ISSN 0554-6397
UDK: 004.032.26
Review article
Received: 23rd March 2023.

Cornelius Röseler
E-mail: cornelius.roeseler@student.jade-hs.de
Jan-Lukas Backhuß
E-mail: jan-lukas.backhuss@student.jade-hs.de
Jade University of Applied Sciences, Friedrich-Paffrath-Straße 101, 26389 Wilhelmshaven, Germany
Saša Aksentijević
E-mail: sasa.aksentijevic@uniri.hr
Edvard Tijan
E-mail: edvard.tijan@pfri.hr
University of Rijeka, Faculty of Maritime Studies, Studentska ulica 2, 51000 Rijeka, Croatia

Cloud Computing for Efficient Data Storage and Processing in Maritime Logistics

Abstract

Considering that the maritime logistics is by volume and financial value the largest logistics sector enabling global trade, the number of supply chains is constantly growing, as well as the number of supply chain stakeholders. Due to the large number of stakeholders in the supply chains, the volume of generated data is enormous. Therefore, it is necessary to implement modern and intelligent solutions for processing and storing the data. One possible solution for processing and storing the data in maritime logistics is cloud computing. There are different approaches to implementing cloud computing in maritime logistics. In this paper, the authors present a detailed structure of the maritime cloud and compare it with the legacy systems. Finally, the advantages and challenges arising from the implementation of cloud computing in maritime logistics are analyzed.

Keywords: Maritime logistics • Cloud computing • Supply Chain

1. Introduction

The maritime logistics sector has been evolving rapidly in recent years due to the increasing globalization of trade and the need for efficient supply chain management. Moreover, due to the Covid-19 pandemic more and more people are buying products and goods online. Therefore, the demand of maritime transportation services is increasing even more. As the ships deliver around 80% of the world trade [1], the importance of the maritime sector continues to grow and is statistically more important than other international transport sectors. The digitization of the maritime logistics industry has brought about significant improvements in data storage, processing, and transmission. With the ever-increasing demand and the involvement of various participants in the supply chain, the amount of data workload is also rising sharply. To address this challenge, cloud computing technology has emerged as a game-changer in the maritime sector, providing a cost-effective and efficient solution for data management. In this paper, the authors aim to provide a comprehensive understanding of the maritime cloud by offering a general overview of its operations. This overview will introduce the reader to the topic and create a basic knowledge of cloud utilization in the maritime logistics. Understanding the intricacies and complexities of the maritime supply chain is crucial for grasping the potential benefits and challenges of implementing cloud computing technology. The next step in this paper involves delving into cloud systems, exploring the concept of cloud computing in general and discussing its characteristics and development. This section will shed light on the fundamental principles of cloud systems, including scalability, on-demand resource allocation, and remote data access. By presenting this information, the authors aim to equip the reader with a solid understanding of cloud computing technology before moving on to its application in the maritime logistics sector. The implementation of cloud computing technology in the maritime logistics sector will be the primary focus of this paper. The authors will examine the benefits that cloud systems can bring to the industry, such as enhanced data accessibility, real-time information sharing, and streamlined collaboration among stakeholders. Additionally, potential dangers and risks associated with cloud adoption will be analysed to provide a balanced perspective on the topic. Furthermore, the authors will analyze the current state of digitalization in the maritime sector, exploring the extent to which cloud computing and other digital technologies have been embraced. By analysing the existing landscape, the paper will provide insights into the challenges faced by the industry and the potential future possibilities for further integration of cloud computing technology. Overall, the authors aim to contribute to the understanding of the maritime acloud and its role in the maritime logistics process digitalization. By examining the role of cloud computing technology, the authors intend to highlight its potential to revolutionize the industry, improve operational efficiency, and foster sustainable growth. Through a comprehensive analysis of its characteristics, main elements and the current state of implementation, this paper will provide insights for industry professionals, policymakers, and researchers alike.

2. The maritime supply chain and its stakeholders

Initially, it is important to note that the maritime logistics is about processes along the maritime supply chain which can be described as follows: “Maritime supply chain refers to the movement of cargo, as well as any related support, involving two destinations and using both maritime (ocean) and land transportation. It's an entire network of interconnecting systems that involve freight forwarders, shipping lines, port terminal operators, and land-based logistics systems". [2]

In order to understand the individual players in the supply chain, it is essential to name them and explain them further. There is a clear differentiation between the "freight forwarders" and the "shipping lines". According to Valentin L., freight forwarders are companies or individuals who only organize the shipping of goods. Shipping lines are companies that own the vessels to carry out these undertakings [2]. Furthermore, there are the actors "port terminal operators" and "land-based logistics systems". Valentin L. describes the Port Terminal Operators as operators who own or lease the space in the ports so that the goods can be delivered and processed there. The Land based logistic systems are described as a part of the maritime supply chain where the goods are transported to the actual destination.[2] This division is shown in Figure 1.

