Cloud Computing in Maritime Industry

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ABSTRACT

The cloud is a global network of interconnected servers we can access via the Internet. It has transformed the way we work, study, play, and relax. Cloud computing has revolutionized maritime communications by providing enhanced connectivity, cost efficiency, data storage capabilities, collaboration tools, flexibility, scalability, and improved cybersecurity. Cloud computing enables optimized utilization of information resources, ultimately reducing the costs for shipping companies and giving operators the possibility to render services at lower prices and an ensured level of quality. Maritime companies are now opening up to the countless benefits cloud computing offers. This paper explores the critical role of cloud computing technology in the maritime industry.

KEYWORDS: *cloud, cloud computing, maritime industry*

INTRODUCTION

Majority of the global trade happens at sea. The maritime industry is at the core of the global economy, yet it still enjoys a lower level of digitization. It plays a decisive role in the modern worldwide digital economy and collaborative environments. In spite of being at the core of the global economy, the maritime industry has been less digitalized. Cloud computing helps maritime companies reduce IT costs by shifting their workloads to the cloud. Cloud computing has several value-enhancing capabilities for these companies [1]

The term "cloud computing" refers to the on-demand delivery of IT resources via the Internet with pay-as-you-go pricing. Instead of buying, owning, and maintaining their own data centers and servers, organizations can acquire technology such as compute power, storage, databases, and other services on an as-needed basis [2].

The cloud is a global network of interconnected servers we can access with an Internet connection. We can store data, run applications, stream videos, manage email, or carry out many other activities on the servers. Cloud computing has revolutionized how industries manage data and operations, allowing for real-time access, updates, and collaboration across the globe. In the maritime industry, this means streamlined operations, from logistics and fleet management to crew scheduling and compliance tracking. Cloud computing is transforming the industry, enabling seamless connectivity and enhancing operational efficiency. It supports maritime digitalization, enhances cybersecurity, and improves overall communications in the maritime industry.

CLOUD COMPUTING BASICS

Cloud computing represents a newly emerging service-oriented computing technology. It is the provision of scalable computing resources as a service over the Internet. It allows manufacturers to use many forms of new production systems such as 3D printing, high-performance computing (HPC), industrial Internet of things (IIoT), and industrial robots. It is transforming virtually every facet of modern manufacturing. It is innovating, reducing cost, and bolstering the competitiveness of American manufacturing [3]. Figure 1 shows the symbol for

cloud computing [4]. Some features of cloud computing are displayed in Figure 2 [5].

The key characteristic of cloud computing is the virtualization of computing resources and services. Cloud computing is implemented in one of three major formats: software as a service (SAAS), platform as a service (PAAS), or infrastructure as a service (IAAS). These services are explained as follows:

SaaS: This is a software delivery model in which software and associated data are hosted on the cloud. In this model, cloud service providers offer on-demand access to computing resources such as virtual machines and cloud storage.

PaaS allows the end-user to create a software solution using tools or libraries from the platform service provider. In this model, cloud service providers deliver computing platforms such as programming and execution.

In the IaaS model, cloud service providers can rent manufacturing equipment such as 3D printers.

Just like cloud computing, CM services can be categorized into three major deployment models (public, private, and hybrid clouds) [6]:

➢ Private cloud refers to a centralized management effort in which manufacturing services are shared within one company or its subsidiaries. A private cloud is often used exclusively by one organization, possibly with multiple business units.

➢ Public cloud realizes the key concept of sharing services with the general public. Public clouds are commonly implemented through data centers operated by providers such as Amazon, Google, IBM, and Microsoft.

➢ Hybrid cloud that spans multiple configurations. and is a composed of two or more clouds (private, community or public), offering the benefits of multiple deployment modes.

These services and models are shown in Figure 3 [7]. Cloud computing finds application in almost every field.

MARITIME CLOUD
Cloud computing is based on the delivery of computing services over the Internet. Instead of maintaining local servers and equipment, companies can access computing resources, such as storage, computing power, and databases, through the cloud. Cloud platforms have changed the way we interact with technology, and the maritime industry is finally catching up. They have transformed the way

companies manage, process, and store data, enabling greater efficiency, scalability, and agility in an increasingly competitive business environment [8]. Figure 4 shows cloud computing in marine environment [9].

