

Research on Data Processing and Routing Optimization of Internet of Ships based on Blockchain

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Abstract

Many researchers have begun to try to apply blockchain technology to different fields to further enhance the performance bottleneck of existing applications. As one of the important application scenarios of the Internet of Things, the Internet of Ships is facing great challenges due to its special communication environment and communication requirements. For this reason, in this article, we will discuss where blockchain technology can be integrated with Internet of Ships. From the three aspects of Internet of Ships data transmission, data sharing, and data security, we will study the application of blockchain technology to Internet of Ships data processing applications. It is used to improve the data processing capacity of Internet of Ships; combine blockchain technology with node clustering algorithm to study the network routing optimization of Internet of Ships, improve network communication efficiency, and further enhance the execution efficiency of Internet of Ships.

Keywords

Blockchain; Internet of ships; Data processing; Route optimization.

1. Introduction

In recent years, the Internet of Things (IOT) network and business have developed rapidly. With the rapid development of IOT, the business demand for IOT is also growing. In addition to the latest information and communication technology developments that can solve the challenges of the IOT system, many experts and scholars have also constantly researching the application of blockchain technology in the IOT to enhance the various performance of the IOT. As the application scenario of the IOT in ship communication, the Internet of ships(IOS) is restricted by various navigation environments and also faces great challenges. The application of blockchain technology in the IOS can also enhance the various performances of the IOS, such as data processing, execution efficiency, etc.

Blockchain is a currency encryption technology born from Bitcoin. It has the characteristics of decentralization, distributed data storage, point-to-point transmission, consensus mechanism, asymmetric encryption, smart contract, transaction security, data immutability and traceability. At present, blockchain technology is widely used in the field of network trust management, such as the Internet of things, smart cities, intelligent manufacturing, supply chain management, digital asset trading, trusted cloud computing, network identity management and many other fields, and will gradually deeply integrate with the real economy to help the transformation and upgrading of the real economy [1].

This article first introduces the development of IOS, then introduces the block chain technology and the communication architecture of the IOS, and finds out the points that can be integrated. The paper puts forward the construction scheme of the data processing platform based on blockchain technology from the aspects of data transmission, sharing and security of the IOS, and combines the blockchain technology with the node clustering algorithm in the self-

organizing network The optimization algorithm of IOS routing is studied, and the routing nodes in the network are simplified to form a more reasonable topology structure of the network.

2. Development of the Internet of Ships

China has a vast ocean area, with a large number of ships and complex types. According to their purposes, it can be divided into ferries, passenger ships, cargo ships, oil tankers, rescue and salvage ships, etc. According to the navigation area, it can be divided into inland river ships, ocean ships, ships outside the port, etc. According to the purpose of the ship and the navigation area, different ships have different communication requirements, equipped with different communication and navigation equipment. In order to better integrate the data of the shipping information system and better realize the information interaction between the ship and the outside world, with the help of the concept of IOT, the Internet of ships also came into being.

In the 1990s, on the basis of summing up the successful experience of river shipping informatization construction in previous Member States, closely combining with the actual situation of transnational and trans regional transportation in Europe, the EU launched the pan European integrated information service for inland river shipping by building and improving the shipping basic measures such as ship tracking and tracking system, electronic message system, inland river electronic River map and display system [2] (RIS) demonstration project. RIS system uses modern information and communication technology to provide comprehensive shipping information services to users at all levels. The remarkable characteristic of RIS is the resource integration and standard unification of cross regional and cross departmental heterogeneous systems. The development and construction of European inland river shipping service informatization can play a good enlightenment role in the informatization construction and development of China's inland shipping [3].

In the construction of China's navigation information service platform, the maritime administration of the Ministry of transport launched the use of the ship's all-in-one card system in 2005. By the end of 2005, the VTS ship traffic management system network covering China's main ports and nearby waters was basically completed. At the end of May 2011, the shore based network of AIS ship automatic identification system covering China's coastal waters was completed. At the same time, before and after 2010, the ship shore wireless communication network has basically covered most of the coastal and inland waters and river reaches. All these have laid a solid foundation for the construction of IOS. In 2012, China launched the National Internet of Things Application Demonstration Project, the Internet of ships project, which was approved by the national development and Reform Commission and the Ministry of finance, which indicates that the IOS has been taken seriously by the state and began to embark on the road of development [4].

