes in UWSNs. In [1], the vector-based forwarding (VBF) protocol was proposed, in which a source node computes a vector from itself towards the sink and the neighboring nodes, around the computed vector up (called routing pipe), participate in forwarding the data packets. However, VBF has certain limitations, of hard assumption of localization of sensors and the unavailability of sensor nodes in the routing pipe.

Hop-by-hop vector-based forwarding (HHVBF) [13] is a successor of VBF and it employs the technique of computing the routing vector at each hop starting from each sender towards the sink. The recomputation at each hop reduces the effect of sparse density but inherits the assumption of the localization.

In [14], focused beam routing (FBR) utilizes different transmission power levels (i.e. ranging from P1 to PN) during the selection of next relay node, by broadcasting an ready to send (RTS) packet, and the receiving nodes reply with a clear to send (CTS) packet. The limitation of the FBR protocol lies in the use of RTS/CTS during the forwarding of the data packets causing increased delay and excessive energy consumption.

In [15], directional flooding-based routing (DFR) uses scoped flooding where a limited number of nodes are allowed to participate in forwarding data. The flooding zone is decided based on the angle among the source, current forwarder and the sink node, and the link quality of the neighboring nodes. DFR tries to limit the number of forwarding nodes. However, redundant packet’s transmission cannot be avoided and the localization assumption limits its applicability.

- **LOCALIZATION-FREE ROUTING PROTOCOLS**

An overview of the routing protocols that do not assume any kind of localization are also presented. In [4], a novel routing protocol called depth-based routing (DBR) uses the depth of the sensor nodes as a routing metric and assumes that each node has a depth sensor. DBR suffers from redundant packet transmissions and excessive energy consumptions, because of the long propagation delay in UWSNs. In H2-DAB [7], hop-by-hop dynamic addressing-based routing protocol, the routing is performed based on an address (called HopID) assigned to each sensor node, based on the hop count from the sink node. The sink node broadcasts a Hello packet. The receiving nodes are assigned a HopID. These nodes then rebroadcast the Hello packet after an increment of one in the HopID. However, only the hop count value for the selection of the next hop node is not suitable in stringent UWS network. In addition, the use of inquiry request and inquiry reply augments the already long end-to-end delay and consumes extra energy.

All these routing protocols [1] to [15] are compared on the basis of their localization techniques, mechanisms for energy minimization and holding time calculations, and a comparative study is conducted to evaluate their performances in different scenarios which can be quite helpful in the design of an efficient routing protocol.

Unique Features of UWSNs

A UWSN is significantly different from any ground-based sensor network in terms of the following aspects:

- **Low bandwidth and high latency in UWSNs.**

Acoustic channels (instead of RF channels) are used as the communication method since radio does not work well in water. The propagation speed of acoustic signals in water is about 1.5 × 103 m/sec, which is five orders of magnitude lower than the radio propagation speed (3×108 m/sec). Moreover, the available bandwidth of underwater acoustic channels is limited and dramatically depends on both transmission range and frequency. According to [14], nearly no research and commercial system can exceed 40 km × kbps as the maximum attainable Range × Rate product.

- **UWSNs are highly dynamic.**

In a UWSN1, the majority of sensor nodes, except some fixed nodes equipped on surface-level buoys, have low or medium mobility due to water current and other underwater activities. From empirical observations, underwater objects may move at the speed of 2-3 knots (or 3-6 kilometers per hour) in a typical underwater condition. This kind of node mobility results in an unstable neighborhood for a node in the network, which is a big challenge for routing protocol design.

- **UWSNs are highly error-prone.**

Underwater acoustic communication channels are affected by many factors such as path loss, noise, multi-path, and Doppler spread. All these factors cause high bit-error and delay variance. Thus, communication links in UWSNs are highly error-prone. Moreover, sensor nodes are more vulnerable in harsh underwater environments. Compared with their counterparts on land, underwater sensor networks have a higher node-failure rate.

- **UWSNs are 3-dimensional.**

UWSNs are usually deployed in a 3-dimensional space. This is different from the 2-dimensional deployment of most land-based sensor networks. These characteristics of UWSNs make the existing work for terrestrial sensor networks unsuitable for UWSNs and bring up many challenges for almost every level of the protocol suite.

Geographic routing protocols:
The major characteristic of geographic routing protocols that is involves location information in routing decisions. Location based routing is very promising for packets transmission in mobile wireless ad-hoc and sensor networks particularly in hostile environments because it does not add any burden in the network design although the localization process itself in this kind of routing is an intrinsic source of communication errors.Although the research on geographic routing being more recent than topological routing, it has received a special attention due to the significant improvement that geographic information can produce in routing performance. Geographic routing does not require that a node performs maintenance functions for topological information beyond its one-hop neighbourhood. Consequently, geographic routing is more feasible for large-scale networks than topological routing, which requires network-wide control message dissemination. Besides that, geographic routing requires lower memory usage on nodes by maintaining the information locally.
The most existing geographic routing protocols adopt different policies to select the next hop. However, these policies cannot be directly applied to mobile UWSNs. First, all the existing geographic routing protocols are proposed for 2-dimensional networks; although the UWSNs are deployed in 3-dimentional environments. Second, mainly geographic routing protocols do not consider the reliability issue. They frequently adopt single forwarding path, and thus are exposed to node failure. Third, many policies are still based on relatively stable network topologies.