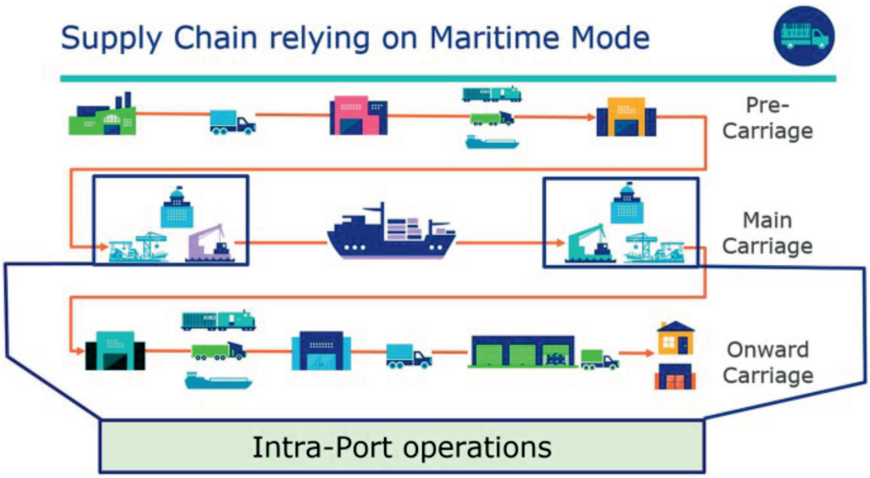

Figure 1: Scheme of the supply chain [3]

These players are then further distributed throughout the supply chain from producer to customer. A distinction is made between upstream, mainstream, and downstream. The main goal of interaction of all these stakeholders is the actual transport of the goods. In most cases, this involves transport by ocean-going vessel across the sea. The pre-carriage and on-carriage therefore represent the transport to and from the main process lanes.

3. An introduction to the cloud concept

Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." [4] A general scheme of a cloud is presented in Figure 2.

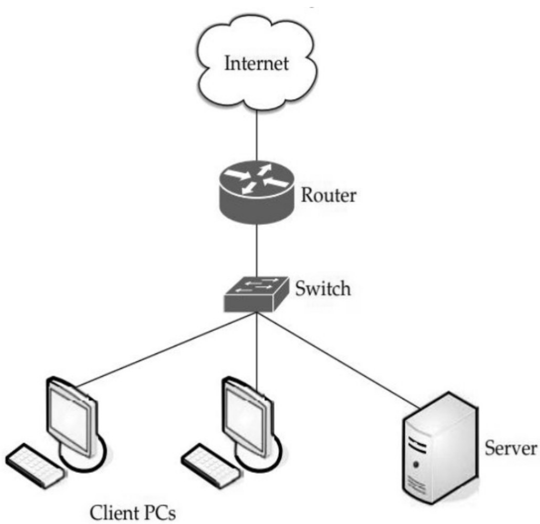

Figure 2: Scheme of a cloud [5]

However, cloud computing is not per se a new technology - it is an advanced form of usage of the Internet in conjunction with scalable local resources (computing, memory and storage) available over the network. [6]. Moreover, cloud computing can be split apart and defined as the development of the Internet and the information technologies. [6]. Caused by the fact that the Internet is a worldwide communication platform, it makes the cloud computing valuable because everyone can access their cloud resources at any time from any location. Access to the cloud is acquired using simple end user devices like a mobile device, laptop, or a computer with an Internet connection. Therefore, the importance of the Internet, smartphones and the connectivity has greatly increased, enabling total connectivity for the end users.

If a closer look is taken at the two components of the cloud computing (development of Internet and information technologies), both increase in their importance. On the one hand, the Internet improved because of the cloud solutions. More data is processed through the Internet, causing widespread utilization of the broadband Internet. This goes hand in hand with the continuous increases in processor performance, advancing miniaturization and the ever cheaper memory and storage solutions. [6] On the other hand, the information technologies improved because of the cloud solution and therefore it was easier to analyse the user's behaviour. This helps firms, their costumers and the consumers to make every cloud solution individual and most convenient, by using acquired data as a valuable commercial resource.

3.1. Development of the cloud systems

The ongoing digitalization has led to a significant surge in user numbers, subsequently driving an increase in processing power and storage capacity requirements. [9] In the following Figure 3. it is clearly evident that the global CPU utilization rises exponentially, and this started being evident specially around the time the digitalization began. Overall, Figure 3. shows the technical evolution of cloud computing systems.