China's Internet of ships is in the initial stage of development, and various experiences and technologies still need to be inherited and explored. There is still a lack of relevant system research and theoretical support in terms of the overall system architecture, functional requirements positioning and operation management mode of the IOS, and the scheme and technology still need to be further studied [5]. In addition, the construction of offshore vessels network outside the inland river, especially in the far sea, is far away from land and lacks the support of shore-based shipping information platform to a certain extent. Basically, it can only rely on satellite links for transmission. Therefore, the construction of offshore vessels is more difficulty.

3. Blockchain Technology and Communication Architecture of IOS

In this chapter, we will describe the blockchain technology and the communication architecture of Internet of ships respectively, and discuss the integration between them, so as to prepare for the data processing platform of IOS based on blockchain in Chapter 3.

3.1. Blockchain Technology

Blockchain is a decentralized distributed public ledger technology[6]. Each node participating in the transaction will synchronously copy the constantly updated ledger data. The information is transparent and can not be tampered with. It was originally designed for encrypting currencies such as bitcoin. As shown in Figure 1, each block in the blockchain structure is a group of aggregated data blocks, each block is identified by hash value, timestamp and Merkle tree value, and the hash value of the previous block is mapped to the next block in chronological order to realize interconnection, so as to form a blockchain.

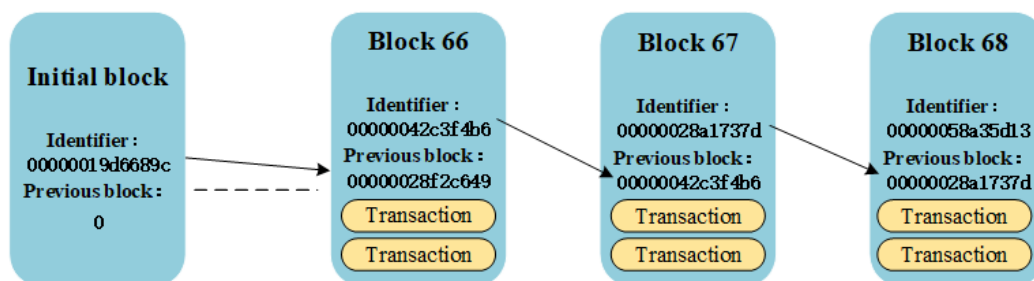


Figure 1. Structure of Blockchain

According to reference [7], the applicability evolution of blockchain (especially public blockchain) starts from digital currency (blockchain 1.0) such as bitcoin, and then evolves to financial markets (smart contract, blockchain 2.0) such as Ethereum, and now it is turning to large-scale commercial applications supporting fairness, efficiency and coordination, such as EOS commercial distributed blockchain operating system (blockchain 3.0). At present, most applications are based on smart contract, which is a piece of decentralized code / protocol that is applied to the blockchain network and automatically executed when certain conditions are met in the transaction verification process.

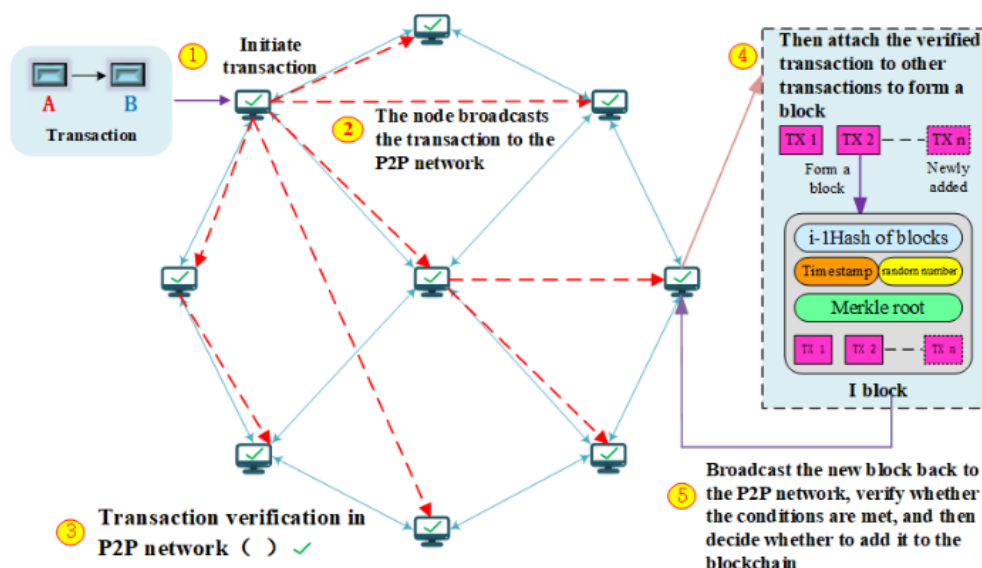


Figure 2. Workflow of Blockchain

3.1.1. Workflow

Take the transaction between user A and user B on the public blockchain as an example, and the workflow is shown in Figure 2.

