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Review of Opportunistic Routing Protocol for Underwater Sensor Networks

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Abstract – Underwater wireless sensor networks have received increased attention in recent years due to its numerous applications in oil spills detection, ocean exploration, submarine detection and disaster avoidance. All these applications make use of a number of sensor nodes deployed in different depths in the ocean for data collection and communication. Efficient communication in the network of sensor nodes requires a dynamic routing approach. In underwater routing protocols, there exist some partially state-full protocols which can guarantee the delivery of packets using excessive communication overhead. However, the design of Opportunistic routing protocols for UWSNs is challenging, due to the characteristics of the underwater acoustic channel. For instance, the high and variable delay, multipath propagation, low bandwidth, and high energy consumption render impractical the use of the up to date protocols developed for wireless sensor and mesh networks. In this paper, we presented the systematic review of different studies of opportunistic routing protocol for underwater sensor networks. The investigation and comparative analysis of recent studies related to the opportunistic routing protocols of the potentials and challenges of opportunistic routing in underwater sensor networks. The outcome of this paper claims the various research gaps identified from the literature review.

Keywords - Wireless Sensor Networks, Routing, Wireless Communication, Protocols, Ad Hoc Networks, Underwater Acoustics.

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1. INTRODUCTION

Underwater Acoustic Sensor Networks (USNs) has been at the forefront of research activities in recent years due to numerous applications in ocean exploration, disaster detection and prevention, ocean climate investigation, oil spill detection, underwater mineral detection and extraction, submarine detection, marine surveillance [1-3], etc. In USNs, numerous sensor nodes are deployed in various depths in the ocean to collect data. These nodes collect the sensed data and send it through the network of sensor nodes to data centers located on the ocean surface. The data received at the stations is stored, processed and used by numerous applications. Efficiency of these applications depends on the accuracy of the data collected at the sink nodes or stations on the surface. The accuracy of data collected depends very much on the rapid and errorless transmission of the data through the networks of sensor nodes in the ocean. High mobility of sensor nodes, varying water pressure, failure of sensor nodes due to errors or exhausted energy, sudden disturbances in the ocean and many factors poses a number of challenges in successful data transmission. Designing an efficient routing protocol that would not only accommodate these limitations but also would give excellent Quality of Service (QoS) to various applications is a very challenging task. A number of efficient routing protocols that guarantee excellent QoS have been already proposed for Terrestrial Sensor Networks [4-7]. Because of the unique features of USNs that include constraint bandwidth, rapid energy discharge and high delay in data transmission, most of these protocols are unacceptable or inefficient in USNs. Moreover radio frequency communication used in traditional sensor networks is unfeasible in USNs and instead acoustic channels are used [8]. So researchers have designed multiple routing protocols exclusively for USNs [9].

Although the Earth's surface is covered by water over 70% compared to the land, human knowledge about the underwater environment is still too shallow as compared to the land. Due to technological advances in wireless sensor networks (WSNs) nowadays, the exploration of knowledge about the land and its structure is able to grow successfully. This remarkably encourages researcher to venture with the same technology for use in the underwater environment which is called Underwater Wireless Sensors Networks (UWSNs)[1]. Due to the reasons of harsh underwater environment, vast area and high water pressure, employing the UWSNs is the way for un-manned exploration in that environment [2].

UWSNs is usually made up of autonomous vehicles and individual sensor nodes that implement monitoring operations as well as storing and forwarding operations to route the data that have been collected to a sink node. Acoustic communications are the typical physical layer technology in UWSNs as other mediums are not feasible to be used in the underwater environment such as radio waves and optical waves [15]. Each of these sensor nodes is equipped with acoustic modem and being deployed manually or randomly in deep or shallow water based on their application requirement. 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 latest Opportunistic routing protocols [16-18] studied for USNs works well with USNs and guarantees high data rate in the network. Opportunistic routing exploits the broadcasting property of the wireless nodes to increase the number of probable forwarding nodes in the network. In traditional routing only one node is selected as the forwarder node which forwards the data packet coming from the source to the next forwarder node [15-17].This limits the packet delivery rate in the network and leads to numerous retransmissions and data losses. Opportunistic routing eliminates this problem by creating a priority list of forwarder nodes in the network. If the best forwarder node that is selected based on some metrics like hop count to destination is unable to forward the data packet within a particular time, the next best forwarder in the list forwards the data packet. Thus data delivery is guaranteed in the network with opportunistic routing.