Routing Challenges in UWSNs:
Same as in terrestrial sensor networks, saving energy is a major concern in UWSNs. At the same time, UWSN routing should be able to handle node mobility. This requirement makes most existing energy-efficient routing protocols unsuitable for UWSNs. There are many routing protocols proposed for terrestrial sensor networks, such as Directed Diffusion [11], and TTDD (Two-Tier Data Dissemination) [25]. These protocols are mainly designed for stationary networks. They usually employ query flooding as a powerful method to discover data delivery paths.
In UWSNs, however, most sensor nodes are mobile, and the "network topology" changes very rapidly even with small displacements. The frequent maintenance and recovery of forwarding paths is very expensive in high dynamic networks, and even more expensive in dense 3-dimensional UWSNs.
The multi-hop routing protocols in terrestrial mobile ad hoc networks fall into two categories: proactive routing and reactive routing (aka., on-demand routing). In proactive ad hoc routing protocols like OLSR [1], TBRPF [18] and DSDV [19], the cost of proactive neighbor detection could be very expensive because of the large scale of UWSNs. On the other hand, in on-demand routing (with AODV [20] and DSR [12] as common examples), routing operation is triggered by the communication demand at sources. In the phase of route discovery, the source seeks to establish a route towards the destination by flooding a route request message, which would be very costly in large scale UWSNs.
Thus, to provide scalable and efficient routing in UWSNs, we have to seek for new solutions. In this paper, we investigate this challenging routing problem in UWSNs, with scalability and energy efficiency as the design objectives. Moreover, robustness is also an important concern due to the high node failure rate and error-prone channels in UWSNs.

III. PROPOSED SYSTEM

The proposed system going to have following operations:

Comparative study of VBF and GOAL
In VBF a source node computes a vector from itself towards the sink and the neighboring nodes, around the computed vector up (called routing pipe), participate in forwarding the data packets. However, VBF has certain limitations, of hard assumption of localization of sensors and the unavailability of sensor nodes in the routing pipe.
GOAL: a geo-routing aware MAC integrating VBF and handshake scheme in cross-layer approach.

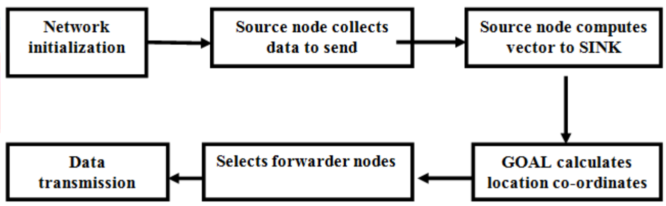

Fig .1 Block diagram showing operation of VBF and GOAL

Comparative study of VBF and R-MAC routing protocols
In this case we are going to make combination of protocols like VBF which is a routing protocol which is going to work with R-MAC which is MAC protocol.

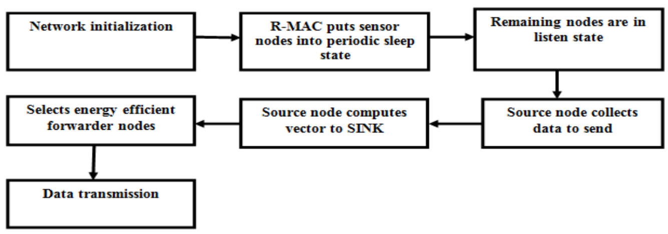

Fig .2 Block diagram showing operation of VBF and GOAL

IV. Implementation

Implementation of VBF + GOAL cross layer routing protocols

In this module, an underwater sensor network is created. Using aquasim package the sensor nodes are created and deployed randomly across the network. VBF is essentially a position-based routing approach: nodes close to the "vector" from the source to the destination will forward the message. In this way, only a small fraction of the nodes are involved in routing.The GOAL – a geographic routing protocol is implemented in the network. And the communication is performed

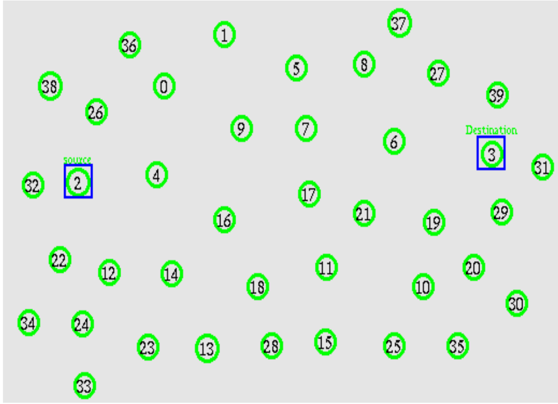

Fig. 4 Nodes Communication

After the network creation stage, nodes are identified within the network as source and destination. Nodes in this network communicate with each other by exchanging the hello packets.