Step 1: User a uses his private key to encrypt and then initiates transaction to user B.

Step 2: The network node broadcasts the encrypted transaction to the P2P network.

Step 3: After other nodes on the P2P network receive the encrypted transaction, they will use the corresponding public key to verify the transaction. If there is any error in the data transmission process, the decryption will fail to ensure the integrity of the transaction.

Step 4: All parties involved in the transaction mutually verify the transaction to reach agreement (consensus). When the P2P network successfully verifies the transaction, the special node miner will add other information to the verified transaction to form a new block.

Step 5: The miner broadcasts the newly generated block to the P2P network, and the node uses the corresponding hash to verify whether the new block contains a valid transaction and whether it refers to the previous block of the chain. If these conditions are not met, the block is discarded; if the above conditions are met, the block is added to the blockchain, so as to realize the update of the blockchain.

3.1.2. Key features

Blockchain technology has the following key features:

1) Decentralization: Unlike traditional centralized methods such as the existence of regulatory agencies, there is no center in blockchain technology. Decentralization is mainly achieved by using P2P network (peer-to-peer network or point-to-point network) technology, such as As shown by the 9 network nodes in Figure 2, each network node can directly connect to each other for communication without a third party (central node).

2) Immutability: The blockchain is composed of continuously linked blocks. The hash value of the previous block is mapped to the next block in chronological order. Any modification to a block will invalidate all subsequent blocks. Therefore, any forgery and tampering of data is easy to detect.

3) Transparency: For most public blockchain systems (such as BTC and Ethereum), as long as a transaction completes the transaction, the transaction data (not detailed data, the specific details of the transaction can be selected not to be published) will be backed up synchronously to all nodes, this data is transparent to every user who can access it.

4) Anonymity: Every user on the blockchain network can interact by using the generated address, and only users with whom they have transactions can see their real address, so as to maintain a certain degree of privacy; in addition, the parties involved in the transaction on the public blockchain can choose to be anonymous to hide their true identity. It is common for the parties in the transaction to not know the identity of the other party.

5) Traceability: Every transaction stored in the blockchain is attached with a timestamp, and all traces and transactions of the transaction are recorded in the block. After analyzing the data, users can easily verify and track the source of historical data items.

3.1.3. Types

There are different types of blockchains depending on the data being managed, the availability of that data, and the operations that users can perform. According to reference [8], blockchains can be divided into three categories: 1) public blockchains; 2) private blockchains; 3) alliance blockchains.

1) The public blockchain is zone without permission. Anyone can join the blockchain without the approval of a third party, and can participate in the negotiation process without any permission. Bitcoin and Ethereum fall into this category.

2) The private blockchain is managed and controlled by a single organization and belongs to the jurisdiction area. For private blockchains, the owner restricts network access. Only the organization to which the blockchain network belongs can write transactions to it. According to the needs, the transaction read can be public or limited to a few nodes. This type of system is usually deployed in the industry.

3) The alliance block chain is between the public block chain and the private block chain. Only the defined nodes can participate in the negotiation process. The permission to read or send can be public, or it can only be provided to a few authorized nodes.