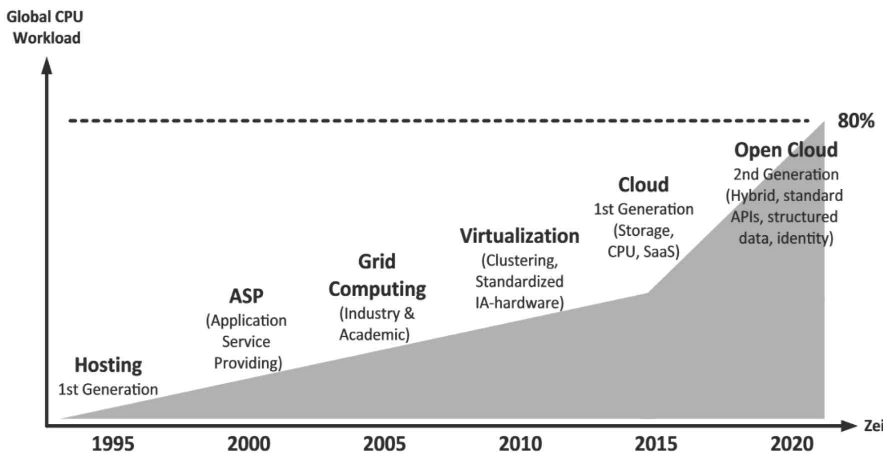

Figure 3: Evolution of the cloud computing [9]

The initial stage of cloud computing systems, known as the first generation, commenced in 1995 with the advent of hosting services. Hosting at the time basically meant the provision of storage in the web space for creating websites and publishing them online. The websites had to be available for the users globally and to grant the availability these websites had to be stored using powerful and efficient servers that were always connected to the Internet. Because of this fact the hosting was called the first generation of cloud computing systems. This function can also be found today in cloud systems in its ability to store data.

In 2000 the simple hosting was upgraded and expanded to the ASP (Application Service Provider"). The application service provider provides his application program to consumers over the Internet. [10] The consumers can rent the application for their use. Therefore, the provider generates money for the time the consumers spend using the software. So, the next step from data storage was towards the provision of software and application over the Internet, nowadays commonly referred to as Software as a Service (SaaS).

Around 2005 the ASP developed further to the grid computing. Grid computing is still used nowadays, but at the time it was the pioneer technology of today's cloud computing. The difference to cloud computing is that grid computing works with decentralized computing where all these computers share data storage, application, and network resources. These computers are in geographically dispersed organizations but they are clustered together in virtual organizations (VO) to provide unused capacity for applications with high resource requirements. [11]

The next important step after the grid computing was the virtualization which happened around 2010. In general, the virtualization is a technology to recreate physical hardware in the virtual computing. Therefore, it refers to compute resources (CPU, storage, network, memory, application stack and database) from applications that then can be used by consumers as a service. [12] This technology allows the multi-tenancy for the cloud computing systems to have a platform that shares resources to multiple consumers. This was an important milestone in the evolution of cloud computing systems because the virtualization refers to the resource pooling characteristic of cloud computing.

Around 2015 the SaaS-clouds were more and more introduced and developed. SaaS is a licensing and distribution model that offers software applications over the Internet." [13] The software is mostly provided by a service-provider and instead of installing the software locally, the consumer can access is functionalities using the Internet. However, the adaptability is often constrained because of the resource pooling.

In parallel, the development of a public cloud ensued, reaching its final full deployment with the migration towards online working and living around advent of the Covid-19 pandemic. "These types of clouds offer a shared hosting environment that is accessible for multi-tenants. Public clouds are typically available by a secured and restricted network connection (e.g. SSL) and provide on-demand pay-per-use services by an ideal pool of resources that is available for many costumers." [8] This led to a sharp increase in the global processing power workload.

A very common topic with the public cloud is the data safety. A public cloud uses all the necessary technologies required to meet diverse security requirements in a comprehensive manner. [14] One such technology is VPN accessibility towards the cloud, which secures the communication. In addition, the total cost of ownership decreases because the amount of incoming and outgoing data transfers is significantly higher. Thus, the costs are divided among the larger volume of data and the individual costs decrease.

3.2. Components of the cloud computing

Before the era of cloud computing started, the integration of an Enterprise Resource Planning (ERP) System was more expensive. It was the usual practice to purchase the software and licenses directly from the provider (developer). But to make the ERP system individual and convenient, the firms had to make changes in the source code. These steps were very costly and even after the implementation of the ERP system the costs continued to be incurred due to administration, support, and maintenance. However, now cloud computing makes it easier and also more cost-effective. Nowadays, a cloud is "[…] a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services)[…]". [4]. Therefore, "Cloud Computing has gained increased attention and diffusion among organizations." [7] In addition, service or more power can be provided at the touch of a button. Essential elements of the cloud computing are, as follows:

1. The first essential element is *On-demand self-service*. A consumer with a need for more computing resources (network storage, CPU time, software, server time and more) can easily upgrade and make use of those resources without any human interaction. [8]
2. The second element is the *Broad bandwidth network access*, which allows the consumers to access the cloud over the Internet by using different devices (mobile phones, laptops, etc.) at the consumer´s location.
3. The third element is the *Resource pooling*, where the cloud providers pool their resources in a multi-tenancy or virtualization model to serve all the consumers. In these models the "different physical and virtual resources are dynamically assigned and reassigned according to consumer demand." [4] The reason why the providers are using this strategy are simply because they can make use of the economies of scale and also the specialization. Therefore, the cloud computing becomes invisible for the consumer because the consumers do not have any knowledge about the location of their data being stored.
4. The penultimate element is the *Rapid elasticity*. The computing resources can be rapidly allotted and released based on the consumer´s demand. More importantly, the consumers can do this whenever they want without any contract which makes these resources infinite and in any quantity in the consumers eye. [5]
5. The last element is the *Measured Service*. This means, although the computing resources are pooled and used by multiple consumers the cloud system is able to measure the exact usage of every resource for each consumer. [4] With this ability to measure the exact resources the cloud is able to generate key performance indicators for each and every user. This feature conduces as a decision support for the provider.