The figure 5 shows the path selection strategy and it can be seen that nodes are periodically have taken into sleep state and after some time they have beem awakened to perform the operation.

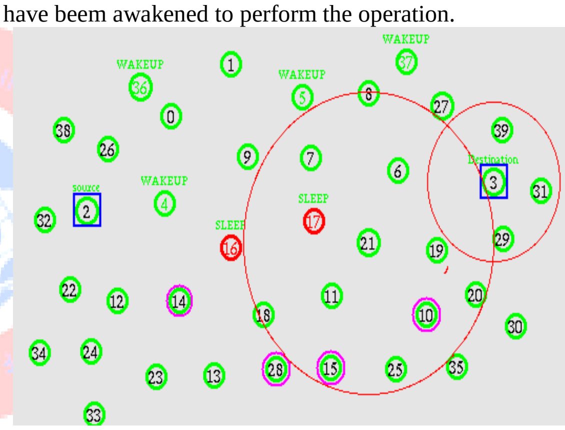

Fig. 5 Path selection stage

Fig. 6 Delay comparison graph

Implementation of VBF + R-MAC protocols

In this module, VBF along with R-MAC protocol is implemented in the network. R-MAC schedules the transmissions of control packets and data packets to avoid data packet collision completely. The scheduling algorithms not only save energy but also solve the exposed terminal problem inherited in RTS/CTS-based protocols.

V. Results

After implementing the proposed system on NS2 platform, the results obtained are as follows:

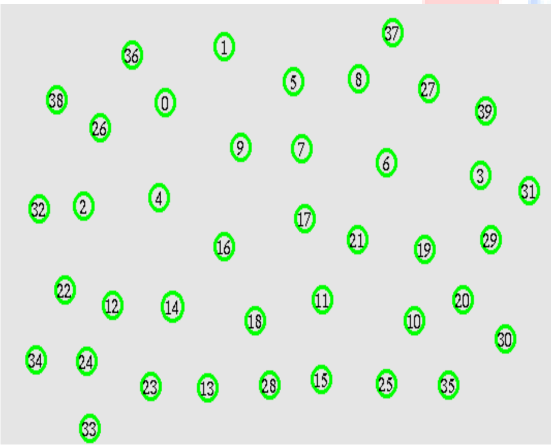

Fig. 3 Network Creation

The above figure shows the network creation stage. The topology of network can be seen.

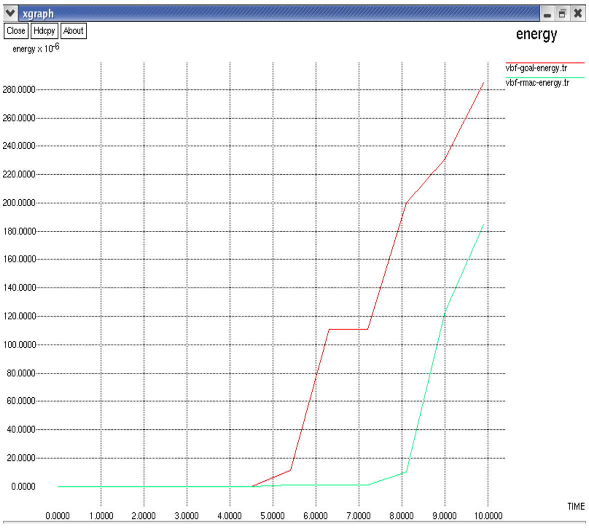

Fig. 7 Energy Consumption comparison graph

In figure 6 the delay comparison graph between VBF-GOAL and VBF-RMAC using Xgraph. The graph shows that delay is less for VBF-RMAC.

In figure 7 the energy consumption comparison graph between VBF-GOAL and VBF-RMAC using Xgraph. The graph shows that the second combination of protocol i.e. VBF-RMAC is going to consume less energy.

VI. CONCLUSIONS

The design of any routing protocol depends on a specific goals and requirements. Development of a geographic routing protocol for the aquatic environments is regarded as a vital research area, which will make these networks much more reliable and efficient. In this paper we have conducted a comprehensive survey of various geographic routing protocols in underwater wireless sensors networks. We classified the geographic routing protocols according to their forwarding strategies into three categories: greedy, restricted directional flooding and hierarchical approaches. We presented a performance comparison of the most relevant routing protocols in terms of forwarding strategy (type, shape region, robustness, scalability, packet overhead), location service (type, robustness), design goal (density, mobility, handling void and destination mobility).Here we have made comparison study VBF & GOAL and VBF & RMAC. The second combination of protocol has performed well compared to earlier type.

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