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Routing issues and challenges in Underwater Wireless Sensor Networks

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***Abstract*—** Sensor networks in underwater environments, that is, forming underwater wireless sensor networks (UWSNs), has been attracted significant attention recently from both academia and industry. The characteristics of underwater sensor networks are fundamentally different from that of terrestrial networks. In this paper, we overviewed the main routing issues and challenges for efficient communications in underwater acoustic sensor networks.

Keywords: UWSN, propagation delay, bandwidth, routing Introduction

I. INTRODUCTION

Sensor networks in underwater environments, that is, forming underwater wireless sensor networks (UWSNs), has been attracted significant attention recently from both academia and industry Underwater wireless sensor networks are a newly emerging wireless technology in which small size sensors with limited energy and limited memory and bandwidth are deployed in deep sea water and various monitoring operations like tactical surveillance, environmental monitoring, and data collection are performed through these tiny sensors[1]. Underwater wireless sensor networks are used for the exploration of underwater resources, oceanographic data collection, flood or disaster prevention, tactical surveillance systems, and unmanned underwater vehicles. Sensor nodes consist of a small memory, a central processing unit, and an antenna. Underwater networks are much different from terrestrial sensor networks as radio waves cannot be used in underwater wireless sensor networks. Acoustic channels are used for communication in deep sea water. Acoustic signals have many limitations, such as limited bandwidth, higher end-to-end delay, network path loss, higher propagation delay, and dynamic topology. Usually, these limitations result in higher energy consumption with a smaller number of packets delivered. The main aim nowadays is to operate sensor nodes having a smaller battery for a longer time in the network. Routing associated issues and challenges in the area of underwater wireless sensor networks have been discussed.

A. Features of UNWSNs:

The features of the underwater wireless sensor networks are given in the following table [2]:

Table 1: Features of UWSNs[2]

	Features	UWSNs
1.	Architecture	Most of the time 3D
2.	Topology	Topology is high dynamic due to continual movement of nodes by water currents
3.	Communication media	Acoustic waves for underwater environment and radio waves for water surface [
4.	Deployment	Sparse deployment due to expensive underwater equipment and the vast area
5.	Position information	Unavailable by GPS, because GPS uses high frequency waves which are rapidly absorbed in water [
6.	Network components	Underwater ordinary nodes, sinks, AUV or ROV, and onshore base station
7.	Frequency	Low frequency (Hz, KHz) because high frequency is quickly absorbed in water
8.	Bandwidth	Bandwidth and data rate are low and they are dependent on distance; short distances have higher bandwidth
9.	Range	Usually used in vast areas
10.	Speed of medium	Acoustic velocity in water is about 1500 m/s
11.	Price	Too expensive, for example, an ordinary sensor costs more than 100USD
12.	Propagation delay	Propagation delay is high due to employing low speed acoustic waves as well as large communication area
13.	Path loss	High path loss
14.	Energy consumption	Energy consumption for sending and receiving is too high and energy for sending is bigger than receiving
15.	Wave movement	Spherical in deep water, but cylindrical in shallow water.
16.	Simulator	There is not any standard simulator for UWASNs
17.	Sinks position	Located on water surface and it usually moves by water current
18.	Routing	Due to high movement of nodes in water current, greedy hop-by-hop routing is employed
19.	Prone to error	Links and nodes are highly prone to error due to

		high propagation delay of acoustic waves and corrosion, respectively,
20.	Sensors size	Large size
21.	Hull	Usually made up of materials such as composite, aluminum, and titanium
22.	Energy scavenging	Usually by kinetic energy

B. Classification of routing protocols in UWSNs:

We can categorise the routing protocols in UWSNs on the base of following points [2]:

1. Based on Energy Efficiency
a. LCAD(Location-Based Clustering Algorithm for Data Gathering)
b. EUROP(Energy-Efficient Routing Protocol)
c. TCBR(Temporary Cluster-Based Routing)
d. DDD ((Delay-tolerant Data Dolphin)
e. REBAR(Reliable and Energy Balanced Routing algorithm)
f. ERP2R(Energy-efficient Routing Protocol based on Physical distance and Residual energy)
g. L2-ABF(Layer by layer Angle Based Flooding)
2. Based on Mobility
a. DBR(Depth-Based Routing)
b. SBR-DLP(Sector-based Routing with Destination Location Prediction)
c. LASR(Location-Aware Source Routing)
d. Hydro Cast
e. H2-DAB(hop-by-hop dynamic addressing-based)
f. DUCS(Distributed Underwater Clustering Scheme)
g. L2-ABF(Layer by layer Angle Based Flooding)
3. Based on Delivery Ratios
a. Multi-path Virtual Sink
b. Adaptive Routing
c. Multi-Sink Opportunistic
d. Packet Cloning
4. Based on Reliability
a. DFR(Directional Flooding-Based Routing)
b. Resilient
c. HH-VBF(Hop-by-Hop Vector-Based Forwarding)
5. Based on Delay Tolerance
a. DDD(Delay-tolerant Data Dolphin)
b. Resilient
c. TCBR(Temporary Cluster-Based Routing)
d. DUCS(Distributed Underwater Clustering Scheme)
6. Based on Localisation
a. Localisation Scheme for UWSNs
b. Localisation Routing Framework

C. Problems[3][4]:

Limited Bandwidth: Acoustic channels offer very limited amount of bandwidth, as radio transmission cannot be used for underwater communication. Acoustic communication requires more energy to send a small amount of data, due to its lower bandwidth.

Propagation Delay: Due to use of acoustic communication, propagation speed becomes five times slower than that of radio frequency, that is, 1500m/sec, which obviously results in high propagation delays in the network.

Limited Energy: Nodes that are used in underwater communication are larger in size; hence they require larger amount of energy for communication. Furthermore, acoustic channels also required more energy for communication than terrestrial network. Batteries in UWSN cannot be recharged or replaced; therefore, use of energy-efficient communication is always a need to provide network with higher life time.

Limited Memory: In UWSN nodes are small in size and therefore they have a limited amount of storage and processing capacity.

Variable Topology: UWSN does not have a specific or static topology as flow of water makes it difficult for node to remain static in one place; therefore, node moves randomly.

More expensive Devices: Underwater sensor devices are more costly. And no more supplier are provides these such kind of devices because these are devices are part of research oriented activity. Underwater sensor devices are not easily available in the market.

High power require for communication: In underwater communication more power require because for exchanging data inside in water need more electricity require.

Hardware Protection requirement: Inside the water lot of underwater devices are available not only for monitoring but also scientific work also there that is why more security is require inside the water for safety of the underwater components.

Intermitted data transfer: Compare to terrestrial sensor network system where very small memory. But in underwater sensor network data transferring could be create big interrupt at the time.

Reading problem in space sensors: Generally terrestrial sensors are related to each other. But In underwater sensor network it may not be possible in higher distance sensors but unlikely it could be co-related in higher distance among sensors.

More sparse deployment: In underwater sensor network the deployment is often sparser but compare to terrestrial sensor networks are densely deployed.

Propagation delay: This is also a major problem which comes underwater sensor networks time. Propagation delay is orders of magnitude higher than in Radio Frequency variable and terrestrial channels.

Impaired channel: The underwater channel is impaired because of multipath and fading.

Fouling and corrosion: Underwater sensors are prone to failures because of fouling and corrosion.

Localization: Localization is the challenging factor that is require for data labeling while some time critical applications require data without time delay.

High Maintenance: Underwater sensors demands are increasing because for underwater sensors are very costly

which are not easily available in the market and underwater sensor supplier and consultants are not available everywhere that is why cost is increasing. Underwater sensors are too costly because for underwater sensor networks high maintenance is required.

Temporary losses: For the connectivity time packet sending time it could be loss between the data transmission.

High bit error rates: In underwater sensor network high bit error rates mostly come at the time of duration.

Reliability: This is one of the major design issues for reliable delivery of sensed data to the surface sink is a challenging task compare to forwarding the collected data to the control centre.

Limited battery power: Battery power is the major issues which mainly comes underwater sensor network because many underwater devices working throw the battery suppose if a underwater sensor device is not working so underwater charging is not possible or it may not be charged.

Limited bandwidth size: In underwater sensor another problem is issue is related to bandwidth because bandwidth size is limited.

II. ROUTING CHALLENGES

A. Challenges Faced by UWSNs[3][4][5]:

1. Limited available bandwidth.
2. Highly impaired channels mainly due to multipath propagation and fading.
3. Propagation delay is five times in order of magnitude greater than terrestrial channels.
4. Limited available power aggravated by the absence of solar energy.
5. High bit error rate and temporary loss of connectivity (shadowing zones) due to the nature of underwater channel.
6. Impairment of sensors due to fouling and corrosion.

