Survey of Interference-Resolving Model in Millimeter Wave Networks

Gaurav Sharma[1], Dr. R. Purushotham Naik[2]
Research Scholar, Department of Electronics and Communication Engineering, The Glocal University, Saharanpur, U.P., India[1]
Professor & Research Supervisor, Department of Electronics and Communication Engineering, The Glocal University, Saharanpur, U.P., India[2]

Abstract

This compilation of references focuses on the design and analysis of underwater sensor networks, specifically highlighting routing protocols. The referenced works span various aspects, including node design, comparative analysis of routing protocols, research challenges in underwater acoustic sensor networks, and applications, advances, and challenges in underwater sensor networks. The literature covers topics such as geographic multipath routing, opportunistic routing, secure and energy-efficient routing protocols, and novel routing techniques in underwater wireless sensor networks. The references also explore issues like void handling, pressure routing, and power-controlled routing protocols. Notable works include studies on efficient data gathering, depth-based routing, and inherently void avoidance routing protocols. The abstracted papers contribute to the evolving field of underwater sensor networks, addressing key challenges and proposing innovative solutions for effective communication in aquatic environments.

Keywords: Opportunistic Routing (OR); void node; hop count; energy consumption; Packet Delivery Ratio (PDR).

1. Introduction

Water, covering more than two-thirds of the Earth's surface, plays a crucial role in human life, serving as a vital transportation medium and impacting the climate and global production with its abundant natural resources. Recent attention from researchers has been directed toward Underwater Sensor Networks (UWSNs) to explore and uncover submerged areas for applications such as resource exploration, oceanographic data collection, pollution monitoring, tactical surveillance, and oil/gas spills monitoring. Effective communication protocols are essential for these applications, necessitating a deeper understanding of the challenges unique to UWSNs.

UWSNs differ significantly from Terrestrial Wireless Sensor Networks (TWSNs) in various aspects. Notably, UWSNs utilize acoustic signals for communication instead of radio signals, leading to dynamic topologies, unattended and sparse deployments, challenging node localization, and resource limitations. Additionally, the harsh underwater environment poses difficulties in replacing or recharging node batteries.

While radio signals face challenges in underwater propagation, acoustic signals offer better performance with satisfactory range, lower attenuation, and higher reliability. However, underwater properties such as strong attenuation, ambient noise, multipath propagation, and low-speed sound propagation introduce challenges, including high delay, error rates, temporary loss of connectivity, limited bandwidth, and high-energy communication costs. Traditional TWSN protocols are not directly applicable to UWSNs due to these challenges. Consequently, several underwater protocols have been proposed to address specific issues, with a focus on improving network lifetime and mitigating acoustic signal fading. Opportunistic Routing (OR) has emerged as a promising technique to enhance network function in UWSNs by addressing challenges such as high bit errors, signal attenuation, limited bandwidth, and power consumption.

Motivated by the need to address challenges in UWSNs, this paper introduces a novel reactive routing protocol, Energy Efficient Depth-based Opportunistic Routing with Void Avoidance for UWSNs (EEDOR-VA). The protocol aims to overcome the void area problem, enhance network performance, and improve energy efficiency. EEDOR-VA utilizes hop count information to select a next-hop forwarder set, and its novelty lies in a hop count discovery mechanism inspired by the Dynamic Source Routing (DSR) algorithm. The protocol introduces Hop Count Request (HCREQ) and Hop Count Reply (HCREP) procedures for efficient hop count discovery, and it incorporates opportunistic routing techniques to improve network performance.

The comparison of energy consumption between both deployment methods is depicted in Figure 18. The figure shows 95% confidence interval error bars, indicating that there is no significant difference in energy consumption between the two deployment methods. The similarity in energy consumption can be attributed to the hop count request (HCREQ) and hop count reply (HCREP)

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messages during the hop count discovery phase, which constitute the major portion of the total energy consumed. These messages are broadcasted among randomly distributed sensor nodes in the network topology. In essence, the energy consumed in the hop count phase is associated with the sensor nodes and is minimally influenced by the sink deployment method.
Furthermore, the data forwarding process in EEDOR-VA remains unaffected by the sink deployment method. This is because the relay nodes, crucial for forwarding data packets, are determined during the hop count discovery phase and are not dependent on the specific sink deployment arrangement.