In the maritime industry, where global operations, regulatory compliance, and crew welfare are paramount, the technological foundation supporting these activities must be both robust and flexible. The evolution of cloud-based solutions represents a significant leap forward, offering scalability, accessibility, and security that traditional systems struggle to match. As ships and ports implement Internet-of-things (IoT) technologies, cloud platforms become critical to monitoring and managing them. The advantages provided by cloud computing technology are reflected in the reduction of operating costs and the price of IT elements (hardware, software, databases, networks), maintenance of computing resources without additional training of new staff, and purchase of new licenses for programs and applications. All these advantages allow shipping companies, particularly ships, to carry out and improve maritime processes controlled by computers.

Maritime stakeholders such as shipping lines, container yards, terminal operators, forwarders/consolidators, and transporters are rapidly leveraging cloud computing. Cloud computing can deliver value to maritime companies and organizations in three ways. First, it can reduce IT costs. Second, a cloud architecture comprising of a data ingestion layer, a data lake, and a client layer can enable cheap, reliable, and efficient collection, storage, and analysis of data at scale. This enables maritime companies to break data siloes and create a single repository for their data from multiple sources. Finally, advanced technologies can be delivered on top of this ingestion and storage layer: raw data can be turned into actionable knowledge with cross-querying and business intelligence services, disseminating insights across the organization and the ecosystem that the organization is part of [2].

APPLICATIONS OF MARITIME CLOUD
Cloud services have potential in any situation where widely dispersed parties need access to shared information and resources, including the maritime industry. Ship management, crewing and training, and performance optimization are obvious applications of cloud computing. Whether it is improving fleet management, streamlining port operations, or ensuring regulatory compliance, the cloud is transforming how the maritime industry operates on a global scale. Common applications of maritime cloud include the following [2,10]:

➢ *Crew Management:* Crew management encompasses a broad range of activities, from recruitment and scheduling to training and payroll. Cloud-based solutions like Adonis HR offer a centralized platform for handling these tasks efficiently. Such tools enhance crew welfare by ensuring transparent communication and access to personal records and payroll information, fostering a positive work environment. The office staff and crew members have access to a centralized database. The software support automatically informs the crew of pre-planned actions, such as the maintenance of an individual component with all the necessary information.

➢ *Fleet Management:* This is one of the most immediate beneficiaries of cloud computing. The impact of technology on the shipping industry will grow in the coming years as companies increasingly introduce cloud-based software and apps in their businesses. By moving fleet management systems to the cloud, shipping companies gain real-time visibility into the location, status, and performance of every vessel in their fleet. GPS and IoT sensors aboard ships feed data to the cloud, allowing fleet operators to track vessels in real time. This enables better route planning, quicker response times to disruptions, and more efficient scheduling. The cloud enables the aggregation of data from different sources (vessels, ports, weather patterns, cargo management systems). Fleet operators can use this data to optimize routes, reduce fuel consumption, and improve overall operational efficiency. Software application allows the planning and execution of ship maintenance procedures and management of spare parts and materials of individual ships as well as the entire fleet.

➢ *Global Deployment:* Cloud computing enables customers to deploy globally in minutes. The fact that stakeholders in the maritime industry are scattered around the world is a feature of the industry. Cloud computing provides a framework of technologies and solutions ideal to establish a global ecosystem of collaboration for the maritime industry. Shipping involves multiple stakeholders stationed across the world, working closely together. Timely communication and information sharing, whether onboard vessels or at the office, is crucial to keep vessels running smoothly.

➢ *Industrial IoT:* The integration of Internet of things (IoT) and cloud computing is transforming the maritime industry by enhancing efficiency, safety, and environmental sustainability in global shipping operations. Connecting assets and devices to the cloud and collect data in real time is the value provided by coupling cloud data lakes with edge services. Billions of these connected devices will be onboard vessels, attached to shipping containers, installed into trucks, ship to shore, and gantry cranes. These sensors already are everywhere and they are typically small, with a limited amount of CPU and disk space. The days when smart trucks, containers, vessels, cranes, and chassis will exchange information with the cloud and between themselves to self-optimize their utilization and repositioning, are not far away.

➢ *Warehouse Management*: Digital warehouse management could enable 24×7 monitoring of activities. Most importantly, it is more reliable when it comes to thwarting challenges such as cargo theft.

