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Review of Opportunistic Routing Protocol for Underwater Sensor Networks

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Abstract - Due to its multiple uses in the detection of oil spills, ocean research, the detection of submarines, and catastrophe prevention, underwater wireless sensor networks have attracted more interest in recent years. For data collection and communication, each of these applications makes use of a number of sensor nodes placed in various ocean depths. A dynamic routing strategy is necessary for effective communication in the network of sensor nodes. There are various somewhat state-full underwater routing techniques that can ensure packet delivery without requiring a lot of communication overhead. However, because of the features of the underwater acoustic channel, designing opportunistic routing strategies for UWSNs is difficult. For instance, the usage of the most recent protocols created for wireless sensor and mesh networks is impracticable due to the high and unpredictable latency, multipath propagation, poor bandwidth, and high energy consumption. The comprehensive review of several research on the opportunistic routing strategy for underwater sensor networks is offered in this study. the examination and comparison of current research on opportunistic routing protocols, as well as its potential applications and difficulties in underwater sensor networks. This paper's conclusion asserts the numerous research gaps found in the literature review.

Keywords - Wireless sensor networks, Routing, Wireless communication, Protocols, Ad hoc networks, underwater acoustics.

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INTRODUCTION

Due to their numerous uses in ocean exploration, disaster detection and prevention, ocean climate research, oil spill detection, underwater mineral detection and extraction, submarine detection, and marine surveillance, among other fields, Underwater Acoustic Sensor Networks (USNs) have been at the forefront of research activities in recent years [1-3]. In USNs, a large number of sensor nodes are installed at various ocean depths to gather data. These nodes gather the detected data and transmit it to ocean surface data centres through the sensor node network. Numerous apps store, analyse, and utilise the data that the stations receive. The accuracy of the data gathered at the surface sink nodes or stations determines how effective these applications are. The speed and error-free transmission of data over ocean networks of sensor nodes is crucial for the accuracy of the data acquired. Successful data transmission is hampered by the high mobility of sensor nodes, fluctuating water pressure, sensor node failure owing to mistakes or depleted energy, unexpected ocean disturbances, and other issues. It is extremely difficult to create a routing protocol that is both effective and provides high Quality of Service (QoS) to a variety of applications while also accommodating these restrictions. For Terrestrial Sensor Networks, a variety of effective routing methods have previously been put forth [4–7]. These protocols ensure great QoS. Most of these protocols are unacceptably slow or ineffective in USNs due to their distinct characteristics, which also include limited bandwidth, fast energy discharge, and substantial transmission latency. Additionally, USNs cannot employ radio frequency communication, like in conventional sensor networks, and instead use acoustic channels [8]. As a result, academics have created a number of routing protocols specifically for USNs [9].

Even though water covers more of the Earth's surface than land does—more than 70%—human understanding of the undersea environment is still limited. Today's wireless sensor networks (WSNs) have made technical advancements that have allowed for effective growth in the investigation of knowledge regarding the land and its structure. This significantly leads researchers to try the same technique, known as Underwater Wireless Sensors Networks (UWSNs), for application in the aquatic

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environment[1]. UWSNs are used for unmanned exploration in that region because to the severe underwater environment, large area, and high water pressure. [2].

UWSNs are often made up of autonomous cars and individual sensor nodes that perform monitoring tasks as well as data storage and forwarding tasks to send the acquired data to a sink node. Since radio waves and optical waves cannot be effectively employed in an underwater environment, acoustic communications are the common physical layer technology in UWSNs [15]. Each of these sensor nodes has an acoustic modem and may be manually or randomly placed in deep or shallow water depending on the needs of the application. However there are several limitations and challenges in UWSNs because of the uniqueness of UWSNs compared to other networking environments like Terrestial Wireless Sensor Networks (TWSNs).