3.2. Communication Architecture of IOS

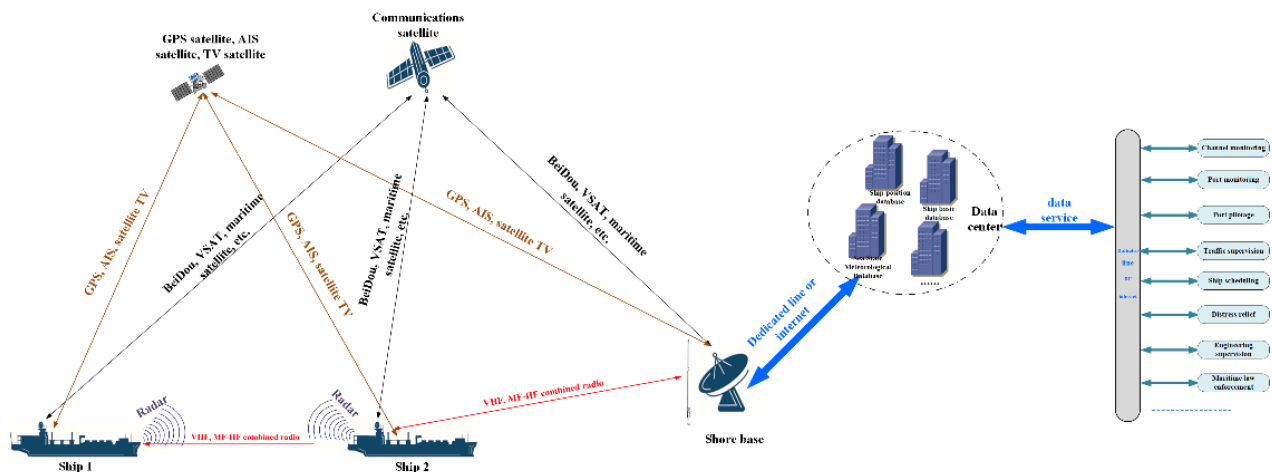


Figure 3. Communication architecture of Internet of Ships

Due to the increasing demand for information exchange between ships and the outside world, the Internet of Ships will be one of the most promising IoT application scenarios in the world. IOS realizes the information exchange between ships and ships, between ships and shore bases, docks, etc., and between ships and people inside ships, including ship equipment operating status information collected by the ship's engine room and bridge, and navigation collected by ship equipment Information, distress information, and information exchanged from the outside world. It can also be considered that all equipment that can communicate information with the outside world on ships is part of IOS, including RFID identification systems commonly used in inland rivers, compasses, radars, autopilots, electronic charts, GPS, AIS, weather instruments, and beacons. Marine navigation equipment such as aircraft, depth sounder, log, VDR; shipborne satellite TV, general fire alarm, radio image transmission system, photoelectric tracking and forensics system, CCTV monitoring system and other avionics equipment; GMDSS standard combination radio, medium and high frequency, VHF, radar transponders, emergency radio beacon, navigation warning receiver, marine handheld intercom and other radio equipment; also such as BeiDou Navigation Satellite System, VSAT, maritime and other satellite communication equipment. The communication architecture of the IOS is shown in Figure 3.

Although the BeiDou navigation satellite system independently developed by China and the fifth generation maritime satellite of International Maritime Satellite Organization(IMO) have been applied to ship communication, the construction of China's IOS is still faced with many challenges, such as how to ensure the effective transmission of complex and heterogeneous massive data, data sharing and data security, data processing and execution efficiency, etc. The application of blockchain technology to the IOS can improve the above capabilities. In Chapter 3, a data processing platform based on blockchain technology is proposed.

4. Construction of Data Processing Platform for IOS based on Blockchain

In this chapter, the construction of data processing platform based on blockchain will be carried out from three aspects: data transmission, sharing and security.

4.1. Data Transmission

The application of blockchain technology to IOS can improve the data transmission capability of IOS. As shown in Figure 4, the ship collects dynamic data, some emergency data and ship self-monitoring data through compass, radar, electronic chart, GPS, AIS, meteorological instrument, beacon, depth sounder, log, VDR, photoelectric tracking forensics system, CCTV monitoring system and other equipment. Some basic and business data of the ship are aggregated together through the ship networking system.