B. Secure routing Challenges in UWSNs[3][4]:

Routing is essential for packet delivery in UWCNs. Routing is specially challenging in UWCNs due to the large propagation delays, the low bandwidth, the difficulty of battery refills of underwater sensors, and the dynamic topologies. Therefore, routing protocols should be designed to be energy-aware, robust, scalable and adaptive. Many routing protocols have been proposed for underwater wireless sensor networks. However, none of them has been designed with security as a goal. Routing attacks can disable the entire network's operation. Spoofing, altering, or replaying routing information affects routing. Although the attacks against routing in UWCNs are the same as in ground-based sensor networks, the same countermeasures are not directly applicable to UWCNs due to their difference in characteristics. Multipath routing would cause high communication overhead as well. Routing is specially challenging in UWCNs due to the large propagation delays, low bandwidth, difficulty of battery refills of underwater sensors, and dynamic topologies. Therefore, routing protocols should be designed to be energy-aware, robust, scalable and adaptive.

- Due to the node movement and failure, the topology of underwater acoustic sensor networks changes frequently. Moreover, the architecture of underwater acoustic sensor networks is 3-dimensional, which is different from terrestrial wireless sensor networks.
- Since underwater GPS devices and underwater location algorithms are expensive and complex, the location information of the underwater sensor nodes is hard to get.

The process of forwarding data from source nodes to command/control stations efficiently is very challenging in UWSNs, especially in mobile UWSNs for long-term applications. In this, saving energy is a major concern. At the same time, routing should be able to handle node mobility. This makes most existing energy efficient routing protocols unsuitable for UWSNs. In mobile UWSNs, most sensor nodes are mobile and the "network topology" changes very rapidly. Geographic routing is considered promising for mobile UWSNs. Underwater sensors are fairly expensive due to housing of additional components such as acoustic transceivers. It needs an external case for protection of hardware from extreme environmental conditions and also needs anchors and buoys for desired deployment.

The most limiting factor of underwater acoustic communications is the extremely low propagation speed of sound, around 1500 meters per second, subject to slight changes due to pressure, temperature and salinity variations.

C. Main Challenges[4][5]:

1. UWSNs are mobile WSNs by nature. When there are water currents, the UWSN sensors may move and suffer from dynamic network topology changes. It is a challenging task to deal with the dynamic changes for underwater networks.
2. Sensors need to have larger capacities for underwater data caching.
3. Compared with radio communications in TWSNs, acoustic communications in UWSNs use a narrow bandwidth. Owing to the narrow bandwidth, the transmission rate in UWSNs is generally very low (approximately 10 kbps). Hence, bandwidth utilization is an important concern for UWSNs.
4. Reliable data transfer techniques are needed, while avoiding traditional transmission of acknowledgement packets, as this will lead to more routing overhead.
5. The underwater channel is several impaired especially due to multipath and fading.
6. Underwater currents can modify the relative position of sensor devices and also cause

connectivity holes, especially when ocean column monitoring is performed in deep waters.

III. ROUTING ISSUES[5][6][7]

In present scenario of routing in wireless networks, so many work has been proposed in past [8,9]. But routing in under water environment is a challenging task, mainly quality of service will be degraded .Underwater sensor networks collect data from the environment and transfer them to the son buoys on the surface to send them to a center for further processing. Because of the acoustic channels common to UWSNs, they have low bandwidth, high error probability, and longer propagation delay compared to radio channels. From the view of routing protocols in underwater sensor networks (UWSNs), the presence of communication void, where the packet cannot be forwarded further using the greedy mode, is perhaps the most challenging issue.

Underwater issues like limited bandwidth, high propagation delays and 3-D topology as well as power constraints of the sensor nodes are challenges for the successful routings.

Algorithms and protocols need to be developed that detect and deal with disconnections due to failures, unforeseen mobility of nodes or battery depletion. These solutions should be local so as to avoid communication with the surface station and global reconfiguration of the network, and should minimize the signaling overhead.
In case of geographical routing protocols, it is necessary to devise efficient underwater location discovery techniques.

IV. CONCLUSION

Routing is a big challenging task in underwater networks. Bandwidth, propagation delay, battery power, battery charging etc. are the major issues in these networks. We have overviewed the issues and challenges in underwater wireless sensor networks. To overcome these issues in underwater wireless sensor networks, routing protocols are still needed to be enhanced.

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