BENEFITS
Cloud computing offers significant benefits to the maritime industry, allowing for real-time data access, streamlined operations, improved collaboration, enhanced connectivity, enhanced data security, improved cybersecurity, reduced costs, and optimal satellite communications services. These benefits make cloud computing an indispensable technology in the maritime industry. As the Internet has become more accessible at sea, we have seen a boom in cloud platforms. Other benefits of maritime cloud include the following [2,11]:

➢ *Enhanced Connectivity:* Traditional communication methods, such as radio and satellite phones, have limitations in terms of coverage and bandwidth. Cloud computing enables seamless connectivity for maritime operations. Anyone with an Internet connection can access cloud services from anywhere. With the cloud, vessels can establish reliable and uninterrupted communication links, regardless of their location. By utilizing satellite-based cloud services, maritime users can access real-time data, communicate with onshore personnel, and collaborate with teams on other vessels, ultimately improving operational efficiency and situational awareness. Cloud-based connectivity solutions offer a wide range of services, including voice, video, messaging, and data transfer. Figure 5 shows access to a centralized database in the cloud [9].

➢ *Cost Reduction:* The deployment of cloud-based tools in maritime operations leads to significant

efficiencies and cost savings. Cloud-based solutions can reduce IT infrastructure costs by eliminating the need for expensive hardware and software. Traditional IT infrastructures can be costly to establish and maintain for maritime organizations. However, by adopting cloud computing in maritime communications, companies can significantly reduce their IT expenses. Cloud services offer pay-as-you-go pricing models, eliminating the need for upfront investments in hardware and software. Cloud-based solutions also reduce maintenance costs, as software updates, security patches, and system backups are handled by the cloud service provider. These cost savings allow maritime companies to allocate their budget towards other important areas, such as research and development, equipment upgrades, and crew training.

➤ *Data Storage:* Data is a critical asset for maritime operations, and the cloud provides a secure and efficient storage solution. The foundation of a data-driven transformation is storage. Over the years, customers have accumulated so much data, and a lot of that data lives in different silos, which makes it hard to do anything with their data, including analytics. Cloud-based storage systems allow maritime companies to centralize their data, making it easily accessible to authorized personnel across the organization. By storing data in the cloud, ships can reduce the need for physical storage on board, freeing up valuable space. Cloud storage offers automatic backups, ensuring that valuable data is protected in the event of hardware failures or disasters.

➤ *Agility:* Cloud computing lets customers quickly spin up resources as they need them, deploying hundreds or even thousands of servers in minutes. This means customers can quickly develop and roll out new applications, and it means that teams can experiment and innovate more quickly and frequently. If an experiment fails, you can always de-provision those resources without risk. Resources can be monitored remotely, and the movement of cargo can be tracked on every milestone.

➤ *Elasticity:* Maritime trade is a cyclical industry with steep fluctuation patterns in transactional volumes. A cloud-based platform enables all these stakeholders to adopt smart capacity handling. They can instantaneously scale up, or down that is in line with the market conditions. Customers used to over provision, buying upfront hardware, and maintaining their own data centers,

to ensure they had enough capacity to handle their business operations at the peak level of activity. However, this is not efficient since during non-peak time these expensive assets are underutilized. With cloud computing, customers can provision the amount of resources that they actually need, knowing they can instantly scale up or down along with the needs of their business. In this way, customers also reduce cost and improves their ability to meet users demands.

➤ *Improved Collaboration:* Cloud computing facilitates collaboration among maritime teams, both onshore and offshore. By storing data and applications in the cloud, crew members can access and share information in real-time, regardless of their location. Cloud-based collaboration tools allow crew members to communicate and collaborate in real-time, share documents, and track progress on projects. This ensures that everyone is on the same page, leading to better operational outcomes. Figure 6 shows collaboration between business leaders [12].

➤ Flexibility: One of the key advantages of cloud computing is its flexibility. Maritime operations often involve dynamic requirements, such as seasonal demand fluctuations or expansion into new geographical regions. Cloud-based solutions allow maritime companies to quickly adapt to changing needs by providing the ability to scale IT resources up or down.

