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Overview of Underwater Wireless Communication Routing Protocols

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Abstract: Underwater wireless communication is the use of acoustic, optical, electromagnetic waves and other technologies to send information underwater. This article reviews existing routing protocols for underwater wireless communication network design. Particular attention is paid to their performance in terms of communication efficiency, data rate, latency, and packet loss. The different types of routing protocols are discussed in detail, highlighting their respective strengths and weaknesses. This article also covers issues related to security and scalability and how they affect the performance of the entire network. Finally, this paper discusses the future trend of underwater routing protocols and proposes promising research directions.

Keywords: Underwater wireless communication; Underwater routing protocols.

1. Introduction

The historical development process behind the development of underwater wireless communication is very tortuous and complicated. In the early days, due to technical limitations, most experimental methods were used to communicate, such as sending and receiving sound signals and emitting light intensity. With the development of science and technology, underwater wireless communication has become a feasible, effective and mature technology, which is not only possible to meet the use of the navy and ocean, but also can be applied to underwater environment monitoring, social problem research, seabed geological exploration, marine biology research and other fields. In the development of underwater wireless communication, traditional communication technologies have been greatly developed, such as acoustic communication, optical communication and electromagnetic communication. In acoustic communications, technology has been fully developed and it is now possible to achieve low-latency wireless connections with distances of up to tens of kilometers. In terms of optical communication, due to the high absorption and refraction of underwater light, it is difficult to achieve long-distance high-speed communication, which is considered to be the "bottleneck" of underwater wireless communication. In terms of electromagnetic communication, relatively speaking, technology is updated, and the current technology can achieve the shorty and medium-distance communication of tens of meters, but long-distance communication is still in the research stage. In addition to traditional technologies, new communication technologies have emerged in recent years, such as waveguide technology and plasma technology, which have great potential for the development of underwater wireless communication technology in the future.

2. Underwater routing protocol

Underwater routing protocols are designed to enable efficient and reliable underwater wireless communication by using a combination of frequency, direction and timing information to help route communication data between nodes. The challenge with underwater routing is that radio waves cannot be used because they cannot travel far enough in the water to connect distant nodes. Instead, acoustic algorithms must be used to route communication data. To achieve this, underwater routing protocols use a mix of algorithms, from basic broadcast algorithms to advanced algorithms using path planning and multi-hop routing.

2.1. Advantages and disadvantages of routing protocols

Routing protocols offer several advantages for underwater wireless communication. First, they transmit data reliably, even with limited range due to acoustic signal loss and interference.Routes are distributed in a decentralized manner, allowing nodes to maintain their own routes independently. This increases the scalability of the system and reduces the dependency on centralized components. In addition, routing protocols allow the system to adapt to changing conditions.If a node fails or an obstacle appears in the water, the system can automatically adjust and create a new route to avoid the obstacle. Finally, routing protocols are important for security and privacy because they ensure secure and dedicated paths for data transmission. Although routing protocols have advantages, there are also some disadvantages.One of the main drawbacks is the increased complexity associated with routing algorithms. Routing protocols can be difficult to implement and require extensive tuning and optimization to ensure that they work properly. Another disadvantage is that routing protocols are not always able to account for changes in the environment and can become obsolete over time. If an obstacle appears in the water, the routing protocol may not detect it and may continue to route communication data through the obstacle. This will result in poor performance.

2.2. Types of routing protocols

Underwater routing protocols can be broadly divided into two broad categories: flood-based routing protocols and location-based routing protocols.

Flood-based routing protocols typically employ a "flood and wait" approach, in which all nodes periodically transmit packets in all directions and wait for a response from the intended receiver. Flood-based protocols are simple and easy to implement, but can incur significant overhead in large networks due to the large amounts of data that must be transferred. Location-based routing protocols, on the other hand, rely on knowledge of the geographic location of nodes to make routing decisions. These protocols are more complex than flood-based protocols, but are able to provide more efficient routing because they can take into account the distance between nodes and the direction of transmission. Within location-based routing protocols, there are several subcategories that can be further divided into active and passive protocols. Proactive protocols attempt to maintain up-to-date information about the network topology so that data can be quickly routed when needed. Reactive protocols, on the other hand, dynamically discover routes when needed.

