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Blockchain in the Maritime Industry

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ABSTRACT

Blockchain is a time-stamped series of a record of data that is managed by several computers that are not owned by any single person or company. The technology has the potential to revolutionize the maritime industry by enhancing transparency, security, and efficiency in global shipping and logistics. It addresses some of the most persistent challenges in maritime logistics, including inefficiencies, fraud, and lack of transparency. Its inherent immutability and use of powerful encryption technology offer high security from fraudulent activities, such as document manipulations. This paper investigates the integration of blockchain technology into the maritime industry.

KEYWORDS: *blockchain, distributed digital ledger, maritime industry*

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INTRODUCTION

The vast, open oceans have long served as conduits for commerce, adventure, and exploration. The maritime sector operates using an information network that involves many parties, e.g., shippers, freight forwarders, and carriers. The shipping industry is complex, involving multiple stakeholders, including shippers, carriers, freight forwarders, customs authorities, and financial institutions. Traditionally, this complexity has led to inefficiencies, delays, and opportunities for fraud. The shipping industry is responsible for transporting an estimated 90% of the world's goods. As the industry evolves, technological advancements have become essential for enhancing supply chain efficiency. One such emerging technology is blockchain. While originally created for use with cryptocurrency, the underlying blockchain technology is already getting tested in dozens of industries, from agriculture to energy to art. The maritime industry is catching up quickly, and the changes are going to be immediately impactful.

The blockchain ecosystem connects all stakeholders in the supply chain, including cargo owners, freight forwarders, inland transportation providers such as rail and trucking, ports and terminals, ocean carriers, customs, and other government authorities. It enables seamless, real-time sharing of cargo details, trade documents, and shipping milestones, ensuring that critical information is secure, immutable, and auditable through blockchain technology [1].

Blockchain offers myriads of features which makes it a technology of the future. The maritime industry is focusing on implementation blockchain as a part of their functioning. That plethora of paper processors has been one of the reasons shipping has lagged other industries in moving to electronic forms. Manual processes are still in place in the shipping industry despite technological advancements.. With the help of blockchain technology, we can expect the shipping and maritime industry to have a completely different mode of operations in the times to come [2[.

WHAT IS BLOCKCHAIN?

Blockchain, a type of distributed digital ledger technology (DLT), is a relatively new and exciting way of recording transactions in the digital age. It is a decentralized and distributed

digital ledger technology that securely records and verifies transactions across multiple computers or nodes in a network. Basically, it is a chain of blocks in which each block contains a list of transactions. The symbol of a blockchain is depicted in Figure 1 [3].The blockchain technology was created as the foundational basis for Bitcoin – a digital currency in which secure peer-to-peer transactions occur over the Internet. It is expected that the spending on blockchain solutions worldwide would grow from 4.5 billion USD (2020) to an estimated value of 19 billion USD by 2024 [4].

Originally developed as the accounting method for the virtual currency Bitcoin, Blockchains are appearing in a variety of commercial applications today. Blockchain technology is a type of distributed digital ledger that uses encryption to make entries permanent and tamper-proof and can be programmed to record financial transactions. It is used for secure transfer of money, assets, and information via a computer network such as the Internet without requiring a third-party intermediary. It is now being adopted across financial and non-financial sectors. As a catalyst for change, the Blockchain technology is going to change the business world and financial matters in major ways.

The first Blockchain was conceived in 2008 by an anonymous person or group known as Satoshi Nakamoto, who published a white paper introducing the concept of a peer-to-peer electronic cash system he called Bitcoin [5,6]. Bitcoin and Ethereum are the first two mainstream blockchains. Other modern blockchains include Namecoin, Peercoin, Ether, and Litecoin. Figure 2 shows different components of blockchain [7].

