

Research on a UUV Cluster Communication Model

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Abstract: The characteristics of low bandwidth and high packet loss of underwater communication restrict the research and development of UUV cluster. This paper proposes a UUV cluster communication model, which increases the overall network throughput and improves the overall data transmission efficiency within the cluster network.

Keywords: UUV; Underwater; Cluster Communication.

1. Introduction

In recent years, with the development of unmanned platforms, many countries have also increased their research efforts on unmanned underwater vehicles (UUV) [1]. However, the performance of a single UUV is difficult to meet the requirements, and its functions and scope of action are constrained. Therefore, researchers began to focus on multi UUV clusters. Multi UUV clusters has great potential. It can expand the perception range of a single UUV, improve efficiency, and can be used for tasks such as detection of seabed mineral resources, detection of underwater targets [2]. At the same time, they have the advantages of low cost, high scalability, high efficiency, strong fault tolerance, and reconfiguration [3].

In recent years, the swarm intelligence technology based on multi UUV clusters has also begun to receive attention and research [4]. The swarm intelligence technology is derived from the research on social organisms such as ants, bees, and is called the next generation artificial intelligence technology, which has high application value. However, the realization of multi UUV cluster and group intelligence depends on high-speed real-time communication between all individuals in the cluster, and the characteristics of underwater environment make the speed and stability of underwater communication difficult to meet the requirements, which has become a bottleneck problem restricting the development of underwater cluster cooperation and group intelligence [5].

Underwater communication has always been the focus of research in various countries, and the current research mainly focuses on the following aspects. 1. Radio communication. As the main transmission mode of modern communication, radio communication has the advantages of long distance and high bandwidth. However, the electromagnetic wave attenuates rapidly underwater, and the higher the frequency is, the greater the attenuation is. The propagation distance of ordinary electromagnetic wave underwater is very limited. Therefore, radio communication mainly relies on VLF and ultra-low frequency communication, and the communication distance can reach hundreds of meters. However, the disadvantage is that the transmission rate is extremely low. Generally, the amount of data transmitted per minute is a few bytes, and only commands or short codes can be transmitted. 2. Underwater acoustic communication. Using the bionic principle and referring to the practice of dolphins, whales and other underwater creatures transmitting information through

sound, the research will transform the signal into sound wave for transmission, and the receiver will convert the sound wave into electrical signal to complete communication. This method has small attenuation and long transmission distance, but it is easy to be affected by underwater noise of different densities, temperatures and types. The communication effect is very poor, the bit error rate is very high, and the transmission rate is not high. 3. New communication methods. With the breakthrough of science and technology, research on underwater communication using other technologies has also emerged, such as blue green laser communication, neutrino communication, quantum communication, etc. The blue green laser has strong penetration ability in water, low attenuation, high transmission rate, large information capacity, strong anti-interference, small receiving antenna, etc., but the directivity of the laser is too strong, so it is necessary to know the accurate location information of the communication partner. Therefore, there are great difficulties in practical application; The physical characteristics of neutrino and quantum communication determine their strong penetrability, confidentiality and anti-interference ability. However, the research on these two kinds of communication is still in the initial stage, and there is still a long way to go from practical application.

To sum up, it can be seen that both radio communication and underwater acoustic communication have the characteristics of low transmission rate, short communication distance, large interference and high packet loss rate. Therefore, how to effectively solve these shortcomings and improve the efficiency of underwater communication is the key to realize the cooperative work of multiple UUV systems and promote the research of underwater group intelligence.

2. Underwater Multi UUV Cluster Communication Model

The communication between UUVs in the underwater environment, whether in radio or underwater acoustic mode, can be broadcast around, that is, UUVs in a certain range around can receive information. These UUVs that can communicate directly constitute a LAN. Each UUV in the network has the ability to store and forward, and assume the function of a routing node.

Therefore, the cluster composed of multiple UUVs is logically similar to the routing multicast communication when communicating with each other, but the links between nodes are characterized by low transmission rate, high packet

loss rate, instability and dynamic change. Each UUV individual in the cluster has the function of store and forward, similar to a router in the network. When the two UUVs cannot communicate directly due to the long distance and strong interference, it can be understood that the link between the two routers in the network is disconnected, and data relay transmission can be completed with the help of other nodes.

At the same time, with the relay transmission of UUV nodes, data transmission between underwater UUV clusters and ships, air planes, space satellites, ground receiving stations and other underwater communication nodes can also be realized. When a UUV rises to the surface, it acts as a relay node between the underwater cluster and the communication nodes on the water. Other UUVs in the underwater cluster do not need to rise to the surface, which not only avoids the risk of exposing, but also enables communication with the nodes on the water. In addition to floating a UUV out of the water as a real-time relay transmission node, in order to reduce the time of exposure on the water surface, it can also use the UUV's own data storage capacity to transmit all other UUV data to the relay node UUV through the cluster networking underwater. After receiving the data from all nodes, the UUV will automatically go to surface and transmit all the data to the node on the water through the normal high-speed radio. Because the radio transmission speed on the water is very fast, the exposure time of the relay UUV on the water can be reduced, thus reducing the risk of being found.