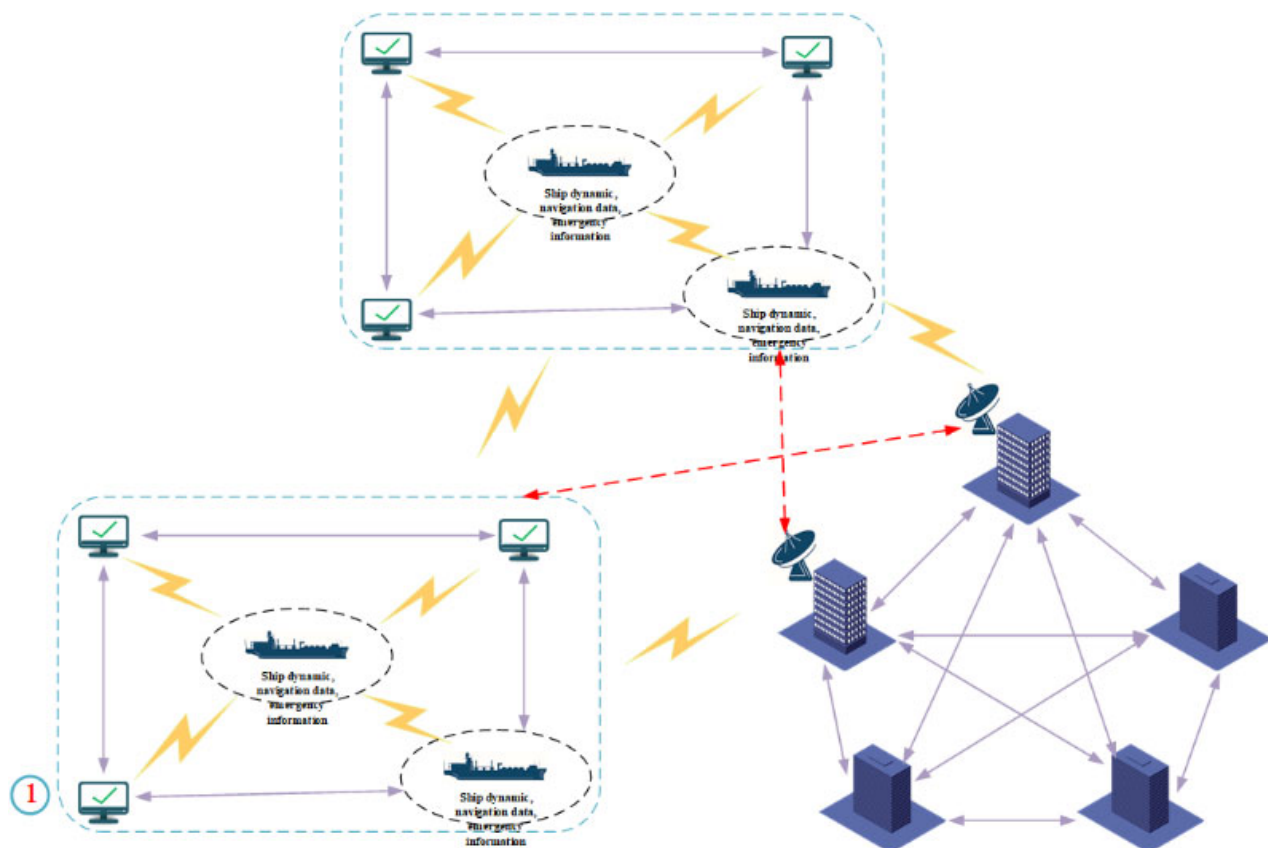


Figure 4. Data transmission framework of IOS based on blockchain Technology

Then transmit to other nodes (which can be other ships or the command center of ship enterprises and affiliated unit) through wired or wireless links such as satellites, private networks, and Internet (Internet (depending on whether the ship is sailing in inland river, offshore or open sea, depending on the communication and navigation equipment equipped)). By using P2P network technology, ship data can be broadcasted, and nearby ships, islands, land and other shore parties can receive the ship's voyage data information and realize point-to-point transmission. At the same time, the data received by the shore party can be simultaneously broadcast to other data centers, allowing data sharing across industries and solving interoperability issues. This greatly improves the data management, data calling and data sharing capabilities of IOS.

4.2. Data Sharing

On the basis of the IOS data transmission framework based on blockchain technology, the idea of layered design is used to propose a IOS data sharing platform architecture based on blockchain technology. The IOS data information collection system (sensing layer) and IOS communication System (network layer), blockchain data platform (data link layer), IOS application layer, ship networking display and control layer are composed of five parts, as shown in Figure 5. among them:

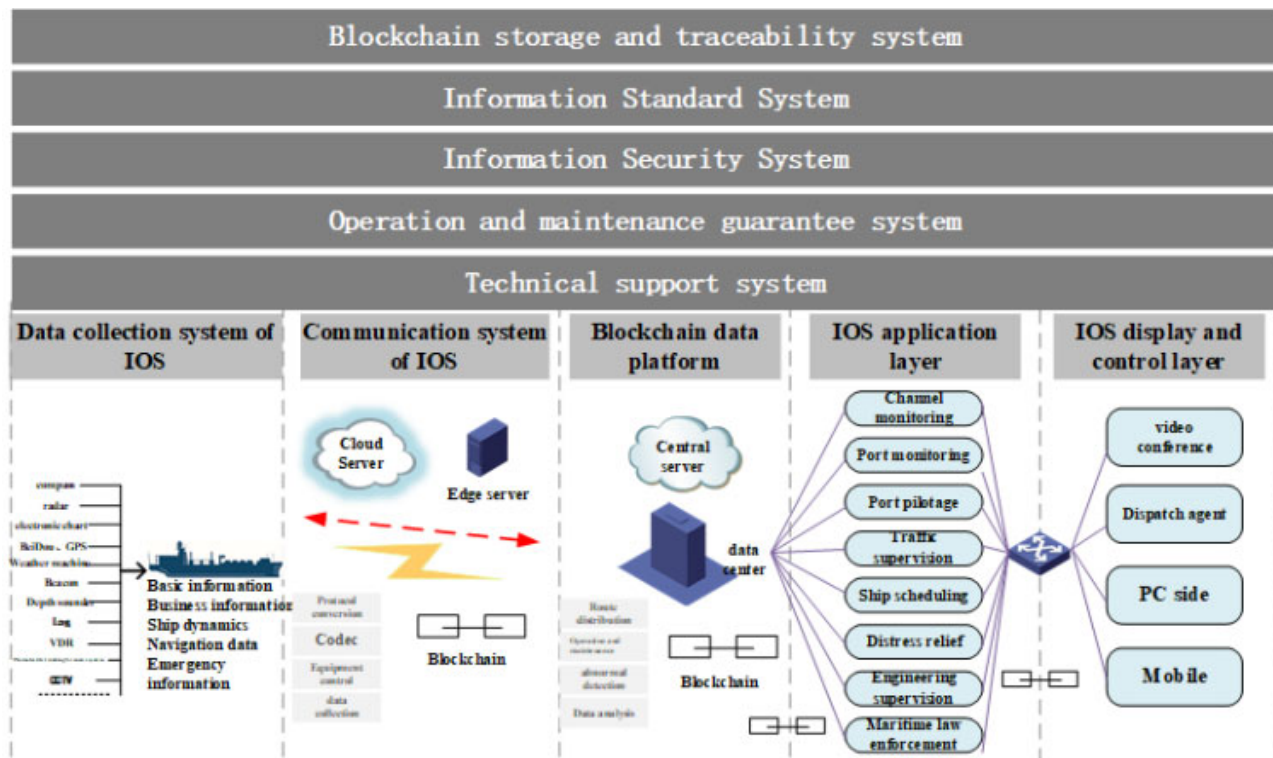


Figure 5. The architecture of the IOS data sharing platform based on blockchain technology

- 1) IOS data information collection system (perception layer): The main carriers are various types of ships including inland rivers, offshore and open seas, basic data, business data on ships, and ship dynamics and navigation data collected by equipment such as avionics on ships.
- 2) IOS communication system (network layer): Combining with the P2P network of the blockchain, the blockchain propagation mechanism, and the blockchain verification mechanism, the collected data is passed through wireless links such as BeiDou, maritime satellite, 4G/5G and other wireless or wired links. The link is broadcast to the data center or other network nodes. In addition, at the network layer, cloud computing and EMC (mobile edge computing) servers can also be expanded to improve the propagation capabilities of the network layer.
- 3) Blockchain data platform (data link layer): The blockchain data platform is the core part of the ship networking data sharing platform. It is generally a data center and a central server, and is loaded with the underlying data of the blockchain and the Merkel tree. It is mainly responsible for summarizing, storing and managing the data collected by the ship networking data information collection system, and at the same time providing data support for the ship networking application layer. Each data center in the blockchain data platform can exchange data with other data centers under the authority to realize the sharing of ship networking data.

4) IOS application layer: Call the IOS data of the blockchain data platform through various applications. At the same time, when each application has cross requirements, various applications can also realize direct interaction and share IOS data.

5) IOS display and control layer: This layer is a platform for users to view IOS applications, communicate with ships, and dispatch ships, usually the control center. The control centers can realize point-to-point communication, share IOS data, discuss and make corresponding dispatching instructions for ships.

The collaboration of all layers helps to achieve the synchronization of information and data and the decentralization of computing. It can be seen that compared with the traditional ship networking, cross-departmental and cross-regional data sharing, the IOS data sharing platform based on blockchain technology has obvious advantage.

4.3. Data Security

The application of blockchain technology in the IOS can improve the data security and ship safety of the IOS. In the process of data transmission and sharing, the timestamp and asymmetric encryption algorithm of blockchain technology can be combined with the ship's AIS information and data broadcasting and other processes are combined.