Blockchain combines existing technologies such as distributed digital ledgers, encryption, immutable records management, asset tokenization and decentralized governance to capture and record information that participants in a network need to interact and transact. As illustrated in Figure 3, a complete blockchain incorporates all the following five elements [8]:

- *Distribution:* Digital assets are distributed, not copied or transferred. A protocol establishes a set of rules in the form of distributed mathematical computations that ensures the integrity of the data exchanged among a large number of computing devises without going though a trusted third party. A centralized architecture presents several issues including a single point of failure and problems of scalability.
- *Encryption:* BC uses technologies such as public and private keys to record data securely and semi-anonymously. Completed transactions are cryptographically signed, time-stamped, and sequentially added to the ledger.
- *Immutability:* The blockchain was designed so these transactions are immutable, i.e. they cannot be deleted. No entity can modify the transaction records. Thus, Blockchains are secure and meddle-free by design. Data can be distributed, but not copied.
- *Tokenization:* Value is exchanged in the form of tokens, which can represent a wide variety of asset types, including monetary assets, units of data or user identities.
- *Decentralization*: No single entity controls a majority of the nodes or dictates the rules. A consensus mechanism verifies and approves transactions, eliminating the need for a central intermediary to govern the network.

Bitcoin and its underlying blockchain technology increasingly impact all facets of society. Bitcoin's status as digital gold is merely the tip of this technology. Figure 4 shows Bitcoin [9], while Figure 5 shows how blockchain works [10]. Although blockchain technology will for all time be associated with Bitcoin due to their common genesis, it has broader applications. Cryptocurrency will increasingly become a factor in family law issues as well.

A blockchain is a tamper-proof, distributed database that stores blocks of information for cryptographically bound transactions via peer-to-peer networks. At the heart of blockchain's functionality is cryptographic hashing. Each block in a blockchain contains a cryptographic hash of the previous block, creating an immutable chain of blocks. If anyone attempts to tamper with the data in a block, it would alter the block's hash. This would disrupt the entire chain, making it virtually impossible to manipulate. The security feature ensures data integrity and prevents unauthorized changes [11].

In a nutshell, blockchain technology involves three basic concepts [12]: (1) It is a system for recording a series of data items (such as transactions between parties); (2) It uses cryptography to make it difficult to tamper with past entries; (3) It has an agreed process for storing copies of the ledger and adding new entries (also called a consensus protocol).

Blockchain is a novel decentralized infrastructure and distributed computing paradigm that uses a chained data structure for verification, storage, and distributed consensus algorithms to generate and update data. Decentralization is a key feature of blockchain

technology, which refers to the distribution of power and decision-making across a network of nodes or participants rather than being controlled by a central authority or system. It provides robustness while eliminating many-to-one traffic flows to avoid delays and single points of failure. Figure 6 shows the decentralized property of blockchain [10]. The advantages of decentralized property of blockchain network include the following [10]:

- The decentralized property of blockchain makes it less prone to failure and more expensive for hackers to attack the network.
- There is no third-party involvement; therefore, there is no added risk.
- Every change made in the network is traceable and concrete.
- Users maintain full autonomy of their properties and are not dependent on third parties to maintain and manage their assets.
- It provides enhanced security.

MARITIME BLOCKCHAIN

Blockchain is the electronic, public ledger system that allows transactions to be verified autonomously. A blockchain consists of a growing list of records called blocks. Each block contains transaction data, a timestamp, and a cryptographic key to the previous block. Business transactions of any kind are recorded in sets or "blocks" of data that build upon each other logically, similar to the entries in a ledger. New database entries are appended to the existing block, resulting in a blockchain. Blockchain data is not housed in a central location, allowing it to operate in real time. As every new block is added, the network is immediately updated, and the recent movement is made visible to all users.

The advent of blockchain in 2008 and the understanding of the characteristics of this new technology has motivated information technology companies to create blockchain-based applications. Blockchain technology has emerged as a potential solution to address the imperative need for enhancing security, transparency, and efficiency in the maritime industry, where increasing reliance on digital systems and data prevails. Maritime blockchain applications include ship operations, marine insurance, and ship finance. These practical applications highlight the revolutionary impact of blockchain technology in addressing real-time challenges and optimizing maritime processes [13]. The impact of blockchain on maritime industry is shown in Figure 7 [14].