➤ *Scalability:* Scalability is a top reason driving the adoption of cloud software solutions. Before cloud platforms took off, companies had to buy and maintain their own servers. If they wanted to expand, they had to buy more servers. Cloud computing offers on-demand scalability, allowing maritime organizations to increase their computing power, storage capacity, and bandwidth as needed. For example, during peak shipping seasons, companies can easily scale up their cloud infrastructure to handle increased communication and data processing needs. Once the busy season is over, they can scale back down, avoiding unnecessary costs. Scalability is offered by the cloud allow companies to adjust their IT resources based on their needs, further reducing costs.

➤ *Regulatory Compliance:* Regulatory compliance, including adherence to the International Safety Management (ISM) Code, the Maritime Labor Convention (MLC), and environmental standards, is a critical concern for maritime operations. Cloud-based tools offer unparalleled benefits in

this area by providing up-to-date templates, regulations, and compliance checklists that can be accessed anytime, anywhere. Cloud providers also ensure regulatory compliance, such as GDPR (General Data Protection Regulation) in Europe, by implementing strict data protection practices. By leveraging cloud computing, maritime organizations can improve their cybersecurity posture and protect their digital assets. Cloud-based solutions can help maritime companies comply with international safety regulations, such as the International Safety Management (ISM) Code.

➤ *Improved Safety:* Cloud-based platforms provide real-time data on vessel performance, weather conditions, and other critical information, enabling better navigation and decision-making. Cloud-based systems can also track and analyze data related to safety incidents, helping to identify trends and implement preventive measures.

CHALLENGES

Nothing is ever perfect. The maritime industry is no stranger to challenges, including complex logistics, unpredictable weather, tight schedules, a highly regulated environment, cybersecurity concerns, reliability of internet access at sea, cost management, and data sovereignty issues. Cloud platforms face ongoing challenges with privacy, security, and authentication. Once you commit to a cloud service, you have only as much control of your data as the cloud provider and the law allow. Collaboration with various agencies like government agencies, customs, customers, logistic providers, and vendors in real-time is not available currently. From staffing disruptions to unforeseen events, shipping can face numerous challenges that could bring operations to a halt, or at least, delay important tasks and decision-making. Other challenges of maritime cloud include the following [13]:

• *Cost:* Pricing for some cloud services can be opaque and convoluted, leading to unexpected expenses. Bandwidth limits and data caps can lead to higher costs if not carefully managed. The flexibility of cloud computing can make it difficult to budget in advance, as resource usage can fluctuate.

➤ *Privacy:* As with everything online, security, privacy and confidentiality are primary concerns. In the maritime industry, we need to juggle multiple countries' legal requirements. The cloud complicates things even further. Data privacy and access laws vary wildly.

➤ *Regulatory Compliance*: The maritime industry faces strict regulations around security and

environmental compliance, which vary from region to region. Cloud computing enhances both data security and compliance processes in several ways. Cloud solutions provide up-to-date regulations and reporting tools to help companies meet industry standards. Whether it is tracking emissions or adhering to the International Maritime Organization's (IMO) regulations, cloud systems simplify the compliance process by automating document generation and submission.

➤ *Fragmentation:* The shipping industry is very fragmented because there are so many people involved. While many are starting to use technology, the industry is progressing rather slowly. The issue is that there is no real platform to collaborate on. It is important to collaborate within the company and ensure that people are not working on different kinds of data. Shipowners then need to ensure there is collaboration with the crew on board, which is hard if you do not have the correct kind of software.

➤ *Cybersecurity:* Cybersecurity is a significant concern in the maritime sector, especially with the growing number of cyber threats. The maritime industry is increasingly reliant on digital systems and connectivity, making it a target for cyberattacks. Cloud deployments can be vulnerable to data breaches, which can have serious consequences for security and economic stability. Insider threats, such as malicious employees or compromised accounts, can also pose a risk to cloud-based systems. Encryption, access control, and regular security updates help safeguard sensitive information and mitigate the risk of cyberattacks.

➤ *Reliability:* While Internet access at sea is improving, it is not always reliable or affordable. Ships can experience communication problems during storms, satellite outages, or even cyberattacks. Until reliable Internet access is widely available, it may not be advisable to rely on cloud platforms for critical functions.