When ship data is broadcast to other nodes, the data will leave a historical record and generate a time stamp after each node rebroadcast, thus realizing the traceability of ship data and ensuring to a certain extent Safe transmission of ship network data. On the other hand, installing and upgrading equipment firmware updates in ships is costly and inefficient. The smart contract protocol can be written into the ship's communication and navigation equipment system. Under certain conditions, such as when the ship is docked, the equipment downloads and installs firmware through the automatic intelligent contract, thus greatly saving the cost of safety maintenance.

1) The public blockchain can be combined with the ordinary public IOS. All ships can freely join the public area IOS for information exchange. The verification and audit technology of blockchain technology can allow new ships to join the communication. It is necessary to automatically disclose its own AIS information to existing ships when they join the communication. On the one hand, it can prevent illegal ships such as smuggling ships from collecting information to conduct illegal activities. On the other hand, as long as they join the public IOS, the corresponding AIS information will be left. The maritime police and other law enforcement agencies can track the specific trajectory of the ship through its database and dedicated network, which brings great convenience to maritime law enforcement and maritime supervision.

2) The alliance blockchain can be combined in the collective network of the IOS, and permissions can be set when multiple industries or multiple departments such as distress rescue, marine engineering supervision, cooperate with each other. Whenever there is a new ship and other new nodes to access the blockchain data platform, the new node must first pass the verification and review of other nodes in the network. Only approved ships can join the network to access data and communicate, ensuring that no unrelated ships enter the system and cause information leakage. Unauthorized sources cannot destroy the safety of the IOS.

3) The private blocks can be combined in the private network of IOS. Blockchain technologies such as asymmetric encryption algorithms and digital signatures can be used in smart maritime, VTS ship traffic management systems or ship enterprise networks to further ensure that IOS is dedicated network data transmission is safe.

5. Routing Optimization of IOS based on Blockchain

Similar to the application of blockchain technology to the Internet of Things, it is very difficult to store the entire blockchain on the ship's IOS equipment due to the limitations of the IOS equipment. We can consider using the following two modes to store blockchain data on IOS equipment: 1) Complete storage, storing the entire blockchain; 2) Partial storage, only storing part of the data block locally. The node that completely stores the blockchain data is named a full node, and the node that partially stores the blockchain data is named a lightweight node.

A complete node can be a cloud server, edge server, or data center with sufficient computing resources, because it requires a lot of storage space to save the entire blockchain and powerful computing power to solve consensus problems. While the resource constrained IOS equipment can be a lightweight node that can only store part of the blockchain data.

In Section 3.1, the application of blockchain technology on the ship networking system can realize the point-to-point transmission of network nodes. While improving the data transmission capacity of IOS, it also wastes network resources due to data redundancy. However, the data transmission of the offshore ship network basically depends on satellite transmission, and the satellite network resources are extremely scarce and expensive. In addition, the control center and server may spend a lot of time and power consumption on data screening, which brings a burden to the control center and server. To solve this problem, in this chapter, we will discuss combining the blockchain technology with the node clustering algorithm in ad hoc network, and propose a network routing optimization method for IOS, which simplifies the routing nodes in the network, forms a more reasonable network topology structure of the IOS.