APPLICATIONS OF BLOCKCHAIN IN MARITIME

Blockchain technology can have numerous applications in the maritime industry as it provides transparency, security, and cost reduction in financial transactions. In the context of shipping, blockchain can be used to track the movement of goods, verify documentation, and facilitate payments, all within a secure and transparent framework. Common applications include the following [3]:

- *Smart Contracts*: Smart contracts are an area of interest for shippers. In their current form, transactions in the shipping sector are inefficient and expensive. The ability to reduce trade documentation, processing costs, delays, data manipulation, fraud and human error through uncompromisable "smart contracts" makes blockchain technology attractive to the shipping world. Smart contracts—self-executing contracts with the terms of the agreement directly written into code—can further automate processes, reducing the need for intermediaries and speeding up transactions. Smart contracts automate customer contracts using blockchain technology. These contracts are machines based on blockchain programmed with rules composing the legal agreement. What makes them different is that the rules are recorded and verified by a machine instead of a human being. Smart contracts allow participants to enter into agreements. These rules must be followed strictly, or else consequences will be executed. Payments, for example, can be held until delivery is validated or until some inspections are carried out.
- *Smart Bills of Lading*: A receipt of services is known as the bill of lading, which includes details like the destination, type, and quantity of goods in a shipment. The bill of lading documents are written on paper, and the shipper receives them via courier. This can be very expensive and often results in delays. If no bill of lading is available, the cargo will be held up and piling up in ports. If you have tried using the bill of lading document to track your shipments, you surely know how unreliable it is. You must spend additional money to issue and transport all these documents to worsen things. Blockchain in shipping can track cargo more efficiently in real-time. Once in the blockchain, documents will also remain secure and safe. This means you can save on courier costs and worry less about losing these pertinent documents.
- *Tracking of Shipments*: Traditional methods of tracking tend to be very slow. Thanks to blockchain technology, however, data is accessible no matter where you are and whatever

time of day or night it might be. This allows you to manage all your shipments efficiently and in real-time.

- *Streamlined Documentation:* The shipping industry is heavily reliant on documentation and paperwork, such as bills of lading, certificates of origin, and customs declarations. These documents are often processed manually, leading to delays and errors. Blockchain can help streamline communication among industry stakeholders. Open platforms allow you to easily and quickly access your data, saving you time from calling and sending emails to access your pertinent data and information. Blockchain allows for the digitization of these documents, making them easily accessible and verifiable.
- *Fraud Prevention:* Fraud is another issue in the shipping industry regarding paper documents. Fraud is a significant concern in the shipping industry, whether it involves counterfeit goods, document forgery, or financial fraud. Signatures can be forged, fake logos can be printed, and inaccurate details can be added to forms. However, once data is encrypted with the help of blockchain in shipping, these frauds will no longer be a concern. Blockchain's immutable ledger makes it nearly impossible to alter records without detection, significantly reducing the risk of fraud.
- *Trust:* Trust affects technology acceptance models. The shipping industry is characterized by multiple and complex relationships, and as a result, cooperation needs trust to work effectively and smoothly. The shipping industry is built on trust, and it is the base for building long-lasting business relations between shipping companies and charterers. Blockchain improves trust and collaboration among various stakeholders, including shipping companies, freight forwarders, and port authorities. By offering a decentralized and secure platform for sharing information, blockchain can facilitate seamless and trusted data exchange. This not only minimizes the risk of fraud and data corruption but also ensures better visibility and traceability throughout the entire supply chain. The information stored on a blockchain-based application can be visible to all interested and authorized parties, ensuring transparency and trust.
- *Decision-Making:* Decision-making is a prolific research area in the internet era, which has propelled globalization and the virtual elimination of many country border barriers. However, effective decision-making in the shipping industry is a time consuming and often complicated process. Organizational decision-making is often influenced by past cases. Decision-making based on the analysis of real-time data is indeed significant for companies. It is being increasingly supported by artificial intelligence and autonomous systems. Decisions based on blockchain technology are also executed much faster than conventional approaches. For example, the use of smart contracts offers an automated mode of decision-making based on predetermined parameters agreed upon by actors.