➤ *Data Sovereignty:* The flexibility of cloud computing can make it difficult to budget in advance, as resource usage can fluctuate. The General Data Protection Regulation (GDPR) may apply to ships with crew members or servers in the European Economic Area (EEA). Ensuring compliance with various regulatory requirements can be challenging when using cloud services.

➤ *Legacy Systems:* Integrating cloud-based solutions with existing legacy systems can be complex and require significant effort. Ensuring

interoperability between different systems and platforms is essential for seamless data flow.

➢ *Complexity:* Maritime operations generate vast amounts of data, which can be challenging to manage and analyze. Their complexity carries big risks. Real-time data processing and analysis are often required for effective decision-making, but can be challenging to implement in a complex structure. Technology design company should come up with a design that significantly reduced the complexity, cost, and weight of their original concept, while increasing its robustness and reducing its complexity. Figure 7 shows a typical maritime shipping complexity [14].

CONCLUSION

The maritime shipping industry, traditionally cautious to embrace new technology, is starting to use cloud computing services to make operations, communications, and collaboration easier for a workforce spread around the globe. Cloud computing is unlocking new opportunities in maritime operations by enhancing efficiency, collaboration, and decision-making. The advantages of using cloud computing for maritime subjects include lower prices of hardware and software, access to software and data from any computer on board ship having an internet connection, lower costs of maintenance of hardware and software, possibility of rendering services to all company ships, possibility of continuous monitoring of maritime processes supported by computer, increased employee efficiency, all information and documents at one location, etc. [9].

Cloud computing, as a new IT technology, introduces a spectrum of new opportunities and challenges ranging from management to application and infrastructure security. By embracing cloud computing, maritime organizations can unlock new opportunities for growth and innovation, ushering in a new era of efficient and secure communication at sea. More information about cloud computing in the maritime industry can be found in the books [15,16] and the following related journals:

➢ Journal of Cloud Computing

➢ IEEE Cloud Computing

➢ IEEE Transactions on Cloud Computing

➢ International Journal of Cloud Applications and Computing

➢ International Journal of Cloud Computing and Services Science

➢ i-manager's Journal on Cloud Computing

➢ Scientific Journal of Maritime Research

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Figure 1 The symbol for cloud computing [4].
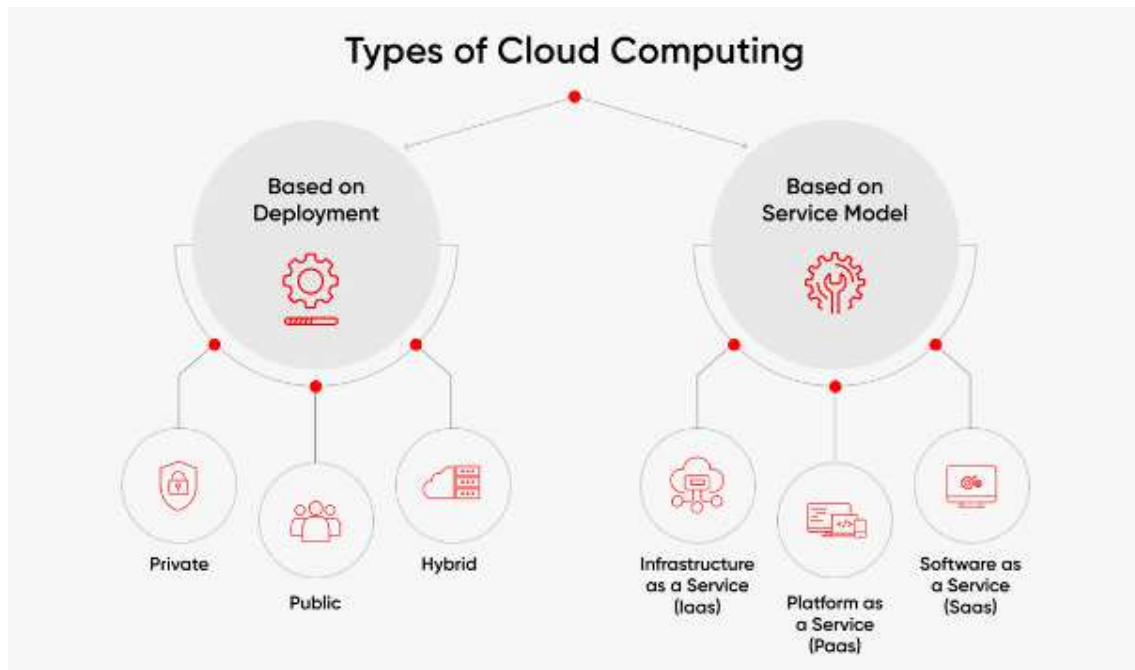

Figure 2 Some features of cloud computing [5].

