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Survey on Latest Energy Based Routing Protocols for Underwater Wireless Sensor Networks

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Abstract—In recent years underwater wireless sensor networks (UWSNs) have emerged as one of the most popular researched areas in the networking field due to its numerous applications in ocean exploration, underwater surveillance and pollution detection. With specific characteristics such as higher delay in transmission, continuously moving nodes, limited storage and battery, most of the routing protocols that work with traditional sensor networks cannot be used in underwater wireless sensor networks. It has been a challenge for researchers to route the data packets efficiently from the source to the destination. With low-cost sensor devices having limited transmit power and limited battery, it is a greater challenge to design energy efficient routing protocols for underwater wireless sensor networks. The objective of this paper is to analyze the working of the latest energy efficient protocols that has been proposed for underwater wireless sensor networks and to identify its issues and limitations. This analysis would help in designing optimized energy efficient routing protocols in future.

Keywords - Energy Efficiency, Performance Analysis, Routing Protocols, Survey, Underwater wireless sensor networks.

I. Introduction

Underwater wireless sensor networks (UWSNs) consist of a group of sensor nodes deployed under the ocean to collect data for many applications in ocean exploration, underwater surveillance, pollution detection etc. As radio signals do not work well due to its quick attenuation in water, all the nodes are equipped with acoustic transceivers to communicate with each other and acoustic channel is used for communication [1-2]. Underwater acoustic sensor networks differ from the traditional sensor networks in many ways. Table I summarizes the differences between underwater sensor networks and traditional sensor networks. The sensor nodes in traditional sensor networks are more static while the sensor nodes deployed under the ocean are dynamic because of ocean currents and sudden changes in the ocean. The propagation delay is higher in underwater sensor networks while the data transfer rate is much lower compared to traditional sensor networks [3-4].

Due to these special characteristics, delivering data from the source to the destination node is one of the major issues in underwater sensor networks. A number of efficient routing protocols have been designed so far for traditional sensor networks and mobile ad hoc networks [5-7]. From traditional topology based routing protocols to the latest geographic routing protocols [8-10] and opportunistic routing protocols [11-16] researchers have been successful in designing efficient protocols for traditional sensor networks. But due to the unique features discussed in Table I, these protocols cannot be used for underwater sensor networks.

In this paper we focus on the energy limitation of the sensor nodes in underwater sensor networks. With low-cost sensor devices having limited transmit power and limited battery, one of the major challenge is to design energy efficient routing protocols for underwater wireless sensor networks. Also in underwater environment, with much higher transmission and receiving power consumptions, the harsh environment for sensor battery replacement and energy harvesting, energy efficiency becomes even more critical and challenging. The energy efficient routing protocols [17-21] proposed for traditional sensor networks does not work well with underwater sensor networks. So the researchers have exclusively designed energy efficient routing protocols for underwater acoustic sensor networks. Most of these protocols try to optimize the number of data transmissions in the network to achieve energy efficiency. Many routing protocols focus on maximizing the lifetime of the network with optimized designs. In order to maximize the lifetime of networks, the routing protocol must ensure that traffic is relayed through nodes which have sufficient battery power. Moreover, the transmission range of each node must be optimized in order to avoid early node failures due to energy depletions.

The objective of this paper is to study and analyze the working of the latest energy efficient routing protocols proposed for underwater acoustic sensor networks and to identify their issue and drawbacks. This would help researchers in designing better energy efficient protocols for underwater acoustic sensor networks in the future. The paper is organized as follows. Section II discusses the working of the latest energy efficient protocols in underwater sensor networks. The various advantages and disadvantages of these protocols are discussed in this section. Section III discusses the open issues and challenges existing in designing energy efficient protocols for underwater sensor networks. We conclude the article in section IV with future research directions.