2.2.1. Flooding Protocol

Flood-based routing protocols use a "flood and wait" the approach to transmit messages throughout the network. They typically rely on periodically broadcasting messages to all nodes in the network to determine available routes and establish communication between any two nodes. Flooding protocols are simple to implement, but can incur significant overhead in large networks due to the large amounts of data that must be transferred. The most common flood-based protocol is the Simple Flood Algorithm (SFA). In SFA, nodes should periodically broadcast packets in all directions until a receiver is found. The main advantage of SFA is simplicity as it does not require any prior knowledge of network topology. One disadvantage of SFA is that it does not account for the distance between nodes or the direction of transmission, resulting in inefficient routing and high overhead. Another type of flooding protocol is the Hash Flood Algorithm (HFA). HFA is similar to SFA in that it relies on periodic broadcasts of packets, but it differs in that it uses hash tables to store previously encountered routes. This allows the algorithm to avoid unnecessary packet retransmission in a known direction, reducing overhead. In addition, HFA are able to account for distances between nodes, providing more efficient routing than SFA.

2.2.2. Geographic Routing Protocol

The geographic routing protocol is based on using geographic coordinates to calculate the shortest path between two nodes. These protocols rely on prior knowledge of node locations and network layouts. This information is used to create a geographic map of the network, which is then used to determine the best route between the two nodes. Robust geo-routing protocols are ideal for networks with a large number of nodes and complex topologies because they provide reliable and efficient communication over long distances. However, they require an accurate understanding of the location of nodes and network layout, which can be difficult to obtain in dynamic networks.

2.2.3. Greedy Routing Protocol

The greedy routing protocol is also a location-based protocol that relies on knowledge of the geographic location of the nodes, employs a greedy strategy to retrieve the nearest destination node, and decides between which nodes the packet is sent between by calculating the topological distance between the two nodes. The Greedy Protocol is simple and flexible, easy to implement and manage. It can quickly retrieve the nearest target node, reducing route search time. Supports multi-hop and reliable routing transmission. However, due to the greedy strategy used by the protocol, there are problems such as low routing turnover ratio and path performance. It cannot cope with topological changes in a dynamic environment, causing the routing process to fall into a local optimal solution and cannot achieve the optimal solution. Rely heavily on updating topology information, which is wasteful and delayed.

2.2.4. Hop-by-hop Routing Protocol

The hop-by-hop routing protocol is based on the exchange of messages between two neighbors. Each node in the network maintains a routing table that contains information about the path of the destination node. When a new route is requested to the destination node, the source node sends a routing request message to its immediate neighbor, which is forwarded to its own neighbor, and so on until it reaches the destination node. This approach is ideal for networks with a large number of nodes and complex topologies. However, hop-by-hop protocols can be susceptible to network congestion and failure because routing relies on the successful delivery of messages between neighboring nodes.

2.2.5. Multihop Routing Protocols

Multihop routing protocols are based on the exchange of messages between multiple hops in a network. These protocols rely on prior knowledge of the network topology to calculate the optimal route between two nodes. Multihop protocols are ideal for networks with a large number of nodes and complex topologies because they provide reliable and efficient communication over long distances. The main disadvantage of multi-hop communication protocols is that they are susceptible to network failures and congestion. Because routing is based on successfully passing messages between multiple hops, a single failed link can disrupt the entire communication path.

3. Opportunities and challenges

Underwater communication routing presents both opportunities and challenges. On the one hand, it offers a greater range of opportunities for data communication as it can reach farther underwater. It also has the potential to increase the speed of communication and reduce latency by avoiding surface-based infrastructure. Underwater routing also offers increased security, as signals are more difficult to intercept than over-the-air or wired mediums. On the other hand, underwater communication routing poses a number of major challenges. Firstly, noise from ships and other vessels can interfere with messages, leading to a need for advanced signal processing techniques to combat these issues. Secondly, due to the attenuation of signals underwater, the bandwidth available for communication is much lower and so the amount of information that can be transferred is limited. Finally, the cost of deploying, maintaining and upgrading underwater communication routing nodes is significantly higher than terrestrial solutions. In conclusion, while underwater communication routing offers advantages in terms of range and security, it is hindered by a number of challenges in terms of cost, limited bandwidth and interference. Advances in technology and more effective methods of signal processing could help to overcome these barriers in the future, offering a new opportunity for data transfers.

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