The opportunistic routing protocols for USNs is classified into two types; location based opportunistic routing protocols and pressure based opportunistic routing protocols, based on the metric used for candidate selection and priority assignment. In this research we present the systematic methodology to study the review of opportunistic routing protocol for underwater sensor networks. Section II presents a literature review of network enhancement aware opportunistic routing protocol for underwater sensor networks. Section III presents the comparative study and research gaps. Section IV presents the conclusion and future work

2. LITERATURE REVIEW

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

The layered routing protocol (PULRP) produced by Sarath Gopi et al. (2008) for a 3D underwater acoustic network works in two stages. The layering phase divides the arena of interest into different concentric circles to get to the sink. The communication phase is resolved on the fly to select the successful next hop to forward the data to the destination. The above would have been competent if it has considered the energy measure that is essential for the underwater environment.

The Energy optimized routing initiated by Sarath Gopi et al. (2010) E-PURLP strongly presents the layering structure of nodes and differs from the traditional method. Here, the nodes are layered in different concentric circles with the one that has a similar hop count. Unlike PURLP, this protocol calculates the transmission energy of the node by fixing boundary conditions. Further, this idea averts the traffic getting overloaded in a particular layer.

The Multi-layered Routing Protocol (MRP) proposed by Wahid et al.(2014) does away with the need of spatial information with the aid of super nodes, which are responsible to forward packets through different layers. The breakdown of a single super node may degrade the performance of the protocol. The Multi-population Firefly Algorithm (MFA) proposed by Xu & 65 Liu (2013) performs the optimization process by restricting energy and bandwidth. Apart from the traditional thought of routing, the firefly algorithm uses intensity and attractiveness of the node that checks the placement and distance for optimization. This enhances the convergence speed and efficiency of the network.

A routing protocol to reduce the overhead (LOARP) introduced by Rony et al. (2013) reduces the overhead of the entire network by performing route discovery and maintenance in a reactive manner. In summation to the above, the traffic is likewise cut back by detecting the failure modes and recovering them intelligently.

3. 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
Hydro Cast [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 II: 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 .

Table I present a summary of the discussed opportunistic routing protocols along with their advantages and disadvantages. Although there are a number of merits with these protocols, we could easily see that only two opportunistic protocols GEDAR and Hydro Cast provide recovery mechanism from communication holes in the network. Also, many of the protocols lead to numerous duplicate retransmissions in the network which could lead to energy drainage of sensor nodes in the network. Another most the important issue with these opportunistic routing protocols is that most of them do not consider energy information of the sensor nodes during data transmission in the network. These are some of the major issues with the latest opportunistic routing protocols in USNs that provide future research directions.

4. RESEARCH GAPS

From above literature review we noticed the some research gaps in order to design and study review of opportunistic routing protocol for underwater sensor networks. As per the progress of research in this domain, we listed the research problems.

- In wireless communication systems, the underwater acoustic channel is recognized as one of the harshest communication media in use today. The underwater acoustic channel is highly unreliable and costly. One big challenge in UWSNs is, then, how can we achieve high rates of data delivery with low energy consumption.

- In turn, opportunistic routing (OR) helps to mitigate the effects of the underwater channel and enhance the poor quality of underwater acoustic physical links, by taking advantage of the broadcast nature of the wireless transmission medium. However, some of their drawbacks (e.g., communication void region problem, high delay, and redundant data packet transmission) are accented in underwater acoustic communication, which can severely diminish UWSN's performance if not carefully considered.

- The bandwidth available is restricted in UWSNs due to the characteristic of acoustic channel that causes more transmission loss with respect to increase in distance and frequency.

- Energy limitation is an important factor in UWSN since it is very complicated to replace or recharge the battery in a rough acoustic environment.

- The UWSN's are prone to failures due to fouling and corrosion.

5. CONCLUSION AND FUTURE WORK

This paper presents the reviews on the latest opportunistic routing protocols used in underwater acoustic sensor networks. We initially discussed the differences between traditional terrestrial sensor networks and underwater sensor networks. The working and advantages of opportunistic routing over other techniques were discussed. The opportunistic protocols for USNs were classified into location-based and pressure based protocols. The working of most popular protocols from both the categories was discussed in detail with their advantages and disadvantages. A comparative analysis was done with these protocols and we finally presented the various issues and challenges faced by them in USNs. This would provide future research directions in designing next-generation routing protocols for underwater acoustic sensor networks.

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