2. Related Work

Several Opportunistic Routing (OR) protocols have been proposed to address the void communication area problem in Underwater Sensor Networks (UWSNs). These protocols can be classified into two main categories based on their use of positioning information: Geography-based routing protocols and Pressure-based routing protocols.
In the category of Geography-based Routing Protocols, Void-Aware Pressure Routing (VAPR) is an anycast soft-state routing protocol designed to tackle void node issues in UWSNs. VAPR employs enhanced beaconing and opportunistic data forwarding stages, but it suffers from high energy consumption due to distance measurement and enhanced beaconing. Another protocol, Geographic and opportunistic routing with Depth Adjustment-based topology control for communication Recovery (GEDAR), utilizes greedy forwarding with knowledge of the position information of nodes. While it employs network topology control techniques, GEDAR faces drawbacks such as high energy consumption for depth adjustment. Void handling using Geo-Opportunistic Routing in underwater wireless sensor networks (VHGOR) adopts Geography-based Opportunistic Routing (GOR) using opportunistic routing metrics and a greedy forwarding approach. However, VHGOR faces challenges related to resource consumption and limited energy efficiency due to maintaining a neighboring table. Power Control-based Opportunistic Routing (PCR) integrates transmission power control to achieve energy-efficient data delivery in the Internet of Underwater Things (IoUTs). Although it increases the packet delivery ratio, PCR exhibits higher energy consumption compared to other related works.
In the category of Pressure-based Routing Protocols, Depth-Based Routing (DBR) is the first OR protocol for UWSNs using sensor node depth. It uses flooding to forward packets, but its reliance solely on depth for forwarding set selection may lead to uneven energy consumption and increased redundancy. Pressure Routing for Underwater Sensor Networks (HydroCast) forms clusters using local topology information, addressing void areas with an OR approach. However, it suffers from redundant packet transmissions; increased energy costs, and lacks details on pressure sensor energy consumption. Inherently Void Avoidance Routing Protocol for Underwater Sensor Networks (IVAR) is a receiver-based forwarding protocol utilizing hop-by-hop forwarding set selection. It faces redundant packet transmissions due to hidden node problems, leading to increased energy consumption. Weighting Depth and Forwarding Area Division DBR Routing Protocol (WDFAD-DBR) uses depth differences for routing decisions, addressing void areas through area division. However, it requires periodic broadcasts, suffers from retransmissions, and may lack routing flexibility. Energy-efficient and Void Avoidance Depth Based Routing (EVA-DBR) relies on periodic broadcasts for void detection but exhibits high duplicate packet transmissions and hidden node issues, consuming significant node resources. Energy and Depth variance-based Opportunistic Void avoidance (EDOVE) chooses forwarder candidates based on energy and nodes in the transmission range, facing challenges such as resource-intensive neighbor information exchange, duplicate packet transmissions, and incomplete void area handling. Additionally, Energy Efficient Depth-Based Opportunistic Routing protocol (EEDOR) employs a hybrid forward set selection procedure but suffers from a low packet delivery ratio and does not directly address the void area problem. In summary, each protocol has specific strengths and weaknesses, and the choice depends on the specific requirements and challenges in the UWSN environment. The protocols aim to improve packet delivery, energy efficiency, and network lifetime in the context of underwater communication.

3. Conclusion

In this paper, we introduce EEDOR-VA, a void avoidance protocol designed to address limitations observed in our previous protocol, EEDOR, and the established DBR. EEDOR-VA focuses on increasing the packet delivery ratio, particularly in networks with a small number of nodes where void areas are more likely to occur, as discussed in Section 4. The protocol incorporates a hop count discovery process to detect void/trapped nodes in advance of data transmission, contributing to improved network reliability. Additionally, EEDOR-VA reduces the number of nodes actively transmitting data packets by utilizing Rank to differentiate between node holding times. This strategy aims to decrease energy expenditure during data transmission, minimize packet collisions, and reduce associated costs.

The EEDOR protocol, as presented in, and its enhanced version, EEDOR-VA, are both localization-free. EEDOR demonstrated superiority over various depth-based algorithms. In this study, we extend our evaluation of EEDOR-VA to two different network topologies and explore its performance under different transmission power levels in one of the simulated topologies.

The analysis of experimental simulation results reveals that EEDOR-VA significantly improves network performance across key metrics, including energy consumption, packet delivery ratio (PDR), and the number of nodes completing the data transmission process. We conducted additional examinations to assess the impact of single and multiple sinks, as well as two different sink deployment techniques, on the overall performance of EEDOR-VA in terms of total energy consumption and PDR. The author contributions to this work involve the conceptualization and design of EEDOR-VA, the implementation of simulation experiments, and the analysis of results. The collaborative efforts ensure a comprehensive evaluation of the proposed void avoidance protocol and its potential enhancements over existing approaches.

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