All of the outlined elements are crucial for the adoption of the cloud in the maritime logistics as it is characterized by many interconnected players that are highly fragmented in their location, needs and system requirements.

4. The Maritime Cloud concept

The Maritime Cloud is an innovative concept that aims to enhance communication and information exchange within the maritime industry. It is a digital platform designed to connect various stakeholders in the maritime sector, including ships, ports, authorities, and service providers. By leveraging cloud-based technology, the Maritime Cloud enables secure and efficient sharing of data and services, promoting seamless collaboration and improved decision-making in maritime operations. This concept holds great potential for enhancing safety, optimizing logistics, and streamlining processes in the maritime domain, ultimately contributing to a more connected and effective maritime ecosystem. Maritime Cloud Development Forum and the Maritime Cloud aim to provide a safe and reliable platform for maritime stakeholders to access technical services during a voyage. It's not a product but a communication framework that allows users to discover and use services such as weather forecasts and route optimization. The system uses standardized web service technologies to facilitate communication between clients and services. The Maritime Cloud's goal is to improve decision-making on board and ashore and create a more efficient and safe maritime industry. [15]

4.1. Technical Concept

Maritime clouds, also known as shipping clouds, are cloud computing platforms designed for the maritime industry. They provide shipping companies with the capability to integrate and analyse real-time data from vessels, ports, and other sources, enabling them to optimize their operations and reduce costs.

According to the Maritime Cloud Development Forum, the communication framework of the cloud needs to be integrated into the existing maritime infrastructure to enable maritime stakeholders to access the Maritime Cloud with its three key elements. The challenge lies in creating a seamless exchange of information across different existing and diverse communication channels for accessing the Maritime Cloud. [16] System components interact with the Maritime Cloud through client-server interactions defined by web services. This facilitates service-oriented communication and the establishment of service-oriented system architectures. The successful integration of legacy systems with cloud-based technologies necessitates careful planning, thorough analysis of existing infrastructure, and the implementation of appropriate middleware solutions. [17] A cloud component refers to a technical client or service that needs to be seamlessly incorporated into or linked with pre-existing maritime systems, such as Electronic Chart Display and Information Systems (ECDIS) or Vessel Traffic

Services (VTS). [18] This serves as the entry point for accessing any technical service registered in the Maritime Cloud. Communication between the cloud component and the Maritime Service Registry and Maritime Identity Registry, as well as other services available in the Maritime Cloud, is facilitated through the roaming device specified within EfficienSea2 or the Maritime Messaging Service (MMS) (see Figure 4). There are three ways to achieve roaming between different communication links. Firstly, the client or service itself identifies the availability of communication links and switches between them, requiring it to know the status of all communication channels and take responsibility for roaming between them. [15]

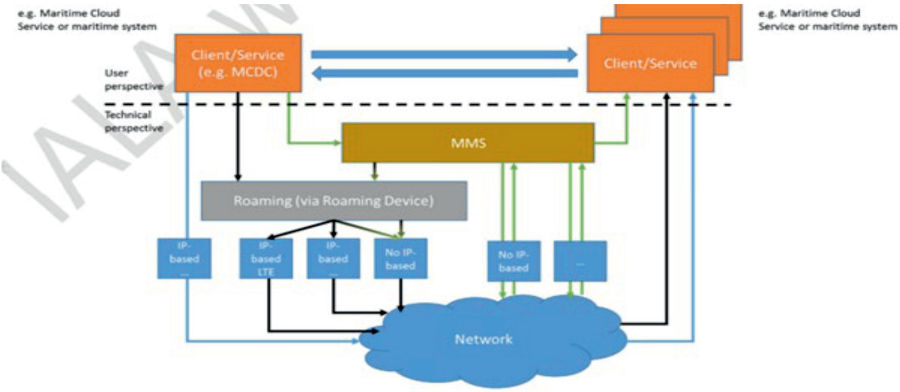

Figure 4: Architecture of a maritime cloud [16]

The second method delegates the roaming from the client/service to the roaming device, which checks the availability of communication links and makes roaming decisions based on a suitable IP or non-IP connection. [16] The third method provides roaming through the Maritime Messaging Service (MMS), which regulates access requests and connects to available communication channels, benefitting from roaming devices or direct non-/IP communication devices. The MMS also queues incoming and outgoing messages if no stable connection can be established. [19] The Maritime Cloud Demonstrator Component (MCDC) serves as a reference implementation for a client or service component [16]

4.2. Technical services and the Maritime Service Registry

The Maritime Cloud aims to create a service-based economy that goes beyond machine-to-machine communication. The Maritime Service Registry (MSR) is a central part of this vision and contains service specifications and provisions for their implementation. The MSR is divided into two areas: service discovery and service management. Service discovery allows users to search for services based on different criteria. Service management allows service providers to publish a service specification and register a service instance. [20] The MSR improves the visibility and accessibility of maritime services and information and enables service providers, consumers, and regulatory authorities to share a common understanding of service standards and provisioned services. [15] Figure 5 demonstrates that the service provider and the service consumer are always linked to each other. The service registry is an important component of the maritime cloud which connects multiple actors, as shown in Figure 5.