TABLE I. DIFFERENCE BETWEEN TSNS AND USNS

Terrestrial SNs	**Underwater SNs**
Dense deployment of sensor nodes.	Sparse deployment of sensor nodes
High data transfer rate	Low data transfer rate
Less delay	More delay
Lower energy consumption	High energy consumption
More number of static nodes	Dynamic nodes
Less error probability in communication	High error probability in communication

II. ENERGY BASED PROTOCOLS

A. Multipath Power-Control Transmission(MPT)[22]

Multipath power-control transmission (MPT) is an energy based multipath routing scheme designed for time-critical applications in underwater wireless sensor networks. MPT is a cross-layer approach. It combines power control with multipath routing and packet combining at the destination. Distributed power-control strategies at the physical layer are used to improve the overall energy efficiency. No hop-by-hop retransmission is allowed in MPT, as that contributes to the low end-to-end delay.

MPT consumes much less energy than the conventional one-path transmission scheme without retransmission. Besides, since no hop-by-hop retransmission is allowed, MPT introduces much shorter delays than the traditional one-path scheme with retransmission.

B. Energy optimized Path Unaware Layered Routing Protocol (E-PULRP)[23]

Energy Optimized Path Unaware Layered Routing Protocol consists of two phases: a layering phase and communication phase. In the layering phase, a layering structure is presented wherein nodes occupy different layers in the form of concentric shells, around a sink node. The layer widths and transmission energy of nodes in each layer are chosen taking into consideration the probability of successful packet transmission and minimization of overall energy expenditure in packet transmission.

E-PULRP is simple, efficient and hence can be implemented without much difficulty for UWSN, even in the absence of routing tables, localization and synchronization techniques. The on the fly nature of the protocol, its re-layering mechanism as well as its energy efficiency enable E-PULRP to combat connectivity losses due to mobility, multipath or energy depletion. The major issue with the protocol is that it assumes that the Bit Error Rates due to multipath is handled in the physical layer.

C. QELAR[24]

QELAR is an adaptive, energy-efficient and lifetime-aware routing protocol that aims at prolonging the lifetime of networks by making residual energy of sensor nodes more evenly distributed. The residual energy of each node as well as the energy distribution among a group of nodes is factored throughout the routing process to calculate the reward function, which aids in selecting the adequate forwarders for packets. By learning the environment and evaluating an action-value function (Q-value), which gives the expected reward of taking an action in a given state, the distributed learning agent is able to make a decision automatically. More specifically, in this Q-learning-based routing algorithm, the energy consumption of sensor nodes and residual energy distribution among groups of nodes are novel considerations that are put into the reward function. With such a reward function, the forwarding policy can be improved at runtime, so as to achieve high energy efficiency and uniform energy distribution, and thus, prolong the network lifetime.

QELAR can be easily tuned to trade latency or energy efficiency for lifetime, and thus, it can be applied to various different applications. The major advantage with this protocol is that in a moderately sparse network, it achieves high delivery rate and energy efficiency. Moreover, because of its early awareness of residual energy distribution, the lifetime of networks is prolonged.

D. Energy-efficient depth based routing (EEDBR)[25]

Energy-efficient depth based routing (EEDBR) scheme is a constructive framework for maximizing the network lifetime by utilizing both depth and residual energy of the sensor nodes. It minimizes the end-to-end delay along with better energy consumption of the low-depth nodes. EEDBR consists of two phases: knowledge acquisition phase and data forwarding phase. During the knowledge acquisition phase, sensor nodes share their depth and residual energy information among their neighbors. In the data forwarding phase, data packets are transmitted from the sensor nodes to the sink node. EEDBR contributes to the performance improvements in terms of network lifetime, energy consumption and end-to-end delay.

E. Adaptive Routing Protocol (ARP)[26]

In Adaptive Routing Protocol the data packets are assigned with different delivery priority based on the packet characteristics, such as emergency level and age (i.e. residence time in the network), and the node status, such as residual battery and the density of the neighborhood. A higher delivery priority corresponds to a larger forwarding area. Clearly, “more important” packets can be delivered within shorter delays. ARP achieves a good trade-off among delivery ratio and end-to end delay. However, the diameter of the forwarding area is still in need of further study.