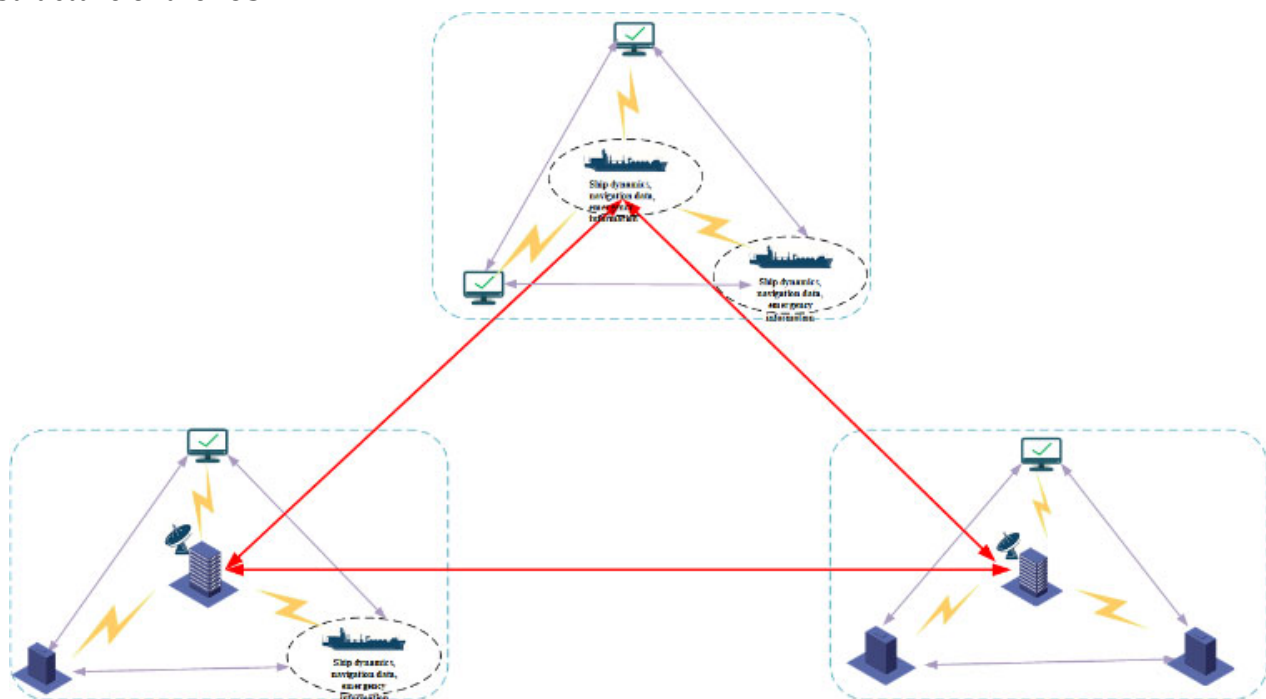


Figure 6. Network routing optimization of Internet of ships

The basic idea of node clustering algorithm is to establish data model first, then select cluster head node to cluster, and finally send data on behalf of node. As shown in Figure 6, in the IOS network, the node clustering algorithm takes the adjacent nodes within a hop range as a cluster[9], selects one of the complete nodes of the IOS as the cluster head, and other lightweight nodes of the IOS as members of the cluster. In a cluster node, the light-weight nodes of the IOS can transmit data to each other, or with the complete node of the IOS. The complete

node is responsible for collecting and integrating the information data of the cluster nodes. Between clusters, data can only be transmitted between complete nodes of IOS.

Using the asymmetric encryption algorithm and digital signature of blockchain technology, the newly added network nodes can be audited and verified. Only the verified nodes can transmit data with other nodes in a cluster or between clusters;

In addition, the network nodes of the ship network are not permanently fixed nodes belonging to a certain cluster. As the ship moves at a high speed, the lightweight nodes use the α – local spatial correlation clustering algorithm to search for the closest complete node for data. When the nearest complete node fails, the lightweight node will also skip the complete node and continue to find the next complete node.

At the same time, when the lightweight nodes in the cluster originally classified as a complete node of the IOS are all transferred to other complete nodes, the fault of the complete node can be further confirmed, and the approximate data and fault situation of the complete node can be judged by using the overlap between the routing distance and the latest transmission data of the complete node.

The above is the optimization of the IOS network routing based on blockchain technology and the integration of node clustering algorithms. The routing optimization of the IOS can simplify the IOS network structure, and the distributed architecture can also weaken the centralization and hierarchization, forming more a reasonable network topology. It can effectively reduce the number of data interactions, facilitate control and management while reducing communication volume and communication distance, and not occupy too much network resources.

6. Conclusion

This article discusses the application of blockchain technology to Internet of ships, and proposes the construction of a IOS data processing platform based on blockchain technology from three aspects of data transmission, sharing and security of IOS, and studies the routing optimization of IOS. Further exploit the potential of the existing communication and navigation equipment for IOS, integrate data and information resources, strengthen cross-departmental and cross-regional data resource collaboration and sharing[10], improve the communication efficiency of IOS, and further provide the implementation efficiency of IOS, and provide intelligent ship management, provide communication guarantees in a refined and refined manner, build refined shipping information service systems, and improve the level of China's shipping informatization. At the same time, the work in this paper can also be further studied in the aspects of real-time data synchronization and incremental data capture and processing.

It must be realized that the application of blockchain technology to other fields is only in the initial stage. The application of blockchain technology to Internet of ships still faces many challenges. If we want to fully explore the blockchain technology and adapt to the specific needs of IOS. To improve the performance of IOS, more technical research is needed.

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