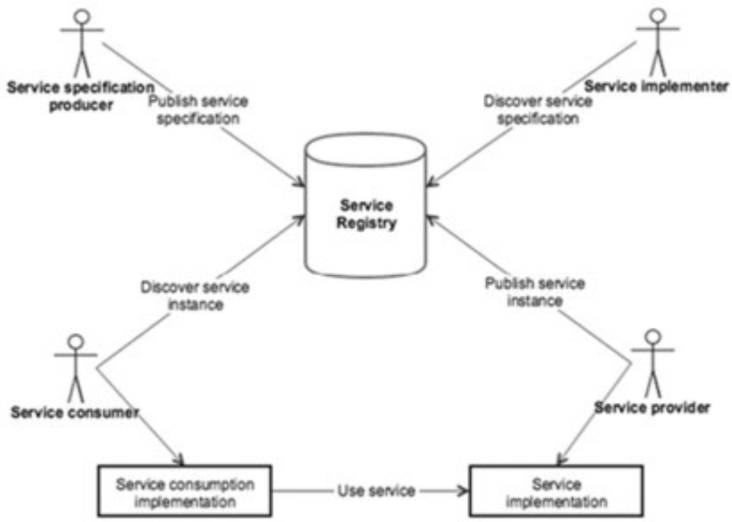

Figure 5: Technical services in the maritime cloud [15]

4.3. Identity Management and the Maritime Identity Registry

The lack of a global digital identity for users, vessels, and systems is a significant barrier to realizing the full potential of a digital maritime revolution. Identity management is the process of managing information about the identity of users and providing means to control access to company resources. The Maritime Identity Registry (MIR) aims to create a solution that satisfies the most common identification needs for the entire maritime industry on a global scale. [21]

When building a Maritime Cloud, there are several key issues to consider in the creation of a Maritime Identity Registry:

1. Data Management: Establishing an effective Maritime Identity Registry involves managing a vast amount of data related to maritime entities such as vessels, organizations, and individuals. Ensuring data accuracy, integrity, and security is crucial to maintaining the reliability and trustworthiness of the registry.

2. Standardization: Developing standardized formats, protocols, and data models for capturing and representing maritime identity information is essential. Consistent standards enable interoperability among different systems and facilitate seamless integration with existing maritime infrastructure.
3. Authentication and Authorization: Implementing robust mechanisms for authentication and authorization is crucial to ensure the secure access and usage of the Maritime Identity Registry. This involves verifying the identity of users, controlling their access rights, and protecting against unauthorized access or misuse of registry data.
4. Privacy and Data Protection: Safeguarding sensitive personal and organizational information is vital when creating a Maritime Identity Registry. Compliance with relevant data protection regulations, such as the General Data Protection Regulation (GDPR), is necessary to ensure the privacy rights of individuals and prevent unauthorized use or disclosure of personal data.
5. Governance and Collaboration: Establishing effective governance structures and fostering collaboration among stakeholders is essential for the successful development and maintenance of a Maritime Identity Registry. Cooperation between maritime authorities, industry organizations, and other relevant entities helps ensure the registry's accuracy, reliability, and continuous improvement.

Establishing the MIR is a complex task that will be delivered over multiple milestones in the coming years. The most important functions, such as support for authentication, will be implemented first, and additional functionality will be added based on user needs. Authentication is the process by which a system verifies the identity of a user who wishes to access it. Authentication is essential to effective security since access control is normally based on the identity of the user who requests access to a resource. [21]

Authentication commonly falls within three distinct categories based on the factors employed for verification: something that the user possesses knowledge of, something that the user possesses physically, and something inherent to the user's identity. Knowledge factors consist of information like passwords, passphrases, pins, and challenge-response details. Possession factors entail tangible items such as ID cards, cell phones, certificates, and similar objects. Inherent factors involve biological or physical attributes like fingerprints, retinal patterns, facial features, and voice characteristics. Currently, the Maritime Cloud is focused on knowledge factors (username/password) for human users and ownership factors (certificates) for machine users. The actual authentication of human users will be the responsibility of the organizations that the users belong to using a brokered identity federation approach. The MIR will create a solution that satisfies the most common identification needs for the entire maritime industry on a global scale. [21]

4.4. The Maritime Messaging Service

According to The Maritime Cloud Development Forum, the proposed messaging service, MMS aims to provide seamless and transparent information transfer between different communication links in a geolocation context-sensitive and carrier-agnostic manner. The MMS targets ship-shore connectivity and uses the Internet for communication, but it can also connect with other communication services through dedicated gateways. The service allows for the transfer of text or structured data, but each communication service may have limitations regarding bandwidth availability, data package size, and latencies. [16]