The most recent opportunistic routing techniques [16–18] investigated for USNs function well with USNs and ensure high data rates in the network. In order to expand the number of likely forwarding nodes in the network, opportunistic routing takes advantage of the wireless nodes' broadcasting capabilities. Traditionally, just one node is chosen to be the forwarder node, which is responsible for sending data packets from the source to the subsequent forwarder node [15–17].This restricts the network's packet delivery rate and causes repeated retransmissions and data loss. This issue is solved by opportunistic routing, which builds a network-wide priority list of forwarder nodes. The next best forwarder in the list forwards the data packet if the best forwarder node, which is chosen based on criteria like hop count to destination, is unable to do so within a certain amount of time. Opportunistic routing ensures data delivery in the network as a result.

Based on the measure used for candidate selection and priority assignment, the opportunistic routing methods for USNs are divided into two types: location-based and pressure-based opportunistic routing protocols. In this article, we evaluate the opportunistic routing strategy for underwater sensor networks using a systematic manner. The network enhancement aware opportunistic routing protocol for underwater sensor networks is reviewed in Section II. The comparative study and research gaps are presented in Section III. Section IV presents the conclusion and future work

LITERATURE REVIEW

In this section, various location-free protocols available to route information in underwater sensor networks are presented.

The Sarath Gopi et al. (2008) layered routing protocol (PULRP) for a 3D underwater acoustic network functions in two steps. To get to the sink, the layering step splits the area of interest into a number of concentric rings. In order to choose the successful next hop and transfer the data to the destination, the communication phase is handled instantly. The information shown above would have been accurate if it had taken into account the energy requirements of the undersea environment.

The Energy optimised routing, developed by Sarath Gopi et al. (2010) E-PURLP, deviates from the conventional approach and prominently shows the layering structure of nodes. Here, the nodes are arranged in several concentric rings, each with a comparable number of hops. In contrast to PURLP, this protocol fixes the boundary conditions before calculating the node's transmission energy. Additionally, this concept prevents a layer from becoming overburdened with traffic.

With the help of super nodes, which are in charge of forwarding packets across many levels, the Multi-layered Routing Protocol (MRP) put out by Wahid et al. (2014) eliminates the requirement for geographical information. The protocol's performance can suffer if a single super node fails. By limiting energy and bandwidth, the Multi-population Firefly Algorithm (MFA), developed by Xu and 65 Liu (2013), accomplishes the optimisation process. The Firefly algorithm employs the node's intensity and appeal in addition to the usual routing concept to optimise placement and distance.. This enhances the convergence speed and efficiency of the network.

By performing route discovery and maintenance in a reactive way, a routing protocol to minimise the overhead (LOARP) developed by Rony et al. (2013) lowers the overhead of the whole network. In conclusion, by identifying the failure modes and skillfully recovering them, the traffic is also reduced.

COMPARATIVE ANALYSIS

Protocol	Metric Used	Retransmission Strategy	Advantages	Disadvantages
VBF [23]	Location Information	Timer Based	• Reduces duplicate retransmissions. • High data delivery rate due to multiple paths through virtual pipes in data transmission. • Highly scalable.	• Low performance when the numbers of nodes are less in the network. • Rapid energy drainage of sensor nodes. • No mechanism to handle communication holes.
HH-VBF [24]	Location Information	Timer Based	• Dynamic candidate set. • High data delivery rate due to multiple virtual pipes from forwarder nodes to the destination.	• Duplicate transmissions with ineffective coordination method • No mechanism to handle communication holes.
GEDAR [25]	Location Information	Timer Based	• Recovery mechanism in case a node encounters a communication hole	• Energy information of the sensor nodes are not considered in routing • Algorithm used by the protocol is much complex

DBR [26]	Pressure Information	Timer Based	• No need of control packets for pressure information. • Highly scalable. • Algorithm used by the protocol is much simple.	• No mechanism to handle communication holes. • Lower data rate with sparse deployment and duplicate retransmissions with dense deployment of nodes. • Energy information of the nodes are not considered in routing
HydroCast [27]	Pressure Information	Timer Based	• Recovery mechanism in case a node encounters a communication hole	• Algorithm used by the protocol is much complex • Energy information of the nodes are not considered in routing
VAPR [28]	Pressure Information	Timer Based	• Provides mechanism to avoid void nodes in the network during data transmission.	• Algorithm used by the protocol is much complex