F. Mobicast Routing Protocol (MRP)[27]

MPT aims to overcome the communication hole problem and minimizes the energy consumption of the sensor nodes while maximizing the data collection. The underwater sensor nodes are randomly distributed in a 3-D underwater environment in the sea to form a 3-D USN. Considering a mobile sink or an autonomous underwater vehicle (AUV), all possible sensor nodes near the AUV form a 3-D geographic zone called a 3-D zone of reference (3-D ZOR). The AUV travels a user-defined route and continuously collects data from sensor nodes within a series of 3-D ZORs at different times. The main issue addressed by this protocol is how to efficiently collect data from sensor nodes within a 3-D ZOR while those sensor nodes are usually in sleep mode for a long period. The routing protocol relies on two phases: the first phase consists of collecting data within a 3-D ZOR, and the second phase consists of waking up those sensor nodes in the next 3-D ZOR to be queried while trying to avoid topology holes. To save power, only sensor nodes in a 3-D ZOR are notified to enter the active mode in order to deliver sensed results to the AUV. The protocol offers performance improvement in successful delivery rate, power consumption, and message overhead.

G. Cooperative Energy-Efficient Protocol for Underwater WSNs (Co-UWSN)[28]

Cooperative Energy-Efficient Protocol for Underwater WSNs is a reliable, energy-efficient, and high throughput routing protocol for UWSN. Destination and potential relays are selected based on distance and signal-to-noise ratio computation of the channel conditions as cost functions. This contributes to sufficient decrease in path losses occurring in the links and transferring of data with much reduced path loss. Utilization of cooperation strategy and SNR enhances the network lifetime, improves the PDR, and reduces the overall network energy consumption. This is especially beneficial for delay-sensitive and time-critical applications.

III. DISCUSSSION AND OPEN RESEARCH ISSUES

This section presents the open research issues existing in the various energy based routing protocols in underwater sensor networks. Table II presents the comparison of the latest energy based protocols proposed for underwater acoustic sensor networks along with the issues and challenges faced by them.

TABLE II. COMPARISON OF ENERGY BASED PROTOCOLS IN UWSNS

Protocol	**Year**	**Multipath Support**	**Over-head**	**Loop free**	**Issues**
MPT [22]	2008	Yes	Low	Yes	Duplicate data packets generated
ARP [23]	2008	Yes	Low	Yes	Issues and complexity of the forwarding area.
EPULRP [24]	2010	No	Low	Yes	Mobility of sensor nodes is not considered
QELAR [25]	2010	No	Low	Yes	High storage space required
EEDBR [26]	2012	Yes	Low	Yes	Transmission loss is higher
MRP[27]	2013	Yes	Low	Yes	Complexity
Co-UWSN [28]	2015	Yes	Low	Yes	End to end delay experienced is higher

Most of the latest energy based protocols proposed for underwater sensor networks suffer from one or more issues and challenges. One of the most important issues is handling the unpredictable mobility of the sensor nodes. Due to sudden changes in the ocean and ocean currents, the sensor nodes are characterized by rapid displacements. It is very important for the routing protocol to incorporate this sudden movement of the node and also ensure energy efficiency in the network. Most of the latest energy based routing protocols suffer from unforeseen changes in node position and highly dynamic topologies. Integrating opportunistic routing with these protocols can be a possible solution to this problem in underwater acoustic sensor networks.

Duplicate data packet generation is another major issue faced by many energy based protocols in underwater acoustic sensor networks. Duplicate data transmissions can lead to increased delay and network congestion in the network.

Limitation in storage space of sensor nodes is another major issue faced by some protocols. Some energy based protocols require high computational power and storage capacity in sensor nodes, which is highly difficult to guarantee in many scenarios.

Minimizing the transmission loss and maintaining the required Quality of Service is a major challenge for most of the latest energy based protocols in underwater acoustic sensor networks. It is very important for the routing protocol to ensure high data delivery rate in the network with minimum delay.

IV. CONCLUSIONS

This research paper analyzed the working of the latest energy efficient protocols proposed for underwater acoustic sensor networks. Working of the latest energy based protocols proposed for underwater acoustic sensor networks was discussed in detail. The various advantages offered by each protocol were presented. Various issues and drawbacks faced by each protocol were presented. We then discussed the major issues and challenges faced by most of the energy based routing protocols in underwater acoustic sensor networks. This analysis and study would further help in designing optimized energy efficient routing protocols for the future underwater acoustic sensor networks.

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