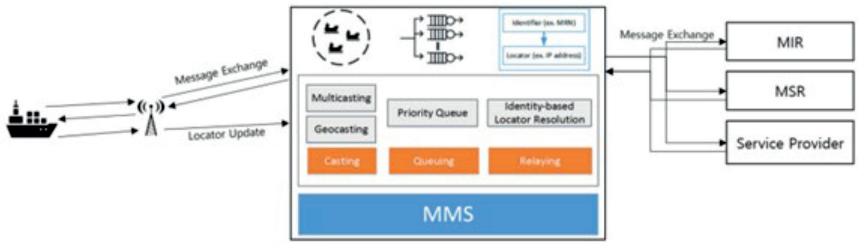

Figure 6: Scheme for the maritime messaging service [16]

The MMS ensures message delivery through any active communication link and even functions as a prioritized store-and-forward queue of messages when a ship temporarily loses its link. The MMS uses a ship's unique identifier to map to its current accessible locator to correctly transmit messages, even when the ship's locator changes dynamically. [16]

The Maritime Messaging Service (MMS) is a crucial component within the maritime cloud, facilitating efficient and secure communication among various stakeholders. Designed to enhance information exchange and collaboration, MMS provides a standardized platform for the seamless transmission of messages across different maritime systems. By leveraging modern communication technologies, such as web services and protocols, MMS enables reliable and real-time messaging capabilities for maritime organizations and vessels. It allows for the exchange of critical information, including navigational warnings, weather updates, port notifications, and other essential communications necessary for safe and efficient maritime operations.

MMS incorporates standardized message formats, ensuring interoperability and compatibility across diverse maritime systems and applications. This enables seamless integration with existing maritime infrastructure, such as Electronic Chart Display and Information Systems (ECDIS) and Vessel Traffic Services (VTS), enhancing the overall efficiency and effectiveness of maritime communication. Furthermore, MMS enhances data security and privacy through robust encryption and authentication mechanisms. This ensures that sensitive information transmitted through the messaging service remains protected from unauthorized access or interception, bolstering the trust and reliability of the communication channel.

5. Real-time deployment of a maritime cloud

Several maritime cloud solutions have been developed over the years, and companies have started to integrate these solutions to improve their operations.

One example of a company that has successfully integrated a maritime cloud solution is Maersk Line, the world's largest container shipping company. In 2017, Maersk Line implemented a cloud-based system called Remote Container Management (RCM) that provides real-time information about the condition of its shipping containers. The RCM system is powered by Microsoft's Azure IoT platform and enables Maersk Line to monitor temperature, humidity, and other parameters that affect the quality of goods being transported. [22]

According to Maersk Line, the RCM system has helped the company reduce the number of damaged goods and improve its customer service. With the real-time data provided by the system, Maersk Line can quickly respond to any issues that arise during transport, thereby minimizing the impact on the quality of the goods. [22]

Another example of a company that has integrated a maritime cloud solution is ABB, a Swiss-based technology company. ABB has developed a cloud-based platform called ABB Ability Marine Advisory System – OCTOPUS that provides ship operators with real-time data on vessel performance, fuel consumption, and other operational parameters. The platform is designed to help ship operators optimize their operations and reduce fuel consumption, thereby reducing costs and minimizing the environmental impact of their operations. [23]

According to ABB, the OCTOPUS system has helped ship operators reduce fuel consumption by up to 20%. The system provides ship operators with detailed information on the most fuel-efficient routes and speeds, as well as recommendations on the best times to take actions such as changing the course of the vessel or adjusting the engine settings. [23]

Maritime clouds are becoming increasingly popular among shipping companies as they provide real-time data and analytics that can help optimize operations and reduce costs. Maersk Line and ABB are just two examples of companies that have successfully integrated maritime cloud solutions and experienced significant benefits as a result. Maritime clouds offer a range of advantages to shipping companies. They provide a centralized platform where data from various sources, such as vessels, ports, and supply chain partners, can be collected, analyzed, and shared in real time. This facilitates better visibility and coordination across the entire maritime ecosystem, leading to improved voyage planning, optimized routing, and enhanced resource allocation. Real-time data and analytics derived from maritime clouds empower companies to proactively address operational challenges and identify areas for improvement. For instance, by leveraging historical and real-time data, shipping companies can optimize fuel consumption, reduce emissions, and enhance vessel performance. Moreover, these solutions enable efficient cargo tracking, allowing for better inventory management and timely delivery, ultimately improving customer satisfaction.With the continued development of cloud computing technology and the increasing demand for real-time data, it is likely that more companies in the maritime industry will adopt these solutions in the future.