BENEFITS

Though blockchain is widely known for underpinning cryptocurrencies, it has become a central component for the efficient dissemination of information and data across the business world. Blockchain gives authorized users access to data tracking orders, accounts, production, schedules, and shipping in real time. One major advantage of blockchain is its high degree of "data integrity", which means that data is particularly reliable and protected from being accessed by unauthorized individuals. Using blockchain in shipping allows information such as that in a bill of lading to be stored in an uncomplicated, secure. and transparent fashion. Other benefits include the following [1,15]:

- *Cost Reduction:* By eliminating intermediaries and automating processes through smart contracts, blockchain can significantly reduce operational costs. The reduction in paperwork, delays, and disputes also contributes to cost savings. Expensive fees for documentation, procedural delays, discrepancies, and errors can be avoided by replacing old methods with a blockchain strategy.
- *Better Customer Experience:* Sometimes packages are lost or damaged while in transit. This can cause customers to choose not to order from a certain company again and damage the reputation of the shipper. Blockchain is able to keep the customer in the loop by showing them exactly where their package is at all times. They would be able to review documentation from the shipper to see the events in the chain of custody and determine where the issue occurred.
- *Improved Transparency:* With blockchain, all information is stored in a location that may be viewed by all parties with the necessary access key, providing an effective means for connecting customers, carriers, orders, and payments in real-time. This makes it much easier for everyone from the supplier to the end consumer to track where their shipment is and when it should arrive.

- *Enhanced Traceability:* One of the most significant advantages of blockchain in shipping is its ability to provide a transparent and traceable record of every transaction and movement within the supply chain. Blockchain technology allows transactions to be tracked and traced infinitely. It can provide end-to-end visibility and traceability. By recording and sharing every transaction and movement of goods on a blockchain, stakeholders can gain real-time insight into the location and status of their shipments
- *Amplified Security:* Blockchain ensures secure data sharing among authorized parties, reducing the risk of unauthorized access and data breaches. All information in blockchain is encrypted, therefore adding a strong layer of security. Users cannot interfere with the system and change any information, therefore preventing fraudulent activities and manipulations. With blockchain, the possession of a shipment or package is tracked at each step which can help eliminate any questions regarding the chain of custody.
- *Quicker Processing Time:* Instead of having to mail or scan documents to various parties, the exchange of information is instant and procedures which normally could take days or weeks to perform can be done in minutes.
- *Increased Shipping Speed:* Instead of waiting for large carriers to fill up shipments on their trunk lines, smaller companies could bid on legs of a journey. Right now, starting a shipping company requires a lot of overhead and upfront costs. In a blockchain system, smaller operators will be able to bid on contracts for certain shipments. This introduces greater flexibility into the entire shipping industry.
- *Boosting Efficiency:* One of the most significant advantages of implementing blockchain in the shipping sector is the enhancement of operational efficiency. By digitizing and streamlining traditionally paper-based documentation processes, blockchain can significantly reduce time, cost, and errors. Blockchain enables real-time tracking and data sharing across the entire supply chain, allowing for better coordination and decision-making. This increased efficiency can lead to faster delivery times and improved customer satisfaction. A US Department of Transportation Maritime Administration report identifies three key areas in which blockchain can increase shipping efficiency: shipment tracking, smart bills of lading, and smart contracts. To boost efficiency—both environmental and business—the shipping industry should invest in standardized blockchain technology.
- *Enhanced Carrier Compliance:* The rise of e-commerce is pushing companies to have faster delivery methods like same-day delivery via local carriers. Blockchain could provide the new technology standard needed to reduce complexity while improving compliance and the integrity of shipping transactions. It is important to note that the carriers will need to choose to participate.

Seven of these benefits are displayed in Figure 8 [15].

CHALLENGES

While the potential benefits of blockchain in the maritime industry are significant, the technology is not without its challenges. Blockchain technology has much potential for the marine sector, but difficulties and impediments to its wider implementation exist. These include the necessity for industry-wide cooperation, regulatory uncertainty, and interoperability problems. The now omnipresent blockchain technology has been met with both confusion and creativity. Other challenges include the following [1,13,16]:

- *Scalability:* One of the main challenges for blockchain in the maritime industry is scalability, as the volume of transactions and data can be massive. Blockchain networks, particularly those that are public and decentralized, can face scalability issues as the volume of transactions increases. Ensuring that blockchain systems can handle the demands of global shipping is essential for widespread adoption.
- *Interoperability*: Ensuring seamless integration of blockchain solutions with existing systems and platforms is crucial. The shipping industry involves a vast array of stakeholders, each with their own systems and processes. Ensuring that blockchain solutions can integrate and communicate with existing technologies and platforms is critical for success.
- *Regulatory Compliance:* The development of regulations and the introduction of standards is one way in which the attractiveness of the technology can be strengthened. The adaptation of blockchain technologies to the maritime industry offers opportunities for innovations, but it also introduces complex compliance and regulatory issues that need to be considered. Blockchain regulations as they relate to maritime operations are evolving. It is a realistic difficulty to ensure compliance with both present and future regulations. To make sure that blockchain implementations comply with regulatory

standards, navigating legal frameworks, particularly in the context of international marine trade, it requires constant monitoring and adaptation. Clear legal frameworks and standards are needed to support the adoption of blockchain in the maritime industry. The adoption of blockchain in shipping requires alignment with regulatory and legal frameworks, which can vary significantly between countries. Establishing global standards and ensuring compliance will be key to the successful implementation of blockchain in the maritime industry. Many countries have strengthened their financial regulations to fight money laundering.

- *Implementation Costs:* The initial costs of implementing blockchain technology can be high, particularly for smaller companies. Additionally, there is a learning curve associated with the adoption of new technologies. Stakeholders will need to weigh the long-term benefits against the short-term costs and challenges.
- *Data Privacy and Security:* While blockchain is inherently secure, the handling of sensitive data, particularly in public or consortium blockchains, raises concerns about privacy and data protection. Balancing transparency with the need to protect sensitive information will be an ongoing challenge.
- *Sustainability:* The conversation around the shipping industry's resiliency is incomplete without considering its environmental impact. Shipping is responsible for about 3 percent of global carbon dioxide emissions, making it one of the most polluting industries in the world. Blockchain technology has the capacity to make it more sustainable through tracking fuels, space maximization, and digitizing paperwork. Digitizing paperwork is also key to reducing the shipping industry's environmental footprint.
- *Social Influence:* This is the degree of an individual's perception of the use of the new system by other essential stakeholders. Employee's social influence (SI) positively affects his/her behavioral intention to adopt blockchain. This paper considers SI as the extent to which the employees are willing to adopt new technologies because other companies and organizations are already using them. Human resources play a vital role in the digital transformation since the inability and reluctance of a company's personnel to understand the benefits of using innovative solutions may jeopardize technology penetration and its multi-layered advantages. The idea of the "absorbing" capacity is essential for adapting an industry to new technologies. Social influence and trust are the two crucial strategic tools that will stimulate the behavioral intention of shipping companies in adopting the new technology.
- *Complex Cost Integration:* There are infrastructural, training, and implementation costs associated with integrating blockchain technology into current maritime systems. For systems with fewer resources, the complexity of cost integration may actually be an obstacle to implementation. This makes the adoption of blockchain not feasible for some businesses which can be decided based on a transparent cost–benefit study.

CONCLUSION

Blockchain has become one of the emerging technologies set to disrupt the maritime industry in the years ahead. It can increase performance and effectiveness in some shipping operations, especially those related to document exchange. It is set to revolutionize the shipping industry by providing a secure, transparent, and efficient way to manage global supply chains. Despite the challenges, the future of blockchain in shipping looks promising. As blockchain technology continues to evolve, its potential applications in the maritime industry are expected to expand. Blockchain could also provide opportunities in supply chain optimization, environmental sustainability, and finance management. As more stakeholders recognize its potential, we can expect to see wider adoption and integration across the industry.

Maritime companies are increasingly exploring to adopt blockchain to stay ahead of competition. The marine sector has a bright future for blockchain technology. The sector may overcome long-standing obstacles and usher in a new age of digitalization and collaboration by using blockchain technology's transparency, effectiveness, and security. More information on the integration of blockchain technology into the maritime industry is available from the books in [17,18] and the following related journals:

- IEEE Blockchain.
- Maritime Transport Research
- Maritime Policy & Management
- Scientific Journal of Maritime Research
- Journal of Shipping and Trade
- Marine Policy

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Figure 1 The symbol of blockchain [3].