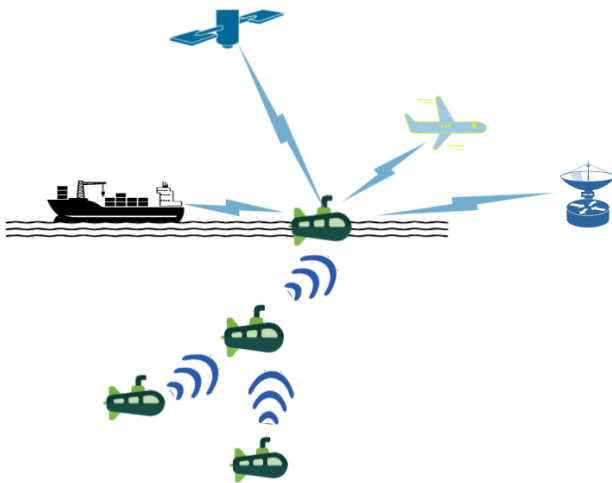


Fig.1 UUV Relay Transmission

3. Optimization Strategy of The Model

The realization of multi UUV cooperative operation and UUV group intelligence often requires that the information of one UUV in the cluster can be transmitted to all other UUVs in the cluster. Therefore, the communication in the cluster needs to solve two levels of problems. First, from the overall perspective of the entire network, it is necessary to realize that the data of each UUV in the cluster can be transmitted to all other UUVs as quickly as possible under the condition of limited underwater communication bandwidth. Second, the point-to-point communication between two nodes should be fast and efficient.

In traditional wireless LAN, multicast is usually used to realize data transmission from node to all other nodes. However, due to the limited point-to-point transmission bandwidth in underwater environment, it is necessary to make full use of the transmission bandwidth to achieve the

maximum multicast capacity. To solve this problem, we use the advantages of network coding technology in traditional routing multicast, and apply network coding technology to underwater multi UUV cluster communication network to adapt to the scene of limited underwater communication bandwidth.

Network coding combines the concepts of coding and routing. By coding and combining information from different links, network nodes can realize both routing and coding functions. Under this network structure, you can make full use of the link bandwidth between nodes. With the help of the node's own sufficient storage and computing capabilities, you can store the received data for coding calculation, and then forward the encoded data, thus reducing the amount of data transmitted on the link. Therefore, it is particularly suitable for network scenarios where the node has sufficient computing capacity and limited link bandwidth. The underwater multi UUV cluster networking transmission just belongs to this type of scenario. Network coding can effectively improve the performance of network multicast, improve the capacity of multicast network, improve link load balance, save node energy consumption, improve network connection robustness, and improve network error correction efficiency.

In addition, aiming at the high packet loss rate of point-to-point communication in underwater environment, the combination of packet coding and automatic retransmission is used to optimize.

In the field of network transmission, the traditional feedback retransmission mechanism is that the sender triggers retransmission of lost packets according to the packet loss information received from the receiver. This technology is suitable for transmission scenarios with low packet loss rate and delay. When encountering scenarios with high packet loss rate and high time delay, the transmission efficiency will become very low. Especially in the case of high packet loss rate underwater, the use of feedback retransmission may lead to multiple feedback retransmissions of data before it can be completely transmitted to the opposite end, which is extremely time-consuming. In this scenario, the combination of packet coding and automatic retransmission can be used to optimize, that is, the sender will automatically send the original packet again no matter whether it is lost, so that the sender does not need to wait for the packet loss information from the receiver, thus avoiding the time loss of waiting for feedback. However, the disadvantage is that automatic retransmission of the original packet will double the amount of data transmitted, In the case of limited underwater communication bandwidth, the transmission efficiency will also be reduced. Therefore, the automatic retransmission mechanism can be combined with the packet encoding technology to change the data packets sent during the automatic retransmission from the original packets to the encoded packets calculated by the data groups composed of several data packets. The receiver can calculate the original packets according to the received encoded packets through the decoding operation, thus avoiding the problem of doubling the amount of data transmitted due to the automatic retransmission of redundant packets.

Taking the link packet loss rate of 0.25 as an example, every three original packets between normal transmission packets 1 and N will automatically send a redundant encoded packet. The three original packets and encoded packets form a data group. The encoded packets in the group are calculated

from three original packets. If any one of the three data packets in the group is lost, the receiver can calculate the lost data packet by using the remaining two original data packets and coded packets, without having to feed back the packet loss information to the sender and wait for the sender to retransmit, which saves time and improves efficiency. If all the packets in the group are received, this coded redundant packet can check whether the original packets in the block are correct, or even correct errors.

4. Summary

This paper describes the great advantages and broad prospects of UUV cluster cooperative work and group intelligence technology in the current underwater environment, and briefly introduces the development status and defects of underwater communication technology. A multi UUV communication model is proposed, and network coding technology is applied to optimize it, so as to improve the utilization of communication link bandwidth and the transmission efficiency between nodes. This technology does not depend on the bottom communication mode, and can be used for underwater wireless communication, underwater acoustic communication, laser communication and other communication methods, with strong practicability and

popularization.

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