6. Risks and advantages of the Maritime Cloud

The cloud computing opens many opportunities for companies in the maritime sector and brings significant benefits. Maritime cloud provides an increased operational management oversight, better workload of the servers and enhances the productivity of the applications. [24] Moreover, it raises the efficiency and lowers the time and costs that have to be invested for the maintenance. "A Maritime cloud also offers efficient optimization of valuable storage, enabling continuous improvement and agility. In addition, by enhancing maritime mobility with network scalability, it can provide an efficient network load balance." [24] The cloud can also satisfy the users requirements by standardizing processes to make the usage for the users as simple and fast as possible. Another possibility for using a maritime cloud is to consider the topic of green IT. By choosing the right architecture and infrastructure of a cloud, it is possible to be energy efficient, eco-friendly and to create a sustainable cloud life cycle.

Even though a maritime cloud is promising and brings many opportunities, the risks must also be assessed, such as "[…] users' privacy, data security, legacy system performance, and disaster recovery, and the transition issues that arise when establishing, maintaining, sustaining, and managing a new Maritime Cloud environment." [24] All these risks can cause trust issues towards implementing and using a maritime cloud or a cloud in general. That´s why it is important to conduct a detailed analysis before implementing the cloud to make sure none of these risks will arise. In addition, there are the "typical" risks of using a cloud in general like cyber-attacks, loss of company secrets or the misuse of data. [25] These risks will arise if insufficient selection criteria were used before implementation.

The interconnected nature of the Maritime Cloud introduces vulnerabilities to cyberattacks, such as unauthorized access, data breaches, and malware. These risks can compromise sensitive information, disrupt operations, and pose safety and security concerns. Robust cybersecurity measures, including encryption, authentication protocols, regular security audits, and employee training, are essential to mitigate these threats.

Data privacy and compliance also pose challenges. The collection, storage, and transmission of data within the Maritime Cloud must adhere to regulations like the General Data Protection Regulation (GDPR). Safeguarding personal information, ensuring proper consent, and complying with data protection regulations are crucial for maintaining trust and legal compliance.

Interoperability issues may arise when integrating diverse maritime systems and legacy infrastructure with the Maritime Cloud. Seamless data exchange and compatibility between different systems, protocols, and data formats require careful planning, standardization efforts, and effective coordination among stakeholders.

Dependency on stable and reliable internet connectivity is a critical risk. Disruptions in connectivity due to network outages, hardware failures, or natural disasters can hinder the availability and accessibility of cloud services, impacting real-time data exchange and decision-making processes.

Organizational change and adoption challenges should also be considered. Implementing the Maritime Cloud often requires changes in processes, workflows, and organizational culture. Resistance to change, lack of user adoption, and inadequate training can hinder successful implementation. Change management strategies, comprehensive training programs, and clear communication are essential to address these risks.

Service reliability and vendor dependence introduce additional concerns. Organizations relying on cloud service providers and third-party vendors face risks such as service disruptions, system failures, or vendor-related issues. Thorough evaluation of service providers, including their reliability, reputation, and support capabilities, is crucial to minimize potential disruptions.

Addressing these risks requires a proactive approach, encompassing robust cybersecurity measures, compliance frameworks, contingency plans for connectivity issues, change management strategies, and thorough vendor evaluation and monitoring. By effectively managing these risks, organizations can maximize the benefits and ensure a secure and efficient implementation of the Maritime Cloud.

7. Conclusion

The maritime supply chain is a complex ecosystem with various actors involved in the movement of goods across the world. Digitalization has been transforming the maritime industry, and cloud computing has emerged as a promising technology with the potential to enhance efficiency and transparency in the supply chain.

The implementation of cloud computing systems can facilitate seamless communication, collaboration, and data sharing among the actors, leading to improved coordination and visibility throughout the supply chain. By leveraging cloud-based solutions, stakeholders can overcome the traditional barriers of time and distance, enabling real-time access to critical information, and fostering better decision-making processes. Moreover, cloud computing, with its characteristics such as scalability, flexibility, and cost-effectiveness, has been gaining traction in the maritime industry. These advantages make cloud technology well-suited for the dynamic and resource-intensive nature of maritime logistics.

The development of cloud systems, from the hardware layer to the application and network layers, has been driving the construction of the maritime cloud, a specialized infrastructure tailored to the unique needs of the industry. This evolution allows for the real-time deployment of cloud-based solutions, enabling stakeholders to leverage advanced analytics, machine learning, and artificial intelligence to optimize operations and improve efficiency. The maritime cloud acts as a central hub, connecting various stakeholders and facilitating the exchange of data, documents, and information in a secure and reliable manner.

However, like any technology, cloud computing also poses risks and challenges in the maritime sector. Concerns such as data security, privacy, and potential disruptions due to technical failures or cyber threats need to be addressed effectively to ensure the safe and reliable operation of cloud-based systems in the maritime supply chain. Robust cybersecurity measures, data encryption, access controls, and regular system audits are essential to mitigate these risks and protect sensitive information.