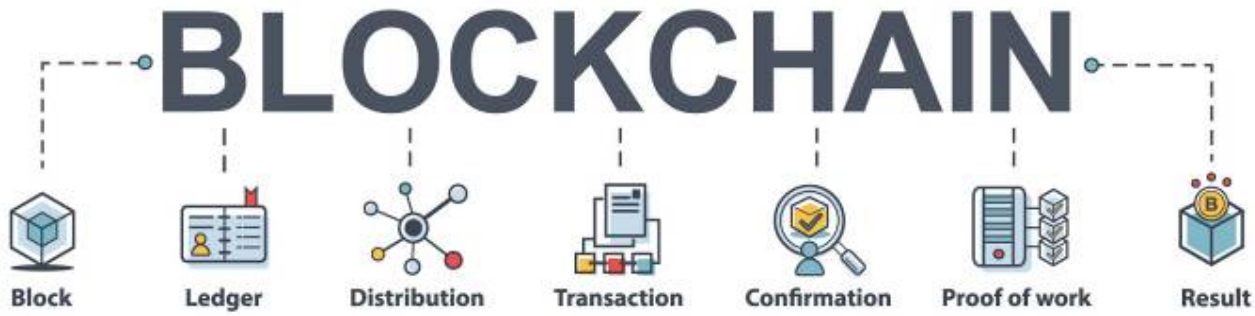

Figure 2 Different components of blockchain [7].

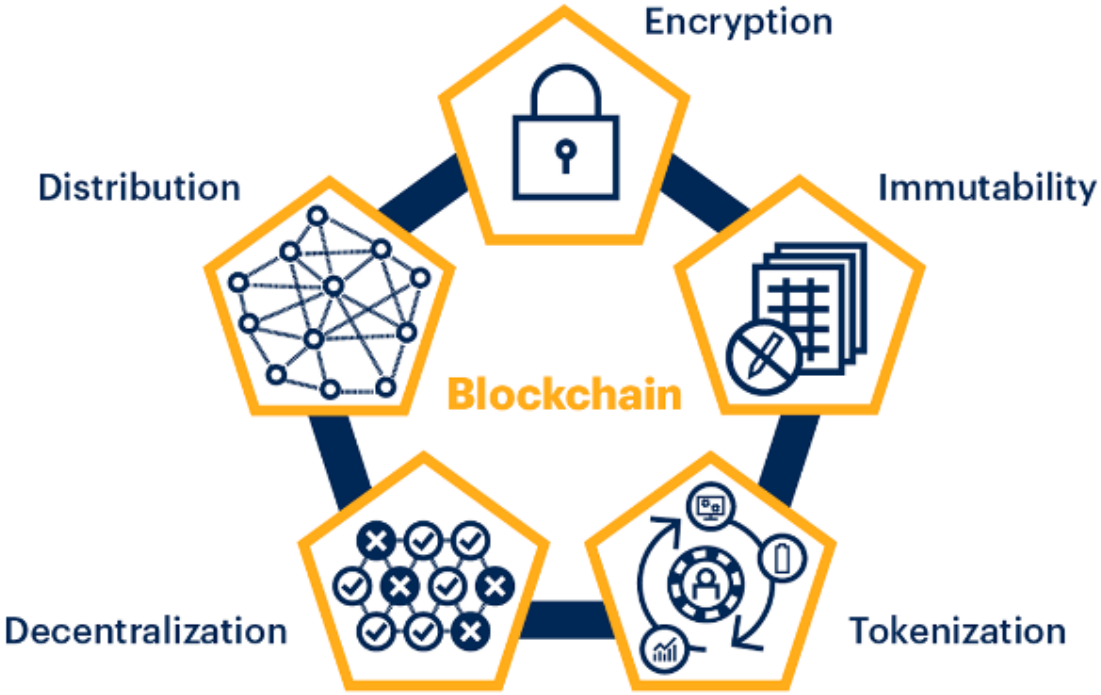

Figure 3 Five key elements of Blockchain [8].

Figure 4 Bitcoin [9].