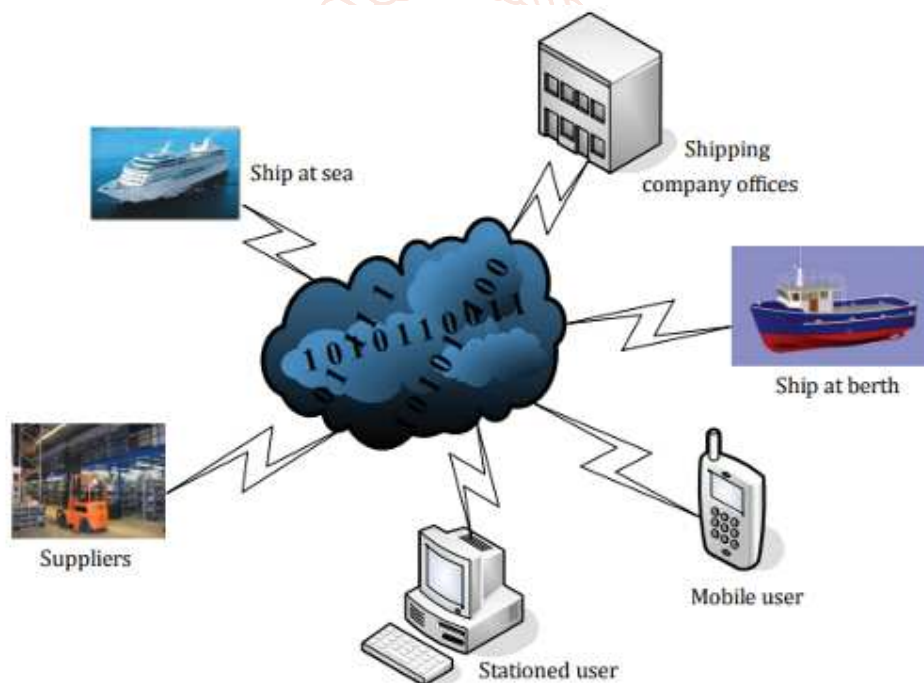**Figure 3 Cloud computing services and models [7].**

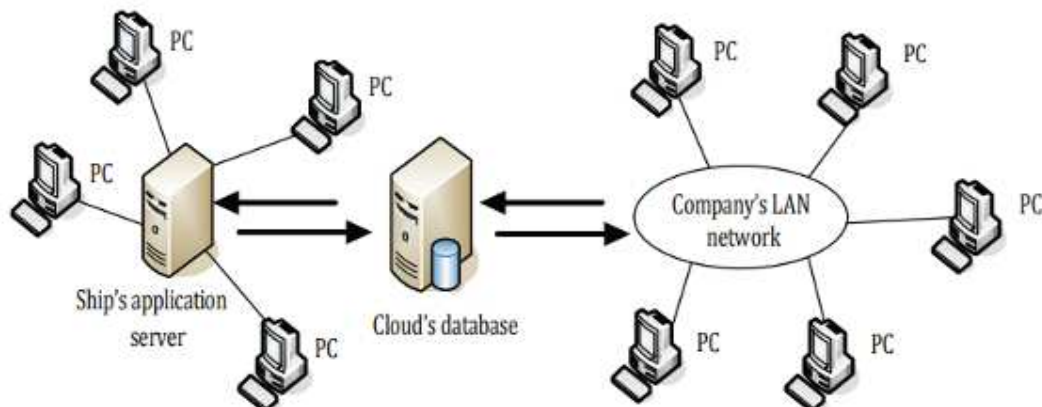**Figure 4 Cloud computing in marine environment [9].**

Figure 5 Access to a centralized database in the cloud [9].

Figure 6 Collaboration between business leaders [12].

Figure 7 A typical maritime shipping complexity [14].