Despite the challenges, the benefits of cloud computing in the maritime sector are significant. Enhanced visibility into the supply chain, from the origin of goods to their final destination, enables stakeholders to track and trace shipments in real-time, reducing delays and improving customer satisfaction. Improved decision-making, based on accurate and up-to-date information, allows for proactive risk management and optimized resource allocation. Furthermore, cloud-based solutions enable collaboration among stakeholders, fostering efficient and streamlined processes across the entire supply chain. This collaboration can lead to reduced operational costs, improved resource utilization, and minimized environmental impact.

In conclusion, cloud computing has the potential to transform the maritime supply chain by enabling digitization and enhancing the efficiency of operations. However, careful consideration of the risks and benefits is necessary for successful implementation. As the maritime industry continues to evolve, cloud computing is likely to play a pivotal role in shaping the future of the maritime supply chain. Embracing cloud technology can unlock new opportunities, empower stakeholders, and create a more interconnected and resilient maritime logistics ecosystem.

References

1. UNCTAD. (2023). Review of Maritime Transport 2022. [Online] Available from: https://unctad.org/rmt2022 [Accessed 15th April 2023].
2. Valentine, L. (March 2022). What is the Maritime Supply Chain? [Online] Available from: https://sinay.ai/en/what-is-the-maritime-supply-chain/#:~:text=Maritime%20supply%20chain%20refers%20to,(ocean)%20and%20land%20transportation [Accessed 25th March 2023].
3. Lind, M., Michaelides, M., Ward, R., et al. (eds). (2021). Maritime Informatics, 1st ed. 2021. Progress in IS. Springer International Publishing; Springer, Cham.
4. Dillon, T., Wu, C., Chang, E. (2010). Cloud Computing: Issues and Challenges.
5. Rashid, A., Chaturvedi, A. (2019). Cloud Computing Characteristics and Services: A Brief Review. ijcse, 7, 421–426. [Online] Available from: https://doi.org/10.26438/ijcse/v7i2.421426 [Accessed 10th June 2023].

6. Barton, T. (2014). E-Business mit Cloud Computing. Springer Fachmedien Wiesbaden, Wiesbaden.
7. Stieninger, M., Nedbal, D. (2014). Characteristics of Cloud Computing in the Business Context: A Systematic Literature Review. Glob J Flex Syst Manag, 15, 59–68. [Online] Available from: https://doi.org/10.1007/s40171-013-0055-4 [Accessed 2nd April 2023].
8. 2015 IEEE 6th Control and System Graduate Research Colloquium (ICSGRC). IEEE.
9. Reinheimer, S. (ed). (2018). Cloud Computing: Die Infrastruktur der Digitalisierung. SpringerLink Bücher. Springer Vieweg, Wiesbaden.
10. Prof. Dr. Richard Lackes. (2018). Definition: Application Service Provider. Springer Fachmedien Wiesbaden GmbH.
11. Hashemi Mohsen, S., Bardsiri Khatibi, A. (2012). Cloud Computing vs. Grid Computing. ARPN Journal of Systems and Software, 188–194.
12. Zhang, Y. (ed). (2012). Future wireless networks and information systems. Lecture notes in electrical engineering, vol 1. Springer, Berlin.
13. Salesforce. (2023). Was ist SaaS? Grundlegendes zu "Software as a Service". [Online] Available from: https://www.salesforce.com/de/learning-centre/tech/saas/ [Accessed 5th May 2023].
14. Gerd Altmann. (2022). Was ist eine Open Cloud? CloudComputing-Insider.
15. Dr. Jin Hyoung Park. (2017). Journal of Ocean Technology.
16. Doyle, S. (2016). The Maritime Cloud Development Forum.
17. Oracle. (2023). SaaS Migration> Why You Should and How to Do It. [Online] Available from: https://www.oracle.com/qa/cloud/saas-migration/ [Accessed 11th June 2023]
18. International Maritime Organization.(2023). Vessel Traffic Services. [Online] Available from: https://www.imo.org/en/OurWork/Safety/Pages/VesselTrafficServices.aspx [Accessed 11th June 2023]
19. Oracle. (2023). Sun Java Systems Queue 3.5 SP1 Administration Guide. [Online] Available from: https://docs.oracle.com/cd/E19701-01/817-6024/ix.html [Accessed 11th June 2023]
20. Microsoft. (2022). Quickstart: Create a new Azure API Management service instance by using the Azure portal. [Online] Available from: https://learn.microsoft.com/en-us/azure/api-management/get-started-create-service-instance [Accessed 11th June 2023]
21. Australian Maritime Safety Authority. (2020). About maritime mobile service identity information: Why you need a maritime mobile service identity (MMSI), and how to apply for one.
22. Carl Collen. (2020). Tech.eu.
23. International Maritime Organization. (2022). International Convention for the Safety of Life at Sea (SOLAS), 1974.
24. Nunes, B., Mendonca, M., Seruya, A. (2017). A Taxonomy for the Internet of Things. IEEE Int Things J, 4, 15–28. [Online] Available from: https://doi.org/10.1109/JIOT.2016.2578798 [Accessed 20th April 2023].
25. Thielemann, J., B. Burghardt. (2016). Augmented Reality for Intelligent Assistance Systems in Manual Assembly.