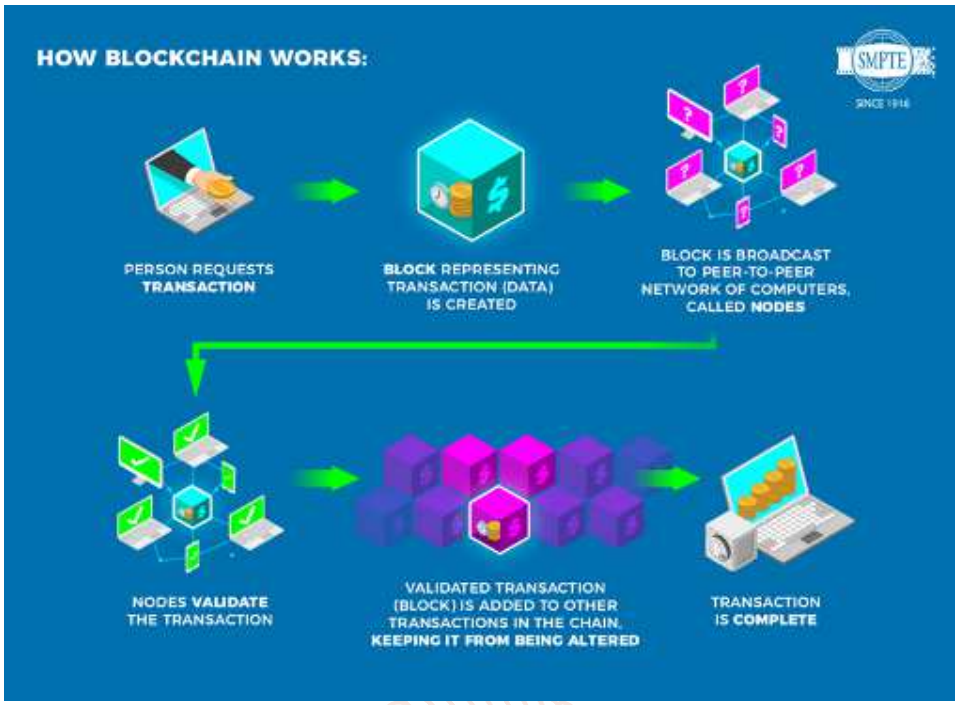

Figure 5 How blockchain works [10].

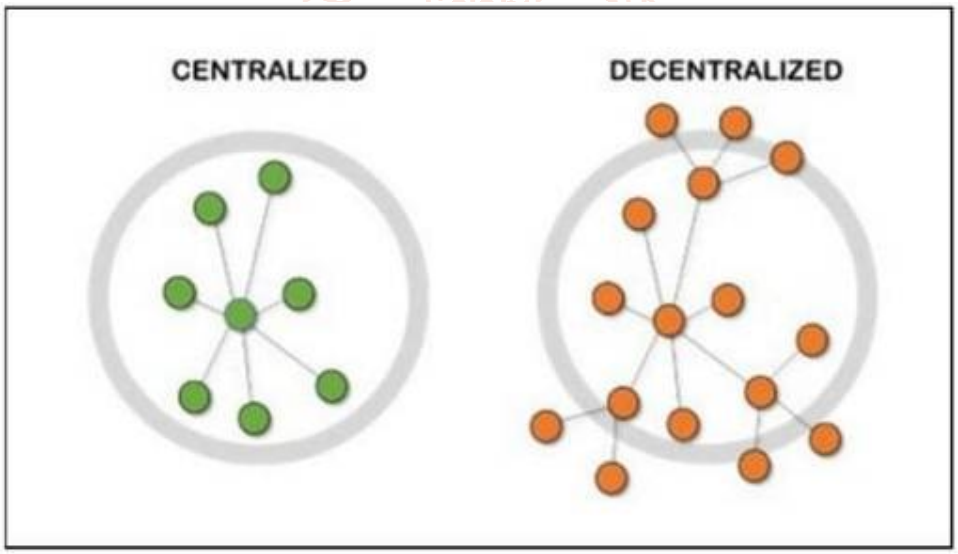

Figure 6 The decentralized property of blockchain [10].

Figure 7 The impact of blockchain on maritime industry [14].

Figure 8 Seven benefits of blockchain in shipping [15].