Table I: Comparison of terrestrial WSN and underwater WSN

Terrestrial WSN	Underwater WSN
Terrestrial applications mostly require dense deployment.	UWSN applications are mostly sparsely deployed.
Once the nodes are deployed they remain stationary.	The nodes after deployment tend to move with 1-3m/s due to water currents.
Node deployment is deterministic.	Node deployment is random, sparse due to the cost. Hence routing protocols play an important role in handling the random deployment.
Radio waves used for communication travel at the speed of light with a minimum propagation delay.	Acoustic waves used for communication travel at the speed of sound with more propagation delay.
The data rate is high in the order of several MHz	The data rate is very low in the order of several KHz.
Draining of battery energy is less during the routing process.	Complex signal processing consumes more battery energy during the routing process.
Batteries can be recharged and replaced with ease.	Battery power is limited and cannot be recharged or replaced without proper mechanism.
Noise and interferences are comparatively low.	Fouling, corrosion and shipping activities cause more noise including ambient noise and interferences.
Bandwidth is not restricted as in UWSN.	Bandwidth is restricted in the order of distance, e.g. very short 20-50 KHz, medium 10 KHz, long 2-5 KHz, very long less than 1KHz .

A overview of the studied opportunistic routing methods is shown in Table I, along with a list of their benefits and drawbacks. Despite the fact that each of these protocols has certain advantages, it is clear that only GEDAR and Hydro Cast, two opportunistic protocols, offer a method of recovering from network communication gaps. Additionally, a lot of the protocols result in a lot of redundant transmissions around the network, which could deplete the energy of sensor nodes. The fact that the majority of these opportunistic routing protocols do not take the energy information of the sensor nodes into account when data is sent in the network is another major problem with them. These are some of the major issues with the latest opportunistic routing protocols in USNs that provide future research directions.

RESEARCH GAPS

In order to construct and analyse a review of an opportunistic routing strategy for underwater sensor networks, we identified several research needs from the aforementioned literature evaluation. We outlined the research issues based on the state of the field's research.

- The underwater acoustic channel is one of the most challenging communication channels currently in use for wireless communication systems. The underwater acoustic channel is expensive and incredibly unreliable. How to accomplish high rates of data transfer while using little energy is one major difficulty with UWSNs.
- Opportunistic routing (OR), which makes use of the broadcast aspect of wireless transmission, in turn helps to lessen the impacts of the underwater channel and improve the subpar quality of underwater acoustic physical linkages. Underwater acoustic communication highlights some of

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its disadvantages, such as the communication void region problem, excessive latency, and duplicated data packet transmission, which can significantly impair UWSN's performance if not carefully taken into account.

- The acoustic channel's characteristic, which increases transmission loss as distance and frequency rise, limits the amount of bandwidth that may be used in UWSNs..
- Since replacing or charging the battery in a noisy environment is exceedingly difficult, energy constraint is a significant concern in UWSN.
- The UWSN's are prone to failures due to fouling and corrosion.

CONCLUSION AND FUTURE WORK

In this research, the most recent opportunistic routing methods for underwater acoustic sensor networks are reviewed. The distinctions between conventional terrestrial sensor networks and underwater sensor networks were first covered. Opportunistic routing was compared to other approaches, and its benefits were examined. Location-based and pressure-based protocols were the two categories under which the USNs' opportunistic procedures fell. The operation of the most common protocols from both groups was thoroughly described, along with their benefits and drawbacks. After conducting a comparative examination of these protocols, we revealed the numerous problems and difficulties that these protocols encountered in USNs. This would offer future possibilities for study in creating routing protocols of the next generation for underwater acoustic sensor networks.

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